“Emerging agricultural hydrology problems in post-conflict Libya”

AUTHORS	Aman Ramali Garth Holloway
ARTICLE INFO	Aman Ramali and Garth Holloway (2012). Emerging agricultural hydrology problems in post-conflict Libya. *Environmental Economics*, *3*(2)
RELEASED ON	Tuesday, 10 July 2012
JOURNAL	"Environmental Economics"
FOUNDER	LLC “Consulting Publishing Company “Business Perspectives”

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
0	**0**	**0**

Aman Ramali (UK), Garth Holloway (UK)

Emerging agricultural hydrology problems in post-conflict Libya

Abstract

This paper develops a conceptual framework for analyzing emerging agricultural hydrology problems in post-conflict Libya. Libya is one of the most arid regions on the planet. Thus, as well as substantial political and social changes, post-conflict Libyan administrators are confronted with important hydrological issues in Libya's emerging water-land-use complex. This paper presents a substantial background to the water-land-use problem in Libya; reviews previous work in Libya and elsewhere on water-land-use issues and water-land-use conflicts in the dry and arid zones; outlines a conceptual framework for fruitful research interventions; and details the results of a survey conducted on Libyan farmers' water usage, perceptions of emerging water-land-use conflicts and the appropriate value one should place on agricultural-use hydrological resources in Libya. Extensions are discussed.

Keywords: emerging agricultural hydrology problems, post-conflict Libya, farmer's perceptions of agricultural water-use value, household survey, extensions.
JEL Classification: O13, Q15, Q25.

Introduction

Water scarcity is a fundamental problem in Libya as well as in other parts of the world. Water shortages are often due to problems of inequitable distribution. The management of existing water supplies in Libya is a case in point and one that could be dramatically improved. Previous studies on Libyan water supply exist, but are mostly focussed on domestic or household water demand. However, this focus neglects one fundamental under-researched subject which is the lack of sufficient hydrological sources in order to service agricultural water demand within Libya. In fact, the agricultural sector uses approximately 78 percent of all available Libyan water resources. Presently, policy within Libya amounts to supplying water freely to farmers; however, this free availability has led to potential inefficiencies in the allocation of this important and vital resource. The lack of knowledge about the relative values of groundwater resources used in specific agricultural activities, the lack of previous research, and the topical nature of the subject given the present political climate in Libya motivate the need for further research.

The notion that natural and non-natural resources should be attracted to those sectors within which their marginal value product is greatest, obviates the need for valuation of agricultural hydrological resource stocks. Thus, an enviable objective is the determination of such valuations. One present objective therefore, is to determine the economic value of water to sustain agricultural production by eliciting farmers' willingness to pay for water use for agricultural purposes in Libya using appropriate methodology. And another ancillary objective, in the absence of formal statistical enquiry, is to detail background that is important in the execution of formal methodology and present preliminary statistical results on water-use value. In this context, our paper has four, specific objectives. The first objective is to provide a detailed background into the agricultural hydrological issue motivating the need for additional empirical enquiry in Libya. The second objective is to lay out cogently the types of methodologies available for empirical investigations concerning Libyan agricultural hydrology resource evaluation. The third objective is to detail the survey methodology used to elicit willingness-to-pay values for agricultural water resources by Libyan farmers. And the fourth and final objective is, in the absence of formal statistical methodology, to present preliminary estimates as derived from the sample survey questionnaire and simple, multinomial-probit intervention.

The remainder of this paper is organized as follows. Section one presents background to the hydrological resource problems within Libya. Section two reviews extant methodology and selects one available methodology as the basis for formal enquiry. Section three outlines the survey methodology and details some important aspects of the survey methodology which, to our knowledge, are the first of their kind to be enacted within the Libyan agricultural sector. Section four presents some informal empirical estimates about farmers' willingness to pay for water resources in the Libyan agricultural sector. Finally, conclusions are offered.

1. Background

Libya is a Mediterranean country that occupies the North-central part of the African continent. The country has a total land area of approximately 1,759,540 km^2 of which the Sahara desert covers approximately 95%. Except for a narrow strip along the northern coast, which has a Mediterranean climate, the Libyan climate is mostly quite arid. One of the major constraints to Libya's agriculture is the scarcity of arable land; sandy soils are prevalent in most of the country and are subject to limited natural fertility. The cultivable area is estimated to be approximately 1.2% of the total area of the country (GAI, 2008). Most arable land is concentrated along the coastline, especially in the Jaffara Plain and the Jabal Alakhdar regions. In this narrow coastal strip, which represents about 2% of the total land area of Libya, irrigated agriculture and dry farming are widely practiced (GAI, 2008). The total population of Libya is estimated to be about 5.29 million people according to the most recent census, which occurred in 2006 (see Figure 1). An important distributional feature concerning the Libyan total population is that approximately 80% of it resides within the Mediterranean coastal strip.

Water resources occupy a prioritized situation when compared with other natural resources within the country. This prioritization should not be surprising because water is one of the important and vital resources deemed to have a strident impact on future economic and agricultural development within Libya. Thus, in summary, water resources and their distribution, in tandem with the distribution of the existing population within Libya, pose seemingly insurmountable problems. The lack of a viable 'water market' and the non-availability of private valuations of water resource stocks pose additional problems for administration. And these features of the present research environment raise considerable scope for nuanced empirical enquiry.

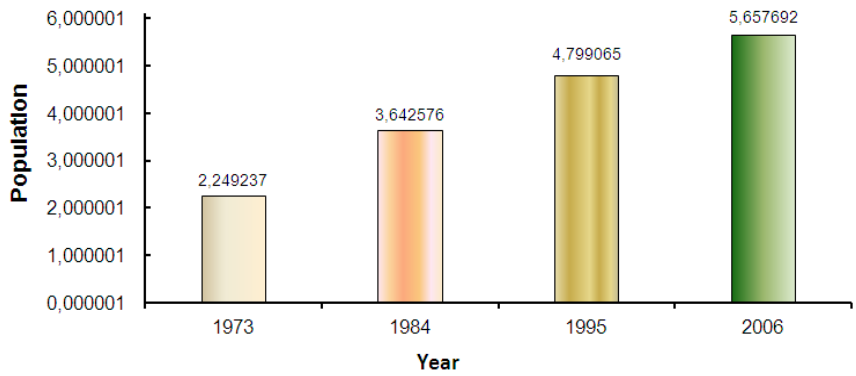

Fig. 1. Libyan human population growth 1973, 1984, 1995 and 2006

Libya is currently facing great challenges in meeting growing demand for safe water, the country being one of the most arid regions on earth. Despite the efforts of preceding administrations, the country is suffering from an unenviable shortage of water resources. The major previous efforts designed to mitigate the water-resource problem in Libyan household and agricultural water-demand include three ones, namely, the construction of dams; construction of seawater desalination, treatment plants; and, significantly, and more recently, inauguration of the so-called 'Man-made River Project.'

Water usage in the agricultural sector which represents the largest demand for available water resources in the country is especially challenging. According to previous work, in order to determine so-termed 'water balance' at the national level, which was initiated by the Libyan General Water Authority in 2005, groundwater supplies provide 95.6% of the total water supply. Surface water contributes 2.3% of the total amount used, whereas desalination of seawater and wastewater treatment comprise a small component of the overall water resource efforts, amounting to 1.4% and 0.7%, respectively. Agriculture has, by far, the highest consumption rate at approximately 78%, while the domestic sector consumes about 12%; industrial consumption, on the other hand, amounts to only about 10% of the total water extracted (LGWA, 2006).

Figure 2 shows the contribution of conventional and non-conventional water resources in Libya compared to available consumption quantities. According to the Libyan General Water Authority (2006), available data on water balances indicates that there is a major water supply deficit occurring in the Jaffara Plain basin region and a less significant deficit in the Jabal Alakhdar basin region. These disparities arise due to population concentration and demand for arable land in the north-western and north-eastern regions of Libya. There is, however, no water deficit in the southern (Murzuk and Kufra-Sarir) basins.

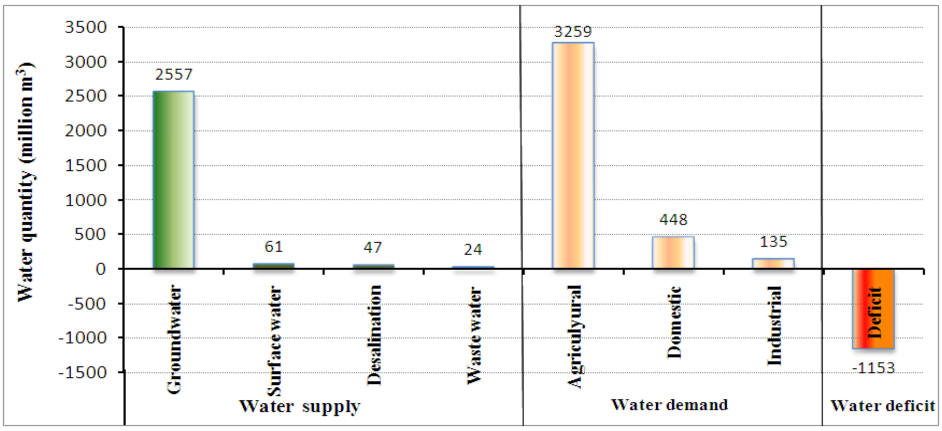

Fig. 2. Water availability and extant water demand 2005

Figure 3 illustrates water balance in the major water basins of Libya in 2005. Currently, most of Libya's water use comes from the Murzuk and Kufra-Sarir basins through the Man-made River Project to the northern regions. In 2006, the Libyan General Water Authority estimates the total water supplies from all water resources in the country to be around 3820 mm^3 per year (LGWA, 2006).

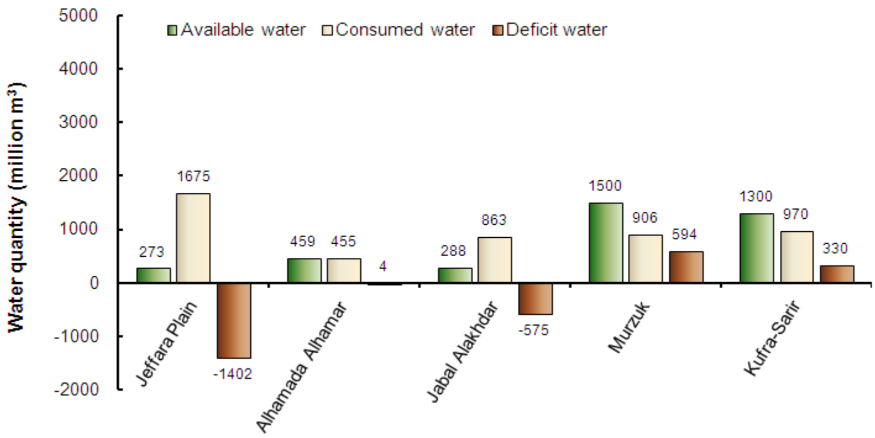

Fig. 3. Groundwater, availability, consumption and deficiency per basin in 2005

In summary, Libya faces extensive water-deficit problems presently and these water-resource shortages are anticipated to increase with Libyan water requirements growing rapidly. Present reports suggest that Libyan water deficit will exceed 4 billion m^3 in 2025. These features of the social laboratory raise enormous scope for the social scientist seeking to aid water valuation and the improved allocation of available resource stocks to their most prioritized needs. Inevitably, these issues raise additional scope in the adoption of appropriate methodologies for shedding light on issues.

2. Available environmental valuation techniques and available environmental valuation methodologies

Generally speaking, environmental valuation is based on the assumption that individuals are willing to pay for environmental gains and, conversely, are willing to accept compensation for environmental losses. The individuals demonstrate preferences, which, in turn, place values on environmental resources, that is, environmental goods and services (Bateman et al., 2002). Environmental goods and services such as attractive landscapes, endangered native vegetation and specific wildlife species cannot easily be valued in the same way that we typically value market-traded goods and services due to lack of available transactions.

Briefly, environmental valuation aims to estimate the non-use values, and there are essentially three distinct ways in which we are able to do this. In recent decades, environmental and natural resource economists have developed the three methods known, respectively, as 'market-based methods', 'surrogate market approaches' or 'revealed preference techniques'; and 'simulated market approaches' or 'stated-preference techniques'. Whereas market-based techniques provide estimates that are grounded in real-market prices, simulated- and surrogate-markets techniques are desirable where actual prices for environmental goods or services are not available. Figure 4 presents some of these techniques and classifies them according to the basis of their monetary valuation, either market-based, surrogate market or non-market based.

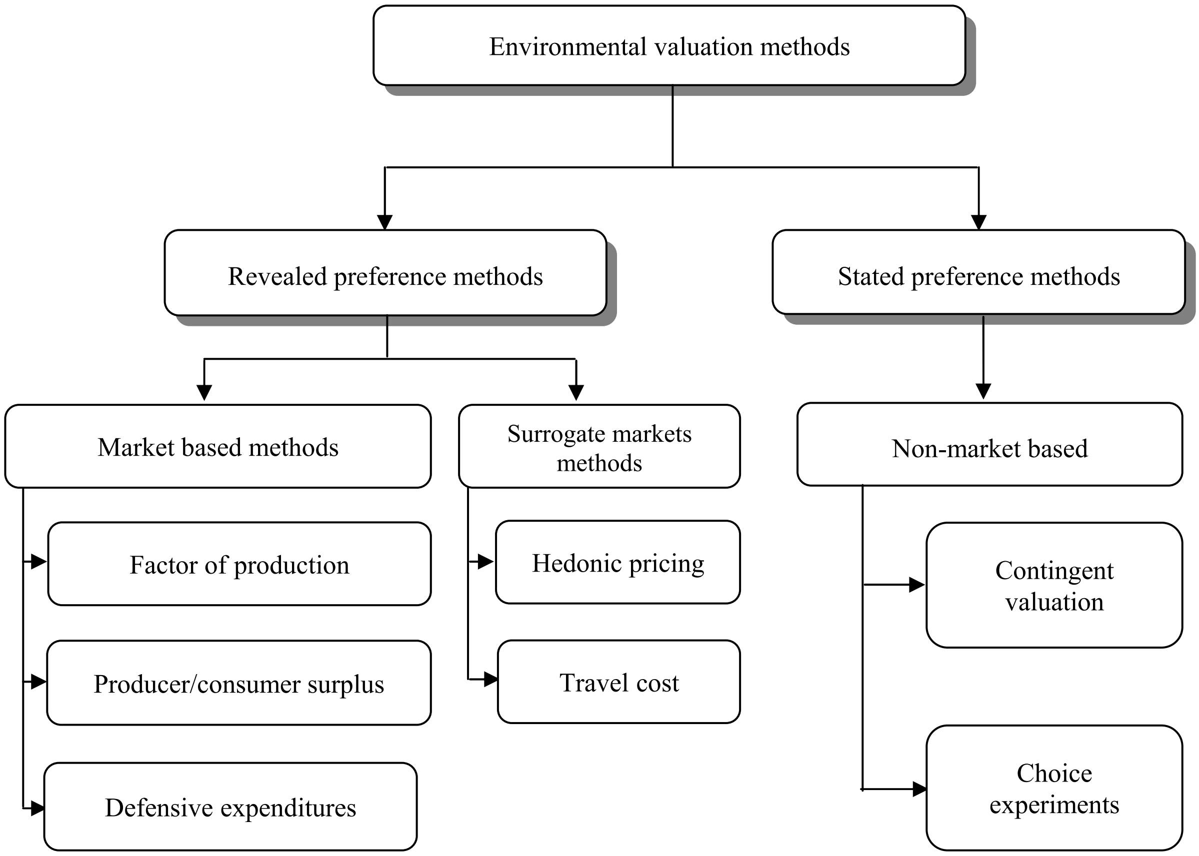

Fig. 4. Schematic representation of environmental valuation techniques

Briefly, and in summary, a variety of available methodologies exist for nuanced enquiry concerning the prices of water resources throughout Libya. Yet, to our knowledge, none of these techniques have as yet been employed in order to ascertain the values one should place on extant water resource stocks within Libya. Hence, scope exists for enactment of formal enquiry using appropriate survey techniques.

3. Choice experiment design

Because it does appear to be a favored methodology in previous water-resource work, we have elected to adopt a formal choice-experiment methodology. Thus, in what follows, we outline the choice-experiment survey methodology that we employ, describe the questionnaire and highlight several significant features of the survey enabling preliminary estimates of water-resource valuation.

3.1. Experimental design. In this section we outline our basic empirical approach to estimating willingness-to-pay. The essential step in choice experiment study is designing the questionnaire (Hensher et al., 2005a). Establishing the choice experiment question-naire depends primarily on consultations with groups of relevant individuals, known as focus group discussions (Blamey et al., 2000). These consultations help to generate the type of information that should be included in the questionnaire such as determining the relevant attributes and their levels. In other words, the main objective of focus-group discussions is to collect information that cannot be obtained using other methods. In order to achieve this objective, three focus groups were carried out in order to help and design the choice experiment questionnaire. The identification of the attributes and their levels for the choice experiment questionnaire are provided in Table 1.

In general, the focus resides in establishing willingness to pay for specific attributes, in contrast to forecasting and prediction, and in this case the ‘unlabelled experiment’ is preferred (Hensher et al., 2005b). The unlabelled experiment is defined as the one which does not name the alternatives. Where the title *Alternative* 1 or *Alternative* 2 does not convey any information to the respondent other than ‘this is simply the first alternative’. Using the so-called ‘full factorial design,’ the full number of possible choice sets, is equal to L^A for unlabelled choice experiments, where L is the number of levels and A is the number of attributes (Hensher et al., 2005b). Consequently, applying the full factorial design for A = 4 attributes each with L = 4 available levels yields 256 (= 4^4) possible choice sets.

Table 1. Water attributes and attributes levels used in the choice experiment design

Attribute	Description	Level
Water quantity	'Water quantity' refers to the amount of available water for agricultural purposes, which have effect on the cultivated area and the type of crops cultivated. This attribute has four levels.	Partial sufficient: Means that the available amount of water can meet 25% of the needs of farm water. Average sufficient: Meets 50% of the needs of farm water. Sufficient: Meets 75% of the needs of farm water. More than sufficient: Meets all of the needs of farm water.
Water quality	The total amount and the kinds of salts present in the water which determine its suitability for use for agriculture. Salt presence in Libyan water resources is usually perceived to be the main impediment restricting water application.	Poor water: Its use is restricted to well-drained permeable soil in production of salt tolerant crops. Good management practices must be used in order to maintain good physical condition of the soil. This water should not be used without advice from trained in irrigation water use. Fair water: It can be used successfully for most crops if care taken to prevent accumulation of soluble salts including sodium in the soil. Good management and irrigation practices must be followed for this water. Good water: It is suitable for use in most crops under most conditions. Excellent water: The total soluble salt content and sodium percentage of this water are low enough that no problem should result from its use.
Water reliability	A measure of the overall stability of water supplies that the government is able to provide to farmers demanding hydrological resources.	Partially reliable: Water supplies can be relied upon to provide 25% of water demand. Average reliable: Water supplies can be relied upon to provide 50% of water demand. Reliable: Water supplies can be relied upon to provide 75% of available water. Heavily reliable: Water supplies can be relied upon to provide 100% of available water.
Price	The price would necessarily impact the water use in agriculture.	0.20 Libyan Dinar/m^3 0.25 Libyan Dinar/m^3 0.30 Libyan Dinar/m^3 0.35 Libyan Dinar/m^3

One benefit of using a full factorial design is that all of the main effects and their interaction can be estimated independently from one another (Hanley et al., 2001), confronting respondents with 256 choice sets will place a significant level of cognitive burden on each participant, in addition to likely decreasing the rates of response and response reliability. To reduce the number of choice sets given to respondents, the so-called *fractional factorial design combined with an appropriate blocking* strategy was used. The fractional factorial design is used to generate the smallest orthogonal design, where all attributes are statistically independent of one another in the orthogonal design. It allows an investigation of main effects without detecting all interactions between attributes (Hanley et al., 2001).

In order to generate statistically efficient design and make the choice experiment simple, SPSS statistical software was used to generate the design (SPSS, Version 15). The SPSS software ensures that the design which is generated will be orthogonal. The design so determined consists of only the main effects. The program creates 32 choice sets, which are blocked into four partitions by using an appropriate blocking strategy. The blocking attribute contains four levels. In essence, therefore, the design has been broken down into four different partitions, each with eight distinct choice sets. Consequently, four varied versions of the survey questionnaire are used with each version comprising eight choice sets. An example of a choice card is provided in Table 2.

Table 2. Illustrative choice set within the questionnaire

Attributes	Option A	Option B	Option C
Water quantity	Partially sufficient 25%	More than sufficient 100%	Partially sufficient 25%
Water quality	Salty poor	Poor water	Excellent water
Water reliability	Partial reliability 25%	Average reliability 50%	Partial reliability 25%
Price	Free of charge	0.30 LD	0.25 LD

Note: Please tick only one Option.

3.2. Survey questionnaire interventions, design and administration. Developing and designing the questionnaire was one of the main tasks of the overall research study. The questionnaire comprises four parts. The first component of the questionnaire contains a detailed description of each attribute and its levels. The second component of the questionnaire includes eight choice experiment questions, which constitutes the main part of the questionnaire aimed to establish willingness to pay for specific water attributes across the respondents. Immediately following the choice experiment questions, in a third component of the questionnaire, are three questions aimed at eliciting the attitudes of the farmers in their answers to the choice sets. In accordance with Bennett & Blamey (2001), these questions were related to the ability to understand the choice experiment questions and the degree of difficulty in answering the questions. These questions were measured on a Likert-scale ranging from one (= strongly disagree) to five (= strongly agree). This component of the survey also includes additional questions aimed at providing some form of context for the day-to-day, on-farm production decisions that have likely impacted the respondent's willingness to pay evaluation. Essentially, the question contains four statements that describe the reasons for selecting the current situation within the questionnaire. Finally, the remainder of the questionnaire solicits socio-demographic information that is conjectured to have an important impact on respondents' willingness to pay. As well as providing some idiosyncratic basis for the related characteristics of the farms in question, this component is used to obtain information on the characteristics of the farmers and their farms with the notion that these covariate quantities may be used in regression interventions in which one may wish to 'control' for additional factors that reside outside our narrow purview of marginal willingness to pay evaluation.

3.3. Survey sites and respondent selection. Libya, in general, comprises five agro-ecological zones, each with limited water resources and limited water availability. The Jaffara Plain and Jabal Alakhdar are considered the most important agricultural regions within the country, and are the most affected by water-shortage problems. More than 75% of the Libyan population is concentrated in these two regions (GAI, 2008). For these reasons emphasis is given to these two regions as study-site areas for this research. The prevailing climatic conditions within the two regions are typically Mediterranean, where the rainfall is erratic in quantity, in frequency and in distribution (El-Darier & El-Mogaspi, 2009). The uses of available land in these regions depend upon the degree of aridity with most agricultural crops being irrigated. In view of these adverse factors, groundwater extraction rates increase to meet the growing water demand in both regions. Groundwater is considered the main water resource and most of the agricultural activities depend upon groundwater supply for irrigation while water supply from the *Man-Made River Project* represents the second water resource in these study regions (LGWA, 2006).

The second stage of the sampling involved selection of the districts within the general geographic sites. The districts are selected in order to represent the main agricultural districts suffering from water shortages and increasing the demand for water to use for agricultural production. Subsequently, we select villages from districts in each region. The selection of villages is based on current water resources as well as being the largest villages in terms of number of farms and farmers. The respondents are typical farmers selected within each village due to their responsibility of making farming decisions. In each village, 200 farmers are selected, yielding a total of 400 households in the entire survey.

The choice data were collected from farmers in the Jaffara Plain region and the Jabal Alakhdar region in Libya between March and July 2010 using face-to-face interviews. Compared with other methods, face-to-face interviews are commonly used in developing countries, because the mail, telephone and Internet infrastructure is limited, poor and often quite costly (Bateman et al., 2002). Nevertheless, it must be acknowledged that there are risks associated with how farmers perceive attributes and, more specifically, how they perceive their levels in choice-experiment design, the cognitive burden of the exercise, in general, and a host of additional factors about which the investigator must be cognizant when conducting face-to-face interviews. In summary, taking appropriate account of all ancillary cautions in order that the sample is representative of actual respondents across Libya's emerging water-land-use complex, we obtain a total of 400 completed questionnaires with the division of 200 from each of two respective zones. Given the eight choice sets confronting each of these 400 respondents, the overall questionnaire activity yields a panel of 3200 observations from which to extract the willingness-to-pay-information that we seek.

4. Empirical models and results

At this stage we are in the process of exploring the data for additional nuanced enquiry. Presently, we report the results of several preliminary investigations using a selection of the full covariate base that the questionnaire contains. Subsequently, we discuss possible extensions by which we hope to substantiate the validity of the preliminary empirical estimates reported within this section.

4.1. Canonical interventions. We estimate our preliminary empirical model using the Bayesian methodology outlined in a series of contributions by McCulloch and Rossi (1994), McCulloch, Polson and Rossi and Nobile (2000). The estimation of the multinomial probit model was performed in three stages and the purpose of this section is to outline the stages.

First, estimation of the model was enacted with only the water attributes included. The basic model with only attributes as the explanatory variables serves as an essential starting point for modelling (Hensher & Greene, 2003). Therefore, the multinomial probit model with water attributes of alternatives is what we refer to henceforth as our 'baseline model.' In this setting, the analysis looked only at the empirical relevance of the water attributes, which means that the model was estimated including neither additional explanatory variables related to socioeconomic characteristics nor attitudinal variables. In essence, this first formulation explains the choices between the alternatives only as a function of their attributes which allows the investigation of the trade-offs between the attributes without adherence to extraneous factors.

Second, in order to determine the joint effects of the attributes and explanatory variables a second intervention was enacted consisting of the water attributes together with all of the available covariate information that we deemed to be relevant to the study. The socioeconomic variables that were included in the survey and thus in this comprehensive and collective second formulation were covariates that are suggested by both economic theory and by previous choice experiment studies (Birol et al., 2006; Kragt and Bennett, 2011). The major motivating influence bringing us to estimate this second formulation is simply that we expect that the socioeconomic characteristics of the respondents may play a crucial role in respondents' willingness to pay for agricultural hydrology stocks.

Finally, our selection of models contains a third formulation within which both water attributes and a few selected socioeconomic variables are included. This third formulation is motivated out of the likely occurrence that inclusion of all available covariate information (formulation two) may weaken inference about marginal willingness to pay as retrieved from the probit due to attendant concerns for multicollinearity in the design matrix.

In order to estimate the multinomial probit model, we employ a standard Gibb-sampling algorithm as derived by McCulloch and Rossi (1994) and modified subsequently by Nobile (2000) following earlier advances that ushered in the Gibbs-sampling revolution in Bayesian inference (Gelfand and Smith, 1990). A useful and highly readable introduction is contained in Casella and George (1992) and a review of the implications of the technique since 1990 is contained in Gelfand (2000). In order to discriminate between models we evaluate the evidence in favor of a particular model by computing what is referred to as the 'marginal likelihood' of a particular model. The comparison across models is then easily derived by computing the posterior probability in favor of a particular formulation which is based intrinsically on the essential input which is the marginal likelihood. Outline of the theoretical measure is developed for the normal linear model in Zellner (1971, pp. 306-312). The multinomial probit model can be evaluated in a similar fashion, except that we must draw on the output of the Gibbs sample in order to derive inferences which is done by simply extending the Gibbs algorithm in a logical way. At this stage, within this preliminary investigation, we compare only these three canonical forms. And while our ultimate intent is to enact a comprehensive model-selection exercise across the entire sample space derived from the totality of potential competing models, we emphasize that the marginal-likelihoods comparison is necessarily restricted.

4.2. Sample willingness to pay quantities. Deriving the preferred estimate of willingness to pay for water use for agricultural purposes is a principal objective and the estimates of the preferred multinomial probit model are used to obtain farmers' marginal willingness to pay and to investigate how preference heterogeneity affects value estimates. After developing Gibbs sampling methodology for each multinomial-probit formulation, the resultant marginal willingness to pay estimates derived from the preferred model are derived. The estimates are presented in Figure 5. The preferred model and thus the reported willingness to pay estimates explain choices between the alternatives solely as functions of their attributes. This finding is particularly convenient. It is convenient because it allows investigation of the trade-offs between the attributes without consideration of further complex relationships. Because the preferred model is devoid of additional 'control' factors, the estimates so obtained permit interpretation as marginal willingness to pay 'averages' for a change in each of the attributes. This point is argued further in Hanemann (1984).

The willingness to pay estimates in Figure 5 show the willingness to pay for a change in one unit of the attribute keeping all other water attributes constant. The results reveal that the total amount that a farmer is willing to pay for water use in agriculture amounts to approximately 0.36 LD/m^3. This result is not too inconsistent with the result obtained from focus groups discussions, where participants initially agreed on a maximum of about 0.35 LD/m^3 of water use for agricultural purposes. Also, according to the annual farm income in the sample during 2009, the total willingness to pay estimate represents approximately 12% of annual gross farm income, which is significant and underscores, further, the importance, and the significance in perceptions across farms, that water is a highly valuable, constraining resource in Libyan agricultural production.

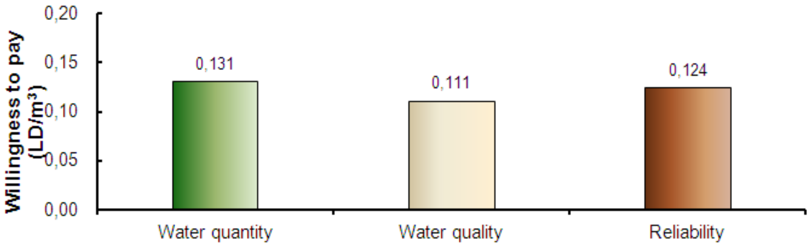

Fig. 6. Willingness to pay estimates

4.3. Factors affecting farmers' willingness to pay. In this section we reference, briefly, ancillary findings related to other factors affecting marginal willingness to pay estimates, which arose throughout the course of considering additional variants of the models. Results confirm a selection of factors that influence positively farmers' willingness to pay, namely, age, education level, farm income, farm ownership, irrigated area and farmer perceptions about water scarcity. These variables appear to be significant factors that influence choices to pay for water supplies and inflate its private values across the sample respondents. In other words, these variables contribute positive increments in addition to preferences. These variables are found to be significant factors influencing farmers' willingness to pay for water use for agricultural purposes in the surveyed areas of Libya. On the other hand, the posterior means of the remaining variables, namely, water consumption and cost of water pumping have negative impacts on farmers' willingness to pay. In fact, these factors are indicative of the reasons that farmers are unwilling to pay for water use within the agricultural sector. In particular, a negative relationship is observed between both consumption of water and the overall cost of water pumping. Consequently, we can state unequivocally that farmers who consume large amounts of water incur substantially higher costs of water pumping and that increases in water-consumption and attendant increases in water-pumping costs decrease farmers' willingness to pay for agricultural hydrology flows.

4.4. Respondents considerations of water attributes. Table 3 presents the results of ancillary information which we deem to be important.

Table 3. Water attributes affecting marginal willingness to pay valuations

Water attributes	Percentage of farmers considering the attribute in valuation
Water quantity	34.00
Water reliability	28.00
Water quality	24.75
Water pricing	13.25

Typically, in choice experiment studies it is assumed that respondents consider the totality of every attribute within and between alternatives when making their choices. However, in reality, respondents are sometimes more concerned about one specific attribute than others when choosing between alternatives within the choice sets. In our questionnaire, therefore, farmers are asked about which attribute they considered to be most important when choosing between alternatives. It was found that 34% of farmers included in the sample considered water quantity when choosing between alternatives in all choice sets as the most important attribute in their psychometric calculations (table 2) and brings us to conclude the following.

Conclusion

Presently, the policy of the Libyan state is to supply water free of charge to farmers. Free availability and lack of additional management cohesion, especially during and post recent conflicts, encourages excessive use by farmers, leading to inefficient use of this important and vital resource within Libya's agricultural sector. In this paper we present background to the water-land-use dilemma throughout key geographic regions in the water-land-use complex and we motivate the need for additional quantitative information that sheds light on the important problem of valuing water use and water resources within Libyan agriculture. We anticipate that the results derived here may be useful, ultimately, in assisting policy-makers to undertake appropriate actions in order to ameliorate the water shortage problem, nationally, and especially in highest deficit areas where the likelihood that even higher valuations exist. We have presented preliminary estimates on the precise valuations of the attributes of typical water supply and have identified some ancillary, socio-demographic factors that influence valuation rates. We have also emphasized that the results here are subject to criticism to the extent that we have yet not evaluated the totality of combinations of competing models across the full, covariate design matrix and the likelihood that some of the valuations presented here, if not the thematic conclusions, may be subject to change. Further work with the sample survey and the multinomial probit framework is needed in order to derive more robust conclusions. The work continues in this direction.

References

1. Bateman, I.J., Carson, R.T., Day, B., Hanemann, M., Hanley, N., Hett, T., Jones-Lee, M., Loomes, G., Mourato, S., Özdemiroglu, E., Pearce, D.W., Sugden, R., Swanson, J. (2002). Economic Evaluation with Stated Preference Techniques, A Maunal, Edward Elgar Publishing Limited, Cheltenham, UK.
2. Bennett, J.W., Blamey, R.K. (2001). *The Choice Modeling Approach to Enviromental Valuation*, Edward Elgar Publishing Limited.
3. Birol, E., Karousakis, K., Koundouri, P. (2006). Using a choice experiment to account for preference heterogeneity in wetland attributes: the case of Cheimaditida wetland in Greece, *Ecological Economics*, 60, pp. 145-156.
4. Blamey, R.K., Bennett, J.W., Louviere, J.J., Morrison, M.D., Rolfe, J.C. (2000). A test of policy labels in environmental choice modelling studies, *Ecological Economics*, 32, pp. 269-286.
5. Bos, C.S. (2002). A comparison of marginal likelihood computation methods. COMPSTAT 2002 - Proceedings of *Computational Statistics*, pp. 111-117.
6. Casella, G., George, E.I. (1992). Explaining the Gibbs sampler, *American Statistician*, 46, pp. 167-174.
7. El-Darier, S.M., El-Mogaspi, F.M. (2009). Ethnobotany and Relative Importance of Some Endemic Plant Species at El-Jabal El-Akhdar Region (Libya), *World Journal of Agricultural Sciences*, 5, pp. 353-360.
8. GAI (2008). Statistics Book, General Authority for Information Yearly Book, Tripoli, Libya.
9. Gelfand, A.E. (2000). Gibbs Sampling, *Journal of the American Statistical Association*, 95, pp. 1300-1304.
10. Gelfand, A.E., Smith, A.F.M. (1990). Sampling based approaches to calculating marginal densities, *Journal of the American Statistical Association*, 85, pp. 398-409.
11. Hanemann, W.M. (1984). Welfare evaluation in contingent valuation experiments with discrete responese, *American Journal of Agricultural Economics*, 66, pp. 332-341.
12. Hanley, N., Mourato, S., Wright, R.E. (2001). Choice modelling approaches: a superior alternative for environmental valuation? *Journal of Economic Surveys*, 15, pp. 1-25.
13. Hanley, N., Wright, R., Adamowicz W. (1998). Using choice experiments to value the environment: design issues, current experiment and future prospects, *Environmental and Resource Economics*, 11, pp. 413-428.
14. Hensher, D.A., Greene, W.H. (2003). The mixed logit model: The state of practice, *Transportation*, 30, pp. 133-176.
15. Hensher, D.A., Rose, J., Greene, W.H. (2005a). Applied Choice A Primer Analysis, Cambridge University Press, Cambridge, UK.
16. Hensher, D.A., Rose, J.M., Greene, W.H. (2005b). Applied Choice Analysis A Primer, Cambridge University.
17. Kragt, M.E., Bennett, J. (2011). Using choice experiments to value catchment and estuary health in Tasmania with individiual preference heterogenity, *Agricultural and Resource Economics*, 55, pp. 159-179.
18. LGAA (2008). Features of the national strategy for food security in Libya, *Libyan General Authority for Agriculture*.
19. LGWA (2006). Water resources of the Libyan Arab Jamahiria, Libyan General water authority, Tripoli, Libya.
20. McCulloch, G. and P. Rossi (1994). An exact likelihood analysis of the multinomial probit model, *Journal of Econometrics*, 64, pp. 207-240.
21. McCulloch, G. and P. Rossi (2000). Reply to Nobile, *Journal of Econometrics*, 99, pp. 347-48.
22. McCulloch, G.N. Polson and P. Rossi (2000). A Bayesian analysis of the multinomial probit model with fully identified parameters, *Journal of Econometrics*, 99, pp. 173-193.
23. Nobile, A. (2000). Comment: bayesian multiniomial probit models with a normalization constraint, *Journal of Econometrics*, 99, pp. 335-345.
24. Zellner, A. (1971). *An Introduction to Bayesian Inference in Econometrics*, New York: Wiley Classics Library Edition.