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Determinants of farmers' waste generation and disposal in rural areas of central China

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Abstract

The treatment of agricultural waste plays an important role in the sustainability of agricultural production and the well-being of rural communities. The present study analyzes the existing sources of agricultural waste in rural communities, their current disposal, and the farmers' attitudes towards waste management. The data is based on a survey in 21 communities in agricultural areas in Shaanxi ($N = 359$ farmers interviewed). The results provide a description of the main agricultural waste in the region based on empirical data. The responses highlight the farmers' experience, reputation, and engagement at recycling domestic waste as the main variables shaping their attitudes towards agricultural waste disposal. Farmers prefer treating primarily biowaste, mostly used for biogas generation or crop fertilizer at the farms. Improving waste management facilities, accessibility and economic incentives are identified as the main factors that could increase recycling rates, as well as the importance of training campaigns and instructions related to waste handling and recycling. The analysis captured the general trends in agricultural waste treatment and future directions and provides a basis for better designing waste and management alternatives.

Keywords Agricultural production · Agricultural waste · Municipal waste · Biogas · Rural communities · Organic waste to energy

Introduction

Agricultural production in China has increased rapidly during recent decades in order to increase the food supply for a growing population. As a result of improved agricultural practices as well as the increased use of pesticides and fertilizers, nowadays, the average grain yield is over six times the 1960s level (Jiao et al. 2018). However, the development of the agricultural sector has also raised environmental concerns related to the sustainability of current practices (Li et al. 2016); shortages of water resources (Jiang et al. 2017) and negative effects on soil organic carbon and nitrogen (Wang et al. 2017) have been identified as potential constraints to present and future crop production. In addition, the rapid growth of intensive farming practices have an impact on soil, water, and atmosphere, as a result of the use of pesticides, wastes, and residues from agricultural production (Jin et al. 2015; Li et al. 2016; Jena and Singh 2021).

In a year, the agricultural sector in China uses a large amount of chemical fertilizer and pesticides, (54 M t and 1.4 M t, respectively, NSB 2019), as well as plastic mulch film in the cultivation of grains and vegetables, (2.4 M t, NSB 2019) and paper bags for fruit bagging. This leads to polluting waste in the form of chemical residues and plastic packages. Besides, crop cultivation and livestock farming produce large amounts of residues and animal manure, estimated in 900 M t of crop straw and 3800 M tons of manure, annually (MOA 2016). The lack of infrastructure and waste management facilities in many rural areas results in uncontrolled disposal, posing both a clear environmental threat (Jin et al. 2015; Li et al. 2016) and a human health hazard (He and Zhang 2014; Hu et al. 2017).

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Enhancing the sustainability of agricultural production and the well-being of rural communities requires adequate policies and technical actions (Zhang et al. 2018). The Environmental Protection Law (GOV 2014) states that agricultural waste must be properly treated to prevent further agricultural pollution (Xu et al. 2018), and direct and indirect financial support from the government has been targeted to agricultural waste management projects and technical training. For example, farmers have financial incentives to return packages of pesticides to the collection station (Jin et al. 2018). At the same time, the rising concern of agricultural waste has also initiated new circular economy strategies aiming to reduce the waste disposal to landfills and enhance waste recycling and incineration (Lee et al. 2020). Since most of the organic waste (e.g., crop residues and animal manure) could potentially be used to generate energy for domestic use by biogas digesters (Deng et al. 2017), the government has subsidized nearly 26 billion CNY to cover around 45% of the cost of installation in rural areas between 2001 and 2012 (Wang et al. 2016).

However, the success of these measures relies on the attitudes and active engagement of local farmers, which is crucial for successfully increasing recycling rates and to enhance rural development (Ma et al. 2018a). For example, previous studies have shown that farmers in agricultural cooperatives are more prone to use organic fertilizer in agricultural production (Wang et al. 2018). Also, previous research highlighted background factors such as age and school education playing an important role: older farmers lack awareness of pesticide toxicity (Fan et al. 2015) and those with higher education are likely to engage in sustainable agricultural practices (Jiang et al. 2018).

Additional recent studies have focused on agricultural waste disposal on rural households in China (Zhang et al. 2015), targeting pesticide packages (Jin et al. 2018), mulch waste (Liu et al. 2014), or recycling of livestock and poultry waste (Li et al. 2016; Jia et al. 2018). However, most of the studies have focused on specific waste sources, overlooking the rural communities' production of simultaneous and varied wastes and the attitudes of local farmers towards their overall disposal and recycling. The present paper aims to analyze the current situation and management options of various agricultural wastes from a large sample of households in several rural communities in central China. The study characterizes the main household wastes and analyzes the farmers' attitudes towards sustainable management of agricultural waste. As well, the study identifies potential barriers and proposes solutions oriented to enhance the sustainability profile of the Chinese agricultural sector. The results of this research aim to assist current policy and economic efforts to develop an integrated bioeconomy in the region.

Material and methods

Study area

In this study, sustainable management of agricultural waste includes actions such as recycling, reusing, and reduction (Lee et al. 2020). The targeted respondents need to have experience in agricultural production, such as farmers of small-scale agricultural land. The study area is located in central China (Chenggu county, Shaanxi province) where residents are largely involved in agricultural activities. The county covers 226,500 ha (CGXZF 2021) and has a total population of 540,000 inhabitants, mainly living in rural communities (62%, CGXZF 2021). The main food crops cultivated are rice, wheat, and rapeseed (CGXZF 2021). In 2019, the total cultivated land was 23,781 ha producing 154,772 tons of cereal (SPBS 2020) and fruits such as apples (546 tons, SPBS 2020), oranges (300,000 tons, CGXZF 2021), and kiwis (21,215 tons, SPBS 2020). Additionally, farming includes around 2.2 million poultry and 0.5 million pigs (CGXZF 2021).

The resulting agricultural waste of farming activities includes mainly biowaste, chemical waste, and plastics packages. The annual chemical fertilizer consumption was 34,465 tons (SPBS 2020) and the plastic agricultural mulch film was 210 tons (SPBS 2020) to keep the soil warm and moisture, especially when cultivating rice, wheat, maize, or vegetables (Liu et al. 2014; Yin et al. 2021). Furthermore, fruits are sometimes covered with paper bags to mature faster and for protection against pests (e.g., apple bags, Fig. 1).

Field survey

The data were collected in 2019 by a face-to-face field survey. A total of 21 rural communities were targeted, distributed in three areas: Juyuan, Laozhuang, and Yuangong (being 88, 142, and 129 farmers interviewed in 5, 9, and 7 rural communities, respectively). In total, 359 farmers, one per household, were interviewed in a semi-structured questionnaire, with the following criteria: the interviewee must have agricultural land and the land must be located within the selected community. Since there is no accessible public registry to implement an effective random selection, farmers at each community were selected in a systematic design, aiming to be representative in a cost-effective and feasible way.

The questionnaire design included information concerning the farmers' background, current agricultural production, awareness of sustainable agricultural production practices and protocols, and their willingness to participate

Fig. 1 Potential sources of agricultural wastes from plastic agricultural mulch film, apple bag, maize straw, and maize cob

in sustainable agricultural activities. Agricultural waste included chemical waste (fertilizer and pesticide residues), packages (fertilizer and pesticide packages, bags from orchard bagging), plastic mulch films, and biowaste (straw residues and animal manure). The waste management methods included the following: reuse of the residues, recycling, and dumping. Some questions concerning the farmer's overall assessment and feedback were open. The treatment of the data was anonymous, and the storage and processing were according to standards of data privacy.

In total, 44 variables were considered. The main response question was defined as "farmers' willingness to participate in the sustainable management of agricultural waste" (*Agri*, as dependent variable). First, nine questions were included to know possible influencing factors due to the personal background, awareness, and willingness (Table 1); these questions referred to farmers' age (*Age*), education background (*Education*), number of household members (*Household*), total cultivated agricultural area (*Area*), agricultural experience (*Experience*), perception of their reputation on sustainable production (*Reputation*), training experience on agricultural production or environmental protection (*Training*), willingness to cooperate with other farmers (*Cooperation*), and willingness of participating the sustainable management of domestic waste (*Domestic*). Then, six variables that defined the current waste management were retrieved and twelve questions addressed the sources of agricultural waste by each farmer and their recycling willingness. A 5-point Likert scale level was applied (*strongly disagree, disagree, neutral, agree, strongly agree*) for the agreement response of farmers, which related to 16 questions concerning farmers' views on the sustainable management of agricultural waste, their awareness on sustainable agricultural production, and their assessment on local agricultural waste systems.

Table 1 Influencing variables considered in the analysis

Variable type	Variable	Description	Value or unit
Personal background	Age	Age of the farmer	(Year)
	Education	Education years of the farmer	(Years)
	Household	Household members	(#Members)
	Area	Agricultural land area	(ha)
	Experience	Experience in agriculture production	(Years)
Awareness	Reputation	Awareness of own reputation on "sustainable agricultural production farmers"	(Yes/no)
	Training	Farmer has training experience of agricultural production or environmental protection	(Yes/no)
Willingness	Cooperation	Willingness to cooperate with other farmers	(Yes/no)
	Domestic	Willingness to participate in sustainable disposal of domestic waste	(Yes/no)
	Agri	Willingness to participate in sustainable disposal of agricultural waste	(Yes/no)

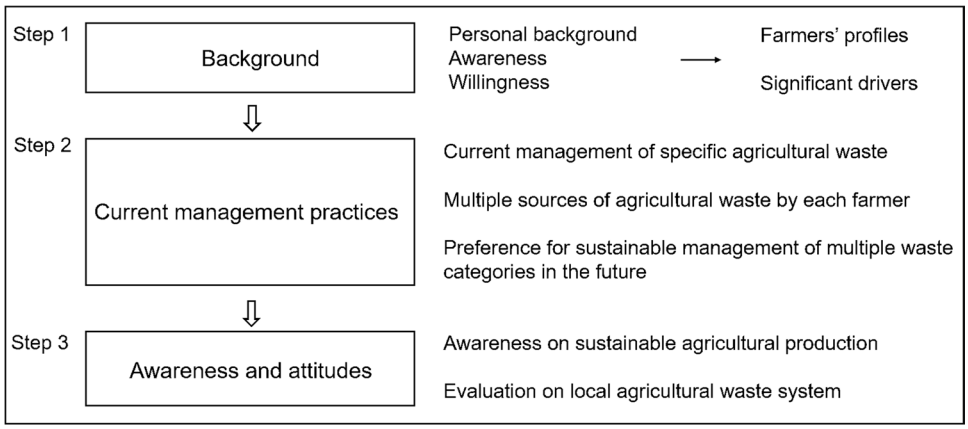

Fig. 2 Framework of the variables considered in the analysis

Theoretical framework

The analysis was structured in three parts (Fig. 2): farmers' general profiles and the significant influencing factors on their willingness to participate in sustainable management of agricultural waste (step 1), farmers' current management by each specific waste category (step 2), and farmers' attitude and awareness towards waste disposal and local waste system (step 3).

A binomial logistic regression model was constructed to identify the main factors related to the farmers' willingness to participate in sustainable agricultural waste disposal in step 1. To address any potential effect due to the hierarchical structure of the data (farmers within communities), a random between-community effect (μ) was included in the model structure, through a mixed-model approach. The model followed the form:

$$logit(p) = logit\frac{p}{1-p} = X\beta + \mu \quad (1)$$

where p is the willingness of a farmer to participate (=1) or not (=0) in the sustainable waste disposal on agricultural production and $\beta_{1\ldots i}$ are parameters to be estimated for each variable X and μ is the between-community effect (assumed to be gaussian distributed with mean = 0 and std. deviation $\sigma_{community}$). The between-community factor, however, accounted for a negligible amount of the variability when the final model was completed and was therefore removed. The significance level for the variables was 0.05. The analysis was computed in the R v4.0.4 statistical package (R core team 2020) and the logistic regression model was fitted with the *lme4* package (Bates et al. 2014).

Results

The results reflected the overall agricultural production in the area. Most of the interviewed farmers cultivated orange (66%), rice (51%), or wheat (14%), and rapeseed (8%); the total cultivated area by the 359 farmers was 119.5 ha. In addition, 74% of the farmers had livestock or poultry. The average farmer profile was around 58 years old with a middle school education level (6 to 9 educational years), living with 4 family members, and cultivating 0.33 ha of agricultural land (Table 2). Disaggregated, only 21% of the farmers were younger than 50 years, 35% of the farmers were between 50 and 59 years and about 44% were over 60 years. The most common education level was middle school (52%), besides, 7% of farmers without education and 2% with university or equivalent education. Around 44% of households had 2 or 3 members in their family. Concerning agricultural production, around 60% had less than 0.33 ha of agricultural land and most households (64%) had over 30 years of agricultural experience.

It must be considered that the farmer could produce waste from several categories simultaneously (Fig. 3). All the interviewed farmers produced more than one type of waste; 4% two, 19% three, 46% four, 26% five, and 5% produced six types of waste (see additional results in

Table 2 Background profiles and attitudes towards sustainable agricultural waste management of the interviewed farmers (N=359)

Variable	Values		
Numeric variable	*Min*	*Mean*	*Max*
Age	20 years old	58 years old	84 years old
Education	0 year	8 years	15 years
Household	1 member	4 members	9 members
Area	0.02 ha	0.33 ha	2.67 ha
Activity	0 year	36 years	65 years
Binary variable	*Yes*	*No*	
Reputation	158	201	
Train	217	142	
Cooperation	121	238	
Domestic	319	40	
Agri	258	101	

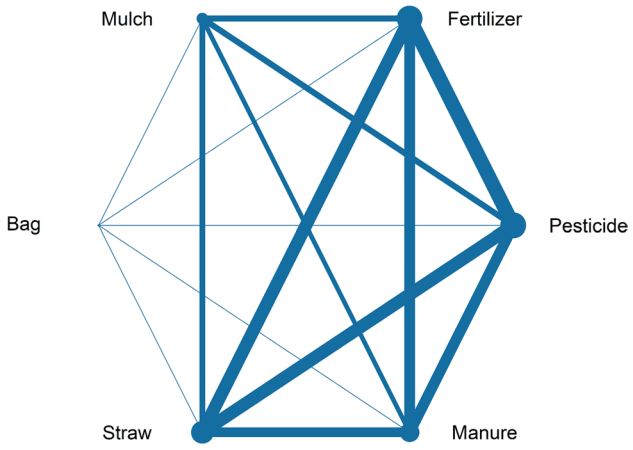

Fig. 3 Farmers' current sources of agricultural waste. Circle's size represents the frequency of the answers and lines address the most common combinations from the same farmers

Appendix 1). Almost all farmers produced wastes from pesticides (99.7%) and fertilizer packages (100%). Biowastes were also common 85% from straw and 67% from manure. Fewer farmers produced waste from agricultural mulch (36%) and fruit bags (5%).

Regarding the current agricultural waste management, the alternatives were diverse and the options vary depending on the waste sources (Table 3). Most of the farmers (87%) kept pesticide residues for later use, but some disposed of to landfills or toilets. Over 90% of farmers recycled packages of pesticide or fertilizer, but only 49% of farmers recycled mulch films. Biowaste from straws (97%) and animal manure (89%) were further processed or recycled, mainly used for biogas generation or crop fertilizer. In total, 37 farmers reported that some of the waste was disposed of without treatment.

Concerning sustainable waste treatment in the future, farmers would prefer to recycle fertilizer packages, pesticide packages, straw residues, and animal manure simultaneously (Fig. 4). Whereas mulch residues and fruit bags were less often considered the option for future sustainable waste management (see Appendix for further details). This preference might be because farmers can get monetary compensation from recycling packages of fertilizer and pesticide, as well they can produce energy from straw residues and animal manure.

By all interviewees, 72% of them showed their willingness to engage in sustainable management of agricultural waste (*Agri*). There were 34% of farmers who would like to have agricultural cooperation with other rural stakeholders (*Cooperation*). However, there were important differences based on the different types of waste. Farmers were more prone towards recycling or environmentally friendly processing of biowaste, animal manure (46% *strongly agree* in *statement F*), and crop straws (43% *strongly agree* in *statement E*, Fig. 5). The sustainable treatment of fertilizer and pesticide packages (*statement A*, *B*) were more supported compared to other waste types. More than 60% of interviewees agreed to

Table 3 Current management options for agricultural waste

Agricultural wastes	Waste management	Frequency
Pesticide residues	Keep for later use	311
	Pour to the land, toilet, or non-agricultural plant	31
	Dump without processing	1
	Others	15
Packages of pesticide or fertilizer	Recycle at waste sites	324
	Burn/bury them	23
	Dump without processing	12
Mulch film	Recycle at waste sites	64
	Burn/bury them	15
	Dump without processing	23
	Others	29
Straw	Generate biogas, feed animals, or return to the farmland as fertilizer	291
	Burn for heating or cooking	13
	Others	11
Animal manure	Sell them to other people	1
	Generate biogas or fertilizer	236
	Dump without processing	1
	Others	29
Bags for fruits	Others	18

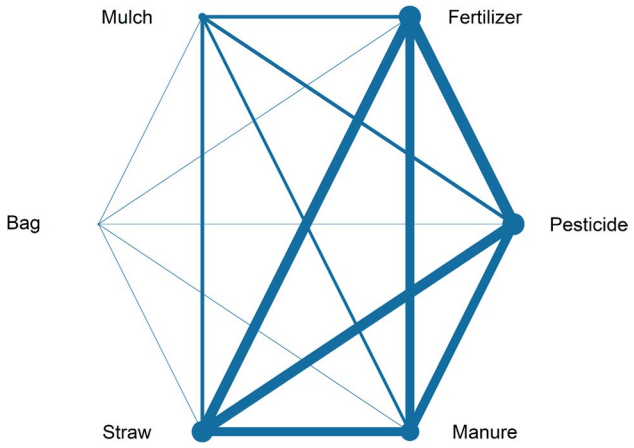

Fig. 4 Farmers' future preferences on waste alternatives of sustainable management. Circle's size represents the frequency of the answers and lines address the most common combinations from the same farmers

recycle mulch films (64%) or paper bags (71%) after their use (*statement C*, *D*).

Farmers were largely aware of sustainable waste management alternatives (Fig. 6) and about 44% of the farmers were concerned about their reputation regarding sustainable agricultural production (*Reputation*); 90% of households knew that inappropriate treatment would cause negative impacts on the environment, such as burying (88%) or dumping (94%) agricultural waste or residues, reflecting a large awareness of the problems associated with waste disposal (*statement A*, *B*). Similarly, 89% of households knew that sustainable management

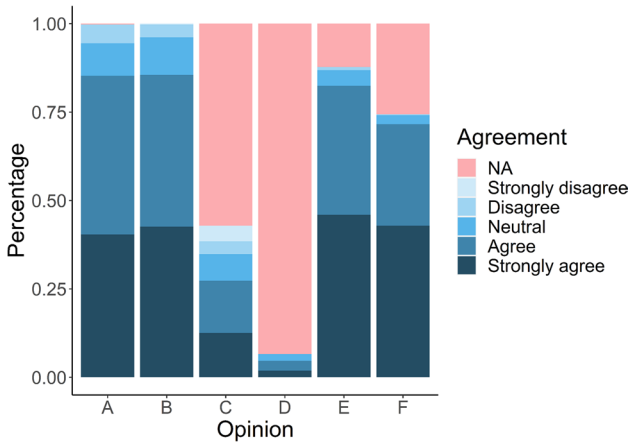

Fig. 5 Farmers' opinion concerning the sustainable management of different types of agricultural residues and waste. A, *I would like to recycle pesticide packages*; B, *I would like to recycle fertilizer packages*; C, *I would like to recycle mulch film*; D, *I would like to recycle bags from bagging fruits*; E, *I would like to recycle straws*; F, *I would like to recycle animal manure*. NA, *no answer/not relevant*

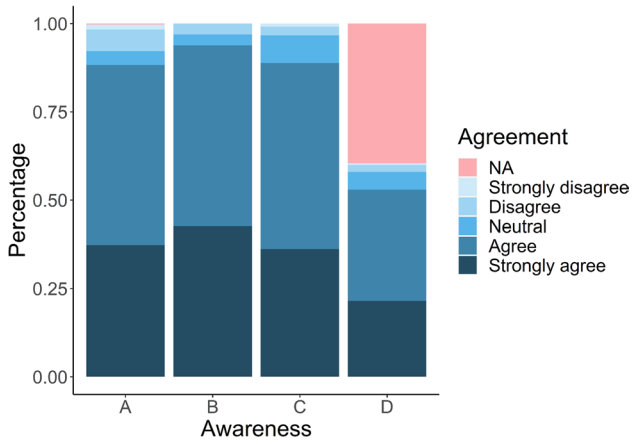

Fig. 6 Farmers' awareness of sustainable agricultural production. A, *Burying agricultural waste can reduce the land quality*; B, *Directly dumping agricultural waste can pollute the environment*; C, *Recycling or processing agricultural waste can enhance the land quality*; D, *My awareness or knowledge about agricultural waste has been raised by training experience from the government*. NA, *no answer/not relevant*

Table 4 Parameters, standard errors (SE), and significance values of the variables included in the model (in bold, values <0.05)

Variables	Estimate	SE	*P*-value
(Intercept)	−0.1331	1.1317	0.9064
Age	0.0287	0.0234	0.2207
Education	−0.0296	0.0440	0.5007
Household	−0.0731	0.0790	0.3550
Area	0.0156	0.0298	0.6007
Experience	−0.0475	0.0186	**0.0105**
Reputation (*Yes*)	1.2036	0.2827	**< 0.001**
Training (*Yes*)	0.4141	0.2704	0.1256
Cooperation (*Yes*)	−0.2889	0.2804	0.3029
Domestic (*Yes*)	1.1156	0.3759	**0.0030**

of agricultural waste or residues could reduce negative environmental impacts (*statement C*). In total, 59% of farmers had training experience related to agricultural production and environmental protection (*Train*). Among the farmers who had training, 88% of them considered their awareness on sustainable agricultural production and waste treatment increased by the promotion and training from the government (*statement D*). Concerning legislation, less than 50% knew the laws regulating sustainable development.

Concerning the overall farmers' willingness towards sustainable waste management from agricultural production, *Experience*, *Reputation*, and *Domestic* showed significant effects (Table 4). Experienced farmers were less willing to do sustainable waste management.

Farmers more concerned about their reputation or willing to recycle domestic waste were also willing to widen the waste management towards agricultural practices. The McFadden's Pseudo R^2 was 0.12 for the model. Variables *Age*, *Education*, *Household*, *Area*, *Training*, and *Cooperation* were not significant when combined in the same model, which was an indication of possible confounding effects.

When asked for feedback on their current waste management system, more than a half of the farmers reported being satisfied with the waste systems in their local communities (Fig. 7), particularly concerning recycling the waste from agricultural production with efficient processes (85%, *statement D*) whereas economic compensation from recycling had a 42% satisfaction rate (*statement E*). The distance to the waste treatment site (*statement A*) and proper services (*statement B*) were also satisfying. Although the majority (63%) considered they had sufficient help from technicians, 19% of the farmers reported lacking technicians' assistance for waste treatment guidance (*statement C*). Finally, 50% of the households praised their communities as having several types of agricultural waste disposal options (*statement F*).

Discussion

Rural communities play a key role in the path towards sustainable agricultural production in China. However, the analysis of farmers' attitudes and perceptions supposes an obvious challenge, since there are economic limitations to produce a fully systematic analysis of the entire Chinese rural population due to the large variability and extension of the country. Having this in mind, the use of case studies in representative areas contributes to assessing the current situation of agricultural waste management in rural communities and the attitudes and preferences that will determine future trends in a cost-effective approach.

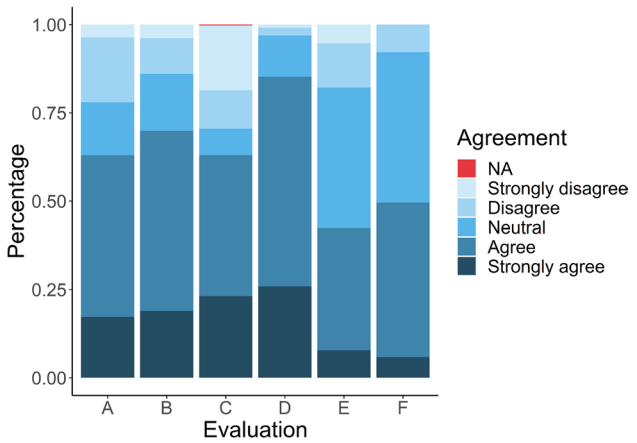

Fig. 7 Farmers' evaluation of local agricultural waste systems. A, *Waste sorting and recycling sites are close and adequate in my community*; B, *My community has proper services for waste sorting and collecting*; C, *Technicians are helping to collect the waste*; D, *I can recycle my production waste efficiently in my community*; E, *Economic compensation at the waste site is reasonable for my waste*; F. *Many kinds of agricultural waste can be collected in my community*. NA, *No answer/not relevant*

The area selected (*Chenggu*) is representative of the central and southern regions of the province between Qinling and Ta-pa Mountains in a sub-tropical climate zone. The region presents large agricultural areas; it is abundant in water resources and presents the most common crops of the Shaanxi province, like rice, wheat, and orchards (SPBS 2020). The interviews were collected from several communities in a systematic approach, to increase the representativeness of the farmer's profile in the area, based on a large and systematic face-to-face questionnaire, involving 21 communities and 359 rural households in a representative agricultural area of central China.

The overall number of farmers included in the analysis compares well with similar studies concerning farmer perceptions and sustainability. For example, O'Connell et al. (2015) interviewed 200 farmers for a study concerning practices and perceptions of sustainable farmers in NC, USA; Huttunen and Peltomaa (2016) interviewed 55 farmers concerning sustainable agricultural practices in Finland, among others. Olum et al. (2020) reviewed a large number studies concerning farmers' perceptions and adoption of innovations in several countries, with samples sizes in line with this study (from 80 studies included, only 20 included a higher number of farmers interviewed). In addition, several of these studies shared similar statistical approach for the data analysis as the one used.

The profile of the farmers interviewed largely agrees with previous studies on rural population covering the whole province (e.g., Qu et al 2016; Zhang et al 2020; Shen et al 2020). The age of respondents was mainly over 60 years (around 45%), reflecting the age structure of agricultural communities, which is explained by the ongoing trends in rural–urban migration and the aging farming population (Zou et al. 2018). In Shaanxi, the total population older than 60 years old increased from 16.24% in 2016 to 18.12% in 2019 (SPBS 2020), and it must be taken into account that this includes the whole population, whereas the sampling aims for farmers. Estimates indicate the trend will double in the next decades in China resulting in a significantly aged rural population (United Nations (UN) 2019).

The results helped identify a series of barriers influencing current practices towards agricultural waste (summarized in Table 5) and provided a complete characterization of the different and simultaneous wastes at household level. Farmers were strongly conditioned by their previous experience

Table 5 Synthesis and assessment of main barriers identified concerning farmer's attitudes affecting agricultural waste sustainably in rural areas of central China

Scale	Main barrier identified	Empirical evidence	Possible solution
Farmer	Lack of experience in waste disposal	Observed recycling domestic waste predisposes positively	Integration with current implementation of domestic disposal
Community	Lack of environmental awareness	Evidence in Zhang et al 2015, Yang et al 2014, Dung et al. 2017	Targeted campaigns, education and training, reach and engagement of younger farmers
	Lack of economic compensation	Reported unsatisfied price for waste recycling. Evidence in Luo et al. 2014; Fei et al. 2016	Search synergies for waste valorization, economic incentives Developing technologies for producing recycled or reusable packages Developing technologies for reusing leftovers from agricultural residues after it collected from farmers (e.g., in pulp industry or energy generation)
	Accessing sufficient technical guidance	Reported lack of expert. Evidence in Fei et al. 2016	Experts to promote expertise
Regional	Waste management infrastructure	Reported unsatisfied waste service in the local community. Evidence in Wang et al. 2014	Design and plan facilities, Installing additional waste-collecting sites in the villages
	Land use planning	Muise et al. 2016	Integration of land use policies, transportation network and agricultural policy

and environmental awareness; their experience of recycling domestic waste strongly shaped their predisposition towards more sustainable disposal of agricultural waste, which has increasing support in rural communities (Han et al. 2018). Regarding environmental awareness, farmers' waste management behavior is based on their environmental knowledge which is related to their education level and participation in training of agricultural production or environmental issues (He et al. 2016a).

In our study, farmers' training experience showed a positive correlation with their willingness to waste recycling. A lack of environmental understanding may therefore become an important barrier for the engagement of rural households to increase their recycling rates. At this respect, education and age (as there is a clear interaction between both) are critical variables; more educated and younger farmers have a better understanding of sustainability concepts and may have the tools to adapt to changing market situations, increasing their acceptance of alternatives. Previous survey studies showed that only 15% of farmers had a deep understanding of sustainability concepts and practices (Zhang et al. 2015), and only 44% knew about the negative effects of pesticides on the environment (Yang et al. 2014). This lack of awareness directly influences the application and further disposal of pesticide residues and may lead to the overuse of pesticides with harmful effects on the environment as well as the overall profitability of the farm (Fan et al. 2015). Another factor expected to influence the farmer's attitudes was cooperative membership (Ma et al. 2018b). In this case, however, the results did not show any significant effect, perhaps confounded by other interacting factors.

Concerning waste management infrastructure, a well-established network of recycling services is necessary to improve the accessibility for farmers (Vox et al. 2016). Although farmers could get economic compensation from waste recycling, long distances to disposal sites could affect their willingness. Similarly, studies in Canada showed long-distance reduced farmers' willingness for transporting their plastic waste to the recycling site (Muise et al. 2016). In fact, the farmers interviewed expressed that well-built waste management services could increase the recycling rates of agricultural waste, particularly when implying shorter distances, a simple returning process and a sufficient level of economic compensation, in agreement with He et al. (2016b), stressing that an efficient design of waste facilities' location can significantly raise the farmers' willingness to reuse and recycle agricultural waste.

In this line, the implementation of modern disposal technologies has already accelerated in the countryside, establishing waste treatment facilities in rural areas. This is important not only for environmental and public health reasons but also for the synergies and rural development opportunities that can be established with direct economic benefits (He et al. 2016a), being the basis for a more consolidated bioeconomy. For example, the valorization of lignocellulosic waste from agricultural production can be converted to either fertilizer, paper pulp, or energy use through combustion or pyrolysis (Dai et al. 2018). In addition, super-absorbent hydrogels derived from lignocellulosic waste can reduce water and nutrient losses (Li and Chen 2020). Collected agricultural plastic waste such as mulch film, packages of containers, and irrigation pipes can be used for energy or produce alternative products within the local bioeconomy (Vox et al. 2016).

The results stressed that a series of policies can increase the awareness and willingness of rural communities to accept and participate in sustainable waste management. The lack of waste disposal guidance reported in the results underlines the need for experts and technicians for promoting expertise in sustainable waste disposal in rural areas. Besides, financial support could increase the farmers' participation rate. The study of Luo et al. (2014) showed that financial support plays an effective role in promoting clean agricultural production to farmers, for instance, providing economic incentives when farmers transport agricultural wastes to the disposal sites (Atinkut et al. 2020). In addition, other rural issues such as agricultural land loss (Zang et al. 2020) and depopulation of rural areas (Liu et al. 2009; Zang et al. 2020) may also have impacts on sustainable waste management and recycling willingness, which can be the focus of further research efforts.

Farmers' choices and attitudes are not only relevant for the direct implementation of effective waste treatment methods, but also indirectly related to the current land uses. For example, it has been studied that land use preferences and management methods influence the levels of awareness regarding waste treatment (Muise et al. 2016), and the increase of farm size can lead to the reduced use of agricultural chemicals, such as pesticides and fertilizer (Wu et al. 2018). In addition, some studies showed that farmers growing vegetables were more likely to overuse pesticides than orchard or grain farmers (Fan et al. 2015), but also, orchard cultivations have higher water and fertilizer demands over other crop growers (Skaf et al. 2019). At the same time, the observed households' pattern of wastes is a direct result of these existing agricultural uses. These complex inter-relations require an integral analysis of the waste streams, from the land use and management perspective to the end-user and treatment facilities. The results of this study could help in these considerations as a basis for future research efforts in order to provide feasible solutions for a more sustainable agriculture.

Conclusions

In rural communities of central China, there is still a considerable amount of agricultural waste left untreated. However, farmers show an overall positive attitude and engagement towards sustainable waste management. Exploring the reasons behind and the obstacles stated by the farmers are a key thing to be solved on the way for sustainable agricultural production. Improving waste management facilities, accessibility and economic incentives were identified as the main factors that could increase recycling rates. In addition, the importance of training campaigns and instructions related to waste handling and recycling were highlighted by the farmers. Despite the importance of more sustainable waste treatment options, there is a general satisfaction concerning the current local waste systems. The analysis captured a general picture of the rural agricultural waste production and treatment, and presents possible future directions based on the farmers' attitudes which could have application for designing waste and management alternatives. The overall results highlight the increasing engagement of farmers in the transition towards sustainable agriculture practices.

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Data availability The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

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