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Characterization of producers who use wastewater for irrigation of vegetables and forages

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ABSTRACT

Objective: To characterize the production systems of the users of Chilhuacán canal waters located in Atlixco, Puebla and to identify the role they play in the persistence of wastewater use in agriculture.

Design/Methodology/Approach: A characterization of regional producers was conducted applying a questionnaire and making field visits to the producers' plots.

Results: There are seven types of producers who specialize in different types of crops (forages and vegetables); they also use agricultural areas of different sizes ($<$3ha, $\leq$6ha and $>$6 ha).

Limitations/Implications: Wastewater use in agriculture is a recurring phenomenon in the world (including Mexico). As a result of the low water availability, wastewater is used to irrigate crops for human consumption.

Findings/Conclusions: The awareness of the producers about the impact of this practice is low and they have no interest in the harmful polluting effects on their plots and their health.

Keywords: Health, pollution, environmental deterioration, typology of producers.

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INTRODUCTION

Nowadays, the Mexican field faces serious problems, but doubtlessly, environmental deterioration is one of the most important. A significant component of this phenomenon is the pollution of rivers, springs, and even the water extracted from deep wells, resulting in serious human health problems —both directly or through the food chain. The state of Puebla plays a key role in the domestic production of vegetables, flowers, and forage. The municipality of Atlixco is known within the state by the widespread sowing of vegetables (coriander, radish, onion, lettuce, and zucchini), flowers (gladiolus, cockscomb, chrysanthemum, and common baby's breath), and forage (alfalfa, corn, and oats). The municipality of Atlixco has a flat soil broken by the Popocatépetl foothills.

Image by Paul Merino at Pixabay

According to the 2010 Population Census data, Atlixco has a population of 127,062 habitants (hab), with a population density of 432.02 hab km^{-2} (INEGI, 2010). The Chilhuacán canal is in this municipality. Its waters come from a deviation of the Nexapa river into which untreated industrial and urban wastewater is discharged; this highly-polluted river also drags a large amount of garbage throughout its riverbed. Despite the pollution of the canal and the increasing pollution rates, these waters have been used for years in agricultural production. Therefore, their use for these purposes has been questioned, since according to NOM-001-SEMARNAT-1996 these waters are categorized as "waters whose agricultural use is subject to certain conditions": their use is restricted for horticultural crops and grains, although it has been allowed for forage and ornamentals. However, due to traditional use conditions and to the lack of alternative water supplies for agriculture in the region, farmers seem highly unwilling to stop using wastewaters and, consequently, continue with this irrigation practice. To analyze the characteristics of those producers, producer groups with similar features and practices (typologies) were identified (Malagón and Prager, 2001). In addition, their economic model was identified according to their resources, level of technology, and the strengths and limitations of the area where they work (FAO/USAC, 1995). The characterization goal is to establish producer groups based on qualitative criteria (similarity), by means of which clear differences can be established between them, disregarding secondary heterogeneities (Apollin and Eberhart, 1999). The elaboration of typologies seeks to simplify diversity among the producers in the same region, by identifying production system groups (types) with similar potentialities and restrictions against one or several chosen elements (Amador *et al.*, 1995). The purpose of this work was to characterize the production systems of the users of Chilhuacán canal waters and to identify the role they play in the persistence of wastewater use in agriculture.

MATERIALS AND METHODS

The study area includes the irrigation zone of the Chilhuacán canal, located to the east of the municipality of Atlixco, encompassing the communities of Santa Ana Yancuiltlalpan, San Félix Almazán, Nexatengo, and La Ciénega. The canal is 4.5 km long and is used to irrigate 680 ha. The number of users per irrigation unit is showed in Table 1.

Table 1. Irrigation units of the Chilhuacán canal and number of users.

Watering units	Number of users
Ejido San Félix Almazán	164
Ejido Santa Ana Yancuitlalpan	86
Ejido Revolución	139
Ejido Flores Magón	104
Ejido Xonacayucan	24
Ejido Loma Larga	24
Pequeña propiedad Maurer	3
Pequeña propiedad Galeazzi	3

Source: User census of the irrigation module 07, Nexapeños del Norte A. C.

The questionnaire was designed based on Pérez's (1994) recommendations. To calculate the sample size, the total number of users of the canal was considered as the study population (547) and the statistical formula of maximum variance was used (Pérez, 1994; Triola, 2009), obtaining a sample size of 60 questionnaires. The following formula was applied to obtain the sample size:

$$\eta = \frac{N\left(\frac{Z_\alpha}{2}\right)^2 (pq)}{N\,d^2 + \left(Z_\alpha\right)^2 (pq)}$$

Where: η=sample size; N=population size; $\left(\frac{Z_\alpha}{2}\right)^2$=Reliability, with $\alpha=0.05$ and $pq=0.25$ d=standard error, 10% (0.10).

The instrument consisted of three sections: 1) Characterization of production units which included questions about the general producer characteristics in the study area, taking into account factors such as age, level of education, number of family members, land area, crop census, and production costs as proposed by Tabares *et al.* (2000) and Rubio (2006); 2) awareness about the environmental problems caused by canal sewage; and 3) point of view of the users about the ongoing use of canal waters for agricultural purposes.

RESULTS AND DISCUSSION

The information collected was used to develop a database with 30 variables from which the most representative ones were selected, as proposed by Berdegué *et al.* (1990). First, the coefficient of variation (CV) of each variable was calculated and those with low discriminant power (<50% CV) were eliminated; subsequently, the association degree between them was determined. Consequently, only the 12 variables with the highest correlation and representativeness were selected (Table 2).

It was possible to differentiate the production limiting factors, the production unit objectives, type of production, technology, relationship with markets, labor, nature of costs, and rationality behind decision-making, as proposed by Valderrama and Mondragón (1999). Regarding the members of the family nucleus (Table 3), 16.4% consists of three or fewer people, 57.4% has from four to six members, and 26.2% is considered a large family (seven to 10 members). The second and third groups (83.6%) surpassed the national and state mean, which is three members per family (INEGI, 2010).

Most producers have a low educational level, although it is higher than in other regions of the state. Regarding land availability, the mean production unit has 3 ha, with a minimum of 0.5 ha and a maximum of 40 ha. The small producer group was made up of individuals with an average age of 55 years, with more than 35 years of experience growing vegetables, and with high school as their highest educational level. On average, the medium size producer is 40 years old, has undergraduate studies, and more than 20 years of experience in forage and vegetable production. The average age of large producers was 45 years old, with 25 years of experience, and an educational level

Table 2. Variables of forage and vegetable producers in Atlixco, Puebla, Mexico.

Variable	Description
A1	Number of family members
A2	Producer's age (years)
A3	Farmer's schooling (years)
A4	Producer's surface (hectares)
A5	Fodder area (hectares)
A6	Vegetable area (hectares)
A7	Income from forages (\$ ha^{-1})
A8	Vegetable income (\$ ha^{-1})
A9	Fodder yield (t ha^{-1})
A10	Yield of vegetables (t ha^{-1})
A11	Production degree of mechanization (high>80%, medium>60% and low <50%)
A12	Years of planting fodder crops and vegetables

Source: Table developed by the authors based on their own field work.

Table 3. Socioeconomic and productive characteristics of the producers.

Variable	Type of producer by farm size		
	Small	Medium	Extensive
Number of family members	2±3	4±6	7±10
Producer's age (years)	82±28	40	45
Farmer's schooling (years)	15±6	12	15
Producer's surface (hectares)	5.5±0.5	11.3	40
Fodder area (hectares)	47	11	40
Vegetable area (ha)	8	0.3	0
Income from forages (\$ ha^{-1})	10000±8000	21000±18000	21000±18000
Income from vegetables (\$ ha^{-1})	18000±15000	21500±19000	0
Fodder yield (t ha^{-1})	15±10	30±20	35±30
Yield of vegetables (t ha^{-1})	20±10	20±11	0
Degree of mechanization in production (high/medium/low)	50±30	70	100
Years sowing fodder and vegetables	40±25	20	25

Source: Table developed by the authors based on their own field work.

of postgraduate studies (Table 3). However, with regard to the age, educational level, and activity experience variables, Vilaboa and Díaz (2009) reported that older producers with low educational level and more experience —as was the case of small producers in the study area— have deep-rooted knowledge about production methods; consequently, they are considered reluctant to change. Meanwhile, producers with more activity experience and a higher educational level may find themselves in a transition process, with greater openness to change regarding both crops and the production methods. Furthermore, there were marked differences between producer groups regarding the productive variables of their plots. Producers with smaller area had low yields (10-20-ton hectares^{-1}), as a result of their cultural practices and labor. For example, the gravity method was the most used irrigation system; they used less machines for weeding and other agronomic practices. This situation restricted their knowledge about the new technologies they could have access to. Medium and large producers have a higher degree of mechanization and better technological packages that allow them to obtain better yields and a better price for their products (Table 3). Most of the operations belong to smallholders, since 96.72% has up to 5 hectares. Meanwhile, 1.64% can be considered as medium size (more than 5 and up to 11 ha) and another 1.64% of the operations are considered large (more than 15 hectares, without surpassing 40 hectares) (Table 4).

The prevailing landholding type is *ejido* (83.6%), followed by the *ejido*-small property combination (9.8%), small property (3.3%), *ejido*-rent combination (1.6%) and finally only rent (1.6%). Agricultural activities in the study area only have access to wastewater: there are no deep wells because it is a closed area. Therefore, there is a limited availability of water, which worsens the situation during the dry season. Consequently, many producers who work in areas greater than 3 ha buy hours of water from other users to supply the needs of their crops, an activity mentioned by Ramos *et al.* (2003). Regarding water cost, Chilhuacán canal users pay an annual fee, which is used to maintain the distribution system, since the cost per hectare of irrigation is around $100.00. Water distribution is shifted among the eight units per total volume of water carried through the canal (around 600 L s^{-1}); therefore, the users of each unit can irrigate at least twice a month. Most users irrigate their plots at night to avoid evaporation, as recommended by the Mexican Institute of Water Technology (IMTA, 2003). Users are aware that it is not recommended to use wastewater to irrigate vegetables, but they are unaware of the potential biological pollution of crops, as mentioned by Guzmán *et al.* (2007); nevertheless, they persist in this practice. Regarding cultivars (such as alfalfa and gladiolus), locally produced seeds are used in most cases. The most widely used agrochemicals in the region are the following: aldrin, dichloro-diphenyl-trichloroethane (DDT), methyl bromide, and parathion, which have been banned in many countries; however, they are still marketed due to poor regulation and control by local, regional, and national authorities (Drechsel *et al.*, 2002). The total area managed by the interviewees was 200 ha; the producers sow from one to three cycles per ha each agricultural year, with an average land operation index of 2.5 crops per year (equivalent to 500 ha). For this work, the three most representative crops were selected, grouping them into two types: forages (alfalfa) and vegetables (onion and coriander). According to Escobar (2003), determining production costs faces some difficulties, caused primarily by the diversity and origin of the inputs used, as well as the variation in the

Table 4. Classification of operations per area.

Classification	Surface area (hectare)	Frequency	(%)
Smallholders	0.5 a 5.5	59	96.72
Medium size	5.6 a 15	1	1.64
Large size	>15	1	1.64

Source: Table developed by the authors based on their own field work.

quantities which complicates its monetary variation. Surface-wise, alfalfa is the most important crop in the study area. Its average total cost of production is estimated to be \$16,580.00 per ha. It is important to indicate that, on average, eight irrigations are applied per hectare for the establishment of this forage, considering that the approximate value of each of them is \$100.00 per irrigation ha^{-1}. Consequently, using wastewater is more profitable than groundwater; however, from the environmental point of view this practice causes damage to soils and crops. Therefore, if we put together the prices of fertilization, growth, harvest, and forage packaging, the average value is \$18,600.00 per ha. Meanwhile, the establishment and development process of onion is one of the most expensive, resulting in a development cost of \$16,413.00 per hectare. If harvesting and transportation costs are added, the costs rise to \$24,033.05 per hectare.

Finally, in the case of coriander, the establishment and development costs are remarkably like that of alfalfa (total cost: \$18,550.55 per hectare). A great diversity of highly heterogeneous variables is involved in the structure and operation of farm units. Therefore, we recommend establishing classification mechanisms for their analysis; a cultivation typology reduces the existing diversity to a level that facilitates the analysis (Murmis, 1980; Berdequé *et al.*, 1990; Landín, 1990; Pérez, 1994; Coronel and Ortuño, 2005). A classification of cultivations was also established based on the following variables: 1) physical dimension and 2) diversity of the operation in terms of its specialization degree in agricultural production. Out of all the possible combinations of these variables, seven dominant types were identified (Table 5) and used as the basis of the analysis of the information collected.

The producers who showed the greatest awareness and interest in the levels of water pollution and its effects specialize in forage and ornamental flowers, crops whose irrigation with these waters is restricted; in this case, there is no health risk, since they are not intended for human consumption.

Table 5. Cultivation typology based on the selected variables.

Area	Number of users	Expertise	Number of users	Characterization
Smallholders (0-2.9 hectares)	34	Forager	22	Type 1. Small farm with dominant forage production.
		Ornamental flowers	4	Type 2. Small farm with dominant production of ornamentals.
		Horticulturist	8	Type 3. Small farm with dominant vegetable production.
Medium size (3-6 hectares)	25	Forager	22	Type 4. Medium farm with dominant production of fodder.
		Horticulturist	3	Type 5. Medium farm with dominant vegetable production.
Large size (>6 hectares)	2	Forager	1	Type 6. Large farm with dominant forage production.
		Horticulturist	1	Type 7. Large farm with dominant vegetable production.

Source: Table developed by the authors based on their own field work.

Furthermore, producers who have a lower awareness level and show little interest in the level of water pollution and its effects specialize in vegetable production. Overall, more than 50% of the users are aware of pollution and its effects; however, they are not interested in this problem, which is perhaps justified by the fact that wastewater is their only source of water. Some health problems (gastrointestinal and skin diseases) that could be caused by wastewater have been detected in most operations; however, producers do not realize that these diseases are the direct result of this practice. Most of the users are uninterested in this problem; this situation is a cause of concern, particularly regarding vegetable production units. Regarding the role that this practice plays for the family economy in the seven units, the agricultural activity is the highest source of income, and, in some cases, it is the only source of income for the family. In addition, the non-existent cost of water is an important aspect for the persistence of this practice in this region since producers only pay an annual fee for maintenance of the distribution system. Consequently, the irrigation cost is $100.00, making irrigation with surface waters from the Nexapa River relatively cheap, because they are polluted. In the future, producers expect to continue this practice, although they are aware of possible solutions that would allow them to stop using this type of water for agricultural purposes. They doubtlessly believe that the problems of plot pollution, as well as damage to the environment and human health, will increase in the future, in the case of operations type 6 and 7.

CONCLUSIONS

There are seven types of producers whose differences lay mainly in their cultivation size and crop specialization (particularly, typologies 1 and 4). Most of the producers are 50 years or older and in average their families have four members. Alfalfa is the predominant crop; vegetables and flowers hold the second and third places, respectively. On the one hand, the users do not care about the polluting effects on their plots and health caused using sewage. On the other hand, despite knowing that the water is polluted, they also cannot stop using it, since it is the only water, they have available. Despite the lack of interest about this problem and the possible solutions, a consensus was reached by most of the producers about the three ways in which this problem could be solved: 1) to establish a treatment plant, 2) to drill deep wells, and 3) to engage in a productive reconversion.

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