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RESEARCH ARTICLE

Explaining farmers' reluctance to adopt green manure cover crops planting for sustainable agriculture in Northwest China

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Abstract

Green manure cover crops (GMCCs) planting has a potential for mitigating greenhouse gas emissions (GHG) in agroecosystems and provides important ecosystem services, thereby achieving the Sustainable Development Goals (SDGs) stipulated by the United Nations. However, the advantages of cultivating GMCCs on arable land are not widely recognized. For example, in the whole of China, the GMCCs planting area is less than 3.5% of total arable land. The aim of this study is to explore reasons for the low adoption rate of GMCCs planting. Using best–worst scaling (BWS) approach, farmers ranked their preferred conservation practices including three types of GMCC cropping systems. Taking Gansu Province in Northwest China as a case study, a survey with 276 farmers was conducted. The findings indicated that three factors are related to the low adoption rate of GMCCs: 1) farmers preferred improving farmland irrigation facilities and substituting chemical fertilizers with organic rather than planting GMCCs; 2) lack of awareness and understanding of government policy on GMCCs and limited access to training courses; 3) financial support and subsidies from the government are insufficient. This study provides insights and strategic implications for policymakers on how to further promote GMCCs in the future.

Keywords: best–worst scaling, farmers' preferences, green manure cover crops, sustainable agriculture, Northwest China

1. Introduction

Green manure cover crops (GMCCs) include a variety of crops that are cultivated between successive crops to capture and supply nutrients and provide ground cover to prevent soil erosion. Planting GMCCs on arable land has been proved to be a great potential for reducing synthetic fertilizer use without sacrificing crop yields (Qaswar *et al.* 2019; Toma *et al.* 2019) and for mitigating the effects of climate change (Kaye and Quemada 2017). Generally, GMCCs planting could achieve several Sustainable Development Goals (SDGs) including SDG 2 (Zero hunger), SDG 6 (Clean water and sanitation), SDG 12 (Responsible consumption and production), SDG 12 (Climate action) and SDG 15 (Life on land). In response to agriculture's contribution to climate change and environmental pollution, the Chinese government has been making efforts to provide national conservation

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measures and incentives in order to encourage farmers to adopt sustainable farming practices such as substituting chemical fertilizers with organic fertilizers, implementing fallow land programs (Zuo *et al.* 2020), halving the use of agro-chemicals, and growing GMCCs (Li *et al.* 2020). Among all these practices, the government enthusiastically advocates GMCCs planting because this can accomplish multiple goals such as water retention, chemical fertilizer reduction, soil fertility enhancement, nitrate leaching reduction and environmental protection. However, the GMCC adoption rate is still very low in the whole of China, especially in the arid and semi-arid regions (Xie and Chen 2012). This paper aims to explore the reasons for the low adoption rate of GMCCs planting in Gansu Province.

In general, providing farmers with subsidies for planting GMCCs is still at the research and development stage in China. The studies on farmers' adoption of GMCCs are limited due to the planting areas covering less than 3%[1] of total arable land in the whole of China (Li 2020). In comparison to European countries, for example, Germany, Austria, the Netherlands and Belgium, more than 50% of farmers use GMCCs on their farms (EIP-AGRI 2015). In China, there are numerous studies focusing on the effects of GMCCs on soil improvement and crop yields (Yang *et al.* 2018; Ma *et al.* 2021). However, there are only few studies investigating farmers' willingness to accept compensation for growing GMCCs (Ntakirutimana *et al.* 2019; Li *et al.* 2020). Their studies found that farmers are unlikely to participate voluntarily in a conservation program if the opportunity costs of planting GMCCs are not sufficiently compensated. For example, Ntakirutimana *et al.* (2019) found that in Guangxi of southern China, increasing production costs of growing GMCCs leads to farmers' reluctance to adopt practices such as intercropping with GMCCs or growing them on fallow land. Li *et al.* (2020) investigated farmers' willingness to adopt the Green Manure Program for paddy rice in the paddy fields region of southern China by estimating the monetary value that farmers would accept. They found that the incentive farmers expected is much higher than current compensation standards.

There are several studies on the adoption of GMCCs worldwide. Bergtold *et al.* (2017) reviewed the GMCCs adoption, production, risk and policy considerations from an economic standpoint. Hijbeek *et al.* (2019) found that costs were a major barrier for the cultivation of GMCCs in Italy. Bunch (2012) indicated there is a widespread misconception that GMCCs do not work under semi-arid conditions in the African Sahel, but actually two GMCCs systems are working very well in this region. In arid and semi-arid regions, GMCCs are still not widely used because they are thought to compete with cash crops for water and nutrients (Alonso-Ayuso *et al.* 2018). However, an appropriate GMCC management could avoid such competition, for example, by selecting appropriate varieties of GMCCs, and by deciding on the appropriate termination dates (Alonso-Ayuso *et al.* 2018). Regarding the situation in China, according to the authors' knowledge, the GMCC adoption studies were mostly conducted in the southern provinces of China (Ntakirutimana *et al.* 2019; Li *et al.* 2020), where the subtropical climate tends to be humid. However, growing GMCCs is also very important for arid and semi-arid regions as it can greatly increase water-holding capacity in the soil (Yao *et al.* 2019). Research regarding GMCCs planting in Northwest China mostly focuses on agricultural technical aspects as well as challenges and opportunities of GMCCs planting (Xie and Chen 2012). The reasons for the low adoption rate of GMCCs planting in relation to individual farmer preferences are rarely explored.

There have been studies aimed at investigating farmer preference regarding individual conservation practices employing the discrete choice experiment method (Defrancesco *et al.* 2007; Christensen *et al.* 2011; Chang *et al.* 2017; Nong *et al.* 2021). Since there is always an opt-out group in the studies of farmer preference for the agri-environmental scheme, the reasons why farmers choose not to participate could only be elicited by follow-up questions on participation conditions, for example, asking farmers whether they would be willing to consider enrolling at a higher payment or not consider participating at all. Many studies usually focus on a specific conservation program but farmers' relative preferability for different conservation practices have been neglected. Glenk *et al.* (2014) used the BWS to investigate dairy farmers' relative preferences for greenhouse gas mitigation measures. They found farmers' current adoption of mitigation practices has a positive impact on the probability of their practice being chosen as the "best". In our study, we also take farmers' current conservation practices into account and hypothesize farmers may have other preferred alternatives in mind leading them to give low priority to GMCCs, and thus, making them hesitate to adopt this.

To better understand whether other alternative arable land conservation practices will affect farmers' adoption of GMCCs planting, we include three practices relevant to

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[1] Total estimated GMCCs cultivated area (3.2 million ha) divided by total arable land area (134.88 million ha) is about 2.4%.

GMCCs planting of a total of nine conservation practices for the best–worst scaling (BWS) approach. Specifically, this paper aims to investigate farmers' preferences mainly for GMCCs planting and for other conservation alternatives in Northwest China. This paper also explores how farmers' socioeconomic status, their previous training experience and their attitude towards governmental support affect their preferences. Therefore, the censored regression model and the latent class model were applied in order to have a deeper understanding of farmer decision-making with regard to planting GMCCs. Since little attention has been paid to the GMCCs adoption in arid and semi-arid areas, Gansu Province was selected for this study as it is a typical dry region in the upper reaches of the Yellow River Basin in Northwest China. In this province, the challenge of water scarcity and soil erosion is particularly far reaching. The area of arable land in Gansu Province is about 5 410 233 ha, and the GMCCs planting area is around 53 333 ha, which is less than 1% of the entire arable land (Xie and Chen 2012). According to the study by Xie and Chen (2012), GMCCs had played a pivotal role in agricultural production in Gansu province before the 1980s. However, after the 1980s, the amount of chemical fertilizer usage increased sharply which resulted in a significant decrease of planting areas for GMCCs. Furthermore, due to the increasing costs of planting GMCCs, slow return of economic benefits, and insufficient support by the government, farmers are not motivated to plant GMCCs. As the government pays more attention to GMCCs, the seeds of green manure are distributed free of charge, and the sowing process is also free. However, there is only one ploughing fee after harvest, for which farmers do not need to pay. In general, planting GMCCs for farmers could earn net benefits, but this income is relatively small compared to growing other economic crops. Therefore, there is still a great potential to expand GMCCs planting area in Gansu Province.

Research on farmers' preferences for sustainable agriculture practices is traditionally based on the analysis of certain underlying attributes. This conventional approach is indirect, does not take into account the preferences farmers may have for other alternative practices, and makes it challenging to evaluate the relative preference of a wide variety of conservation options. Although governments are passionate about promoting certain sustainable agriculture practices for arable land conservation and climate change mitigation, if farmers have other alternative choices in mind, the participation rate for the programs offered will be limited. GMCCs planting is regarded as an ideal measure to improve soil health and mitigate climate change simultaneously (Kaye and Quemada 2017). Therefore, this study considered: (1) the reasons for the low adoption rate of GMCCs planting; (2) farmers' preferences towards different GMCCs planting practices and their preferences when given the choice of other conservation practices; and (3) what government could do to promote the GMCCs planting.

This research offers two contributions: (1) This study contributes to the growing body of literature using BWS to understand farmers' decision-making. It highlights the usefulness of BWS on policy support, particularly at the early stages of policy development when policymakers are faced with a large number of options to choose from; and (2) Our findings indicated key factors for the low adoption rate of GMCCs planting. This study provides information for policymakers to consider a new approach rather than just increasing monetary incentives to encourage participation and adoption.

This paper is organized as follows: Section 2 presents the experimental design and data collection; in Section 3, we present the methods, followed by the analysis results and discussion in Section 4. Finally, in Section 5, we summarize key findings and provide policy recommendations.

2. Designing the best–worst scaling experiment

2.1. Experiment design

The survey was designed to obtain information about farmer socioeconomic characteristics, attitudes and preferences towards arable land conservation practices. This section describes the choice of conservation practices, the design of the BWS experiment and its implementation in the survey. We use the BWS method to prioritize farmers' concerns regarding growing GMCCs and their relative importance between the various arable land conservation practices. The conservation options that we investigated in the BWS survey were chosen based on a comprehensive literature review, expert opinions and representative farmers' responses to a pre-survey.

Table 1 includes the arable land conservation practices identified for this study along with a brief description of each. The following nine conservation practices were selected: (1)–(3) three practices related to growing GMCCs: planting GMCCs on fallow land, intercropping with GMCCs, and crop rotation with GMCCs (Deng *et al.* 2006; Hong *et al.* 2017); (4) improving farmland irrigation facilities: due to the water shortage in Gansu Province, we would like to find out whether improving farmland irrigation facilities is a preferred alternative by farmers and whether this could hinder the adoption of green manure crops planting. Irrigation efficiency improvements help to reduce the frequency and

Table 1 List of arable land conservation practices and measures

Land conservation practices	Description of protection measures
1. Using cover crops	(1) Crop rotation with green manure cover crops (GMCCs) (2) Interplanting with GMCCs (3) Growing GMCCs on fallow farmland
2. Sustainable water management	(4) Improving irrigation facilities
3. Reducing agro-chemical inputs	(5) Substituting chemical fertilizer (CF) with organic fertilizer (OF) (6) Applying biochar-based fertilizer (7) Halving chemical fertilizer and pesticide input
4. Conservation tillage	(8) Returning crop residues to the field (9) Leaving land fallow for a whole year

severity of water shortages, and minimize salinization issues in arid regions (Tomer 2014); (5) one current subsidized conservation policies in China: substituting chemical fertilizer (CF) with organic fertilizer (OF); (6) applying biochar-based fertilizer (Nair *et al.* 2017); (7) halving chemical fertilizer and pesticide application; (8) returning crop residue or straw to the field after harvest; and (9) leaving arable land fallow for a whole year (Zuo *et al.* 2020).

There are two reasons for having a diverse range of conservation practices: (1) to give a broader context and better understanding of farmer perception and preferences in these practices; (2) to investigate how the green manure policy could take the potential green manure planting program one step further. The nine conservation practices (attributes) were assigned to subsets using a Balanced Incomplete Block Design (BIBD) (Louviere *et al.* 2015). The BIBD is one of the widely used designs in BWS literature because it is balanced and orthogonal (Flynn and Marley 2014), which ensures that each statement appears a set number of times. In this study, each practice appeared eight times across the design, and each pair of practices appeared once. The design resulted in 12 choice sets, each including six conservation options. The 12 choice sets were divided into two blocks. Farmers were randomly assigned to each block. Farmers were asked to select one conservation practice as the best (most preferred) and one as the worst (least preferred) among six conservation practices for each BWS question. The following instructions were given: "We would like to ask you six questions regarding your preference for arable land conservation practices. Each question is composed of six conservation practices. Which practice do you think is the best (most preferred) and which is the worst (least preferred)?" (Appendix A).

2.2. Data collection

Gansu Province with its ecological vulnerable regions is particularly important in Northwest China because of its economic and ecological conditions. It is an agricultural province and contains a large portion of China's rural poor. The climate is not conducive to agricultural production. The annual precipitation is about 300 mm, and droughts are a common occurrence. The distribution of rainfall is inconsistent over the year, and it often varies greatly every year (Liao *et al.* 2008). It is one of most typical arid and semiarid regions with water scarcity in China, and has been subject to severe ecological degradation, such as soil desertification, leading to a decrease in arable land use intensity (Yang *et al.* 2019).

After piloting and pretesting, a field survey was conducted to collect the data face to face by the research team in four regions of Gansu Province in April 2019. Using a stratified sampling approach, four regions were chosen as sampling units based on geographical distribution; three townships in each region and two villages in each township were selected, and then around 20 farm households were chosen randomly from each village. The four regions involved in the survey were Linxia Hui Autonomous Prefecture, Pingliang, Wuwei, and Zhangye cities. Wuwei and Zhangye are located in northwestern Gansu, with an average precipitation of 161 and 131 mm per year, while Linxia and Pingliang are in the southwest and east of Gansu, respectively, with an average annual precipitation of 492 and 532 mm. The main crops are wheat and potato, and the main intercropping systems consist of wheat/maize, cumin/maize, watermelon/maize. Approximately 80% of the freshwater is consumed by irrigation for agricultural purposes in these regions (Akiyama *et al.* 2018). A total of 349 surveys were conducted, from which only 276 were valid for analysis due to 29 survey were interviewed with cooperative mangers who were not farmers, 23 surveys not having completed all BWS tasks and 21 surveys not having socioeconomics information.

3. Methods

To present more comprehensive results of farmer preference, we applied three statistical methods for analyzing the data from the BWS object case (BWS case one), censored regression model (Tobit model) and latent class analysis. BWS is an attribute-based technique that allows survey respondents to select the "best" and "worst" attributes across multiple repeated choice sets. This method is especially useful to rate a large number of items in terms of their value to or choice by individuals (Erdem and Rigby 2013). Regarding the fact that the distribution of the dependent variable having an upper and lower limit, we chose a Tobit model to explore the influence of farmer preference on conservation practices related to green manure. Three green manure-related conservation practices were chosen as dependent variables, resulting from the farmers' individual best–worst score for each of the practices. Finally, we use the latent class model to identify latent groups, which is particularly useful when there is hidden heterogeneity of the respondent due to variations in choice behavior that may not be related to observable socio-economic characteristics (Garrod *et al.* 2012). We used the R package (Yee 2015; Sarrias and Daziano 2017; Aizaki 2020; Croissant 2020) for the analyses.

3.1. Best–worst scaling: Counting approach

The BWS (case one) or the so called counting approach as an efficient means of inferring the relative importance of statements in a list with relatively low cognitive burden for respondents in contrast to ranking exercises (Louviere *et al.* 2013). A BWS score counts the number of times an item is considered "best" and subtracts the number of times it is considered "worst" providing an indication of relative importance of farmer perception on practices of arable land conservation. Nevertheless, the case I BWS score shows little information about the relative importance between each practice, here the ratio score is introduced to enable us to compare the relative importance of each practice. The ratio scores are calculated by taking the square root for all best/worst practices and scaling them by a factor, so that the most important practices with the highest square root (B–W) have an interval scale of 100 (Adamsen *et al.* 2013).

3.2. Best–worst scaling: Regression analysis

For case 1 in BWS, the measure of impact is calculated by asking the farmer to indicate which attribute is the most preferred and which the least (Louviere *et al.* 2013). According to the research work of Lusk and Briggeman (2009), we use I_{nit} to represent the true or latent unobserved level of importance for individual *n*, choosing *i* as the best practice in each BWS question *t*. The euqation is given below:

$$I_{nit}=\tau_{nit}+\varepsilon_{nit} \quad (1)$$

where ε_{nit} is the random error term, and τ_{nit} represents the measured utility (i.e., preference) given by eq. (2):

$$\tau_{nit}=\beta_{it}x_{nit} \quad (2)$$

where β_{it} is the estimated coefficient of the best item, x_{nit} (indexed by individual *n* and BWS question *t*).

Regarding the worst attribute *i´* chosen by individual *n*, the true or latent unobserved level of importance, $I_{ni't}$, can be defined in the following manner:

$$I_{ni't}=\tau_{ni't}+\varepsilon_{ni't} \quad (3)$$

The overall utility (U_{nkt}) in the BWS task representing the difference in utility between the best and the worst attributes, associated with farmer *n*, who chose the best and the worst pair *k* (including the attribute *i* and *i´*) in the choice set *t* is given by:

$$U_{nkt}=\tau_{nit}-\tau_{ni't}=\beta_{it}x_{nit}-\beta_{i't}x_{ni't} \quad (4)$$

The probability of the individual farmer *n*, selecting (*i*, *i´*) as the best and worst practices is equal to the probability that the difference in I_{nit} and $I_{ni't}$ is greater than the differences in all other best–worst combinations available in each BWS question *t*.

3.3. The Tobit model

In this study, the standard Tobit model (or Type 1 Tobit) defined in Amemiya (1984) is employed. The standard Tobit model represents the one originally proposed by Tobin (1958) which assumes the solution of maximization subject (uncensored part), denoted by *y**, to be normally distributed and the censored part to be the same for all individuals. As addressed in Section 2.3, only positive preferences are considered, hence the Tobit model being censored at zero and above. The standard Tobit model for individual farmer *n* can be expressed in the following equations:

$$y_n^*=x_n\beta+\varepsilon_n \quad (5)$$

$$y_n=\begin{cases} y_n^*, & y_n^*>0 \\ 0, & y_n^*\leq 0 \end{cases} \quad (6)$$

where x_n is the vector of attributes from farmer *n*, and the β represents the vector of coefficients. The error term ε_n is assumed to be i.i.d drawing from $N(0, \sigma^2)$. The y_n^* is unobserved if $y_n^*\leq 0$. In general form, the likelihood function of the Tobit model can be expressed as follows:

$$L=\prod_0 F_n(y_{0n})\prod_1 f_n(y_n) \quad (7)$$

where F_n and f_n are the distribution and density function respectively for $y_n^*\leq 0$ and $y_n^*>0$.

By applying the standard normal distribution and density to the F_n and f_n given in eq. (7) respectively, the standard Tobit model can be represented as follows:

$$L=\prod_0[1-\phi(x_n\beta/\sigma)]\prod_1\sigma^{-1}\varphi[(y_n-x_n\beta)/\sigma] \quad (8)$$

where ϕ and φ are respectively the distribution and density function of the standard normal variable.

3.4. Latent class model

The purpose of using latent class analysis is to identify heterogeneity within the population. Each individual is assigned to a class by probabilities. Thus, this results in subgroups of individuals that are most similar to one another and most distinct from others in their classes (Berlin *et al.* 2013). In the mixed logit model, the density of parameter, $f(\beta_n)$ in eq. (a4) in Appendix B can be discrete, with β taking a finite set of values (Train 2009). The discrete form of mixing distribution becomes the latent class model, and the choice probabilities can be expressed as:

$$P_{nii'}=\sum_{k=1}^{K} S_k \prod_{t}^{T_n} \frac{\exp[\beta_{kit}x_{nit}-\beta_{ki't}x_{ni't}]}{\sum_{\substack{j,j'\epsilon M \\ j\neq j'}} \exp[\beta_{kjt}x_{njt}-\beta_{kj't}x_{nj't}]} \tag{9}$$

The S_k in eq. (9) represents the probability of membership of class k and can be given in the following form:

$$S_k=\frac{e^{\lambda_s Z_i}}{\sum_{s=1}^{S} e^{\lambda_s Z_i}} \tag{10}$$

where the λ_s is the vector of parameters and Z_i is the vector of socioeconomic characteristics and stated behavior.

4. Results and discussion

A summary of descriptive statistics is presented in Table 2. About 97% of the respondents were male and 3% were female. The mean age of the participants was 53 years old. Most farmers are doing arable farming (77%), those remaining do mixed farming (23%, a combination of arable and pastoral farming). About 41% of respondents has an off-farm job. The average farm size for mixed farming was 1.54 ha (23.1 mu) and for arable farming this was 1.34 ha (20.1 mu). The most common crops grown by our respondents are wheat, maize and potato.

4.1. The ranking of the arable land conservation practices

The ranking of each of the arable land conservation practices based on the BWS standard score (column 5) and standardized scale (column 11) are presented in Table 3. The counting approach counts the number of times an item is considered "best" and "worst", and then, the BW score is calculated by subtracting the "worst" from the "best". After that, the BW scores are converted into a standard score column (4) for each attribute by dividing the BWS score by the frequency in which each practice appears (8 times) in the design multiplied by the number of survey observations (n=276).

Table 2 Socio-economic characteristics of respondents

Indicators	Number	Proportion (%)
Age (mean)	53	
Male	267	97
Education		
1=elementary school and below	118	43
2=junior high school	102	37
3=high school	47	17
4=college and above	9	3
Linxia Hui Autonomous Prefecture	71	26
Pingliang City	44	16
Zhangye City	87	31
Wuwei City	74	27
Arable farming farmers	212	77
Mixed farming farmers	64	23
Family income (annual CNY)		
1=≤20 000	64	23
2=20 001–40 000	79	29
3=40 001–60 000	44	16
4=≥60 001	89	32
Portion of on-farm income		53.8
Farm size (mean, ha)	1.58	

The ranking of the conservation practices based on the BWS standard score is listed in column (5). Improving irrigation facilities was the most preferred practice (selected 284 times, with a standard score of 0.129), followed by substituting chemical fertilizer with organic fertilizer and crop rotation with GMCCs. The BWS standard score presents the ranking of the most or least preferred conservation practices. However, it does not show the relative importance of the conservation practices, but it suggests the following questions: Was the second most favored practice close or distant to the most preferred practice? How important was the third-ranked practice compared to the first?

In order to make a comparison of the relative importance of each practice, the ratio scores of the best–worst scores are calculated by taking the square root for all the best and worst practices and by multiplying that by 100, so that the most significant practice with the highest square root provides the interval scale (Ochieng and Hobbs 2016). Columns (10) and (11) of Table 3 show the ranking of relative importance using the standardized scale.

Based on interval scale ranking, 'substituting chemical fertilizer with organic fertilizer' becomes the most important practice, followed by 'improving irrigation facilities' which is 0.812 times as influential as the top ranked practice. 'Substituting chemical fertilizer with organic fertilizer' is considerably more influential than the third ranked practice 'crop rotation with GMCCs', which has a standardized square root interval score of 54, compared to the score of 100 for the top ranked practice. Furthermore, 'interplanting with GMCCs' ranked as number 4, which is 0.444 times as influential as the top ranked one, while 'growing GMCCS in fallow land' is

Table 3 Best–worst scaling (BWS) model[1]

Arable land conservation practices[2]	(1) Total best	(2) Total worst	(3) B–W score	(4) B/W standard score	(5) Ranking based on standard score	(6) Mean B–W	(7) Stdev B–W	(8) Stdev/ Mean	(9) Sqrt B–W	(10) Std.sqrt BW (interval scale)	(11) Ranking based on (10)
Improving irrigation facilities (BWS7)	381	97	284	0.129	1	2.00	2.127	2.067	1.982	81.2	2
Substituting CF with OF (BWS8)	316	53	263	0.119	2	1.85	1.746	1.832	2.442	100.0	1
Crop rotation with GMCCs (BWS5)	188	108	80	0.036	3	0.56	1.628	5.616	1.319	54.0	3
Interplanting with GMCCs (BWS4)	122	104	18	0.008	4	0.12	1.387	21.263	1.083	44.4	4
Halving CF and PS input (BWS3)	137	226	–89	–0.033	5	–0.627	1.843	–5.716	0.779	31.9	6
Growing GMCCs in fallow land (BWS9)	68	179	–111	–0.050	6	–0.782	1.263	–3.139	0.616	25.2	9
Biochar (BWS2)	122	195	–73	–0.062	7	–0.514	1.163	–6.099	0.791	32.4	5
Returning crop residues to the field (BWS6)	102	261	–159	–0.072	8	–1.120	1.730	–3.004	0.625	25.6	8
Fallow for a whole year (BWS1)	220	433	–213	–0.096	9	–1.500	2.647	–3.430	0.713	29.2	7

[1] Column (3)=Column (1)–Column (2); Column (4)=Column(3)/(276×8), 276 is the number of survey observations, 8 is the frequency which each incentive appears in the design; Column (8)=Column (7)/Column (6); Column (9)=square root of Column (1)/Column (2); Column (10), standardized square root interval scale.

[2] Conservation practices in the left column are ordered by column (5) ranking based on the BW standard score. GMCCs, green manure/cover crops; CF, chemical fertilizer; OF, organic fertilizer; PS, pesticides.

0.252 times as influential and makes it the least preferred practice.

The results show that farmer perception of the most effective practices for the arable land conservation is consistent with the current government supported fertilizer replacement program: substituting chemical fertilizer with organic fertilizer. The least preferred practice according to the Standard Score is 'leaving land fallow for a whole year' whereas for the Standardized Scale it is 'growing GMCCs in fallow land'.

The standard deviation of the individual BWS scores indicates the degree to which the choice made by farmers was consistent or whether those choices exhibited heterogeneity (Ochieng and Hobbs 2016). The standard deviations for all conservation practices in column (7) of Table 3 are greater than 1, suggesting the presence of heterogeneity in responses. The individual standard deviation to the individual mean of the B–W score (Stdev/Mean) is used to assess the degree of heterogeneity (column 8). The high absolute ratio of Stdev/Mean signals higher heterogeneity, while absolute ratios close to zero suggest a high degree of agreement regarding the importance of the conservation practice. Thus, the results from Table 3 show a high degree of heterogeneity.

Farmers in our survey are generally more concerned about the water supply than planting GMCCs because improving irrigation facilities was the most preferred. As groundwater supplies are often inaccessible in Gansu Province, farmers must rely on rainfall to supply their crops' needs (Cook *et al.* 2000). Therefore, irrigation plays an important role in agricultural production, socioeconomic development and environmental protection in Gansu Province. However, improper irrigation has caused runoff and erosion, resulting in contamination of surface water. Thus, in this study, it is reasonable for farmers to rank improving irrigation facilities as the most preferred and effective way to conserve arable land. Responding to water shortages in the region, some local governments, e.g., in Wuwei City, have promoted the production of high yielding crop systems with lower water demand by reducing the irrigation water allocated to farmers. From 2005 onwards, the intercropping of maize and pea was one of the systems that emerged due to water restriction (Mao *et al.* 2012). Studies presented the benefits and drawbacks (Fageria 2007; Stagnari *et al.* 2017) in using GMCCs in farm production, and they found that water consumed by growing GMCCs in dry regions may lead to water deficiency for subsequent commercial crops. Hence, water availability is crucial for crop production in arid and semi-arid regions. Therefore, crop production through intercropping or crop rotation should be designed in such a way that the amount of water used to grow GMCCs will not compete with the water required to raise cash crops. With limited water availability, it would be more beneficial to select drought tolerant GMCCs. When appropriate GMCC types are chosen according to regional climatic conditions, crop yields will not be compromised.

Li *et al.* (2020) found that insufficient payment may result in farmers' reluctance to participate in the green manure planting program. However, this may also be due to farmers having other perspectives. In our study, the farmers rate improving irrigation facilities as more important than GMCCS planting.

4.2. The main factors affecting farmers' preferences towards GMCCs planting

In order to explore heterogeneity across the best–worst scores specifically for planting green manure crops (BWS4, BWS5, BWS9), censored regression analysis was applied. The following explanatory variables were used: residential cities, income (income level, access to off-farm income), farm size, whether the farmer was participating in training courses for GMCCs or for agriculture production technology, whether the farmer is currently adopting conservation practices (crop rotation, growing GMCCs, substituting CF with OF on the farm). In addition, farmers were asked if given financial support, would they be willing to accept the following practices: "conducting soil analysis and thereafter following the recommendations of fertilizer use", "reducing chemical fertilizers", "growing green manure crops", and "returning straw residue to the fields after harvest". Censored regression results are shown in Table 4.

Respondents who have access to off-farm income were significantly hold negative attitude to BWS4 (intercropping with GMCCs). Respondents who has higher income level were significantly more likely to choose BWS5 (crop rotation with GMCCs) as the best. Those farmers who had participated in training workshop for growing GMCCs hold negative views towards the BWS9 (growing GMCCs on fallow land). Moreover, those farmers who had training for production technology were more likely to choose BWS9 as the best. Farmers who are currently substituting CF with OF are more likely to choose BWS5 and BWS9 as worst practices. Farmers who are not implementing any conservation practices on their farms hold negative attitudes to BWS9. Meanwhile, the results show that if the financial support was provided, farmers who were willing to plant GMCCs were more likely to choose BWS5 as the best practice. Whereas respondents who were willing to do the soil testing would prefer BWS4. Therefore, providing financial incentives to farmers to practice crop rotation with GMCCs and to test their soil quality could be an option for promoting GMCCs planting in the region.

A study by Yang and Sang (2020) found that farmers who work part-time with off-farm income were able to adopt conservation agriculture more effectively. It may be due to off-farm income being useful to alleviate economic concerns. However, other research by Huang *et al.* (2019) shows that farmers' adoption of soil and water conservation technology is negatively impacted by off-farm employment. It may be that full-time farmers are more likely to adopt time-intensive practices. Our study shows that farmers, who have access to off-farm income, are not willing to practice intercropping with GMCCs (BSW4). It is not yet clear why the off-farm income influences the adoption of GMCCs, this would require further research. A Tobit model for other conservation practices (BWS1, BWS2, BWS3, BWS6, BWS7, and BWS8) is presented in Appendix C.

4.3. Farmers' heterogeneity and preferences towards GMCC planting

Using the latent class analysis, three groups of farmers were identified. The results of the latent class analysis are presented in Table 5. Class 1 accounts for 38% of the sample. It is more likely to be comprised of farmers who have negative attitudes towards all practices. Farmers in Class 2 accounts for 44% of the sample. This group of farmers finds improving irrigation facilities and substituting CF with OF to be most important. These farmers rate halving CF and PS, returning crop residues to the field and applying biochar as equally important. In terms of class membership, the farmers from Wuwei City and Zhangye City were not planting green manure on their farmland and did not attend training courses on GMCCs planting but have attended training courses on agricultural production technology. Class 3 accounts for 18% of the sample. This group of farmers finds improving irrigation facilities to be most important. These farmers have higher coefficients relating to crop rotation and intercropping with GMCCs, growing GMCCs on fallow land. Farmers in Class 3 were most interested in GMCCs planting. The farmers from Pingliang City were more likely to have a higher portion of off-farm income, only doing arable farming, and not attending training courses on GMCC planting, although they had participated in training courses on agricultural production technology. However, in general, the three classes of farmers (Class 1, Class 2 and Class 3), who attended the training course on GMCCs planting, are very few in number, only 8, 4 and 2, respectively.

Moreover, even those farmers who did not attend the GMCCs planting training course were still willing to try GMCCS planting. It is assumed that there were not enough courses for the demand and the distance

Table 4 Tobit model

Variable[1]	Intercropping with GMCCs (BWS4)	Crop rotation with GMCCs (BWS5)	Growing GMCCs in fallow land (BWS9)
	Coef. (Std.Err)	Coef. (Std.Err)	Coef. (Std.Err)
Pingliang City	–0.4943 (0.6216)	–0.6373 (0.5650)	–0.3163 (0.6008)
Zhangye City	–2.2458**** (0.6426)	–1.1147** (0.5075)	–0.5508 (0.5529)
Wuwei City	–1.6914*** (0.6418)	–2.3049**** (0.5973)	–0.8598 (0.5826)
Mixed crop-livestock farming	–0.2126 (0.5699)	0.0340 (0.4903)	–0.8296 (0.5564)
Farm size	–0.0013 (0.0038)	–0.0024 (0.0032)	–0.0010 (0.0031)
Access to off-farm income	–0.9486* (0.5342)	–0.6041 (0.4613)	–0.0287 (0.4963)
Income level	0.1826 (0.2092)	0.3630**(0.1832)	–0.1091 (0.1957)
Attended training courses on growing GMCCs	–0.8500 (1.0952)	–0.7535 (0.8935)	–2.3729* (1.2251)
Attended training courses on production technology	0.2935 (0.4617)	–0.3282 (0.4051)	1.01225** (0.4253)
Currently adopting crop rotation on farm	0.3684 (0.6612)	0.4446 (0.5862)	–0.3300 (0.5736)
Currently growing GMCCs on farm	0.4178 (0.9367)	0.8246 (0.8230)	–0.1902 (0.8733)
Currently substituting CF with OF	0.4116 (0.7324)	–1.1719*(0.6683)	–1.5300** (0.7317)
No conservation practices	–2.6093 (0.7095)	0.6765 (0.6237)	–1.3285** (0.6416)
WTA soil testing	1.5304** (0.6279)	–0.1618 (0.5653)	–0.0318 (0.5953)
WTA reduce CF	–1.2742** (0.5997)	–0.8414* (0.4956)	–0.6040 (0.5360)
WTA green manure crops	0.2535 (0.5170)	1.3855*** (0.4481)	0.49164 (0.4757)
WTA return straw residue	–1.3605** (0.6406)	–1.4812*** (0.5521)	–1.1227* (0.6370)
Log-likelihood	–240.9	–300.7	–172.9

[1] GMCCs, green manure/cover crops; CF, chemical fertilizer; OF, organic fertilizer; WTA, willingness to accept.
*, *P*<0.1; **, *P*<0.05; ***, *P*<0.01; ****, *P*<0.001. All variables are binary except for farm size and income level

Table 5 Latent class model

Variable[1]	Class 1 (38%)		Class 2 (44%)		Class 3 (18%)	
	Coef.	Std. Err	Coef.	Std. Err	Coef	Std. Err
Improving irrigation facilities	–1.856****	0.249	2.977****	0.212	6.245****	0.682
Substituting CF with OF	–0.741****	0.172	2.752****	0.198	4.321****	0.570
Crop rotation with GMCCs	–0.875****	0.154	1.357****	0.158	4.806****	0.656
Interplanting with GMCCs	–1.432****	0.180	1.462****	0.163	4.693****	0.674
Biochar	–1.745****	0.224	1.995****	0.186	1.093****	0.241
Halving CF and PS input	–1.732****	0.207	1.922****	0.214	0.999****	0.236
Growing GMCCs in fallow land	–2.148****	0.195	1.260****	0.167	4.358****	0.704
Returning crop residues to the field	–2.825****	0.237	1.940****	0.209	3.242****	0.552
Class membership						
Pingliang City			–1.292	1.142	1.061***	0.329
Zhangye City			0.915****	0.276	–0.551	0.350
Wuwei City			1.417****	0.320	–11.253	108.736
Household income ratio of on-farm income			–0.160	0.239	–1.212****	0.358
Mixed crop-livestock farming			–0.382	0.271	–1.362*	0.804
Currently planting green manure			–1.706**	0.720	–0.481	0.586
Attended training courses on GMCCs planting			–1.263**	0.522	–2.000****	0.520
Attended training courses on agriculture production technology			1.882****	0.303	2.984****	0.359
Log-likelihood	–4 920					

[1] CF, chemical fertilizer; OF, organic fertilizer; GMCCs, green manure/cover crops; PS, pesticides.
*, *P*<0.1; **, *P*<0.05; ***, *P*<0.01; ****, *P*<0.001.

to travel to the course locations was too far. According to the results of the latent class model, some of the heterogeneity may be explained by groupings of respondents who have similar preferences. As the Class 1 farmers holds negative attitudes towards all conservation practices including GMCCs planting, it may be difficult to influence this group of farmers through the incentive alone. Those Class 2 farmers who have moderate interests in arable land conservation practices could be from Wuwei and Zhangye cities. We found that farmers in Wuwei and Zhangye cities have a higher share of preference for intercropping with GMCCs. Farmers may think that intercropping and mixed cropping provide greater overall production and income stability than monocultures (Matsuda 2013). There is a significantly higher probability of belonging to Class 3 if off-farm employment is the primary source of household income. These farmers are likely to be doing arable farming and be located in Pingliang City. Farmers may be concerned about the income loss from planting GMCCs. Since Class 3 has a higher portion of off-farm income, their willingness to adopt the GMCCs planting is higher than the other groups. This could be relevant in a policy context of where to encourage GMCCs planting as a pilot area.

In general, very few farmers (14 farmers in total) attended the GMCCs training courses. This explains why there is a lack of awareness and knowledge of GMCCs. We agree with Xie and Chen (2012) and Bergtold *et al.* (2017) that by increasing awareness and knowledge of GMCCS, farmers may consider adoption. Ntakirutimana *et al.* (2019) investigated Chinese farmers' preferences on planting GMCCs in fallow croplands, and the results show that the most important factors are subsidies and planting training courses for the farmers. Another study shows that adoption of GMCCs among Paraguayan smallholder farmers are influenced by training events, access to GMCCs information, social participation and technical assistance (Pratt and Wingenbach 2016). Pham *et al.* (2021) found that effects of informal social learning channels, such as through peers and agricultural groups are as important as the effects of those channels provided by extension agents. Since the attendance of the GMCCs training course was low, we suggest the government could also consider promoting GMCCs through both formal and informal social learning channels. Extension agents could organize training courses and introduce successful case studies in their communities. Thus, those farmers who have not yet adopted GMCCs could learn *via* the example of peer networks.

In terms of methodologies, the findings revealed differences between the analysis methods, which is useful in identifying key factors affecting farmers' adoption. The counting approach may be a sufficient method to analyze object case BWS data when the researcher only intends to analyze the ranking of farmers' preferences. The latent class analysis reveals the heterogeneity of respondents. A regression analysis (the Tobit model) would be useful for researchers who would like to explore the influence of farmers' preferences on specific alternatives. Furthermore, we also applied two additional models, namely the multinomial logit and the mixed logit (random parameter model) to reflect the relative importance of each conservation practice, presented together with a summary of models in Appendix B.

4.4. Farmers' cognition of GMCCs planting

Farmers' adoption of sustainable farming practices is determined by how they learn, understand and interpret these practices, including the difficulties, advantages and other cognitive elements (Dessart *et al.* 2019). Table 6 shows 27.9% of respondents think it is difficult to learn GMCCs planting techniques. Many farmers believe planting GMCCs could improve the environment (67.75%) and soil quality (76.09%), reduce chemical fertilizer application (51.82%) and could effectively cover bare soil (52.54%). Although many farmers recognize the environmental benefits of GMCCs planting, 69.2% of respondents disagreed or strongly disagreed regarding their understanding of the government's policy on GMCCs planting. Therefore, the information distribution on GMCCs planting should be enhanced.

5. Conclusion and policy recommendations

In this paper, we analyzed survey data of 276 farmers in Northwest China and investigated the factors for the low adoption rate of GMCCs planting. Our results indicate that three factors are related to low adoption: (1) Farmers prefer improving irrigation facilities and fertilizer substitution rather than GMCCs planting; (2) there is lack of awareness and understanding of government policy on GMCCs and limited access to training courses; (3)

Table 6 Statistical results of farmers' cognition of GMCCs planting (%)

Statements	Strongly disagree	Disagree	General	Agree	Strongly agree
It is easy to learn GMCCs planting techniques	4.71	23.19	25.36	34.42	12.32
Planting GMCCs could conserve the environment	9.78	11.59	10.87	57.61	10.14
Planting GMCCs could improve soil quality	3.26	6.88	13.77	47.10	28.99
Planting GMCCs could reduce chemical fertilizer application	9.78	23.91	14.49	42.03	9.79
Planting GMCCs could diminish pesticide usage	17.39	25.72	15.58	36.59	4.72
Planting GMCCs could prevent soil erosion	22.46	28.62	0	39.49	9.42
Planting GMCCs could effectively cover bare soil	15.94	31.52	0	37.68	14.86
Planting GMCCs could enhance biodiversity in farmland ecosystems	10.87	11.23	28.99	36.59	12.32
I understand the government's policy on GMCCs planting	45.29	23.91	13.04	12.68	5.07

financial support and subsidies from the government are insufficient. The findings provide evidence that low adoption could be due to farmers having other preferred alternatives as well as a lack of understanding of the economic and ecological values of GMCCs planting. Farmers' willingness to accept sustainable farming practices requires a complete understanding of the factors affecting their adoption. Our results show that particularly at an early stage of policy development, it is important to investigate farmers' preferences for targeted practices and identify other alternatives which might deflect from such targeted practices. This could enhance the design of more resilient and more sustainable agricultural climate policies. The role of behavior factors in farmers' adoption need to be further investigated for future research in order to scale-up GMCCs planting effectively and efficiently.

The results from this study address the needs of farmers. Most of the farmers in this study think improving irrigation facilities and substituting CF with OF are far more important than growing GMCCS. Besides irrigation improvement, farmers ranked substitute CF with OF as the second most preferred conservation practice, which indicates the effectiveness of the current national fertilizer substitution program, as well as confirming our hypothesis that such adopted conservation practices have a positive impact on farmers choosing their current practice as the "best". Since there were very few farmers participating in the GMCCs training courses, this low participation rate shows farmers have limited access to these training programs. Thus, it is important to increase farmers' awareness and knowledge of GMCCs. This can be accomplished by enhancing extension or advisory services.

Based on our findings, policy interventions should consider the following support strategies: (1) Enhancing the publicity and training. For example, government could establish a modern agricultural extension system carrying out publicity and training online and offline. Meanwhile, optimizing training content according to farmers' need, their knowledge and literacy thereby enhancing training effectiveness and learning efficiency. So that farmers could gain technical knowledge on GMCCs planning and understand the economic and ecological value of GMCCs. (2) Promoting the appropriate variety of seeds for GMCCs planting according to regional suitability. (3) Establishing more experimental demonstration sites, so that farmers could see the examples of GMCCs planting. (4) Providing economic incentives to farmers as this could alleviate farmers' economic concern about perceived risks of adoption. Policy-makers should emphasize the economic benefits of GMCCs adoption rather than just the environmental benefits, since this is a more effective way to motivate farmers to adopt new farming practices.

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Declaration of competing interest

The authors declare that they have no conflict of interest.

Appendices associated with this paper are available on http://www.ChinaAgriSci.com/V2/En/appendix.htm

References

Adamsen J M, Rundle-Thiele S, Whitty J A. 2013. Best–Worst scaling...reflections on presentation, analysis, and lessons learnt from case 3 BWS experiments. *Market & Social Research*, **21**, 9–27.

Aizaki H. 2020. Support BWS: Tools for case 1 best–worst scaling. R package version 0.4-2. [2020-3-10]. https://CRAN.R-project.org/package=support.BWS

Akiyama T, Kharrazi A, Li J, Avtar R. 2018. Agricultural water policy reforms in China: A representative look at Zhangye City, Gansu Province, China. *Environmental Monitoring and Assessment*, **190**, 9.

Alonso-Ayuso M, Quemada M, Vanclooster M, Ruiz-Ramos M, Rodriguez A, Gabriel J L. 2018. Assessing cover crop management under actual and climate change conditions. *Science of the Total Environment*, **621**, 1330–1341.

Amemiya T. 1984. Tobit models: A survey. *Journal of Econometrics*, **24**, 3–61.

Bergtold J S, Ramsey S, Maddy L, Williams J R. 2017. A review of economic considerations for cover crops as a conservation practice. *Renewable Agriculture and Food Systems*, **34**, 62–76.

Berlin K S, Williams N A, Parra G R. 2013. An introduction to latent variable mixture modeling (part 1): overview and cross-sectional latent class and latent profile analyses. *Journal of Pediatric Psychology*, **39**, 174–187.

Bunch R. 2012. *Restoring the Soil: A Guide for Using Green Manure/Cover Crops to Improve the Food Security for Smallholder Farmers*. Canadian Foodgrains Bank, Canada.

Chang S H E, Wuepper D, Heissenhuber A, Sauer J. 2017. Investigating rice farmers' preferences for an agri-environmental scheme: Is an eco-label a substitute for payments? *Land Use Policy*, **64**, 374–382.

Christensen T, Pedersen A B, Nielsen H O, Mørkbak M R, Hasler B, Denver S. 2011. Determinants of farmers' willingness to participate in subsidy schemes for pesticide-free buffer zones — a choice experiment study. *Ecological Economics*, **70**, 1558–1564.

Cook S, Li F R, Wie H L. 2000. Rainwater harvesting agriculture in Gansu Province, People's Republic of China. *Journal of Soil and Water Conservation*, **55**, 112–114.

Croissant Y. 2020. Estimation of random utility models in R: The mlogit package. *Journal of Statistical Software*, **95**, 1–41.

Deng X P, Shan L, Zhang H P, Turner N C. 2006. Improving agricultural water use efficiency in arid and semiarid areas of China. *Agricultural Water Management*, **80**, 23–40.

Defrancesco E, Gatto P, Runge F, Trestini S. 2007. Factors affecting farmers' participation in agri-environmental measures: A northern Italian perspective. *Journal of Agricultural Economics*, **59**, 114–131.

Dessart F J, Barreiro-Hurle J, van Bavel R. 2019. Behavioural factors affecting the adoption of sustainable farming practices: A policy-oriented review. *European Review of Agricultural Economics*, **46**, 417–471.

EIP-AGRI (The Agricultural European Innovation Partership). 2015. Final report EIP-AGRI focus group on soil-borne disease october 2015. [2022–01–30]. https://ec.europa.eu/eip/agriculture/sites/default/files/eip-agri_focus_group_on_ipm_practices_for_soil-borne_diseases_final_report_2015.pdf

Erdem S, Rigby D. 2013. Investigating heterogeneity in the characterization of risks using best worst scaling. *Risk Analysis*, **33**, 1728–1748.

Fageria N K. 2007. Green manuring in crop production. *Journal of Plant Nutrition*, **30**, 691–719.

Flynn T N, Marley A A J. 2014. Best-worst scaling: Theory and methods chapters. In: Hess S, Daly A, eds., *Handbook of Choice Modelling*. Chapter 8. Edward Elgar Publishing, UK. pp. 178–201.

Garrod G, Ruto E, Willis K, Powe N. 2012. Heterogeneity of preferences for the benefits of Environmental Stewardship: A latent-class approach. *Ecological Economics*, **76**, 104–111.

Glenk K, Eory V, Colombo S, Barnes A. 2014. Adoption of greenhouse gas mitigation in agriculture: An analysis of dairy farmers' perceptions and adoption behaviour. *Ecological Economics*, **108**, 49–58.

Hijbeek R, Pronk A A, van Ittersum M K, Verhagen A, Ruysschaert G, Bijttebier J, Zavattaro L, Bechini L, Schlatter N, ten Berge H F M. 2019. Use of organic inputs by arable farmers' in six agro-ecological zones across Europe: Drivers and barriers. *Agriculture Ecosystems & Environment*, **275**, 42–53.

Hong Y, Heerink N, Jin S Q Q, Berentsen P, Zhang L Z, van der Werf W. 2017. Intercropping and agroforestry in China — Current state and trends. *Agricultural Ecosystems & Environment*, **244**, 52–61.

Huang X, Lu Q, Wang L. 2019. Does aging and off-farm employment hinder farmers' adoption behavior of soil and water conservation technology in the Loess Plateau? *International Journal of Climate Change Strategies and Management*, **12**, 92–107

Kaye J P, Quemada M. 2017. Using cover crops to mitigate and adapt to climate change. A review. *Agronomy for Sustainable Development*, **37**, 4.

Li F D. 2020. Farmers' green manure planting practice and its incentive mechanism. Ph D thesis, Chinese Academy of Agricultural Sciences. (in Chinese)

Li F D, Ren J, Wimmer S, Yin C B, Li Z Y, Xu C X. 2020. Incentive mechanism for promoting farmers' to plant green manure in China. *Journal of Cleaner Production*, **267**, 122197.

Liao L, Zhang L, Bengtsson L. 2008. Soil moisture variation and water consumption of spring wheat and their effects on crop yield under drip irrigation. *Irrigation Drainage System*, **22**, 253–270.

Lusk J L, Briggeman B C. 2009. Food values. *American Journal of Agricultural Economics*, **91**, 184–196.

Louviere J J, Flynn T N, Marley A A J. 2015. *Best–Worst Scaling*: *Theory*, *Methods and Applications*. Cambridge University Press, Cambridge.

Louviere J J, Lings I, Islam T, Gudergan S, Flynn T. 2013. An introduction to the application of (case 1) best—worst scaling in marketing research. *International Journal of Research in Marketing*, **30**, 292–303.

Ma D K, Lin Y, Ju W L, Li X K, Liu X X, Deng X P, Wang SW. 2021. Meta-analysis of green manure effects on soil properties and crop yield in northern China. *Field Crops Research*, **266**, 108146.

Mao L, Zhang L, Li W, van der Werf W, Sun J, Spiertz H, Li L. 2012. Yield advantage and water saving in maize/pea intercrop. *Field Crops Research*, **138**, 11–20.

Matsuda M. 2013. Upland farming systems coping with uncertain rainfall in the central dry zone of Mayanmar: How stable is indigenous multiple cropping under semi-arid conditions? *Human Ecology*, **41**, 927–936.

Nair V D, Nair P K R, Dari B, Freitas A M, Chatterjee N, Pinheiro F M. 2017. Biochar in the agroecoszstem-climate-change-sustainability nexus. *Front Plant Science*, **8**, 2051.

Nong Y X, Yin C B, Yi X Y, Ren J, Chien H P. 2021. Smallholder farmer preferences for diversifying farming with cover crops of sustainable farm management: A discrete choice experiment in Northwest China. *Ecological Economics*, **186**, 107060.

Ntakirutimana L, Li F D, Huang X L, Wang S, Yin C B. 2019. Green manure planting incentive measures of local authorities and farmers' perceptions of the utilization of rotation fallow for sustainable agriculture in Guangxi, China. *Sustainability*, **11**, 2723.

Ochieng B J, Hobbs J E. 2016. Incentives for cattle producers to adopt an *E. Coli* vaccine: An application of best–worst scaling. *Food Policy*, **59**, 78–87.

Pham H G, Chuah S H, Feeny S. 2021. Factors affecting the adoption of sustainable agricultural practices: Findings from panel data for Vietnam. *Ecological Economics*, **184**, 1–13.

Pratt O, Wingenbach G. 2016. Factors affecting adoption of green manure and cover crop technologies among Paraguayan smallholder farmers. *Agroecology and Sustainable Food Systems*, **40**, 1043–1057.

Qaswar M, Huang J, Ahmed W, Liu S, Li D, Zhang L, Liu L, Xu Y, Han T, Du J, Zhang H. 2019. Substitution of inorganic nitrogen fertilizer with green manure (GM) increased yield stability by improving C input and nitrogen recovery efficiency in rice based cropping system. *Agronomy*, **9**, 609.

Sarrias M, Daziano R. 2017. Multinomial logit models with continuous and discrete individual heterogeneity in R: The gmnl package. *Journal of Statistical Software*, **79**, 1–46.

Stagnari F, Maggio A, Galieni A, Pisante M. 2017. Multiple benefits of legumes for agriculture sustainability: An overview. *Chemical and Biological Technologies in Agriculture*, **4**, 2.

Tobin J. 1958. Estimation of relationships for limited dependent variables. *Econometrica*, **26**, 24–36.

Toma Y, Sari N N, Akamatsu K, Oomori S, Nagata O, Nishimura S, Purwanto B H, Ueno H. 2019. Effect of green manure application and prolonging mid-season drainage on greenhouse gas emission from paddy fields in Ehime, Southwestern Japan. *Agriculture*, **9**, 29.

Tomer M D. 2014. Watershed management. In: Elias S A, ed., *Elsevier Reference Module on Earth Systems and Environmental Sciences*. England: Elsevier, London.

Train K. 2009. *Discrete Choice Methods with Simulation*. 2nd ed., Cambridge University Press, Cambridge.

Xie C J, Chen J. 2012. Problems and strategies of producing green manure in Gansu Province. *Plant Fiber Sciences in China*, **34**, 1671–3532. (in Chinese)

Yang L, Bai J, Liu J, Zeng N, Cao W. 2018. Green manuring effect on changes of soil nitrogen fractions, maize growth, and nutrient uptake. *Agronomy*, **8**, 261.

Yang X, Sang Y. 2020. How does part-time farming affect farmers' adoption of conservation agriculture in Jianghan Plain, China? *International Journal of Environmental Research and Public Health*, **17**, 5983.

Yang Y, Zhang S L, Wang L. 2019. Distribution of soil erodibility K value in Gansu Province based on positioning monitoring data. *IOP Conference Series Earth and Environmental*, **356**, 012011.

Yao Z, Xu Q, Chen Y, Liu N, Huang L, Zhao Y, Zhang D, Li Y, Zhang S, Cao W, Zhai B, Wang Z, Adl S, Gao Y. 2019. Enhanced Stabilization of soil organic carbon by growing leguminous green manure on the Loess Plateau of China. *Soil Science Society of American Journal*, **83**, 1722–1732.

Yee T W. 2015. *Vector Generalized Linear and Additive Models*: *With an Implementation in R*. Springer, New York, USA.

Zuo A, Wang J X, Huang Q Q. 2020. Willingness to accept compensation for land fallowing: Results from a survey of village representatives in Northern China. *Australian Journal of Agricultural and Resource Economics*, **59**, 1–22.

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