Farmers' adoption of agricultural innovations: A systematic review on willingness to pay studies

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Abstract

This study aims to conduct a systematic review on willingness to pay (WTP) as a proxy for adoption of agricultural innovations by farmers. It systematically looks at adoption of agricultural innovations in general as opposed to most previous reviews that focused on specific innovation dimensions. In addition, it reports WTP by farmers for the agricultural innovations and the determinants of WTP, but also analyzes the methods applied.

From a total of 6,211 articles that were collected from searching into web of science, 63 WTP studies were included in the review. The review revealed that majority (n=28) of primary studies that reported WTP by farmers focused on innovations targeted towards improved agricultural water provision while 23 of them focused on environmental improvement and the remaining 12 studies handled crop and animal improvement innovations such as high yielding varieties, biotechnology and animal resource conservation. Most of the studies are performed in developing countries using the stated preference methods for assessing farmers' WTP, with 54% of the studies (n=34) applying contigent valuation techniques while 32% (n=20) applied choice modelling approach. Farmers are genreally willing to pay premium for improvement in agriculture technologies. The WTP values (premium) reported depend on the innovation under considerations, for example, premium values ranged from about 0.125 to 2 USD/m^3 of water depending on the specific water provision systems e.g. ground versus surface water. The determinants of WTP by farmers can be grouped into socio-demographic, biophysical, technological, institutional and behavioural factors. In conclusion, this review demonstrates that farmers embrace most technologies, illustrated by relatively high WTP values regardless of the context they are involved and methods applied.

Key words: Farmers, willingness to pay, agricultural innovations, stated preference, premium

Introduction

Agricultural innovations have huge potential to increase food production, and improve health and nutrition (Carletto, Ruel, Winters, & Zezza, 2015; Patterson et al., 2017; Welch & Graham, 2005). Nevertheless, their adoption by farmers, especially smallholder farmers, has been slow and low (Jack, 2013; Kabunga, Dubois, & Qaim, 2012; Llewellyn, Lindner, Pannell, & Powles, 2007; Moser & Barrett, 2006).

Previous reviews on adoption of agricultural innovations have specifically examined single types of innovations, such as agroforestry innovations (Mercer, 2004), precision agricultural technologies (Tey & Brindal, 2012), agricultural management practices (Baumgart-Getz, Prokopy, & Floress, 2012), and conservation agriculture by farmers (Knowler & Bradshaw, 2007), resource-poor farmers (Pannell, Llewellyn, & Corbeels, 2014), South African small-holder farmers (Andersson & D'Souza, 2014) or rural landholders (Pannell et al., 2006). Without neglecting the contributions of these innovation-specific reviews, a more comprehensive review on all types of agricultural innovations is needed. More than two decades ago, Feder and Umali (1993) carried out such a review, though in a non-systematic way, which is known to increase the risk of selection bias(Pace et al., 2012; Wong, Cheung, & Hart, 2008).

Furthermore, regarding the factors that aid adoption, literature has remained rather inconclusive. A number of studies have found different determinants as important in making adoption decision by farmers (Arslan, McCarthy, Lipper, Asfaw, & Cattaneo, 2014; Kabunga et al., 2012; Mariano, Villano, & Fleming, 2012; Pannell et al., 2014). The failure to find unequivocal determinants of adoption by many studies could be related to the complex interaction of factors that influence farmers' decision making (Aubert, Schroeder, & Grimaudo, 2012; Marra, Pannell, & Ghadim, 2003; Meijer, Catacutan, Ajayi, Sileshi, & Nieuwenhuis, 2015) and the wide variety of methodological approaches applied by the researchers. The currently existing review studies not only target a specific type of innovation (Pannell et al., 2014; Prokopy, Floress, Klotthor-Weinkauf, & Baumgart-Getz, 2008), but many do not take in consideration the type of methods that are used to explain adoption by farmers.

This review aims to conduct a systematic review on farmers' adoption of agricultural innovations. Due to the wide diversity of methods reported in farmer adoption literature, our study specifically focuses on economic valuation studies, i.e. studies that elicit farmers' willingness to pay (WTP) for innovations that they have adopted or are intending to adopt. As the uptake of agricultural technologies often requires willingness and financial ability of farmers (M. Aydogdu & Yenigun, 2016; M. H. Aydogdu & Bilgic, 2016; Matuschke, Mishra, & Qaim, 2007), WTP is considered an important proxy for adoption or adoption intention for an innovation or a product (Marechera & Ndwiga, 2015; Tey & Brindal, 2012), especially in a developing country's context where (smallholder) farmers may have preferences for certain (aspects of) innovations but often fail to adopt them due to financial constraints (Binswanger & Pingali, 1988; Collier & Dercon, 2014; Douthwaite, Keatinge, & Park, 2001).

This study differs from past reviews on adoption of agricultural innovations in many aspects; (1) It offers the first systematic review on adoption of agricultural innovative practices by farmers, (2) while also looking at the wide spectrum of agricultural innovations; (3) It focuses on farmers' WTP as an important proxy of adoption, and (4) provides insights in the variety of economic valuation methods and the statistical models used to, respectively, analyze WTP and its key determinants.

Methods

Study selection

The scope of this review on farmers' WTP is intentionally broad to capture the breath of agricultural practices that are innovative in nature, without specifically relying on one type of innovation or technology/practice

Published articles were searched from Web of Science in January 2017 using combinations of key words and their synonyms. We took a broad definition of key words based on previous reviews covering the topics (and related topics) of farmers, WTP (as a proxy for adoption), and agricultural innovations (De Steur, Wesana, Blancquaert, Der Straeten, & Gellynck, 2016; Ingebrigtsen et al., 2014; Lewis & Pattanayak, 2012; Or & Karsh, 2009; Osborne et al., 2012; Pannell et al., 2006; Peek et al., 2014; Rosenstock et al., 2016).

The key words for farmers included: Farmer* OR "farming household*" OR "primary producers" OR landholder*. The key words for WTP, which were extended with synonyms for adoption to ensure that all economic valuation studies were included, are: adopt* OR accept* OR choice OR choos* OR preference* OR "willingness-to-pay" OR "willingness to pay" OR WTP OR "willingness-to-accept" OR "willingness to accept" OR WTA OR "willingness-to-adopt" OR "willingness to adopt". The key words for agricultural innovations included: innovation* OR intervention* OR technolog* OR "improved variet*" OR "plant variet*" OR "high yielding variet*" OR bioforti* OR Bt OR "GM crops" OR "genetically modified" OR GMO OR "iron pearl millet" OR "iron beans" OR "vitamin A maize" OR "vitamin A cassava" OR "orange sweet potato" OR "Zinc wheat" OR "zinc rice" OR "conservation agriculture" OR "conservation farming" OR "sustainable practices" OR "integrated pest management" OR fertilizers OR fertigation OR limining OR "organic agriculture" OR "organic farming" OR "best management" OR "precision agriculture" OR "climate smart" OR "climate-smart" OR "integrated soil fertility management" OR "integrated soil nutrient management" OR irrigation OR "soil and water conservation" OR "water storage" OR "water harvesting" OR "cover crop" OR evergreen OR "green manure" OR "drought resistant" OR "crop diversification" OR "alley farming" OR "integrated weed management" OR intensification OR "water-saving technology" OR "fruit production" OR "harvesting techniques" OR "heat detection technolog*" OR "remote sensing".

We used combinations of these key words to capture a wide breath of information on adoption of innovations but limiting the selected studies to those that focus on farmers' WTP. Our database search resulted in a total of 6, 211 references that were subjected to screening.

Screening process.

While this study aims to provide a comprehensive overview of farmer adoption studies, only studies that conform to the following main inclusion criteria were included : 1) The study was done at farm level, that is, looks at adoption of innovations by farmers or farming households or farming communities or landholders, 2) The study is original (collected primary data), and written in English, 3) the study employed qualitative, quantitative or mixed methods of research, 4) the study reports WTP (e.g. full price or premium) for agricultural innovation. The study should also report clear methods used to measure WTP and statistical techniques to examine its determinants, 5) the study looks at WTP for agricultural practices or technologies which are innovative in nature. For the purpose of this study, agricultural innovation is considered as technological advances or novel ways of farming that remarkably improve yield and production function, soil quality, natural capital, and food and nutrition security. As a consequence, articles targeted towards traditional agricultural practices e.g. crop rotation, intercropping, mulching etc. were excluded from the review, unless they have an innovative component in them (e.g.). In addition, studies looking at the impact of the innovation (e.g. yield increase) or adoption intensity (e.g. number of technologies adopted, acreage of production) were excluded. Two researchers with expertise in agricultural sciences worked separately and together to decide on whether or not particular practice(s) reported in each article have innovative components that could qualify them for inclusion in the systematic review. Table 1 shows the inclusion and exclusion criteria used in the eligibility screening.

Figure 1 shows the search and screening stages for the articles. Out of 6,211 articles that were initially obtained, 4 duplicate references were removed, 5245 papers were removed after evaluating their titles, because they were (1) not related to technology adoption by farmers or (2) they were reviews. Abstract search of the remaining 962 articles revealed that 875 articles were not eligible for consideration in our study. The remaining 87 articles were subjected to a full text screening and were assessed for inclusion (see inclusion criteria in Table 1). At this stage, 24 references were removed for different reasons as specified in Figure 1. This resulted into 63 articles that were included for analysis.

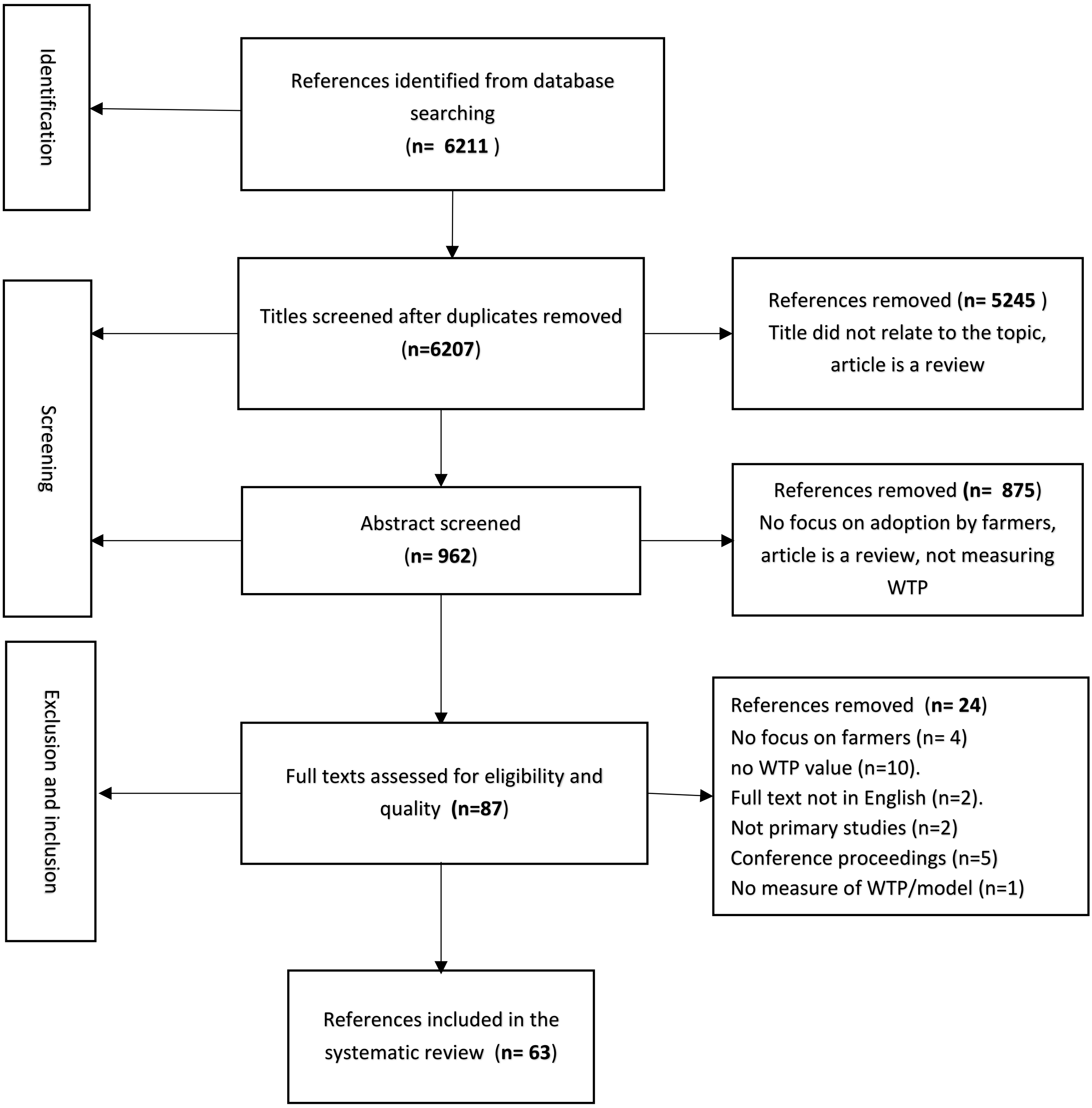
Identification
References identified from database searching (n= 6211)
Screening
Titles screened after duplicates removed (n=6207)
References removed (n= 5245) Title did not relate to the topic, article is a review
Abstract screened (n= 962)
References removed (n= 875) No focus on adoption by farmers, article is a review, not measuring WTP
Exclusion and inclusion
Full texts assessed for eligibility and quality (n=87)
References removed (n= 24)
No focus on farmers (n= 4)
no WTP value (n=10).
Full text not in English (n=2).
Not primary studies (n=2)
Conference proceedings (n=5)
No measure of WTP/model (n=1)
References included in the systematic review (n= 63)

Table 1: Criteria for inclusion and exclusion of references

PICOS	Inclusion criteria	Exclusion criteria
Population	Farmers/farming households	Consumers, processors, and others
Intervention	Farm level innovative agricultural practices/technologies/intervention	Non-agricultural practices, non-farm level practices e.g. off farm processing, marketing
Comparator	The traditional agricultural technologies/practices	None
Outcome	Willingness to pay values/premium AND Determinants of farmers' WTP	Adoption or adoption intention without WTP measure
Study design	Economic valuation (WTP) methods AND Statistical techniques/models for evaluating potential determinants	None

Data extraction

Key data were extracted from each selected study in line with the objective of this review. These included the characteristics of the studies (information on authors, year and country of study), In addition, we extracted data on the agricultural innovation(s) or practices studied, the methods and models employed to investigate farmers' WTP, the reported values and the determinants of WTP.

Results

Study characteristics

From a total of 6211 articles that were collected, 63 primary studies that reported WTP by farmers and comply with the inclusion criteria were reviewed (see Figure 1). The study characteristics are summarized in Table 2. In terms of type of innovation, most of the studies (n=28) focused on innovations targeted towards the improvement of agricultural water supplies, followed by environmental improvement (23 studies), e.g. agri-environmental schemes (AES) or payment for ecosystem services (PES), and crop and animal improvement innovations (n=12), such as high yielding varieties and animal genetic resource conservation. The majority of the studies were carried out in developing countries (n=44), as compared to developed countries (n=19). Among the studies done in the developing countries, Ethiopia dominates with 7 studies, followed by India (5), Kenya (4) and South Africa (3). While the most studied developed countries were Spain (4 studies), Italy (3), Turkey (3) and USA (3).

Table 2: Summary of key features of farmers' WTP studies included in the review

Characteristics	Number of studies
Type of agricultural innovations	
Agricultural water provision or improvement	28
Environmental improvement technologies	23
Crops and animal improvement technologies	12
Level of economic growth	
Developing countries	44
Developed countries	19
Country of study	
Ethiopia	7
India	5
Spain	4
Kenya	4
USA	3
Italy	3
Turkey	3
South Africa	3
Others (≤ 2 studies per country)	30

Methods of assessment of WTP

Most of the studies reviewed employed stated preference methods for eliciting farmers' WTP for agricultural technologies or their attributes. In quantitative terms, 55.5% of the studies applied direct valuation (contingent valuation) method, while 32% applied choice modelling approach. Most studies applied regression approach to model the influence of various factors on the amount that farmers are willing to pay for an innovative agricultural technology or the attributes of the technology. The methodology applied in studying farmers valuation as well as analytical methods are presented in Table 3.

Determinants and value of willingness to pay

The review shows that farmers are willing to pay for improvement in technologies or innovations with the value of the premium (average WTP) differing among the types of innovation studied. However, as soon in Table 4, those studies that investigated farmers WTP for improvement in agricultural water supply mainly measured WTP in terms of the amount farmers are willing to pay for a given volume of water supplied or the amount of farm land to be irrigated. A critical look at these studies reveals that farmers are willing to pay premium ranging from around 0.1 to 2.0 US dollars per cubic meter of irrigation water provided (Table 4).

The determinants of WTP by farmers depended largely on the type of technologies or technology attributes studied. However, as soon in Table 4, socio-demographic characteristics of the farmers or their farming households tended to be studied across all the studies reviewed. In Table 5, we have categorized the factors that significantly determined farmers WTP in the studies reviewed. We have grouped the determinants into 5 categories; socio-demographic, bio-physical, technological, Institutional factors, and Farmers' perception and behavioral factors.

The socio-demographic information relate to the farmers' individual characteristics (e.g. age, sex, level of education) or that of his or her family household (e.g. household size, income). In the studies reviewed, the most widely significant socio-demographic factors reported are education level of the farmer, his age, gender and household income.

Bio-physical factors are the agro-ecological factors that include on-farm natural endowments (e.g. land, vegetation) and operational factors (Tey & Brindal, 2012). The agro-ecological factors found to be significant in explaining farmers WTP for agricultural innovations in most of the studies reviewed include; amount of land owned, season of production (dry/wet season), previous environmental/weather shocks such as dry spell, water quality (salinity, water level, Ph), sources of agricultural water (ground or surface), amount of irrigated area, cropped area, crop variety, environmental adaptability of improved varieties or breeds and amount of production per unit of land cultivated (on-farm production).

Technological factors. These are factors to do with the technology itself, such as costs, usefulness, familiarity with the technology, and its different attributes. Most WTP studies that applied choice modelling measure WTP for different attributes and the attributes preferred determines the amount farmers are willing to pay for them. A shown in Table 5, the most widely significant technological factors include the cost, type of technology (e.g. irrigation type, ecosystem services) and usability.

Institutional factors. The most widely significant instructional factors in the studies reviewed include access to and sources of information (e.g. from extension workers), access to credits and remittance, and in the case of environmental improvement technologies, availability of incentives to conserve the environment was also found significant (Table 4 & 5).

Farmers' perception and behavioral factors. These relate to the psychological state (e.g. intention to try) of farmers and their subjective evaluation of innovative agricultural practices (Tey & Brindal, 2012). Under this category, the following factors have been found significant in the studies reviewed; perceived risks, risk awareness & aversion, trust in service providers, attitude towards the innovation, satisfaction with the innovation, and expectation of future value/usefulness (Table 5).

Table 3: Methods applied to investigate farmers' valuation of agricultural technologies

Reference	Technology	Method of assessing WTP/Premium	Statistical model(s) used
Abu-Madi, 2009	Irrigation water pricing	Interviews	Multiple Linear Regression
Akter et al., 2016	Weather-indexed crop insurance	Choice Experiment	Probit Regression
Alcon et al., 2014	Agricultural water supply reliability	Choice Experiment	Mixed Logit Model
Asrat et al., 2010	Crop variety traits	Choice Experiment	Random Paramter Logit Model
Atreya, 2007	Intergrated pest management training	Dichotomous Choice And Open-Ended Techniques	Probit Regression
Aydogdu & Bilgic, 2016	Efficient irrigation	Censored Tobit Model	Tobit Regression
Aydogdu & Yenigun, 2016	Sustainable water use	Interviews	Probit & Logistic Regression
Aydogdum, 2016	Irrigation water (with optimal management	Contingent Valuation And Double Bond Maximum Likelihood	Limited Dependent Variable (Logit) Model
Bakopoulou et al., 2010	Recycled water	Contingent Valuation	Multinomial Logistic Regression
Barrowclough et al., 2016	Conservation agriculture	Choice Experiment	Random Paramter Logit Model
Bell et al., 2014	Surface water relaiblility	Choice Experiment	Random Paramter Logit Model
Bhaduri & Kloos, 2013	Water & non-water related services	Choice Experiment	Conditional Logit And Mixed Logit (Random Parameter) Models
Bogale, 2014	Weather indexed insurance	Contigent Valaution	Bivariate Probit Model
Bozorg-Haddad et al. 2016	Agricultural water	Probabilistic Optimization	Non-Linear Programming Model & Monte Carlo Simulation
Buckley et al., 2012	Riparian buffer zones	Contingent Valuation	Generalised Tobit Interval Model
Chandrasekaran et al., 2009	Tank irrigation systems	Contigent Valuation & Production Function Analysis	Logit Model
Chellappan & Sudha 2015	Soil conservation	Contingent Valuation	Multinomial Logit Model
Conner et al., 2016	Best management practices (BMPs)	Conjoint Analysis	Weighted Least Squares Regression

Copper & Signorello 2008	Agri-environmental Conservation	Discrete Choice Survey	Cummulative Distribution Function & Semi Non-Parametric Distribution
Cuyno et al., 2001	Integrated pest management (IPM)	Contigent Valuation	Logit model
Dahlin et al., 2016	Green Fertilizers	Discrete Choice Experiment	Hierarchical Bayes estimate & latent class model
Dalton, 2004	New upland rice varieties	Contigent Valuation	Hedonic model
Danso et al., 2002	Urban Waste Compost	Contingent Valuation	Probit model
De Grooteet al., 2007	Herbicide-coated imidazolinone-resistant (IR)maize	Choice Experiment	Linear regression
Dupraz et al., 2002	Environmental schemes	Contingent Valuation	Probit model
El Chami et al., 2008	Ground water quality	Contingent Valuation	General linear regression
Garming & Waibel, 2009	Low-toxicity pesticides	Contigent Valuation	Logit and log-linear regression models
Ghorbani & Kulshreshtha, 2013	Integrated Weed Management	Contigent Valuation	Multinomial logit model
Giannoccaro et al., 2015	Water trading	Contigent Valuation	Student t-test and chi-square
Gottardo et al., 2011	Veterinary &dehorning	Interview	Chi-square
Gulati & Rai, 2015	Soil and water conservation	Contigent Valuation	Nominal logistic regression
Harun et al., 2015	Irrigation water	Contigent Valuation	Probit model
Hill etal., 2013	Weather-indexed insurance	Contigent Valuation	Probit model
Hite et al., 2002	Water quality improvement	Contigent Valuation	Probit model
Jaghdani & Brümmer, 2016	Groundwater	Revealed WTP	Probit model
Kaczan et al., 2013	Ecosystems services	Choice experiment	Latent class model
Kassahun et al., 2016	Irrigation water access	Contigent valuation	Integrated Choice and Latent Variable
Kenkel & Norris, 1995	Mesoscale weather info	Contigent valuation	Maximum likelihood regression
Krishna & Qaim, 2006	Bt eggplants	Contigent valuation	Multinomial logit regression
Larue et al., 2014	BMP-induced water quality	Choice experiment	Mixed logit model
Mahadevan & Asafu-Adjaye, 2015	Green revolution package	Choice experiment	Random paramter model
Marra et al., 2010	Cotton yield monitor	Contigent valuation	Probit model

Matuschke et al., 2007	Hybrid wheat	Contigent valuation	Constant-only bid function & probit models
McIntosh et al., 2013	Weather indexed insurance	Contigent valuation	Probit model
Mesa-Jurado et al., 2012	Guaranteed water supply	Contigent valuation	Tobit regression
Mulatu et al., 2014	Water-related Ecosystems	Choice experiment	Mixed logit model
Narjes & Lippert, 2016	Native pollinting bees	Choice experiment	Mixed logit model
Ndunda & Mungatana, 2013	Improved waste water	Choice experiment	Random paramter logit model
Qaim & Janvry, 2003	GM (Bt) cotton	Contigent valuation	Log likelihood model
Saldías et al., 2016	Waste water frameworks	Choice experiment	Conditional logit and latent class model
Salman & Al-Karablieh, 2004	Ground water	Parametric linear programming model	Linear programming
Scaringelli et al., 2016	Biodegradable mulching films	Contigent valuation	Not stated
Schreiner & Latacz-Lohmann, 2015	GMO free milk production	Discrete choice model	Logit and latent class models
Shultz & Soliz, 2007	Water restoration	Contigent valaution	Logit model
Speelman et al., 2011	Water right systems	Contigent valuation	Ordered logit and Hanemann models
Storm et al., 2011	Irrigation water	Contigent Valuation	Tobit regression
Tang et al., 2013	Irrigation water	Contigent Valuation	Logit model
Tesfaye & Brouwer, 2015	Irrigation water supply	Choice Experiment	Mixed logit model
Villanueva et al., 2015	Agri-environmental scheme	Choice Experiment	Latent class model
Yedra et al., 2016	Irrigation water	Net income change/ productivity change	Productivity change method
Yokwe, 2009	Smallholder irrigation	Contigent valuation	
Zander et al., 2008	Conservation of animal genetic resources	Contigent valuation	Tobit regression
Zeng, 2010	Irrigation water	Contigent valuation	Dichotomous choice bidding model

Table 4: Determinants and values of farmers' WTP for innovative agricultural technologies

Technology	Determinants of WTP	Average premium (WTP)	Reference
Agricultural water improvement technologies			
Irrigation water pricing	water prices, irrigation area, annual farm income, frequency of irrigation	$0.125/m3.	Abu-Madi, 2009
Agricultural water supply reliability	amount of water supply, water supply measure, price of water.	0.35 s/m3 (50% premium)	Alcon et al., 2014
Efficient irrigation	Primary education, use of modern irrigation, crop pattern, marital status, property ownership, gravity irrigation use	$133.7 per hectare ($0.013m3)	Aydogdu & Bilgic, 2016
Irrigation water (with optimal management	price of irrigation water, education, location, irrigation type (gravity or pumping), and attitudes toward associations	234.7 Turkeys Liras/ha (0.023Liras/m3)	Aydogdum, 2016
Recycled water for irrigation	sex of farmers, farmers' education level, monthly income, farmers' cultivation land area, water shortage	Half of fresh water price	Bakopoulou et al., 2010
Improvement in surface water reliablility	Groundwater salinity, surface water reliability, share of irrigation from groundwater sources, Total irrigation costs	Rs.-150- Rs. 700/acre	Bell et al., 2014
Bundling water with non-water services	amount spent on irrigation & drainage, school, microcredit, health	$1.64/1000 m3- $6.86/1000 m3	Bhaduri & Kloos, 2013
agricultural water	price of water, the distribution of water shortage, the type of irrigation system, and the crop type	0.168 currency units per cubic meter.	Bozorg-Haddad et al., 2016
Tank irrigation systems	family labor force, area under rice cultivation, water requirement, season (wet or dry season)	INR 218.50/ha/year	Chandrasekaran et al., 2009
Ground water quality	ownership of land, quality & quantity of production, source of water and level of education	102 US$ /166.67 US$ yr-1	El Chami et al., 2008
Water trading	perception of water as non-tradable item, experience with water trading, period of year e.g. dry season	0.17 EUR/m3 - 0.21 EUR/m3	Giannoccaro et al., 2015
Irrigation water	bid amounts, water deficit, source of water, cultivated area, education, age , main agricultural activity	11.49 USD/10 m3- 20.28 USD/10 m3	Harun et al., 2015
Water quality improvement (precision application technology)	abatement levels, believe that the tech can give cleaner environment, gender, employment, education	$46.97 for 10% abatement level and $ 49.94 for 20% abatement	Hite et al., 2002

Ground water	Participation in water market, using other wells, having other jobs, number of fragmented plots, average age of trees in garden, land endowment, water level, water pH	1860.45 IRR/m3	Jaghdani & Brümmer, 2016
Irrigation water access	Expectation about future irrigation, irrigation experience, household income, dependency ratio.	ETB 1531000-1,557,000	Kassahun et al., 2016
Guaranteed water supply for irrigation	age, household income, agricultural training, household size, olive trees per ha and perceived water quota	€0.39/tree (5 year guarantee), €0.74/tree (9 year guarantee)	Mesa-Jurado et al., 2012
Improved waste water treatment	quality & quantity of treated wastewater, riverine ecosystem restoration, age, education, gender, employment status, health and environmental risks awareness of farmers	Kshs.90.57/month	Ndunda & Mungatana, 2013
Waste water reuse frameworks	trust for service providers, water quality and level of restrictions on use practices	ZAR 2.37 per m3 (Private Scheme model)	Saldías et al., 2016
Ground water	Price of water, quantity of ground water used, effect on production	US$ 0.35/m3	Salman & Al-Karablieh, 2004
Water restoration	cost of water, knowledge of the causes of irrigation water quality and supply problems, satisfaction with current water supplies.	$17 per hectare annually	Shultz & Soliz, 2007
change in water right systems	Water right system, duration, quality of title, price, agent based transfer, market transfer	0.0143 TND (Tunisia), 0.024- 0.146 Rand/m3 (South Africa)	Speelman et al., 2011
Irrigation water	Surface or ground water supply option, season (summer/winter), age of farmer, water pumping cost.	Ground water 0.88 DH/m3 - 2.75 DH/m3 (depending on season)	Storm et al., 2011
Irrigation water	family size, household income, type of water supply (surface or ground)	80.4 RMB/mu/yr	Tang et al., 2013
Improvement in irrigation water supply	irrigation frequency, irrigation water price, use of water-saving sprinkler irrigation, involvement or not in transboundary cooperation	US$0.7- US$1.6 per hectare	Tesfaye & Brouwer, 2015
Irrigation water	farm size, annual farm revenue, irrigated area, yield, production cost	1.48–1.75 USD/m3	Yedra et al., 2016

Smallholder irrigation schemes	gross margin, type of farmer (subsistence, specialized, pensioner commercial farmer, transition, full-time commercial farmer), irrigation scheme used.	R 0.01- 0.19/m3	Yokwe, 2009
Irrigation water	family size, income, attitude of farmers	1021 RMB/ha/yr	Zeng, 2010
Sustainable water use (irrigation training)	age, education level, land amount, ownership type, modern irrigation method and offered amount for training	170.6/ year	Aydogdu & Yenigun, 2016
Evironmental improvement technologies			
Conservation agriculture	Four year yield, planting labor, weeding labor, Soil Erosion	0.11-1.77% of production cost	Barrowclough et al., 2016
weather-indexed crop insurance	Gender, trust in technology, financial literacy	Flood ($11.64-13.70); Hail ($10.19-12.58); wind ($11.0-13.15)	Akter et al., 2016
Community Intergrated pest management training	awareness of adverse effect of pesticide, understanding of pesticide levels, education, gender, income/economic status	US $25.23 per household/year	Atreya, 2007
Rainfall based indexed insurance	experience of moisture stress, education, worry about weather, access to credit, non-farm income, remittance	Birr 119.90/ year/ hectare of maize.	Bogale, 2014
Riparian buffer zones in agricultural catchement	Economic, attitudinal and farm structural factors	€1513/ha	Buckley et al., 2012
Soil conservation	cropped area, farm size, on-farm income, Family size, age of the farmer	Rs. 4,687/ha. ($ 78.1/ha)	Chellappan & Sudha 2014
Best management practices (BMPs)	BMPs that are familiar, simpler, and easy to integrate into existing management practices, monetary incentives	$85.99- 349.48/acre	Conner et al., 2016
Agri-environmental Conservation	Production cost (return on conservation), risk perception.	US$125 per hectare	Copper & Signorello 2008
Integrated pest management (IPM)	type of environmental risks, information source, farm size and awareness of IPM	551-680 pesos/cropping season	Cuyno et al., 2001
Green fertilizers	Fertilizer type, price, brand status, product labeling and nutrient values	€6-12/2.5Kg pack	Dahlin et al., 2016
Urban Waste Compost	Compost experience, ability to pay, availability of alternative soil inputs, farming systems, cities, urban vs peri-urban farmers	US$ 0.1-3.0/ 50kg bag	Danso et al., 2002

environmental schemes	environmental awareness, farm revenue index, livestock density per forage area, the share of low productivity meadows	FB 8,000 (Euro 198) in less favored agricultural area, FB 15,000 (Euro 372) other areas	Dupraz et al., 2002
Low-toxicity pesticides	farmers' experience with poisoning, income, current exposure to pesticides	28% premium	Garming & Waibel, 2009
Integrated Weed Management	Total annual income, area under irrigated wheat, yield loss due to weeds, nature of the weeds, awareness of weed resistance to herbicides, rain-fed (dryland) wheat cultivation, larger number of plots on the farm.	US$ 26.26/ha	Ghorbani & Kulshreshtha, 2013
soil and water conservation	qualification, total income, off-farm income, previous irrigation experience, age, dependency ratio, market access and livestock holding	US$1302.2 or 1207 labor days/month	Gulati & Rai, 2015
weather-indexed insurance	education, age, gender, wealth, risk aversion, consumption risk, contract price, provision of insurance in groups,	10-40 Birr/month	Hill etal., 2013
payment for ecosystems services	constant and variable annual cash payment to individual farmers, upfront manure fertilizer payment.	59.6–78.6 USD individual payment, USD 140 per acre for manure fertilizer payment	Kaczan et al., 2013
Mesoscale weather information	Gross sales, having irrigated area, past weather losses, raw data/value added weather information.	$5.83 for raw weather data, $ 6.55 for both raw and value added information	Kenkel & Norris, 1995
BMP-induced water quality improvements	age, farmers' experience, costs	US$0.54-1.10/acre for 1% phosphorus, US$ 0,43-1.28 coliform reduction	Larue et al., 2014
Green revolution package	attributes of green revolution selected, location of households, food security status, gender of household head	6.26-30.06 US$/acre	Mahadevan & Asafu-Adjaye, 2015
weather indexed insurance	education, area of farmed land, frequency of production reductions due to weather shocks, use of a variety of coping strategies, risk aversion, drought shock in previous year	276.7 birr	McIntosh et al., 2013

Water-related Ecosystem services	Type of ecosystem services, participation in previous ecosystems payment, access to information, experience in agroforestry, farm land size, income levels	USD 2.44 (Riparian land); USD 135.37 (for environment-friendly farming); USD 7.70 (Reforestation).	Mulatu et al., 2014
biodegradable mulching films	price, strength, durability, mechanical harvesting, transparency of the material, age and education of respondents, agronomic performance of the films	464.11 (€/ha)	Scaringelli et al., 2016
Agri-environmental scheme	Cover crops area, Cover crops management, Ecological focus areas, Collective participation, monetary incentives.	€8–9/ha per additional 1% of the farmland devoted to Ecological focus area	Villanueva et al., 2015
Crop improvement techologies			
Crop variety traits	Environmental adaptability, yield stability, resource endowment, farming experience, contact with extension officers	Sorghum 17.49-294.52 Ethiopian Birr	Asrat et al., 2010
New upland rice varieties	Production and consumption characteristics, type of variety	265 CFAF/Kg (vairety replanted), 91CFAF (non-replanted variety)	Dalton, 2004
herbicide-coated imidazolinone-resistant (IR)maize	price of improved varieties, colour of the cob..	US$1.79/kg	De Grooteet al., 2007
Bt eggplants	price of hybrid, income status of farmers, farm size, household size, education, etc	Rs. 4642/acre (US$ 106)	Krishna & Qaim, 2006
Cotton yield monitor	previous experience with precision technologies, price	US ($) 6609.9, 8899.0	Marra et al., 2010
Hybrid wheat	seed prices, access to information and credit	847 rupees/acre	Matuschke et al., 2007
GM (Bt) cotton	price, arable area owned, education, information access	US $48/ hectare	Qaim & Janvry, 2003
Animal production technologies			
Veterinary cost of dehorning	difficulty in handling horned cattle, perceived pain to animals	USD 0.35- 1.40/calf	Gottardo et al., 2011
Conservation of native pollinating bees	attitude towards native bees, gender, engagement in related bee activities, education, cultivated acreage, income	711.29 THB (€18.1)	Narjes & Lippert, 2016
GMO free milk production	Farmers' attitude towards cultivation GM soy, market potential of GM free milk and future prices, farmers age, education and current feeding regimens	0.80 eurocent/Kg GMO free milk	Schreiner & Latacz-Lohmann, 2015

Conservation of animal genetic resources (local cattle/Borana)	type of farmer, number of cattle, awareness about decreasing number of local animals (Borana), perceived importance of crossbreds, age, awareness of land and pasture degradation, perceived importance of keeping exotic breeds..	€7/animal/year (Ethiopia), €50/animal/year (Kenya)	Zander et al., 2008

Table 5: Categorization of significant factors that determine farmers WTP for innovative agricultural technologies

Category of determinants	significant variables	References
Water improvement technologies		

Socio-demographic data	Education of farmer	Aydogdu & Bilgic, 2016; Aydogdum, 2016; Bakopoulou et al., 2010; Bhaduri & Kloos, 2013; El Chami et al., 2008; Harun et al., 2015; Hite et al., 2002; Mesa-Jurado et al., 2012; Ndunda & Mungatana, 2013; Aydogdu & Yenigun, 2016
	Age	Harun et al., 2015; Mesa-Jurado et al., 2012; Ndunda & Mungatana, 2013; Storm et al., 2011; Aydogdu & Yenigun, 2016
	Marital status	Aydogdu & Bilgic, 2016;
	gender	Akter et al. 2016; Bakopoulou et al. 2010; Hite et al., 2002; Ndunda & Mungatana, 2013;
	Employment status	Hite et al., 2002; Ndunda & Mungatana, 2013;
	Household/farmers income	Bakopoulou et al., 2010; Kassahun et al., 2016; Mesa-Jurado et al., 2012; Tang et al., 2013; Zeng, 2010
	Family size & labour	Chandrasekaran et al., 2009; Mesa-Jurado et al., 2012; Tang et al., 2013; Zeng, 2010
Biophysical factors factors	Irrigated area	Abu-Madi, 2009; Chandrasekaran et al., 2009; Yedra et al., 2016;
	Land endowment & cultivated area	Bakopoulou et al., 2010; El Chami et al., 2008; Jaghdani & Brümmer, 2016; Yedra et al., 2016; Aydogdu & Yenigun, 2016;
	Crop type	Aydogdu & Bilgic, 2016; Bozorg-Haddad et al., 2016; Mesa-Jurado et al., 2012;
	Water supply type (ground/surface)	El Chami et al., 2008; Jaghdani & Brümmer, 2016; Storm et al., 2011; Tang et al., 2013;
	Water features (Ph, salinity, quality, level)	Bell et al., 2014; El Chami et al., 2008; Jaghdani & Brümmer, 2016; Ndunda & Mungatana, 2013; Saldías et al., 2016;
	Season (wet/dry)/ water shortage	Bakopoulou et al., 2010; Bozorg-Haddad et al., 2016; Chandrasekaran et al., 2009; Giannoccaro et al., 2015; Storm et al., 2011;
	Amount of water supply and frequency	Abu-Madi, 2009; Alcon et al., 2014; Salman & Al-Karablieh, 2004; Tesfaye & Brouwer, 2015;
	Yield/ amount of production	El Chami et al., 2008; Yedra et al., 2016;
Technological factors	Cost of irrigation/water	Alcon et al., 2014; Bell et al., 2014; Bhaduri & Kloos, 2013; Bozorg-Haddad et al., 2016; Salman & Al-Karablieh, 2004; Shultz & Soliz, 2007; Speelman et al., 2011; Storm et al., 2011; Tesfaye & Brouwer, 2015; Yedra et al., 2016; Aydogdu & Yenigun, 2016;
	Type of irrigation	Aydogdu & Bilgic, 2016; Aydogdum, 2016; Bozorg-Haddad et al., 2016; Tesfaye & Brouwer, 2015; Yokwe, 2009; Aydogdu & Yenigun, 2016
	Usefulness of technology	Hite et al., 2002; Aydogdu & Yenigun, 2016;
Farmers perception and behavioral factors	Attitudes & participation in water trading & association	Aydogdum, 2016; Giannoccaro et al., 2015; Jaghdani & Brümmer, 2016; Tesfaye & Brouwer, 2015; Zeng, 2010;

	Satisfaction with water supply	Mesa-Jurado et al., 2012; Shultz & Soliz, 2007; Speelman et al., 2011;
	Environment risk awareness	Ndunda & Mungatana, 2013;
	Expectation about future irrigation	Kassahun et al., 2016
	Trust in service providers	Saldías et al., 2016;
Environmental improvement technologies		
Socio-demographic data	Education of farmer	Atreya, 2007; Bogale, 2014; Gulati & Rai, 2015; Hill etal., 2013; McIntosh et al., 2013; Scaringelli et al., 2016;
	Age	Chellappan & Sudha 2014; Gulati & Rai, 2015; Hill etal., 2013; Larue et al., 2014; Scaringelli et al., 2016
	Gender	Akter et al., 2016; Atreya, 2007; Hill etal., 2013; Mahadevan & Asafu-Adjaye, 2015
	Household/farmers income	Atreya, 2007; Bogale, 2014; Buckley et al., 2012; Chellappan & Sudha 2014; Garming & Waibel, 2009; Ghorbani & Kulshreshtha, 2013; Gulati & Rai, 2015; Mulatu et al., 2014;
	Family size & labour	Chellappan & Sudha 2014;
	Farming experience	Larue et al., 2014;
Biophysical factors factors	Land endowment & cultivated area	Chellappan & Sudha 2014; Cuyno et al., 2001; Ghorbani & Kulshreshtha, 2013; Kenkel & Norris, 1995; McIntosh et al., 2013; Mulatu et al., 2014; Villanueva et al., 2015;
	Crop type	Ghorbani & Kulshreshtha, 2013;
	Yield/ amount of production	Barrowclough et al., 2016; Dupraz et al., 2002; Ghorbani & Kulshreshtha, 2013; Gulati & Rai, 2015; McIntosh et al., 2013; Scaringelli et al., 2016;
	Previous environment/weather shocks	Barrowclough et al., 2016; Bogale, 2014; Garming & Waibel, 2009; Kenkel & Norris, 1995; McIntosh et al., 2013;
Technological factors	Technology/environmental/ ecosystem services attributes	Conner et al., 2016; Cuyno et al., 2001; Dahlin et al., 2016;Danso et al., 2002; Hill etal., 2013; Mahadevan & Asafu-Adjaye, 2015; Mulatu et al., 2014;
	Ease of use & Usefulness of technology	Conner et al., 2016; Danso et al., 2002; Gulati & Rai, 2015;Mulatu et al., 2014; Scaringelli et al., 2016;
	Cost of technology/production	Copper & Signorello 2008; Dahlin et al., 2016; Danso et al., 2002; Hill etal., 2013; Larue et al., 2014;
Farmers perception and behavioral factors	Environmental risk awareness	Atreya, 2007; Dupraz et al., 2002; Garming & Waibel, 2009; Ghorbani & Kulshreshtha, 2013;
	Risk aversion/perception	Bogale, 2014; Copper & Signorello 2008; Hill etal., 2013; McIntosh et al., 2013;
	Trust in Technology/services	Akter et al., 2016; Buckley et al., 2012
Institutional factors	Access to credit & remittance	Bogale, 2014; Gulati & Rai, 2015;

	Incentives for environmental services	Conner et al., 2016; Kaczan et al., 2013; Villanueva et al., 2015;
	Access to & source of information	Cuyno et al., 2001; Dahlin et al., 2016; Kenkel & Norris, 1995; Mulatu et al., 2014;
	Market access	Gulati & Rai, 2015;
Crop/animal improvement technologies		
Socio-demographic data	Education of farmer	Krishna & Qaim, 2006; Qaim & Janvry, 2003; Narjes & Lippert, 2016; Schreiner & Latacz-Lohmann, 2015
	Age	Schreiner & Latacz-Lohmann, 2015; Zander et al., 2008
	Gender	Narjes & Lippert, 2016
	Household/farmers income	Krishna & Qaim, 2006; Narjes & Lippert, 2016;
	Family size & labour	Krishna & Qaim, 2006
	Farming experience	Asrat et al., 2010; Marra et al., 2010;
Biophysical factors factors	Land endowment & cultivated area	Krishna & Qaim, 2006; Qaim & Janvry, 2003; Narjes & Lippert, 2016;
	Crop type/ variety	Dalton, 2004; Schreiner & Latacz-Lohmann, 2015;
	Environmental adaptability of improved variety or breeds	Asrat et al., 2010
	Yield/ amount of production	Asrat et al., 2010; Zander et al., 2008.
Technological factors	Production/consumption features improved	Dalton, 2004; De Groote et al., 2007;
	Price of varieties/attributes	De Groote et al., 2007; Krishna & Qaim, 2006; Marra et al., 2010; Matuschke et al., 2007; Qaim & Janvry, 2003;
	Ease of use (previous experience) of technology	Marra et al., 2010; Gottardo et al., 2011; Narjes & Lippert, 2016;
	Usefulness of technology	Zander et al., 2008;
Perception and behavioral factors	Attitude towards the technology	Narjes & Lippert, 2016; Schreiner & Latacz-Lohmann, 2015;
	Risk awareness	Zander et al., 2008; Gottardo et al., 2011.
Institutional factors	Access to credit	Matuschke et al., 2007;
	Access to & source of information	Asrat et al., 2010; Matuschke et al., 2007; Qaim & Janvry, 2003;

Discussion

Methods and statistical approach

Approaches for measuring WTP can be placed in two broad categories; the Revealed Preference (RP) and the Stated Preference (SP) methods. With the RP (indirect) techniques, WTP a premium for a product or a service is derived by observing individual behavior in real market situations. It involves methods such as experimental auctions, hedonic pricing, travel cost methods (El Chami et al; Haab & McConnell, 2002). In the case of SP (direct) techniques, prices (WTP) are derived by directly asking participants about their preferences (Ghorbani, 2013). Most of the references reviewed in this article have applied SP methods. This might be due to the fact that SP methods are able to estimate both the use and non-use values of a product or a service, compared to the RP approaches that measure only the use values (Bozorg-Haddad etal 2016; Saldias et al. 2016). In fact majority of the references that qualified for inclusion in our review measured WTP for water and environmental improvement innovations. Both categories of the innovations have non-use values (e.g. sustainability of irrigation water innovations), making them perfect avenues for application of SP approaches of WTP estimation. In addition, SP approaches are direct and do not involve a lot of logistics to provide the actual product during the WTP estimation (Mclntosh et al. 2013). However, the SP methods have some inherent disadvantages that need to be minimized to ensure more accurate WTP estimations. Given that they do not simulate real market situations, the most common limitation of SP is hypothetical bias since participants do not have to pay the stated amount (Cuyno et al. 2011; El chami et al; Hill et al. 2013). The other common biases in SP methods are information, strategic and starting point biases (Cuyno et al. 2001). Examples of SP methods, which have been most widely applied in the studies reviewed are contingent valuation method (CVM) and choice modelling (CM) methods. A CM approach involves estimating the implicit values of different elements of a product with the advantages of being able to compare the preferences for the attributes (elements) as well as being able to rank/ rate them according to their level of importance/preference (Saldias et al. 2016; Asrat et al. 2010). The CVM on the other hand, involves asking participants what they would be willing to pay for a given whole product if it was offered to them. Alternatively, participants are asked if they would be willing to pay a given price to take a particular good or service (Krishna & Qaim, 2007; Garming & Waibel, 2009; Harun et al. 2015).

Econometric approaches. In modelling the influence of various factors on farmers' WTP, statistical methods are selected mainly based on the valuation methods used. CM approaches are based on random utility model, which states that individuals make choices based on the attributes of a product or service and the random component that occurs due to unique preferences of the individuals (Saldias et al. 2013; Genius et al. 2012; Kaczan et al. 2013). An individual therefore chooses an alternative whose utility is greater than a certain benchmark. The multinomial logit model (MLM), which assumes a homogenous preferences across study participants is commonly applied to study the determinants of WTP in CM situation. However, preferences are not often homogenous among the respondents which is a limitation of the MLM. Thus , a latent class model (LCM) and random parameters Logit model (RPL) are often used to relax the assumption of homogeneity in preferences, as applied in most of the studies reviewed in this article (Villanueva et al., 2015; Bell et al., 2014; Asrat et al., 2010). The CVM generates many possibilities of econometric models including the MLM. However the most common statistical model applied to CVM situations as reported in the studies reviewed is the probit model, very likely because of its bivariate normal density function which allows for non-zero correlation, that is not possible with logistic regression (Bogale , 2014; Hill et al. 2013; Jaghani & Bruinner 2016). In addition, it allows one to calculate the change in WTP brought by product characteristics (Hill et al. 2013).

Determinants of WTP & the premium

When investigating WTP for an innovation or attributes of innovation, different factors tend to determine the exact amount the farmers are willing to pay for them. Below, the 5 categories of the determinants of WTP are discussed:

Socio-demographic factors. Education is the most common socio-demographic determinant studied. Commonly measured by the number of years of formal schooling, the education attainment of farmers is required to aid them in making critical decision on how much to pay for an improvement in agricultural technologies or practices. The decision to adopt or try an improvement in the traditional farming system requires knowledge and analytical capacity to understand such improvement as well as the added values that accompany the improvement. As such, level of education of the farmer is hypothetically expected to positively influence their WTP for an agricultural innovation. Indeed majority of the farmer studies on WTP presented here, have demonstrated this kind of results (Aydogdu & Bilgic, 2016; Aydogdu, 2016; Scaringelli et al. 2016; Atreya, 2007). However, in some studies, negative effect of education of WTP has been shown. In those stances where, education had a negative influence on farmers' WTP for agricultural innovation, it is viewed in the way that farmers who have higher education always have alternative employment or investment and hence are not willing to pay more for an improvement in a selected agricultural practice (Harun et al. 2015; Ndunda & Mungatana, 2013; Chandrasekaran et al.,2009). The influence of age on WTP has produced mixed results, with some studies showing that younger farmers tend to pay more than the older ones, for agricultural innovation, while other studies show otherwise. In most of the studies reviewed however, younger farmers have been shown to be willing to pay more for innovative technologies (Hill et al. 2013; Storm et al. 2011), partly because they tend to be less conservative than the older farmers (Chellappan & Sudha, 2014) but also because they expect to enjoy the benefits over a longer period (Larue et al.2014). In the instances where older farmers have been shown to be willing to pay more than the younger farmers, it is more related to their farming experience that enable them to better appreciate the benefits of such improvement in the farming system or technology (Chandrasekaran et al. 2009). Another outstanding socio-economic factor in this review is the influence of household or farmer's income on WTP. The level of income has been shown to have a positive influence on WTP, with wealthier farmers willing to pay relatively higher premium for innovative technologies (Hite et al. 2013; Gulati & Rai, 2015; Zeng 2010) which is in line with the basic economic concept. Krishna & Qaim (2007) shows that increase in per capita income, increases farmers' WTP for Bt eggplants in India. In the environmental improvement innovations such as soil and water conservation, and ecosystem payment, farmers with high level of income are willing to pay more because they have higher flexibility to invest in future sustainable farming systems (Gulati & Rai, 2015). In our review, the significance of household or farmers' income on WTP has been more pronounced for environmental or water improvement innovations than in crop and animal improvement innovations. This is likely so because payment for environmental protection e.g. ecosystem services are sometimes voluntary with no direct benefits to the individual farmers, making it likely that only wealthier farmers offer to pay for those services. For instance, Buckley et al. (2012) showed that preference to provide just a 10m riparian buffer zone was highly determined by economic factors.

The other socio-demographic factors that were reported to be significant in some of the studies reviewed, include gender, marital status and family size. Family size is in most instances related to the amount of labor for farm work as well as to diverse sources of family income. Therefore, in our review, family size is largely found to have positive effect on WTP by famers (Krishna & Qaim 2007; Meso-Jurado et al. 2012; Chadrasekaran et al. 2009). In the few instances where family size had a negative effect on WTP for agricultural innovations or new technologies (Zeng 2010; Tang etal. 2013), it can be argued that bigger families have more chance to engage in non-farm activities (Tang et al. 2013) and hence may not be willing to pay higher premium for an innovative agricultural services.

Biophysical factors. Land endowment and its associated factors such as cropped area or irrigated area are the most commonly significant biophysical factors determining farmers' WTP for agricultural innovations. The amount of farm land owned is a proxy for economy of scale and as stated by Tey & Brindal, (2012), larger farms have a greater capacity to absorb costs and risks associated with new technologies or innovation. In addition, the bigger farms can spread those costs and risks over a larger production base. Indeed in our review, farm size, irrigated and cropped area have been found to have a positive effect on farmers' WTP for agricultural innovations, irrespective of the type of innovations/technologies studied (Abu-Madi, 2009, Yedra et al. 2016; Jaghdani & Brummer 2016; Bakopoulou et al. 2010).

The amount of production per unit area cultivated is also found to positively influence WTP by farmers (Yedra et al. 2016; Barrowclough et al. 2016; Dupraz et al. 2002; Ghorbani and Kulshreshth, 2013). This might be related to income generated from production which is then invested in improving production. The other biophysical factors that were found significant in some of the studies review include the environmental adaptability of improved variety or breeds which has a positive effect (Asrat et al. 2010), for water improvement practices, WTP also depended on the type of water supply (ground/surface water) (Storm et al. 2011; El Chami et al. 2008) and production season (dry or wet season/summer/winter) which relates to the availability of water. In the season of water shortage, farmers were more willing to pay for water compared to the wet season (Giannoccaro et al. 2015; Storm etal. 2011). In the case of environmental improvement technologies, previous weather shocks (e.g. moisture stress) or health risks are found to motivate farmers to pay for environmental protection (Garming & Waibel , 2009; Bogale, 2014).

Technological factors. The cost of the agricultural innovation has been found to be more often significant than insignificant in determining farmers' WTP in most of the studies reviewed. Costs of an innovation e.g. price for providing an improved water supply is more often negatively affecting WTP, than positively, with most farmers only willing to pay the values less than the cost of the technology according to this review (Bhaduri & Kloos, 2013; Bozorg-Haddad et al. 2016; Marra et al. 2009). The cost and WTP relationship is found to depend on the type of innovation and its attributes. For instance, while cost of the innovation tends to negatively determine WTP, for water and environment improvement innovations, that involves incentives, WTP is seen to vary positively with cost e.g. Alcon et al. (2014), shows that farmers were Willing to pay as much as twice the irrigation water supply given government guaranteed supply programs. The other widely studied technological factors include the ease of use and usefulness (usability) of the agricultural innovations which were found significant and positive in determining WTP. Once farmers know how to implement a particular technology, their WTP increase (Gottardo et al. 2011), which might call for training in the case of less familiar innovations.

Institutional factors: Access to information allows farmers to learn about an innovation and has been shown to positively influence their WTP (Matuschke et al. 2007; Qaim & Janvy, 2003; Asrat, 2010). In addition, the sources as well as quality (and source) of information have an influence on WTP and adoption of agricultural innovations (Qaim & Janvy, 2003Khonje et al., 2015; Kubunga et al. 2012). Limited access to credit has been shown to negatively influence WTP by farmers in the studies reviewed (Matuschke et al. 2007). While this could be due to low purchasing power, limited access to credit has been shown to increase the level of risk aversion which negatively affects WTP (Qaim & Janvy, 2003).

Perceptions & behavioral factors. Only few of the articles reviewed have studied farmers perceptional and behavioral intrinsic factors that could inform their preference for agricultural innovations. Herath (2010) emphasized that the acceptance of new technologies are dependent on stakeholders' (e.g. farmers) behavioral change, which are determined by their norms, beliefs and attitudes. These and other intrinsic factors have not been widely considered in technology acceptance or adoption studies as well as WTP studies, as shown in this review. However, risk aversion, risk awareness and perceptions have been found to significantly influence WTP by farmers (Zander et al., 2008; Gottardo et al., 2011; Copper & Signorello 2008; Hill etal., 2013; McIntosh et al., 2013).

Conclusion and future research

This article presents the first systematic review of studies on farmers' adoption of farm level innovations without focusing on specific innovation dimensions. The article uniquely focused on those studies that report farmers' WTP for the innovative agricultural practices or technologies being adopted. Majority of the studies applied SP methods of determining farmers WTP, owing to their relative ease of application and applicability to most farmers' WTP studies that often involve measuring the non-use values of agricultural innovations. We however, recommend that future studies look at how to minimize hypothetical bias that is common in SP approaches.

We have shown that farmers are generally willing to pay for innovations in farming practices. While both the WTP values (premiums) and the determinants depend on the specific innovations studied, the determinants can easily be placed into 5 categories; socio demographic; agro-ecological (biophysical); technological; Institutional; and behavioral factors. However, we have shown that many farmers adoption and WTP studies do not actually investigate intrinsic factors (such as perceptions, attitudes, intentions) and is therefore an area of future research. In addition, we recommend that future research could carry out Meta-analysis by considering WTP for specific innovation type in order to establish the average WTP values (premium) that farmers are willing to pay for those specific types of innovations or technologies. We could not carry out a Meta-analysis in this review as farmers pay for different units when considering adopting specific innovations e.g. WTP for innovations in irrigation water supply system is commonly measured per acre or hectare to be irrigated or volume of water supplied, while WTP for an improved crop variety might be measured per kg of seeds to be purchased.

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