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Analysis of farmers' attitude toward irrigation with desalinated brackish water in Israel's Arava Valley

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ABSTRACT

Desalination has been proposed as a more sustainable alternative to brackish water irrigation in arid areas such as the Arava Valley in Israel. We explore the perception of 128 farmers in the Central and Northern Arava Valley regarding limiting factors in desalination, policies to address them, and willingness to irrigate with desalinated water. Most respondents are aware of the electro-conductivity of their irrigation water (95%) and are concerned about its increase over time (89%). About half is either planning to switch to desalinated water (18%) or intends to do so over the next few years (32%). Economic reasons are identified by 87% of respondents as the main limiting factor in the transition. The results of an ordered logistic regression show that water electro-conductivity, cultivation of at least one salt-sensitive crop, and attribution of high importance to water saving in agriculture are the main factors affecting the willingness to switch to desalinated water. When asked about their preferred type of financial assistance in transitioning to desalinated water, partial coverage of construction costs is preferred over assistance in switching to new (salt-sensitive) cultivations. Overall, the results support the notion that the agricultural sector in the region is mature for transitioning to irrigation with desalinated water.

Keywords: Agriculture; Brackish water; Innovation; Israel; Membrane desalination

1. Introduction

Saline water irrigation is practiced in arid regions with access to brackish groundwater resources, such as the Arava Valley in Israel (from 30°57′N–35°23′E to 29°33′N–34°58′E). As of May 2013, 640 families in the Central and Northern Arava Valley, out of a total local population of 820 families, were estimated to depend on agriculture and brackish water irrigation for their livelihood [1]. Local farmers have relied on brackish water irrigation for decades, but the sustainability of this practice is questionable due to limitations on marketable yields, choice of crops, and large water use to cope with leaching requirements [2]. Moreover, salinity increase over time presents additional challenges to local agriculture [3]. Desalination may be a resource-efficient alternative to brackish water irrigation, but implementation has thus far been limited [4]. High costs, lack of essential ions for crop growth, and brine disposal are often cited as limiting factors, but the farmers' perspective regarding their relative importance and how to overcome such limitations is currently absent from the literature. Previous research on famers' willingness to innovate has focused on other type of technological innovations, including improved irrigation techniques [5,6], fertilizers and seeds [7], and agricultural insurance [8]. Age, education and socio-economic status are generally found to be the main factors affecting farmers' willingness to innovate [5–8]. Farmers' perceptions of technology characteristics may also significantly affect their adoption decisions [9]. This study uses survey-based techniques to analyze irrigation practices in the Arava Valley, farmers' attitude and concerns toward desalinated water,

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and their willingness to use and pay for desalinated water for agricultural use.

2. Experimental

A questionnaire was developed and distributed in May 2016 among farmers residing in seven villages ("moshavim") in the Central and Northern Arava Valley (Ein Tamar, Ein Yahav, Faran, Hazeva, Idan, Neot HaKikar, and Zofar). In total, 128 questionnaires were collected through face-to-face interviews. Of the 28 questions, nine are designed to gather information regarding the current farming practices, including water use and salinity. The central section consists of 14 questions that focus on assessing: (1) familiarity with desalination and its use in agriculture; (2) attitude toward environmental issues (e.g., water conservation, environmental impacts of desalination, renewable energy desalination); (3) willingness to switch to desalinated water, including willingness to pay for a private or communal desalination plant; and (4) concerns in adopting desalination and preferred policy approaches to deal with them. The remaining five questions collect general demographic and socio-economic statistics.

After being reminded about the potential advantages of using desalinated water as well as the higher costs for water than would be entailed, respondents were asked to state their willingness to switch (*WS*) to irrigation with desalinated water by choosing between four options: already planning to switch (*WS* = 1); intending to switch within a few years (*WS* = 2); possibly switch in the long-term (*WS* = 3); not interested (*WS* = 4). In order to identify the variables that most affect the farmers' attitudes toward using desalinated water, we analyse the responses to this question in the context of an ordered logistic regression. One key assumption underlying this model choice is that the four given options are perceived along an ordered gradient of acceptance but the perceived "distance" between categories may not be constant (e.g., the perceived distance between "already planning to switch" and "intending to switch within a few years" may not be the same as the distance between "possibly switch in the long-term" and "not interested"). Table 1 shows the explanatory variables used in the regression model, the relative descriptive statistics, and *a priori* expectations regarding their sign in the regression results. Given the coding of the dependent variable *WS*, a negative regression coefficient indicates a better odd to state a higher willingness to switch to desalinated water. Listwise deletion of missing data was applied for the regression, which leads to unbiased parameter estimates assuming data is missing completely at random (MCAR). Information on crop salinity tolerance is derived from [10,11]. The Akaike Information Criterion (AIC) is used to select the subset of explanatory variables that best fit the given data, using exhaustive subset search [12]. Confidence intervals for the parameter estimates are obtained by profiling the likelihood function. All statistical analyses were conducted in R (version 3.2.3) [13].

3. Results and discussion

Most respondents own the fields they cultivate (63%), whose median extension is 5 ha. Pepper is cultivated by 54%, followed by dates (33%) and melons (19%). Sensitive crops (mango, lemon, sabra) are cultivated by 6%. The majority of respondents recognize high importance to water saving (56%), while only 7 and 9%, respectively, state that it has no or little importance. About one third changed the crops they cultivate within the past five years, out of which 53% did so in the last year. Almost half (47%) of the interviewed farmers has been active in the Arava region for 20 years or more. The most commonly used growing methods include advanced techniques such as net houses (32%) and greenhouses (28%).

The average reported electro-conductivity of the water is 3.0 ± 0.5 dS/m. Most respondents are aware of the electro-conductivity of the irrigation water they use (95%), are concerned about its increase over time (89%), and are familiar with the possibility to use desalinated water in agriculture (97%). Previous research in the area [2,4] has focused on the advantages of desalination by means of nano-filtration (NF) membranes rather than reverse osmosis (RO) for agricultural use. Only 25% of the respondents, however, are aware of the possibility to desalinate brack-

Table 1
Independent variables of the regression model, with respective descriptive statistics and a priori expectations

Variable	Type (levels)	N	Mean/mode	Expected sign
Cultivated land area [ha]	N	128	10.3	–
Land ownership	C (3)	124	Owned	+ for rented
Type of crops	C (3)	126	Moderately sensitive	+ for tolerant
Importance of saving water in agriculture	C (4)	120	High importance	– for high importance
Water electro-conductivity [dS/m]	N	121	3.0	–
Concerned about increasing water salinity	C (2)	125	Yes	– for yes
Familiar with desalination in agriculture	C (2)	126	Yes	– for yes
Concerned about environmental impacts	C (3)	128	No	+ for yes
Age [y]	N	126	50	+
Income	C (5)	107	Above average	– for high income
Education	C (3)	123	High school	+ for high school

Note: N = numerical; C = categorical; O = ordinal; "+" and "–" indicate positive and negative sign, respectively.

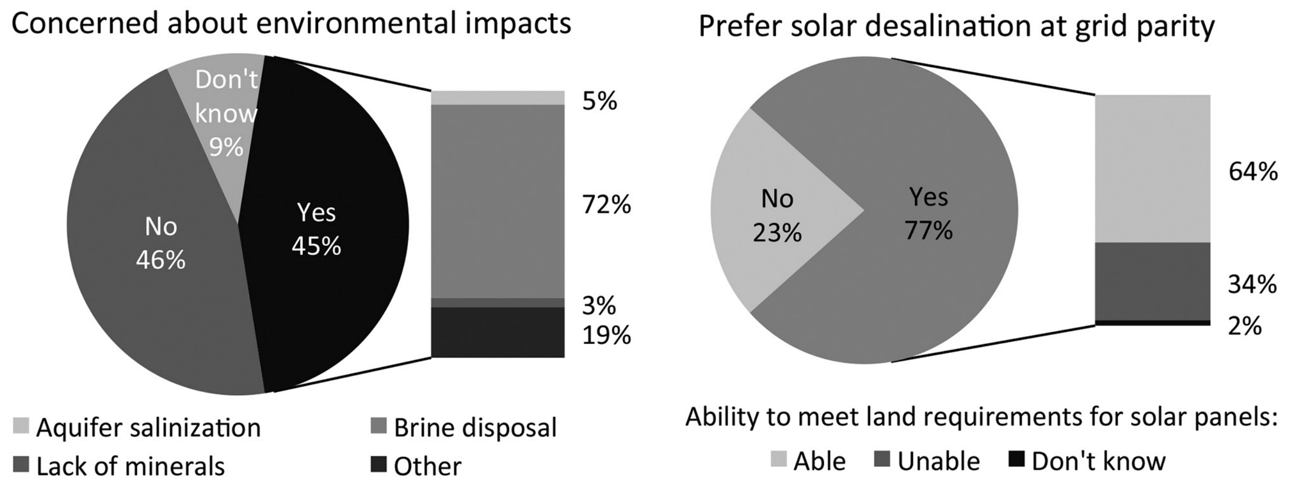

Fig. 1. Distribution of survey responses regarding environmental concerns with desalination (*left*) and willingness to adopt solar desalination at grid parity (*right*).

ish water with NF membranes. About half is either already planning to switch to desalinated water (18%) or intends to do so over the next few years (32%). Only 7% is contrary to irrigate with desalinated water. A positive willingness to pay for investment in desalination is stated by 23% of the respondents. At grid parity, 77% of the respondents would be interested in exploring solar desalination options and, out of these, 64% estimate to have enough land available to locate the required photovoltaic panels (Fig. 1).

With desalinated irrigation water, most farmers (56%) would keep growing the same crops as today, aiming at higher yields with better water quality. Among those who would change cultivations (34%), salt-sensitive (apricots, strawberries, peaches, mango) and medium-sensitive crops (grapes) are frequently indicated. When asked to list the top concerns in transitioning to irrigation with desalinated water, economic reasons are cited by 87% of respondents; only 6% is concerned of potential damages to crops. Brine disposal is most frequently indicated by the 45% of respondents who express environmental concerns related to desalination (Fig. 1). The preferred solution to deal with the desalination brine is the cultivation of halophytes such as *Salicornia europaea* (42%).

When asked about their preferred type of assistance in transitioning to desalinated water, 55% of respondents choose governmental incentives. Financial incentives covering 50% of construction costs are preferred over incentives covering 70% of the costs to switch to new cultivations, which is consistent with their reticence to adopt new cultivations even in the presence of higher quality water. Technical assistance in operation and maintenance of the desalination plant is indicated by 20% of respondents, followed by assistance with marketing (19%), assistance with the removal of brine after the desalination process (19%), and, finally, supplement of fertilizers as compensation to nutrients loss during the desalination process (17%). In the framework of non-structured comments made during survey administration, several respondents observed the need for guidance by the authorities during the transition, both in terms of financial assistance and devising of comprehensive solutions to address the concerns and challenges involved in the desalination process.

Table 2 shows the results of the ordered logistic regression. Land area and ownership, education level, and concern about environmental impacts of desalination are dropped from the model with minimum AIC (AIC = 211.847). Concern about increasing water salinity and familiarity with the option of using desalinated water in agriculture, which are shared by the vast majority of respondents, are also dropped from the best-fit model. All regression parameters in Table 2

Table 2
Results of ordered logistic regression of willingness to switch to desalinated water, in ordered log odds

Variable	Value	95% confidence interval
Type of crops		
Moderately sensitive	–0.258	[–1.570, 1.044]
At least one sensitive crop	–3.163**	[–6.606, –0.257]
Importance of saving water in agriculture		
Somewhat important	1.199**	[0.104, 2.345]
Low importance	–0.534	[–1.907, 0.816]
Not important	1.887	[–0.568, 4.571]
Water electro-conductivity [dS/m]	–1.331***	[–2.223, –0.472]
Age	2.747	[–0.010, 0.081]
Income		
Low	2.747	[–0.854, 6.495]
Average	2.422	[–0.949, 5.971]
High	1.759	[–1.500, 5.2155]
Very high	–0.694	[–4.346, 3.050]

Note: N = 85; AIC = 211.847; statistical significance at the 1 and 5 percent levels is indicated with *** and **, respectively. Intercepts: 1|2 = –2.504; 2|3 = –0.486; 3|4 = 2.413.

have the expected sign. Variable coefficients that are significant at the 5% level or higher include water electro-conductivity, type of cultivated crops, and perceived importance of saving water in agriculture. As expected, high water salinity, as measured by the electro-conductivity parameter, is highly positively correlated with the propensity to consider desalinated water as a viable option. Farmers that cultivate at least one salt-sensitive crop are also more likely to state an interest in desalination compared to farmers that grow only or primarily salt-tolerant crops. Farmers who attribute high importance to water saving in agriculture are more likely to be in favour of switching to desalinated water than farmers who only identify it as "somewhat important". The difference with farmers who assert low or no importance, however, is not statistically significant.

4. Conclusions

Overall, the results of the study support the notion that farmers in the Central and Northern Arava Valley in Israel are aware of the issues involved in brackish water irrigation and are open to the idea of exploring the use of desalinated water in irrigation as an innovative, alternative option to the current practices. The interviewed farmers appear to be well-informed about the salinity of their irrigation water, the issues involved with its deterioration over time, and the opportunities and challenges offered by desalination. The analysis identifies that water salinity, type of cultivated crops, and attitude towards water saving are the main factors affecting farmers' willingness to accept desalinated water. Such results may provide guidance to policy-makers interested in efficiently guiding the transition to sustainable water management practices in the Arava Valley and other areas with similar characteristics.

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