博士論文

Research on Adoption of Sustainable Agriculture Practices of Smallholder Farmers in the Northwest and Southern China

（中国西北と西南地域における小農の持続可能な農作方式の採用意識に関する研究）

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RESEARCH ON ADOPTION OF SUSTAINABLE AGRICULTURE PRACTICES OF SMALLHOLDER FARMERS IN THE NORTHWEST AND SOUTHERN CHINA

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As with all efforts of this kind, friends and family are essential. Mine were always ready and willing to encourage me when I was open to the idea. My parents, in particular, are tireless supporters and help to take care of my daughter. Finally, my daughter, Qirui Ma, because of her, I am feeling more determined and fuller of strength in the pursuit of dreams on the academic road.

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DEDICATION

To my parents, Zaizu Li, Weilin Nong and my daughter, Qirui Ma

ABSTRACT

Implementing sustainable agriculture practices (SAPs) is of great importance for increasing agricultural productivity and ensuring long-term sustainable development for smallholder farmers amid the agricultural structural changes in China. This dissertation investigates the adoption of sustainable agricultural practices in three stages of the decision-making process, using survey data from northwest and southern China. The aim is to clarify smallholder farmers' decision on SAPs adoption, by which to recognize how farmers choose to adapt SAPs into their farming systems and the main influencing factors, as well.

To this end, several approaches including the Best-worst scaling, Discrete Choice experiment, bivariate-probit, and effect analysis were applied to explore the decisions from adoption intention, adoption behavior to the adoption performance in two study areas with significant geographic and climate differences, by which a thorough and clear elaboration on key factors affecting decisions is presented. The studies investigating the decisions in the early stage of decision-making of northwest China found that the climatic feature of precipitation had a positive relation with the cover crop related practices; household income was correlated with more diverse adoption of the practices. Similarly, livestock farming expanded the usages of cover crops, increasing the odds of its cultivations. More importantly, farmers prefer practices that bring fewer changes to their current farming system or the gradual adjustment of the cropping pattern. Also, along with the structural changes in agricultural production, farmers have more capacity for choosing diversified practices and cropping patterns.

From adoption intention to adoption behavior, the bivariate-probit model was applied to analyze the effect of perception on adoption intention and behavior in southern China. Results from the estimations strongly support the conjecture that positive perception influences the intention and behavior of cover crop adoption for soil conservation. On the other hand, the empirical results show the cash crop cultivation had a negative effect on the consistency between the behavioral intention and behavior, implying the potential risk of the foregone cash crop production and the sequent income have kept farmers from cover crop adoption. For the adoption performance, effect analysis was conducted to analyze the comprehensive value of the application cover crop in the orchard ecological system. More importantly, by exploring the costs and benefits in the production, the main factors affecting the economic benefits of the integrated model were clarified, providing insights that could reduce the costs in the future.

In the face of structural changes in agricultural production of northwest and southern China, the precipitation level, livestock raising, cropping system and perception have significant effects on smallholder farmers' choices for SAPs. As the economic risks and the potential opportunity cost embodied in the new sustainable farming strategies are the major restricting factors, the incentive payment along with the easily adaptable cropping patterns of the SAPs within a shorten trial period should be provided to the farmers. The findings have important policy implications for agricultural sustainability and food security in many developing regions and countries, where farming is dominated by millions of smallholder farmers.

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ABBREVIATIONS

BWS	Best-worst scaling
CAIC	Consistent akaike information criterion
CCA	Cover crop adoption
CCI	Cover crop intercropping
CCR	Cover crop rotation
CCML	Cover crop marginal land
CL	Conditional logit
DCE	Discrete choice experiment
EUT	Expected utility theory
FAO	Food and Agriculture Organization
LC	Latent Class
RPL	Random parameter logit
SAP	Sustainable agricultural practice
SFM	Sustainable farm management
TARA	Technical assistance to reduce agrochemicals
TPB	Theory of planned behavior
WTA	Willingness to accept

CHAPTER 1
INTRODUCTION

1.1 Background

1.1.1 Status of soil degradation and fertilizer consumption in China

China is now subjected to the world's most severe soil degradation, with over 40% of its arable land (3-4 million km^2) is degraded by erosion, loss of grazing, deforestation, and salinization (China Daily 2017). The soil erosion has caused an economic loss that is equivalent to about 3.5% of China's GDP and has severely affected the Loess Plateau area and the extensive Western regions (L. Chen et al. 2012; Rao et al. 2015). According to the Food and Agriculture Organization (FAO), although the average fertilizer consumption in China had decreased from 463.72 kg/ha in 2014 to 391.67 kg/ha in 2018, it is still much higher than the world average (120 kg/ha), 4.63 times that of the EU, 3.04 times of the United States, 1.54 times of Japan and 2.23 times of India (**Figure 1. 1**). China uses over 30% of global fertilizers and pesticides on only 9% of global cropland (Wu et al. 2018).

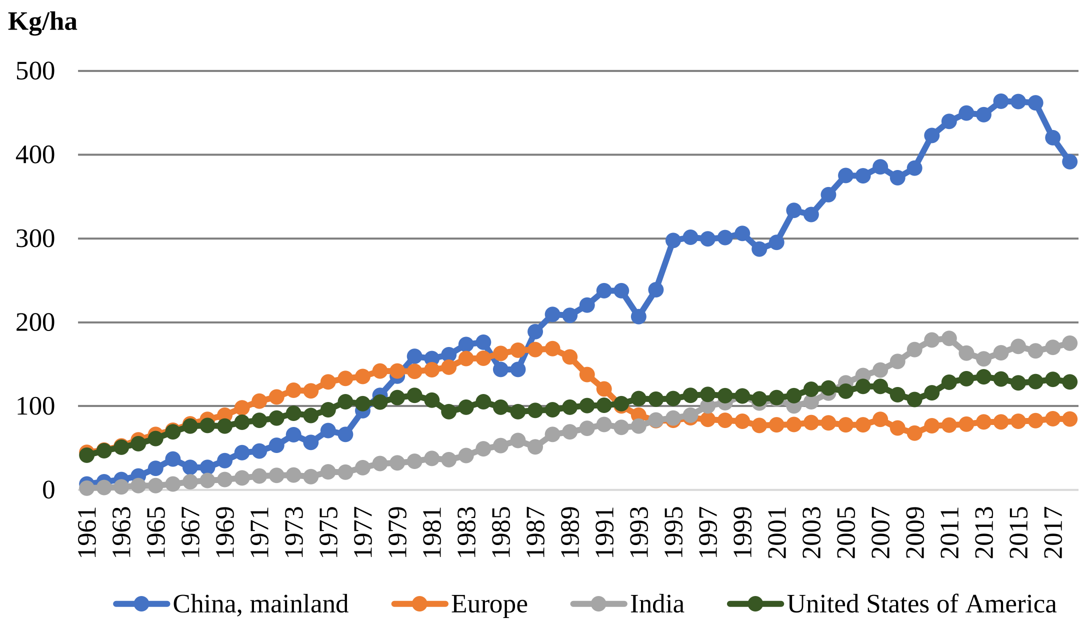

Figure 1. 1 The consumption of chemical fertilizer in four regions (1961-2018)

Sources: FAOSTAT

Long-term excessive use of agrochemicals such as synthetic fertilizer and pesticide has caused nonpoint pollution, soil acidification, air pollution, and soil compaction (Ouyang et al. 2018). Meanwhile, to offset the shrinkage of arable land, more and more marginal land was explored for agricultural uses, even though the land has a higher risk of erosion and nutrient depletion (Zhang et al. 2007). Consequently, the deterioration of the ecological environment caused by excessive application of chemical fertilizer and pesticide, over-exploration of vegetation, and improper uses of agricultural film, has not only put natural resources under great pressure but also threatened the development of rural society and economy. Therefore, with only 6.4% of the global land area and 7.2% of the world's farmland, China has to feed 22% of the world's population, and thus the sustainable productive land management is critical for the country's long-term agricultural economy (Berry 2003).

1.1.2 Structural changes in China's agricultural production

The rapid economic growth in China has been accompanied by significant structural changes in the agricultural economy. As presented in **Table 1.1**, one obvious change is the increasing production of higher-valued cash crops, for example, the share of the sown area of vegetables has grown from 7.08% to 13.28%. It is interesting to note that the rapidly growing cash-crop sector is also shown in small farms (Huang et al. 2012).

The analysis of the changes in planting structure on the agricultural inputs indicates the shifting of planting structure from grain crops to cash crops with an increasing demand for chemical fertilizers per unit area, which accelerates soil and water contamination and degradation (Wu et al. 2018). Low use efficiency of agricultural chemicals that results in detrimental impacts with nitrate loss to the soil is commonly found in the knowledge-poor smallholder farms. Therefore, within the cropping structural adjustment and an increasing share of cash crop cultivation, reducing the use of agricultural chemicals by the smallholder farmers to an optimal level is a crucial challenge for sustainable agricultural development in China.

Table 1. 1 Share of crop-sown areas in China (1995-2017)

	1995	**2000**	**2005**	**2010**	**2015**	**2016**	**2017**
Grain crops	73.43	69.39	67.07	70.99	71.31	71.42	70.94
Rice	20.51	19.17	18.55	19.13	18.45	18.42	18.49
Wheat	19.26	17.05	14.66	15.54	14.74	14.79	14.73
Maize	15.20	14.75	16.95	22.23	26.95	26.46	25.49
Soybean	7.49	8.10	8.30	7.02	5.05	5.56	6.04
Potato	2.29	3.02	3.14	3.11	2.87	2.88	2.92
Other grain crops	8.68	7.30	5.47	3.96	3.23	3.31	3.26
Vegetables	7.08	11.06	12.82	11.71	13.07	12.98	13.28
Oilseed crops	8.74	9.85	9.21	8.70	7.98	7.90	7.95
Cotton	3.62	2.59	3.26	2.77	2.26	1.92	1.92
Sugar crops	1.21	0.97	1.01	1.15	0.94	0.93	0.93
Tobacco	0.98	0.92	0.88	0.83	0.75	0.72	0.68
Herbs	0.19	0.43	0.78	0.80	1.12	1.16	1.30
Hemp crops	0.25	0.17	0.22	0.06	0.03	0.03	0.04
Others	4.49	4.70	4.78	2.98	2.53	2.93	2.97

Sources: China Statistical Yearbook (2018)

1.1.3 The development of sustainable agriculture in China

Facing the challenges of feeding a growing large population in China, agricultural development has been dependent on intensified cultivation. Since the 2000s, the Chinese government took a series of strong policy measures, including setting up the agricultural subsidy program in 2004 and the abolition of the agricultural taxes and fees in 2006 to achieve food, particularly grain, self-sufficiency in the past several decades. As shown in **Figure 1. 2**, the total production and per unit area production of grain crops have been increasing since 2004.

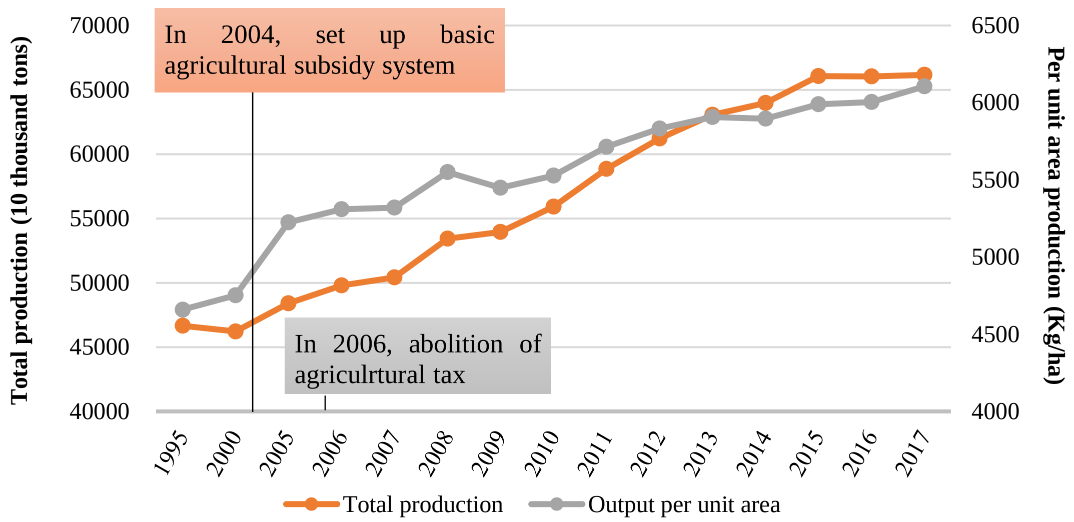

Figure 1. 2 Production of grain crop in China (1995–2017)
Source: National Bureau of Statistics, China Statistical Abstract, 2018

As China had achieved nearly full self-sufficiency in rice and wheat in the past decade and the per capita disposable income of rural areas increased dramatically from 1978 to 2017 (**Figure.1.3**), China has gradually shifted its agricultural policy from mainly focusing on production growth to improving sustainable and harmonious development of agricultural production.

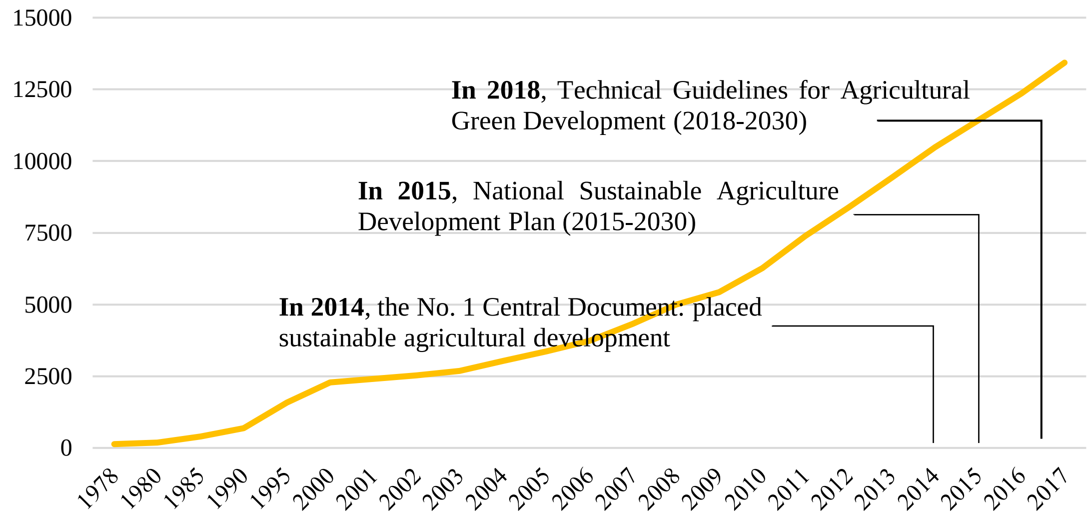

Figure 1. 3 Per capita farmers' income, 1978–2017 (CNY/person/year)
Source: National Bureau of Statistics, China Statistical Abstract, 2018

Recognizing the resource constraints and challenges in sustainable development, the Chinese government has made a strong commitment to promoting sustainable agriculture. As one of the national development goals, the aim is to improve land productivity and ensure long-term food security through developing sustainable agriculture. In this regard, China also announced several significant policy initiatives and plans, for example, the No. 1 Central Document (2014), the Agricultural Sustainable Development Plan (2015-2030) (Ministry of Agriculture and Rural Affair of the People's Republic of China 2015) and the Guiding Opinions on Promoting Sustainable Development of Agriculture in Arid Northwest China (Ministry of Agriculture and Rural Affair of the People's Republic of China 2017a).

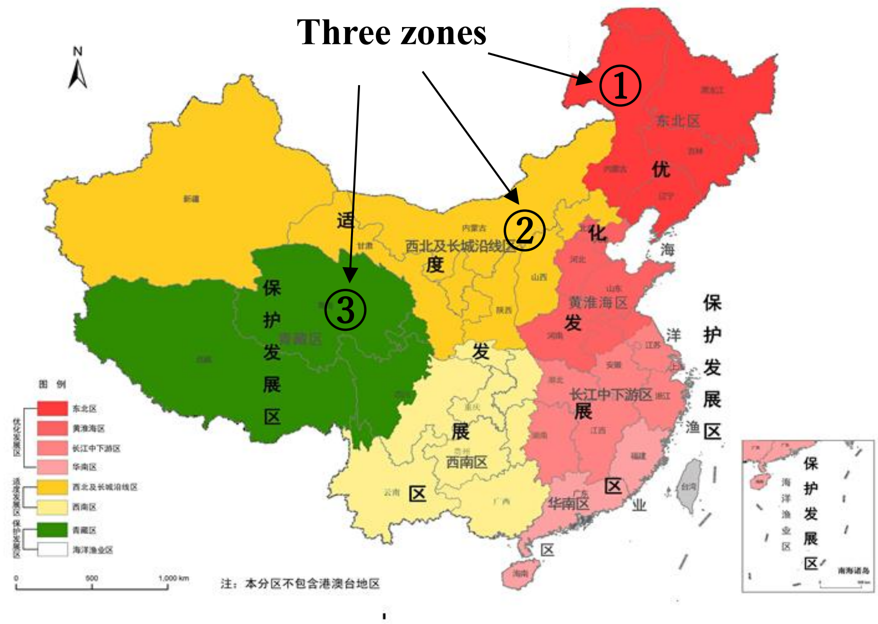

Figure 1. 4 Three zones of the Agricultural Sustainable Development Plan (2015-2030)
Source: Ministry of Agriculture and Rural Affair of the People's Republic of China

As shown in the Agricultural Sustainable Development Plan (2015-2030) of **Figure 1. 4**, mainland China is divided into three zones, namely ① optimized development areas (partition within red color), ② moderate development areas (partition within yellow color), and ③ protected development areas (partition within green color). The division was taken into account factors such as agricultural resources, environmental capacity, and ecological types. Consequently, northwest and southwest China are categorized as the moderate development area, and the policy design prioritizes developing adaptable practices that fit into the local capacity of agricultural production resources and environmental capacity.

1.1.4 Study areas

In this research, two study areas with significant geographic and climate differences, and presentative farming systems were selected from the moderate development area: the arid and semiarid regions in northwest China (the Hexi corridor and the Loess Plateau), and humid southern China (Guangxi and Yunnan). Firstly, the Hexi corridor and the Loess Plateau are among the high soil erosion regions in arid and semiarid regions of northwest China, and human intervention and farmland misuse, including removing natural vegetation, applying excessive agrochemicals, degrading marginal lands, and over-exploiting the vegetation, have exacerbated soil degradation (Nolan et al. 2008). It is thus essential to promote sustainable agriculture in this region to maintain long-term productivity.

Another study area is in southern China, where the climatic condition is more favorable for agricultural production. While facing similar problems as northwest China, the potential risk of ecological environment damage and soil and water pollution of this region has increased due to the removal of soil cover, overuse of agrochemicals, and growing cash crop plantation. Therefore, this study focuses on these two regions, aiming to exploring farmers' attitudes towards different SAPs and analyzing their preferences and intention to adopt these practices based on the site-specific conditions and agroclimatic characteristics. It is hoped that we may find more practical and applicable implications for future policy design.

1.1.5 Main classification of sustainable practices in China

Although the sustainable agriculture practices (SAPs) do not refer to a standard set of agricultural practices, some methods or practices involving less use of inputs and more depending on locally available resources could be included and categorized (M. Rodriguez et al. 2009). According to two classification dimensions of farming management and planting process, SAPs are divided into several technology types. Firstly, farming management consists of matching soil nutrients and maintaining pest tolerance levels and soil physical properties. Secondly, based on the stages of a plantation, there are conservation tillage and advanced seed technology before the plantation, technologies for reducing fertilizer, pesticide, and energy during the plantation, and practices relating to crop residue management and mulching after the plantation.

In this study, SAPs refer to the practices that involve reducing the use of agrochemicals and improving soil quality, mainly focusing on the utilization of cover crops, organic fertilizer, crop diversification with cover crops, and crop residue management.

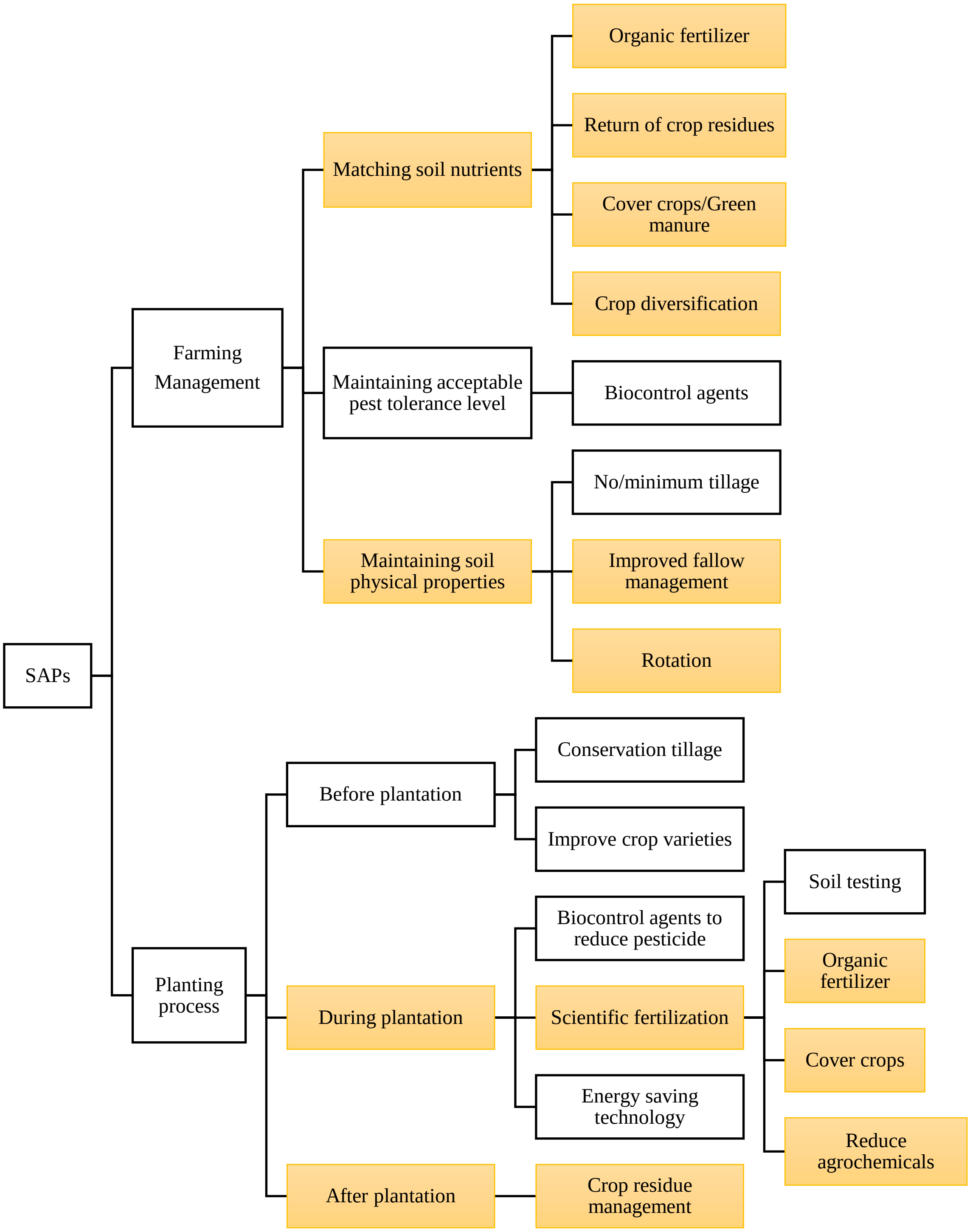

Figure 1. 5 Classification of SAPs (practices in yellow color are the focuses of this research)

Source: organized and summarized by author

1.2 Problem Statement

Sustainable agricultural development was defined as the management and conservation of the natural resource base, and the orientation of technological change in such a manner as to ensure the attainment of continued satisfaction of human needs for present and future generations (FAO 2014). Within the scheme of Sustainable Development Goals (SDGs) of the UN's Post-2015 Development Agenda, identifying and implementing policies, strategies, and technologies that contribute to sustainable agriculture play an essential role in conserving land, water, and plant and ensuring natural resources basis (United Nations 2012). Despite the attractive alternatives that SAPs represent for many farmers and given the well-established economic and environmental benefits, widespread adoption of SAPs has not yet occurred. For example, China began to promote conservation agricultural practices in the dryland regions in 2002 and not until 2014, the application area only reached 86 million hectares, a share of 6.4% of the total cultivated area in China (W. Li et al. 2017). Nevertheless, there is extensive literature on the adoption and diffusion of agricultural technologies and innovations, of which the adoption of SAPs is one hot topic that has attracted much attention by scholars and public sectors.

The synthesis and meta-analysis of the adoption studies by Knowler and Bradshaw (2007) show showed that there is rarely any universally significant independent variable that could simply explain the adoption of innovations, while several variables related to environmental awareness did reveal consistent results. Additionally, review studies highlight the importance of regional conditions, as these contextual factors reflect the particular features of individual locales (Carlisle 2016). Accordingly, analyzing the adoption of SAPs should focus on site-specific features, preferably, regional or village-level farming systems or cropping patterns.

In this case, whether a single or a type of farming practices could be widely promoted to the smallholder farmers depends on the intention of the farmers in adopting the practices in their major farming systems. As explained in 1.1.2, along with changes in food demand, the structure of agricultural production has been gradually adjusted to produce more cash crops, and this trend is also seen in the regions with less favorable conditions for agricultural production (highly erodible soil and steep slope, etc.) (Xin Wen and Zhen 2020b; Huang and Yang 2017). Consequently, recognizing major cropping systems is the first step for analysis, and based on this, analyzing farmers' decisions on adapting and modifying the cropping systems with SAPs should provide practical and applicable implications for the policy implementation. However, there is still a lack of evidence on how localized features and cropping systems affect farmers' decisions and diversify choices. Also, the discrepancy help identifying the characteristics of farmers and farms within the choices, which could be further explored.

Furthermore, taking into account the fact that the immediate positive yield benefit of SAPs is often absent, in particular in arid and semiarid regions, the rapid effect of the practices is hardly seen (Corbeels et al. 2014). Consequently, the practical application of SAPs was constrained among smallholder farmers due to their limited economic and resource availability. It raises the question of whether the agricultural structural changes and growing farmers' income can broaden the capacity of choices for SAPs and diversify their choosing patterns. A study on the possibility of adopting different SAPs into farming systems by farmers may answer the question, allowing the gradual adjusting process and the factors behind the decision-making to be explored. It helps better understand the aspirations and active participation of smallholder farmers in improving sustainable agricultural production and ecological conservation.

On the contrary, in the more favorable environment for agricultural production, like southern China, climatic conditions are beneficial for cash crop cultivation and SAPs adoption. However, the use of chemical fertilizer has been growing with the cash crop cultivation despite high intention of SAPs adoption among farmers. Therefore, we might wonder is the willingness of SAPs adoption consistent with their behavior, and how far from the adoption intention to the adoption behavior? What led to the gap between the intention and behavior and by what means can improve the consistency? Therefore, it is important to analyze different stages of decision making regarding SAPs adoption, and clarify the key influencing factors in affecting the choices among smallholder farmers. This study is one step toward this end.

1.3 Research Objectives

This study aims to analyze the smallholder farmers' decisions on SAPs adoption and identify the main influencing factors, which will provide insights for site-specific policy design in the face of structural changes in agricultural production in northwest and southern China. How the decision is made on SAPs adoption was divided into three stages: behavioral intention, behavior, and the confirmation of the behavior. Based on the current literature and survey data, the principal objectives are provided as following:

The first objective is to clarify the intention of SAPs adoption based on a survey in northwest China. To begin with the intention of adoption, we first focus on adoption preferences of SAPs among two main kinds of smallholder farmers, i.e., the grain crop farmers and cash crop farmers. How these two types of farmers prioritize to adopt SAPs in their current farming system would be clarified. Then taking into consideration the preferences, a specific design adoption package including details of the adopting process and supplementing technical assistance was provided for farmers, and the aim is to estimate farmers' decisions on how to proceed with the practice within different cropping systems. Through the choices of detailed procedures that farmers decide, the perceived adaptability of SAPs would be further explored. Moreover, as the individual farmer has a different utility to each SAP, the discrepancy of choices would be identified to characterized farmers and farms.

The second objective is to first identify the gap and consistency between behavioral intention and behavior of SAPs adoption, and secondly to examine the effect of perception on the consistency between the behavioral intention and behavior of cover crop adoption among smallholder farmers using the bivariate-probit model. The connection of perception between intention and behavior will be analyzed and factors affecting the perception, behavior intention, and behavior will be examined.

And the third objective is to evaluate the economic and ecological effects of the cover crop adoption in orchards, to confirm the influence of the practice adoption and improve the comprehensive effects of practice adoption. Through the perspective of costs and benefits in production, the study helps to is to clarify how the benefits increased by adopting SAPs in the farming system.

1.4 Contributions of the Study

Firstly, the significance of localized features and cropping systems in affecting the early stage of decision-making was further proved in the studies of northwest China. Specifically, the effect of precipitation on the adoption of cover crops related practices, and the influences of detailed farming strategies including cropping patterns, duration of adoption on diversifying farmers' decisions and ensuring long-term adoption were clarified. Additionally, the potential opportunity cost of foregone cash crop production is shown to be a significant barrier in the use of cover crops in southern China.

Secondly, the empirical results of discrete choice models in arid and semiarid northwest China offer precise proves showing that the intention to adopt SAPs is not only related to the localized features but also is closely related to how farmers perceive the adaptability of the practices and how easy these practices can be adjusted to the current cropping systems. For example, intercropping is found to be more favorable than rotation for adopting cover crops in the double-cropping system of the northwest China. Also, the localized features and farming strategies further depict how farmers decide to adapt SAPs to their farming systems and help to explain the trade-offs in their decisions.

Thirdly, the study also analyses three stages of decision-making in the context of the agricultural structural adjustment. Although studies of conservation agriculture and technology adoption are not new, the scheme taken here is novel. This study extends the hierarchy of the influencing factors in three stages of decision-making and provide a thorough and clear elaboration on key factors affecting decisions of SAPs adoption. In the early stage of behavioral intention, discrete choice models were employed to identify adoption preferences for SAPs and predict the choices regarding how to proceed the practices. The existing researches mostly apply binary or ordinary logit probit models to analyze the adoption behavior, and rarely connect the intention and behavior and identify the connect between them. Therefore, the study fills this gap by examining the consistency between the adoption intention and adoption behavior and analyzes the influencing factors as well. The findings have important policy implications for agricultural sustainability and food security in many developing countries, where farming is dominated by millions of smallholder farmers.

1.5 The Structure of the Dissertation

This thesis is organized into eight chapters. Chapter 1 first describes the basic dimensions of environmental degradation and agricultural development in China and the motivation of this research. Based on the statement of problems regarding the low adoption rate of SAPs and the lack of study on how the smallholder farmers decide to adopt SAPs along with the adjustment of their agricultural production and cropping structure, the research objectives were presented and the main contribution of this study was discussed.

Chapter 2 reviews the theoretical and empirical studies that provide the theoretical base and empirical evidence of the adoption analysis. As multiple practices regarding SAPs were discussed in the previous studies, this chapter focuses on the use of cover crops, crop rotation, conservation tillage of crop residue mulching, and fallow. The body of this chapter consists of a narrative review of influencing factors, motivations for and barriers to the adoption, as well as a summary of recommendations and suggestions relevant to the reviewed studies. This review intends to provide the conceptual model and analytical framework for this study.

Chapters 3-5 present a series of models that make up the analytical analysis of field study in northwest China. Analyses in these chapters make use of different approaches and parameter values to explore the decision on SAPs. Chapter 3 uses a best-worst scaling approach to examine the adoption preferences for nine SAPs among grain and cash crop farmers and investigates the influence of farm and climatic characteristics on adoption preferences. This chapter helps to understand how farmers in diverse agroclimatic zones perceive and respond to different conservation practices regarding SAPs.

Chapter 4 introduces a discrete choice model to investigate the decision-making regarding diversifying farming with cover crops for sustainable farm management (SFM) and examine whether the adoption decisions differ in different cropping systems. In this study, based on the face-to-face surveys in two regions of the Hexi corridor (D1) and the west Loess Plateau (D2) in northwest China, the smallholder farmers' adoption preferences for preferable cropping patterns of cover crops, duration of adoption, and supplementing technical support for reducing agrochemicals regarding SFM were investigated. Also, the empirical analysis was used to identify factors affecting farmers' decisions, and the differences between the two regions were compared.

Chapter 5 provides the latent class analysis for investigating the heterogeneity in farm and farmers' characteristics in shaping decision-making. Based on the Best-worst scaling (BWS) and Discrete Choice Experiment (DCE) choice survey conducted in chapter 3 and chapter 4, this chapter intends to divide the surveyed farmers into different classes for a better understanding of the decision-making of the proposed practices and packages. The primary goal of this chapter is to provide policy implications derived from the results of the divided classes.

Chapter 6 and Chapter 7 shift focus from northwest China to southern China and examine the specific practice of cover cropping. Chapter 6 contains a case study of Guangxi by investigating the adoption decision on cultivating cover crops. Using the bivariate-probit model approach, this study estimates the effect of perception on the intention and behavior of cover crop adoption among smallholder farmers in southern China. Also, the consistency between intention and behavior of cover crop adoption was examined.

Chapter 7 contributes to the understanding of the comprehensive effect of SAPs from the aspects of the cost and benefit of production and ecological value. A concise statistical assessment of orchard production in Yunnan, southern China with and without integrating livestock and cover crops is presented. The economic and ecological values of integrating livestock and cover crops as a technology for alleviating soil degradation and providing forage in orchard agriculture are also assessed to explain the comprehensive effect of SAPs adoption based on a precise case study.

Chapter 8 summarizes the analytical and empirical findings of this study. It also discusses the policy implications and indicates future areas for research, in particular for the regions possessing similar geographic and climatic features as northwest and southern China. The focus of this chapter is on the interactions between northwest and southern China.

CHAPTER 2
REVIEW

Adoption of technology is not an instantaneous process, hence understanding the processes of technology adoption and how the decision is made by farmers during the process plays a critical role in designing effective research and agricultural extension programs. The objectives of this chapter are to identify basic stages in adoption analysis and to review the theoretical studies and provide a conceptual and theoretical framework for the later methodological and empirical chapters. This chapter firstly outlines the most frequently used adoption theories and models in estimating the probability of practice adoption and then reports results from recent studies on the adoption of SAPs.

2.1 Expected Utility Theory

Smallholder farmers are the main unit of agricultural production and management in China, and their corresponding behavior is the foundation of sustainable agricultural technology adoption and farm management. Schultz (1964) and Popkin (1979) regards smallholder farmers as rational economic men and who will make the production decision to maximize expected profit or utility through the optimal allocation of resources and evaluation of the long-term and short-term benefits and risk factors. The assumption that a decision-maker maximizes expected utility has been frequently employed in model specifications of agricultural economics (Meyer 2002).

The expected utility model for technology adoption was first proposed by Just and Zilberman (1983), which recognizing differential uncertainties in both traditional and modern technologies. The expected utility model assumes that adoption decisions are based on the maximization of expected utility or profit. The profit depends on the farmer's choices and selections from farming resources including land, credit, labour, and other constraints relating to outputs (Mercer 2004). With constraints of the resources, individuals will make the optimal choice that maximizes their total utility (Schultz 1964). The utility level could be depicted by the indifference curve (**Figure 2. 1**), on which all possible combinations of two goods provide the individual with the same level of utility (Snyder, Nicholson, and Stewart 2012).

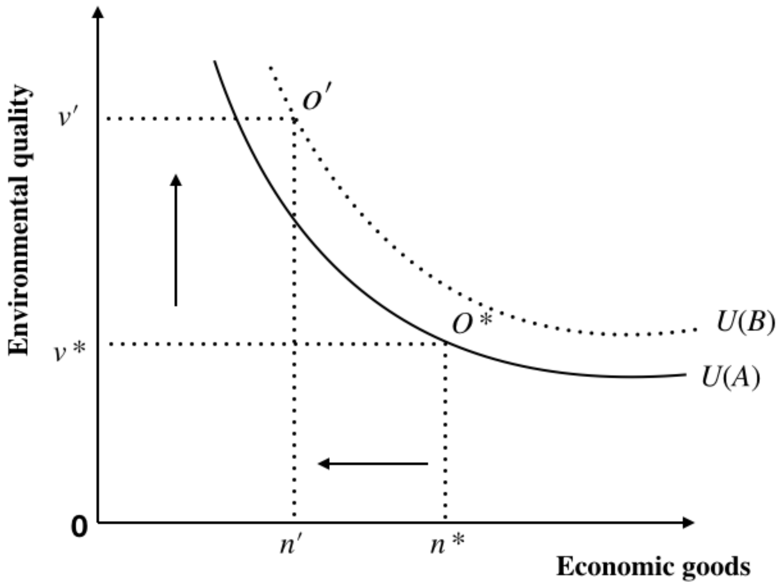

Figure 2. 1 Trade-off between environmental quality and economic goods
Source: Min et al. (2018)

Within certain budget constraints, the single indifference curve shows the preferred trade-offs between the improvement of environmental quality and economic goods. Here, the initial optimal combination of the environmental quality and economic goods locates in O^*, which is the utility-maximizing choice made by the farmer considering the limited budget constraints. The original indifference curve of $U(A)$ implies that the farmer is indifferent between any combinations of the environmental quality and economic goods. However, farmers have different budget constraints and heterogeneous expectations about their adoption. If a farmer expects their adoption of the SAP will increase the environmental quality from v^* to v' with the expend from n^* to n', the new optimal point will be located in O', shown in **Figure 2. 1**, where the budget constraint is tangent to the indifference curve of $U(B)$. Accordingly, the higher utility gained from the improvement of environmental quality will lead to the tendency to adopt the SAP. On the other hand, if the expectation about the improvement of environmental quality is lower than v', the increase of utility from the improvement of environmental quality cannot cover the loss of utility from reducing economic goods, which results in the turndown of the adoption.

However, taking into account the fact that the immediate positive yield benefit of SAP is often absent, the decision on SAP might not be the optimal choice among the smallholder farmers. Therefore, the evaluation of farmers' adoption of technological innovations has to take into consideration more details of site-specific information.

2.2 Innovation-diffusion Theory

From a sociological viewpoint, adoption is the mental process from first hearing about an innovation to deciding to make full use of the new idea (Mercer 2004). As an important research agenda in rural sociology, the diffusion theory first emerged in the 1940s and 1950s (Ruttan 1996). The innovation-decision was process described as "an information-seeking and information-processing activity, where an individual is motivated to reduce uncertainty about the advantages and disadvantages of an innovation", which involves five steps: (1) Knowledge, (2) Persuasion, (3) Decision, (4) Implementation, and (5) Confirmation (Rogers 2010).

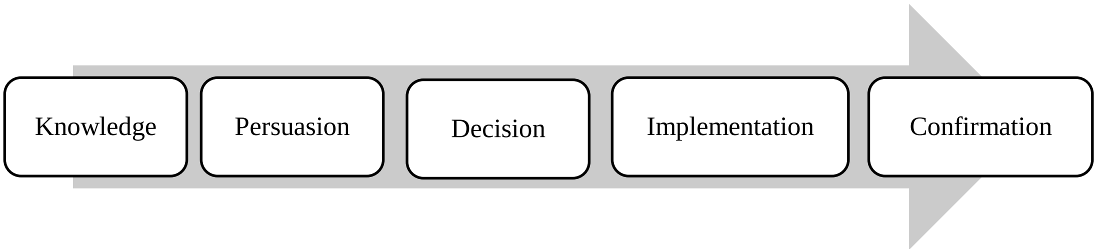

Figure 2. 2 A model of five stages in the Innovation-decision process
Source: Diffusion of Innovation, Rogers (2010)

The agricultural technology adoption studies viewed the adoption process from a multi-dimensional perspective, such as perceived profitability, costs of establishment, compatibility with current agricultural systems, and the knowledge and information between and among adopters and potential adopters (Mercer 2004).

2.3 The Theory of Planned Behavior

According to Ajzen's (1991) Theory of Planned Behavior (TPB), when the actual control conditions (e.g., individual capabilities, opportunities, resources, etc.) are sufficient, attitude toward the behavior, subjective norms, and perceived behavior control are the three main variables that determine behavioral intention. The behavioral intention directly determines the behavior. The TPB provides a theoretical framework for understanding how a farmer's attitude and perception toward SAPS can influence behavioral intention and further behavioral performance.

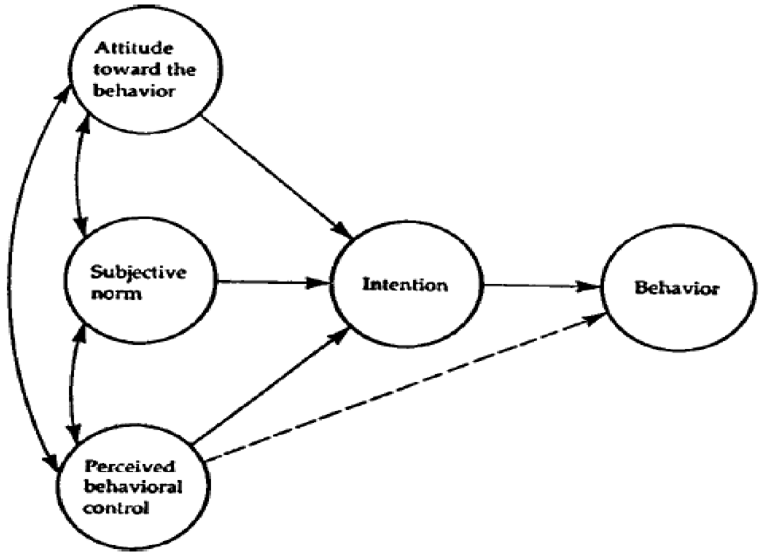

Figure 2. 3 The theoretical framework based on the theory of planned theory
Source: Theory of planned behavior, Ajzen (1991)

Attempts to promote sustainable agriculture will require to understand how behavioral change can be influenced. Both the Innovation-Diffusion Theory and the Theory of Planned Behavior offer exhaustive framework to understand and predict specific behavior. Nonetheless, TPB suggests the attitude, subjective norm and perceived behavioral control will make significant impact on behavioral intention and behavior, while diffusion theory emphasizes on the steps of diffusion process. This study learns from both of them and focus on the factors affecting decisions including behavioral intention and behavior, and also on the step after practice implementation, the confirmation on the effect of SAPs adoption.

2.4 Key Factors Affecting the SAPs Adoption

The growing literature and experimental studies afford substantial insights into the development and diffusion of agricultural technologies and practices. Carlisle (2016) provided a narrative review on the adoption literature of soil health practices including cover cropping, conservation tillage, and crop rotation in the United States. The review found emergent themes including interaction among soil health practices and noneconomic farmer motives, and therefore recommended to utilize interpretive frames that elucidate interactions among groups of farmers and address farm and food system context. Smith and Siciliano (2015) conducted a contemporary synthesis of complex and inter-related factors affecting the excessive use of fertilizer in an intensive farming system and the constraints to the mitigation of diffuse water pollution in China. The results confirm that a single policy measure cannot work alone, and effective management in the farm requires integrated policy measures and frameworks from the central government to the local support.

Multiple conservation practices were mentioned under unifying labels of sustainable agriculture (SA), environmentally friendly agriculture (SFA), and conservation agriculture (CA). We intentionally address practices that improving soil nutrients, including chemical fertilizer reduction, use of cover crops or green manure, crop diversification by rotation and intercropping, conservation tillage of crop residue mulching, and fallow management. These practices generally involve modification and adjusting management of farms as they require the adopters to establish a new set of the input-output process during production (Mercer 2004).

Table 2.1 to **Table 2.4** summarized the main empirical studies of four types of SAPs, cover crop, conservation tillage and organic fertilizer/fertilization application, and the environmentally friendly program. As the focus of this study, these four types of the practices were promoted to smallholder farmers for sustainable farm management by the government. Main factors found to be effective in the practices adoption studies were summarized as attitude and perception, farming resource, information source and policy support.

2.4.1 Attitude and perception

As summarized in **Table 2.1**, by studying farmers' understanding of the multiple effects of cover crops in improving production and soil quality, mitigating soil erosion, and conserving diversification, Li et al. (2020a) found that farmers who are aware of the positive effects on yield growth and soil quality of cover crops will accept less compensation for adopting the practice. The perceived values of the SAPs have also shown a negative effect on the adoption. In addition to the cover crop adoption, in a case study in the semiarid Loess Plateau of Northwest China listed in **Table 2.2**, farmers with a better understanding of conservation tillage were less likely to adopt this technology (Han, Siddique, and Li 2018). The reason for this result is that using the conservation tillage will not bring too many economic benefits under the changing cropping structure of growing spring maize and decreasing winter wheat. Based on prior information and experience, the perceived ease of use and usefulness of the technology will influence the duration of adoption (Gao et al. 2019)

Risk perception and preference are associated with the concern about the environmental impact of the current farming practices and climate change (Liu 2013). Regards to the environmental friendly program adoption, the rating scores of costs, risks, and observability indicate that profit maximization was the main concern among farmers (Luo et al. 2016) (**Table 2.4**). In terms of cover cropping in the orchard, Ren et al. (2020) found that the attitude of severity in soil degradation influences the decision on cover crop adoption. The forgone grain and cash crop production is perceived as one important opportunity cost for rotating cover crops in the multiple cropping systems (Bergtold et al. 2019; Yu et al. 2019a).

Farmers are not adverse to change, but proposed changes must fit into their farming systems without altering too abruptly the methods they have developed over time to reduce risk and spread out labor use (page 135) (Norton, Alwang, and Masters 2009). Decisions often reflect attempts to manage these risks. Risk alleviation could be reliance on diversified livelihood strategies through planting multiple crops on a single plot of land in a single season, for example, maize is intercropped with sweet potato, groundnuts, and other food, depending on location.

2.4.2 Farming resources

Agricultural production is associated with the allocation of types of farming resources, such as labor, capital, and land management, presenting the trade-offs of opportunity costs associated with food crop production (Carlisle 2016). The SAP adoption literature does not show a consistent conclusion with respect to the influence of production factors that are associated with farm capacity and capital capability. The empirical analysis of cover crops adoption in the paddy fields in southern China shows that the number of household members 16–65 years old who provide labor in the agricultural field has a positive impact on rotating green manure cover crops with rice cultivation (Ntakirutimana et al. 2019). The same results were also reported in Spain that labor productivity was one critical component that was positively and significantly related to the adoption of cover crops in olive groves (Rodríguez-Entrena, Arriaza, and Gómez-Limón 2014).

As listed in the **Table 2.1** to **Table 2.4**, it is hypothesized that farmers with a larger scale of farms, more agricultural labor inputs, and higher household income, are more likely to adopt the SAPs (Ntakirutimana et al. 2019; Chen, Si, and Zhao 2019; Gao et al. 2019; Li et al. 2017; Min et al. 2018), while the effect is complicated. The increase in farm size is found to have a positive influence on the adoption of the green manure cover crop in the paddy field, but at the same time, it also requires higher compensation levels for accepting the cover crops cultivation plan (Li et al. 2020a). One explanation is that large-scale farmers are more sensitive to future earnings and long-term sustainable development, but also possess a high opportunity cost to apply the practice (Chen, Si, and Zhao 2019). Many studies on smallholder farmers found no such relation (Li et al. 2017; Wang et al. 2018; Wang et al. 2016). But to the specific practice of conservation tillage, the land fragmentation impeded the adoption of technology (Li et al. 2017). The household income was also found contradictory results on cover crop adoption (Ntakirutimana et al. 2019; Li et al. 2020).

Also, a higher share of income from non-farm work is found to have a negative relation to the adoption of organic fertilizer (Zhu, Feng, and Zhang 2012). In particular, smallholder farmers depending on subsistence agriculture are more sensitive to the variation of production and income

(Meijer et al. 2015). In a study of the main producing area of high-quality rice in Wuhu, Anhui province, Zhao and Cai (2012) found that the family agricultural labors have a positive effect on the adoption of labor-intensive technologies.

2.4.3 Information sources

Base on Rogers' innovation-diffusion theory (2010), access to information is the key factor determining adoption decisions. Zhu et al. (2012) pointed out that the agricultural material seller is the main information source for farmers. As the sellers tend to sell more chemical fertilizers to the farmers and therefore might provide erroneous or one-sided information for their self-interest, leading to the negative impact of information on the use of commercial fertilizer and animal manure (**Table 2.3**). Similar results were also found by Fan et al. (2015), in which case the pesticide retailers play an important role in providing information and guidance on the selection by a farmer, while the technical staff in local communities on improving farmers' awareness and behavior is rather ineffective. Studies on cover crop adoption (**Table 2.1**) found that as an important information source, agricultural training and publicity play a critical role of improving perception on the effects of cover crops.

2.4.4 Policy support

Numerous studies credited the incentive payment in increasing the likelihood of adoption, while the practices required more substantial changes in the farming systems, such as cover cropping and rotation between current food crops (e.g. grain or vegetables) and legume crops, and the up-take among farmers has been slow. The same results were also found in research by Dobbs and Pretty (2008) that the Agri-environment programs are more financially attractive by grazing and less-intensive agriculture. The research recommends separating crop and livestock-related payments for improving specialization in both cereal and livestock sectors, which contributes effectively in environmental enhancement and sustainability.

Yet with the current incentive payment for compensation to farmers, the adoption of cover crops in the government testing regions is not sustainable in a long run. Hence, eco-compensation should take into account the costs associated with the adoption of cover crops and cooperate with other supplementary measures for improving farmers' ecological consciousness and risk awareness (Fuduo Li et al. 2020a). However, the incentive scheme for sustainable farming with cover crops is relatively simple compared to those in the EU, the U.S., which provide additional compensation measures including technical assistances and special protective measures (Reimer, Thompson, and Prokopy 2012; Yu et al. 2019a; Ren, Yin, and Duan 2020).

Table 2. 1 Key findings from the cover crop adoption literature

Reference	Region	Sample size	Farm size (ha)	Household income (10,000 CNY)	Labor	Crop type	Cropping system	Factor found to increase adoption	Factor found to decease the adoption	Recommendation
Ntakirutimana (2019)	Guangxi	336	n/a	n/a	1.50[a]	Rice	multiple cropping systems	Preference for a type of subsidy (funds, seeds, or mechanical services; training; belief in the effects of a standard subsidy on promoting green manure planting; agricultural labor; farm size;	Household income;	Farmers' perceptions of using rotation fallow had a significantly positive influence on planting green manure
Li (2020a)	Southern paddy field	1217	0.45	6.53	3.46	Rice	multiple cropping systems	Perception of the positive effects on yield growth and soil quality; village leader; age; household income; Farm size	Cost; land; Strict in policy management	Perceived cost, economic and ecological effect would influence the adoption; excessive government intervention will do not benefit the implementation of the policy
Ren (2020)	Human	423	6.45	2.84	4.62	Orchard	n/a	Trusty in information from neighbor and relatives; perception of positive effects of cover crops; understanding of the policy	-	Design differentiated ecological compensation schemes for different agricultural management groups; strengthen the relationship between local government and farmers by mutual communication
Wang (2019)	Heilongjiang	342	-	-	-	Rice and Soybean	n/a	Subsidy	-	Raise subsidy standard; focus on large-scaled farms; enhance agricultural technology

*[a] indicates the number of agricultural labor (person)

Table 2. 2 Key findings from the conservation tillage adoption literature

Reference	Region	Sample size	Farm size (ha)	Household income (10,000 CNY)	Labor	Crop type	Cropping system	Factor found to increase adoption	Factor found to decease adoption	Recommendation
Gao (2019)	Huang-Huai-Hai Plain	366 traditional households (THs); 364 family farms (FFs)	0.941 (TH); 9.254 (FF)	Financial status:1 to 7	2.618 (TH); 5.969 (FF)	n/a	n/a	Gender; educational; financial status; number of laborers; perceived ease of use; perceived usefulness; media propaganda; training; farm size (TH)	-	improved guidance for price assessments improved risk prevention mechanisms, and the implementation of land transaction dispute mediation and arbitration measures
Han (2018)	Loess Plateau	385	0.54	n/a	2.35	Winter wheat; Spring maize	double cropping system	Education; the distance of farmers' house to the nearest agricultural market; actual planting area of winter wheat; the number of arable plots per household; training; lead in a demonstration	Number of family labor; understanding of the conservation tillage; total area farmland owned	within the change of increasing spring maize cultivation and decreasing winter wheat cultivation, the winter wheat-based conservation tillage is hard to be accepted by farmers
Li (2017)	Loess Plateau	476	0.37	n/a	1.63 (agricultural labor)	Winter wheat; Spring maize; Winter Wheat-Spring maize	Double cropping system; Single cropping system	Education; risk prefer; understanding of technology; perception of economic effect; household income; communication; internet study; subsidy; demonstration	Age; risk reverse; share of agricultural income; fragmentation degree of cultivated land	
Xu (2018)	Heilongjiang; Henan, Zhejiang, Sichuan	1064	If scaled farm	n/a	n/a	Heilongjiang; Henan (Maize); Zhejiang, Sichuan (Rice)	double cropping system	Scaled farm; education; straw burning ban; subsidy;	n/a	In the process of inter-period agricultural technology promotion, large-scale households are the "breakthroughs"; The government needs to make a more complete system for non-agricultural employment and rural social security.

Table 2. 3 Key findings from the organic fertilizer/fertilization application adoption literature

Reference	Region	Sample size	Farm size (ha)	Household income (10,000 CNY)	Labor	Crop type	Cropping system	Factor found to increase adoption	Factor found to decease the adoption	Recommendation
Xu (2014)	Huang-huai-hai Plain (Shandong); Song nen Plain (Jilin); Ili River Basin (Xinjiang)	476	2.37ha	5.85	2.39-2.57	Cotton (Shangdong); Rice (Jilin); Rice, corn, soybeans, and cotton (Xinjiang)	Single cropping	Knowledge of land tenure; want to take mortgage the land use right; subsidy; existing technology system	Paddy field; age; education; transferred land; need land adjustment;	Increase the scale of a single crop field and decrease the degree of fragmentation of cultivated land
Wang (2018)	Certified apple growing areas (northwest China)	359	0.86	n/a	n/a	Apple	Orchard	Cooperatives; subsidy, acreage	n/a	Develop incentive policies to promote farmers to join agriculture cooperatives; provide practical subsidies; provide in form of organic fertilizer instead of money
Zhu (2012)	Zhejiang; Jiangsu	Zhejiang (320); Jiangsu (478)	0.838 (Zhejiang); 1.556 (Jiangsu)	7.41 (Zhejiang); 46.33 (Jiangsu)	2.69	n/a	n/a	Commercial fertilizer: cooperatives; training. animal manure: training, livestock.	Commercial fertilizer: age, education, non-agricultural income; livestock, animal manure: non-agricultural income, farm size, information	Improve training of agricultural technologies and information transfer from cooperative; enhance the land transfer of non-agricultural farmers; build up the cooperative relationship between cultivation and livestock
Zhang (2017) Bivariate-probit	Shandong	279	0.276	n/a	n/a	Apple	Orchard	Years of the plantation; standardized orchard; off-farm work experience; perception of the negative effect of over-fertilization; training	Female; education; fragmentation of farmland	Promote the training of scientific fertilization planting techniques, and promote more environment-friendly techniques.to fruit farmers; expand the farm-scale and create a standardized orchard

Table 2. 4 Key findings from the environmentally friendly program adoption literature

Reference	Region	Sample size	Farm size (ha)	Household income (10,000 CNY)	Labor	Crop type	Croppin g system	Technology	Factor found to increase adoption	Factor found to decease the adoption	Recommendation
Luo (2016)	Henan	150	<1ha	n/a	2.57	Grain crops	n/a	No/minimum tillage; soil Testing; controlled fertilizer release; application of organic fertilizers; returning straw to field	Knowledge of land tenure; want to take mortgage the land use right; subsidy; existing technology system	Cost; income risk; observability	Strengthen environmental awareness; provide incentives; reward their adoption; increase farmers' access to field demonstrations, provide scientific and technical training in fertilization
Min (2018)	Xishuangb anna (Yunnan)	612	0.7	5.025	n/a	n/a	Rubber	Reduce rubber planting area	Household income; tourism	Positive environmental perception of rubber	Ethnicity;
Wang (2016)	Shandong	646	0.398		-		grain crop	Applying organic fertilizers; conservative tillage; not burning residue after harvest; crop rotation; growing green manure; formulated fertilization	multiple cropping systems	Knowledge; risk; perception; adoption attitude; the degree of fertility; training; insurance; interaction with other farmers; cooperative	Availability of farming funds

2.5 Conceptual Model and Analytical Framework

As proposed by Ajzen (1991), the decision for the adoption of new technology such as SAPs is guided by three kinds of consideration, behavioral beliefs, normative beliefs, and control beliefs. These considerations can be further elaborated into a certain attitude, subjective norm, and behavioral control factor, respectively (Yadav and Pathak 2017). Therefore, we conceptualize the model of this study as **Figure 2. 4**.

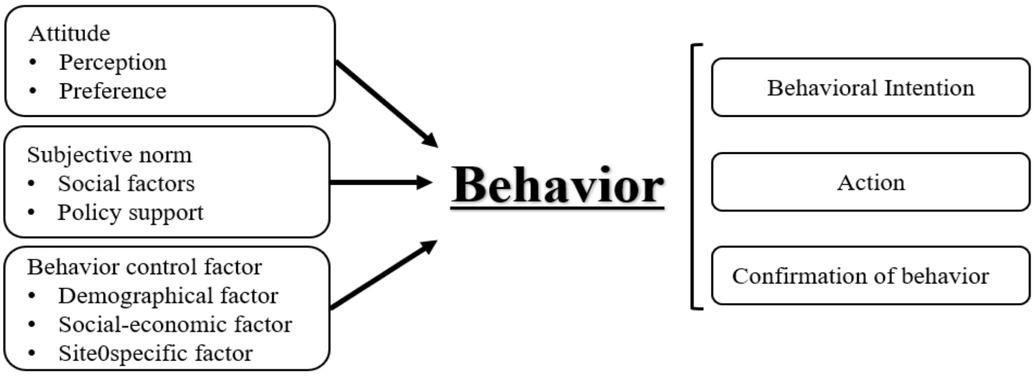

Figure 2. 4 Conceptual model

Source: organized and summarized by author

The present study deals with the farmers' intention and behavior towards sustainable agricultural management. Therefore, this study is based on the assumption of farmers' behavior of SAPs include the behavioral intention, actual action and the confirmation of behavior, which is determined by attitude, subjective norm, and behavioral control factors. Within the context of attitude, the adoption preference and the perception of SAPs are the focuses as empirical studies of SAPs adoption consistently indicate the importance of farmers' attitude toward the practices in affecting their decisions (Bergtold et al. 2019; Yu et al. 2019a; Fuduo Li et al. 2020b; Ntakirutimana et al. 2019). Social factors refer to the information sources and motivations, and policy supports of economic incentives are included in subjective norm. As for the behavioral control factor, in addition to the social-demographic and social-economic factors, the site-specific agroclimatic factors are also taken into account in the analysis.

Based on the conceptual model, Chapter 3 to Chapter 8 are organized into four parts (shown in **Figure 2. 5**). The first part of the behavioral intention is also called the early stage of decision-making. The studies were conducted in northwest China, in which the adoption preferences for nine SAPs and cropping patterns with economic incentives are analyzed. As there are differences in the adoption preferences across the sample, the latent class analysis making use of the choices for nine SAPs and cropping patterns is conducted to identify cluster segmentations of farmers. Then the sociodemographic characteristics and social economic and agroclimatic factors are used to characterize the features of farmers in each cluster.

The second part related to the consistency between behavioral intention and behavior. As southern China has more favorable agricultural conditions (e.g. individual capabilities, economic resources, and natural conditions, etc.), the focus lies in the decision-making from the early stage to the final stage of the decision-making. In particular, the impact of the positive effect of perception on behavioral intention and behavior is analyzed.

Next, a crop-livestock integrated model with cover crop usage is selected for the confirmation of the actual adoption, aiming to provide a better understanding of the comprehensive effect of the practice adoption. Also, the confirmation section allows us to clarify the major concerns before the actual adoption of the practice.

The last chapter of this study further discusses the results concluded from the previous five chapters and explores a greater depth in the theoretical and empirical roles of the key factors within different stages of decision-making.

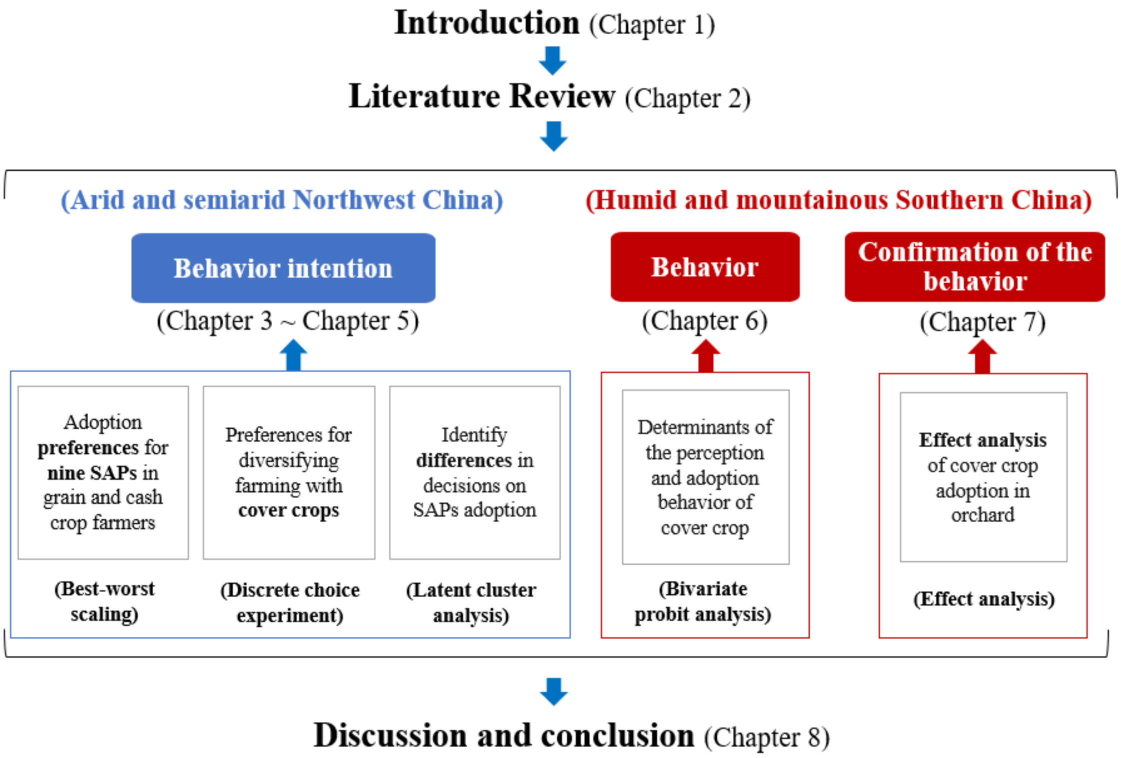

Figure 2. 5 Analytical framework

Source: organized and summarized by author

CHAPTER 3

FARMERS' ADOPTION PREFERENCES FOR SAPS IN GANSU

This chapter is an empirical study of adoption intention, mainly focus on the adoption preference in the early stage of decision-making. A face-to-face survey was conducted in northwest China, we provided grain crops and cash crop farmers with options of SAPs and asked about their preferences for applying these practices in their current farming system. Then using the survey data, farmers' adoption preferences for nine SAPs and factoring affecting the decisions were analyzed.

3.1 Introduction

In China, one-half of the land area is arid or semiarid and 26.6% has average precipitation below 200 mm per year (Peng and Zhou 2017). Among the high soil erosion regions in arid and semiarid northwest China, human intervention and farmland misuse, including removing natural vegetation, applying excessive agrochemicals, degrading marginal lands, and over-exploiting the vegetation, have exacerbated soil degradation (Nolan et al. 2008). As such, for many arid or semiarid South and Central Asian and African countries, implementing SAPs to restore soil quality and mitigate degradation is essential for agricultural sustainability.

Gansu province is a representative area of the arid and semiarid climate and fragile ecological environment in northwest China (**Figure 3. 1**). Traditional crop production practices involve intensive cultivation by ploughing and harrowing soil two to three times between harvest and spring sowing, while crop stubbles and residues are usually removed from the field for forage or fuel use (L. Li et al. 2011). The sparse vegetation soil cover and seasonal rainfall decrease the structural instability and production potential of the soil in this province.

Gansu is one of the poorest provinces and home to the national bottom 40% of the rural poor in China (Bank 2009). To achieve environmental protection and poverty reduction, the Chinese government has invested heavily in ecological restoration and conservation programs (e.g., Three

Norths Shelter Project, Grain for Green Project, Gully Land Consolidation Project), while also campaigning for increasing the production of cash crops to reduce the reliance on grain production (Xin Wen and Zhen 2020b). During the transitions of planting structure, understanding how farmers in the diverse agroclimatic zones perceive and respond to different conservation practices is important for policymakers to determine the favorable SAPs and what relating policies should be designed.

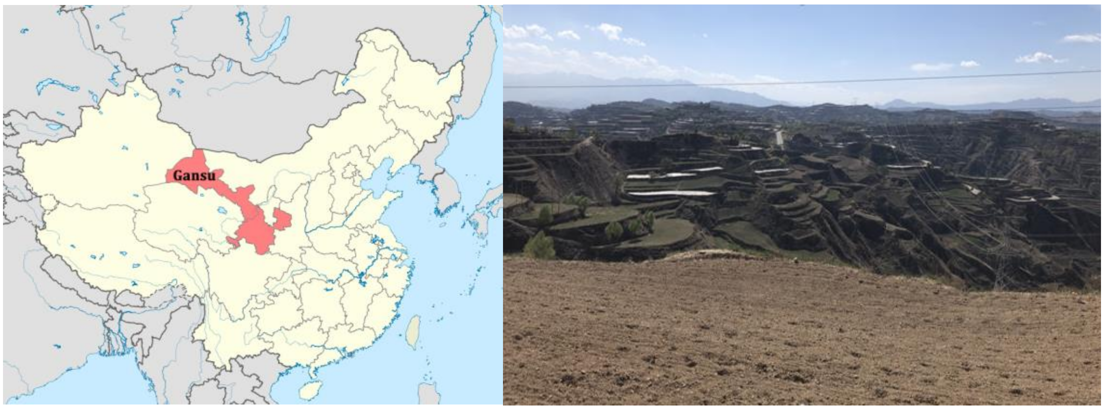

Figure 3. 1 Location and terrace of Gansu

Although introducing SAPs to promote long-term soil fertility and productivity, along with minimizing water use and lowering pollution levels at the farm level, bring profound changes in farm management, the results from adopting SAPs by farms has been limited, despite the extensive research and policy implementation investments (Nolan et al. 2008; Giller et al. 2011; Luo et al. 2016).

On one hand, SAPs are only favorable to certain farmers in certain areas, implying the importance of recognizing the diverse resource endowments and farming systems at the farm and field levels (L. Li et al. 2011; Corbeels et al. 2014). On the other hand, some practices fit better certain farming systems and are approved by farmers, raising the questions regarding which SAPs are more preferred by farmers and how they fit within current farming systems (Luo et al. 2016).

So far, aside from the engineering techniques of check dams and terraces regularly arranged by the government, the success with adopting SAPs, such as fertilizer technologies, alternative rotation of cover crops, conservation tillage (e.g., fallow or minimum tillage), and straw mulching, have mostly depended on farmers' willingness to adopt them, rather than being enforced by the government (Xin

Wen and Zhen 2020b). While extant studies employing farmers' adoption preferences have thus far provided useful information on the determinants of the adoption of various conservation practices, namely demographics (Jones et al. 2013), perception and awareness (Fan et al. 2015), and current practices (Glenk et al. 2014), few studies have focused on planting differences and climatic features, which directly affected farmers' self-sufficiency, agricultural production, and subsequent income (Nolan et al. 2008; Fan et al. 2015). This study thus focuses on the adoption preferences for SAPs by grain and cash crop farmers in the arid and semiarid northwest China.

Aiming to investigate farmers' preferences for the adoption of SAPs within the context of planting structural adjustments, this study first assesses grain and cash crop farmers' perceived importance of potential SAPs; and second, it improves the understanding for the farm and climate characteristics underlying farmers' preferences regarding the adjustment of cropping structures. Our paper intends to enhance the current discussion on farm management and adoption of SAPs, which is essential for agricultural sustainability and food security in arid and semiarid impoverished areas.

3.2 Materials and Methods

3.2.1 Study area

Gansu province (32° 31′-42° 57′ N and 92° 13′-108° 46′ E) lies at the conjunction of Loess Plateau, Qinghai-Tibetan Plateau, and Mongolia Plateau in inland northwestern China (**Figure 3. 2**).

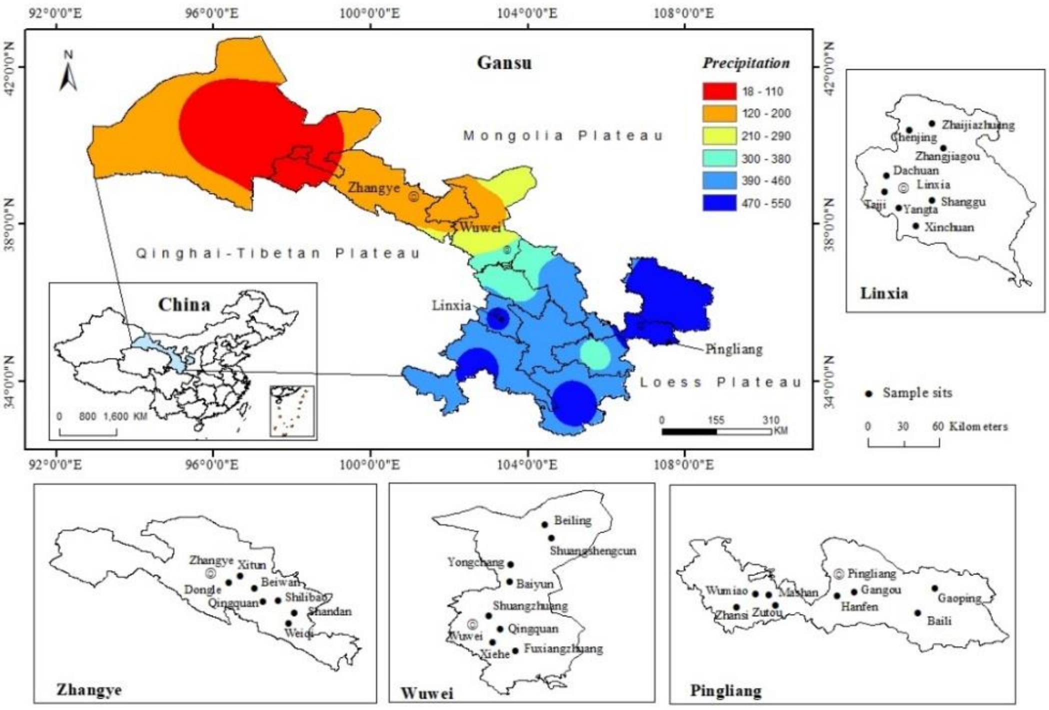

Figure 3. 2 The geographical locations of sample areas: Zhangye, Wuwei, Linxia, and Pingliang.

The topography of Gansu is diverse, including mountains, plateaus, plains, river valleys, desert areas, and the Gobi Desert (Yue et al. 2006). The climate ranges from cold arid, with a mean annual rainfall of 40 mm in the northwest, to a continental monsoon-influenced, semi-arid climate with an annual rainfall of 600 mm in the southeast (Xiaohu Wen, Wu, and Gao 2017).

The four districts of Zhangye, Wuwei, Linxia, and Pingliang were selected to provide an overview of the diverse geographic and climatic characteristics of Gansu. Zhangye and Wuwei are on the northwestern side, with average precipitation of 131 mm and 165 mm per year, while Linxia and Pingliang are on the southeast Gansu, with average precipitation of 492 mm and 532 mm per year, respectively (**Figure 3. 3**). These regions experience hot wet summers when rain falls concentratedly from July to September and long dry winters with little rainfall. A combination of topographical features and water resources deficit lead to limited cultivated land with low soil fertility in terms of the agricultural production in Gansu.

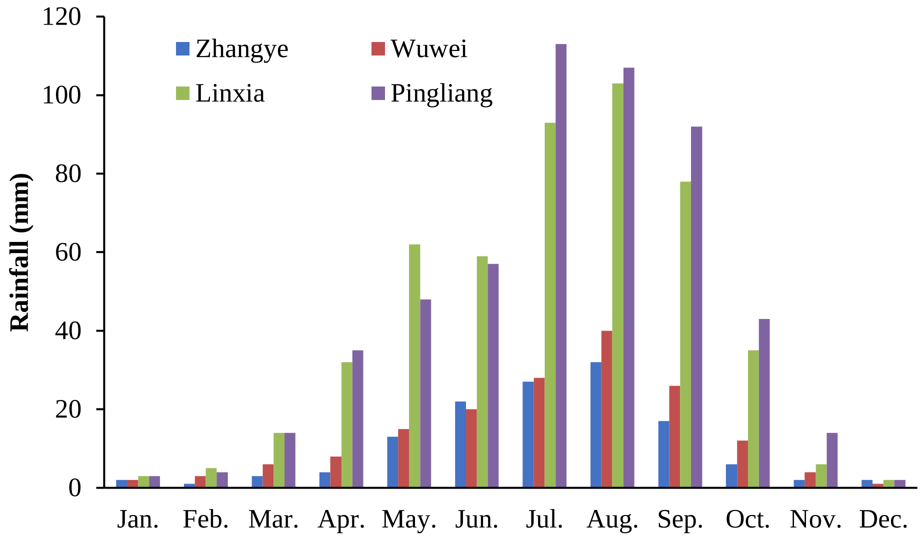

Figure 3. 3 Average monthly rainfall (mm) of the four districts (1982–2012).
Source: Data obtained from the Gansu Meteorological Bureau.

Although having been equipped with basic irrigation systems, the entire regions are still facing severe water shortage problems and crop water requirements can be barely met in northwest Gansu (Yao, Zhao, and Xu 2017). Based on the survey, farmland is irrigated once a year in Zhangye, one to two times in Wuwei, and in the southern districts of Gansu, more times of irrigation can be provided in Linxia and Pingliang.

3.2.2 Data collection

A pre-survey was conducted to determine farmers' understanding of the questions and how long they needed to complete the questionnaire. Based on the preliminary results, we revised the questionnaire and shortened the questions to ensure a higher response rate. We conducted face to face surveys from May to June 2019. Zhangye (seven villages), Wuwei (eight villages), Linxia (eight villages), and Pingliang (eight villages) were selected as sample sites (**Figure 3. 3**). We randomly selected 616 households with 2553 residents from 31 villages for interviews (0.68% of the total population). The final sample size was 554 (89.93% response rate), 38 households refusing to participate and 24 returning incomplete questionnaires. A token incentive payment of USD 2.8 was provided to the participants who agree to take the questionnaire.

All surveys were voluntarily conducted, and respondents were free to refuse the survey without any justification. The household heads or their spouses who are highly involved in the decision making of agricultural production and expenditure were assumed to be the decision-maker in the adoption preferences studies. Among the survey respondents, 385 households cultivated grains crops (wheat and maize) and 169 cash crops (oilseed crops, vegetables, and Chinese herbs). The surveyed sample matched the share of grain and cash crops across the sample district in the study areas. The numbers of grain and cash crop farmers in four sample sites are summarized in **Table 3.1**, showing that Linxia and Piangliang have more cash crop farmers comparing to Zhangye and Wuwei.

Table 3. 1 The summary of cultivated areas and sample sizes

	Share of cultivated area				**Survey samples**	
	Grain	**Oilseed**	**Vegetables**	**Herbs**	**Grain**	**With cash crops**
Zhangye	73.76%	10.59%	6.24%	5.32%	103	37
Wuwei	60.29%	9.77%	17.15%	4.37%	96	28
Linxia	79.97%	8.81%	8.24%	2.50%	108	69
Pingliang	83.51%	9.10%	5.42%	0.92%	58	55

3.2.3 Survey design

A survey questionnaire was designed to obtain the perceived importance of SAPs associated with their likelihood of adoption by using the method of best-worst scaling (BWS). The BWS approach is a preference elicitation technique developed by Finn and Louviere (1992), in which respondents are invited to choose the best (or most preferred) and the worst (or least preferred) items from a series of choice sets (Dumbrell, Kragt, and Gibson 2016). BWS has been shown to better differentiate amongst objects perceived to be of similar importance over alternative rating and direct ranking methods (Glenk et al. 2014) and is widely used in several disciplines, including the agricultural environment (Jones et al. 2013; Glenk et al. 2014; Dumbrell, Kragt, and Gibson 2016), health (Mori and Tsuge 2017), and marketing (Sackett, Shupp, and Tonsor 2013).

The questionnaire surveyed the socio-demographic characteristics of respondents (i.e., age, gender, educational level, family size) and income, sources of income, farm practices, and attitude towards new farming practices or technologies and government policies. We ensured the BWS choice questions in the last section to measure the relative importance each farmer places on the practices. The proposed nine practices were based on literature reviews (L. Li et al. 2011; Xin Wen and Zhen 2020b) and group discussions with experts in agriculture and representative farmers during the pre-survey. To ensure the respondents, have a basic familiarity with the proposed practices, farmers were provided with detailed explanations of each practice in front of the choice questions (**Table 3. 2**).

The practices fall into four categories: (1) Conservation tillage: long-term fallow (1–3 years) and return crop residues to the field are practices for minimizing the frequency or intensity of tillage operations and retaining more cover of crop residues on the soil surface. (2) Reduce chemical input: three practices of using organic fertilizers, biochar, and cut off 50% use of chemical fertilizers are provided for reducing the total amount of chemical fertilizers and pesticides applied, thus help to reduce environmental contamination. Biochar is proposed as a new type of compound fertilizer to improve crop productivity and reduce greenhouse gas emissions. (3) Use of cover crops: three alternatives of cover crops rotation, intercropping, and planting in marginal land were introduced for increasing vegetation cover to protect the soil against raindrops and provide an additional source of organic matters. (4) Agricultural water-saving: applying water-saving measures for sustainable water use. Only the practice of long-term fallow was clarified with 1-3 years adoption period, and the rest of the proposed practices were considered as regular techniques that could be applied in farm work.

Table 3. 2 List of SAPs used in the BWS choice sets.

Description
Conservation tillage:
Long-term fallow (1–3 years) to minimize the frequency or intensity of tillage operations and conserve soil resource (Fallow) (1)
Return crop residues to the field (Return crop residues) (7)
Reduce chemical input
Use organic fertilizers to replace chemical fertilizers (Organic fertilizer) (9)
Apply biochar as a substitute for chemical fertilizers (Biochar) (2)
Cut off 50% use of chemical fertilizers and pesticides (Reduce 50% chemicals) (3)
Use of cover crops
Cover crops rotated with current crops (Cover crop rotation) (4)
Cover crops intercropped with current crops (Cover crop intercropping) (5)
Plant cover crops in marginal farmland (Cover crops in marginal land) (6)
Agricultural water-saving
Improve irrigation practices for sustainable water management (Improve irrigation practices) (8)

Note: The numbers between parentheses refer to **Table 3.4**.

In the "classic" case of BWS, an "object case" was used to identify what SAPs farmers "most" or "least" preferred. Following Louviere et al. (2015) and Dumbrell et al. (2016), we employed a balanced incomplete block design method (BIBD) and obtained 12 choice sets. One choice set contains six practices (**Figure 3. 4**).

Most Prefer	Sustainable Agriculture Practices	Least Prefer
□	Long-term fallow period conserve soil resource (1–3 years)	□
□	Apply biochar as a substitute for chemical fertilizers	□
□	Cover crop rotation	□
□	Return crop residues to the field	□
□	Improve irrigation practices for sustainable water management	□
□	Use organic fertilizers to replace chemical fertilizers	□

Figure 3. 4 Sample of BWS questions.

Table 3.3 depicts the full BIBD experimental design. Farmers were invited to choose the best (or most likely to adopt) and worst (or least likely to adopt) practices in each choice set.

Table 3. 3 Balanced incomplete block design (BIBD).

Choice set no.	Item no.					
1	1	2	5	7	8	9
2	1	3	4	7	8	9
3	2	3	5	6	7	9
4	3	4	5	6	7	8
5	1	2	3	4	6	9
6	1	2	4	5	6	8
7	1	2	3	4	5	7
8	1	2	3	6	7	8
9	2	3	4	5	8	9
10	1	3	5	6	8	9
11	1	4	5	6	7	9
12	2	4	6	7	8	9

3.2.4 Data analysis

The process of choosing the best and worst alternatives is described as discrete choice behaviors, which is consistent with the random utility theory (Louviere, Flynn, and Marley 2015). We assumed that the respondents make errors, but when choosing repeatedly, their choice frequencies indicate how much they value the alternatives under consideration. The pair of attributes chosen by the respondent represents the maximum difference on the underlying, latent scale of the perceived importance of attributes.

In this case, the utility of the difference (U) between the best and worst attributes is comprised of an observable, deterministic component (v) and an unobservable, error component (ε) (Dumbrell, Kragt, and Gibson 2016). The deterministic component (v) can be estimated by the indicator variables of the i attributes and interactions between the i attributes and j independent variables on-farm and climatic characteristics. The interaction effects allow us to understand how farm and climatic characteristics influence farmers' preferences for the proposed SAPs. The equations to be estimated are:

$$\mathrm{U} = v + \varepsilon = \beta_0 + \sum_{i=1}^{9} \beta_i x_i + \varepsilon, \tag{1}$$

$$\mathrm{U} = v + \varepsilon = \beta_0 + \sum_{i=1}^{9} \beta_i x_i + \sum_{\substack{i=1 \\ j=1}}^{9} \beta_j x_i * INT_j + \varepsilon, \tag{2}$$

where v denotes the deterministic component of utility, β_0, β_i, β_j are coefficients, x_i, $i = 1, \dots, 9$ denotes the attributes, INT_j represents the independent variables selected to interact with the attributes, and ε is the random error term.

This study assumed a sequential decision process with best choice being followed by worst choice as proposed by Glenk et al. (2014). Thus, the sequential conditional logit model was selected as it depicts the choice probabilities with each practice as sequence of best-worst choices. Based on these assumptions, using a conditional logit model to estimate the possibility of choosing practice k as the best (most likely to adopt) practice in choice set X is:

$$Prob(k = best) = \frac{exp\ (\beta v_k)}{\sum_{i \in X} exp\ (\beta v_i)}. \tag{3}$$

Respectively, the probability of choosing practice k' as the worst (least likely to adopt) practice among the remaining practices in choice set X is given by:

$$Prob(k' = worst) = \frac{exp\ (-\beta v_{k'})}{\sum_{i' \in X} exp\ (-\beta v_{i'})}. \tag{4}$$

The probability of choosing k as the best and k' as the worst alternatives is expressed as:

$$Prob(k = best \cap k' = worst) = \frac{exp\beta(v_k - v_{k'})}{\sum_{\substack{i,i' \in X \\ i \neq i'}} exp\beta(v_i - v_{i'})}. \tag{5}$$

Each estimated utility (coefficient) is frequently converted into a share of preference based on the forecasted probability of each attribute, which is defined as:

$$Share_k = \frac{e^{\beta_k}}{\sum_{i=1}^{9} e^{\beta_i}}. \tag{6}$$

The shares of importance for the given attributes relative to the attribute ranked as the least important is normalized to zero (Sackett, Shupp, and Tonsor 2013). These shares of preferences are estimated on a ratio scale and their sum equals 1; they thus indicate the relative importance respondents place on the attributes.

3.3 Results

3.3.1 Descriptive statistics

Descriptive statistics for the groups of grain and cash crop farmers are presented in **Table 3.5**. Male Female respondents were 77.23% and 82.18% of the grain and cash crop farmers, respectively. Further, farmers' average ages were 51.82 and 53.88 years, and average education levels 7.88 and 7.65 years, respectively. The agricultural labor inputs were low, namely, 2.30 persons in grain farms and 2.34 persons in cash crop farms. The average farm sizes in both groups were below 1 hectare. The cash crop farmers earned higher incomes for larger farm sizes than grain farmers. More grain farmers (0.35) raised livestock (sheep, goat, cattle, or pig) than cash crop farmers (0.22). On the other hand, the precipitation of cash crop farms (323.14mm) was higher than that of grain farms (264.31mm).

Table 3. 4 Basic information among groups.

	Grain (385)		With cash crops (169)	
	Mean	**Std. dev.**	**Mean**	**Std. dev.**
Gender (male = 0, female = 1)	0.23	0.42	0.18	0.39
Age (years)*	51.82	10.22	53.88	9.77
Education (year)	7.88	3.69	7.65	3.65
Agricultural labor (number of person)	2.30	1.04	2.34	1.13
Farm size (1 mu = 0.0667 hectare)	11.78	11.35	13.20	12.84
Household income (10,000 yuan)*	5.14	3.90	5.90	5.03
Livestock (yes = 1, no = 0)*	0.35	0.48	0.22	0.41
Precipitation (mm)**	264.31	144.36	323.14	133.42

Note: * and ** indicate statistically significant differences at $P < 0.05$ and $P < 0.01$.

According to the provincial census data, the sown area of grain crops decreased from 73.06% to 70.79%, of which the wheat sown area decreased from 23.76% to 20.50% of the total arable land shown in the (**Table 3. 5**). On the contrary, as shown in **Figure 3. 6**, the cash crops of vegetables increased from 6.46% to 9.01%, and traditional Chinese herbs increased from on 4.09% to 6.06% from 2010 to 2017 (Gansu Provincial Bureau of Statistics 2019).

Table 3. 5 The share of sown area of main crops in Gansu

Item	**2010**	**2015**	**2016**	**2017**
Sown Area of Grain Crops	73.06	71.99	71.50	70.79
➢ Cereal	52.41	53.84	53.35	52.25
● Rice	0.15	0.11	0.11	0.11
● Wheat	23.76	21.38	20.63	20.50
● Corn	22.92	28.23	28.15	27.84
➢ Soybeans	4.63	3.37	3.39	3.42
● Soja	2.12	1.62	1.71	1.72
➢ Tubers	16.02	14.77	14.76	15.12
Oil-bearing Crops (Peanuts, rapeseeds)	9.57	9.10	9.55	9.27
Cotton	1.36	0.77	0.41	0.52
Tobacco (Flue-cured Tobacco Materials)	0.09	0.06	0.05	0.04
Vegetables	6.46	8.33	8.62	9.01
Melon	1.30	1.15	1.18	1.36
Traditional Chinese Medicine	4.09	5.51	5.82	6.06
Others	3.94	3.01	2.79	2.83

Sources: Gansu Statistical Yearbook (2018)

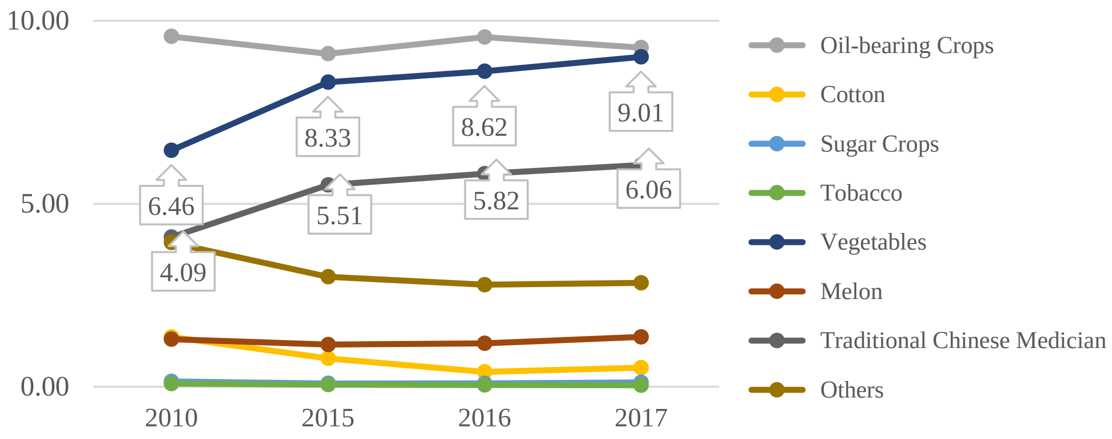

Figure 3. 5 Shares of the sown area of cash crops in Gansu (%)

Sources: Gansu Statistical Yearbook (2018)

The main sown crops are presented in **Figure 3. 7**, 35.71% and 30.95% of farmers have planted maize and wheat, respectively. In recent years, the share of potato cultivation also has increased, and of the sample, 13.76% of farmers have planted potato. The share of sown crops for traditional Chinese herbals and medicine is 12.96%.

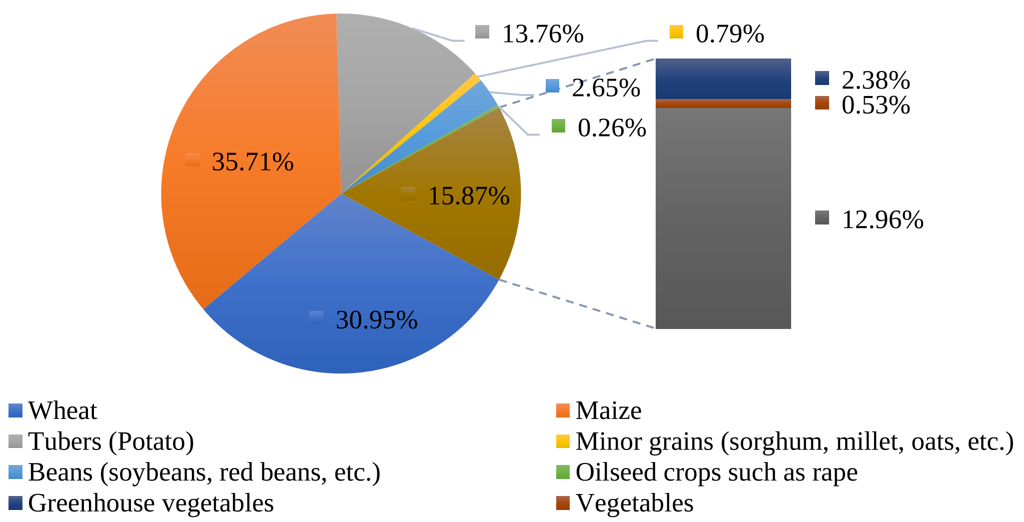

Figure 3. 6 The main sown crops in the sampled area

As is shown in **Figure 3. 8**, 26% of the farmers have adopted any SAP. There are 36% of the respondents indicated that they have been rotating the main crop varieties in the past five years.

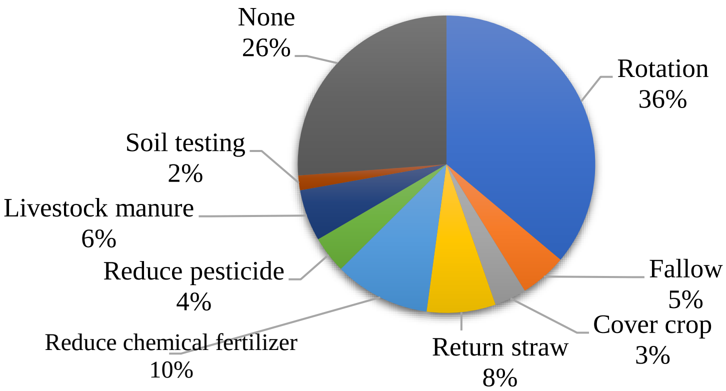

Figure 3. 7 The status of SAPs adoption in the sampled area

And the major cropping systems of rotation include wheat-maize rotation (59%) and maize-potato rotation (12%) (shown in **Figure 3. 8**). The practices of reducing chemical fertilizer and pesticide shared 10% and 4%. Surprisingly, only 3% of the farmers have adopted the cover crops and 8% of returning straw to the filed. Same as the provincial data, the main sown crops in the sampled area are wheat (30.95%) and maize (35.71%), potato (13.76%).

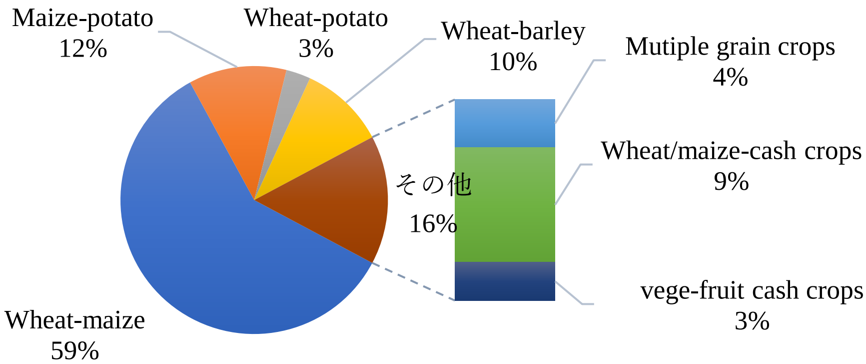

Figure 3. 8 The main rotation cropping systems

3.3.2 Relative importance of SAPs

Conditional logit estimations based on Eqs. (1), (5), and (6) were performed using R software (version 3.2.3, R Core, 2015). The results are shown in **Table 3.6**. The coefficients were converted into preference shares on a ratio scale to provide more intuitive details on the relative importance of attributes for grain and cash crop farmers.

Table 3. 6 Relative importance of SAPs among groups.

Practices	Grain			With cash crops		
	Coef.	**Std. error**	**Share**	**Coef.**	**Std. error**	**Share**
Organic fertilizer	2.391***	0.047	26.7%	2.138***	0.070	26.2%
Improve irrigation practices	2.206***	0.047	22.2%	1.776***	0.070	18.2%
Cover crop rotation	1.567***	0.463	11.7%	1.520***	0.070	14.1%
Cover crop intercropping	1.501***	0.462	11.0%	1.505***	0.070	13.9%
Cover crops in marginal land	1.236***	0.046	8.4%	1.062***	0.068	8.9%
Biochar	1.053***	0.045	7.1%	0.679***	0.066	6.1%
50% Reduce chemicals	0.852***	0.044	5.7%	0.508***	0.065	5.1%
Return crop residues	0.676***	0.043	4.8%	0.367***	0.064	4.5%
Fallow	fixed	-	2.4%	fixed	-	3.1%

Note: *** indicates significance at the 0.001 level.

The results indicate that using more organic fertilizers to replace chemical fertilizers was the most preferred practice, with the highest shares of 26.7% and 26.2% for grain and cash crop farmers, respectively. The next highest share was improving irrigation practices, with the preference share being higher for grain farmers (22.2%) than cash crop farmers (18.2%). Three practices related to cover crop applications ranked next in the relative importance of preference. It is worth noting that cash crop farmers placed higher importance on cover crop rotation (14.1%) and intercropping (13.9%) than grain farmers, indicating stronger preferences for applications associated with cover crops by cash crop farmers.

Compared with the highest preference share of using organic fertilizers, cover crop-related practices perceived approximately half the importance of using organic fertilizers. This result indicates that, despite the roles of legume and non-legume cover crops in reducing soil erosion, conserving soil moisture, and fixing atmospheric nitrogen, the adoption of these practices is still hindered by concerns over high seed cost and extra-economic constraints (Blackshaw, Molnar, and Moyer 2010). Overall, the practice of long-term fallow was the least likely to be adopted, with proportions of 2.4% and 3.1% for grain and cash crop farmers, respectively. Additionally, the practice of returning crop residues to the field was selected as the second least likely to be adopted by both grain (4.8%) and cash crop (4.5%) farmers.

3.3.3 *Adoption preferences of SAPs with interaction effects*

For a better understanding of how the farm and climatic characteristics influence the decision-making related to SAPs, multiple models were run to analyze adoption preferences with interaction effects based on Eqs. (2)–(5). The results in **Table 3.7** indicate the adoption preferences of SAPs in relation to household income, livestock status, and precipitation.

The household income indicates farmers' financial situation to improve farming practices. As one major source of income, livestock can utilize leguminous cover crops as forage and produce organic manure (W.-S. Zhang et al. 2012). The climatic feature of precipitation is critical not only because it effects the growth of crops and vegetation cover but also because it determines water content and water-holding capacity of the soil for crop residues treatments (Shuqin and Fang 2018). Therefore, these three variables had been selected to interact with the nine SAPs for grain and cash crop farmers. Taking into consideration of these research objectives, using the conditional logit model to estimate the interaction effects was better than the latent class model in illustrating the impact of selected variables on the adoption preferences in this study. Both models fit the data well based on the McFadden's pseudo R2 measures (Sackett, Shupp, and Tonsor 2013). All parameter estimates are relative to the reference item, where positive coefficient values indicate farmers are more likely to adopt a practice and negative values suggest the practice is less likely to be adopted compared with fallow.

When considering interaction effects, grain farmers were more likely to improve irrigation practices, use more organic fertilizers or biochar to replace chemical fertilizers, resort to cover crop rotation and intercropping and reduce by 50% the use of chemicals inputs. Further, there were no significant differences in planting cover crops in marginal land. Grain farmers were also less likely to return crop residues to the field. Household incomes, livestock, and precipitation interacted significantly with some practices, especially those related to household income and livestock. Farmers with higher household incomes were more likely to adopt cover crop rotation and return crop residues to the field, as these are practices that require extra costs, such as seeds and machinery costs. Grain farmers with livestock were more likely to replace chemical fertilizers with organic ones, improve irrigation practices, and reduce by 50% the use of chemical fertilizers and pesticides, but less likely to adopt cover crop intercropping. When precipitation increases, grain farmers were more likely to adopt cover crop-related practices and use more organic fertilizers.

Table 3. 7 Conditional logit model estimates for the interaction effects

	Grain		With cash crops	
Practice	**Coef.**	**Std. error**	**Coef.**	**Std. error**
Organic fertilizers	1.787***	0.284	1.337***	0.449
Improve irrigation practices	2.395***	0.324	0.859	0.524
Cover crop rotation	0.670***	0.226	-0.124	0.370
Cover crop intercropping	0.746***	0.206	0.221	0.337
Cover crops in marginal land	0.210	0.246	0.338	0.404
Biochar	0.900***	0.155	0.313	0.293
Reduce 50% chemicals	0.355*	0.197	-2.07***	0.351
Return crop residues	-0.428*	0.255	0.249	0.400
Interaction effects				
Organic fertilizers × Household income	-0.038**	0.018	0.090***	0.023
Improve irrigation practices × Household income	0.022	0.027	0.141***	0.023
Cover crop rotation × Household income	0.062***	0.017	0.110***	0.021
Cover crops in marginal land × Household income	-0.020	0.018	0.081***	0.020
Reduce 50% chemicals × Household income	-0.011	0.017	0.127***	0.019
Return crop residues × Household income	0.054***	0.020	0.131***	0.021
Organic fertilizers × livestock	0.337**	0.170	0.421	0.285
Improve irrigation practices × livestock	0.905***	0.192	-0.321	0.265
Cover crop rotation× livestock	-0.045	0.162	0.830***	0.240
Cover crop intercropping × livestock	-0.267*	0.155	0.577*	0.239
Reduce 50% chemicals × livestock	0.387***	0.140	1.153***	0.255
Organic fertilizers × Precipitation	0.002***	0.001	0.001	0.001
Cover crop rotation × Precipitation	0.002***	0.001	0.001	0.001
Cover crop intercropping × Precipitation	0.003***	0.000	0.003***	0.001
Cover crops in marginal land × Precipitation	0.002***	0.001	0.002***	0.001
Reduce 50% chemicals × Precipitation	0.000	0.000	0.002***	0.001
Log-likelihood	-9938.1		-4207.1	
Observations	4620		2028	
McFadden’s pseudo R^2	0.435		0.379	

Note: *, **, and *** indicate significance at the 0.05, 0.01, and 0.001 levels, respectively.

Cash crop farmers were more likely to use more organic fertilizers instead of chemical ones and less likely to reduce by 50% the use of chemical fertilizers and pesticides. Household income had significant positive effects on using organic fertilizers, cover crop rotation and intercropping, and planting cover crops in marginal land. Like the estimations for grain farmers, cash crop farmers with higher household incomes were also more likely to return crop residues to the field. Conversely, cash crop farmers with livestock tended to adopt cover crops related practices. As grain farmers, cash crop farmers with livestock were also more likely to reduce by 50% the use of chemical fertilizers and pesticides. Higher precipitation had a positive effect on cover crop intercropping and reducing by 50% the use of chemical fertilizers and pesticides.

Overall, farmers were more open to organic fertilizers and responded positively to water deficit problems, such as by improving irrigation practices and increasing the vegetation cover. The significant coefficients of the interactions between household income and precipitation with the SAPs indicate that financial and climatic considerations were considered in the decision making for SAPs. As an income source, livestock was also considered important to organic manure production, which can provide a substitute for chemical fertilizers.

3.3.4 Factor analysis of BWS data

Table 3.8 shows the results obtained using principal component factor analysis with varimax rotation and Kaiser Normalization to clarify a small number of common factors that account for the variation in adoption preferences for different practices. Four factors had been identified that together explain 65.97% of the variance in adoption preferences for SAPs. Attributes in each independent dimension with the highest positive and negative factor loadings imply the utility drivers are influencing farmers' adoption preferences. The first factor explains 21.04% of the variance. Because of the high cross-correlation coefficients of 0.749, 0.691, and 0.640 in cover crop practices, we called this factor as "Prefer cover crop". The second factor counting for 17.92% of the variances is labeled as "Maintaining farm work". The highest negative cross-correlation coefficient of -0.800 in "Fallow" shows that farmers in this utility dimension strongly oppose fallow.

Table 3. 8 Principal component analysis of SAPs

Utility factors	**1**	**2**	**3**	**4**
Percentage	21.04%	17.92%	14.75%	12.26%
Factor name	Prefer cover crop	Maintaining farm work	Fertilization	Reduce inputs
Cover crop rotation	**0.749**	-0.269	-0.112	-0.097
Cover crop intercropping	**0.691**	-0.077	0.227	0.047
Cover crops in marginal land	**0.64**	0.293	0.178	0.285
Fallow	-0.248	-0.8	-0.307	-0.329
Return crop residues	-0.003	**0.673**	-0.288	-0.377
Organic fertilizer	-0.316	0.219	**0.62**	-0.062
Biochar	-0.336	0.074	**0.577**	-0.242
Improve irrigation practices	-0.263	**0.473**	-0.575	0.291
50% reduce chemicals	-0.319	-0.283	0.081	**0.783**

During the survey, many farmers expressed that only if there is an adequate amount of water, straw can be decomposed in the field. It explains high loadings of 0.673 and 0.473 in both "Return crop residues" and "Improve irrigation practices". The third utility factor is characterized as "Fertilization" for the high loading scores on the usages of organic fertilizer and biochar, which is considered as the substitutions for chemical fertilizers. Meanwhile, the negative loading on "Improve irrigation facility" shows that farmers prefer seeking substitutions of chemical fertilizer than improving irrigation facility in this utility dimension. The last essential attribute loading of the fourth factor is the certificate for a 50% reduction of inputs in chemical fertilizers and pesticides. Also, the high importance of grass mulch to bare soil indicates another way to improve soil fertility without using more fertilizer.

3.3.5 Latent class analysis of BWS data

The factor analysis identifies four different utility dimensions of adoption preference for SAPs. To identify the segments of smallholder farmers based on four utility factors within an individual level, we take a Latent Class (LC) approach employing the software Latent Gold 4.5 (Statistical Innovation Inc., Belmont, MA, USA). A three-clusters solution was selected from LC cluster analysis for its lowest BIC value (6156.7402) comparing from one to five clusters as reported in **Table 3.9**.

Table 3. 9 Criteria for selecting the optimal number of cluster

	LL	BIC(LL)	AIC(LL)	AIC3(LL)	CAIC(LL)	Npar	Class.Err.
1-Cluster	-1609.6152	6335.2693	6300.732	6308.732	6343.2693	8	0
2-Cluster	-1362.3492	6170.3692	6096.9774	6113.9774	6187.3692	17	0.0746
3-Cluster	-2996.247	**6156.7402**	6044.494	6070.494	**6182.7402**	26	0.1027
4-Cluster	-2969.6179	6160.3365	6009.2358	6044.2358	6195.3365	35	0.1344
5-Cluster	-2949.459	6176.8732	5986.918	6030.918	6220.8732	44	0.1493

A detail description of three clusters including specific proportions and estimates of indicators is shown in **Table 3.10**. The first row presents the cluster size, also known as the probabilities of respondents, belong to each cluster. The first cluster counts for 63.59% of the total sample, and the other two clusters occupied the remainder (36.41%) of the sample. The ANOVA test indicates that there is a significant difference across the classes.

Table 3. 10 Means of utility factor scores for three-Clusters solution

	Cluster1	Cluster2	Cluster3		
Cluster size	**63.59%**	**24.92%**	**11.50%**	**Wald**	**p-value**
Prefer cover crops	0.12	-0.48	0.38	52.54	0.00
Maintaining farm work	-0.47	0.66	1.20	335.66	0.00
Fertilization	-0.03	0.42	-0.73	64.48	0.00
Reduce inputs	0.14	-0.37	0.01	29.45	0.00
Covariates					
Age	52.00	52.97	53.50	0.89	0.41
Gender	0.20[ab]	0.28[a]	0.15[b]	2.87	0.06
Education	1.79	1.67	1.62	3.21	0.14
Labor	0.25[a]	0.20[a]	0.42	1.11	0.00
Area	0.25[a]	0.22[ab]	0.11[b]	0.03	0.04
Income	2.47	2.54	2.38	0.39	0.33
Off farm	0.28[a]	0.18[b]	0.24[ab]	6.34	0.04
Livestock	0.31	0.31	0.32	3.37	0.98
Precipitation	290.46[a]	253.00	308.98[a]	4.95	0.01

Note: Means within a row with the same superscript letters are not statistically different (α = 0.05, post-hoc Tukey test). Means in rows with no superscript are not statistically different across clusters.

Table 3.10 shows the cluster differences of individual factor loading scores. Farmers' choices of the Cluster 1 are mainly affected by the high loading on the utility factors of "Prefer cover crop" and "reduce inputs" and the lowest loading on "Maintaining farm work". Low loadings on the utility factors of "prefer cover crop" and "reduce inputs" shown the Cluster 2 indicate that these two factors linked to the presented policies are least valued for the respondents in Cluster 2. On the contrary, the "Maintaining farm work" factor loads a medium value compared with Cluster 1 and 3. Farmers in cluster 2 held a neutral opinion towards farm work and prefer traditional fertilizer substitutions, such as organic fertilizer. The last Cluster was characterized by the highest loading on the "Ensure farm work". Opposite to Cluster 2, respondents in Cluster 3 prefer cover crop more than the third factor of "fertilization". We conducted the ex-post analysis and characterize farmers in these three clusters by sociodemographic variables as well as by farm characteristics. Statistically significant covariates include the gender of respondents, number of labor forces, size of the farm, percentage of off-farm income, and annual status of precipitation.

A quick oriented in farmers of Cluster 1 are relatively fewer labor forces, larger farm size, a higher percentage of off-farm income, and annual precipitation. This is consistent with our assumption that the farmers who have high off-farm income share are easier to transit. Farmers in this cluster consider 50% reduce inputs of chemical fertilizer and pesticide by applying cover crop rather than seeking substitutions like biochar. Again, it is easy to understand that for the farmers whose off-farm income share is getting higher, they are more likely to reduce inputs in farming. Cluster 2 has a higher share of female farmers, fewer labor force, and the lowest annual precipitation. The lowest labor force level also shows that when lack of labor, farmers are not intend to apply new practices that require some extra labor inputs. The lowest precipitation level again explained the lowest utility level of cover crop. For farmers in Cluster 2 with a lower share of off-farm income, they value agricultural production more and preferred practices related to ensuring farm work. Farmers in Cluster 3 prefer cover crop more than Cluster 1 and 2. They are more likely to be male, have higher labor input, smaller farm size and the annual precipitation is higher.

3.4 Discussion

For identifying reasonable measures to mitigate soil degradation and maintain agricultural sustainability in the arid and semi-arid areas in northwest China, this study used the BWS approach to explore the adoption preferences for SAPs and how farm and climatic characteristics affect decision making. Farmers were shown to prefer using organic fertilizers to replace chemical fertilizers other than planting cover crops, returning crop residues to the field, and applying new fertilizers such as biochar. One key measure of the "Achieving zero growth in the use of chemical fertilizer and pesticides by 2020" policy launched by the Ministry of Agriculture in China (MOA) is, reducing by 50% the use of chemical fertilizers and using organic fertilizers instead for cash crops, which has been promoted in the northwest ecological fragile district of Gansu since 2015 (Shuqin and Fang 2018). Many farmers are familiar with this practice and recognize its benefits.

However, compared with the cost of recycling straw and stubble to produce organic compost, organic fertilizers were proved to reduce costs and fertilizer inputs for the dryland farming of wheat and corn (H. Xu et al. 2014). Particularly, due to dryland soil moisture deficits, straw treatments, such as chopping and smashing, are required for the decomposition of straw, thus adding machinery costs and labor inputs (Dumbrell, Kragt, and Gibson 2016). The interaction effects further indicated that households with higher income preferred to return crop residues to the field. Therefore, a low-income level and extra processing expenditures could pose constraints for crop residues being returned to the field in impoverished and semiarid regions in China.

Based on our results, although grain and cash crop farmers were most likely to adopt organic fertilizers, there is less agreement over reducing by 50% the use of chemical fertilizers and pesticides by cash crop farmers. This is in line with Nolan et al. (2008) and Fan et al. (2015), in that in many lower-income districts and countries, the profits from cash crops of vegetables, oilseed, and fruits commonly make up more than 50% of the household income, while also playing an important role in increasing annual income by over 30%. Therefore, the pursuit of production and high income impedes farmers from reducing chemical inputs, particularly cash crop farmers, who generally use more chemical fertilizers and pesticides. Based on **Table 3.7**, grain farmers were more supportive to reducing by 50% the use of chemicals.

Grain farmers stated a stronger preference for improving irrigation practices than cash crop farmers. Indeed, many grain farmers struggle with water deficit problems for self-sufficient and agricultural production. This result was amplified by the positive effects of precipitation in the interaction analysis. The interaction effects indicated that, along with favoring irrigation practices, cash crop farmers with higher household incomes also prefer cover crop rotation and intercropping. Data from the survey showed that cash crops account for 15% to 25% of the cultivated areas and commonly include legumes such as field pea (*Pisum sativum L.*) and lucerne (*Medicago sativa L.*), and oilseed crops such as linseed (*Linum usitatissimum L.*) and rapeseed (*Brassica napus L.*), which are also considered as cover crops. Therefore, as the current users and adopters of cover crops, cash crop farmers preferred to continue these practices. From a survey of Scottish dairy farmers, Glenk et al. (2014) also found that current adoption has a significant positive impact on the probability to choose a practice as "best." Additionally, cover crop rotation had a higher preference share than intercropping with cover crops. This could be explained by the concerns over water deficits and the probability of soil water depletion that can negatively affect crop yields when intercropped with cover crops.

It is worth noting that the results of the interaction effects between cover crops with livestock contradicted our expectation that planting cover crops would provide forage for livestock, thus being favorable to farmers. However, because only less than 10% of the cultivated land being devoted to legumes and cover crops for forage, the above-ground biomass of dryland tolerant legume or non-legume cover crops could not meet the demand of forage (W.-S. Zhang et al. 2012). Furthermore, instead of using cover crops as forage, crop residues, and by-products, such as corn straws, were the primary sources of forage for livestock. Therefore, livestock did not interact with cover crop-related practices for grain farmers. This inference is also supported by the low preference share of returning crop residues (4.8%) to the field. However, livestock had significant positive effects on reducing by 50% the use of chemical fertilizers and pesticides for both grain and cash crop farmers. The organic manure produced by livestock has been considered an important substitute for chemical fertilizers.

This study provides novel insights into comprehensive policy design for SAPs in the arid and semiarid northwest areas of China. China has had a long history of policies designed to guide the agricultural sector for improving the rural environment and boosting the productive capacity and agricultural income. However, large-scale attempts to restore degraded and vulnerable farmland need to consider the local environment, particularly in impoverished regions with water-use deficits (Luo et al. 2016). Otherwise, the same conservation project with the same level of standard compensation throughout the study areas would lead to lower participation and slower progress in the promotion of the conservation programs (S. Cao et al. 2010).

The comparisons of climatic and farm characteristics between four study sites indicate that Linxia and Pingliang obtain more precipitation and have more cash crop farmers than Zhangye and Wuwei. Taking into consideration the district differences, practices relating to organic fertilizer and cover crops might be plausible suggestions to the cash crop farmers in the semiarid areas with a certain level of rainfall. Furthermore, maize is often grown in crop-livestock farming systems in northwest China (Soon and Lupwayi 2012), so integrating maize rotated with leguminous cover crops into the system could be favorable and beneficial for farmers, as both maize straw and leguminous forages can be fed to livestock and converted back to the soil as organic manure.

One critical consideration in this study is to address the awareness of the perceived importance of different SAPs by farmers and the need for diverse SAPs at the farm level. The interactions findings revealed that, in addition to economic conditions, the cropping differences and climatic features influenced decision making in terms of adoption preferences. Therefore, diversifying SAP combinations by considering diverse cropping and geographic factors would be beneficial for soil conservation management and wide application (Jones et al. 2013; Xiaohu Wen, Wu, and Gao 2017). For example, organic fertilizers and cover crops should be specifically targeted to cash crop farmers, based on the positive correlations of cover crops and livestock in the interaction analysis. The practices challenged by extra-economic input more likely to have more limited adoption and therefore required greater interventions including incentive payment or technical advices and support.

The price subsidy mechanism has been proved to be a necessary and effective technical support to stimulate farm households to apply SAPs in the resource-poor northwest China (Xin Wen and Zhen 2020b; Fan et al. 2015; Shuqin and Fang 2018). The incentive levels varied greatly in different regions with practices of crop rotation, managed fallow, and green manure cover crops planting. The government provides a payment of 1091 yuan per hectare to farmers who convert arable lands into forests or permanent pastures on sloped cultivated land in the upper reaches of the Yellow River basins (Xin Wen and Zhen 2020b). Consistent with former research (Luo et al. 2016), this study further amplified cost as an important factor influencing farmers' acceptance of the SAPs. Therefore, high compensation could be required for the implementation of long-term fallow and return crop residues to the field. In contrast, relatively low incentive payments to the use of organic fertilizers and water-saving practices could be accepted by the farmers in arid and semiarid regions.

3.5 Summary

This study provides useful implications for farmers in the arid and semiarid areas of northwest China in terms of SAPs and considering cropping differences and climatic conditions. The results show that balancing crop yield and sustainable development influence farmers' decision making. Grain farms within lower precipitation level areas favored replacing chemicals with organic fertilizers and the improvement of irrigation practices. In addition to these two practices, cash crop farmers also selected cover crop-related practices, which require a certain level of rainfall. The different perceived importance of these practices suggests new combinations or packages for soil conservation programs during the adjustment of the cropping structure in Gansu. As such, using BWS and considering social-economic and climatic characteristics in identifying the types of farming systems and numbers of conservation practices can help in the early stages of policy design and for determining the adequate levels of economic incentives.

Based on the current findings, some policy implications are suggested. Firstly, a technical cost reduction for replacing chemical fertilizers with organic fertilizers and water-saving practices by government subsidies would be efficient to improve the likelihood of adoption. Secondly, incentive programs should focus on the adoption period of the cover crops. Thirdly, rotation or intercropping is an alternate method for the promotion of cover crops in the intensive farming areas. Nevertheless, for districts like Zhangye and Wuwei with extremely limited water resources, the evaluation of trade-off decisions between traditional and sustainable agricultural practices by farmers is indispensable to the implementation of the SAPs.

This study selected geographically separated areas with different precipitation, which enables us to compare the responses for different social-economic and agroclimatic conditions. However, there is no guarantee that a practice perceived as most likely to be adopted will indeed lead to its future application due to the wider range of constraints and obstacles, such as unpredictable climatic changes and natural disaster risk, which can result in production and income fluctuation. Hence, an in-depth investigation of cropping systems with detailed agricultural inputs and geoclimatic factors with a larger sample size may improve evaluation. To strengthen and extend the range of the study, the adoption constraints of risk perception and attitude and spatial heterogeneity of different geo-climatic sites could be considered in future research

CHAPTER 4
ADOPTION OF DIVERSIFYING FARMING WITH COVER CROPS IN NORTHWESTERN CHINA

Chapter 3 presented how grain crop farmers and cash crop farmers preferred different SAPs and identified the farming resources and climatic features as important determinants of choices. Given the adoption of specific practice involves detail implementing procedures and supplementing requirements, one might expect to find empirical evidence on which requirements or attributes to draw for the practice adoption. To the end, this chapter undertakes an empirical investigation of decisions on the designed package for the cover crop adoption. The purpose of this chapter is to find empirical evidence on the influence of the practice implementation procedures on farmers' decision-making by introducing dynamic farm portfolio choices for farmers.

4.1 Introduction

Increasing production through intensive farming and monoculture involves excessive use of agrochemicals (e.g., synthetic fertilizers and pesticides) and leads to loss of diversity and resilience of the agroecosystem (Alcon et al. 2020). In the arid and semiarid regions of northwest China, resource-poor smallholder farmers manage the risk-prone steep slope lands. The intensive cropping system in this region and removal of vegetation cover have accelerated soil degradation, leading to a decline in agricultural productivity (X. Li et al. 2016). This has necessitated the enhancement of vegetation cover for conserving soil quality, mitigating drought stress (Kaspar and Singer 2015; Schaafsma, Ferrini, and Turner 2019), and shifting the current farming system toward sustainable agricultural intensification (Gan et al. 2015; Rosa-Schleich et al. 2019).

The National Agricultural Modernization Plan (2015-2030) (Ministry of Agriculture and Rural Affair of the People's Republic of China 2015) and the Guiding Opinions on Promoting Sustainable Development of Agriculture in Arid Northwest China (Ministry of Agriculture and Rural Affair of the People's Republic of China 2017a) highlighted the use of cover crops, especially of leguminous species, within sustainable farm management (SFM) to tackle the reducing plant cover and decreasing productive capacity of land. Considered a kind of living mulch, cover crops can be either harvested as fodder for livestock or plowed into the soil as green manure. They offer an alternative in diversifying farming during the fallow period (Fengrui Li, Zhao, and G. T 2000) by rotating (Gan et al. 2015; K. Liu et al. 2020) or intercropping with grain crops or cash crops (Alcon et al. 2020; Y. Hong, Heerink, et al. 2019). This maintains yield benefits in the long run and ensures ecological security in northwest China. Additionally, diversifying farming with cover crops is an important component of the Sustainable Development Goals of food security (SDG-2) and climate resilience (SDG-13) (Schaafsma, Ferrini, and Turner 2019).

However, the use of cover crops must take into account site-specific conditions and farmers' decisions regarding changing or adjusting the cropping systems (Rosa-Schleich et al. 2019; Zeng et al. 2016). For example, in the Hexi arid oasis region of northwest China, the conventional monoculture of maize (*Zea mays* L.) and wheat (*Triticum aestivum* L.) and wheat–maize strip intercropping have been in practice for decades (W. Yin et al. 2018). The climatic conditions in this region allow only one-season cropping patterns annually. Moreover, the use and adoption of cover crops might influence agricultural production and household income (Bergtold et al. 2019; Fuduo Li et al. 2020a); hence, the process of identifying suitable cropping patterns of cover crops must consider farmers' preferences. The more agriculturally intensive region of the west part of the Loess Plateau largely employs the double-cropping (two crops per year) system. The primary crops are winter wheat followed by maize or soybean [*Glycine max* (L.) Merr.], or cash crops of oilseed crops or herbs (Zeng et al. 2016). When cover crops are used in this environment, besides the technical aspects of species selection and termination timing, the opportunity costs of money and labor input as well as the effects on production act as barriers in the use of cover crops (Fengrui Li, Zhao, and G. T 2000; K. Liu et al. 2020).

The upfront input costs and additional management expenditure hinder the adoption of cover crops (Roesch-McNally et al. 2018). Hence, economic incentives are necessary to promote cover crops so as to compensate farmers for the additional production costs. Previous works have analyzed farmers' willingness-to-accept (WTA) compensation for adopting cover crops as either green manure for paddy fields or for soil cover during the fallow period in regions with highly degraded soil in China. The compensation levels vary from 3323 CNY/ha/year for cover crop rotation in southern paddy fields (Li et al., 2020) to 10500 CNY/ha/year for cover crop fallow in heavy metal-contaminated farmland (Yu et al., 2019) and 11400 CNY/ha/year for SFM regarding watershed ecosystem conservation in the northern regions of Beijing (Feng et al. 2018). Compared to the WTA estimation studies of different countries and regions, analyses of China's context focus primarily on the payment level, and rarely discuss other compensation measures, mostly because the simplified standard is convenient for government implementation (Yu et al., 2019). Most of the agri-environmental programs were under the strict government command-and-control with little regard for farmers' detailed needs and wishes (Li et al., 2020; Luo et al., 2016). However, the wide range of compensation levels highlights the necessity of examining the non-monetary factors that affect farmers' decision-making and the compensation schemes (Schaafsma et al., 2019; Yu et al., 2019). In developed countries like Germany, the United States and other western countries, other schemes besides income subsidy, were found to significantly influence farmers' responses to the proposed programs. These included alternative compensation schemes for the conservation requirement of growing leguminous crops on the Ecological Focus Area (EFA) (Schulz, Breustedt, and Latacz-Lohmann 2014), flexibility in contract conditions (Greiner 2016; Duke et al. 2012) and short contract duration in Denmark (Christensen et al. 2011; Schulz, Breustedt, and Latacz-Lohmann 2014). For developing countries and regions with more smallholder farmers such as those in China and sub-Saharan Africa, the compensation policies need modifications such as the inclusion of flexible cropping patterns (Luo et al. 2016; Schaafsma, Ferrini, and Turner 2019) and extra technical support when learning from other countries (Yu et al., 2019).

Although there have been many WTA studies conducted in southern and northest China, few studies focus on the ecologically fragile arid and semiarid regions of northwest China. In these regions where water is the limiting factor and the short-term effects of cover crops used as green manure on yield are often negative (Alcon et al. 2020), the potential decreased soil water for co-planting and following cash crop may be a cost of adoption (Bergtold et al. 2019). Intercropping and rotation provide alternatives for these areas to better adjust farming systems toward sustainable production (Alcon et al. 2020; Y. Hong, Heerink, et al. 2019). Therefore, choosing a cropping pattern implies opportunity costs perceived by farmers and further trade-offs between environmental and economic benefits (Rosa-Schleich et al. 2019). There is a dearth of studies that identify farmers' adoption preferences for cropping patterns of cover crops among different agriculturally intensive cropping systems regarding farming diversification for sustainable development. Research on this issue is conducive to understanding farmers' decision-making in adjusting the production structure and reducing China's overwhelming budget burden of high compensations (Gale 2013; OECD 2020), and the results will be applicable to other countries that facing similar challenges.

Considering farmers' differentiated choices for cropping patterns of the cover crop within different agriculturally intensive cropping systems have not been clarified, this study aimed to analyze smallholder farmers' adoption preferences of diversifying with cover crops regarding SFM and examined whether adoption decisions differed among cropping systems. A discrete choice experiment (DCE) was carried out in the Hexi Corridor and the west Loess Plateau in northwest China. The DCE survey was designed to elicit farmers' preferences for cropping patterns of cover crops, duration of adoption, and technical guidance to reduce agrochemicals, supported with different incentive levels. Empirical analysis was conducted to identify the factors that affected farmers' decisions, and the differences between the two regions were compared. The results of the perceived marginal cost of the non-monetary factors at the farm household level provide important site-specific policy implications to promote diversification in cropping systems with cover crops in northwest China. To the best of our knowledge, this study is the first to employ the DCE approach to analyze farmers adoption decisions on how to use cover crops to adjust production structure toward sustainable farming under the premise of incentive payments in the ecologically fragile regions of northwest China. Our research provides a comprehensive understanding of policies and strategies that are more adaptable to site-specific conditions, and help encourage wider use and adoption of this practice.

4.2 Materials and Methods

4.2.1 Study areas

This study was conducted in a representative area of the arid and semiarid climate and fragile ecological regions in northwest China (**Figure 4. 1**). One study region is the Hexi Corridor (D1) in Gansu province, which is known as a key part of the Silk Road Economic Belt and the main commodity grain base in northwest China (Guan et al. 2018). This region has a typical arid feature with an annual mean precipitation of 50–150 mm and evaporation of 1500–2500 mm (X. Li et al. 2016). Single cropping (annual, one-season cropping pattern) and relay intercropping with annual rotation are practiced in this region. The main grain crops are spring wheat and maize, and the main cash crops are oilseed crops, sunflower (*Helianthus annuus* L.), rapeseed (*Brassica napus* L.), and sesame (*Sesamum indicum* L.) (X. Li et al. 2017).

The other study area is in the upper reach of the Yellow River Basin region, also called the semiarid west Loess Plateau (D2). Compared with D1, this region has more precipitation, at 185–780 mm annually, and is more suitable for planting autumn crops (Zhai and Feng 2009). In recent years, not only has the agricultural output of maize increased but cash crops such as potatoes (*Solanum tuberosum* L.), sorghum [*Sorghum bicolor* (L.) Moench], oil crops, and buckwheat (*Fagopyrum esculentum* Moench) have also thrived in D2 (S. J. Wang, Yang, and Zhou 2017). The main farming system in D2 is the double cropping system of winter wheat production, or planting a small proportion of spring wheat, followed by maize or cash crop cultivation (Han, Siddique, and Li 2018; Nolan et al. 2008). The development of agricultural sustainability in these two regions is seriously affected by the agronomic practices of fertilization, pesticide, and agricultural film. This has led to an increased need for proper farming practices, such as cover crop mulching, agrochemical reduction, and adaptable cropping systems that help in sustainable improvement of production (Xin Wen and Zhen 2020b).

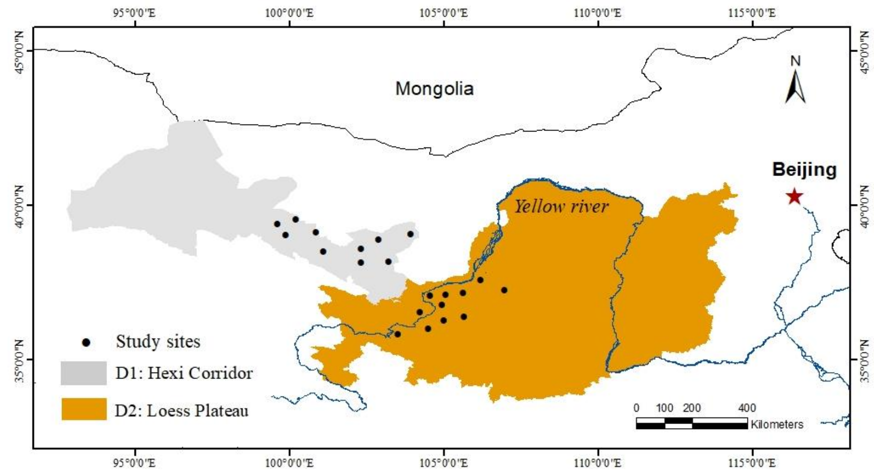

Figure 4. 1 Study area

4.2.2 Survey design and data collection

This study was designed to elicit farmers' preferences for diversifying farming with cover crops using a stated preference DCE approach. A specifically designed questionnaire was divided into three parts. The first part captured the demographic information of the farmers: age, gender, and educational level. The second part was related to the farm characteristics of crop types, farming practices, yields, agricultural labor inputs, total household income, and share of off-farm income. In the third part, the purpose of the DCE choice tasks was briefly introduced and their attributes and levels explained (**Table 4.1**). In the survey, respondents were asked to indicate their preferences from a choice set of multiple alternatives.

Table 4. 1 Attributes and level descriptions

Attribute	Level descriptions	Coding
Cropping patterns with cover crops	Cover crop intercropping (CCI) Cover crop rotation (CCR) Cover crop in marginal lands (CCML)	Dummy
Duration of adoption	One year, Three years, Five years	Dummy
Technical assistance to reduce agrochemicals (TARA)	TARA 15%, TARA 25%, TARA 35%	Dummy
Incentive payment (CNY/year/ha)	4500, 6000, 7500, 9000	Discrete

The first attribute refers to the cropping pattern of cover crops. It indicates the arrangement of cover crops within the current cropping system, which consists of cover crop intercropping (CCI), cover crop rotation (CCR), and planting cover crops in marginal land (CCML). A wide range of examples, including milk vetch (*Astragalus sinicus L.*), alfalfa (*Medicago sativa L.*), lentil (Lens culinaris Medik.), pea (*Pisum sativum L.*), and Faba bean (*Vicia faba L.*), were provided to give a broad image of cover crops to the respondents. The second attribute was the duration of adoption required by farmers for the selected package; this was important because the benefits of cropping technologies cannot always be found in the short term as they involve long-term and cascading effects on crop yield and soil quality (Snapp et al. 2015). The longest duration of adoption is five years for current government policies and plans in China are mostly managed for five years. The third attribute was technical assistance to reduce agrochemicals (TARA), which varies according to three levels of reduction: 15%, 25%, and 35% (Jat et al. 2015; Fusuo Zhang et al. 2012).

The fourth attribute was the incentive payment, based on Zhen et al. (2018) and Li et al. (2020a) and the current agricultural subsidy. According to the Pilot Program of Exploration and Implementation of Arable Land Fallow and Crop Rotation System, the standard subsidy level for seasonal crop rotation varies from 2250 CNY/ha to 3750 CNY/ha. The annual fallow standard in the severely degraded areas in northwestern China was 12000 CNY/ha in 2016, which decreased to 7500 CNY/ha in 2017 (Ministry of Agriculture and Rural Affair of the People's Republic of China 2017b; 2018). On the one hand, farmers' willingness to participate pilot program in the declines with the decline in subsidies. On the other hand, the flexible subsidy standards, including base compensation plus additional subsidy for plowing cover crops into the soil and technical support for farmers in diversifying the uses of farmland, improve the effectiveness and sustainability of the policy (J. Zhang, Shi, and Han 2019).

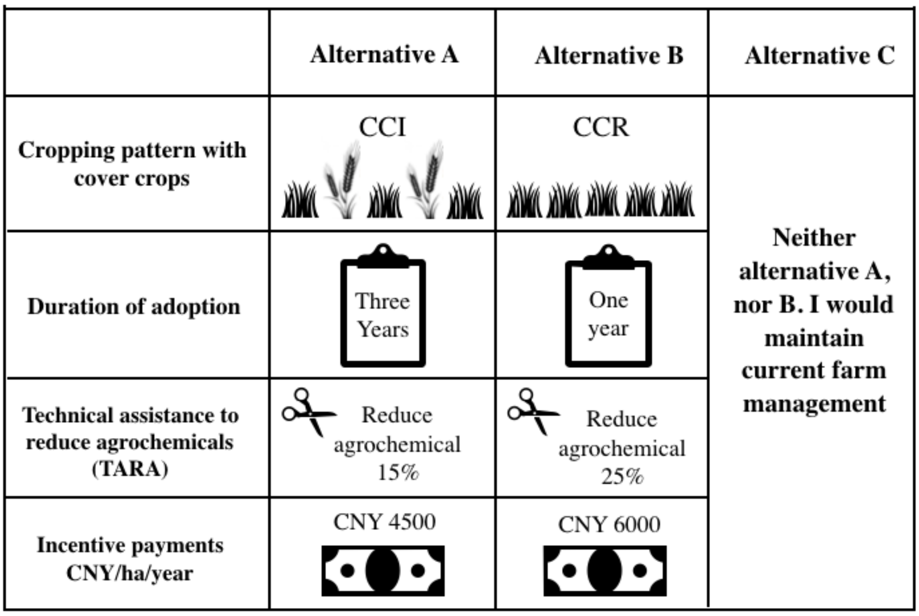

Figure 4. 2 Example of a choice task (translated from Chinese)

Figure 4. 2 presents an example of a choice task in our study. Each choice task consisted of two hypothetical SFM packages and an opt-out (status quo) option. With four attributes and three to four levels each, the questionnaire would be far too heavy if all possible combinations of attribute levels were submitted to respondents (Chèze, David, and Martinet 2020).

According the literature, efficient designs have been shown to lead to lower standard errors than orthogonal designs, therefore, the design of the DCE was generated by using the SAS software following a D-efficient design procedure with non-informative prior (Kuhfeld 2010). The design consisted of 16 choice sets divided into four blocks. Following Greiner et al. (2016) and Sculz et al., (2014) the final DCE questionnaire presented each respondent with four choice sets, which is a reasonable number with appropriate cognitive load for respondents (Schulz, Breustedt, and Latacz-Lohmann 2014).

Face-to-face interviews were also conducted between June and July 2019 for data collection. Using stratified sampling procedure, 10 villages of D1 and 11 villages of D2 were firstly selected as sampling unites based on the geographical distribution in the study areas, and then around 20 households were selected randomly from the household head list in each village. The number of effective samples was 209 (effective rate: 89.7%) in D1 and 202 (effective rate: 90.3%) in D2. Regarding the DCE questions, the farmers were informed that a project on farming diversification with cover crops regarding SFM is about to be launched, and the organizers are interested in knowing whether they will accept any of the SFM packages in the choice tasks. The questionnaires were answered voluntarily by the farmers, and they were free to stop the interview without providing any reason. Since each respondent answered four DCE choice sets, 836 and 808 properly filled-in DCE choice questionnaires were obtained. The farm sizes of the samples were all less than 1 ha.

4.2.3 Methodology

Based on Lancaster's (1966) new demand theory and McFadden's (1974) random utility theory, the respondents are assumed to make the choice that derives maximum utility. Therefore, the utility (U) of respondent (i) associated with the choice (j) from a choice task (n) is determined by a systematic component (V_{ijn}) and an error term (ε_{ijn}), which can be described as

$$U_{ijn} = V_{ijn} + \varepsilon_{ijn} \tag{1}$$

The probability of respondent i selecting the alternative j over another alternatives k from a choice task (n) is given by

$$P_{ijn} = Pr\left[\left(V_{ijn} + \varepsilon_{ijn}\right) > \left(V_{ikn} + \varepsilon_{ikn}\right)\right] \forall \text{ k} \neq \text{j} \tag{2}$$

The probability of choosing alternative j could be estimated by the conditional logit model (CL), in which the error term ε_{ijn} is assumed to be independent and identically distributed (IID), with a Gumbel distribution of Type I. While the random parameter logit model (RPL) relaxes the restrictions of the CL model, it assumes that the parameters change randomly between individuals. Thus, it can more effectively reflect heterogeneity (Train and Weeks 2005). In this case, the respondents' indirect utility function deterministic component (V_{ijn}) can be specified as

$$V_{ijn} = ASC_i + (\beta_{jn} + \delta_{jn})X_{jn} \tag{3}$$

$$V_{ijn} = ASC_i + ({\beta'}_{jn} + {\delta'}_{jn})X_{jn} + \gamma_i ASC_i \cdot Z_i \tag{4}$$

Here, ASC is the alternative specific constant, which indicates the utility of the opt-out alternative in the choice task, or the unobservable components beyond the proposed attributes in the DCE

(Meyerhoff and Liebe 2009). X_{jn} is a vector of attribute variables of the choice task (n), β_{jn} and β'_{jn} are the sums of the population means, and δ_{jn} and δ'_{jn} are individual deviations (Hensher, Rose, and Greene 2005). For our analysis, ASC is taken as 1 if respondent i chooses to opt out from the task. Farmer and farm characteristics (Z_i) were introduced into the model by interacting with ASC, which can explain the decision of opting out. The basic model of function (3) and the interaction model (4) under the CL and RPL analysis are estimated to test the robustness of the results. Following Duke et al. (2012) and Meginnis et al. (2020), the variable of incentive payment was specified as the fixed parameter. The other three attributes were dummy-coded variables and treated as random parameters.

The estimates of the coefficients indicate the average utility weight of the attributes included in the choice sets (Schaafsma, Ferrini, and Turner 2019). The willingness to accept the value of moving from the status quo for each non-monetary attribute (j') can be calculated as

$$\text{WTA} = -\frac{\beta_{j'}}{\beta_p} \tag{5}$$

Here, $\beta_{j'}$ and β_p represent the coefficients of j' and the incentive payment, respectively.

4.3 Results

4.3.1 Descriptive statistics

The descriptive statistics are depicted in **Table 4. 2**, **Figure 4. 3** to **Figure 4. 5**. Compared with D2, D1 has a higher share of male farmers and of farmers in the age groups of 50–60 years and 60–80 years. A total of 79.43% and 85.15% of the respondents in D1 and D2, respectively, were below the educational level of junior high school. Most households had 1–2 persons engaged in agricultural labor, indicating the labor shortage in the sampled areas. Regarding annual household income, D1 has a lower share of respondents earning more than 50,000 CNY per year. Furthermore, 9.57% and 20.57% of farmers in D1 have an off-farm income share of 50–80% and 80–100%, respectively, much higher than in D2. Also, 38.28% and 14.83% of the farmers in D1 raise livestock and plant cash crops, respectively. Of the 839 and 808 choices made in D1 and D2, 15.31% and 16.46% of respondents rejected the SFM package, respectively.

Table 4. 2 Statistical results of D1 and D2

Variables		D1		D2	
		n	%	n	%
Age	0 to 30	4	1.91	11	5.45
	30-40	16	7.66	30	14.85
	40-50	43	20.57	68	33.66
	50-60	93	44.50	63	31.19
	More than 60	53	25.36	30	14.85
Gender	Male	178	85.17	106	52.48
	Female	31	14.83	96	47.52
Education	Primary	88	42.11	115	56.93
	Junior high	78	37.32	57	28.22
	High school	38	18.18	24	11.88
	College	5	2.39	6	2.97
Agricultural labor (number of person)	1-2	147	70.33	153	75.74
	3-5	58	27.75	47	23.27
	6-8	4	1.91	2	0.99
Total household income** (10,000 yuan)	0-1	36	17.22	13	6.44
	1-3	43	20.57	27	13.37
	3-5	48	22.97	47	23.27
	5-8	47	22.49	71	35.15
	>8	35	16.75	44	21.78
Share of off-farm income*** (proportion)	0-25	56	26.79	46	22.77
	25-50	90	43.06	152	75.25
	50-75	20	9.57	2	0.99
	75-100	43	20.57	2	0.99
Livestock*** (1=yes, 0=no)	Raise livestock	80	38.28	45	22.28
	No livestock	129	61.72	157	77.72
Cash crops*** (1=yes, 0=no)	Plant cash crops	31	14.83	60	29.70
	No cash crops	178	85.17	142	70.30

Note: *, **, *** indicate significance at 5%, 1% and 0.1%, respectively.

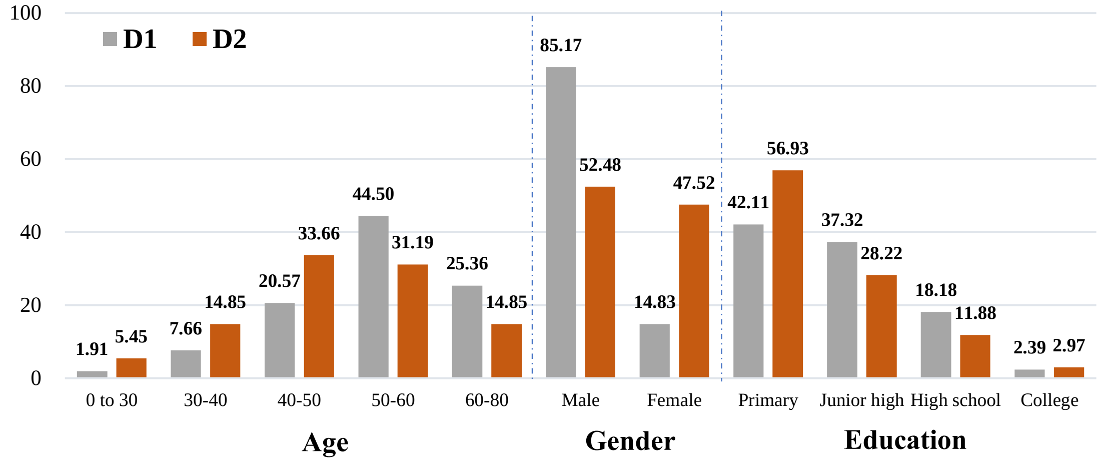

Figure 4. 3 Percentage share of age, gender, and education of the respondents in D1 and D2.

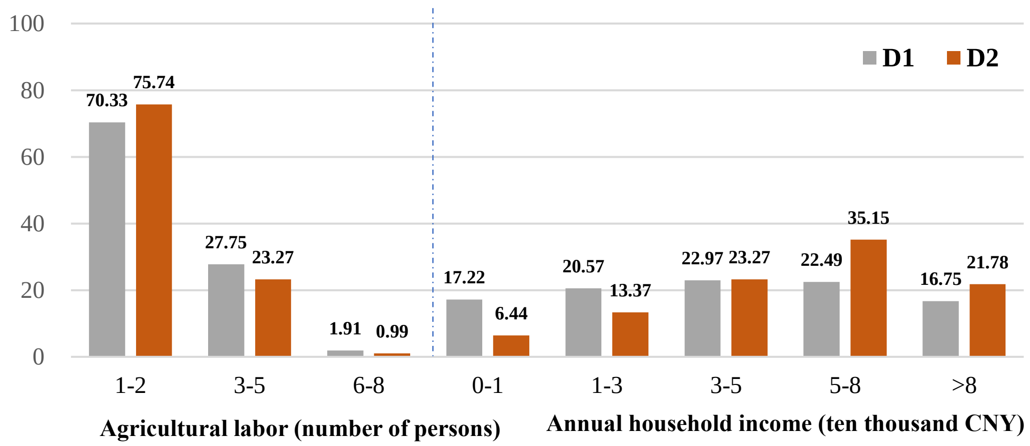

Figure 4. 4 Percentage share of agricultural labor and household income in D1 and D2.

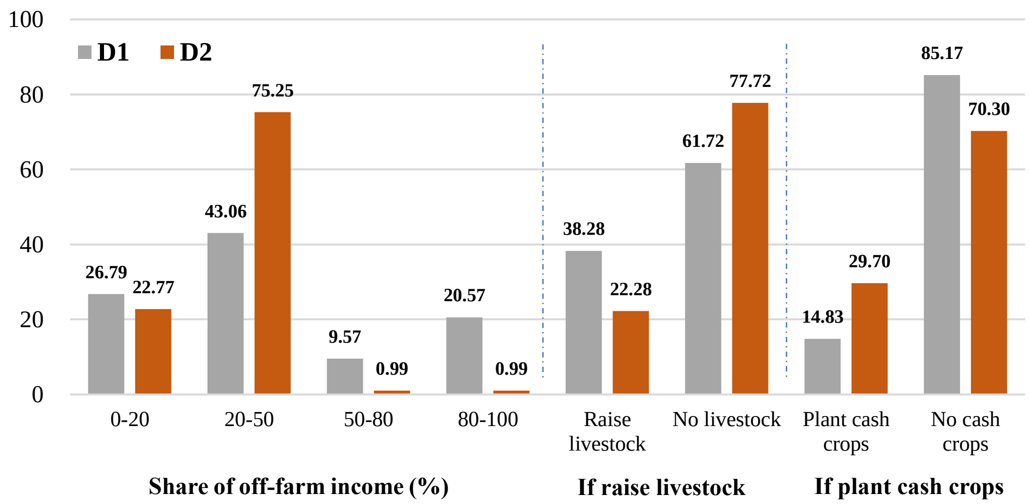

Figure 4. 5 Percentage share of off-farm income and status of livestock and cash crops in D1, D2.

4.3.2 The estimations of the basic model

The CL and RPL models were estimated individually for both study areas using the R software (version 4.0.2, R Core, 2020), and the results are presented in **Table 4.3**. The baselines of the cropping pattern of cover crops, duration of adoption, and TARA are the CCI, one year, and 35%, respectively. The perceived preference heterogeneity is estimated by RPL models with 100 random Halton draws, in which the random coefficients are assumed to be correlated. Based on the Akaike and Bayesian information criteria, the RPL model outperforms the CL model.

In the results of the CL estimations, the ASC related to the opt-out alternative in both sites has negative and statistically significant coefficients, revealing stronger preferences for choosing one of the packages rather than opting out. Although the coefficients of ASC in RPL are non-significant, the standard deviations are large and highly significant (7.965 and 4.222 in D1 and D2, respectively), indicating strong preference heterogeneity of the ASC in both sites. As expected, the higher the incentive payment, the higher the likelihood of a farmer choosing the SFM package. The incentive payment attribute has consistently been identified in the literature as an important factor in the decision on cover crop adoption (Chèze, David, and Martinet 2020; Fuduo Li et al. 2020a; Schaafsma, Ferrini, and Turner 2019).

The respondents in D1 and D2 differ significantly in their preferences for the non-economic attributes. In the ranking of the cropping pattern of cover crops, the baseline of CCI ranked the highest, followed by CCR and CCML. In D1, the parameters associated with CCML are negative and statistically significant at the 1% level, reflecting the least relative utility of planting cover crops to the marginal land compared with intercropping. However, the parameter estimate for CCR is insignificant, indicating that it is not perceived differently from the baseline. As for D2, the coefficients of CCR and CCML are -0.803 and -0.809, respectively, and both are statistically significant at the 1% level. This indicates that farmers in D2 are more reluctant to adopt CCR and CCML compared to adopting intercropping. In the areas with land constraints, farmers prefer intercropping systems to rotations because they believe that the overall yield penalty and loss of area dedicated to original crops would be minimal (Alcon et al. 2020; Rosa-Schleich et al. 2019; Thierfelder, Cheesman, and Rusinamhodzi 2012). The results in Table 4.3 show that smallholder farmers perceived CCI to have the highest utility in adjusting the cropping system, especially in D2.

Table 4. 3 Estimation of the basic model

	D1 (CL)		D1 (RPL)		D2 (CL)		D2 (RPL)	
	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.
ASC	-0.592*	0.331	2.032	1.355	-0.670**	0.338	1.038	0.913
Incentive payment	0.004***	0.001	0.011***	0.002	0.005***	0.001	0.009***	0.002
CCR	-0.155	0.156	-0.048	0.330	-0.370**	0.160	-0.803*	0.431
CCML	-0.277**	0.120	-0.803**	0.310	-0.233*	0.121	-0.809**	0.338
Three years	0.180	0.147	-0.282	0.333	-0.086	0.151	-0.387	0.309
Five years	-0.247**	0.115	-0.640**	0.272	-0.148	0.118	-0.388	0.289
TARA 20%	-0.062	0.123	-0.069	0.189	-0.361***	0.126	-0.596***	0.232
TARA 10%	-0.188	0.106	-0.109	0.220	-0.455***	0.109	-0.690***	0.242
SD								
ASC			7.965***	1.467			4.222***	0.68
CCR			0.100	0.651			2.577***	0.699
CCML			2.536***	0.663			3.164***	0.649
Three years			2.033**	0.916			1.130**	0.534
Five years			1.881***	0.612			2.447***	0.534
TARA 20%			0.207	0.301			0.331	0.527
TARA 10%			0.769	0.503			0.591	0.408
Number of events	836		836		808		808	
Obs	2508		2508		2424		2424	
Rho-squared	0.114		0.237		0.120		0.284	
AIC	1647.785		1303.835		1582.289		1334.717	
BIC	1695.071		1374.765		1629.235		1405.135	
Log-likelihood	-813.89		-636.92		-887.679		-652.36	

Note: *, **, *** indicate significance at 5%, 1% and 0.1%, respectively.

The estimates for the duration of adoption and TARA show interesting results. In general, increasing the duration of adoption lowers the probability of choosing the SFM package. The parameter of five years was negative and statistically significant in D1, indicating that respondents in D1 were less likely to choose the five-year adoption, while no significant difference was observed for the three-year policy. This is consistent with previous research; most smallholder farmers are conservative and adopt a wait-and-see attitude, leading them to prefer a trial period for outcome observation (Luo et al. 2016).

However, respondents in D2 did not show significant preferences in this attribute. Conversely, the parameters for TARA 20% and TARA 10% were negative and statistically significant in D2, indicating that the higher level of TARA 35% increases the likelihood of adoption. These results show that farmers in D2 are more concerned about reducing the use of agrochemicals than farmers in D1. Therefore, TARA can improve the adoption of cover crops in D2. With a high proportion of cash crops accounting for the household income, farmers in D2 engage more in relevant measures to reduce the production cost of agrochemicals to improve agricultural productivity (Nong et al. 2020; Fusuo Zhang et al. 2012).

4.3.3 The estimations of the interaction model

As an extension of the basic model, the interaction terms depict the characteristics of the farmers who opt out in the choice experiment. The results of the CL and RPL models are presented in Table 4. The variables of farmer and farm characteristics include age, gender, level of education, agricultural labor, annual household income, livestock, cash crops, and share of off-farm income. The estimations of the attribute variables were consistent with the basic models in Table 4.3, indicating that the estimations are robust, as confirmed by Schaafsma et al. (2019) and Chèze et al. (2020).

The negative and significant effect of age on ASC for D1 (Table 4, the first four columns) shows that elder farmers in D1 are less likely to opt out, implying a higher possibility to adopt the SFM package. The interaction between females and ASC was positive and significant based on the CL estimation, indicating high probability of opting out among female farmers in D1. This is in line with previous findings that female farmers with lower labor ability to engage in farm work are less willing to apply practices that require extra input, especially in low-income, impoverished regions (Yu et al. 2019a). Likewise, farmers with higher annual household incomes are less likely to choose the SFM package, showing that income significantly affects farmers' decisions in D1.

As for D2 (**Table 4.4**, the last four columns), the coefficients of agricultural labor and livestock interactions were negative and statistically significant, which suggests that higher agricultural labor availability and raising livestock increase the possibility of SFM package being chosen by farmers. Labor input is an important factor in intensive farming areas as the smallholder farmers prefer to allocate the inadequate labor force to increase agricultural production and total household income (Y. Hong, Heerink, et al. 2019). The significant negative sign of livestock on ASC in D2 may be explained by cover crops offering a new source of forage for livestock. Conversely, the cross term of livestock is not significant in D1, indicating that farmers raising livestock in D1 are less likely to adopt cover crops. It might be because D1 has a higher share of farmers raising livestock such as cattle, sheep, and goats, as well as grain crops. However, with limited farm size, the biomass production of cover crops cannot replace the forage provided by grain crop residues and byproducts, which are the primary sources of forage (W.-S. Zhang et al. 2012; Nong et al. 2020).

Table 4. 4 Estimation of interaction models

	D1 (CL)		D1 (RPL)		D2 (CL)		D2 (RPL)	
	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.
ASC	-0.930	0.700	0.361	2.830	-0.733	0.761	3.960	3.586
Incentive payment	0.004***	0.001	0.011***	0.002	0.005***	0.001	0.009***	0.002
CCR	-0.146	0.156	-0.040	0.318	-0.356**	0.164	-1.230**	0.545
CCML	-0.278**	0.120	-0.745**	0.291	-0.234*	0.123	-0.923**	0.405
Three years	0.165	0.147	-0.172	0.310	-0.099	0.154	-0.47	0.369
Five years	-0.249**	0.115	0.671**	0.263	-0.153	0.119	-0.560*	0.331
TARA 20%	-0.055	0.106	-0.057	0.187	-0.358	0.110	-0.730***	0.272
TARA 10%	-0.182	0.124	-0.145	0.215	-0.456	0.127	-0.828***	0.276
Interact with ASC								
Age	-0.009	0.010	-0.092*	0.048	0.003	0.010	-0.075	0.054
Female	0.640**	0.269	2.364	1.890	0.174	0.226	0.511	0.813
Education	-0.029	0.133	-0.367	0.777	0.666***	0.167	2.357***	0.769
Agricultural labor	0.001	0.094	-0.246	0.487	-0.633***	0.104	-1.822***	0.480
Annual household income	0.035	0.026	0.287*	0.168	-0.003	0.036	-0.010	0.141
Livestock	0.159	0.209	-0.960	1.263	-0.743***	0.242	-3.080***	1.169
Cash crops	0.867**	0.392	6.843**	2.722	0.849***	0.268	2.580**	1.057
Share of off-farm income	0.001	0.003	-0.009	0.018	0.012*	0.006	0.058**	0.028
SD								
ASC			7.523***	1.352			4.552***	0.911
CCR			0.130	0.699			3.657***	0.792
CCML			2.574***	0.631			3.918***	0.875
Three years			1.800**	0.705			1.690***	0.576
Five years			1.761***	0.496			2.749***	0.684
TARA 20%			7.523***	0.350			0.776	0.462
TARA 10%			0.130	0.505			0.292	0.446
Number of events	836		836		808		808	
Obs	2508		2508		2424		2424	
Rho-squared	0.122		0.286		0.163		0.367	
AIC	1651.403		1308.391		1524.462		1304.800	
BIC	1741.247		1417.129		1613.658		1408.080	
Log-likelihood	-806.71		-631.19		-743.23		-632.01	

Note: *, **, *** indicate significance at 5%, 1% and 0.1%, respectively.

Farmers with higher education levels are less likely to choose the SFM package in D2. Furthermore, an increase in the share of off-farm income raises the probability of opting out. During the survey, many farmers in D2 explained that most of their off-farm incomes come from part-time jobs in local large farms or nearby towns, and they come back home during the busy farming seasons; thus, they do not have extra labor for adopting cover crops. It is worth pointing out that cash crop cultivation had a strong negative effect on adoption in both D1 and D2. This implies that the higher opportunity cost of available land area and water resources for replacing the cash crops with cover crops led to a reluctance to move away from the current status.

4.3.4 WTA estimates

The marginal WTA between attribute and incentive payment was estimated using the basic RPL model. The WTA estimates imply that incentives are required for adoption. Their 95% confidence intervals are presented in **Table 4.5**. As can be observed from **Table 4.5**, the WTA of CCML of D1 and D2 are equivalent to additional payments of 1095.00 CNY/ha and 1348.35 CNY/ha per year, respectively. Besides, farmers in D2 are willing to accept 1338.30 CNY/ha to adopt CCR. Regarding the duration of adoption, farmers in D1 need to receive an additional payment of 872.70 CNY/ha to accept five years of adoption. The smallholder farmers in D2 were willing to accept 993.30 CNY/ha and 1150.05 CNY/ha for the TARA 20% and TARA 10%.

Table 4. 5 Willingness-to-accept (WTA) estimates (95 % confidence intervals)

Attribute	D1		D2	
	WTA	[95% Conf. Int.]	WTA	[95% Conf. Int.]
ASC	-2770.95	(-6392.40; 850.65)	-1729.95	(-4712.40; 1252.50)
CCR	65.4	(-816.60; 947.40)	1338.30*	(-69.60; 1246.02)
CCML	1095.00**	(266.40; 1923.60)	1348.35**	(244.20; 2452.50)
Three years	384.6	(-505.50; 1274.55)	645.00	(-364.35; 1654.35)
Five years	872.70**	(145.80; 1599.75)	646.65	(-297.45; 1590.90)
TARA 20%	94.05	(-411.00; 599.25)	993.30***	(235.50; 1751.25)
TARA 10%	148.65	(-439.35; 736.65)	1150.05***	(359.40; 1940.55)

Note: *, **, *** indicate significance at 5%, 1% and 0.1%, respectively.

4.4 Discussion of Model Results

Using the choice modeling approach, this study elicited the adoption preferences of smallholder farmers in northwest China for diversifying farming with cover crops. The comparisons of the estimates between two typical arid and semiarid regions, D1 and D2, helped us understand how preferences differ between two agriculturally intensive cropping systems. The results indicate that compared with CCI, one-year, and three-year adoption, the attributes of CCR, CCML, and five-year adoption were less preferred by the smallholder farmers in both study sites. Besides, TARA was highly appreciated by the respondents in D2. Therefore, apart from incentives, the cropping pattern of cover crops and TARA should also be considered in policy design when promoting farming diversification with cover crops for SFM (Alcon et al. 2020; K. Liu et al. 2020).

4.4.1 Two features of farmers' preferences for the cropping pattern of cover crops

The estimates revealed that farmers in D1 were more willing to adopt CCI and CCR than CCML. However, the smallholder farmers in D2 were more likely to adopt CCI than CCR and CCML. These results indicate two features of farmers' preferences for the cropping patterns of cover crops. First, intercropping is highly appropriated within two study areas, especially for D2, which currently uses the double cropping system. Thus, when using cover crops as an alternative for adjustment of the current cropping system, intercropping can reduce the risk of losing crop production by replacing existing crops with cover crops by rotation and also potentially generate higher resource-use efficiencies by exploiting complementarities between species (Alcon et al. 2020; Y. Hong, Heerink, et al. 2019). Hong, Heerink et al. (2019) found that intercropping or relay-strip intercropping improves technical efficiency. Meanwhile, the potential negative effects of intercropping on the efficiency of labor and other resources are more than offset by its higher land-use efficiency compared with monocropping. Based on these results, sustainable farming with cover crops, intercropping, or rotation with extra incentive payment should be offered for the agriculturally intensive double cropping system in D2.

The second feature points to the relatively higher opportunity cost of rotating cover crops with the current cropping system. For the resource-poor low-income regions, the pursuit of higher income strongly impacts cropping decision-making (Y. Hong, Berentsen, et al. 2019). Rotation is much riskier if a drought occurs in the second year, which can leave farmers with no harvest for two cropping seasons. In this case, if farmers obtain higher shares of off-farm income, such as in D1 (**Figure 4. 4**), CCI or CCR will not make much difference to them in compensating for low agricultural income. Liu et al. (2019) reported the same results: under the water-constraint condition, farmers either prefer to grow cash crops like vegetables or crops that do not require heavy capital investment. Hence, the adoption preference for rotating cover crops with the current single cropping system in D1 is higher than in D2. Moreover, the positive interaction effect of the ASC and cash crops in Table 4 implied that smallholder farmers cultivating cash crops were more reluctant to move away from the current cropping system. Hence, the results suggest that an optimal cropping plan should include cover crop rotation with the grain crops and increase the share of land under intercropping of the cover crops with cash crops (Alcon et al. 2020; Fuduo Li et al. 2019; K. Liu et al. 2020; Schaafsma, Ferrini, and Turner 2019).

Further exploration of the results informed the extra WTA for CCR among farmers in D2. Rotation requires a longer period of farm management involving the allocation of resource endowments including labor, money, land, and water resources (Fengrui Li, Zhao, and G. T 2000; F.-R. Li et al. 2002). Hence, simply rotating with cover crops cannot guarantee more grain yield or greater water use efficiency. It is necessary to develop complete and compact adoption packages, including an arrangement of cropping times and selection of species. For example, winter wheat can be cultivated and then followed by a 3-month (end June or early July to late September) legume fallow cover crop in the first year and a summer crop cultivation in the next year. Else, winter wheat can be followed by 15-month leguminous species cultivation in the first and second years and then a summer crop in the third year. These packages provide soil cover during rainy periods while also leaving the soil bare for months to better conserve soil and water resources (F.-R. Li et al. 2002).

4.4.2 How to utilize the duration of adoption and technical assistance

Respondents in both sites were willing to accept shorter adoption periods of one and three years and required an additional incentive payment for five years of adoption (872.70 of D1 and 646.65 of D2). These results are in line with the evidence in previous literature that the longer the adoption period, the higher the risk of production loss and stronger the reluctance to adopt (Chèze, David, and Martinet 2020). While Schaafsma et al. (2019) found the adoption period to have no significant effect in their study on the species of soybean and sorghum with either rotation or intercropping with maize, these commonly used cropping systems would not make much difference to the current systems. On the contrary, in this study, the SFM packages were introduced to farmers for diversifying farming with cover crops, which is expected to bring changes in their current cropping systems. More importantly, the negative utility of increasing the adoption period implies that it is necessary to increase the incentive levels along with the adoption period to stabilize farmers' participation and reduce the risk of them giving up halfway (Yu et al. 2019a).

Different utilities for TARA in the two regions highlight that effective technology guidance to increase fertilizer use efficiency also plays a critical role in cover crop adoption, especially for knowledge-poor smallholder farmers who expect higher income from cash crop cultivation or intensive farming in semiarid regions like D2 (Fan et al. 2015; Nong et al. 2020). Moreover, a gradual transition from synthetic fertilizer inputs to legume-based crop cultivation to improve crop productivity requires the consideration of not only the variable weather patterns of rainfall in dry or wet years that affect the subsequent crops (D. Zhang et al. 2016), but also of government publicity and training work to improve farmers' understanding of the effectiveness of technologies and the species of cover crops to choose (D. Zhang et al. 2016).

Empirical results in the developed countries reflect that flexibility in contract conditions reduces payments required and increases the odds of the conservation project being accepted by farmers (Christensen et al. 2011; Greiner 2016). For example, Christensen et al. (2011) found that Danish farmers accept a reduction in payment of 137 Euro/ha/year (1070.68 CNY/ha/year) if they get an opportunity to break the contract once a year. As Schaafsma et al. (2019) and Yu et al. (2019), the flexible options selected in this study were in a general way and fewer than those in developed countries, based on the rural development and low educational and cognitive levels of smallholder farmers in northwestern China.

4.5 Summary

The results indicate the adoption preference of using cover crop intercropping and rotation among farmers in the Hexi Corridor and prioritization of cover crop intercropping in the Loess Plateau to adjust production structure toward sustainable farming. The results show that economic incentive is not only the prerequisite for accepting the practice but also essential for long-term adoption. Furthermore, technical assistance to increase fertilizer use efficiency is valued in the more agriculturally intensive region of the Loess Plateau. Our study specifically focuses on the adoption decisions among two different agriculturally intensive cropping systems and providing policy suggestions on site-specific conditions.

The results from the analysis in this paper provide important implications for the policy design of SFM with cover crops in arid and semiarid northwest China. First, intercropping cover crops to adjust the production structure of cropping systems toward sustainable farming within a short trial period of one to three years would increase the likelihood of adoption among smallholder farmers. In particular, highly intensive cropping systems combined with technical assistance for reducing agrochemicals improve the adoption. Second, rotating cover crops with the current cropping system should be supported by extra incentive payment and technical guidance on how to implement three years or five years of adoption packages involving species selection and cropping time. The benefits of implementation require long-term adoption and a complete plan to reduce the risk of losing agricultural production. Third, technical assistance and agricultural training for introducing cover crops in managing sustainable farming are of great importance for improving technology adoption. The educational level of smallholder farmers in developing countries is much lower than that of farmers in developed countries. Therefore, site-specific training with practical applications of fertilization combined with the utilization of cover crops would help promote policy implementation.

Although this analysis used a standard sample size, there are some limitations in this study. Our findings offer insights on social economic characteristics of the potential cover crop adopters in two different cropping systems without giving a total subsidy estimation. Also, the study design could be further extended to include more details of the SFM package such as the share of cover cropping area and its corresponding duration of adoption and insurance to reduce the risk of possible loss in yield. Future research should pay more attention to collect data with respect to different types of crops and cropping systems and follow up to research on new measures and applications of cover crops .

CHAPTER 5
HETEROGENEITY OF FARMERS' PREFERENCES

Analyses reported in chapter 3 and chapter 4 indicated the adoption preferences toward nine SAPs and proposed SFM packages are diverse within crop types and cropping systems. In this chapter, the heterogeneity of farmers' decisions on SFM with the cover crop will be further explored.

5.1 Aims of the Chapter

One of the main challenges for policy design for SAPs is to understand how farmers understand the practices and the features of farms and farmers. Apart from differentiating the adoption preferences for SFM with cover crops, identifying and interpreting the heterogeneity of farmers' social demographic, social-economic characteristics, and attitude toward sustainable farming is conducive to depict the farmers' profiles, which is becoming increasingly important for policymaking.

The recent literature about farmers' decision-making reflects this increasing interest in the farmers' behavior as well as the heterogeneity of farm attributes. Kassie et al. (2009) found that heterogeneity exists in the influencing factors of adoption decision, of which the household endowments and access to information are the most significant influencing factors. Prager et al.(2011) offer a critical review of the current knowledge about the effectiveness of soil conservation policies and conclude that the optimal design to incentivize farmers to participate needs to take into consideration the diverse individual and local characteristics. Wen and Zhen (2020b) reviewed the soil erosion control practices in the Chinese Loess Plateau practices and found that the assessment of soil degradation and use of practices can be affected by different cropping systems and tillage systems.

The empirical studies of farmers' decision-making usually assumed the same utility function for all individuals (Fuduo Li et al. 2020a; Ntakirutimana et al. 2019; Ren, Yin, and Duan 2020).The BWS and DCE surveys offset the problem that heterogeneity in decisions being neglecting in the previous studies by requiring respondents to make a trade-off between items of interest to reveal their relative preferences for each item. As it is proved in chapter 3, differences were shown in adoption preference among individuals according to utility factors, and the estimations further indicate the discrepancy existing in characteristics and capabilities of farms. Therefore, this chapter identifies respondents' priorities between attributes based on DCE data, allowing policymakers to compare and assess the likely future adoption rate.

Accordingly, based on the DCE survey data, this chapter aims to analyze the heterogeneity of the adoption preferences for the SFM package and investigate farmers' prioritization in the attributes of the SFM package. To this end, firstly, latent class analysis will be conducted to identify the cluster segmentations that identifie the heterogeneity of the decisions. Then, the social-demographic, social-economic, and attitude toward sustainable farming were used to characterized farmers in each cluster. The rest of the chapter is arranged as follows. This part is followed the results of the analysis on latent segmentation and then profile of farms and farmers within each segmentation. Finally, the results of the study are discussed, focusing on interpretation of farmers' profile in each cluster, along with future lines of research on the topic.

5.2 Identifying Clusters Based on DCE Data

A Latent Class (LC) approach employing the software Latent Gold 4.5 (Statistical Innovation Inc., Belmont, MA, USA) was conducted to identify the segmentations of smallholder farmers. Following Yeh et al. (2020) and Bozdogan (1987), the optimal number of latent classes (segments) is based on the minimum estimates of the consistent Akaike information criterion (CAIC). As shown in **Table 5.1**. three-clusters solution provided the best fit to the data. Although the indicator of Bayesian information criterion (BIC) further improved as more clusters were added, the changes were much smaller from the three-cluster to four-clusters. Therefore, taking into consideration CAIC, the estimations of the three-clusters solution will be interpreted.

Table 5. 1 Criteria for selecting the optimal number of clusters

	LL	BIC(LL)	AIC(LL)	CAIC(LL)	Npar	df	R2
1-Cluster	-1609.62	3261.361	3233.23	3268.361	7	313	0.1233
2-Cluster	-1362.35	2814.977	2754.698	2829.977	15	305	0.343
3-Cluster	-1295.1	2728.636	2636.208	2751.636	23	297	0.4905
4-Cluster	-1268.95	2724.478	2599.902	2755.478	31	289	0.5192

The results of attribute importance are shown in **Table 5.2**, which are considerably different between the three clusters.

Table 5. 2 Result of latent class analysis of DCE data

Segmentations	Cluster 1	Cluster 2	Cluster 3
Segment size (N = 411)	52%	31%	17%
R2	0.470	0.353	0.512
Attributes			
CCI	0.472	**0.878**	**1.059**
CCML	0.717	-0.846	-0.382
CCR	0.525	**1.141**	-2.206
Duration of adoption	**0.152**	-0.503	-0.078
TARA	0.005	0.022	**0.046**
Incentive payment	**0.011**	0.002	0.008
ASC	2.150	-0.138	**4.957**

Note: CCI, CCR and CCML represent cover crop intercropping, cover crop rotation and cover crop in marginal land; TARA represents technical assistance to reduce agrochemicals.

Firstly, cluster 1 has the largest size in respondents, shares 52% of total respondents, following by 31% of cluster 2 and 17% of cluster 3. If we compare the relative difference between the parameters between these three clusters, the variables of the *Duration of adoption* and *Incentive payment* are the most important attribute identified in cluster 1, indicating respondents in this cluster are much sensitive to the incentive level and willing to accept the SFM package for a longer period. It also shows that farmers in this cluster are much oriented by the economic stimulation of incentives. Under this precondition, farmers are open to arranging farms with diverse cropping patterns.

For cluster 2, *CCI* and *CCR* are shown to be the most significant attributes, implying that respondents in this cluster are more prefer intercropping and rotating cover crop with the current farming system compared to the other two clusters. However, the significant negative results of the *Duration of adoption* and *CCML* show respondents of cluster 2 strongly dislike CCML and prefer a short adoption period. Also, farmers are least likely to opt-out in this group as *ASC* shows the smallest result comparing to the other clusters. On the contrary, ASC is the most important attribute in cluster 3, indicating respondents are not interested in the SFM packages. It worth mentioning that respondents in clusters 3 are more prefer TARA and CCI comparing than the other groups, indicating combining technical assistance and the CCI might be a solution for encouraging farmers to participate. To further interpret the results of the latent class analysis, the means of the attribute values are shown in **Table 5.3**.

Table 5. 3 Mean of the attribute value for clusters

	Cluster1	Cluster 2	Cluster 3
Attributes			
CCI	0.4622	**0.3604**	**0.1775**
CCML	**0.8474**	0.0923	0.0603
CCR	0.5058	**0.4872**	0.007
Duration of adoption			
1	0.3152	0.521	0.1638
3	**0.5638**	0.2514	0.1848
5	**0.7535**	0.0906	0.1559
TARA			
15	0.6585	0.2646	0.0769
25	0.604	0.2894	0.1066
35	0.5124	0.3198	**0.1677**
Incentive payment (CNY/year/ha)			
4500	0.1931	**0.6803**	0.1265
6000	0.3276	**0.5126**	0.1598
7500	**0.4858**	0.3376	0.1765
9000	**0.6332**	0.1955	0.1713
ASC			
0	0.2471	0.7476	0.0053
1	**0.6015**	0.1848	**0.2137**

In cluster 1, the mean value of 7500 CNY/year/ha and 9000 CNY/year/ha are 0.4858 and 0.6332, respectively. Also, the value of CCML is the highest at 0.8474. Distinct from cluster 1, lower incentive levels of 4500 CNY/year/ha and 6000 CNY/year/ha are valued higher in cluster 2 with relatively high values in both CCI and CCR. Comparing the values in cluster 2, of which ASC is the highest with 0.2137. Of all the attributes, it is noticeable that CCI is highly valued in three clusters, as well as one year of duration and 35% of TARA.

5.3 Farmers Heterogeneity

Based on the LC cluster analysis, three clusters of farmers were revealed in **Table 5.4**. The ex-post analysis of variance was conducted to find the additional significant differences in the social-demographic, social-economic characteristics, and attitudes toward sustainable farming between three clusters.

Table 5. 4 Means of statistical information for clusters

Variables	Cluster1	Cluster2	Cluster3
Age (years)	51.79^{a}	50.84^{b}	51.48^{ab}
Gender (Female=1, male=0)	0.71^{a}	0.70^{a}	0.61
Education level (1=primary school, 2=junior high school, 3=senior high school, 4=collage)	1.72	1.79	1.53
Number of household labor	2.27	2.38^{a}	2.44^{a}
Annual household income (ten thousand CNY)	5.45^{a}	5.33^{ab}	5.02^{b}
Share of off-farm income (%)	39.82^{a}	39.83^{a}	35.03
If raising livestock (1=yes, 0=no)	0.27	0.34^{a}	0.34^{a}
Awareness of soil degradation (1=yes, 0=no)	2.45	2.36^{a}	2.34^{a}
Feeling self-responsible for soil conservation (1=yes, 0=no)	0.15^{a}	0.15^{a}	0.09
If plant cash crop (1=yes, 0=no)	0.22^{ab}	0.24^{a}	0.20^{b}
If only plant grain crop (1=yes, 0=no)	0.78^{ab}	0.76^{a}	0.80^{b}
If apply the practice of rotation (1=yes, 0=no)	0.39^{a}	0.43^{b}	0.41^{ab}
If apply cover crops (1=yes, 0=no)	0.17	0.24	0.11
Total number of SAPs	0.79^{a}	1.02	0.77^{a}

Note: Means within a row with the same superscript letters are not statistically different ($\alpha = 0.05$, post-hoc Tukey test).

On one hand, farmers in cluster 1, which accounted for the largest share of the samples (52%), ranked the highest in average age, female respondents, the share of off-farm income, awareness of soil degradation, and feeling self-responsible for the soil conservation in three clusters. On the other hand, cluster 1 has the least mean value in household labor, the share of raising livestock, if apply the practice of rotation. Farmers in cluster 2 have the highest educational level in three clusters. Comparing with cluster 1, cluster 2 has more labor inputs and a higher share of off-farm income, more importantly, farmers of cluster 2 are applying more SAPs, in particular, crop rotation and cover crop. Cluster 3 ranked the lowest in the education level, total household income, the share of off-farm income, awareness of soil degradation, and self-responsible for soil conservation and applying cover crops, while, the household labor input was higher than the other clusters.

5.4 Discussion

The emergence of three clusters and the existence of statistically significant differences between clusters are consistent with other studies that have underlined the inherent heterogeneity in farmer behavior (Broch and Vedel 2012; Martin-Collado et al. 2015; Karali et al. 2013). However, the clusters indicate that farmers can be grouped by their adoption intentions of SFM packages.

This study has shown that although farmers' decisions to adopt the SFM package are partly influenced by the incentive payment, their attitudes are not affected solely by economics. For example, although farmers in cluster 1 are most likely influenced by the incentive payment, other factors like the duration of adoption and CCML are co-affecting the decision-making. More importantly, 31% of the respondents are more orientated by the copping patterns of CCI and CCR, but not the incentive payment. This result indicates that farmers could also be motivated by diversified cropping patterns with cover crops in a relatively lower level incentive payment. Farmers in cluster 3 are most likely to opt-out of the SFM package. The TARA was highly valued for the farmers in cluster 3, implying that instead of apply cover crops, providing technical assistance to reduce chemical fertilizer could be another alternative for farmers to participate in SFM.

In addition to the identification of different behavioral intentions of SFM packages, it is equally important to interpret the farmers' features in each cluster. However, limited conclusions could be drawn here about whether or not the correlation between certain characteristics could also imply causation (Karali et al. 2013). Considering the education level, for example, it was noted that CCI and CCR were more valued by farmers in cluster 2. However, it is uncertain whether education was the cause of higher preferences for these cropping patterns (Burton and Wilson 2006). However, statistical tests and other quantitative methods are important in ascertaining heterogeneity and explaining the characteristics of farm and farmer.

The analysis also demonstrated relationships between farmers' attitudes toward sustainable farming and their adoption preferences, suggesting the influential power of attitude and perception on farmer environmental decisions (Meijer et al. 2015; Glenk et al. 2014; Karali et al. 2013). Furthermore, the understanding of self-responsible for soil conservation shown high value in cluster 1 and cluster 2, implied a potential relationship between farmer attitudes for being responsible for soil conservation and their decisions in adopting the SFM package. This also indicates the need to consider the effect of self-awareness (i.e. emotions, values, thoughts) and social norms in better understanding observed farmer decisions as suggested by Karali et al. (2013).

5.5 Summary

This study analyzed the heterogeneity and complexity of farmer behavior intention in adopt cover crops regarding SFM. Differences in farmers' adoption preferences were identified by conducting the latent class analysis. Although incentive payment is one important factor in the decision-making, profit maximization was not the only determinant of farmer decisions. Instead, diversified cropping patterns with cover crops, duration of adoption, and TARA were also shown to be influential factors. The study distinguished three clusters of farmers' profiles. Three clusters of farmers differed in their social demographic, social-economic, and attitude toward sustainable farming.

The farmers preferring to adopt the SFM package are identified in cluster 1 and cluster 2. These farmers have a higher educational level and annual householder income, more aware of soil degradation problems, and feeling self-responsible for soil conservation. More importantly, more farmers are currently applying cover crops on their farms. On the contrary, farmers most likely to reject the SFM packages are identified in cluster 3. These farmers have a lower education level, more household labor inputs, and less household income and less share of off-farm income. Regarding the attitude toward sustainable farming, they are least aware of the soil degradation and did not feel self-responsible for the conservation.

CHAPTER 6
PERCEPTION, INTENTION, AND ACTION OF GREEN MANURE CROPS ADOPTION

In the previous chapters, adoption intention toward SAP and SFM package has been examined. From this chapter, the focus shifts to the consistency between the perception, intention, and behavior green manure adoption (GMA). Considering southern China is more favorable for agricultural production compared to northwest China, this chapter explores the impact of perception of a specific practice of green manure crops on the adoption intention and behavior. Apart from this, the consistency between intention and behavior is explored. The aims include to test the effect of perception and investigate the gap between intention and behavior of CCA among farmers in Guangxi.

6.1 Introduction

Government and environmental policymakers have increasingly emphasized farmers' sustainable farming behaviors for reducing chemical fertilizer and mitigating soil degradation. Use of excessive chemical fertilizers is common among knowledge-poor smallholder farmers, which leads to a large volume of agrochemical release, increased nitrate loss in soil, and deterioration of the agricultural environment in China (Huang et al., 2012; Zhang et al., 2016). According to the Food and Agriculture Organization (FAO), although the average fertilizer consumption in China decreased from 463.72 kg/ha in 2014 to 391.67 kg/ha in 2018, it is still much higher than the world average (120 kg/ha), 4.63 times that of the EU, 3.04 times that of the United States, and 2.23 times that of India. The Chinese government imposed the "Zero-Growth Action on Fertilizer" (MOA 2014) and encouraged farmers to apply green manure crops (GMC) to conserve fields, reduce agrochemical usage, and mitigate soil pollution (Li et al., 2020; Shuqin and Fang, 2018). On the one hand, relying on economic incentives, farmers show high intention of green manure adoption (GMA) (Li et al., 2020); on the other hand, their spontaneous adoption of the practice has been declining (W. Cao and Huang 2009). Therefore, to ensure effectiveness of policy instruments and long-term adoption of GMC, decisions on intention and adoption behavior (action) of GMA should be examined. It provides a more detailed understanding for policymakers and practitioners regarding smallholder farmers' decisions on practice applications before policy implementation.

Green manure crops such as Chinese milkvetch (Astragalus siniucus L.), alfalfa (Medicago sativa L.), and lentil (Lens culinaris Medik.) have proven their efficacy in reducing dependence on chemical fertilizers, maintaining and enhancing soil organic matter and soil fertility (W. Cao and Huang 2009) and reducing soil erosion (Bergtold et al. 2019; Liding Chen et al. 2007). Moreover, GMC also serve as forage for livestock (Nong et al., 2020; Zhang et al., 2012). The integration of GMC into various farming systems by rotation, intercropping, and winter fallow cropping has been utilized in tropical or subtropical regions since many years (Ali, 1999; Li et al., 2020; Pratt and Wingenbach, 2016; Valadares et al., 2016). In southern China, approximately 46 million ha of fields, particularly the spare fields after the rice harvest, are available for green manure crop cultivation (Yan et al. 2009). Taking advantage of this availability, participatory on-farm trials of GMA with economic incentives have been conducted in the demonstration zones in the paddy fields of southern China before the large-scale promotion.

Financial subsidies have been used as a primary tool to compensate and encourage smallholder farmers to participate in various conservation policies in China. For example, with a compensation of 1091 CNY/ha per year, GMC were promoted to farmers for converting degraded farmland to permanent pasture with the aim of reducing soil erosion in arid and semiarid northwest China (Xin Wen and Zhen 2020a). Farmers in the demonstration regions were provided with approximately 375 CNY/ha to 675 CNY/ha per year for seasonal rotation of GMC with food crops (Li et al., 2020). Farmers were asked to scatter the green manure crop seeds around October, harvest the plants, and incorporate them into the soil in the early spring of the following year to provide nutrients for the soil. With long-term economic and governmental support, farmers expect financial support, causing a strong reliance on policy and a tendency to accept the proposal with incentives (Yu et al., 2019). Consequently, the adoption of GMC may stop if the subsidies are cut off or decreased, as voluntary adoption among smallholder farmers has been observed to be very low (Li et al., 2020; Luo et al., 2016). Hence, investigating farmers' adoption decisions is needed to clarify the gap between the adoption intention and action.

Many previous studies have attempted to explain smallholder farmers' willingness to adopt sustainable farming practices using qualitative approaches. These studies emphasize the importance of perception in practices' effect and soil degradation status (Kenee and Feyisa, 2020; Zhang et al., 2017), economic incentives (Li et al., 2020; Villanueva et al., 2017), and agricultural technical training (Pratt and Wingenbach 2016; Ren, Yin, and Duan 2020). Li et al. (2020b) investigated the determinants and willingness to accept for GMA in the paddy fields in southern China. They found that farmers who perceived positive effects of GMC on yield growth and soil quality accept less compensation for adoption; also, policy publicity and subsidies are major influencing factors. In terms of planting GMC in the orchard, Ren et al. (2020) found that awareness of the severity of soil degradation influences farmers' decision on GMA. Given the relatively low educational level of Chinese smallholder farmers, sources of information such as agricultural training and neighbors' opinions are critical in improving the perception of practices and affecting adoption decisions (Fan et al. 2015; Luo et al. 2016).

On the one hand, the perception was found to play a moderating role in affecting farmers' adoption decisions (Li et al., 2021; Zhang et al., 2017). Meanwhile, the extension service and concern about environmental degradation have a substantial influence on the perception.(Kenee and Feyisa 2020). Also, improving farmers' knowledge of the proposed practices' environmental and ecological functions is effective in strengthening farmers' satisfaction and enthusiasm toward policy implementation (Zhu et al., 2018). However, to the best of our knowledge, no substantive empirical evidence exists on the specific effect of perception on improving behavioral consistency of GMA among smallholder farmers. On the other hand, farmers' acceptance of GMC measured by intention showed higher than that measured by their actions (Li et al. 2020, 2021; Wang et al., 2016). In particular, practices that involve farm modification and adjusting management, such as rotating GMC for sustainable farming or crop diversification, require adopters to establish a new set of input-output processes during production (Mercer 2004). Consequently, the forgone grain and cash crop production would be a significant opportunity cost for GMA in cropping systems (Bergtold et al., 2019; Yu et al., 2019). Therefore, apart from farmers' adoption intention of GMC, evidence on factors that affect farmers' action of GMC is critical for improving a more detailed understanding of farmers' adoption decisions. Accordingly, it is imperative to identify smallholder farmers' intention-action consistency in GMA while considering the moderating effect of perception (Zhang et al., 2017).

This study explores the smallholder farmers' decisions on GMA and provides targeted policy suggestions to increase farmers' intention-action consistency in GMA. To this end, farmers' adoption intention and action on GMC, and their perceptions of GMC effects were first surveyed. Then, different factors affecting intention, action, and intention-action consistency of GMA were estimated. To the best of our knowledge, this study is the first attempt to explore the intention-action consistency of GMA among smallholder farmers while addressing the importance of perception in improving the consistency. This research investigates different factors that drive smallholder farmers' intention and action towards GMA. It clarifies farmers' underlining aspirations toward policy implementation, which is conducive to optimizing the related policies, and providing suggestions to facilitate GMC in countries and regions with smallholding farms.

6.2 Materials and Method

6.2.1 Study area

The Guangxi Zhuang Autonomous Region (hereafter Guangxi) is located in the subtropical zone of southern China (**Figure 6. 1**). Mountains, hills, and stone mountains account for 69.7% of the total area of Guangxi. The area of arable land is 4.39 million ha, and at the end of 2018, the per capita arable land was approximately 0.08 ha. Consequently, the farmers of this region depend on intensive farming on a limited farmland. In addition to traditional grain crops such as rice and corn, major farming crops include oil crops such as peanuts and camellia seeds, and cash crops such as sugarcane. The proportion of agricultural output value in total production value was 24%, which is twice the national level. Meanwhile, grain crops' sown areas decreased sharply from 63.8% to 46.9%, of which rice decreased from 42.3% to 29.3% from 1995 to 2018. On the contrary, the overall sown areas of cash crops exceeded grain crops by 6.2% in 2018 (Guangxi Statistical Bureau 2019).

From 1972 to 1991, the average annual cultivated area of GMC in winter increased from 0.48 to 0.67 million ha in Guangxi (Li, 2015). The main species included Chinese milkvetch (Astragalus sinicus L.), hairy vetch (Vicia villosa L.), rape (Brassica napus L.), and ryegrass (Lolium multiflorum L.), which are planted in the winter fallow period in a double-cropping or three-cropping system (W. Cao and Huang 2009). Their total cultivated area was reduced by more than 80% to 0.13 million ha from 1990s to 2013 (Guangxi Statistical Bureau 2019). Meanwhile, the consumption of chemical fertilizers increased seven times to 2.56 million tons in Guangxi since the 1990s. The average per hectare chemical fertilizers input reached 661.5 kg, approximately 50% higher than the 434.3 kg upper limit of the national input specifications. Reacting to "The Action to Achieve Zero Growth of Chemical Fertilizer Use by 2020," in 2013, the Agriculture Department in Guangxi issued the "Guiding Opinions on Developing Green Manure Production and Promoting the Construction of Beautiful Countryside" to promote the use of GMC. However, their cultivated areas have grown very slowly, and the share in the total sown area has maintained 1.2% since 2010.

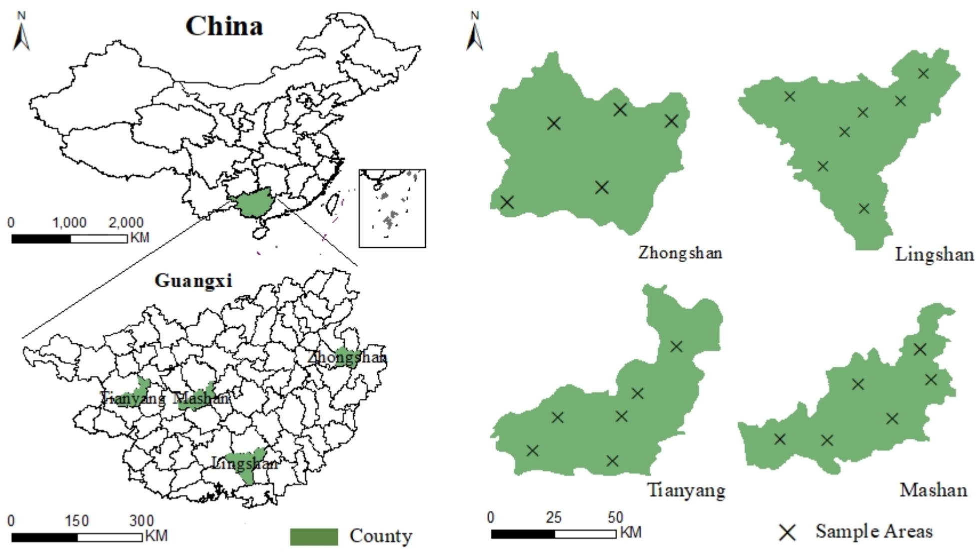

Figure 6. 1 Location of Guangxi and sampled areas

6.2.2 *Field survey*

As this study aimed to investigate farmers' intention to adopt GMC before the policy implementation, as well as farmers' spontaneous adoption of GMC, a stratified random sampling approach was applied in regions where farmers with small holdings could potentially apply GMC while not being chosen in on-farm trials. Data were collected between April and May 2018 from four prefectures in Guangxi (**Figure 6. 1**). First, five to seven counties were selected from each prefecture, and then two to three villages from each county were selected randomly. The unit of analysis was one household. The household head often made decisions regarding major farming issues. Through face-to-face interviews with farmers, 264 households in 24 townships were analyzed. With 240 valid responses, the questionnaire's effectiveness rate was 90.9%. The questionnaire was designed to capture detailed information about the characteristics of the households and farms, farming status including farm systems and crops choices, the social environment of subsidy provision by the government and opinions from neighbors, production conditions of agricultural training and conservation training, adoption intention and action of GMC, and farmers' perceptions of the effects of GMC. Based on Fang et al. (2021) and Arbués and Villanúa (2016), three questions were asked to ascertain farmers' intention, action, and perception of GMA regarding soil conservation and sustainable farming: 1. Do you intend to adopt GMC in the field? 2. Have you planted GMC in the field? 3. Do you perceive the positive effects of GMC adoption?

6.2.3 *Conceptual framework*

To date, various theories and models, including the theory of planned behavior (TPB) (Ajzen 1991), Roger's theory of innovation diffusion (Rogers 2010), have been employed to study farmers' practice adoption behaviors in various realms, such as sustainable farm management (Pratt and Wingenbach, 2016; Yu et al., 2019; Zhang et al., 2017) and environmental friendly practices (Arbués and Villanúa, 2016; Fang et al., 2021; Li et al., 2021). Considering the main objective of this study which is to explore the importance of perception in affecting smallholder farmers' adoption intention, action, and intention-action consistency, a conceptual framework is developed based on the innovation diffusion theory and TPB, which connects two decisions of adoption intention and action of CCA and highlights the moderating role of perception (**Figure 6. 2**).

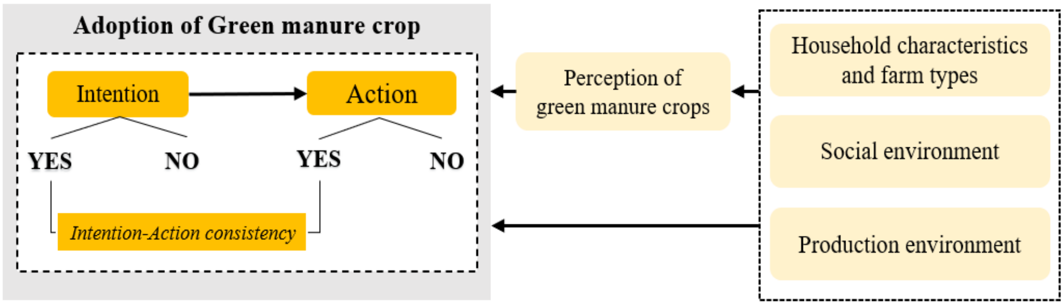

Figure 6. 2 The conceptual framework of farmers' intention-action consistency of GMA

Learning from Arbués and Villanúa (2016), Zhang et al. (2017) and Li et al. (2021), the enhancement of perception can help improve and modify behavior, other explanatory variables might work on adoption decisions through perception. Therefore, the relationship between perception and other explanatory factors was considered in the theoretical framework. The explanatory factors were categorized into three groups: household characteristics and farm types, social environment, and production environment. The variables are classified and defined in **Table 6.1**. Within the theoretical framework, the intention and action of GMA, as well as intention-action consistency, are affected by the perception of GMC' effects, characteristics of households and farms, social environment and production environment.

Table 6.1 Variable definition and description

Variables	Description	Mean	SD	Min	Max
Intention	1 for intend to adopt GMC, zero otherwise	0.73	0.46	0	1
Action	1 for have adopted GMC, zero otherwise	0.12	0.32	0	1
Perception	1 for a positive perception of GMA, zero otherwise	0.68	0.47	0	1
Household characteristics and farm types					
Age	Age of household head (years)	45.72	8.91	27	77
Gender	1 for female, zero otherwise	0.57	0.50	0	1
Education	The educational level of the household head (1 to 4)*	1.50	0.93	0	4
Member	Number of people in the household (numbers)	4.05	2.19	1	12
Mixed farm	1 for mixed crop-livestock farm, zero otherwise	0.28	0.45	0	1
Rice	1 for only cultivated rice, zero otherwise	0.13	0.34	0	1
Social environment					
Subsidy	1 for government should provide subsidy for GMA, zero otherwise	0.52	0.50	0	1
Neighbor	1 for opinion from neighbors have positive influence on GMA, zero otherwise	0.60	0.49	0	1
Production environment					
Training	Times of agricultural training received per years (numbers)	2.04	2.43	0	20
Conservation training	1 for had received conservation training, zero otherwise	0.09	0.28	0	1
Soil quality	1 for GMC could improve soil quality, zero otherwise	0.70	0.46	0	1
Pest control	1 for GMC could control pest, zero otherwise	0.40	0.49	0	1
Landscape	1 for GMC could improve landscape, zero otherwise	0.66	0.47	0	1
Zhongshan	1 for Zhongshan, zero otherwise	0.25	0.40	0	1
Lingshan	1 for Lingshan, zero otherwise	0.25	0.44	0	1
Tianyang	1 for Tianyang, zero otherwise	0.26	0.46	0	1
Mashan	1 for Mashan, zero otherwise	0.25	0.44	0	1

Note: *1=primary school and below; 2=junior high school; 3=high school; 4=college and above.

6.2.4 Model specification

Following Zhang et al. (2017) and Arbués and Villanúa (2016), this study preliminarily applies a probability model, such as the probit model, to analyze the discrete binary variables. The model is expressed as follows:

$$y_1 = \alpha X_i + \varepsilon_i \tag{1}$$

where y_1 is the latent variable representing the utility of respondent i, which allows individuals to choose either of the two options (quantified by 1 and 0). α represents the parameters to be estimated. X_i is the selected explanatory variable. ε_i is the error term.

As the explanatory factor of perception could be endogenous and might lead to inconsistent estimates, which justified the use of a bivariate-probit model as follows:

$$\begin{cases} y_1 = \alpha X_i + \theta y_2 + \varepsilon_i \\ y_2 = \beta Z_i + \mu_i \end{cases} \tag{2}$$

where y_1 and y_2 correspond to the variables of *intention* and *perception*, respectively. Maximum likelihood estimation was performed to estimate the possibility of GMA intention using the two-equation model (2). Then, the same approach was applied to estimate the GMA action, where y_1 and y_2 correspond to the variables of *action* and *perception*, respectively. Following the procedure presented by Wooldridge (2002) and Arbués and Villanúa (2016), the vector of X_i must include some variables that are not included in Z_i. The variables included in X_i and Z_i are listed in **Table 6.2**. ε_i and μ_i are the error terms following a two-dimensional joint normal distribution, as follows:

$$\begin{pmatrix} \varepsilon_i \\ \mu_i \end{pmatrix} \sim \left\{ \begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & \rho \\ \rho & 1 \end{pmatrix} \right\} \tag{3}$$

where ρ is the correlation coefficient of the distributions of ε_i and μ_i. The expected variance of this distribution is 0,1, and ρ. In the bivariate probit model of equation (2), if the null hypothesis of $\rho = 0$ is true, the result of equation (2) is equal to the result of two independent probit estimations; otherwise, the bivariate probit model is needed for the appropriate estimation.

Table 6. 2 Variables included in vector $\boldsymbol{X_i}$ and $\boldsymbol{Z_i}$

Vector $\boldsymbol{X_i}$	Vector $\boldsymbol{Z_i}$
Perception	Age
Age	Age^2
Age^2	Gender
Gender	Education
Education	Member
Member	Mixed farm
Mixed farm	Training
Rice cultivation	Conservation training
Training	Soil quality
Conservation training	Pest control
Subsidy	Landscape
Neighbor	Zhongshan
Zhongshan	Lingshan
Lingshan	Tianyang
Tianyang	Mashan
Mashan	

Furthermore, the consistency of intention and action is represented by the average marginal effects of the intention and action taking two different values (0 and 1) (Ek and Söderholm 2010). The intention-action consistency (*intention* =1, *action* =1) was analyzed by calculating their marginal effects. In this paper, intention-action consistency implies that farmers have both the intention and the action of GMA, excluding the situation where farmers have neither the intention nor the action of GMA.

6.3 Results and Discussion

6.3.1 Descriptive statistical analysis

The descriptive statistics of the mean, standard error, and minimum and maximum values of the relevant variables are listed in **Table 6.1**. Compared with a high proportion of farmers who have a positive GMA perception and intention, only 12% of farmers have adopted this practice. The average age of heads of households surveyed was 45.72 years, and the education level was low. The average number of household members was 4.05. Approximately 28% of the farms were mixed crop-livestock farms, and the livestock were mainly cows, goats, and pigs. Additionally, 13% of farmers cultivated only rice, and the remaining cultivated grain crops with cash crops. Farmers received an average of 2.04 times of agricultural training, while only 8.9% of the farmers had received training related to environmental conservation. Fifty-two percent of respondents indicated that the government should provide subsidies for the GMA. Moreover, 60% of them were influenced by neighbors' opinions. Regarding the functions of GMC, improving soil quality and landscape is approved more than pest control by farmers.

Figure 6. 3 – 6.5 depict the consistency between perception, intention, and action of GMA. As shown in **Figure 6. 3**, 55% of the respondents had both positive perception and intention of GMA. However, the respondents' positive perceptions have not fully translated into their intentions. Thirty percent of respondents had perceptions inconsistent with their intent. Among them, 12% of the respondents had a positive perception but did not want to adopt the practice. Another 18% of the respondents had no positive perception but wanted to adopt GMC. Fifteen percent of the respondents had neither positive perceptions nor intentions to perform GMA. As shown in **Figure 6. 4**, the consistency between perception and action was low. Only 11% of the respondents had both positive perception and action. On the contrary, respondents who revealed positive perception, but no action, shared the highest proportion (56%). Another 32% of the respondents had no positive perception and behavior. As shown in Figure. 5, 61% expressed their intention to adopt GMC while not taking action. Twenty-seven percent of the respondents had neither intentions nor actions. The remaining 12% of the respondents showed consistency in their intentions and actions. In **Figure 6. 3 – Figure 6. 5**, we see a high share of respondents who have revealed both positive perception and intention of GMA while not taking action.

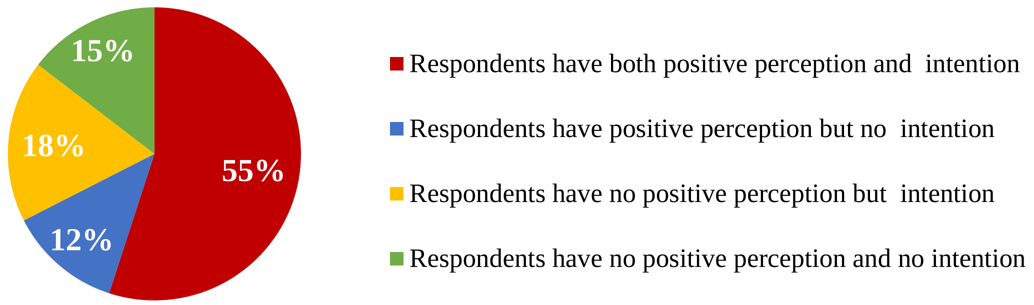

Figure 6. 3. Perception and intention of GMA among respondents (n = 240)

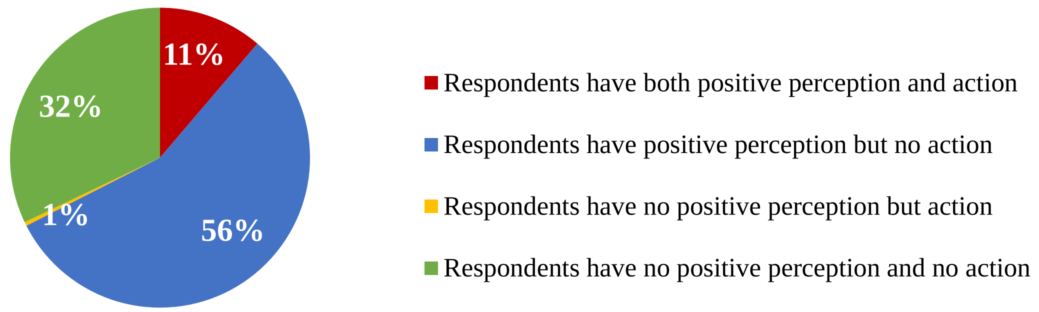

Figure 6. 4. Perception and action of GMA among respondents (n = 240)

Figure 6. 5. Intention and action of GMA among respondents (n = 240)

To ascertain the attitude toward GMC' functions, farmers were asked if they agreed with the following statements (1= least agree, 2= moderately agree, 3= most agree): 1. GMC could improve soil quality; 2. GMC could control pest; 3. GMC could improve landscape. As shown in **Figure 6. 6**, of the 240 respondents, 70.4% agree with the soil quality improvement effect. The landscape improvement effect was also strongly agreed upon by 159 farmers (66.3% of the total farmers). Pest control was least selected, and only 97 farmers (40.4%) agreed with this function.

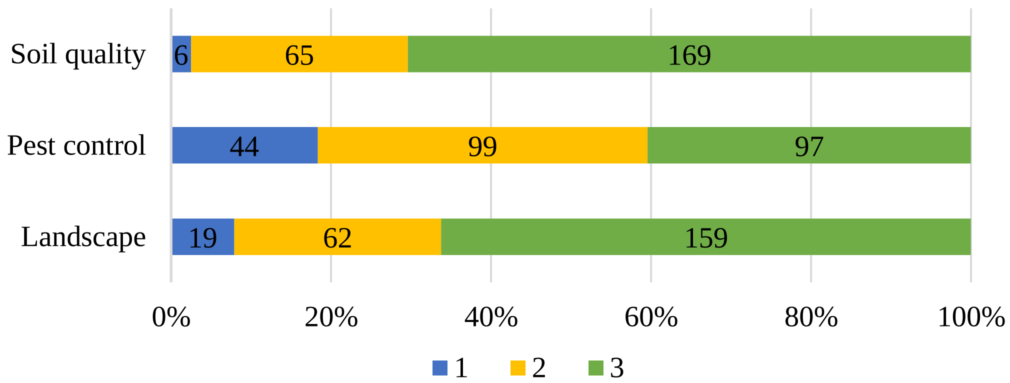

Figure 6. 6. Farmers' attitude toward functions of GMC (n = 240)
(1= least agree, 2= moderately agree, 3= most agree).

6.3.2 Results of empirical analysis

This section presents the results of the estimation of the two-equation model (2), where binary variables y_1 and y_2 correspond to the variables of *intention* with *perception*, and the variables of *action* with *perception*, respectively. We previously carried out estimations to test whether the *perception* variable is endogenous. The relevant tests are summarized in **Table 6.3**. The results of the p-value for perception with intention and with action are both 0.000, and the null hypothesis (H0: $\rho = 0$) can be rejected. The disturbance terms of the two-equation model (2) are correlated; therefore, the estimation is adequate.

Table 6. 3 Wald test and likelihood ratio test of bivariate-probit model

Two models	Wald test		Likelihood ratio test	
	Wald chi^2	p-value	Athrho	Log pseudolikelihood
Perception and intention	171.69	0.0000	0.667***	-181.431
Perception and action	124.07	0.0000	0.998***	-131.659

Note: *** denotes statistically significance at 1% levels.

As shown in **Table 6.4**, the coefficient of perception positively and significantly affects both intention and action of GMA. This result is consistent with previous findings that farmers who have a positive perception of GMC's effects are more likely to adopt GMC (Li et al., 2020; Ntakirutimana et al., 2019; Ren et al., 2020). Furthermore, the higher coefficient in GMA action estimation shows a more substantial impact of perception on GMA action.

First, we focused on the intention to adopt GMC. Female farmers showed a higher intention than male farmers. In Li et al.'s (2020b) study on the intention to accept compensation for GMA, a similar result was reported that female farmers have a higher acceptance rate of the subsidy, showing that female farmers are more easily persuaded by government publicity. The coefficient of *mixed farms* is also positive, as GMC are often used as forage. Moreover, the coefficient of *subsidy* is positive and significantly affects GMA intention, indicating that farmers expect the government to provide subsidies if asked to adopt GMC. Opinions from neighbors have positive and significant effects on GMA intentions. Social learning was found to be a powerful force for adopting new technologies and even more persistent than learning from extension services (Krishnan and Patnam 2014; L. Zhu, Zhang, and Cai 2018). Subsidy does not significantly affect GMA action. The variable of *rice cultivation* is positive and significant, implying that farmers who cultivate rice are more likely to adopt GMC, consistent with Bergtold et al. (2019) and Nong et al. (2020). A foregone cash crop could be the most glaring opportunity cost for GMC, leading to the reluctance to adopt. The positive and significant coefficients of *training* and *conservation training* imply that training is effective in improving GMA intention. In particular, except for traditional agricultural training, conservation training further improves GMA action and perception.

Table 6. 4 Estimations for the *intention* and *action* of GMA with an endogenous variable of *perception*

Variables	Dependent variable: *intention*		Dependent variable: *action*	
	Coef.	Std. Err.	Coef.	Std. Err.
Perception	0.944***	0.265	2.542***	0.509
Age	-0.159	0.108	0.028	0.087
Age2	0.002	0.001	0.000	0.001
Gender	0.419*	0.255	-0.315	0.310
Education	-0.049	0.121	0.107	0.136
Member	-0.051	0.059	0.036	0.065
Mixed farm	0.593**	0.285	0.407	0.292
Rice cultivation	-0.276	0.336	0.843**	0.348
Training	0.048	0.057	0.102**	0.043
Conservation training	-0.308	0.411	0.730*	0.409
Subsidy	0.783***	0.225	0.020	0.248
Neighbor	1.066***	0.224	0.501	0.251
Zhongshan	0.353	0.352	1.061***	0.381
Lingshan	-0.181	0.307	-0.147	0.440
Tianyang	-0.247	0.303	0.536	0.396
Mashan	0.000	(omitted)	0.000	(omitted)
Cons	2.752	2.539	-5.270**	2.365
	Dependent variable: *perception*		Dependent variable: *perception*	
Age	0.118	0.162	0.115	0.111
Age2	-0.001	0.002	-0.001	0.001
Gender	-0.561	0.382	-0.377	0.336
Education	-0.537***	0.189	-0.459***	0.168
Member	0.069	0.089	0.046	0.077
Mixed farm	1.113**	0.441	0.919**	0.395
Training	0.001	0.057	0.038	0.061
Conservation training	1.166*	0.642	1.081	0.700
Soil quality	2.949***	0.460	2.787***	0.414
Pest control	0.099	0.365	0.075	0.337
Landscape	1.999***	0.398	1.849***	0.376
Zhongshan	-0.367	0.494	-0.511	0.450
Lingshan	-0.153	0.468	-0.142	0.481
Tianyang	0.494	0.464	0.433	0.443
Mashan	0.000	(omitted)	0.000	(omitted)
Cons	-5.427	3.762	-5.171**	2.603

Note: *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

In terms of which factor affects the GMA perception, the coefficients of *education* are negative and significant in both models, which is contrary to our expectations that farmers with a higher education level are more likely to obtain more information and, therefore, have a positive perception. The reason for this opposing result might be the low education level of farmers in rural China. The statistical analysis results show that 85% of the respondents had middle school or lower education levels. Of these, 59.6% had a primary school or lower education level. The same result was reported by Zhang et al. (2017), who found that educational level has a negative relationship with awareness of the overuse of chemical fertilizers. Moreover, farmers with high school educational levels tend to obtain more economic income from intensive farming instead of replacing current crops with GMC (Fan et al. 2015).

Mixed crop-livestock farms are more likely to have a positive perception of GMC. The positive coefficient of *conservation training* on perception shows that specific environmental conservation training positively impacts perception. Additionally, the positive and significant coefficients of *soil quality* and *landscape* showed a positive correlation with perception in terms of soil quality and landscape improvement. Moreover, there were no spatial differences between the four locations, except for Zhongshan, in the GMA action. The reason might be the relatively high rate of rice cultivation compared to other three prefectures.

6.3.3 The consistency between intention and action

As shown in Figure. 5, 61% of the respondents have the intention to adopt GMC, but took no action. That is, the promotion of GMC should focus on increasing the intention-action consistency. Following Arbués and Villanúa (2016) and Fang et al. (2021), we conduct a bivariate probit estimation of intention and action. The estimation of variables was consistent with the estimation in **Table 6.4**, indicating robust results. The marginal effects of consistency between intention and action are shown in **Table 6.5**.

Table 6. 5 Estimation results of the farmers' intention-action consistency of GMA

Variables	GMA intention		GMA action		Intention-action consistency	
	Coef	Std. err.	Coef	Std. err.	Odds ratio	Std. err.
Perception	0.778***	0.228	1.347***	0.49	0.109***	0.036
Age	-0.144	0.114	0.039	0.102	0.003	0.008
Age2	0.002	0.001	0	0.001	0	0
Gender	0.397	0.255	-0.499	0.328	-0.04	0.027
Education	-0.077	0.121	0.107	0.156	0.009	0.012
Member	-0.046	0.057	0.039	0.062	0.003	0.005
Mixed farm	0.668**	0.285	0.457	0.294	0.037	0.028
Rice cultivation	-0.28	0.329	0.753*	0.397	0.061*	0.032
Training	0.071	0.058	0.089**	0.044	0.007*	0.004
Conservation training	-0.267	0.419	0.806**	0.407	0.065*	0.037
Subsidy	0.802***	0.22	0.206	0.274	0.017	0.023
Neighbor	1.083***	0.216	0.431	0.287	0.035	0.023
Zhongshan	0.432	0.362	1.110*	0.384	0.090*	0.04
Lingshan	-0.083	0.316	-0.189	0.455	-0.015	0.037
Tianyang	-0.122	0.305	0.58	0.395	0.047	0.033
Mashan	0	(omitted)	0	(omitted)	0	(omitted)
Number of obs	240					
Log-likelihood	-151.127					
Wald	Wald chi2(30) = 158.96, Prob > chi^2=0.0000					

Note: * and *** indicate statistical significance at the 10% and 1% levels, respectively.

The result confirms the positive impact of the perception that with a positive perception, the consistency between intention and action increases by 10.9%. The consistency increased by 6.1% for farms that only cultivated rice. Moreover, agricultural training and conservation training improved consistency by 0.7% and 6.5%, respectively.

6.4 Discussion

The consistency between perception, intention, and action of GMA was clarified, and the estimated results of bivariate probit analysis showed discrepancies in the influencing factors of GMA adoption decisions among smallholder farmers in Guangxi.

6.4.1 Gap between intention and action of GMA

The adoption of sustainable farming practices among smallholder farmers lags behind the Chinese government's expectations (Li et al., 2021; Luo et al., 2016; Wei et al., 2009). In a study conducted by Li et al. (2020b) in the GMC demonstration zones in the paddy fields of southern China, the adoption rate of GMC ranged from 30.8% to 49.9% with subsidy provision of 375 CNY/ha to 675 CNY/ha. The survey results in this study indicate that without economic incentives, the current adoption of GMC in the sampled area is only 12%. Despite the mere 12% application rate of GMC in the sampled area, the respondents showed a high intention to adopt GMC in the future. Consequently, 61% of the respondents showed inconsistencies between their intention and behavior (**Figure 6. 5**). However, this is the status before the GMC are promoted with economic incentives, implying that this gap could be quickly narrowed down by economic support. Incentives manifested by economic subsidy, to some extent, can change farmers' behavior toward sustainable farming (Yu et al., 2019; Zhu et al., 2018). The empirical analysis in **Table 6.4** further indicates that farmers who expected financial support from the government have a higher intention to adopt GMC. However, within the current adoption of GMC, the *subsidy* variable is not significant, indicating that these farmers are influenced by other factors, including rice cultivation. agricultural training and conservation training, instead of economic incentives. Whereas subsidy is an important driver for practice adoption, the analysis in **Table 6.4** generates insights on positive impact of perception on adoption intention and action of GMA and the perception is more influential for the action. Therefore, the strong link between perception and intention-action consistency of GMA should be considered in policies and interventions to address the gap between intention and action (Kenee and Feyisa 2020),.

The adoption rate of GMC in other countries is higher than that in China (Pratt and Wingenbach 2016; Rodríguez-Entrena, Arriaza, and Gómez-Limón 2014; Villanueva et al. 2017; Wauters et al. 2010). In Belgium, Wauters et al. (2010) elicited factors explaining the adoption of soil erosion control practices and found that 50% of the surveyed farmers (69 out of 138 farmers) used GMC, followed by 12% and 13% of reduced tillage and buffer strips, respectively. In Spain, Villanueva et al. (2017) found that GMA in mountainous rain-fed groves is approximately 42.6% compared with 17% of rain-fed and 21.6% of irrigated olive groves. In these studies, profitability and perceived difficulties in practice adoption are the main predictors of adoption (Rodríguez-Entrena, Arriaza, and Gómez-Limón 2014; Wauters et al. 2010). However, the average farm size in these studies ranged from 4 ha to approximately 33 ha. For resource-poor and limited-farm-size holder farmers in China, the opportunity cost causes reluctance in practical adoption. The empirical results of this study also verified that farmers with rice cultivation farms are more likely to adopt GMC than those with cash crop cultivation farms (**Table 6.4**).

6.4.2 Discrepancy in factors affecting intention and action of GMA

Interestingly, regarding the factors affecting the intention and action of GMC, the empirical studies offer varied results. Firstly, besides the positive effect of perception on both intention and action of GMA, the expectation of subsidy increases the farmers' intention for GMA, which is consistent with previous studies (Ntakirutimana et al. 2019; Ren, Yin, and Duan 2020). Although economic incentives are an effective tool to increase farmer participation, long-term adoption still depends on improving farmers' understanding of the effects of GMC, including soil quality and landscape improvement. Zhu et al. (2018) conducted a comparative study in three provinces in China and found that improving farmers' knowledge of the practice is conducive to increase their enthusiasm and satisfaction toward policy implementation. Maximizing the practice's functions is conducive to increasing their acceptance by farmers (Nong et al. 2020).

Secondly, mixed crop-livestock farms have a higher GMA intention, whereas this variable is insignificant in GMA action. Although GMC can be harvested and used as forage, only GMC cannot meet the needs of livestock, and other crop residues are also required (Zhang et al., 2012) and the time cost of GMC is higher than that of the current food crop residue (Nong et al. 2020). Availability and feasibility in production environment are important elements that can interfere in actualizing the behavioral intention (Floress et al. 2018). Therefore, diversifying cropping patterns of intercropping and rotation to gradually adjust the farming systems with GMC could be more acceptable for mixed crop-livestock farms. Moreover, if cultivating GMC means that farmers need to give up the same field for current crops, the pursuit of production and high income impedes farmers from participation, particularly cash crop farmers (Fan et al. 2015; Nong et al. 2020). The positive result of the rice cultivation further certifies that the farms with only rice cultivation are more likely to adopt GMC.

6.4.3 How to improve the positive perception of GMA

The positive coefficients of the *soil quality* and *landscape* suggest that farmers who pay attention to improving soil quality and landscape are more aware of the positive effects of GMA. In previous studies in China, the soil quality improvement effect was more frequently discussed than improving the landscape. Farmers who realize the value of GMC to enhance soil quality are more likely to accept lower economic compensation. In contrast, the values for improving diversity and reducing soil erosion were not found to be effective (Li et al., 2020). Previous studies have primarily focused on the effect of soil conservation, including reducing soil erosion and increasing soil quality, with less focus on its aesthetic effects. Accordingly, aside from soil conservation, it is meaningful to study farmers' different expectations from GMA. Additionally, as ecotourism has been gaining popularity in China, improving the landscape contributes to achieving economic and ecological objectives (Min et al. 2018). Access to available information, such as extensive agricultural training and social connections, provides opportunities for farmers to learn conservational agricultural technologies (Krishnan and Patnam 2014). In particular, conservation training has a positive influence on GMA and intention-action consistency, consistent with the study of willingness-behavior consistency by Li et al. (2021). It has been indicated that households' insufficient knowledge about the composition of the complex fertilizer and fertilization techniques to a large extent has caused the excessive use of fertilizer in rice production in China (Sun, Hu, and Zhang 2019). Apart from incentive payments, combining the fertilizer use technologies with the multi-functional effects of GMC is potentially conducive to increasing farmers' perception of GMC and stabilizing the practice adoption (Yu et al., 2019).

6.5 Summary

This study aimed to investigate smallholder farmers' attitude toward GMC and explore the key factors influencing farmers' decisions to adopt GMC. According to the research objectives, a framework of the influencing factors of farmers' intention, action, and intention-action consistency of GMA was built based on literature research, innovation diffusion theory, and TPB. Then, using a bivariate probit model, a more detailed understanding of farmers' adoption decisions and the importance of perception in improving intention-action consistency was obtained. The main conclusions are as follows.

First, farmers show an intention-action consistency share of 12%, whereas 61% of farmers had a deviation between adoption intention and action. Second, the perception of GMA is effective in improving intention, action, and intention-action consistency of GMA. Moreover, awareness of the soil quality improvement effect and landscape improvement effect influences the adoption decision by working on GMA perception. Third, the empirical results show that the expectation of subsidies from the government, neighbors' opinions and mixed crop-livestock farming cause high GMA intentions. Rice cultivation and training help increase GMA action. Additionally, mixed crop-livestock farms have a higher perception and intention toward GMA. Throughout the estimations, agricultural training, especially conservation training, has a positive effect on the perception and action of GMA.
The findings of this study indicate that related policies and measures should work to increase the intention-action consistency. Based on the estimation results, three policy implications are provided. First, subsidy provision is effective in the early stage of GMA, while long-term adoption should work to improve farmers' GMC perception and environmental awareness. Therefore, multiple uses of GMC, including improving soil quality and landscape, and nutritious effects as forage, should be emphasized when encouraging farmers to adopt GMC. Second, for the knowledge-poor smallholder farmers in rural areas of China, agricultural training, especially soil conservation training, should be provided to establish a positive perception of GMC. Thus, organizing communication and training programs helps to increase knowledge of soil conservation and the intention to participate in conservation practices.

Last, the potential risk of losing crop production and subsequent income hinders adoption. Therefore, supplementing assistance and backup plans to secure farmers' livelihood income, such as agricultural insurance, are required during policy implementation.

Our findings offer insights into the high intention and low action of GMC applications among smallholder farmers. A more detailed investigation of GMC application involved adoption rules and regulations, such as the share of farmland for GMA, adoption period, and specific species with variate incentive levels, might help to elicit farmers' precious adoption preferences for GMC (Floress et al., 2018; Yu et al., 2019). Future research should focus not only on the different influencing factors of adoption intention and adoption behavior, but also on the main factors affecting the intention-action consistency of practice adopters.

CHAPTER 7
EFFECT ANALYSIS OF THE ORCHARD-GRASS- LIVESTOCK INTEGRATED MODEL

Moving from the behavior of CCA to the confirmation of its performance, in chapter 7, an integrated model of fruit-grass-livestock (goat) in orchards is selected as the application of CCA. The economic and ecological effects of the integrated model and the traditional clean cultivation model will be evaluated to provide a comprehensive analysis of the total effects of the practice adoption.

7.1 Introduction

The report of the 19th National Congress of the Communist Party of China raised the topic of strengthening the construction of the ecological civilization and proposed that building a beautiful China should take a green, low-carbon, and circular economic development path. Applying the "3R" principles (e.g reduce, reuse, and recycle) of the circular economy to agricultural production systems can improve resource utilization efficiency, reduce ecological burden, and add value to each production progress, which is an important path for the construction of ecological civilization and green development (C. Yin, Tang, and Zhou 2006). With unique natural conditions and geographical characteristics of terrain and hills, it is an advantage for the southwest regions in China to develop a fruit industry. In the meantime, the ground management in the orchard of the southwest regions is mainly based on clean cultivation plus herbicide weeding (Q. Cao, Shen, and Wang 2016), easily leading to the simplified planting model and causing many problems including soil loss and high level of evaporation. Also, uneven precipitation and large mountainous areas further exacerbating the severe soil erosion and fertility degradation in these regions. All these factors cause the decreasing competitiveness of agricultural products and seriously restrict the sustainable development of the fruit industry economy in southwest China. Therefore, it is urgent to explore a new model of circular agricultural development.

Grass mulching in the orchard as an important application of CCA, can not only increase productivity and improve product quality but also promote the circulation of the nutrients such as soil organic matters and nitrogen, which contribute to mitigating soil degradation, improving soil structure, conserving water, regulating the climate of the orchard and enriching biological diversity (H. Li, Zhao, and Zhang 2005; Q. Li et al. 2000; Yanting Wang, Ji, and Wu 2015). The commonly used species for grass mulching are ryegrass (*Loliumpereenne*), alfalfa (*Medicago sativa*), white clover (*Trifoliumrepens*), etc. These varieties have the characteristics of the shallow root system and large grass quantity and are rich in nitrogen, phosphorus, potassium, and protein, of which the nutrients such as fat and trace elements can often be used as high-quality pasture to feed herbivorous livestock (Z. Shi et al. 2017). Therefore, using grass as a link to the circle agricultural model, on the one hand, can integrate forage planting into agricultural production, on the other hand, can improve soil quality and provide livestock with forage. The representative models include the fruit-grass-livestock/poultry model and cattle-biogas-grass/field crop mode (C. Hong, Liu, and Li 2015).

With the adjustment of the agricultural industry structure and the promotion of grass mulching technology in the orchard, the local governments have carried out the promotion and demonstration of the integrated agricultural and livestock model to explore the suitable model that fits with the local climate, water, and soil resources and other natural conditions. There are two main problems found in the process of model promotion. First, the technology is complex, which is reflected in requiring farmers to master planting and breeding skills at the same time, leading to low acceptance among farmers (P. Shi, Zhao, and Zhao 2016). Second, lacking a comprehensive analysis of these integrated systems. Therefore, it is necessary to conduct comprehensive evaluation and research on the economic and ecological environmental effects of the integrated agricultural circular model and provide a practical and theoretical basis for the government to formulate promotion and support policies.

Existing studies mainly discuss and analyze the comprehensive effects of the integrated agricultural model from the perspectives of resource utilization efficiency, ecological environmental effects, and nutrient and energy cycles (Bell et al. 2015; X. Liu, Jiang, and Li 2017; P. Shi, Zhao, and Zhao 2016). Additionally, the research on the integrated crop-livestock agricultural model in orchard mostly focuses on the effects of grass mulching on soil structure, fertility, and soil ecological environment. There still lacking evaluation of the circular mechanism and comprehensive analysis of both economic benefit and ecosystem service value of grass mulching in the orchard.

Based on field investigations on orchard farmers in Luxi County, Yunnan, this research first systematically analyze the fruit-grass-livestock (goat) integrated agricultural and livestock circular model in Southwest China (hereinafter referred to as the integrated model) based on the ecological circular agriculture theory; second, calculate the ecosystem service value using the ecosystem value evaluation model and the economic benefit; finally, the comprehensive economic and ecological environmental effects of the integrated model and clean cultivation model are compared. This study aims at providing a reference for promoting the use of grass mulching and green agricultural production in orchards.

7.2 Material and Method

7.2.1 Study area

The survey is conducted in Luxi County, Honghe Hani, and Yi Autonomous Prefecture, Yunnan Province (**Figure. 7. 1**). The location is in a low-latitude plateau with a distinct dry and wet climate, which is an advantageous pear producing area in southwest China. The county has 21,900 hm^2 of arable land, 69,100 hm^2 of woodland, 6,000 hm^2 of barren grassland, and close to 50% of low and medium yield fields. Soil degradation is the main ecological problem in Luxi. Consequently, improving soil quality, transforming the low and medium yielding fields, and developing an efficient ecological circular agricultural model that integrates ecological protection and economic development are the keys to the sustainable agricultural development of Luxi.

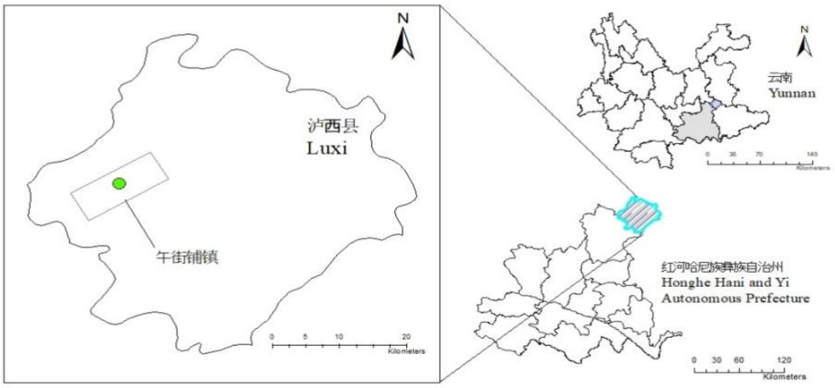

Figure 7. 1 Study area

7.2.2 Data collection

The data was collected by face to face interview in the study area from July to August 2019. The specific implementation is first dividing the 64 orchards in the study area base on their farm-scale and production level according to the statistical data provided by the agricultural technology extension department. Then the random classification is used to sample 25 households from different levels. The total area of the sample orchard is 74.74hm^2, of which the orchard area of the integrated model is 14.74hm^2, accounting for 20% of the total sample orchard area. The content of the survey includes basic information of farmer households, input and output of production, and land use. Here, 25 farms are divided into a clean cultivation model and an integrated model. The basic statistical information is provided in **Table 7.1**.

Table 7. 1 Basic information

Models	Number	Education (year)	Age (year)	Agricultural labor (person)	Farm size (hm^2)
Clean cultivation model (A)	23	8.4	45.8	2.3	2.65
Integrated model (B)	2	7.5	49.0	2.0	7.37

It can be seen from **Table 7.1** that the education levels of the sample households in the two models are mostly from primary to junior high school, and the average age is over 45. Although there are only two sample households in the integrated model, the sampled farms reach a certain scale and provide a demonstration function in the local area. The scale effect of the surveyed sample is not considered in the comparative analysis.

7.2.3 Analysis

A systematic analysis of the integrated model will be firstly conducted to analyze the circulation path of material nutrients and the internal mechanism. Then we will calculate and compare the direct economic benefits, ecological environmental effects, and comprehensive effects of the integrated model and the clean cultivation model, to evaluate the cost and benefits of CCA in orchards.

First of all, the direct economic value includes the cash expenditure of inputs and the cash income of outputs. Then the direct economic benefits are calculated by using the statistical analysis methods to calculate the effect of the integrated model in reducing the production costs such as fertilizers, pesticides, and feed. The total income minus the total expenditure is the net profit. The net profit reflects the differences in the economic benefits of the integrated model.

Secondly, the ecological environment effects are represented by the positive and negative effects of agricultural production on the environment. The agricultural ecosystem includes three parts: the biological components of plants, animals, and microorganisms; the environmental components such as water, soil, and gas, which function as material circulation and energy transfer; the interconnection between biological components and environmental components (Zheng, Wang, and Li 2019). The research on the evaluation of the service value of agricultural ecosystems is generally carried out in two ways. One is to define the measuring indicators and parameters of each component of water, soil, and gas, and use experimental research methods to carry out quantitative research. However, the results of this method are based on indicators and the parameter selections, leading to a big difference in the result. The second is based on the ecosystem service function value evaluation model proposed by Xie et al., (2008) and Costanza et al., (1997) and the "China Ecosystem Service Value Equivalent Factor", to calculate the value of ecosystem services on different spatial scales and agricultural model. This method is one major approach in modern ecology research. Generally, the service function value equivalents are determined based on the value of food production, but they are widely used in different land-use types such as woodland, grassland, and orchard (Jing and Duanwang 2011; Zhao, Gong, and He 2015).

Regarding unifying the evaluation indicators and value coefficients, and comprehensively evaluate the value of the orchard ecosystem, this paper adopts the ecosystem service value evaluation method proposed by Xie et al., (2008) to calculate the service value per unit area (1hm^2) of the orchard ecosystem (positive environmental effects). The ecosystem service consists of 7 aspects: air regulation, climate regulation, water conservation, soil conservation, nutrient recycling, biodiversity, landscape improvement. Since the ecosystem functions of the integrated model are similar to those of woodland and grassland, we first assume that the orchard is a combination of woodland and grassland, and the ecological service function is positively related to the biomass of the system while the mutual disturbance between systems is not considered. The service value of the orchard ecosystem per unit area can be calculated as:

$$V_I = V_{Orchard} + V_{Grass} \tag{1}$$

$$V_{Orchard} = E_i \cdot K_F \cdot L \cdot R_F = E_i \cdot K_F \cdot \left(\frac{1}{1+e^{(1/en-3)}}\right) \cdot R_F \tag{2}$$

$$V_{Grass} = E_i \cdot K_G \cdot L \cdot R_G \cdot AR = E_i \cdot K_G \cdot \left(\frac{1}{1+e^{(1/en-3)}}\right) \cdot R_G \cdot AR \tag{3}$$

Here, V_I,$V_{Orchard}$ andV_{Grass}represent the ecosystem service value of the integrated model, clean cultivation model, and grassland. E_i is the value of food production services provided by the farmland ecosystem per unit area, which is calculated based on the ecosystem service function value evaluation model (Xie et al. 2008). Using data from the 2018 Yunnan Statistical Yearbook and National Agricultural Product Cost and Income Collection 2018, the calculation result is 1774 CNY/hm^2. K_F and K_G are the value equivalents of forest land and grassland ecosystem functions per unit area, respectively. L is the coefficient of the development stage, which is calculated according to the Pearl Growth Curve and the Engel coefficient (en), e is the base of the natural logarithm; R_F is the forestland reduction coefficient. When a high-biomass ecosystem transforms into a low-biomass ecosystem, functions such as air, climate, carbon cycle, and nutrient maintenance will reduce. Accordingly, the planting density of fruit trees per unit area compared to the density of forest land is 0.35 (Ge, Gang, and Ren 2013). R_G is the grassland reduction coefficient, that is, the proportion of the orchard area covered by grass to the total area, taking the value of 0.85; AR is the adjustment coefficient, taking the value of 0.3 according to the experimental results of forage growth cycle and nutrient return ratio (He et al. 1994).

In environmental economic analysis, the environmental cost is used to reflect the economic losses caused by the negative external effects of agricultural production (Guo, Mao, and Ran 2000). We calculate the carbon emissions and chemical pollution costs caused by the input of chemical fertilizers and pesticides.

The environmental cost estimation model of carbon emissions is

$$Q_e = \sum_{i=1}^{n}(C_i \cdot \delta_i \cdot P) \quad (4)$$

Here Q_e is the environmental cost of total carbon emissions, C_i is the amount of carbon emission sources used by the crop i, δ_i is the emission coefficient of the crop, and P is the carbon trading price.

The environmental cost estimation model of chemical pollution is

$$C_p = \sum_{i=1}^{n}(Q_i \cdot MEC_i) \quad i = 1,2,3 \quad (5)$$

Here, C_p is the environmental cost caused by chemical substance pollution, Q_i is the chemical substance input of the crop, and MEC_i is the environmental cost of chemical substance unit input. Referring to Song (2013), Xiang et al (2005), and other scholars on the environmental cost of chemical fertilizers and pesticides in southern my country, the MEC_i value of chemical fertilizers was determined to be 0.54 CNY/kg, and that of pesticides was 25.73 CNY/kg.

7.3 Results

7.3.1 Fruit-grass-livestock (goat) integrated model

The fruit-grass-livestock (goat) integrated model uses grass as a link to connect the three main bodies of fruit trees, livestock (goat), and soil, achieving a multi-level resource and energy utilization (**Figure 7. 2**).

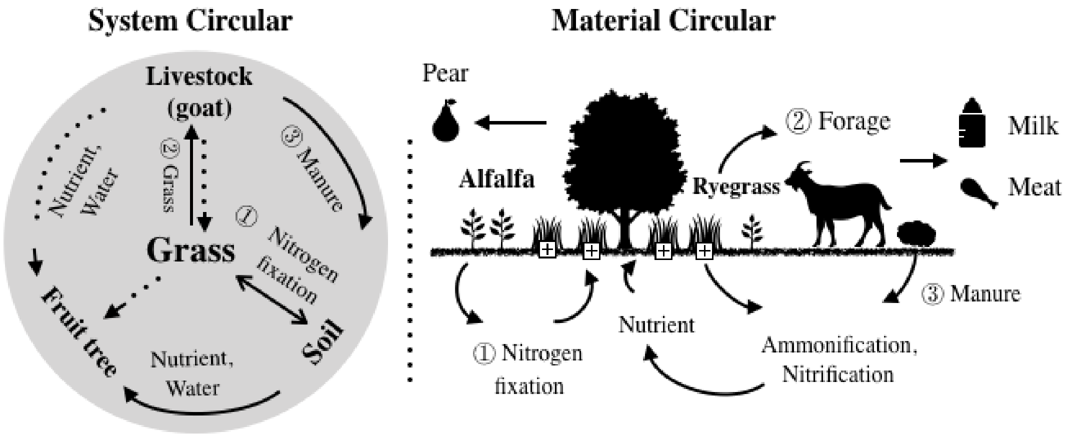

Figure 7. 2 Fruit-grass-livestock (goat) integrated model
Source: drawn by the author

The grass (ryegrass and alfalfa) growing in the orchard first forms the interaction between grass and soil. As the southwest region has abundant precipitation and sufficient sunlight, grass mulching increases the vegetation coverage of the orchard, help to reduce the impact of rain on the soil, including increase the porosity and water infiltration and reduce water evaporation and the soil temperature difference between day and night (Q. Cao, Shen, and Wang 2016). Planting legumes (alfalfa) and grasses (ryegrass) together can promote the accumulation of nutrients such as soil nitrogen and organic matter, increase the microbial diversity and enzyme activity, expand ecological capacity, and enhance natural enemies for pest control, thereby reducing the use of pesticides and fertilizer (Hui, Li, and Long 2010).

Mowing forage to feed livestock forms the connection between planting and breeding systems. Feed input accounts for a relatively high proportion of the breeding cost. Using grass to feed the goat thus can reduce forage input and convert the plant cellulose and lignin contained in the pasture into energy for the goat. Substances are eventually transformed into economic products (meat, goat milk). After digestion and absorption by the goat body, the remaining part is returned to the soil as livestock manure fertilizer, and the soil microorganisms help to produce a series of reactions such as ammonification and nitrification, which increase the soil organic matter and increase the soil nitrogen mineralization rate. The process provides nutrients for both goats and trees while increasing nutrient absorption efficiency (Q. Cao, Shen, and Wang 2016). Comparing the clean cultivation mode, the integrated model extends the food chain with grass and livestock, enriches the orchard ecosystem, changes the nutrient and energy flow paths in the system, which not only improve the utilization efficiency of light, heat, water, fertilizer, and other resources but also achieve the increase of output and economic benefits.

7.3.2 Economic benefits

Figure 7. 3 compares the composition ratio of the planting input cost of the two models. Among them, the proportion of fertilizer input is significantly different, especially the difference in the proportion of chemical fertilizer.

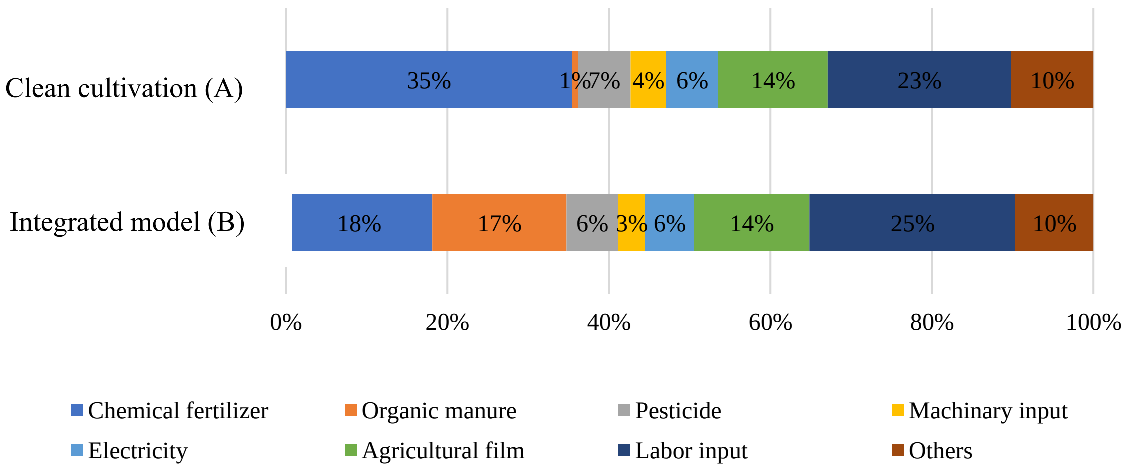

Figure 7. 3 Comparison of the proportion of input costs between the two models

The proportion of chemical fertilizer input in the clean cultivation mode is 35%, and the proportion of organic manure is only 1%, while the proportion of chemical fertilizer input in the integrated model is 18%. The manure ratio reaches 17%. From the perspective of the overall fertilizer input ratio, there is no obvious difference between the two, but its content is quite different. This is reflected in a large amount of manure input in the integrated model. This has been verified in the survey, that farmers of integrated farm appraised the effects of manure. The gap between other cost components is not obvious. The cost of labor input accounts for a large proportion of the total input as the main steps in the production, such as fertilization, bagging, picking, and pruning, all rely on human labor. At the same time, the integrated model increases the step of mowing forage, and the proportion of labor input in the production cost is two percent higher than that of the clean cultivation model.

Alfalfa and ryegrass are planted under the fruit trees. The annual production is 10,344kg/hm^2 and 93,000kg/hm^2 respectively. The daily diet of an adult goat (50kg) is 4kg of grass. Using grass to replace the purchased concentrated corn stalks and other roughages, each goat can save 0.2kg of purchased concentrated feeds and 1.5kg of corn stalks and other roughages every day, saving feed cost 326 CNY a year. Consequently, feeding 60 goats with alfalfa and ryegrass can save 19,560 CNY per year. Through the combination of forage grass, the digestibility and nutrient absorption efficiency of crude protein, crude fiber, and crude fat by goat can also be improved, thereby reducing the amount of concentrated feed and so as the costs (Gou, Zhang, and Li 2007).

The annual output and input of the two models are shown in **Table 7.2** and **Table 7.3**. The fertilizer required for planting fruit trees is returned to the field through goat manure. Comparing the inputs between the two models in **Table 7.3**, the average input of fertilizer is reduced by 6496 CNY/hm^2 (B-A), shared 55% of the model (A). The pesticide input is reduced by 426 CNY/hm^2, shared 19%, the total fertilizer input is reduced by 2,183 CNY/hm^2, shared 18%. The inputs of the integrated model (B) increase in grass seeds, 900 CNY/hm^2. Overall, the integrated model saves parts of the costs in chemical fertilizers, pesticides, and feed, and the output includes fruits, goat, and their by-products. Therefore, not only the total income of the integrated model increase but the net income also increases by 44,399 CNY/hm^2.

Table 7. 2 Comparison of the output of the two models

Model	Total income (CNY/hm^2)		
	Fruit	Meat	Goat milk
Clean cultivation model (A)	94200	-	-
Integrated model (B)	93100	59200	13040

Table 7. 3 Comparison of the input of the two models

Model	Production cost (CNY/hm^2)					Breeding cost	Total cost	Net profit
	Fertilizer	Manure	Pesticide	seed	Others			
Clean cultivation model (A)	11821	264	2292	-	19048	-	33425	60775
Integrated model (B)	5325	4577	1866	900	17298	30200	60166	105174

7.3.3 Ecological environment effect

According to formulas (1)-(3), the results of the ecological service value of the two models of orchards are shown in **Table 7.4** and **Table 7.5**. The total environmental positive effects of the clean cultivation model and the integrated model are 15,413 CNY/hm^2 and 20,338 CNY/hm^2, respectively. The integrated model is 32% higher than that of the clean cultivation model. Also, the inputs of chemical fertilizers for the clean cultivation model and the integrated model are 1,427 kg/hm^2 and 643 kg/hm^2, and pesticides are 46 kg/hm^2 and 38 kg/hm^2, respectively. According to formulas (4) and (5), the carbon emissions and chemical pollution of chemical fertilizers and pesticides are calculated. The negative environmental effects of the clean cultivation model and the integrated model are 2,012 CNY/hm^2 and 1,354 CNY/hm^2, respectively.

Table 7. 4 Positive environmental effects of orchard ecosystem in two models

Model	Positive effect (CNY/hm2)						
	Air regulation	Climate regulation	Water conservation	Soil conservation	Nutrient recycling	Biodiversity	Landscape
Clean cultivation (A)	2684	2528	2541	1069	2497	2802	1292
Integrated model (B)	3363	3235	3229	1666	3511	3648	1686

Table 7. 5 Negative and total environmental effects of the orchard ecosystem

Model	Negative effect (CNY/hm^2)				Total (CNY/hm^2)		
	Fertilizer		Pesticide		Positive	Negative	Net
	C	P	C	P			
Clean cultivation (A)	-49	-771	-8	-1184	15413	-2012	13401
Integrated model (B)	-22	-347	-7	-978	20338	-1354	18984

Note: C: carbon emission, P: chemical pollution; fertilizer and pesticide carbon emission coefficient: 0.8956kg/kg, 4.9319 kg/kg

The integrated model is 33% lower than the clean cultivation model. It can be considered that grass growing in the integrated model increases the net biomass of the orchard ecosystem, increases the amount of carbon sequestration and the amount of oxygen released, and at the same time increases the vegetation coverage, and improves the main air pollution such as SO_2, NO_x and dust retention. The purification function of the air, and thus the value of the air and climate regulation function has been improved. Planting grass can improve the physical and chemical environment of the orchard soil, increase the number of soil aggregates, reduce the soil bulk density, and improve the soil's ability to intercept, absorb and store precipitation, which is concentrated in the water conservation and soil conservation service functions (Hui, Li, and Long 2010). On the other hand, the biodiversity of the integrated model has been significantly improved. As one of the green pest prevention and control technologies, orchard growing grass provides a place for the reproduction and habitat of natural enemies by changing the structure of the orchard biological community and increases the types and numbers of natural enemies, resulting in reducing the pesticide input. The result of the comprehensive analysis is that the integrated model has a higher ecological environmental effect of 5,583 CNY/hm^2 than that of the clean cultivation model.

7.3.4 Comprehensive effect

Combining the economic benefits and ecological environmental effects of the two models, a comprehensive effect comparison analysis is provided in **Table 7.6**. Compared with the clean cultivation model, the integrated model has significant effects in terms of economic benefits and ecological environmental effects. Among them, in terms of economic benefits, the total output value of the integrated model is 165,340 CNY/hm^2, which is 1.76 times that of the clean cultivation model, and the net economic benefit is 44,399 CNY/hm^{2}more than the 60,775 CNY/hm^{2}of the clean cultivation model. In terms of ecological environmental effects, the positive effect of the integrated model is 20,338 CNY/hm^2, which is 1.32 times that of the clean cultivation model, and the negative effect of the ecological environment is 2,012 CNY/hm^2, lower than that of the clean cultivation model. The net ecological environment effect is 18,984 CNY, which is 1.42 times that of the clean cultivation model. Therefore, the comprehensive economic and ecological environmental effects of the integrated model are higher than that of the clean cultivation model by 49,982 yuan/hm^2.

Table 7. 6 Comprehensive effects of orchard ecosystem in two models

Model	Economic benefits			Ecological environment effect			Comprehensive effect	B-A
	Total output	Total input	Net profit	Positive effect	Negative effect	Net effect		
Clean cultivation (A)	94200	33425	60775	15413	-2012	13401	74176	49982
Integrated model (B)	165340	60166	105174	20338	-1354	18984	124158	

7.4 Discussion

In recent years, problems such as agricultural non-point source pollution caused by the increasing application of pesticides and fertilizers have attracted increasing attention. Therefore, reducing the input of chemical fertilizers and pesticides, developing green, environmentally friendly ecological circular agricultural models are the future development directions of agriculture.

It can be seen that the orchard extended the circular system by growing grass and integrated the fruit, grass, and livestock, realizing the efficient use of agricultural resources. It is an orchard ecological circular model with coordinated development of ecology and economy. This study provides insights into the understanding and cognition of the comprehensive value of the orchard ecological system. At the same time, it provides new ideas for sustainable agricultural development in Yunnan and other southwestern regions by exploring the complementary model of planting and breeding industries.

It is worth noting that although the comprehensive effect of the integrated model is higher than that of the clean cultivation model, it also increases the production cost, of which labor input accounts for a large proportion. Given the aging and shortage of rural labor force faced by agricultural production, higher labor costs are the main restricting factors affecting the economic benefits of the integrated model as well as its promotion and application. The high threshold of breeding technology is also the bottleneck of the development of the integrated model. Therefore, there is necessary to improve the technical level of the labor force, increase agricultural productivity, develop small and medium-sized high-efficiency agricultural machinery for the hilly areas of the southern region, and standardize the production and management of orchard. For example, Japan also faces problems in many hilly areas, land shortages, and an aging population. Therefore, the development of small and medium-sized, easy-to-operate agricultural machinery plays an important role in their agricultural production. Therefore, the retention rate of agricultural machinery is high with diverse developing models and completed agricultural mechanization systems. The combination of agricultural mechanization and integrated agricultural management systems can not only alleviate the labor pressure, but also improve agricultural income, increase farmers' production enthusiasm, and promote sustainable use of farmland.

The policy implications are as follows: first, design and improve ecological circular models with the support of scientific guidance, such as grass species and growing methods, which are suitable for the natural resources in various regions, aiming at increasing direct economic benefits while obtaining higher ecosystem service value. Second, take the successful ecological agricultural model as a demonstration, refine the planting and breeding technologies with specific norms and standards. In the meantime, enhancing cooperation with agricultural technology extension stations to carry out technical guidance and demonstrations for lowering technical thresholds and increasing farmers' enthusiasm. Third, it is necessary to reduce the input cost of grass seeds and other production materials to stabilize the income of farmers for the promotion of the integrated model. It is also necessary to provide more subsidies or compensation policies for farmers to adopt relevant technologies. At the same time, it is necessary to improve and strengthen the research on the ecological circular models.

With a limited number of samples and data, this article has not been able to conduct a more in-depth discussion on farmers with multiple planting models and production scales. In the future, it can be classified according to crop types, farming methods, and production models to improve the difference and effectiveness of model comparison and effect analysis. Also, the evaluation and analysis indicators of the comprehensive effects of the model can be further refined, for example, experimental indicators such as changes of fruit quality, breeding weight gain efficiency, and meat quality improvement, to improve the data for a more comprehensive value evaluation.

7.5 Summary

This study analyzed the grass-orchard-livestock integrated circular agriculture model and its economic and ecological environmental effects for promoting the multiple applications of growing grass in the orchards. Based on the ecological cycle theory, this study first systematically analyzed the grass-orchard-livestock (goat) integrated circular model using field survey data from Luxi, Yunnan Province in 2019. Then we calculated the ecological service value of the orchard ecosystem of the clean cultivation model and the grass-orchard-livestock integrated circular agriculture model by utilizing the ecosystem service value model and followed with a comparative analysis of economic and ecological environmental effects.

The results suggested that compared with the clean cultivation, the chemical fertilizer and pesticide savings of the grass-orchard-livestock integrated circular agriculture model were 6496

CNY/hm2 and 426 CNY/hm2, which reduced 18% and 19% of the total fertilizer cost and pesticide cost. Meanwhile, substituting purchasing forage with grasses reduced the forage cost of 19560 CNY/hm2, the direct economic benefit increased 44399 CNY/hm2. Regarding the ecological environmental effect, the grass-orchard-livestock integrated circular model increased 32% of the ecological service value and reduced 33% of the environmental costs for the reduction in the fertilizer and pesticide inputs, resulting in an overall net benefit of 49982 CNY/hm2.

CHAPTER 8

DISCUSSION AND CONCLUSION

In China, there are 200–300 million smallholder farmers with a few hectares of land on each farm, thus the agricultural system relies heavily on high-to-excessive inputs (Cui et al. 2018). To mobilize and encourage them to adopt technologies that simultaneously address production and pollution problems and improve agricultural sustainability has been difficult. In particular, under the structural changes in agricultural production with the growing trend of cash crop productions, smallholder farms tend to use more agrochemicals, which put more risks to the environment. Therefore, examining how the farmers make decisions toward detailed farming practices has important policy implications for the site-specific policy design.

In this study, we focused on the decision-making process from the behavioral intention to behavior and confirmation of the behavior (see **Figure 2. 5** in chapter 2), which was not adequately investigated previously. The decision-making toward SAPs adoption includes three parts: the first part is the stage of behavioral intention (described in chapter 3, chapter 4, and chapter 5), which is further divided into the adoption preferences and the adoption intention toward SFM package; the second part includes both adoption intention and behavior, focusing on the impact of the perception and the gap between the intention and behavior (Chapter 6); and the last part is confirmation of the behavior, meaning to evaluate the comprehensive effects of the behavior (Chapter 7). With these three parts in mind, this final chapter summarizes the findings of chapter 3 to chapter 7 and further discusses the conclusion and policy implications based on these results.

8.1 Discussion

By investigating how the farmers choose to adopt SAPs in various circumstances and analyzing the discrepancy of the choices between the farm households, this dissertation has applied different approaches to examine farmers' decisions on diverse SAPs choice sets or patterns. Farmers are not adverse to change, but proposed changes must fit into their farming systems without altering too abruptly the methods they have developed over time to reduce risk and spread out labor use (page 135) (Norton, Alwang, and Masters 2009).

8.1.1 Precipitation and detail farming strategies

This research shows that applying the discrete choices models (e.g. BWS and DCE) in the process of decision-making about soil conservation or sustainable management can be effective and applicable. As a producer, smallholder farmers do face with various choices, such as which type of SAPs to apply and how to implement the practices in the current farming system. Such models are conducive to proposing hypothetical scenarios of the farming choices, helping to predict the probabilities of choices among farmers. Also, the discrepancy arises in the context of adoption preferences and intentions, both of which characterize farms and farmers in sustainable farming in the northwest and southern China.

Based on the estimation of the BWS estimation, precipitation is a subjective climatic feature affecting the decomposing of cover crops and crop residues in the field. Also, livestock raising show opposite results in grain crop and cash crop farmers, as the grain crop residues are the common forage for livestock instead of cover crops in the northwest regions (W.-S. Zhang et al. 2012). Cash crop farmers are reluctant to cut 50% use of the chemical fertilizers and strongly approve of using organic fertilizer, which could be influence by the long-term influence of training and publication by the government on the effect of organic fertilizers (including commercial and livestock manure) (Shuqin and Fang 2018). Precipitation and livestock raising are important indicators that influence adoption preferences.

The result of cover crop related practices ranked third in the BWS analysis indicated the relatively high possibility of adoption among smallholder farmers in northwest China. Still, the majority of smallholder farmers cultivate grain crops annually. Therefore, the study of DCE was further conducted to identify decisions on diversifying farming with cover crops within two cropping systems. On an empirical level, this research establishes a wide range of results concerning cover crop adoption, which include policy, econometrics estimations, and simulation modeling efforts. To summarize the main empirical findings, **Table 8.1** lists the main results in chapter 3 to chapter 5 in the form of cover crops adoption. Through the cover crop adoption, some evidence of farmers' decisions toward sustainable farming can be obtained.

Table 8. 1 Summary of findings relating to cover crops adoption (northwest China)

	BWS model (Nine SAPs)
1	Both grain and cash crop farmers prefer to cultivate cover crops than **fallow and return crop residue to the farm.**
2	Farmers with **higher income** prefer cover crop cultivation.
3	Compared with grain crop farmers, **cash crop** farmers who raise **livestock** prefer the practice of cover crop cultivation.
4	The cover crop is a plausible solution to the cash crop farmer in the semiarid areas with relatively high **precipitation** levels.
	DCE model (SFM package)
1	Cover crop **intercropping is highly appropriated** in the study area, especially in the D2 with the double cropping system.
2	Cover crop **rotation with extra incentive payment** should be offered for the agriculturally intensive double cropping system.
3	The economic incentive levels **increase** along with the **duration** of SFM adoption.
4	Although with heterogeneity in choosing SFM package, the opportunity cost of cover crop cultivation by **cash crop** farmers is higher that led to opt-out of adoption.

The results indicate that besides the incentive payment, non-economic attributes of cropping patterns, duration of adoption, and technical assistance are effective in predict farmers' decisions in northwest China. Intercropping is generally most preferred in single-cropping and double-cropping systems. Additionally, the cropping pattern of rotation is less favorable in the double-cropping system.

Therefore, intercropping is regarded as the most preferable cropping pattern for cover crop adoption for minimizing the effect of interventions on the current farming system.

The conditional logit estimations in chapter 3 indicate that cover crop is more preferred than the practices of long-term fallow, 50% reduction of chemical fertilizers and pesticides, returning crop residue to filed and biochar. Farmers with higher income and livestock raising are more likely to adopt cover crops, which is consistent with the analysis in chapter 4. Besides, the random parameter logit model estimations further indicated that intercropping is more likely to be chosen to adjust the cropping system toward sustainable development. In part, this is likely due to the higher risk of losing crop production by rotation with current crops. Most importantly, econometric evidence supports that farmers prefer practices that bring fewer changes to their current farming system or the gradual adjustment of the cropping pattern. Apart from these, the latent class analysis of chapter 5 shows that 83% of the respondents (52% of cluster 1 and 31% of cluster 2) is willing to participate in the CCA. These farmers are multiple goals oriented, including incentive payments and duration of adoption of cluster 1, and CCI and CCR oriented of cluster 2.

The problem statement in chapter 1 explained the changes in food demand and in the structure of agricultural production and raised the question of how the adoption differs from the changes. Chapter 3 answered the question and provided statistical results to support the conjecture that grain crop and cash crop farmers differ in their preference for nine SAPs, also household income is correlated with more diverse adoption of the practices. Similarly, livestock farming expanded the usages of cover crops, increasing the odds of its cultivations. Although grain crop farmers were found less likely to adopt cover crops, the estimations showed a positive relationship between wider acceptance and high income of grain crop farmers, indicating that the agricultural structural adjustment brings more capacity for choosing diversified practices and cropping patterns.

8.1.2 Adaptable cropping pattern of SAPs

This research presents studies of smallholder farmers' decisions in different stages of decision-making for SAPs. Within the process of adoption, SAPs are required to be applicable and attractive to farmers under their farming system, and this fact helps explain what is preferred by farmers and which practice they are more reluctant to adapt. Although the preferences and decisions for SAPs were not directly explained by the independent variables of risk and uncertainty, they were explained by the choice for diverse farm management portfolios and packages. For example, five years of duration was the least preferred in the single cropping system as a longer adoption period is accompanied by the higher risk of production loss. Also, the negative utility in the duration of adoption implied higher compensation is needed for ensuring the long-term effect of practices. More importantly, the cropping patterns, duration of adoption, and the technical support for the adoption of the package generate better predictions of farmers' choices. For instance, higher utilities of technical assistance to reduce chemical fertilizer in the double-cropping system show that in the intensive farming area, smallholder farmers are more willing to engage in the measures that help reducing production cost. Costs and risks are the more important factors affecting farmers' decisions to adopt a practice (Luo et al. 2014). Furthermore, the heterogeneity of the choices is remarkable and helpful in characterizing the decision-makers.

This study further confirms that the decision-making of SAPs adoption is made in conjunction with farming portfolios or packages decisions, while farmers may prefer to apply several types of practices (chapter 3), and the detailed technique combinations can alter their decision (chapter 4). Furthermore, opportunity cost can influence the opt-out of participation by farmers. Because their farming choices are made primarily to ensure less impact on the current status, so they must be sensitive to the incentive and the required adjustment to the farm. Without recognizing this point, the research on behavioral intention and actual behavior could be severely disconnected, which is also proved in statistical results in chapter 6. Therefore, research much be performed on the site-specific adoption package closely related to the practical farming decision.

8.1.3 Perception and practice performance

Chapter 6 presented bivariate-probit models to analyze the effect of perception on adoption intention and behavior. Results from the estimations strongly support the conjecture that positive perception influences the intention and behavior of cover crop adoption for soil conservation. However, statistical results also showed that there is a large gap between behavioral intention and behavior. Therefore, for the knowledge-poor smallholder farmers in rural China, training in agricultural technologies and sustainable farming is of great importance. There results are consistent with the previous studies on cover crops adoption among paddy field farmers that training about the soil quality and landscape improvement effects of cover crops increase the participation possibility (Ntakirutimana et al. 2019; Fuduo Li et al. 2020b).

Chapter 7 took the mixed crop-livestock application as an example to evaluate the effects of cover crop adoption in orchards. Results from this chapter demonstrated the increase of the economic and ecological effect in the mixed crop-livestock model compared with the traditional clean cultivation model. As shown, the multiple usages of cover crops not only reduce fertilizer and pesticide but also save cost for purchasing forage. Unlike the other chapters, chapter 7 analyzed the comprehensive value of the application of cover crop in the orchard ecological system. More importantly, by exploring the costs and benefits in the production, the main factors affecting the economic benefits of the integrated model were clarified, providing insights on which part of the costs could be reduced in the future.

8.1.4 Policy implications

As noted in chapter 3, in addition to economic conditions, the cropping differences and climatic features influenced decision making in terms of adoption preferences. Therefore, diversifying SAP combinations should consider local features. Also, within the early stage of decision-making, the smallholder farmers show the tendency of choosing the SAPs and adoption packages with fewer changes to the current farming system. Considering cover crop adoption in both the single-cropping and double-cropping systems of northwest China, the empirical result suggests that the intercropping pattern is more favorable for farmers as they can adjust their farming by gradually adding cover crops into the system. This implies that early adoption should be encouraged by proposing practical intercropping packages with specific crop types and planting seasons involved. Also, an increase in economic incentives increases the probability of package adoption. A longer duration of adoption requires extra incentive for keeping the long-term effect.

Given the results of cover crop adoption and the multi-usages of cover crops explored by early adopters, the public sector should further commit to the practical functions of cover crops and emphasize their multiple uses. At the current stage, building awareness of environmental degradation and establishing a positive perception of the SAPs are proved to be effective in strengthening behavioral intention and behavior. However, the results from southern China did reveal the gap between intention to adopt and the actual behavior of farmers, implying that the potential risk of losing the cash crop production and the sequent income affects their decisions in the practical production. Therefore, successful implementation of such practices requires supplementing technology and program assistance, even a backup plan for securing farmers' livelihood income, such as agricultural insurance.

The incentive payment has been proved to be a necessary and effective approach to stimulate the resource-poor smallholder farmers to adopt SAP. The results in northwest china further imply that the SAPs programs for different practices of crop rotation, managed fallow, and cover crops should allow a flexible subsidy mechanism, considering the utility of the duration of adoption and addition technical requirements are significant for the farmers. More importantly, it is necessary to increase the incentive levels along with the adoption period as the longer duration increases the risk of farmers giving up halfway. Therefore, a mid- or long-term dynamic incentive program should be longer than 3 to 5 years which makes use of the utilities of the cropping patterns of SAPs and the technical supports.

In the study areas where farmers are knowledge poor and among the aged population, agricultural production can no longer simply rely on labor, so the applications of agricultural machinery technology are in urgent need. These outcomes partly arose from the analysis of the behavior performance in chapter 7, and partially from surveys with farmers. This fact possibly has been ignored in environmental policymaking, as the early stage of the SAP adoption primarily focuses on how to stimulate farmers into participation, while how to maintain practices becomes a secondary issue. Therefore, more assistance should focus on reducing the hurdles during practice applications, for example, providing unified supporting machinery and technical services and broadening the access of information.

8.2 Conclusion

This study identifies the key influencing factors in the three stages of decision-making among smallholder farmers in the context of the agricultural structural adjustment. The localized features and farming portfolios have been recognized during each stage of adapting SAPs to the farming systems. Firstly, in the early stage of decision-making, farmers have more capacity for choosing diversified practices and cropping patterns under the condition of agricultural structural adjustment in northwest China. And within these choices, farmers prefer to adapt their current farming systems with practices that require fewer interferences to the land. Also, the incentive payment is one effective tool for encouraging farmers to adopt SAPs, while easily adaptable cropping patterns for the SAPs application help stabilize the long-term adoption. Secondly, the importance of perception has been further proved in both behavioral intention and behavior, therefore, educating farmers on the soil degradation status and improving their involvement in the sustainable farming program will strengthen the influence and impact of the program. Lastly, the confirmation of the SAPs adoption is essential for testing the effects of SAPs and the results reveal that the increasing cost of labor input, high threshold of technology adoption, and lacks of small and medium-sized, easy-to-operate machinery for the hilly areas of the southern regions are the main restricting factors affecting the SAPs promotion and application.

This research established the analytical framework based on the Expected Utility Theory and Planned Behavior Theory. Evidence reported in this study suggests that such transformations of the decision-making among farmers are possible, although the economic risks embodied in new strategies and the potential opportunity cost may be a significant barrier to the investment and adoption of SAPs by smallholder farmers. As farmers' decisions for SAPs adoption are diverse and based on their choices, farmers could be categorized into different clusters. In this study, the proposed packages of SAPs did not take account of the adoption preferences in each cluster. Therefore, the improvements of the SAP packages should involve different levels of incentive payments, preferable technical support, types of insurances to reduce the uncertainty and risk during adoption corresponding to each cluster. With a limited number of samples and data, this study did not conduct a more in-depth evaluation of the environmental and economic outcomes of the SAPs adoption models. Therefore, future research needs to identify detailed experimental indicators such as crop types and farming methods, in order to improve the effectiveness of model comparison and accuracy of effect analysis. Also, more scientific connections between behavioral intention and behavior need to be investigated.

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