Sustainable water management and resource recovery and reuse contracts in agricultural in Burkina-Faso for Ecosystem Services sustainability: Using choice experiments to estimate the farmers' welfare.

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Abstract

This paper describes the results of a choice experiment measuring social benefits for sustainable management practices related to water and resource recovery and reuse solutions in agricultural in Burkina-Faso for ecosystem services preservation. Sustainable management is conceptualized with four illustrative practices that impact water availability, water save, soil restoration, soil fertility improvement and productivity growth: storing water with small water infrastructure in rainy season, complete fresh water with waste water from household, watering crop with drip irrigation and fertilizing with organic matter of sludge from septic tank (human faeces). Data for a choice experiment are collected using a face-to-face survey of farmers practicing off-season production in two region (Dano and Ouagadougou) in Burkina-Faso. Results identify substantial benefits for ecosystem services preservation, the use of small water infrastructure, drip irrigation, waste water and organic matter from human faeces. Results also suggest that the estimated household benefits of all fours sustainable management practices combined are similar in magnitude to the benefits from ecosystem services alone. Based on model results, policy and future research may wish to examine possibilities for subsidizing sustainable management practices in urban-influenced areas as a more cost-effective means of providing benefits similar to those realized through ecosystem services sustainability.

Key words: Choice experiment, Water, Organic matter, Drip irrigation, Burkina-Faso.

1. Introduction

Understanding the economic value of nature and the services it provides to humanity has become increasingly important for local, national, and global policy and decision making (Turner et *al.*, 2010). Ecosystems directly or indirectly provide a wide range of vital goods and services such as supporting services, regulation services and cultural services (Lui et *al.*, 2010; Pedrono et *al.*, 2015). Supporting services (nutrient recycling, soil formation and retention, oxygen production, primary production of biomass etc.) are the prerequisite for three other sets of ecosystem services provisioning[1], regulating[2] and cultural[3] (Chevassus-au-Louis et *al.*, 2009; Dupras et *al.*, 2013; Pedrono et *al.*, 2015). However, ecosystems are increasingly subjects of serious degradation in regard to their ability of providing services (Dupras et al., 2013). Indeed, ecosystem services are generally influenced by human activities on the one hand and climate change on the other. Human activities affect ecosystem services mainly through agricultural practices such as intensive use of chemical fertilizers and pesticides, which cause the degradation of land leading to soil erosion, nutrient runoff and sedimentation of waterways (Zhang et *al.*, 2007). Ongoing climate change is expected to reduce water supply in arid and semiarid areas and also negatively impact water quality (Wang et *al.*, 2015). Also, climate variability will generate two major phenomena in the Sahel like frequent droughts and dry spells increasingly broad may be observed between two rain events and a great uncertainty will concern the determination of the starting date and duration of the growing season (Karambiri et *al.*, 2011).

In Burkina Faso, where frequency of annual droughts and of extreme seasonal hot temperatures has increased, Agricultural Water Management (AWM) strategies have been extensively promoted by numerous development projects in the dry and vulnerable Sahel to improve agricultural productivity and generate livelihood benefits (Douxchamps et *al.*, 2013). These management strategies involve mainly the construction of borehole and reservoir for runoff water storage during the rainy season and the promotion of drip irrigation to save water use in agriculture. Add to this, resources recovery and reuse through the treatment of wastewater to supplement the amount of available fresh water and organic matter from sludge (human faeces) for soil fertilization. The recovery and reuse of wastewater can contribute to reducing poverty, improving food security, improving nutrition and health, and managing natural resources more sustainability to protect ecosystems and build climate resilient communities (Hanjra et *al.*, 2015). Wastewater use is seen as an essential component of local and national efforts to adapt to climate change and enhance food security (Wichelns et *al.*, 2015). Qadir et *al.* (2007), showed that yields of wastewater irrigated crops are often about 10–30 % higher than those of freshwater irrigated crops. According to Qatir et *al.*,2007; farmers preferred wastewater because it is a source of nutrients and enable using less chemical fertilizer in agricultural production. Organic waste recycling (human faeces, animal

[1] Food, fresh water, bioenergy, fibre, useful molecules, genetic resources, soil, air

[2] Climate regulation, disturbance regulation, flow regulation, water purification, air purification, disease regulation, erosion control.

[3] Inspiration, aesthetics, education, recreation, sense of belonging, cultural, scientific and educational heritage, spiritual benefits.

faeces, vegetable waste), in agriculture can enhance the efficiency of nutrient cycles and directly or indirectly reduce major and increasing sources of greenhouse gas emissions. It can also boost soil fertility and agricultural resilience to climate change (Wassenaar et *al.*, 2015). Solutions for water management in agriculture and the resources recovery and reuse are therefore strategies for ecosystem services conservation in the agricultural landscape in Burkina Faso (see Figure 1).

However, assessing the value of ecosystem service, or determining the monetary worth of the service provided by an ecosystem encourages people to pay more attention to the ecosystem and its role by providing both a theoretical and practical basis for utilizing and protecting the ecological environment (Wanga et *al*., 2015). In line with this purpose, the Research Program on Water, Land and Ecosystems (WLE) has initiated a New Project: "Invest in Water", Supporting Investment Decisions in Water and Land Management across the Rural-Urban Continuum in the Volta - Niger Focal Region including Burkina-Faso. In the framework of the Research Program on Water, Land and Ecosystems (WLE), four specific interventions have been selected in Burkina-Faso for a holistic analysis using ecosystem-based approach: (1) Small water infrastructure (SWI) for small holder irrigation; (2) Drip irrigation; (3) Safe and productive water reuse; and (4) Nutrient and organic matter recovery from human faeces.

In Burkina Faso, the researches on the economic valuation of ecosystem services mainly related to solutions for water management in agriculture and for the treatment of waste water and organic matter from human faeces are still limited. In addition, these solutions are designed to improve farmers's economic welfare in a context of climate change while preserving the environment health. As such, what is the potential of each of them to increase the utility / welfare of farmers? What are the most appropriate solutions for the preservation of ecosystem services? This research aim to identify the most appropriate or adequate solutions to improve the farmers' welfare while protecting the environment. Thus it will assist policy making by providing information about farmers demand decision for water management and resources recovery and reuse solutions in agriculture in Burkina-Faso. Specifically, this research attempts to analyze farmers' welfare from water management and resources recovery and reuse solutions using in agricultural.

2. Theorical framework

Several methods are used to estimate the value of ecosystem services. These methods can be divided into three main groups according to the principle of their basic analysis: methods based on (i) the observable cost; (ii) the revealed preferences; (iii) and stated preferences. In each category, there are a variety of appropriate techniques for each value. But only the methods based on stated preferences allow an assessment of the total economic value (see Table 1).

Estimating the total economic value of ecosystem implies the use of stated preferences methods. Contingent evaluation, which consists in directly requesting people their willingness to pay (WTP), remains the most widely used. But since two decades, it has been the subject of harsh criticism due to numerous biases encountered in its design as the ecosystem services do not have a price. This has led to the use of multi-attributes evaluation methods especially the choice experiment. It is considered as the Grail of non-market goods evaluation methods (Bennett and Adamowicz, 2001). The goal of this method is to assess population's marginal utility following a marginal change in the quantity or quality of ecosystem services. It stems from contingent evaluation and conjoint analysis but requests people to choose an ecosystem good based on its attributes (or characteristics) instead of classifying or evaluating it (Adamowicz and Boxall, 1998). It generally requires respondents to choose repeatedly (6-8 times) their preferred option from the status quo (current state) and a set of environmental goods options (Bennett and Adamowicz, 2001). Each alternative is described by attributes (characteristics) broken down into levels (qualitative or quantitative). The method aims to calculate the marginal rate of substitution (TMS) between the different attributes (Hanley et al., 2001). The questionnaire design requires the identification of the various attributes and their levels influencing the decision. In this research, the choice experiment is used to evaluate farmers' marginal utility from water management solutions and resources recovery and reuse in agricultural in Burkina-Faso.

3. Methodology

3.1 The choice experiment

The choice experiment presented here aims to provide policy-makers with the constraints that hamper farmers from changing production system and the institutional-economic conditions needed to convince them to use water management and resource recovery and reuse solutions in agricultural. The features of the water management and resource recovery and reuse in agricultural were selected on the basis with International Water Management Institute (IWMI), West African Science Service Center on Climate Change and Adapted Land Use (WASCAL) and International Development Entreprise (iDE) Burkina. The features have been discussed in focus group with farmers and the following attributes and levels of attribute have been selected for the choice experiment analysis. The table 2 presents the attributes features and levels.

The agricultural water management and resources recovery and reuse solutions are:

- **Small water infrastructure (SWI) for small holder irrigation**: Farmers in Burkina-Faso, produce vegetable crop in off-season with run-off water stored in reservoir in rainy season. Also, some farmers have boreholes built on shallow ground water for water supply. As water infrastructure, drilling is the most appropriated to supply water to farmers in all time.
- **Drip irrigation:** Drip irrigation is a method to supply water in small and frequent quantities to the root zone of crops through a system of perforated plastic pipes. Smallholder drip irrigation is widely held as a promising technology for water saving, poverty reduction and food security, especially in sub-Saharan Africa (Wanvoeke et *al*., 2015). Burkina Faso is one of the countries where development initiatives centred on the promotion of smallholder drip irrigation have multiplied over the last 10 years (Wanvoeke et *al*., 2015). The iDE

Burkina experimental work and also monitoring results of producers who use drip irrigation showed that the drip irrigation saves water, save time, reduce the hardness of watering, to produce in quantity and quality with a rapid return on investment. However, the farmers still practice hand watering with small buckets, small gourds, and they are constantly experiencing a water shortage for gardening activities in off –season.

- **Waste water treated:** In a context of scarcity of fresh water, waste water is increasingly used in urban and peri-urban agriculture and qualities depend on the source that is to say waste water from household and waste water from industries (Qadir et *al*., 2015). Sou, (2009) showed that treated wastewater from households contain a low content of heavy metals and therefore do not present any specific risk for vegetable products. Household wastewater is therefore an alternative to the water scarcity in agriculture. In Ouagadougou (Capital of Burkina-Faso), waste water is treated for peri-urban agricultural production but this practice is not yet extended to other areas of the country.
- **Organic matter from human faeces:** Widespread availability wastes of urban are alternative sources of nutrients for vegetable cropping (Kiba et *al*. 2011). Sludge from septic tank (human faeces) and from animal contains essential nutrients for plants (e.g. nitrogen and phosphorus) and is potentially a very beneficial fertilizer. The organic carbon in the sludge, once stabilized, has also potential as a soil conditioner because it improves soil structure for plant roots (Mateo-Sagasta et *al*., 2015). In the case of agriculture in general and vegetable production in particular, the use of chemical fertilizers is both a danger to soil degradation, crop contamination and health of the individual.
- **Monetary value:** This value represents the cost per 500 m^2 acre spent by farmers for water charge and chemical fertilizer. We now ask farmers how much they would be able to add or substrate to the current cost spent on 500m2 to accept the agricultural water management and resources recovery and reuse solutions. By doing so, we estimate the lower and upper WTP of farmers which has been considered as monetary value.

The five contract features and their different levels result in 3*2*2*2*6= 144 possible contract designs. This number was reduced to 18 choice tasks that were divided in 3 blocs of 6 choice tasks each based on a D-efficient main effects statistical design procedure in STATA Software. The table 3 present an example of choice set to be presented to farmers.

3.1 Econometric model

The Choice Experiment approach is consistent with Lancaster's theory of consumer choice (Lancaster 1966), which postulates that consumption decisions are determined by the utility that is derived from the attributes of a good, rather than from the good per se. The econometric basis of the approach rests on the behavioural framework of random utility theory, which describes discrete choices in a utility maximizing framework (McFadden 1974, Ben-Akiva and Lerman 1985). Statistical analyses of the responses obtained from choice experiment can be used to derive the marginal values for attributes of a good or policy with a more desirable combination of characteristics. Thus, it can be assumed that farmers, when asked to value different AWM and RRR solutions alternatives for ecosystem sustainability, make their choices on the basis of the specific AWM and RRR solutions features. The utility obtained from a certain AWM and RRR solutions profile is thus the sum of the utilities obtained from each of the five AWM and RRR solutions contract features. Random utility theory assumes that individuals aim to maximise their utility and thus choose the alternative (i) that renders most utility given by:

$$U_i = V_i + \varepsilon_i \quad (1)$$

U is the true but unobservable utility of an individual for alternative i, V is the deterministic and observable component of utility, and ε_i is a random variable that captures the unobservable influences on choice. V can be expressed as a linear function:

$$V_i = \propto_{0i} + \propto_{1i} X_{1i} + \propto_{2i} X_{2i} + \cdots + \propto_{Ki} \quad (2)$$

Where $\propto_{1i}$ is the marginal utility parameter associated with attribute X_1 and individual i, and $\propto_{0i}$ is the alternative specific constant. In this research, X represent respectively the change in water infrastructure (reservoir, borehole and drilling), irrigation system (hand irrigation and drip irrigation), waste water using in agricultural (use of waste water and no use of waste water), type of fertilizer (chemical fertilizer and organic matter from human faeces), monetary value.

The utility function is extended by a vector of random coefficients of the attributes X_k for individual i representing individual preference variation in (3). The utility coefficients vary according to individual i $\propto_i$ with a density function $f(\propto)$. The density can be a function of any set of parameters, and represents in this case the mean and covariance of $\propto$ in the sample population.

$$U_{ij} = \alpha X_{ij} + f(\alpha) X_{ij} + \varepsilon_{ij} \quad (3)$$

The equation (3) postulates that and individual i will choose an alternative j of the choice set C if the indirect usefulness of j is greater than that another alternative k.

The most fundamental model for the analysis of discrete choice data is the multinominal logit model (MNL) (McFadden, 1974). Due to several shortcomings of this model, random parameter logit models (RPL) are most widely used in choice data analysis. RPL relaxes the independence of irrelevant Alternatives (IIA) assumption of the MNL model and accounts for preference heterogeneity (Kanninen, 2007; Hensher et al., 2005).

3.3 Data collection

The questionnaire consists of three parts. In part 1, information was gathered on farm characteristics (the socio-economic characteristics of farmers' activities, farm size, farming activities). The second part elicited information about farmers' perception towards Agricultural Water Management and Resources Recovery and Reuse related ecosystem services in Agricultural. Their interest water management and resource recovery and reuse in agricultural and key requirements are elicited. The choice experiment was implemented in part 3. The survey was pretested in two rounds of interviews with 5 and 10 interviews, respectively. After the pretest minor modifications to the questionnaire were made, while the second pretest did not result in further changes. 300 farms were selected randomly in Dano and Ouagadougou based on a list of farmers. The survey was conducted in the form of face-to-face interviews with appointment with farmers in their farm during three weeks.

4. Results

4.1 Farmers' characteristics

The variables used in the analysis which are derived from the attributes and attributes level are described in the table 4. There are small water infrastructures, drip irrigation, waste water and organic matter. Farmers socio-economics characteristic are included in the model.

The opinion responses (not reported in a table) from the scale questions that followed the descriptions of the water management practices and resources recovery and reuse practices contracts show baseline respondent preferences. Over 90 % of respondents supported that borehole and drilling are more sustainable to supply water for off-season crop production. In their perspective, all the farmers support that drip irrigation contributes to save water and time comparing to hand irrigation. Hand irrigation is really painful to farmers due to fact that they must carry water far away to water their crop. Waste water using in agricultural received 70% of support that it could complete the fresh water at water scarcity period. Organic matter from human faeces received a positive support with 95.6% supporting or strongly supporting the practice. The remains expressing that for social reason it looks hard in the society to produce with human faeces. According to farmers, the chemical fertilizer cost is high and also its using contribute to soil fertility loss while organic matter especially from sludge of septic tank (human faeces) contribute to restore soil fertility.

4.2 Choice Experiment Results

As described above, respondents' choices were analyzed using a RPL model. The models have a decent goodness of fit with an estimated McFadden pseudo-R2 of 0.32 and 0.35, respectively (Table 4). A likelihood ratio test demonstrates the joint statistical significance of estimated model coefficients ($p<0.0001$). The model is also an improvement over a model specification with fixed (non-random) parameters at ($p<0.001$). The derived standard deviations of parameter distributions indicate the existence of heterogeneity in preferences among farmers for all of the contract design attributes. The alternative specific constant (ASC) is a dummy variable and has a value of 1 for the two contract options and 0 for no contract. It reflects the probability of not choosing one of the two contract options when holding all observable factors fixed. The negative sign of the ASC implies that farmers, all other things equal, are reluctant to move away from the status quo and choose one of the agricultural water management and resource recovery and reuse contracts. The hypotheses that agricultural water management (Reservoir, Borehole, Drilling and Drip irrigation) and Resource Recovery and Reuse (waste water and organic matter from septic tank) increase farmers utility and cost decreases utility cannot be rejected. The latter result validates the law of demand wherein an increase in contract cost decreases the probability a respondent will choose it. The results imply that farmers collectively favor the agricultural management and resource recovery and reuse solutions. As such, any management strategies related to those solutions would increase farmers' welfare.

The results provide evidence that the impact of agricultural water management and resource recovery and reuse on utility is heterogeneous. First, interacting socio-demographic variables with the status quo indicator (ASC) estimates observed heterogeneity. The statistically significant, negative parameter estimates suggests that respondents are more likely to select a contract. The statistically significant, negative parameter estimate for revenue suggests that an increase in respondent income tends to increase the probability of selecting a contract.

Second, heterogeneity is assessed in the RPL model by inclusion of a parameter examining the standard deviation of each contract attribute. The results show that homogeneous preference hypotheses can be rejected for the attributes: ASC, Reservoir, Boreholes, Drilling, drip irrigation, waste water and organic matter from septic tank. The normal distribution is centered on the mean contract parameter and is distributed according to the standard deviation parameter, implying that the distribution of utility for the choice attribute and the proportion of the population anticipating positive and negative utility. This approach shows that 98.8% of households associate increased utility with contracts that increase drip irrigation. Organic matter from septic tank, borehole and waste water increase utility respectively by 3.75%; 1.65% and 1.45%.

Conclusion

Water management and resources recovery and reuse in agricultural constitute a new strategy to build farmers' resilience to climate change. The findings of this research suggest that small water infrastructure (reservoir, borehole and drilling), drip irrigation, waste water and organic matter from septic tank support ecosystem services sustainability and contribute to strength farmers resilience to climate change. Those solutions have positive impact on farmers' welfare. Thus regional and national policy must invest on them in order to support farmers.

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Figure 1: Ecosystem services from agricultural water management (AWM) and resource recovery & reuse (RRR) solutions.

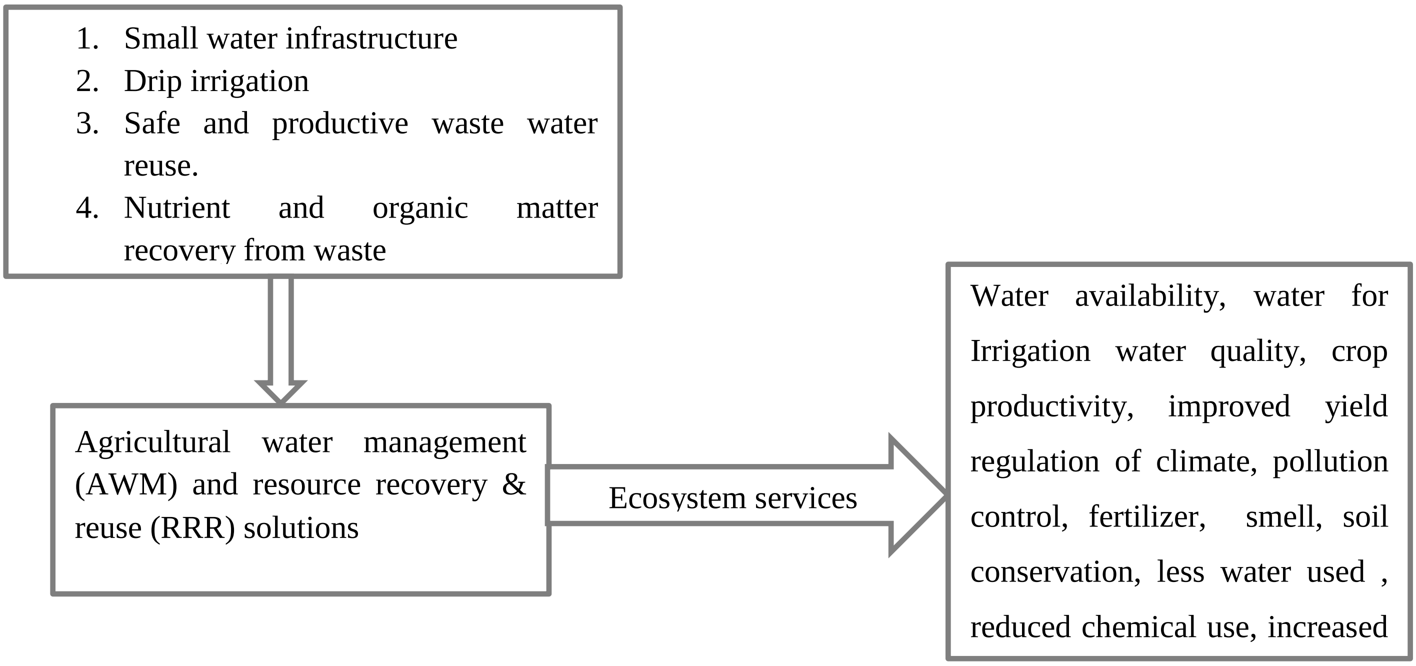

Table 1: Relation between assessment methods and the types of value

Approach		Method	Value
Market valuation	Price-based	Market price	Direct and indirect use
	Cost-based	Avoided cost	Direct and indirect use
		Direct and indirect use	Direct and indirect use
		Replacement cost	Direct and indirect use
	Production-based	Production function approach	Indirect use
		Factor income	Indirect use
Revealed preference		Travel cost method	Direct (indirect) use
		Hedonic pricing	Direct and indirect use
Stated preference		Contingent valuation	Use and non-use
		Choice modeling/conjoint analysis	Use and non-use
		Contingent ranking	Use and non-use
		Deliberative group valuation	Use and non-use

Source: Pascual et *al.* 2010

Table 2: Attributes and attributes level

Attributes	Attributes level
Small water infrastructure	Reservoir; Borehole; Drilling
Irrigation system	Hand irrigation; Drip irrigation
Waste water using	No waste water; Waste water using
Fertilizer	Chemical fertilizer; Organic matter from excreta
Cost F CFA per $500m^2$	12480 ; 14040; 15600*; 17160; 18720; 20280

15600* is the current cost from which we estimate the lower and upper WTP of farmers.

Table 3: Example of choice set

Choice	Contract alternative 1	Contract alternative 2	None of the two
Small water infrastructure	Drilling	Borehole;	
Irrigation system	Drip irrigation	Hand irrigation;	
Waste water using	Waste water using	No waste water;	
Fertilizer	Organic matter from human faeces	Chemical fertilizer	
Cost per $500m^2$	20280	17160	
Which contract alternative do you prefer	○	○	○

Note: Farmers must choose only one.

Table 4: Variables descriptions and summary statistics.

Variables	Mean (mini, max)
Cost (F CFA)	17532 (12480; 20280
Reservoir	0.2 (0, 1)
Boreholes	0.5 (0, 1)
Drilling	0.3 (0, 1)
Drip Irrigation	1 (0, 1)
Waste Water	0.8 (0, 1)
Organic matter	0.95 (0, 1)
Age	42.12 (23, 53)
Experience	15.23 (5, 23)
Education	0.12 (0, 1)
Revenue	250 302 (102000, 358 000)

1 Dollar USD= 600 F CFA

Table 5: Farmers preferences for agricultural water management and resource recovery and reuse for sustainable ecosystem services management: panel random parameter logit estimation.

Variables	Parameters	Std error
Random parameters		
ASC	-3.015***	0.562
Reservoir	1.251***	0.1423
Boreholes	1.652***	0.1412
Drilling	1.568***	0.124
Drip irrigation	2.901***	0.254
Waste water	1.782**	0.123
Organic matter	3.245***	0.192
Nonrandom parameters		
Cost	-0.035***	
Parameters on heterogeneity in status quo utility		
ASC*age	-0.022	0.016
ASC*Experience	-0.012***	0.003
ASC*Education	-0.965**	0.128
ASC*Revenue	-0.127**	0.452
Standard deviation of random parameters		
ASC	-3.242***	0.175
Reservoir	1.123***	0.164
Boreholes	1.652***	0.129
Drilling	1.456***	0.125
Drip irrigation	1.874***	0.136
Waste water	1.452***	0.152
Organic matter	3.754***	0.196