Accepted Manuscript

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PII:	S0048-9697(18)32907-3
DOI:	doi:10.1016/j.scitotenv.2018.07.410
Reference:	STOTEN 28004
To appear in:	*Science of the Total Environment*
Received date:	1 May 2018
Revised date:	28 July 2018
Accepted date:	29 July 2018

Please cite this article as: F. Alcon, S. Tapsuwan, R. Brouwer, M. Yunes, O. Mounzer, M.D. de Miguel , Modelling farmer choices for water security measures in the Litani river basin in Lebanon. Stoten (2018), doi:10.1016/j.scitotenv.2018.07.410

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Abstract

Lebanon is facing an increasing water supply deficit due to the increasing demand for freshwater, decreasing surface and groundwater resources and malfunctioning water governance structures. Technological and policy changes are needed to alleviate the impact of water scarcity and secure water in the future. This paper investigates farmers' preferences and willingness to pay (WTP) in a choice experiment for a series of water saving measures at plot and irrigation district level, including more timely information of water delivery. These measures are expected to strengthen water security and use water more efficiently. Farmers are willing to pay higher water prices of $0.32/m^3 and $0.22/m^3 to support the implementation of water saving measures at plot level and the installation of water metering devices across the irrigation district, respectively. They are not willing to pay extra for obtaining information related to their water delivery earlier in time if this means that they will also have to pay earlier in the year for the water. Farmers with higher income and education levels who decide on their cropping pattern based on expected rainfall data are more interested in taking action than farmers whose cropping decisions are primarily based on last year's sales prices. The study shows that when aiming to design more effective sustainable water management strategies, accounting for farmers' needs and preferences, their age also has to be considered: younger farmers (< 40 years) are on average more interested in and willing to pay more for new water saving measures than older farmers (>40 years).

Keywords: choice experiment, water security, irrigation, Lebanon, water saving, water pricing, willingness to pay

1. Introduction

Irrigated agriculture accounts for nearly 85% of the total consumptive use of water by humans worldwide (Gleick, 2003). A small improvement in irrigation water use could result in a substantial reduction in global freshwater withdrawal (Grant et al., 2012). However, such improvement depends on both supply and demand management strategies aimed to achieve efficient and sustainable use of water. Like in many parts of the world, dealing with water scarcity is one of the major water policy challenges in the European Mediterranean region.

On the supply side, it is common practice to use a combination of groundwater and surface water sources for irrigated farming. In times of water scarcity, groundwater pumping is intensified in order to supplement the deficit created by drying surface water sources. Therefore, groundwater sources become even more depleted. Years of pumping have led to overexploitation of some of the aquifers that require strict government regulation to manage groundwater abstraction (Gómez and Pérez, 2012).

On the demand side, all farmers know how essential water is for crop production and that any shortage may have a negative impact on crop yield. Farmers may be risk averse and choose to over-irrigate to avoid water-related yield losses, and ignore the adoption of water saving practices, especially when the economic cost of the water saved does not outweigh the investment. The introduction of modern drip technologies that increase water application efficiency and distribution uniformity together with water allocation and management strategies aimed to ensure profitable production levels could be the solution for eliminating unsustainable water use behaviour (Cason and Uhlaner, 1991; Skaggs, 2001).

At the irrigation district level, the adoption of water metering is a key element for controlling water withdrawal and improve water allocation. However, the implementation of metering devices is usually hindered by monitoring and surveillance challenges (Molle and Berkoff, 2007), and the water charges may not cover the costs of implementing the metering system (Tsur and Dinar, 1997). Installing surface or groundwater meters at farm level would allow the adoption of a volumetric water tariff system that promotes incentives for water saving because payments are directly linked to actual water delivered (Dono et al., 2010).

In Mediterranean countries, the adoption of more efficient irrigation technologies is affected by institutional and financial factors such as water supply and pricing policies (Alcon et al., 2011). Water pricing is seen as an incentive for water saving and enhancing the sustainability of water use (Turner et al., 2004; Dinar and Mody, 2004), but its effectiveness depends on other water policy initiatives embedded in an institutional context. Policies aimed to reduce uncertainty around water resources management based on transparent sharing of information have become more relevant in recent years (Molden, 2007). In this context, the use of economic valuation has been advocated to assist the design of efficient, equitable and sustainable policies for water resources management (Birol et al., 2006).

Contemporary studies on economic valuation of irrigation water have primarily focused on the intrinsic attributes of water supply, such as the quantity or quality of the supplied water (e.g. Rigby et al., 2010; Birol et al., 2008; Alcon et al., 2014). The institutional aspects and characteristics of water management have been underexposed in the existing valuation literature, and irrigation water governance has only recently received more attention (e.g. Speelman et al., 2010; Tesfaye and Brouwer, 2016). There is a lack of information on how smallholder irrigators respond to climate change and water scarcity and adopt water policy measures and new water saving technologies (Shiferaw et al., 2008). This study tries to fill this gap by focusing on farmers' attitudes and preferences for different possible water management measures at field, irrigation community and river basin scale. This will allow us to assess not only the social acceptance of these water policy measures, but also at which scale their adoption is going to be most successful.

In Lebanon, the quantity and quality of water resources are subject to severe pressures driven by over-extraction, inefficient use and pollution due to a fragmented sectoral management approach. To alleviate these pressures and improve water resources management, the Lebanese public administration launched a water sector reform in the year 2000, aiming to regroup 22 autonomous water offices (AWO) and 210 local irrigation committees into four regional public water organizations. These organizations are formally financially independent but fall under the responsibility of the Ministry of Energy and Water (MEW). As part of the proposed reforms, the implementation of Water Users Associations (WUAs) in irrigation schemes was considered one of the most urgent and necessary reforms. Nonetheless, more than a decade after ratification of the reform law, the improvement in operational efficiency, the reduction of water management failures and the negative impacts on environment and human wellbeing remains very limited. The reform seems to have focused more on restructuring the existing organizational structure than strengthening it. The shortcomings of the reform are reflected in fuzzy institutional boundaries, marked by gaps and overlaps (El Kadi, 2012). Improved understanding of farmer's water use behaviour, water management needs and preferences would help water managers and policy makers to move an important step closer towards designing and implementing more sustainable and efficient water use programs based on a combination of available supply and demand management options.

In this context, the objective of this paper is to evaluate farmers' acceptance of and willingness to pay for a series of catchment-wide water saving measures using a choice experiment. These proposed measures are designed to help farmers use water more efficiently, better plan when to irrigate, and communicate more effectively with the irrigation district or river basin authority. The overall goal of these measures is to ensure that farmers have guaranteed access to irrigation water so as not to compromise farm productivity and output in the future. The South Beqaa region in Lebanon is used as the case study area.

2. Methodology

2.1. Case study description

Lebanon has been known as an oasis of abundant water resources, but the actual water distribution infrastructure, political situation and the lack of governance has led this country to experience water shortage problems. The Litani River is the longest and most important river in Lebanon with an estimated average discharge rate of 8-cubic meters per second (Saadeh et al., 2012), used for irrigating some 77,000 ha of agricultural land, as well as for tourism and domestic water use. Geo-morphologically, the Litani basin is divided into two sub-basins, namely the upper (USB) and lower sub-basin (LSB). The irrigated agricultural area in the USB varies from 33,000 to 45,000 ha every year. An annual water deficit is already present and considerable declines in ground water levels have been observed, reaching more than 50 m in some cases (REF?). This situation is mainly driven by the use of surface water for irrigation over a long irrigation season of 6-

8 months, the absence of sufficient precipitation and any water metering or pricing policy, and poor awareness among farmers to improve irrigation water productivity.

In the USB, the 2,000 ha irrigation scheme called the "South Bekaa Scheme" (SBS) is a demonstration project aimed to highlight the potential of a collective irrigation network in terms of precision farming, water guarantee to farmers and increased water and crop productivity. The present study took place in the SBS as this is the first fully irrigated area since the water policy reform in the year 2000. The current phase is part of a bigger ongoing development project intended to ultimately serve a total of 8,600 ha on the left bank of the Litani River (Figure 1).

Figure 1. Around here

The SBS has a total of 450 to 500 famers. Each farmer owns on average 15.1 ha of agricultural land (LRA, 2017). Nearly 60% of all the agricultural land in the SBS is used for growing horticultural crops (potatoes and vegetables rotated with wheat) and 56% of the land is irrigated with sprinkler systems, and to a lesser extent drip irrigation technology (LRA, 2015). The Litany River Authority (LRA) is the public institution responsible for operating and maintaining the SBS water distribution network, as well as for allocating water resources among farmers.

The SBS is supplied with irrigation water through an 18 km long open aquaduct at 900 m altitude back-to-back to the Qaraoun dam. This canal is officially named "Canal_900" and is fed by 75 million of cubic meters of water coming out from 4 wells plus some additional 30 million of cubic meters pumped out at the bottom of the dam. Secondary pumps send water from Canal_900 up to large reservoirs situated at a higher level. Water is allocated to farmers through an underground pressurized (3.5-4 kg/cm^2) distribution network.

Farmers' preferences for using private wells or the LRA's pressurized network is variable and depends largely on the LRA's readiness to deliver water on time and in the required quantity (the LRA restricts water delivery during May and November due to unfavourable weather conditions and maintenance requirements), and its seasonal fees as compared to fuel cost for pumping up groundwater.

At the moment, only a third of the planned irrigated area can be supplied with water from Canal_900 due to hydraulic deficiencies (USAID, 2013). The off–farm irrigation system is unable to deliver water simultaneously to all farms. In order to balance the existing (limited) hydraulic capacity of the water distribution network and the actual amount of water requested by local farmers, the LRA calls the SBS farmers to register their seasonal water needs every year early in the season (from March onwards) and pay the corresponding water fees based on the cultivated area to be irrigated. Afterwards, the LRA guarantees water delivery from May until November. For farmers, the sooner this happens, the easier it is for them to plan their farming activities for the year. The current tariffs are 450,000 LBP/ha for winter crops and 900, 00 LBP/ha for summer crops (this is equal to 2018 USD 300 and 600 per hectare, respectively). These tariffs were proposed due to the competition with private wells who sell irrigation water at cost price, which is largely driven by fuel costs. Farmers use the Canal_900 water when fuel prices are high, and the number of farmers demanding water from the Canal is directly related to the fuel prices registered early in the season.

2.2. Focus group discussions

To ensure that the design of the choice experiment reflects the relevant water management issues at hand in the study area, it was informed by a combination of key informant interviews and two focus group discussions with local farmers. In person interviews were conducted in September 2012 with representatives from 6 main stakeholder groups. This included the LRA, MEW, the Cooperative Society to organize irrigation water services in West Bekaa, the Water Establishment in the Bekaa, the Lebanese Agricultural Research Institute, and the Association of the Friends of Ibrahim Abdel AAL (AFIAL). The objective of these interviews was to gain a better understanding of the key issues of concern relating to irrigation water supply and demand, and the possible solutions that could resolve these issues. Insights gained from those interviews with these stakeholder representatives were used to formulate the initial design of the choice experiment and the survey.

Once the draft survey was designed, two focus groups were conducted in October 2012 with farmers sampled from the study region to test the validity and reliability of the choice experiment design and the survey questions. Feedback from farmers were used to revise the design of the choice experiment and other questions in the survey. For example, questions that were considered too hard to understand by farmers. These questions were reworded in easier understandable terms.

2.3. Choice experiment

Information collected from the focus groups provided important insight into the key water demand and supply management measures that were pertinent to farmers in the study region. Given that there were multiple issues and water characteristics to investigate, the choice experiment method was considered the most appropriate elicitation method of willingness to pay (WTP) for the improvement of irrigation water supply. The method is based on random utility theory for explaining choices among pairs of offerings in line with Lancaster's model of consumer choice (Lancaster, 1966). The relevant attributes included in the choice experiment design are water saving measures at plot level, metering of water use, timing of when water delivery is announced and the price of water.

Table 1 provides the list of attributes and attribute levels of the choice experiment design. At the farm level, we included two attributes, replacing sprinklers or furrow irrigation systems with drip irrigation and receiving irrigation scheduling advice from extension service officers. At the irrigation district level, we included an attribute related to the installation of a water metering system on every farm in the entire irrigation district in order to monitor how much water is used by each farm and from which source (surface or ground water). At the river basin level, we included an attribute that captures the point in time (which month of the year) at which the LRA will inform farmers about when and how much water they will receive.

The cost attribute was defined as the price of water per cubic meter that farmers would have to pay in order to achieve the desired level of water saving, metering and delivery. Farmers were informed that they would not have to pay for the investment costs of buying and installing the drip irrigation system and the metering devices. The LRA would pay for these investment costs. The increase in the price of water would cover the increased implementation costs of these measures. The price of water in this design is between 17% and 167% higher than the current price farmers pay. The price range offered in the design is based on possible water prices used by the LRA in order to achieve full cost recovery of the water delivering services.

The Ngene 1.0.2 software package (Rose et al., 2010) was used to generate an s-efficiency design that would help to minimize the sample size required to estimate significant parameter values. An s-efficiency design was most suited for this study because the sample size is constrained by the limited number of farmers in the study area. The priors were estimated based on 12 pre-test interviews with randomly selected farmers in the case study area. The design consisted of 36 choice sets blocked in 6 groups. Each block was randomly assigned to a farmer during the survey. Hence, each farmer saw and answered six choice sets.

Table 1. Around here

The introduction to the choice experiment briefly described the current water management situation in the LRA and the potential for improving it. Farmers were then shown an example of a choice set and explained what the choice set represented and what they were asked to do. Farmers could choose between two hypothetical options to improve water security at a cost (price increase), and an opt-out option. The opt-out option refers to the status quo, which is the current state of water supply in the basin where farmers will not have to pay an increase in the water price, or implement any water saving measure. The LRA will not inform farmers until March or later when water will be delivered, as currently is the case, and there is no guarantee that farmers will receive their requested level of water supply.

The current price of water is US \$0.06/m^3. If farmers choose one of the two hypothetical options over the status quo, the price per cubic meter of water will be higher than what they currently pay, but they would secure their water supply and the LRA would assist in the technology implementation and take the required measures for supplying the water on time. An example of a choice set is provided in Figure 2.

Figure 2. Around here

2.4. Statistical Model

The most commonly applied statistical method for modelling choices is the conditional logit model. A conditional logit model assumes that the utility U_{ij} for individual *i* from an alternative *j* is given by:

$$U_{ij} = V_{ij} + \epsilon_{ij} \quad (1)$$

where ϵ_{ij} is a random term with an independent and identically distributed extreme value distribution (Train, 2003), and V_{ij} represents the deterministic elements of utility. Assuming linearity in these elements, the latter can be rewritten as:

$$V_{ij} = \sum \beta_k X_{ijk} \quad (2)$$

where X_{ijk} is a vector including the observable determinants of utility, either just the choice attributes *k* in alternative *j* or also interactions between the choice attributes and individual respondent *i* characteristics, and β_k contains the associated coefficient estimates for the marginal utilities.

The conditional logit model assumes that the parameters β_k are homogeneous across the population and can therefore be restrictive in practice (Train, 2003). Alternatively, the mixed logit model relaxes the assumption of independence of irrelevant alternatives and allows the parameters to be randomly distributed across the population to capture unobserved preference heterogeneity (Ben-Akiva and Lerman, 1985). The utility from choosing a particular option is determined by the characteristics of the attributes (in this case these are the measures to secure water supply, the water metering options, the water delivery time and the water price) and individual specific characteristics. The functional form for the utility (V_{ij}) of individual *i* for alternative *j* is specified in this study as:

$$V_{ij} = \beta_0 SQ_j + \beta_1 DRIP_j + \beta_2 AIS_j + \beta_3 SM_j + \beta_4 GM_j + \beta_5 WDF_j + \beta_6 WDJ_j + \beta_7 PRICE_j + \epsilon_{ij} \quad (3)$$

where β_0 is the coefficient for the status quo alternative (SQ_j), β_1 and β_2 are the coefficients for the water saving measures drip irrigation and assisted irrigation scheduling (*DRIPj* and AIS_j respectively), β_3 and β_4 refer to the surface and groundwater metering (*SMj* and GM_j), β_5 and β_6 are associated with the water delivering information dates (*WDFj* for January and WDJ_j for February), and β_7 is the coefficient for the increase in the water price (*PRICEj*). Additionally, interactions between attributes and socio-economics variables can be added to the utility function.

It is expected that farmers are willing to pay a higher water price to secure water access in the future. However, it is difficult to hypothesize which particular water saving measure is preferred most or ranked higher than the others, or whether water metering and the timing of obtaining the relevant information about water access are preferred at all.

How much farmers are willing to pay for each attribute can be estimated using the parameter estimates for the attribute of interest and the price attribute using the following equation:

$$WTP = -\beta_k/\beta_7 \quad (4)$$

where β_7 is as before the coefficient of the price attribute and β_k is the coefficient of the attribute of interest. Assuming again a linear utility function of the attribute levels, the welfare change or the economic value associated with the proposed implementation of specific water saving measures to improve water security in the future can be estimated comparing the utility of the specific alternative to the status quo. The corresponding so-called consumer surplus welfare measure is specified in Equation (5) (Bennett and Blamey, 2001):

$$CS = -(\beta_{sq} + \sum \beta_k X_{ijk})/\beta_7 \quad (5)$$

where β_{sq} is the coefficient related to the status quo and the sum of $\beta_k's$ relate to the specific water saving measures of interest, multiplied by the relevant level of the attribute(s) representing the specific measure (0 or 1 depending on whether the attribute is excluded or included in the welfare measure).

2.5. Survey implementation

The questionnaire used for the survey consisted of three main sections. The first section contained questions related to specific farm characteristics (e.g. farm area, type of crop grown, type of irrigation system used, and the amount of water used for irrigation). This section also contained questions to elicit farmers' perceptions and attitudes towards the increasing water scarcity problems in area and their cropping pattern decisions based on expected water availability or crop prices. These attitudinal questions were measured using a five point Likert-scale, from 1 = total disagree to 5 = total agree. The next section contained the previously described choice sets and follow up questions to check farmers' motivations to participate (or not) in the choice experiment (including protest), while the last section of the questionnaire consisted of socio-economic questions related to farmer characteristics, such as age, education and income.

The survey was administered between January and March 2013 to a random sample of 150 farmers in the SBS by a trained interviewer based on previous telephone appointments. The selection of farmers was random based on probability sampling, meaning that every farmer in the study area had an equal chance to be included using existing lists of local irrigators. This random sampling approach was believed to give a representative sample of famers. No prior census data and information about the farming communities in the study area were available to guide a more targeted, stratified sampling procedure. Only after implementation of the survey the LRA provided more background information about the farmers. This was subsequently used to formally test the representativeness of the sample compared to the available population statistics. The sample size, for a 95% confidence level, provided a sample error term, for intermediate and extreme proportions, below 9 and 5%, respectively. In this specific case, considering that the proportion of farmers' willingness to pay is over 90%, excluding protest answers, the confidence interval sample error is reduced to 5%.

Table 2. Around here

3. Results

3.1. Focus groups

Findings from the focus groups suggest that there were several problems associated with the suboptimal use of water, at the plot, district and basin level.

Firstly, crop water application is mainly estimated by farmers based on their previous personal experience. Little technical advice is given to farmers on the optimal watering regime. The main farm water application system is sprinkler or gravity fed. These two irrigation schemes promote excessive water consumption and yield very low water application efficiencies. Only a few plots cropped with potatoes are irrigated by localized drip emitters.

Secondly, there are no incentives for saving water from both surface and groundwater sources due to the lack of regulatory enforcement around surface and groundwater extraction. More efficient use of water can be achieved by means of water tariffs, but a meter must be installed first.

Lastly, it is crucial for farmers to know in advance when they will be receiving their water allocations each year, i.e. when pressurized water delivery starts, in order to plan the cropping pattern for the season. The earlier the LRA informs them about when they will receive the water and how much, the better farmers can plan.

3.2. Descriptive sample statistics

The main characteristics of the farmers surveyed are reported in Table 2. A total of 118 respondents were retained in the dataset for further analysis after removal of 32 farmers (21%) who refused to participate in the choice experiment. The average age of farmers is just over 50 years, while the youngest farmer surveyed is 22 and the oldest 82. Most of the farmers surveyed hold at least a secondary school qualification (77%). Around 75% of them earn less than US$12,000 per year. Only one in every fifth farmer (19%) is a member of an agricultural cooperative. On average, 0.5 person of the family works on the farm and most farms have no hired workers. More than half of the farmers believe that water scarcity problems will increase in the coming years. The average area that is farmed every year is around 15 ha. The main crops grown are horticultural crops (39%), followed by cereal crops (27%) and fruit crops. The combination of crops grown (i.e. crop pattern) suggests that cropping decisions are primarily based on expected sales prices. Expected rainfall and expected water allocation are rarely used to inform cropping decisions. Around 53% of farmers use sprinkler systems and 11% use only drip systems. Based on data provided by the LRA, the latter group of farmers are slightly overrepresented in the sample. Yearly water use on the farm is on average around 7,748 m^3/ha. Mean differences tests for continuous variables and Pearson Chi square tests for categorical variables were applied to compare the sample and population characteristics. The sample deviates from the total population from which it was drawn in a number of significant ways, namely in terms of (i) the number of family members working on the farm (0.5 in the sample compared to 2.0 in the whole population), (ii) education level (twice as many farmers in the sample (12%) than in the population (6%) indicated to have had no education), (iii) cropping pattern (although fruits were equally represented, farmers in the sample were relatively more involved in horticulture (39% compared to 27% in the population) and slightly less in wheat farming (27% compared to 31% in the population)), and (d) irrigation water use (farmers in the sample used on average 15% less irrigation water than farmers in the whole population). The sample was representative, however, for key characteristics such as the size of the farm (hectares), the irrigation technology farmers used, and membership of cooperatives.

3.3. Estimated choice models

The utility function was been modelled using several specifications of the conditional (CL) and mixed logit (ML) model. Table 3 presents the estimated main effects CL model (Model 1) and the main effects CL model with socio economic interaction terms (Model 2). Model 3 is a random parameters logit (RPL) model with age interactions and Model 4 presents the RPL main effects model with socio-economic interactions and allowing the attributes to be randomly distributed.

A Log Likelihood Ratio test (LR) rejects the null hypothesis of no significant differences in model performance (LR = 106; $\chi^2_{0.05,13} = 22.36$) and confirms that Model 2 performs better than Model 1. A number of main effects are not significant in Model 1, but are significant in Model 2 when interaction terms with socio-economic variables are included. Model 2 shows a pseudo-R^2 goodness of fit statistic equal to 0.37, a value which is considered as providing an extremely good fit by Louviere et al. (2000). Comparing Models 3 and 4, the LR statistic shows that Model 4 is preferred because of a significantly better fit (LR=58.36; $\chi^2_{0.05,9} = 16.92$). The introduction of random parameters improves the model results as the AIC and BIC are lower. Therefore, further discussion of the results will be based on Model 4.

Table 3. Around here

The results from Model 4 show a significant negative parameter value for the status quo variable (*SQ*), which is consistent with *a-priori* expectations that farmers are unhappy with the current water management and allocation situation and are even willing to pay a higher water price to move away from this situation irrespective of the specific measures taken.

The parameter values for the water saving measures are significant and positive, indicating that farmers obtain a utility gain from installing drip irrigation on every farm (*DRIP*) and receiving irrigation scheduling advice from extension service officers (*AIS*). The parameter values for surface (*SM*) and groundwater (*GM*) metering are also positive and significantly different from zero. Hence, farmers are also open to adopt water metering technologies and installing groundwater and surface water meters on every farm. Parameter values related to the timing of when the LRA will inform farmers about their water supply delivery (*WDF* and *WDJ*) are significant but negative. This finding goes against expectations as farmers were expected to positively value receiving information about water supply delivery earlier in the year, i.e. before March, than currently is the case.

Farmer preferences to move away from the status quo is driven by a number of socio-economic characteristics, as indicated by the significant parameters of the status quo interaction terms in Model 4. The negative coefficient on the interaction term between the status quo and farm income indicates that farmers with a higher income are more interested in moving away from the current water management situation in the area than farmers with a lower income. A similar effect is found for education, where farmers with a higher education level are more likely to choose one of the two hypothetical alternatives to secure future water supply than stay with the status quo. The influence of rainfall information on cropping pattern decisions also has an effect on farmer preferences to move away from the status quo. Farmers who use expected rainfall information to decide on their cropping pattern are more averse to the current water management situation. However, farmers who are more likely to make cropping pattern decisions based on last year's sales prices prefer to stick to the current situation, and do not seem to base their decision-making on the current or future water management situation.

Despite their inclination to choose for a change in the current water management situation (as indicated by the significant negative status quo parameter), farmers attach a negative utility to any technological or policy initiative. In general, farmers like to secure their water supply, but they are averse to the offered technological changes, i.e. the installation of a drip irrigation system, assisted irrigation scheduling by extension services or water metering. However, these values for the technological attributes are driven by particular socio-economic background characteristics. The interaction terms between the technological attributes for water saving measures and water metering and a farmer's age are all significant and negative, indicating that younger farmers are more likely to favour the proposed technological changes than older farmers. Although farmers generally show a disutility for receiving information about water delivery before March, also here some variations are detected among farmers, depending on their perception of droughts. More specifically, farmers who believe that water scarcity problems will increase in the coming years prefer to have their water delivered earlier than farmers who believe that water scarcity will not be a problem in the coming years.

Finally, the WTP estimations for water security and water saving and water metering measures can be found in Table 4 for Model 4. Overall, farmers are willing to pay extra to secure their water supply, but are somewhat indifferent between the various proposed water saving measures. The analysis of the water saving scenarios consisting of water saving measures and water metering for three alternative water delivery information dates shows that farmers are willing to pay \$0.32/m^3 and \$0.22/m^3 to improve water security by adopting water saving and water metering measures, respectively in the current situation where information about water delivery is provided in March or later. As expected, the estimated economic values decrease if earlier dates are proposed for the release of water delivery information (Table 4).

Table 4. Around here

4. Discussion

The WTP estimate for the SQ option (\$0.258/m^3) highlights the importance farmers attach to securing water supply. Thus, the effect of the SQ option plays an important role in the welfare estimation. Other studies have reported similar findings, particularly when farmers are averse to their current situation (e.g. Alcon et al., 2014) or the other way around if they do not wish to change their current practices (e.g. Villanueva et al., 2015; Villanueva et al., 2016; Vaissière et al, 2018). The WTP estimates for water saving measures (\$0.035/m^3 for drip irrigation and \$0.025/m^3 for extension services) are greater than the WTP estimates for groundwater and surface water metering (\$0.0034/m^3). Therefore, if the government were to impose any technological policy change to reduce irrigation water use, installing drip irrigation and promoting assisted irrigation scheduling would be preferred over the installation of water meters. However, these results primarily indicate an investment priority. In practice, the combination of measures in a policy mix will generate the highest welfare (Bouma et al., 2018). Higher WTP for groundwater metering over surface water metering could reflect the fact that farmers believe groundwater resources to be more at risk of overexploitation and overuse could lead to catchment-wide longer term economic losses (Takatsuka et al., 2018). Higher prices, as reflected in higher WTP, may be seen as a way to better balance groundwater use (Rezadoost and Allahyari, 2014).

Farmers are less interested in receiving water supply delivery information earlier than March. A follow-up interview was conducted with 20 farmers to try and understand why this is the case since the focus group discussions indicated that the timing of the water delivery information could be improved. These follow-up interviews revealed that farmers were under the impression that if they wanted to receive information earlier, they would also have to pay for the water in advance too, i.e. pay for water in January or February if they would want to receive the information by January or February. Hence, the reason why these farmers were reluctant to choose this option despite the fact that it would enable them to better plan their cropping pattern. This finding might possibly also be explained along the lines in Goetz et al. (2017) who showed that more efficient new water allocation rules might not be adopted by irrigators if it would cause the number of losers to outweigh the number of winners.

Farmer’s preference heterogeneity and the high variability in choice behaviour suggest that any uniformly applied water policy focused on the implementation of catchment-wide water saving measures would be problematic if individual farmer characteristics would be ignored. Especially in cases where heterogeneity in the target group and normative aspects related to fundamental aspects such as water rights are generally considered to be key for the sustainable adoption of water conservation measures in policy-making processes (Yazdanpanah et al., 2014). An analysis of the marginal utility associated with each specific measure reveals that there is a negative slope associated with farmers' age. The fixed parameter model suggests that the utility from adopting groundwater metering becomes negative for farmers aged 47 and older. The utility from adopting assisted irrigation scheduling and installing groundwater metering systems becomes negative for farmers who are older than 42. Finally, the adoption of drip irrigation technology is only considered to provide benefits to farmers who are younger than 35 years. The impact of age classes, in particular younger and older than 40 years on farmers' support for implementing different technologies is illustrated in Figure 3. On average, younger farmers are willing to pay more for water saving measures, while older farmers are mostly concerned about having their water supply secured, regardless of the specific water saving measure. WTP variability is furthermore considerably higher among older farmers and relatively uniform among younger farmers.

Figure 3. About here

In order to compare the estimated WTP with the costs of the proposed measures in the choice experiment, the Equivalent Annual Cost (EAC) method was used. The EAC method is used to quantify the annual cost of operating a capital asset over its entire lifespan (Egea et al., 2017). Table 5 presents the investment and operation costs for the specific water saving and water metering measures in the study area as estimated by the LRA and their EAC, considering a lifespan of ten years and a discount rate of 3.5% (Almansa and Martinez-Paz, 2011).

Table 5. About here

The benefits of installing drip irrigation on every farm is estimated on the basis of the average WTP values for drip adoption and average water allocations in the study area, yielding an average gain of US$272 per hectare per year. This value is clearly higher than the estimated AEC. The estimated investment cost of $850/ha is in line with the costs estimated in similar water scarce areas in Spain (€994-1576/ha) by Romero et al. (2006) and Pérez-Pérez et al. (2010). Regarding the assisted irrigation scheduling by extension services, a benefit of $197 per hectare per year is obtained. Scaling up this benefit to the entire irrigated area, a total economic value results of US$394 per year, which is also higher than the expected costs. The calculated benefits of the proposed groundwater metering of US$26/ha would also exceed the corresponding AEC, while surface water metering results in negative benefits. Thus, despite the fact that the estimated choice model results show a negative utility from surface water metering, the joint estimation of the benefits of a combination of water saving measures and water metering shows that the full costs of the proposed measures can be recovered through an increase in existing water prices, independent of when the information about the water delivery will be made available.

This ex-ante economic evaluation provides critical input for the design of a more effective water management strategy, where farmers' preferences and acceptance of the technologies have been taken into account. This is in line with recommendations for effective and sustainable water resources management in water scarce areas (Hadizadeh et al., 2018).

6. Conclusion

Farmer preferences for water saving measures to reduce water supply uncertainty in one of the major irrigated areas in the Litani river basin in Lebanon was evaluated using a choice experiment. Results suggest that farmers are mostly concerned about their water security and are willing to pay a higher water price to have their water supply guaranteed. The manner in which water supply is managed i.e. either through catchment-wide installation of metering devices or the implementation of water saving measures at plot level such as assisted irrigation scheduling or drip irrigation, is not as important as long as the current status quo is avoided and irrigation water security is improved.

Despite farmers' aversion against institutional changes, the results reveal that farmers are willing to pay between 3 to 4 times more than the current water price, and on a volumetric basis rather than an area-based payment system that is currently used. Moreover, farmers are willing to pay more to support water management measures at their farm level than at the irrigation district level or river basin level. In fact, farmers show no support for water management measures at the basin level in particular related to improved water delivery information if this means that they have to pay earlier on in the year for their water. The estimated increase in farmers' willingness to pay is expected to cover the investment, operation and maintenance costs of the proposed new technologies. This study therefore provides important indications of anticipated future welfare gains as a result of future investments in water saving technologies and crop water needs information, the costs of which can be fully recovered from a simultaneous water pricing policy reform.

Acknowledgements

This work was carried out under the FP7-FOOD-CT-2009-245159 project SIRRIMED funded by DG Research of the European Commission and the project AGRISERVI funded by the Spanish Ministry of Science, Innovation and Universities under the European Regional Development Fund (ERDF) [AGL2015-64411-R (MINECO/FEDER)]. Useful comments provided by the journal's reviewers are gratefully acknowledged.

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Figure 1. Study area

Figure 2. Example of a choice set

Figure 3: WTP estimations for irrigation water by technology and age ($/100m^3)

Table 1: List of attributes and attribute levels underlying the choice experiment

Attributes	**Levels**
I. Water saving measure	- Installing drip irrigation on every farm (*DRIP*) - Assisted irrigation scheduling by extension service (*AIS*) - No measure to save water (*SQ*)
II. Water metering	- Installing surface water meters on every farm (*SM*) - Installing groundwater meters on every farm (*GM*) - No water metering (*SQ*)
III: Water delivery information date	- LRA will inform farmers by January (*WDJ*) - LRA will inform farmers by February (*WDF*) - LRA will inform farmers by March or later(*SQ*)
IV. Price for irrigation water ($/m3)	- 0.06 *(SQ)* - 0.07 - 0.10 - 0.13 - 0.16

Table 2. Descriptive statistics of the sample and the population from which it was drawn

Variable	Description	Sample		Study area[+]		
		Mean	Std. Dev.	Mean	Std. Dev.	t test (p-value)
AGE	Age of farmer (years)	51.25	12.29	48.25	5.4	2.97 (0.00)
SIZE	Cropping area (ha)	15.06	27.96	15.1	4.32	-0.02 (0.98)
SCARCITY	I believe water scarcity problems would increase in the coming years (Total disagree=1; Total agree=5)	2.66	1.63			
EXPWA	I plan my cropping pattern based on expected water allocation (Total disagree=1; Total agree=5)	1.55	1.14			
EXPRA	I plan my cropping pattern based on expected rainfall (Total disagree=1; Total agree=5)	1.66	1.32			
EXPPS	I plan my cropping pattern based on this year's expected sales prices (Total disagree=1; Total agree=5)	2.29	1.64			
EXPYBPS	I plan my cropping pattern based on last year's sales prices (Total disagree=1; Total agree=5)	1.83	1.41			
WATERU	Water use (m3/ha)	7,747.95	1,788.33	9100	535	-8.95 (0.00)
COOP	Cooperative (Cooperative membership =1; Otherwise=0)	0.19	0.39	0.20	0.40	-0.29 (0.77)
FAMILY	Family worker (number of family members working on the farm)	0.51	1.02	2	1.05	-5.70 (0.00)
		Percentage		Percentage		Pearson chi2 (p-value)
CROP	Crop type (%)					3.67 (0.30)
	Fruits	21.50		22.67		
	Horticultural	38.91		27.06		
	Cereals	26.62		31.02		
	Ohers	12.97		19.24		
DRIP	Farmers who own only drip	11.33		8		0.55 (0.90)
SPRINK	Farmers who own only sprinkler	52.66		56		
DRIP-SPRI	Farmers who own drip & sprinkler	32.66		33		
SURF	Farmers using surface irrigation systems	3.33		3		
STUDY	Highest level of education attainment					
	No education	12.00		6		3.48 (0.32)
	Primary school	10.67		16		
	Secondary school	36.67		35		
	University	40.67		43		
INCOME	Farm income per year					
	<$3,000	26.43				
	$3,001-$,6000	22.14				
	$6,001-$9,000	15				

$9,001-$12,000	12.14
$12,001-$15,000	2.86
$15,001-$18,000	5
$18,001-$21,000	2.14
$21,001-$25,000	3.57
>$25,000	10.71

[+]Data provided by the Litany River Basin Authority.

Table 3. Estimated choice models

	Model 1 Clogit			Model 2 Clogit i			Model 3 RPL			Model 4 RPL		
	Coef.	Std. Err.	P>z	Coef.	Std. Err.	P>z	Coef.	Std. Err.	P>z	Coef.	Std. Err.	P>z
Mean												
SQ	-4.14	0.32	0.00	-3.10	0.55	0.00	-7.83	0.98	0.00	-7.13	1.60	0.00
DRIP	-0.50	0.25	0.05	1.15	0.65	0.08	0.89	0.41	0.03	1.60	0.31	0.00
AIS	-0.28	0.26	0.29	2.22	0.67	0.00	1.76	0.25	0.00	1.97	0.25	0.00
SM	-0.12	0.12	0.31	0.96	0.44	0.03	1.07	0.37	0.00	0.85	0.40	0.03
GM	0.03	0.23	0.90	1.77	0.90	0.05	1.31	0.56	0.02	0.86	0.52	0.10
WDF	-0.65	0.16	0.00	-1.19	0.27	0.00	-1.30	0.32	0.00	-2.36	0.60	0.00
WDJ	-1.59	0.21	0.00	-2.30	0.35	0.00	-4.04	0.69	0.00	-5.61	1.18	0.00
PRICE	-0.18	0.03	0.00	-0.19	0.03	0.00	-0.30	0.05	0.00	-0.32	0.07	0.00
*AGE*DRIP*				-0.03	0.01	0.00	-0.08	0.02	0.00	-0.13	0.03	0.00
*AGE*AIS*				-0.05	0.01	0.00	-0.13	0.03	0.00	-0.16	0.04	0.00
*AGE*SM*				-0.02	0.01	0.01	-0.07	0.02	0.00	-0.06	0.02	0.00
*AGE*GM*				-0.04	0.02	0.03	-0.08	0.04	0.06	-0.05	0.03	0.10
*INCOME*SQ*				-0.27	0.07	0.00				-0.34	0.13	0.01
*EXPWA*SQ*				0.00	0.13	0.99				0.14	0.35	0.68
*EXPRA*SQ*				-0.47	0.13	0.00				-1.23	0.37	0.00
*EXPPS*SQ*				0.07	0.09	0.44				0.20	0.21	0.33
*EXPYBPS*SQ*				0.27	0.10	0.01				0.95	0.27	0.00
*COOP*SQ*				-0.13	0.36	0.73				-0.45	0.78	0.56
*STUDY*SQ*				-0.30	0.13	0.02				-0.43	0.31	0.17
*SCARCITY*WDJ*				0.25	0.10	0.01				0.35	0.26	0.17
*SCARCITY*WDF*				0.19	0.08	0.02				0.32	0.16	0.05
SD												
DRIP[a]							1.11	0.27	0.00	0.82	0.18	0.00
AIS[a]							0.61	0.13	0.00	0.59	0.11	0.00
SM[a]							0.54	0.12	0.00	0.66	0.17	0.00
GM[a]							0.48	0.20	0.02	-0.57	0.31	0.07
WDF[b]							-1.16	0.32	0.00	0.98	0.47	0.04
WDJ[b]							-2.42	0.51	0.00	2.62	0.59	0.00
Log likelihood	-535.53			-482.37			-449.46			-420.28		
LR chi2	484.57			577.70			129.57			124.88		
Pseudo R2	0.31			0.37								
Number of farmers	118			118			118			118		
AIC	1087.06			1006.75			934.02			888.56		
BIC	1132.35			1125.45			1035.77			1024.22		

[a] log-normally distributed coefficients, [b] normally distributed coefficients

Table 4. Mean WTP for specific water saving measures ($/100m^3) and water saving and water metering measures at different timings of the water delivery information

Measure	**Mean**	**Std. Dev.**	**Min**	**Max**
Willingness to pay				
DRIP	3.51	9.37	-9.89	49.42
IAIS	2.54	9.67	-15.87	33.38
SM	-4.16	3.20	-10.01	10.39
GM	0.34	2.91	-10.19	8.81
WDF	-4.20	1.33	-8.01	0.46
WDJ	-13.04	4.57	-20.90	1.49
Consumer Surplus				
Water saving measures (March)	31.88	15.08	4.22	85.92
Water metering (March)	22.01	4.70	8.39	33.13
Water saving measures (February)	22.35	16.67	-9.71	79.91
Water metering (February)	20.87	5.45	4.51	32.36
Water saving measures (January)	13.02	17.01	-22.69	69.90
Water metering (January)	11.54	7.21	-9.16	28.78

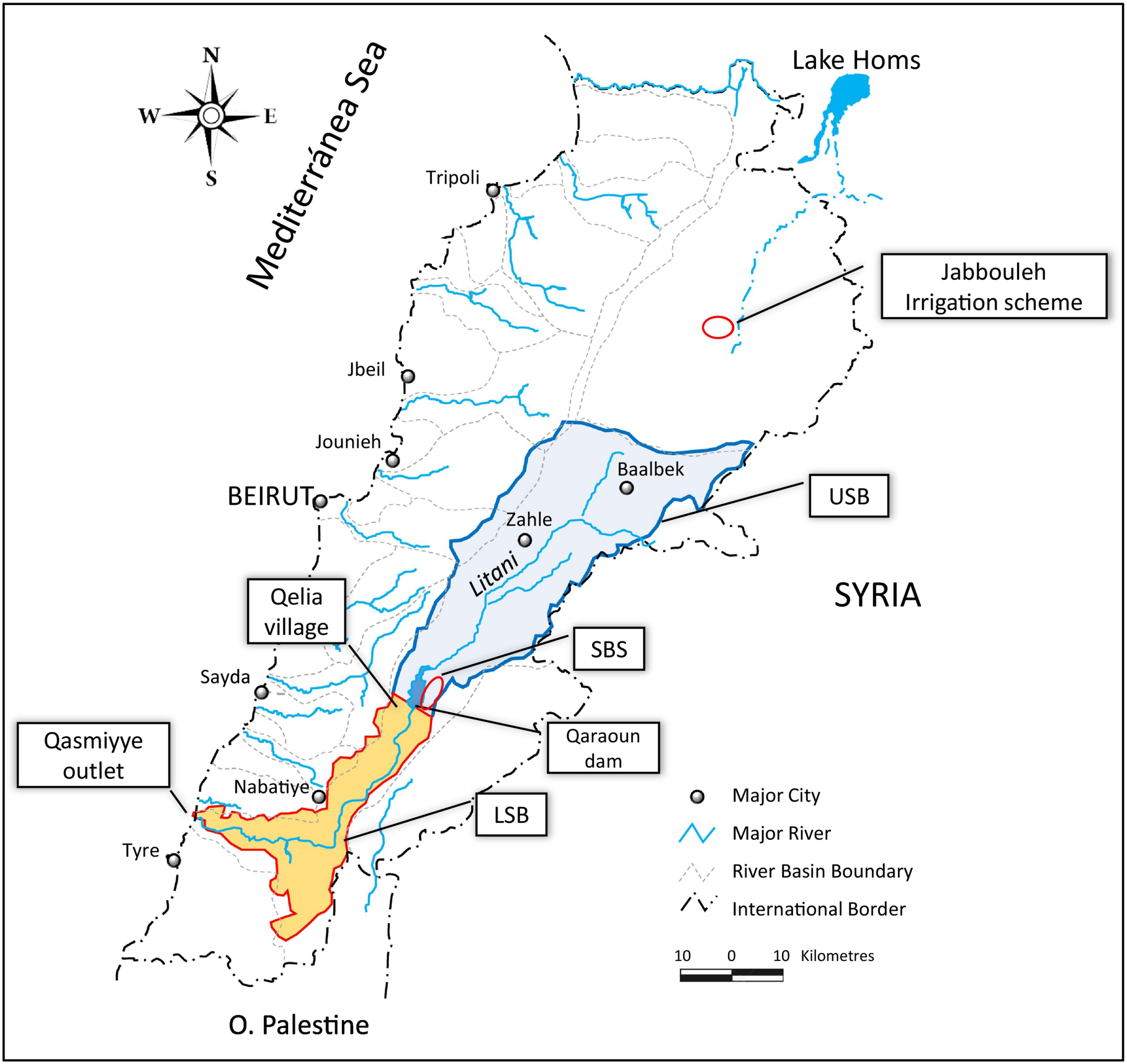
Table 5. Investment and operation costs of the water saving and metering measures

Measure	Investment concept	Cost ($)	Operational concept	Cost ($/yr)	EAC ($/yr)	EAC_{ha} ($/yr ha)
DRIP	Drip irrigation network including plot filter station	1,700,000	Maintenance and emitter lines replacement	134,000	338,410	169
LAIS	Agrometeorological stations and cloud services	43,000	Data management & processing, maintenance. Advising services	41,000	47,223	24
SM	Counters and remote monitoring system	165,000	Maintenance	20,000	40,353	20
GM	Counters and remote monitoring system	137,500	Maintenance	17,000	33,970	17

Source: own elaboration based on LRA communications.

Highlights

- Farmers are asked for their water security needs and preferences in a survey
- New water saving technologies are proposed at plot and irrigation district level
- Farmers are willing to pay higher water fees to secure water supply in the future
- New irrigation technologies and policies at plot level are preferred
- Investment costs can be recovered from water pricing policy reform


N
S
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Mediterránea Sea
Lake Homs
Tripoli
Jabbouleh
Irrigation scheme
Jbeil
Jounieh
BEIRUT
Baalbek
USB
Zahle
Litani
SYRIA
Qelia
village
SBS
Sayda
Qaraoun
dam
Qasmiyye
outlet
Nabatiye
LSB
Tyre
Major City
Major River
River Basin Boundary
International Border
10 0 10 Kilometres
O. Palestine

Figure 1

Please indicate the option you most prefer. You can also choose neither one of the two proposed options. If you choose 'Neither', you will not have to pay an increased water price, nor implement any water saving or water metering measure, you will be informed when water supply will be delivered later than February and your water supply will not be guaranteed. Below is an example of the card. Please consider the following are proposed measures that will come along with an increase in the price of irrigation water and your level of disposable income before answering this question.

	Option A	**Option B**	
I. Water saving measure	Installing drip irrigation	Assisted irrigation scheduling by extension service	**Neither**
II. Water metering in farms	Installing surface water meters	Installing groundwater meters	
III: Water delivery information date	LRA will inform farmers by February	LRA will inform farmers by January	
IV. Price you should pay for water used (€/m3)	0.10 $/m3	0.16$ /m3	
Please choose your most preferred option	☐	☐	☐

Figure 2

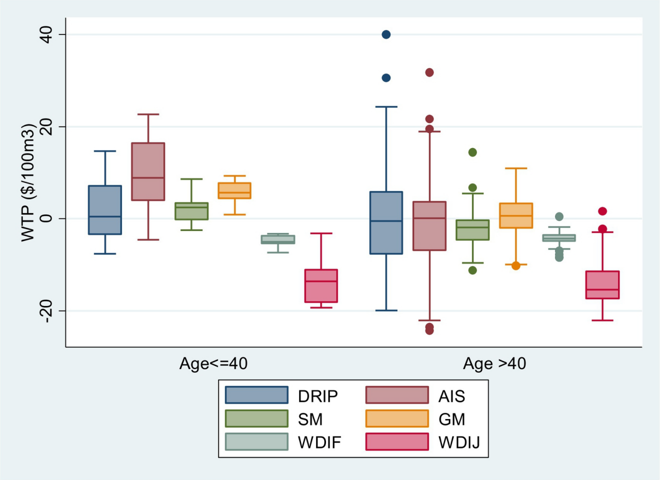

Figure 3