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Designing Effective Agri-environmental Schemes in Asia: Empirical Evidence on Farmers' Preferences and Adoption Behaviour

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Summary

Agriculture plays a vital role in the economies of many Asian countries. However, the adoption of intensive agricultural production systems has led to significant environmental challenges such as biodiversity loss, water pollution, soil degradation. Moreover, agricultural production is a significant contributor to greenhouse gas (GHG) emissions, including methane (CH4), nitrous oxide (N2O), and carbon dioxide (CO2), which results in climate change. Therefore, it is essential to promote sustainable agriculture practices (SAPs) in this region to achieve the United Nations' Sustainable Development Goals (SDGs) related to climate action, rural development, and sustainable agriculture. Despite the promotion of SAPs in many Asian countries, their adoption rate remains low. The objective of this thesis is to enhance our understanding of Asian farmers' decision-making regarding the adoption of SAPs and to design effective agri-environmental schemes (AES). The thesis comprises three empirical studies and one systematic review, which examine farmers' behaviour and preferences related to AES and SAPs. The studies cover the following regions: China, Taiwan, and Southeast Asian countries.

The first study is titled "Investigating Rice Farmers' Preferences for an Agri-Environmental Scheme: Is an Eco-Label a Substitute for Payments?" It highlights the negative effects of chemical fertilizer use in agriculture, such as nitrogen pollution and biodiversity loss. The study employs the Discrete Choice Experiments (DCE) approach to investigate rice farmers' preferences in Taiwan for a Chemical Fertilizer Reduction Scheme (CFRS) in order to optimize fertilizer use and examines whether an eco-label and intermediate approach to fertilizer reduction would be attractive to farmers. The findings show that farmers have a significant preference for an eco-label and are willing to accept lower payments in exchange for such labels. They also prefer to retain some flexibility and to opt for partial land enrollment in the AES.

The second study is entitled "The Role of Rice Farmers' Attitude and Trust in Government in Decision-making for Participating in a Climate-related Agri-environmental Scheme". Rice cultivation is identified as a significant source of greenhouse gas emissions, but optimal nutrient management could help to reduce such emissions. Therefore, a Chemical Fertilizer Reduction Scheme (CFRS) is proposed

as a potential tool for reducing agro-chemical inputs. While monetary incentives and regulations may prompt initial adoption decision, they are often insufficient to contribute to long-term changes in farmers' production practices. Hence, the inclusion of psychological factors in AES design is crucial to understand its influences on farmers' sustained commitment and engagement. We employed the hybrid choice model (HCM) which integrates the discrete choice model (DCM) with the structural equation model (SEM) to account for latent psychological variables. In the latent segmentation of the HCM, two distinct farmer classes emerged based on the use of chemical fertilizers. We found farmers who use more chemical fertilizers display a negative attitude towards SAPs and have less trust in government, favouring higher entry payments over the eco-label. Conversely, those using fewer chemical fertilizers value eco-label over monetary incentives. These insights suggest that the contract tailored to farmers' preferences could enhance their engagement.

The third study entitled "Explaining farmers' reluctance to adopt green manure crops planting for sustainable agriculture in Northwestern China". This paper examined data from a survey conducted in Northwest China identifying the reasons behind the low adoption rate of Green Manure Cover Crops (GMCCs) planting. This study proposed a Best-Worst-Scaling method that presents farmers with a set of scenarios involving different bundles of conservation practices, including three types of GMCCs planting. This study also applied the censored regression model, the latent class model and the mixed logit model to understand farmers' preferences. Our findings revealed three factors contributing to the low adoption of GMCCs planting: (1) farmers showed a preference for improving irrigation facilities and substituting chemical fertilizer with organic over GMCC planting, indicating they have other alternative solutions in mind for arable land conservation; (2) limited awareness and understanding of government policies on GMCCs, and (3) insufficient financial support from the government.

The fourth study is entitled "Factors influencing the adoption of sustainable agricultural practices for rice cultivation in southeast Asia: A review". This study follows the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines to examine the most common SAPs for rice cultivation in the region. It delves into the factors influencing farmers' decision to adopt sustainable practices and identifies research gaps for future studies. The findings of this study could help policymakers prioritize and promote SAPs for the future development of rice cultivation in SEA.

Overall, this dissertation enhances our comprehensive understanding of rice and grain farmers' attitudes and preferences in decision-making concerning the AES design and the adoption of sustainable practices. By combining empirical research and systematic analysis, this work not only advances our knowledge but also offers practical insights for policymakers seeking to promote sustainable farming and improve the effectiveness of agri-environmental schemes.

Zusammenfassung

Die Landwirtschaft spielt eine entscheidende Rolle in den Volkswirtschaften vieler asiatischer Länder. Die Einführung von intensiven landwirtschaftlichen Produktionssystemen hat jedoch zu bedeutenden Umweltproblemen geführt, wie dem Verlust der Artenvielfalt, Wasserbelastung und Bodendegradation. Darüber hinaus ist die Agrarproduktion ein bedeutender Verursacher von Treibhausgasemissionen, einschließlich Methan (CH4), Distickstoffoxid (N2O) und Kohlendioxid (CO2), die zum Klimawandel beitragen. Es ist daher unerlässlich, nachhaltige Agrarpraktiken (SAPs) in dieser Region zu fördern, um die Nachhaltigen Entwicklungsziele (SDGs) der Vereinten Nationen in Bezug auf Klimaschutz, ländliche Entwicklung und nachhaltige Landwirtschaft zu erreichen. Trotz der Förderung von SAPs in vielen asiatischen Ländern bleibt ihre Einführungsrate gering. Das Ziel dieser Arbeit ist es, unser Verständnis über die Entscheidungsfindung asiatischer Landwirte hinsichtlich der Einführung von SAPs zu vertiefen und wirksame agrarumweltmaßnahmen (AES) vorzuschlagen. Die Dissertation umfasst drei empirische Studien und eine systematische Überprüfung, die das Verhalten und die Vorlieben der Landwirte in Bezug auf AES und SAPs untersuchen. Die Studien decken die folgenden Regionen ab: China, Taiwan und südostasiatische Länder.

Die erste Studie mit dem Titel "Investigating rice farmers preferences for an agri-environmental scheme: Is an eco-label a substitute for payments?" hebt die negativen Auswirkungen der Verwendung von chemischen Düngemitteln in der Landwirtschaft, wie Stickstoffbelastung und Artenverlust, hervor. Die Studie verwendet den Ansatz der "Discrete Choice Experiments" (DCE) um die Vorlieben der Reisbauern in Taiwan für ein Chemical Fertilizer Reduction Scheme (CFRS) zur Optimierung der Düngemittelanwendung zu untersuchen und prüft, ob ein Öko-Label und ein Zwischenansatz zur Düngerreduktion für die Bauern attraktiv wären. Die Ergebnisse zeigen, dass die Bauern eine signifikante Präferenz für ein Öko-Label haben und bereit sind, für solche Labels geringere Zahlungen zu akzeptieren. Sie bevorzugen es auch, eine gewisse Flexibilität und anteilige Flächenregistrierung im AES beizubehalten.

Die zweite Studie trägt den Titel "The role of rice farmers' attitude and trust in government in decision-making for participating in a climate related agri-environmental scheme". Reisanbau wird als bedeutende Quelle für Treibhausgasemissionen identifiziert, aber optimales Nährstoffmanagement könnte dazu beitragen, solche Emissionen zu reduzieren. Daher wird ein Chemical Fertilizer Reduction Scheme (CFRS) als potenzielles Werkzeug zur Reduzierung von agrochemischen Eingaben vorgeschlagen. Während monetäre Anreize und Vorschriften möglicherweise eine anfängliche Entscheidung zur Einführung anstoßen, reichen sie oft nicht aus, um langfristige Veränderungen in den Produktionspraktiken der Landwirte herbeizuführen. Daher ist die Einbeziehung von psychologischen Faktoren in das AES-Design entscheidend, um seinen Einfluss auf das anhaltende Engagement und die Beteiligung der Bauern zu verstehen. Wir haben das Hybrid-Choice-Modell (HCM) verwendet, das das Discrete Choice Model (DCM) mit dem Structural Equation Model (SEM) verknüpft, um latente psychologische Variablen zu berücksichtigen. Im latenten Segment des HCM tauchten zwei unterschiedliche Bauernklassen auf, basierend auf dem Verbrauch von chemischen Düngemitteln. Wir fanden heraus, dass Bauern, die mehr chemische Düngemittel verwenden, eine negative Einstellung zu SAPs haben und weniger Vertrauen in die Regierung haben und höhere Einstiegszahlungen gegenüber Öko-Label bevorzugen. Im Gegensatz dazu schätzen diejenigen, die weniger chemische Düngemittel verwenden, Öko-Label über monetäre Anreize. Diese Erkenntnisse legen nahe, dass die Anpassung von Verträgen das Engagement der Bauern erhöhen könnte.

Die dritte Studie trägt den Titel "Explaining farmers' reluctance to adopt green manure cover crops planting for sustainable agriculture in Northwestern China". Diese Arbeit untersuchte Daten aus einer Umfrage, die in Nordwest China durchgeführt wurde, um die Gründe für die geringe Einführungsrate von Gründüngerpflanzen (GMCCs) zu identifizieren. Diese Studie schlug eine Best-Worst-Scaling-Methode vor, die den Bauern eine Reihe von Szenarien mit verschiedenen Bündeln von Erhaltungspraktiken vorstellt, einschließlich dreier Arten von GMCC-Pflanzungen. Diese Studie verwendete auch das Censor Regression Model, das Latent Class Model und das Mixed-Logit-Model, um die Vorlieben der Bauern zu verstehen. Unsere Ergebnisse zeigten drei Faktoren, die zur geringen

Einführungsrate von GMCCs beitragen: (1) Bauern zeigten eine Vorliebe für die Verbesserung von Bewässerungseinrichtungen und Düngemittelsubstitution gegenüber GMCC-Pflanzungen, was darauf hindeutet, dass sie andere alternative Lösungen für den Ackerland-Schutz im Kopf haben; (2) begrenztes Bewusstsein und Verständnis für die Regierungspolitik gegenüber GMCCs und (3) unzureichende finanzielle Unterstützung von der Regierung.

Die vierte Studie trägt den Titel "Factors influencing the adoption of sustainable agricultural practices for rice cultivation in southeast Asia: A review ". Diese Studie folgt der PRISMA-Richtlinien, um die gebräuchlichsten SAPs für den Reisanbau in der Region zu untersuchen. Sie geht auf die Faktoren ein, die die Entscheidung der Bauern beeinflussen, diese nachhaltigen Praktiken zu übernehmen, und identifiziert Forschungslücken für zukünftige Studien. Die Ergebnisse dieser Studie könnten den politischen Entscheidungsträgern helfen, SAPs für die zukünftige Entwicklung des Reisanbaus in SEA zu priorisieren und zu fördern.

Insgesamt trägt diese Dissertation zum umfassenden Verständnis der Einstellungen und Vorlieben von Reis- und Getreidebauern in Bezug auf die Gestaltung von AES und die Einführung nachhaltiger Praktiken bei. Durch die Kombination von empirischer Forschung, Literatur und systematischer Analyse trägt diese Arbeit nicht nur zur Erweiterung unseres Wissens bei, sondern bietet auch praktische Einblicke für politische Entscheidungsträger, die nachhaltige Landwirtschaft fördern und die Wirksamkeit von Agrarumweltmaßnahmen verbessern möchten.

Scientific Contributions

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Yi, X., Zu, L., Chang, S.H.E., Yin, C., Wang, H., Zhang, Z. (2021). The effects of China's Organic-Substitute-Chemical-Fertilizer (OSCF) policy on greenhouse vegetable farmers. Journal of Cleaner Production. 297, 126677
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Yi, X., Zou Q., Zhang, Z., Chang, S.H.E. (2023). What motivates greenhouse Vegetable farmers to adapt Organic-substitute-Chemical-Fertilizer (OSCF)? An Empirical study from Shangdong, China. International Journal of Environmental Research and Public Health, 20(2), 1146.
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List of Abbreviations

AES	Agri-environmental Scheme
AECS	Agri-environmental-Climate Scheme
CA	Conjoint Analysis
CFRS	Chemical Fertilizer Reduction Scheme
DCE	Discrete Choice experiment
DCM	Discrete Choice Model
GHG	Greenhouse Gas Emissions
GMCC	Green Manure Cover Crops
HCM	Hybrid choice model
FAO	Food and Agriculture Organization
LCM	Latent Class Model
MNL	Multinomial Logit
MXL	Mixed Logit
PES	Payment for Ecosystem/Environmental Services
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RUM	Random Utility Model
RPL	Random Parameter Logit
SAP	Sustainable Agricultural Practices
SEM	Structural Equation Model
SEA	Southeast Asia
SDGs	Sustainable Development Goals
SP	Stated Preferences
TPB	Theory of Planned Behavior
WTA	Willingness to Accept

1 Introduction

Addressing the increasing demand for food while reducing environmental degradation remains a critical challenge today. Agri-environmental schemes (AES) represent a partnership between agricultural production and environmental stewardship, aiming to harmonize agricultural practices with ecological sustainability (European Commission, 2017). AES are often promoted by offering financial incentives to encourage farmers to engage in environmentally sustainable practices. Unlike the comprehensive and established frameworks in the European Union, AES in Asia presents a different scenario, where such programs are either in the early stages of development or have not yet been implemented. This distinction is crucial, as it not only underscores the relevance of this study to the Asian context but also highlights the substantial opportunity to contribute to an area of policy that is still emerging. Understanding the perceptions and preferences of Asian farmers towards AES can provide foundational knowledge for the development of these schemes, tailored to the specific environmental, economic, and societal contexts of the region's agricultural sector.

To date, most research examining farmers' willingness to engage with AES has focused on evaluating the schemes post-implementation. Such studies are critical for refining the planning and management of existing programs, providing valuable insights into areas for improvement. However, the perceptions and motivations of farmers can evolve over time, particularly as they gain direct experience with specific policies (Teff-Seker et al., 2022). Therefore, understanding pre-implementation perceptions of potential AES in the regions where these polices are still in the developmental phase can offer novel and impactful insights. This understanding can aid in customizing and advocating for AESs that are more aligned with local contexts. This is particularly relevant in various countries in Asia, where AES may not align directly with the European model.

Governments in these regions are increasingly recognizing the need to develop such programs, necessitating research into farmers' preliminary perceptions and the specific dynamics of local agricultural practices. The success of an AES is largely determined by the active participation and commitment of the farming community. Therefore, it is essential for shaping AES that align with farmers' needs, values, and expectations.

Subsequent sections will delve into agricultural production and its environmental challenges in certain Asian countries, shed light on farmers' preferences concerning AES participation, explore factors affecting the adoption of sustainable agricultural practices (SAPs), and present case studies from Taiwan, China, and Southeast Asia. The final subsection of Chapter One outlines the objectives and structure of this dissertation.

1.1 Agri-environmental Challenges and the Role of AES in Asian Region

The Asia region accounts for nearly 60% of the global population, and with its diverse agricultural landscape, it has always been central to global food production, contributing nearly one-fifth of the value of worldwide agricultural and fish commodities output (OECD/FAO 2023). While the Green Revolution brought transformative changes to Asia over the past 50 years, its evolving dependence on agro-chemicals and intensified farming practices has culminated in substantial environmental concerns and is jeopardizing the long-term sustainability of agriculture in Asia (Aryal, 2022).

Agricultural activities contribute to environmental degradation such as biodiversity loss, soil erosion, and water pollution (Ghosh, 2004; Sutton et al., 2011; Stuart et al., 2014). Moreover, the agricultural sector in Asia is responsible for 37% of the world's total GHG emissions produced by agriculture (ADB, 2009). These GHG emissions, including methane (CH4), nitrous oxide (N2O), and carbon dioxide (CO2). Excessive use of chemical fertilizers, particularly nitrogen additions, has been identified as a significant driver of NO2 emissions (Makowski, 2019; Tian et al., 2020). N2O, a potent GHG, is approximately 300 times more harmful to the climate than CO2 (Benghzial et al., 2023). Menegat et al. (2022) estimated global GHG emissions resulting from manufacture, transportation, and application of synthetic nitrogen fertilizers in agricultural systems and also found that the Asian agricultural sector is a significant contributor to GHG emissions. For instance, China leads with 19.3% of global direct soil emissions, followed by India with 13.6%. This has highlighted the urgent need to reduce GHG emissions from agricultural activities while promoting climate-resilient practices in Asia.

Given that more than 41% of the total population in the region relies on agriculture for their livelihoods, it has become imperative to promote and ensure the adoption of sustainable SAPs. These efforts align with multiple Sustainable Development Goals (SDGs), including SDG 2 (Zero hunger), SDG 6 (Clean water and sanitation), SDG 12 (Responsible consumption and production), SDG 13 (Climate action), and SDG 15 (Life on land).

Rice cultivation, widely practiced in Asian regions, plays a vital role in global food security and sustainability of agricultural systems. According to FAO (2014), rice is the most significant crop in Asia, with approximately 90% of the world's production and consumption in this region. However, it is important to recognize that rice cultivation is a notable source of GHG emissions as it releases both methane (CH4) and nitrous oxide (N2O) from rice fields (IPCC 2007). To mitigate these emissions, it is crucial to implement optimal nutrient management strategies and reduce the application of chemical fertilizers (Ahmad et al., 2009; Richards and Sander, 2014; Wang et al., 2017). In addition to rice farming, reduction of chemical fertilizers application is also vital for other staple crops such as wheat and maize (Kumar et al., 2021). The strategies aim to improve nutrient use efficiency, minimize fertilizer runoff and leaching, and mitigate GHG emissions.

In addition to decreasing the reliance on chemical fertilizers, the cultivation of green manure cover crops (GMCCs) in the field of staple crops is recognized as an effective measure for capturing and supplying nutrients, while also offering ground cover to prevent soil erosion (Yang et al., 2018). Implementing GMCCs on arable land has demonstrated significant potential in reducing the reliance on synthetic fertilizers without compromising crop yields (Qaswar et al., 2019; Toma et al., 2019). Moreover, it has been identified as an effective strategy for mitigating climate change (Kaye and Quemada, 2017).

While there have been numerous studies examining agrochemical reduction technologies (Wan et al., 2013; Chantre et al., 2015), there has been a limited focus on understanding farmers' willingness to reduce agrochemical usage. Understanding farmers' decision-making processes is crucial to bridge this gap in knowledge between the implementation of agrichemical reduction technologies and achieving higher adoption rates of SAPs. The low adoption rate of SAPs in Asia has hindered progress in reducing GHGs emissions and mitigating environmental degradation (Castella and Kibler, 2015; Hou and Hou, 2019). Therefore, there is an urgent need to develop effective methods to encourage farmers to adopt these sustainable practices.

In recent years, there has been an increasing focus on addressing the impact of agricultural activities on climate change and environment (Colombo and Rocamora-montiel 2018; Spur et al., 2018; Pakeman and McKeen 2019). In response to the need to address climate change and environmental challenges, the focus of Agri-environmental schemes (AES) has progressively shifted to incorporate concerns related to climate change, leading to the emergence of Agri-environmental-climate schemes (AECS). These schemes aim to tackle both environmental and climate-related issues in the agricultural sector by promoting practices that enhance environmental sustainability and reduce GHG emissions (Hasler et al., 2019).

In Asia, AES can be conceptualized as a type of Payment for Ecosystem Services/Payment for Environmental Services (PES), specifically orientated towards the agricultural sector (Prokofieva 2016). AES generally establish a framework of guidelines and management practices for conserving soil, water, biodiversity, and landscapes that farmers agree to follow, and in exchange, they receive financial compensation to offset potential income losses and additional expenses incurred due to these practices. PES, on the other hand, represents a broader concept that entails compensatory payments to landowners for managing their land in a way beneficial to ecosystems, such as carbon sequestration, water purification, or habitat conservation (Leimona et al., 2015). PES can be applied across diverse ecosystems, including forest, wetland, and agricultural land.

In many Asian countries, PES has been utilized to conserve forests and watersheds, playing an instrumental role in protecting and sustainably managing these vital ecological resources (Leimona et al., 2015; Pan et al., 2017). Moreover, PES in these Asian nations typically relies on funding from governmental initiatives or non-governmental organizations (NGOs). However, these sources often provide only short-term financial support. The absence of stable, long-term funding presents a significant challenge to the ongoing viability and effectiveness of PES programs. Furthermore, AES, which specifically attempt to integrate environmental care into agricultural practices, are notably less prevalent across the region. As of now, comprehensive AES have not been broadly implemented in Asia. This reflects a focus on forest ecosystems within the PES framework, with agricultural landscapes often being addressed through other policy instruments or significantly absent from agri-environmental policy.

In Europe, AES have been well-integrated into agricultural policy frameworks, offering clear data on adoption rates and budget allocations. However, in Asian contexts, such as in China, Taiwan, and Southeast Asia, AES manifest differently, shaped by unique environmental challenges, socio-economic conditions, and policy landscapes. In China, large scale programs, such as the Grain for Green initiative and the Organic-Substitute-Chemical-Fertilizer (OSCF) policy, demonstrate the government's commitment to environmental sustainability (Yi et al., 2021). In Taiwan, agri-environmental policy often features efforts to promote organic farming (Tsai et al., 2021). Meanwhile, in Southeast Asia, PES are diverse, ranging from watershed management to agroforestry (Dang et al., 2021).

1.2 Farmers' Preferences Toward Agri-environmental Schemes

When exploring farmers' preferences and decision-making regarding AESs, it is important to delve into the underlying utility theories. These theories provide a critical insight into how farmers evaluate and choose among various AES options. Utility, in this context, represents the levels of satisfaction or benefit that farmers derive from their choices. Lancaster (1966) suggests that individuals make decisions based on the utility or value they perceive from the attributes of the goods or choices available to them. This utility is subjective and varies among farmers based on their individual preferences and circumstances. The **expected utility theory** framework (von Neumann and Morgenstern, 2004), a traditional cornerstone in the study of economic behaviour, posits that farmers make decisions by considering the expected outcomes of their actions. This theory assumes rational behaviour whereby farmers weigh the potential benefits and risks associated with AESs to maximize their expected utility. For example, by comparing different AES scenarios, farmers assess which option delivers the highest utility. They evaluate factors such as potential yield increases/loss, environmental impacts, and financial incentives to make decisions that align with their economic interests and farming goals (Bocquého et al., 2014). According to the **random utility theory** (McFaccden 1974), which is detailed in Section 2.1., a farmer's decision to choose an AES involves both predictable and unpredictable elements. While farmers make choices based on rational considerations, such as the features of different AES options, their decisions are also influenced by random, idiosyncratic factors.

On the other hand, the **cumulative prospect theory** (Tversky and Kahneman, 1992) offers a more nuanced understanding of farmer preferences, especially under conditions of uncertainty and risk (Finger et al., 2023). It acknowledges that farmers' decision-making is not always purely rational but is also influenced by psychological factors and heuristics. This theory is particularly relevant in explaining why farmers may sometimes make choices that deviate from what is predicted by traditional utility models, such as exhibiting risk-averse or risk-seeking behaviours under different conditions (Bocquého et al., 2014).

In the context of AES, **total utility** refers to the overall satisfaction a farmer gains from participating in such programs, which may include benefits such as improved soil health, financial incentives, or fulfillment of environmental stewardship. **Marginal utility**, on the other hand, is the additional satisfaction gained from an incremental increase in participation or adherence to the scheme's practices. The law of diminishing marginal utility is particularly pertinent when considering farmers' ongoing engagement with AES (Le Coent et al., 2021). Initially, the benefits or satisfaction derived from participating in these schemes may be high. However, as farmers continue to invest more resources or effort, the additional utility gained may start to diminish. This principle can help explain variations in the level and intensity of farmers' participation in such schemes over time.

The correlation between individual preferences and behavioural intentions, as identified in psychological research by Banks (1950), is also pertinent to agricultural contexts. For instance, a farmer's preference for environmentally sustainable practices typically correlates with a stronger intention to adopt AES. This correlation is depicted in **Figure 1**. Individual preferences are influenced by socio-demographic factors, farm management practices, institutional contexts such as policy and regulatory environment, along with a farmer's level of awareness and knowledge of environmental issues. By evaluating the utility derived from these various aspects, we can gain insights into what drives farmers' preference and choices regarding AES participation. The **theory of planned behavior** (TPB), a classic theory used to explain individual's behaviour, suggests that behavioral intentions are influenced by three key elements: (1) Attitudes, encompassing an individual's beliefs, perspectives, and viewpoints about a specific behaviour; (2) Subjective norms, referring to the extent to which an individual perceives a behaviour aligning with the actions of their peers; and (3) Perceived behavioural control, relating to the individual's assessment of their ability to perform a behaviour and their perceived autonomy in decision-making (Ajzen 1991). The TPB has been utilized in discrete choice experiments, serving as a framework to explain the underlying reasons for preference heterogeneity (Sok et al., 2018).

The interaction of these heterogeneous preferences with specific AES attributes, such as incentive payments and contractual obligations, plays a crucial role in shaping farmers' perceived utility. This utility reflects the expected satisfaction or benefits from participating in AES and significantly influences farmers' **stated preferences**. These preferences, indicative of their intentions to engage with AES, are typically elicited through structured surveys with hypothetical AES scenarios. They offer insights into potential actions farmers might take under given conditions.

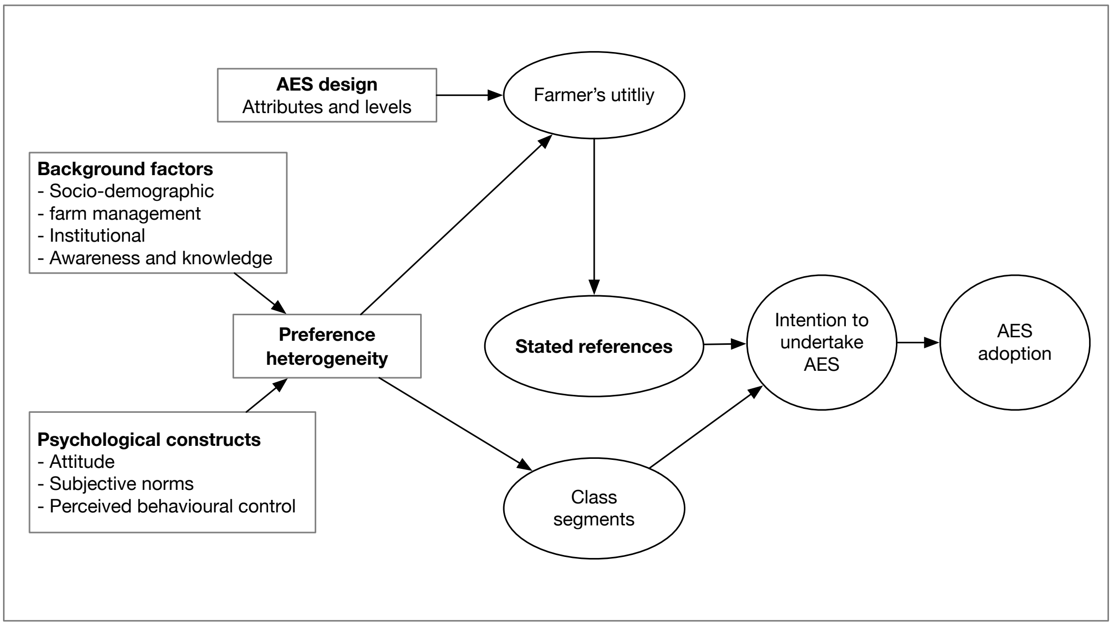

Figure 1 Farmers' preferences and adoption of AES
(Source: Author's own adaptation based on Fishbein and Ajzen (2010))

In terms of farmers' preferences towards AES, an expanding array of empirical investigations have delved into the trade-offs inherent in contract attributes among various farmer groups. Preferences are revealed when a farmer weighs the potential loss of income from reduced crop yields against the long-term sustainability and environmental benefits AES offer. In the other hand, farmers must also evaluate the specific attributes of the AES, such as payment levels, contract lengths, and requirements for management practices, and how these align with their own farm's operational capabilities and future plans.

The study from Ruto and Garrod (2009) found that farmers preferred shorter contracts and less paperwork. Santos et al. (2015) arrived at a similar conclusion, indicating that farmers also preferred shorter contract durations. Lienhoop and Brouwer (2015) discovered that farmers favored shorter contracts and expressed their willingness to accept a lower subsidy if they were offered technical forest management advice and the opportunity to revert to arable land use after the contract termination. Kanchanaroek and Aslam (2018) found that farmers preferred options with moderate reductions in chemical use and shorter contract lengths, demonstrating an aversion to drastic changes in their farming practices. Espinosa-Goded, et al. (2010) found that farmers were willing to accept lower compensation for programs with less stringent restrictions on farm management. Broch and Vedel (2012) found the option of contract cancellation decreased farmers' required compensation level, while including monitoring as an attribute increased their required compensation requirements. Moreover, the research conducted by Hasler et al. (2019) highlight the significant heterogeneity in compensation requirements among different types of farms, noting particularly that crop farmers tend to require higher compensation for set-aside contracts and lower for efficient fertilizer utilization as compared to livestock farmers.

This diversity in preferences highlights the complexity of designing AES, revealing that farmers' choices are not solely driven by economic considerations but also by how well these schemes algin with their environmental values, operational capabilities, and long-term sustainability goals. By acknowledging and incorporating the heterogeneity of preferences into AES design, policymakers can enhance the relevance and appeal of these schemes, thereby increasing their uptake and effectiveness in promoting SAPs. Preference heterogeneity will be addressed in section 2.3.

Farmers' decision-making regarding AES is influenced by a multitude of factors. This variability underscores the need for a detailed exploration of the drivers, barriers, and prevailing gaps in AES adoption, which will be addressed in the subsequent section.

1.3 Adoption of AES in Asia: Drivers, Barriers, and Existing Research Gaps

The adoption of AES has been well-documented in Western countries, revealing various factors that motivate or hinder farmers' participation. However, in Asia, the concept of AES is relatively new, with only a few countries like Japan, Korea, and certain provinces in China having initiated such programs (Zhu et al., 2018; Kim 2020; Maharjan, et al., 2022). Due to the limited data on AES adoption in Asia, this study used the adoption of SAPs, such as organic farming and integrated pest management, or the adoption of PES for agroforestry, as a proxy to understand the possibility of AES adoption in the Asian context. These SAPs and PES, characterized by voluntary adherence and environmental stewardship, share conceptual parallels with AES adoption, though they differ in specific policy mechanisms and incentives. Such an analogy, while not perfect, provides a tentative framework for exploring the potential drivers of and barriers to AES adoption in Asia.

The following content differentiates between influential factors and determinants. Influential factors are a broad category that include the entire range of elements from socio-demographic conditions to behavioural factors, covering all variables that may positively or negatively influence a farmer's decision. Determinants include both 'drivers', which positively motivate farmers towards AES adoption, and 'barriers,' which discourage adoption.

Influential factors

Recent studies in the Asian context provide insights into the factors influencing the adoption of SAPs. Begho et al. (2022) conducted an analysis of factors influencing farmers' decision to adopt sustainable crop farming practices in South Asia. Their study revealed that education, training, extension programs, and access to credit significantly impact farmers' adoption choices. Misa (2014) found that desires for personal health, quality produce, and rural development are factors related to adoption of organic farming in Nepal. In Vietnam, Tran-Nam and Tiet (2022) found that peer influences such as communication frequency and proximity to organic farming neighbors, significantly encourage the transition to organic agriculture. Lu et al. (2023) found that contract farming notably increases the likelihood of adopting organic practices in China, particularly among farmers with less awareness of organic agriculture or those operating on a smaller scale.

Wei et al. (2022) found that farmers joining cooperatives are more likely to adopt green farming practices, with a 35.6% reduction in chemical fertilizer use and a 22% increase in organic fertilizer use. In northwest China, a region grappling with soil erosion and water scarcity, a study by Nong et al. (2020) provides insights into grain and cash crop farmers' adoption preferences for SAPs. Their research found that farmers have notable variances in preference based on household income, livestock ownership, and local precipitation patterns. Ma et al. (2017), exploring the adoption of organic farming among Chinese apple farmers, underscored the significant role of information acquisition. They found that factors such as environmental awareness, access to credit, and information availability positively affect farmers' decisions. Niu et al. (2021) analyzed the impact of the Cultivated Land Protection Fund (CLPF) in western China and shed light on the role of economic incentives in promoting SAPs. They also highlight that factors such as gender, education, household income, and policy awareness significantly affect these behavioural changes.

In Taiwan, a study by Tsai et al. (2021) on the adoption of organic farming among rice farmers found that factors such as the age and education level of farm operators, and the proportion of middle-aged or older household members with college degrees, significantly influence the likelihood of adoption. A study by Takagi et al. (2021), focuses on the adoption of smart agriculture among commercial organic farmers in Taiwan. Their study finds that the perceived attributes of the technology – compatibility with existing farming operations, ease of learning and use, and the potential to increase yield and farm income – are the primary determinants of adoption. Additionally, the opportunity for a trial or test-run significantly increases the likelihood of adoption.

A study in the Philippines by Digal and Placencia (2019) found that factors such as gender, education level, experience in rice production, farm size, and cost per hectare significantly affect the likelihood of adopting organic rice farming. Li et al. (2022) found that risk perception and the environmental regulation of agricultural green production (AGP) significantly influence farmers' willingness to adopt SAPs, with economic risk having the greatest negative impact, and voluntary environmental regulation having the most substantial effect. Their study emphasizes the role of government policies in mitigating economic risks and enhancing sustainable agricultural behaviours through regulatory and voluntary measures. Key determinants identified by Thapa and Rattansuteerakul (2011) include the amount of organic fertilizer consumption, perception of the harmful effect of inorganic pesticides, and experience in growing vegetables. A study from Bui and Nguyen (2021) indicated that farm size, training, access to credit, and market opportunities positively influenced the adoption of organic tea production in Vietnam, while economic motives were a key driver despite awareness of the health and environmental benefits of organic farming.

Drivers of AES adoption

After reviewing the influencing factors, it becomes evident that there are multiple drivers for the probability of adopting AES. Key drivers include economic incentives, policy support, peer influence, environmental awareness, personal health concerns, contract farming, cooperative participation, access to credit, education level, knowledge dissemination, and market opportunities. **Table 1** shows the anticipated drivers and barriers of AES adoption. Below I focus only on the most impactful drivers.

Table 1 Anticipated drivers and barriers of AES adoption

Drivers	Barriers
- Economic incentives	- Economic constraints
- Access to credit	- Environmental constraints
- Environmental awareness	- Political and regulatory constraints
- Extension services	- Risk aversion
- Peer influence	- Lack of awareness
- Personal health concern	- Lack of institutional support
- Contract farming	- Insecure land tenure
- Join cooperatives	- Resource constraints
- Education level	
- Knowledge and Information Dissemination	
- Market opportunity	

Economic Incentives and Access to Credit: Despite budget constraints in many Asian countries that limit government initiatives and policies to support sustainable farming through financial incentives, such incentives remain a significant motivator for farmers. Ma et al. (2010) found that farmers participate in PES programs largely based on whether the financial benefits outweigh the costs. This economic consideration is crucial for small-scale farmers operating under tight budget constraints, as the economic viability of a scheme directly impacts their livelihood. A**ccess to credit** enables farmers to manage the costs associated with SAPs adoption, demonstrating that financial concern is a pivotal factor in the decision-making process. This highlights the crucial role of financial support in mitigating the initial barriers that farmers face when transitioning to AES.

Environmental Awareness: The growing environmental consciousness among farmers could lead to a preference for AES adoption. Xie and Huang (2021) note that farmers with strong environmental awareness are likely to adopt pro-environmental agricultural technologies. Li et al. (2020) suggest that enhancing farmers' awareness of the environmental benefits of practices such as green manure planting could be a more cost-effective strategy for encouraging their adoption.

Extension services: Extension services and training as highlighted by Tran et al. (2019), Sapbamrer and Thammachai (2021), Pham et al. (2021), and Begho et al. (2022), play a crucial role in improving adoption rates in Asia. Policy-driven extension services play a vital role in educating farmers about the AES. By providing training and technical support, governments can help bridge the knowledge gap that often hinders the adoption of AES.

Barriers to AES adoption

Understanding the obstacles faced by farmers when adopting SAPs and PES is also crucial for designing effective AES. In Asia, recent studies have shed light on the constraints. Adhikari (2009) and Leimona et al. (2015) review several PES case studies in Asia, while Yap et al. (2019) in Lao PDR; Pham et al., (2021) in Vietnam, Sujianto et al., (2022) in Indonesia; Lumbo and Salamanca (2023) and Josue-Canacan (2022) in the Philippines; Cao and Solangi, (2023) in China, have all identified a range of barriers to the adoption of SAPs and PES. Their studies have highlighted several key constraints that form crucial areas for attention:

Economic constraints: Transitioning to AES often involves substantial initial costs, which can be a significant barrier, particularly for smallholders (Adhikari 2009). These costs include new equipment, learning new farming practices, and potential decreases in yield during the initial transition phase (Lumbo and Salamanca 2023). Lack of capital was one of the prominent obstacles to adopting SAPs

(Josue-Canacan, 2022). Moreover, economic hurdles, such as the absence of adequate financial incentives and insufficient government support, are key factors that hinder farmers from adopting SAPs in China (Cao and Solangi 2023).

Political and regulatory constrains: The governmental policies exhibit a contradictory situation, as they simultaneously promote organic farming practices, which inherently emphasize no use of chemical inputs, while also subsidizing chemical fertilizers for conventional agriculture (Lumbo and Salamanca 2023). This contradictory policy approach not only confuses the agricultural community but also hinders the broader adoption of organic farming by failing to provide consistent and supportive frameworks that fully align with the principles of sustainable agriculture. Regulatory obstacles, such as bureaucracy and the complicated process of obtaining organic certification (Pattanapant and Shivakoti 2009), not only delay the certification but also place farmers at a competitive disadvantage in terms of market access and optimal pricing opportunities (Lumbo and Salamanca 2023).

Risk aversion: The tendency to avoid risk is particularly prevalent among farmers who are cautious about transitioning from conventional to sustainable farming practices. Their apprehension largely stems from uncertainties associated with the outcomes of adopting new practices. Farmers frequently express concerns about potential decreases in yield, the unpredictability of market price, the variation in weather, and the threat of pests and diseases (Sujianto et al., 2022). Farmers weigh these factors heavily before adopting new agriculture practices. Risk-averse farmers may be hesitant to adopt AES due to uncertainties about the impact on farm productivity, income stability, or the effectiveness of new practices. They may prefer status-quo or tried-and-tested schemes with predictable outcomes.

Environmental constraints: These constraints often stem from the specific ecological conditions of a region, such as soil quality, water availability, and local biodiversity (Pham et al., 2021), which can significantly impact the feasibility and effectiveness of AES. For instance, in areas with poor soil fertility or limited water resources, the implementation of certain AES might not yield the desired outcomes, thereby discouraging farmers from adopting these practices. Moreover, regions that frequently experience extreme weather events, such as frequent droughts, or areas affected by persistent pests and diseases (Yap et al. (2019), face additional challenges. These environmental constraints can diminish the efficacy of AES, making them less attractive to farmers who are already grappling with the uncertainties of agricultural production.

Other drivers exist, such as peer influence (Pham et al., 2021), personal health concerns (Misa 2014), contract farming (Lu et al., 2023), joining cooperatives (Wei et al., 2022), education level (Adhikari 2009), knowledge and information dissemination (Adhikari 2009; Pham et al., 2021), and market opportunity (Adhikari 2009). **Other barriers,** such as lack of knowledge and awareness (Sulaiman and Misnan, 2022; Cao and Solangi 2023), insecure land tenure (Adhikari, 2009; Leimona et al., 2015), and resource constraints, such as insufficient number of laborers (Pham et al., 2021), prevent the adoption of SAPs. However, a detailed exploration of each barrier and constraint is beyond the scope of this study.

Existing research gaps

The above literature discussion reveals several critical gaps that require further exploration, particularly in the context of Asia. Firstly, there is an insufficient focus on the farmers' preferences for specific AES requirements. For example, it is not well understood whether farmers in Asia prefer partial land enrollment or a gradual reduction in agro-chemical input as an intermediate steps toward sustainable farming. Secondly, most existing studies focus on the economic dimensions of AES adoption, often overlooking the complex interplay of non-monetary incentives and psychological factors. Those studies often isolate socio-economic, psychological, or contract-related factors without considering their integration, which is crucial for a holistic understanding. Thirdly, there is limited insight into how farmers in Asia navigate and how to make trade-offs when presented with different SAP options. Most research neglects the importance of understanding farmers' relative preference for various conservation options and alternative practices. This aspect is crucial, as it may significantly influence their willingness to participate in AES. These gaps highlight the need for in-depth research to develop a more comprehensive understanding of the diverse factors influencing AES adoption in Asia. These gaps form the basis of my research questions (detailed in section 1.5).

1.4 Case Studies

Asia's agricultural sector is characterized by intensive farming practices that have been instrumental in meeting the food demands of its vast population. However, these practices often come with high environmental costs, including soil depletion, water scarcity, and pollution due to overuse of agrochemicals.

Table 2 Agro-chemical consumption in selected Asian countries (2021)

Countries	Chemical Fertilizers (kg/ha)	Pesticides use (kg/ha)
Malaysia	2,146	5.51
Taiwan	1,082	13.40
Vietnam	428	4.28
China	375	1.90
Japan	217	11.24
Indonesia	279	5.29
Philippines	232	3.37
Thailand	139	0.84
Lao PDR	51	0.14
Cambodia	50	3.64
Myanmar	39	0.94

Source: The World Bank (2021) and FAO (2021)

Table 2 presents a comparative overview of agro-chemical consumption across various Asian countries for the year 2021, revealing considerable difference in the use pattern of chemical fertilizers and pesticides. Notably, countries such as Malaysia and Taiwan rank as two of the highest for chemical fertilizer consumption in Asia. Central to Asia's agriculture is the prevalence of smallholder family farms. These small-scale farms face unique challenges and constraints, making the adoption of AES both crucial and complex. This highlights the necessity for AES that are not only region-specific but also sensitive to the unique needs of smallholder farmers.

As countries such as China, Malaysia, Taiwan, the Philippines and Vietnam contend with the impact of intensive agricultural practices, their governments need to design and implement effective AES. The region has witnessed rapid economic growth, urbanization, and demographic shifts over the past few decades, all of which have profound implications for agriculture and land use. As such, the way Asian countries navigate the balance between agricultural productivity and sustainability can offer invaluable insights for the rest of the world.

From this perspective, my dissertation presents case studies that specifically focus on grain farmers' preferences and adoption behaviour within distinct Asian contexts. The primary focus is on Taiwan and China. Additionally, a comprehensive systematic review specifically addresses diverse SAPs related to rice cultivation across Southeast Asian nations. Given that AES is not yet implemented in SEA, the insights from this review aim to inform policymakers about the current state of SAP adoption and explore possibilities for future AES policy development and implementation.

1.4.1 Overuse of Chemical Fertilizers in Taiwan

The government in Taiwan has historically focused on subsidizing chemical fertilizers to improve yields. Taiwan has had high fertilizer consumption, with an alarming rate of 1,525 kg/ha in 2005, the second highest in the world (Esty et al., 2005). The extension service has been actively involved in promoting rational fertilizer use since 2007. However, the impact of their efforts on reducing agro-chemical inputs has been slow, with a marginal reduction of 1,352 kg/ha in 2014 (Li, 2015). The provision of chemical fertilizer subsidies has aimed to lower farmers' production costs but is deemed unsustainable due to ecological concerns and budgetary constraints of the government. To address the limitations of the fertilizer subsidy, a study by Chen et al. (2012) suggested implementing a "payment for environmental service (PES)" as a substitute. This alternative scheme could encourage farmers to reduce chemical fertilizer usage without straining the government's budget. Several on-farm field experiments in Taiwan have demonstrated that farmers can save on input costs without significant yield loss by using less chemical fertilizer. Over-application of chemical fertilizer leads the weakening of plants, as excessive nutrient uptake can disrupt the balance of essential elements, inhibit root development, and make plants more susceptible to disease and pests. Several studies have shown that decreasing chemical fertilizer usage by 26% resulted in a 61% reduction in pesticide costs and a 4% increase in yield (Hualien District Agricultural Research and Extension Station, 2009; Liao and Zhu, 2009; Tainan District Agricultural Research and Extension Station, 2009; Tan et al., 2009). To monitor and regulate fertilizer usage, Taiwan implemented the Fertilizer Purchasing Information System (FPIS) in 2015 (Yang, 2015). This system records farmers' fertilizer purchases and can serve as a mechanism to monitor and control the quantity of chemical fertilizer used on each farm.

Although efforts were made to reduce fertilizer consumption through training and showcasing alternative practices, the impact was limited. In 2017, additional subsidy programs were introduced to promote environmentally friendly farming practices, including the subsidies for shipping costs of organic compound fertilizers, microbial fertilizer, farmland fertility improvement fertilizer, organic fertilizers, as well as the continued promotion of rationalized fertilization (COA 2017). We took rice farmers in Taiwan as a case study, since rice farming represents one of the key agricultural sectors of Asian countries. In Taiwan, rice cultivation plays a significant role in the agricultural sector. The annual rice producing area covers approximately 271,506 hectares, which accounts for 33.9% of the total arable land (Huang et al., 2020). This vital crop is primarily cultivated by small-scale producers, highlighting the importance of understanding the preferences and decision-making processes of rice farmers in promoting SAPs.

While previous studies have discussed different approaches to reduce chemical fertilizer application including raising fertilizer prices, enhancing farmers' awareness through extension services, introducing crop management strategies, implementing regulatory restrictions, and offering subsidy incentives (Ghosh, 2004; Wang et al., 2018; Yang et al., 2020; Fan et al., 2023), limited research has been conducted on farmers' preferences for an environmental scheme specifically focusing on chemical fertilizer reduction. Moreover, previous studies examining farmers' preferences for AES have not specifically focused on non-monetary incentives, such as eco-labels, as rewards for complying with agri-environmental regulations. A study conducted by Tanaka et al. (2022) in Japan explored farmers' preferences for eco-certification schemes in relation to outcome-based payment for ecosystem services (PES). It is important to note that their study was published after the data collection and publication of my paper in 2017 (Study I) entitled "Investigating rice farmers' preferences for an agri-environmental scheme: Is an Eco-label a substitute for payment?". Thus, the study of Tanaka et al (2022) could not serve as a basis for my research.

My Study I addressed farmers' preferences for non-monetary rewards, such as eco-labels for complying with agri-environmental regulations. We also offered an intermediate approach for the scheme design to investigate farmers' preferences for gradual reduction of chemical fertilizer use and partial land enrollment. Furthermore, acknowledging the significant impact that psychological factors have on farmers' decision-making, my Study II delves into the role of trust and attitudes towards AES adoption by integrating these psychological dimensions with observable data. This integrative approach allows for a thorough examination of how intrinsic factors, such as trust in government and attitude towards implementing SAPs, interact with external factors, including the specific features of AES contract and the socio-demographic contexts of the farmers.

1.4.2 Green Manure Crops Planting in China

In the 1990s, a fertilizer manufacturing subsidy (FMS) policy was implemented in China to ensure the availability of affordable fertilizers (Wang et al., 2022). Despite its aim to support agriculture, the policy led to environmental pollution due to the overuse and misuse of chemical fertilizers. Guo et al. (2022) further revealed that financial support has a notable negative effect on carbon emissions, and significantly influences the usage of chemical fertilizer. In response to growing concerns regarding the agricultural sector's contribution to climate change and environmental pollution caused by excessive chemical fertilizer usage, the Chinese government has been actively implementing national conservation measures and incentives in order to encourage farmers to adopt sustainable farming practices. These measures include “zero growth in the use of chemical fertilizers and pesticides by 2020” (Jin and Zhou, 2018), eco-compensation (Zhu et al., 2018), implementing fallow land programs (Zuo et al. 2020), promoting the cultivation of green manure/cover crops (GMCCs) (Li et al. 2020), and substituting chemical fertilizers by organic fertilizers (Yi et al. 2021). Besides substituting chemical fertilizer by organic fertilizers, GMCC planting is particularly emphasized by the government as it can serve multiple purposes, including water retention, reduction of chemical fertilizer usage, improvement of soil fertility, mitigation of nitrate leaching (Zuo et al., 2020) and of climate change (Kaye and Quemada, 2017).

Despite these benefits, the adoption rate of GMCCs remains low, especially in arid and semi-arid regions of China, such as the northwest (Xie and Chen, 2012). Study III was conducted in Gansu Province, which is recognized as one of the most representative arid and semi-arid regions in China, grappling with water scarcity and severe ecological degradation such as soil desertification, which has resulted in a decline in arable land utilization (Yang et al., 2019). Gansu is one of the provinces in China which exhibits higher yield scaled GHG emissions for wheat and maize production (Chai et al., 2019). This province holds significant importance in Northwestern China due to its economic and ecological conditions, particularly in its ecologically vulnerable regions. As an agricultural province with a substantial rural population, it is faced with challenging ecological circumstances. The region experiences a climate that is unfavorable for agricultural production, characterized by an annual precipitation of approximately 300mm and frequent droughts. Rainfall distribution is inconsistent throughout the year and varies significantly on an annual basis (Liao et al., 2008). The survey for Study III covered four cities[1] in Gansu Province: Linxia (Hui Autonomous Prefecture), Pingliang City, Wuwei City, and Zhangye City. The primary crops cultivated in these regions are wheat, maize and potato, while common intercropping systems include wheat/maize, cumin/maize, and watermelon/maize.

[1] According to the administrative divisions of the People’s Republic of China, there are three levels of cities, namely provincial-level, prefecture-level cities, and county-level cities. Linxia is a county-level city, and Pingliang City, Wuwei City and Zhangye City are prefecture-level cities.

Notably, approximately 80% of freshwater resources are utilized for agricultural irrigation purposes in these areas (Akiyama et al., 2018).

To gain a better understanding of how alternative practices may impact farmers' adoption decision, Study III allowed farmers to make trade-offs choosing the most preferred and least preferred of the nine arable land conservation practices. This research provides valuable insights for policymakers by highlighting the need for a new approach that goes beyond solely increasing monetary incentives to promote the AES participation. By considering farmers' broader preferences and evaluating the relative preference for different conservation practices, policymakers can design more effective strategies to encourage participation, leading to more sustainable outcomes.

1.4.3 Sustainable Agricultural Practices in Southeast Asia

To complement specific studies in China and Taiwan and provide a broader perspective, a systematic review of adopting SAPs for rice cultivation, centered on Southeast Asia, has been included. Southeast Asia (SEA) is renowned for its rich biodiversity and encompasses several global biodiversity hotspots (Ng et al. 2020). The region consists of eleven countries, with agriculture, fisheries, and forestry playing vital roles in their economies. However, the rapid growth of population and economic development have resulted in conflicts between natural resource conservation and human activities. Moreover, the agricultural intensification, involving the use of chemical fertilizers and pesticides, has contributed to environmental pollution. According to projections by Sodhi et al. (2010), it is estimated that by the year 2100, SEA could lose between 13% and 42% of its species, with potentially half of these losses leading to global extinctions. Additionally, it was projected that ecosystems in SEA will continue to deteriorate throughout the coming century (Estoque et al., 2019). A systematic review conducted by Lam et al. (2017) suggests that agricultural intensification poses significant health risks for communities in the region. These studies collectively highlight the urgent need to balance economic growth with sustainable practices and conservation efforts in SEA to protect its rich and unique biodiversity. Consequently, researchers propose that this region should employ a variety of interventions, including improved crop management methods and pest control as well as risk reduction in lowland rainfed ecosystems (Yuan et al., 2022).

SEA accounts for 26% and 40% of global rice production and exports (Yuan et al. 2022). Rice production is both a victim of and contributor to climate change. In addition to climate change, SEA confronts multiple challenges including degrading ecosystems, biodiversity loss, soil erosion, and water scarcity (Dang et al., 2021). These environmental issues further exacerbate the challenges faced by the rice production sector. The six major rice-producing countries in SEA are Cambodia, Indonesia, Myanmar, Philippines, Thailand, and Vietnam. It is worth noting that rice production in SEA predominantly relies on smallholder farmers, who play a vital role in sustaining local and regional food security. One of the significant constraints for achieving sustainable rice production in the region is the rapid growing use of agro-chemicals, which not only poses environmental risks but also affects the long-term productivity and resilience of rice ecosystems. Furthermore, emissions from rice fields and burning of rice straw further contribute to air pollution and environmental challenges. Addressing these challenges requires concerted efforts in promoting sustainable rice production practices, improving resource management, enhancing resilience to climate change, and supporting smallholder farmers in adopting more sustainable and efficient farming techniques.

1.5 Objectives and Structure of the Thesis

Many Asian countries have recognized the significance of SAPs and have implemented various measures to encourage their adoption. My dissertation aims to contribute valuable insights into the development and implementation of effective AES that align with the needs and preferences of farmers in Asia. Considering Asia's significance in the global agricultural landscape and the need for sustainable practices, promoting AESs is important when mitigating the adverse environmental effects of agriculture, ensuring food security, and enhancing farmers' livelihood.

According to Batáry et al. (2015), the effectiveness of AES depends on how easy it is to implement, and its scalability and acceptability to farmers. The implementation of AES requires significant financial support. However, the level of funding may not be sufficient in most Asian countries, making AES design for these regions more challenging. As highlighted by Leimona et al. (2015), the interplay between financial and non-financial incentives is crucial for farmer engagement in Asia. While financial payments are important, adjusting them to cover the actual opportunity costs of farmers is often challenging due to funding constraints. Governments might be able to enhance farmers' engagement with AES by complementing financial incentives with non-financial benefits, especially where the monetary compensation may not fully meet farmers' needs. Therefore, the objective of this dissertation is to explore innovative approaches and strategies for designing AES that can maximize environmental benefits while considering the financial constraints in Asian agricultural systems. The importance of effective AES design for addressing environmental challenges and climate change has grown, making them a valuable policy instrument for incentivizing Asian farmers and addressing specific environmental concerns.

The following research questions are crucial in assessing farmers' preferences for AES:

- What is the influence of non-monetary incentives compared to financial incentives in motivating farmers to participate in AES?
- What do farmers prefer for the intermediate approach? Partial land enrollment or gradual reduction of agro-chemical inputs?
- What role do psychological factors play in farmers' decision-making regarding AES participation?
- How do farmers assess the necessity for trade-offs when considering various SAPs?
- How can policy interventions be designed and tailored to align better with farmers' preferences and to maximize the effectiveness of AES?

This dissertation delves into the decision-making processes of farmers, exploring the trade-offs they face when considering SAPs adoption and participation in AES. This dissertation employs various choice modeling techniques to investigate farmers' preferences and adoption patterns, contributing to the existing knowledge in this field. By investigating farmers' preferences and examining the factors that influence their choices, including economic, environmental, and socio-psychological considerations, this dissertation aims to provide policymakers with valuable insights for the design and implementation of effective AESs.

The dissertation consists of three empirical studies conducted in Taiwan (Study I, II), China (Study III), along with a systematic review covering Southeast Asian countries (Study IV). An overview of the studies included in the dissertation is depicted in **Figure 2**. Study I focuses on assessing farmers' preferences for the Chemical Fertilizer Reduction Scheme (CFRS) using the Discrete Choice Experiment (DCE) approach to assess farmers' preferences for scheme attributes in rice cultivation. Study II extends the first study and aims to deepen our understanding of complex farmers' preferences for AES by integrating socio-economic and psychometric factors simultaneously. The Hybrid Choice Model (HCM) is employed to integrate psychological factors with observable attributes in the choice modeling. Study II contributes to the existing literature by providing a thorough analysis that takes into account contract attributes, socioeconomic and psychometric variables in understanding farmers' decision-making processes regarding AES participation.

Study III aims to investigate Chinese farmers' preferences in planting GMCCs by applying the Best-Worst Scaling (BWS) method. Study IV presents a systematic review focused on the adoption of SAPs in rice cultivation across Southeast Asia. This comprehensive analysis aims to identify and synthesize the key factors influencing SAPs adoption in the region. By incorporating the findings and factors identified in this dissertation, future AES can be tailored to the specific needs and challenges of Asian countries, ensuring that they are well-suited to the local contexts and address farmers' preferences.

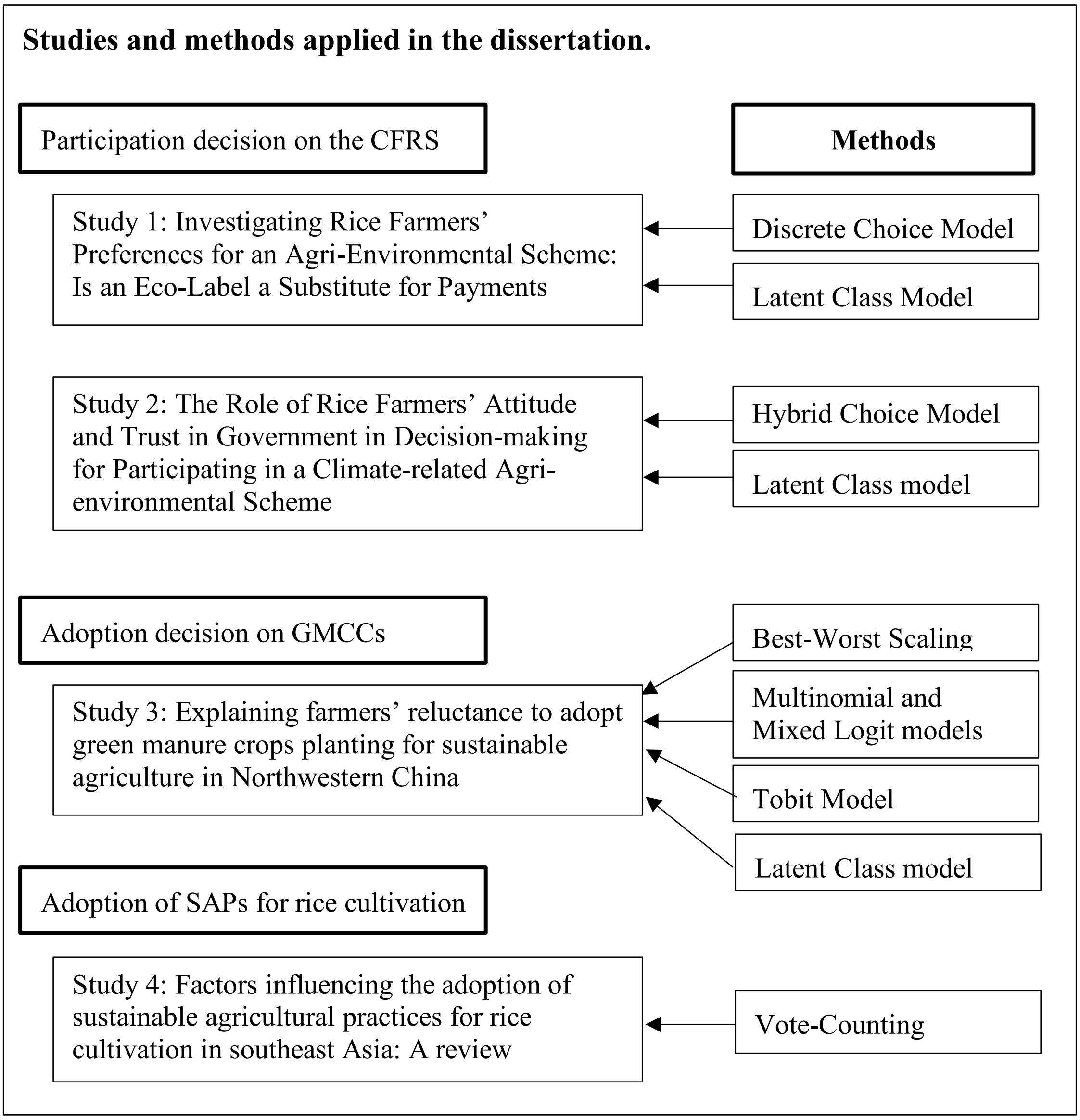

Figure 2 Overview of studies in the dissertation

Chapter 2 presents the conceptual framework, introducing essential concepts that set the stage for the research. Chapter 3 delves into the materials and methods employed throughout the dissertation. Chapter 4 summarizes three empirical studies conducted in China and Taiwan. Chapter 5 presents a systematic review of SAPs for rice cultivation in SEA. Lastly, Chapter 6 discusses the findings of the research, drawing connections between the empirical studies, addressing the limitations, and providing recommendations for future research and policy development.

2 Conceptual Framework

In the conceptual framework of this dissertation, three central pillars shape farmers' decision-making regarding AES adoption: Random utility maximization, opportunity costs and preferences heterogeneity. We assume a farmer, aiming for profit maximization, is faced with the choice of entering an AES contract or not. The decision to adopt AES is driven by the anticipated rise in land profitability due to a shift in farming practices or land allocation. In making this decision, farmers weigh up the immediate and future benefits of AES against the opportunity costs, which may include foregone profits from conventional farming practices or investments in other ventures. Further, the heterogeneity in farmers' preferences, influenced by their individual experiences, beliefs and situations, complicates this decision-making. This framework is depicted in **Figure 3**. It segregates variables into observed and unobserved variables. Observed variables, such as farmers' preferences on AES contract attributes, their socio-demographic backgrounds and farm-specific characteristics, provide tangible insights into their decision-making. On the other hand, unobserved variables rooted in psychological elements highlight the latent influences that affect farmers' preferences and choices.

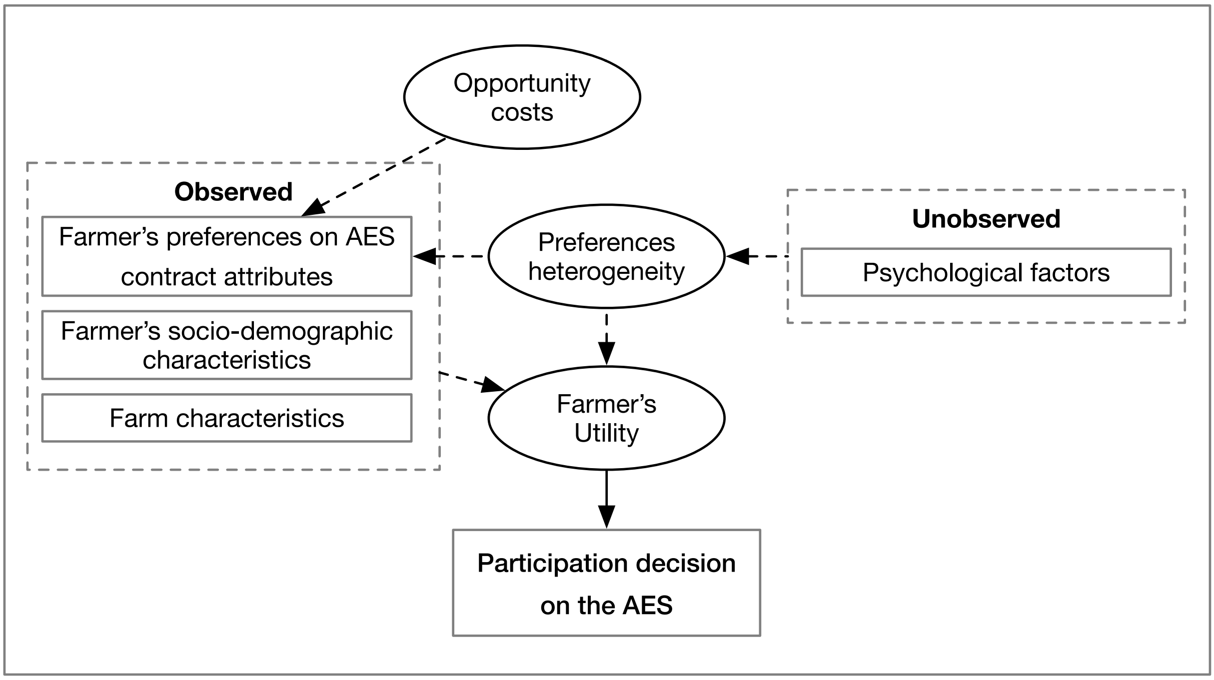

Figure 3 Conceptual framework of factors influencing AES adoption decision

2.1 Random Utility Maximization

Random Utility Theory (RUT) serves as a fundamental framework in discrete choice modeling (McFadden, 1974), representing the most common approach used to analyze individual choice behaviour. Its roots can be traced back to psychology, with Thurstone (1927) introducing the Law of Comparative Judgement. Thurstone's concept explored the theoretical implications of choice probabilities resulting from maximizing utilities that contain random elements. Later, Marschak (1959) further linked the concept of random utility to the theory of individual choice behaviour developed by Luce (1959). The concept of Random Utility Maximization (RUM) posits that individuals faced with various alternatives aim to maximize their utility or satisfaction (McFadden 1986), comprising both observed attributes of the alternatives and unobserved (random) elements that account for individual preference. When individuals make decisions, they are aware of the opportunities and constraints presented by different choices. By gathering and evaluating information about the attributes of available alternatives, they form perceptions and beliefs about these options (Kamargianni et al., 2014).

2.2 Opportunity Costs

Opportunity costs refer to the value of the next best alternative that must be foregone when a particular choice is made. In the context of AES, understanding opportunity costs is crucial as it represents the trade-offs that farmers face when allocating resources between agricultural practices and environmental measures. Opportunity costs play a crucial role in farmers' decision-making when choosing between different options. According to Schaub et al. (2023), opportunity costs for a farmer are defined in line with the conventional economic perspective, referring to what farmers sacrifice in terms of utility, considering both costs and benefits, when they choose one option, such as adopting environmentally friendly practices, over an alternative option. When farmers consider participating in AES or adopting SAPs, the opportunity costs arise from the trade-off between implementing environmentally friendly practices and pursuing profit-maximizing activities (Mewes et al., 2015). Farmers consider the benefits (e.g., environmental gains, long-term sustainability) relative to the potential foregone profits from not pursuing more profitable alternatives. In my study, these costs represent the value of the next best alternative that farmers sacrifice when they decide to adopt measures reducing chemical fertilizer usage in their farming practices.

These opportunity costs arise from multiple factors, including market conditions, land and environmental characteristics, farm management practices, and AES contract design (Schaub et al., 2023). Market conditions, such as fluctuating prices for agricultural products, impact the economic viability of implementing SAPs. Farmers need to evaluate the potential benefits of adopting these practices against the potential income loss from not pursuing traditional farming methods. Land and environmental factors play a crucial role in determining opportunity costs. Soil fertility, for instance, directly affects crop yields and production costs. When farmers choose to allocate land to AES or SAPs, they must weigh up the advantages and disadvantages between conserving land for environmental benefits and utilizing it for higher-yielding conventional crops. Farm management practices, including the level of management intensity and resource allocation, also influence opportunity costs. Different management practices may require varying levels of investment, labour, and time commitment for AES or SAPs, affecting overall costs and benefits.

Incentives offered by the scheme, such as financial support, can offset some of the opportunity costs and encourage farmers to participate. The area of land enrolled in the scheme is another critical factor, as larger enrollments may have greater impacts on farm operations and income. Contract length is another consideration affecting opportunity costs. Longer contracts provide more stability in incentives but may limit farmers' flexibility in adapting to changing circumstances. Shorter contracts offer greater adaptability but might result in uncertainties regarding future incentives and long-term commitment. The required agro-chemical reduction percentages or SAPs outlined in the AES scheme are essential in assessing opportunity costs. Farmers need to evaluate how these requirements align with their existing practices and how they might impact crop productivity, income, and overall farm sustainability.

Farmers with high opportunity costs require higher incentives compared to those with lower costs, particularly if they have intensive management practices which potentially cause more adverse environmental impacts (Schaub et al., 2023).

2.3 Preference Heterogeneity

Preference heterogeneity refers to the variations in choices and values individuals attribute to different decision criteria in identical choice situations. Such heterogeneity is underscored by a multitude of factors, including differing socioeconomic backgrounds, personal experiences, and deeply held beliefs (Boxall and Adamowicz, 2002). Moreover, heterogeneity may be explained by observable characteristics or remain unexplained due to latent factors or complex, misunderstood relationships between characteristics. Within the context of AES, this variation is particularly pronounced. Given the intrinsic diversity in their motivations, resources, and constraints, farmers do not uniformly appraise AES options. Their choices reflect a blend of economic imperatives, perceived benefits and risks, and distinct environmental and ethical convictions.

Traditionally, studies have assumed homogenous preferences within a sample. This assumption oversimplifies the reality, where preferences are often heterogeneous among individuals or groups. It has increasingly been recognized that preferences may indeed exhibit heterogeneity among individuals or groups within a population (Garrod et al., 2012; Banerjee et al., 2021). To elucidate this diversity in preferences, two primary approaches can be employed: stated preferences (SP) and revealed preferences (RP), as outlined by Broch and Vedel (2012). The SP method, through the technique like Discrete Choice Experiment (DCE), directly queries individuals about their preferences in hypothetical scenarios. Individuals express their preferences for different attributes without actual transactions taking place. In the realm of AES, the SP method is particularly useful in designing AES, by presenting farmers with potential AES scenarios, it captures their perceived preferences and provides insights into how farmers weight contract attributes. On the other hand, the RP method offers a complementary perspective by examining farmers' actual engagements with existing agri-environmental contracts, providing real-world insights into their preferences and free from hypothetical biases.

In the context of AES, latent preference heterogeneity refers to the degree of variation in individual farmers' preferences and attitudes toward these schemes, which results from unobserved factors that researchers have not been able to capture. Farmers' decision-making may be greatly impacted by this variance. The three most common approaches to modeling preference heterogeneity are the random parameters logit model (RPL), the covariance heterogeneity model (Cov-Het), and the latent class model (LCM). In the RPL, utility is decomposed into an unobserved, preference heterogeneity component and a deterministic component (McFadden and Train, 2000); this model allows individual-level variation in preferences across the entire population. The Cov-Het Model focuses on modeling the variability in the error component of the utility function, acknowledging that this variability can be systematically related to observable characteristics (Bhat, 1997). The LCM, first proposed by Kamakura and Russell (1989), addresses preference heterogeneity by simultaneously grouping individuals into latent segments while also estimating a choice model. Within each latent segment, which is unobserved, preferences are assumed to be homogeneous. However, these preferences, may differ across the segments. The LCM which will be further addressed in section 3.4.

3 Material and Methods

This dissertation employs a mixed-methods approach. Specifically, the Discrete Choice Experiment (DCE) was applied in Study I, the Hybrid Choice Model (HCM) in Study II, and the Best-Worst Scaling (BWS) in Study III. Additionally, the Latent Class Model (LCM) was utilized across all three studies to examine the heterogeneity among farmers. Each method was selected for its specific strengths in addressing the research questions. The DCE in Study I allows for a detailed understanding of farmers' preferences for an AES aiming to reduce chemical fertilizer use. Moreover, the HCM in study II integrates latent psychological factors with observable choices to DCE, and the BWS in Study III offers insights into the relative importance of different SAPs. The LCM complements these methods by revealing segments within the farmer population, showing the preference heterogeneity.

Traditional surveys often rely on a singular query to gauge respondent preferences. However, a one-time question may not truly reflect a respondent's stable preference. By contrast, the DCE and the BWS repeatedly present respondents with a set of alternatives across different scenarios, enabling researchers to observe patterns and identify consistent choices. Studies I and II utilized data from the same survey conducted in Taiwan, focusing on rice farmers as the target group. In Study III, the survey was conducted in China, specifically targeting grain farmers in Gansu province. Lastly, Study IV is a systematic review focusing on rice farmers in southeast Asia.

3.1 Discrete Choice Experiment

The discrete choice experiment (DCE), a survey-based stated preference (SP) technique, presents respondents with a set of hypothetical scenarios and asks them to choose between different options. The evaluation of decisions in DCE is based on the random utility theory (McFadden, 1974). This methodology is considered an efficient way to identify and evaluate the choices made by individuals in hypothetical situations, especially the preference for new alternatives or attributes (Louviere et al., 2000). The act of choosing between these alternatives provides insights into the respondents' implicit trade-offs among attribute levels, thereby revealing their underlying preferences (Louviere et al., 2000). Furthermore, to capture realistic decision-making behaviour and to acknowledge the pull of the status quo, choice experiments should ideally include an opt-out option. This ensures that participants are not forced into choices they would not make in real-life scenarios. The characteristics in a choice experiment must align with the expectation of policymakers while also resonating with the respondents (Bateman et al., 2002). Researchers use DCEs to investigate farmers' preferences for agri-environmental contract, focusing on observable variables such as scheme attributes and socioeconomic characteristics, which influence their decision making (Ruto and Garrod, 2009; Espinosa-Goded, et al., 2010; Broch and Vedel, 2012; Lienhoop and Brouwer, 2015; Santos et al., 2015).

In the DCE, farmers confront various choice scenarios, each differing in terms of payment, contract duration, or conservation practices required. They are requested to select an alternative from each set based on the anticipated highest utility. Alternatively, they may choose to opt out entirely. Within these experiments, the concept of utility is often divided into two parts: a systematic component that can be explained by observed factors and a random component that encompasses unobserved factors affecting the choice.

Mathematically, the utility U that respondent *n* derives from alternative *i* in the choice situation *t* is given by

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

Where V_{int} is the observed component of the utility, depending on the explanatory variables, which are attributes in the discrete choice model x_{int} and vectors of attribute parameters β. ε_{ij} is an error term defined as a Type-1 extreme value distributed. If utility U_{int} is linear in β, then $V_{int} = \beta x_{int}$. For the choice model integrating latent variables, the observed component of the utility V_{int} depends not only on attributes but also on latent variables z_n and vectors of parameters Γ associated with latent variables. Thus, in the latent class framework consisting of choice attributes and latent variables, the random utility vector of individual *n* in class *m* and the choice alternative *i* in the choice situation *t* is modelled below.

$$U_{int}^{m} = \beta_m X_{int} + \Gamma_m z_n + \varepsilon_{int} \tag{2}$$

Here, β_m refers to the parameters of choice attributes. X_{int} is the vector of choice attributes. Γ_m is a matrix of parameters associated with latent variables presented in the utility function. z_n refers to the set of latent variables. Finally, ε_{int} is a random component of the utility function (Chang et al., 2023).

3.2 Hybrid Choice Model (HCM)

In typical choice modelling application, it is assumed that rational individuals maximize their utility based on socio-demographic characteristics and attributes of the available choices. However, real-world decision-makers are not isolated individuals; they live in complex environments that shape their perceptions, and consequently, influence their decision-making. Defrancesco et al. (2008) identified that not considering psychological factors and trade-offs indicates that regulations and financial incentives alone may be insufficient to prompt long-term changes in farmers' production practices.

The Hybrid Choice Model (HCM), also known as an Integrated Choice and Latent variable model (ICLV), represents a sophisticated evolution of standard Discrete Choice Models (DCMs) (Kim et al., 2014). By simultaneously incorporating a latent variable model with a DCM, the HCM enhances the explanatory power of the choice process by considering the impact of decision-makers' latent attitudes, allowing researchers to analyze the influence of both observable variables (such as decision-maker characteristics and alternative attributes) and unobservable variables (such as psychological factors) on farmers' decision-making (Ben-Akiva et al., 2002). This approach offers deeper insights into why certain preferences exists and unravels the influence of socio-psychological factors on scheme or practice adoption. For instance, while farmers may primarily select an AES based on economic considerations, their deeper inclinations towards sustainable practices might be shaped by their personal beliefs about climate change, trust in authorities or peer influence.

To identify the latent attitudes, a set of attitudinal indicators is used through a multiple indicators multiple causes (MIMIC) model. The MIMIC model consists of a set of structural and measurement relationships, where the indicators represent responses to survey questions related to different latent attitudes. The strucutral equation explains the latent variables in terms of observable exogenous variables. The strucutural equation for the q-th latent variable of total Q may be writen as follows:

$$LV_{qn} = B_q w_n + \zeta_{qn} \tag{3}$$

where w_n is a vector of explanatory variables which in our case being a vector of the sociodemographic variables of respondent n; B_q is a vector of unknown parameters; $\zeta_{qn}$is an error term that has a normal distribution with a zero mean and a standard deviation $\eta_{q\zeta}$.

The measurement equations link latent variables to the indicators, corresponding to attitudinal questions. These indicators are not considered attributes on their own, but rather an expression of underlying attitudes and perceptions. The measurement equation of *k*th indicator for respondent n and latent variable q is defined as:

$$I_{qkn} = \Lambda_q LV_{qn} + \omega_{qn} \quad (4)$$

where the $\Lambda_q$is a vector of unknown parameters and ω_{qn} is a normally distributed error term with an identity covariance matrix.

In the present model, some indicators are collected using a Likert type with *L* levels, $i_1, i_2, \dots, i_L$, and other indicators are collected by a binary type response scale. For the *k* indicator which takes *L* possible ordered values, the measurement equation for the individual decision maker *n* is modelled as an ordered logit model below.

$$I_{qkn} = \begin{cases} i_1 & if -\infty < LV_{qn} < \propto_{qk1} \\ i_2 & if \ \propto_{qk1} < LV_{qn} < \propto_{qk2} \\ & \dots \\ i_L & if \ \propto_{qk(L-1)} < LV_{qn} < \infty \end{cases} \quad (5)$$

where $\propto_{qkl}$ is the *l* threshold parameter to be estimated for the *k* indicator at the q latent variable. On the other hand, the measurement equation for indicator with a binary response becomes:

$$I_{qkn} = \begin{cases} 0 & if \ LV_{qn} < \propto_{qk1} \\ 1 & if \ \propto_{qk1} \leq LV_{qn} \end{cases} \quad (6)$$

The two-step sequential estimation method of the HCM includes defining latent variables and incorporating them as additional explanatory variables in the DCM (Ashok et al., 2002). The simultaneous approach could estimate both the choice model and the latent variables model concurrently. The full-information log-likelihood function given by integration over ζ_{qn} is presented as follows:

$$LL(\beta, \Gamma, \delta, B, \Lambda, \propto) = \sum_{n=1}^{N} ln \int \left(P_n \prod_{k=1}^{K_q} \prod_{q=1}^{Q} L_{I_{qkn}} \right) g(\zeta) d \tag{7}$$

where the joint log-likelihood function depends on the parameters β and Γ of the choice kernel, offset δ in latent class estimation, B of latent variables, Λ for the measurement equation and on the threshold parameters for the indicators (Chang et al., 2023).

As previous studies have not simultaneously considered all relevant factors, potentially leading to an overestimation of the importance of certain factors. To bridge this gap, Study II adopts an integrated approach that combines perspectives from economics and social psychology using the Hybrid Choice Model (HCM) with Latent Class Model (LCM). This integrated approach, as demonstrated by Raveau et al. (2010), allows for the incorporation of psychological factors into a Random Utility Model (RUM), thereby bridging the gap between behavioural sciences and disciplines dedicated to the study of individual choice. Furthermore, the study conducted by Mariel and Arata (2021) found that the use of attitudinal indicators is effective in revealing the heterogeneity of preferences among respondents.

The structure of the latent segmentation in the Hybrid Choice Model (HCM) is illustrated in **Figure 4**. This model combines a Discrete Choice Model with a Latent Variable Model, which consists of a structural component and measurement indicators. In the diagram, ellipses represent variables that are not directly observable, referred to as latent variables. Rectangles represent observable variables, including explanatory variables and indicators of latent variables. On the right-hand side of **Figure 4**, a set of indicators captures respondents' attitudes. The participants' responses to these indicators are attributed to the latent variables: "trust in government" and "attitude towards implementing SAP". These latent variables, along with other attributes (depicted on the left-hand side of **Figure 4**), are used as predictors in the DCM to explain respondents' preferences regarding the contract (Chang et al., 2023).

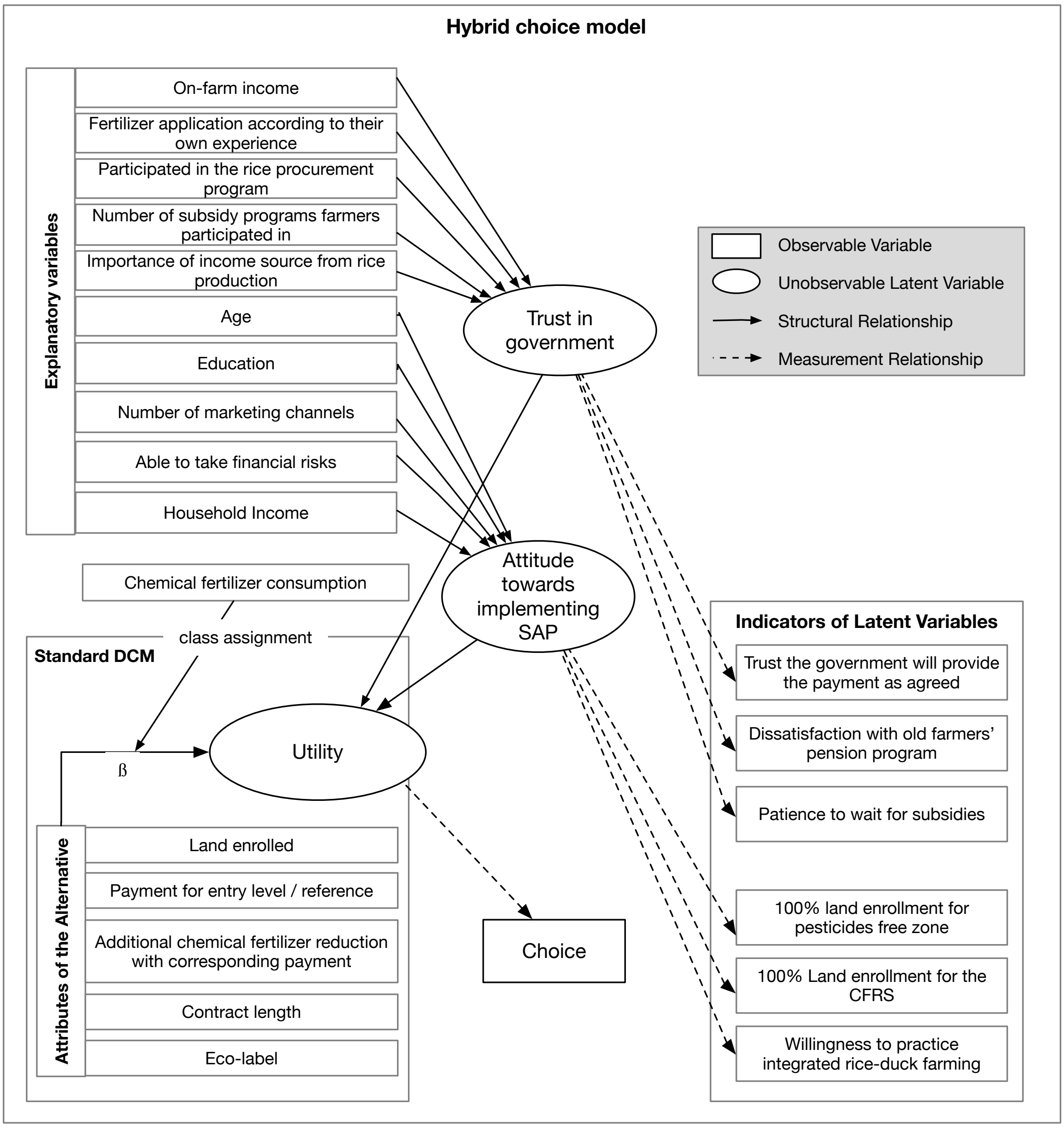

Figure 4 Path diagram of the latent segmentation of the Hybrid Choice Mode (Chang et al., 2023)

3.2.1 Experimental Design and Data Collection for Study I and II (Taiwan)

The survey conducted for Studies I and II comprised choice sets, socio-economic questions and a set of attitudinal questions. The determination of the number of choice sets, attributes, and attribute levels was a multi-stage process involving literature reviews, expert interviews, and a pilot survey with rice farmers in Taiwan. Table 3 presents attributes and levels of the choice experiment. For a detailed description of the attributes, please refer to Study I (Chang et al., 2017).

Table 3 Attributes and levels in choice experiment

Scheme attribute	Description	Levels
Land to be enrolled in the CFRS	Amount of land to be enrolled in the CFRS	- 25% eligible area - 50% eligible area - 100% eligible area
Payment for entry to the scheme (reference level)	Fixed payment for join the CFRS scheme (ha/year)	- NT$ 2,000 /ha/year - NT$ 2,500 /ha/year - NT$ 3,500 /ha/year
Additional chemical fertilizer reduction with corresponding payment	The additional amount of the chemical fertilizer reduction with corresponding reward payments (ha/year)	- only comply with reference level (no payment) - apply 15% less than reference level (NT$ 1,000) - apply 30% less than reference level (NT$ 2,000) - give up the use of chemical fertilizer (NT$ 5,000)
Contract length	Duration of the contract	- 2 years - 5 years
Eco-Label	An eco-label for farmers who successfully comply with the standard	- Yes - No

The questionnaire was divided into two parts. The first part consists of a Choice Experiment (CE) focused on the Chemical Fertilizer Reduction Scheme (CFRS). Farmers were asked to choose their preferred alternatives from each of eight choice sets. The respondents who chose at least one of the alternatives from the choice sets are identified as potential participants, and those who chose "I do not wish to participate" from all eight choice sets are identified as the opt-out group. The second part of the questionnaire encompasses five subsections: (1) socio-economic aspects, (2) farm operation factors, (3) management practices, (4) preference for environmental friendly farming practices on their land, and (5) farmers' perceptions of governmental support. To avoid bias, considering that most farmers in the sample use agrochemicals with their farming practices, direct questions about their environmental concerns were avoided. For instance, questions such as "the use of pesticides and chemicals is extremely dangerous to the environment" may lead to bias. Some farmers might respond with "yes, strongly agree" to present themselves as environmentally conscious individuals.

In Taiwan, the collection of pre-test/piloting surveys and formal surveys took place from November 2014 to April 2015 in 15 counties of Taiwan, encompassing most rice cultivation areas known for practicing intensive, double crop rice cultivation for several decades. Random sampling was employed to gather surveys from three sources: group-administered, self-administered, and face-to-face interviews. In total, 309 respondents were sampled; however, due to insufficient information, seventeen observations were excluded, resulting in a final sample size of 292 respondents.

3.3 Best-Worst-Scaling

BWS is another survey-based method (stated preferences, SP) that requests participants to choose the best and worst options from a set of alternatives. It was originally developed by Louviere in 1987, and its initial application was published in 1992 by Finn and Louviere, demonstrating the usage of the object case. There are three variations of BWS, namely, object case (Case 1), profile case (Case 2), and multi-profile case (Case 3), that share the common characteristics of respondents selecting both the best and worst alternatives from a set of three or more attributes, rather than solely identifying the best alternative (Louviere et al., 2015).

The first variant is known as the object case (Case 1). This case aims to determine the relative importance of attributes, which have only one level or none. The choice scenario differs based on the subset of attributes presented. The object case of BWS offers distinct advantages compared to other traditional ranking methods such as rating and Likert scales. One of its key strengths is its ability to prompt respondents to make trade-offs, allowing for a more comprehensive understanding of their preferences (Louviere et al., 2015). The second variant of BWS is the profile case (Case 2). Unlike the object case, the profile case displays the level of each attribute. Thus, the attributes remain the same in each scenario, while their levels vary. Respondents evaluate and select both the most preferred (best) and least preferred (worst) attribute levels within each scenario presented. The third variant is the multi-profile case of BWS (Case 3). In this case, respondents are required to repeatedly choose between alternatives including all attributes, with attribute levels varying in a sequence of choice sets. This approach resembles a Best-Worst Discrete Choice Experiment (BWDCE).

The BWS is widely recognized for effectively eliciting preferences; it overcomes issues faced by other measurement and rating methodologies (Mühlbacher et al., 2016). By requesting respondents to discriminate between alternatives, BWS provides valuable information and allows researchers to expand choices and measure individual preferences comprehensively. For instance, if a respondent selects option A as the best and option D as the worst from a set of {A, B, C, D}, it reveals that A > {B, C, D}; B > D; C > D. Additionally, if the respondent is required to choose the "next best" option and he/she chooses B, then we know A > {B, C, D}; B > {C, D}; C > D. This method can further extend choices, such as selecting the "next best' option, to derive preference for various alternatives (Loureiro and Arcos, 2012).

In Study III of my dissertation, Case 1 of the BWS method is employed to determine the significance of various attributes associated with arable conservation practices. Farmers were asked to indicate their preferences by selecting the most preferred and the least preferred attributes among the given set of attributes. This approach enables us to estimate their relative importance and gain insights into the farmers' priorities and preferences regarding conservation practices. Moving beyond AES, we use BWS to investigate farmers' relative preference for planting green manure cover crops (GMCCs) in Northwestern China.

3.3.1 Experimental Design and Data Collection for Study III (China)

In Study III, respondents were presented with a series of choice sets, each containing a subset of all the items to be evaluated. Traditional research on farmers' preferences for conservation practices typically focuses on analyzing specific underlying attributes, not considering farmers' preferences for alternative conservation practice options. This approach also makes it challenging to evaluate the relative preferences for a wide range of conservation practices. In the light of the Chinese government's emphasis on promoting GMCCs, it becomes essential to address the following questions: What are farmers' preferences regarding different GMCC planting practices, and how do their preferences, when given a choice, compare with other arable land conservation practices? To answer these questions, a survey was designed to gather information on farmer socioeconomic characteristics, attitudes, and preferences towards conservation practices.

The survey utilized the Best-Worst-Scaling (BWS) method to prioritize farmer concerns regarding different arable land conservation practices. Nine conservation practices were selected for the BWS survey based on a comprehensive literature review, expert interviews, and representative farmers' responses to a pre-survey. Table 4 provides a brief description of each of these nine conservation practices investigated in the study, including three practices related to GMCCs, as well as other measures such as improving irrigation facilities, adopting organic fertilizer, using biochar-based fertilizer, reducing chemical fertilizer and pesticide application, returning crop residue to the field, and leaving arable land fallow for a year.

Table 4 List of arable land conservation practices and measures

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

Including diverse range of conservation practices serves two purposes: (i) providing a broader context and a better understanding of farmer perceptions and preferences regarding these practices, and (ii) exploring the potential of the green manure policy by further investigating the green manure planting program. A Balanced Incomplete Block Design (BIBD) was employed to assign the nine conservation practices to subsets. BIBD is a widely used in BWS designs due to its balanced and orthogonal nature, ensuring equal representation of each statement (Louviere et al., 2015). Each conservation practice appeared eight times in the design, with each pair appearing once. By employing BIBD, we obtain 12 choice sets, each consisting of six conservation options, which were divided into two blocks. Farmers were randomly assigned to one block and asked to select the best (most effective/most preferred) and the worst (least effective/least preferred) conservation practice for each BWS question. The question was: "We would like to ask you six questions regarding your preference for arable land conservation practices. Each question is composed of six conservation practices. Which practice do you think is the best and which is the worst? (**Figure 5**)."

MOST effective	Choice Set 1	LEAST effective
▢	Leaving fallow for a whole year	▢
▢	Applying biochar-based fertilizer	▢
▢	Halving chemical fertilizer and pesticide application	▢
▢	Interplanting leguminous green manure crops	▢
▢	Crop rotation with leguminous green manure crops	▢
▢	Returning residue or straw to the field after harvest	▢

Figure 5 Example of BWS choice set

The field survey was carried out by the research team in April 2019, following piloting and pretesting, in four cities of Gansu Province. A total of 349 surveys were conducted; however, only 276 surveys were considered valid for analysis. This was due to 29 surveys being conducted with cooperative managers who were not farmers, 23 surveys lacking completion of all Best-Worst Scaling (BWS) tasks, and 21 surveys missing socio-economic information.

3.4 Latent Class Model

The Latent Class Model (LCM) approach has been utilized to include preference heterogeneity in choice modeling. LCM is a mixed logit model with discrete parameter distribution, making it particularly useful for assessing respondents' preference variations and identifying underlying causes (Greene and Hensher, 2003). The LCM suggests a discrete distribution of preferences, wherein individuals are essentially grouped into various segments (Boxall and Adamowicz, 2002), with each segment predicting choice behaviour based on its unique characteristics (Colombo et al., 2009; Garrod et al., 2012).

The latent class model (LC) hypothesises that individuals can be sorted into M classes (Greene and Hensher, 2003), each with a certain class-specific β_m. The population in each class has its own preferences but the population across classes has different preferences. In the latent class discrete choice model, given that the class membership m and the observed component of the utility $V_{int} = \beta x_{int}$, the probability of chosen alternative i by individual n with a vector of offset constant δ is represented by:

$$P_{ni} = \sum_{m=1}^{M} s_m \left(\frac{\exp(\delta_m + \beta'_m x_{ni})}{\sum_{j=1}^{J} \exp(\delta_m + \beta'_m x_{nj})} \right) \tag{4}$$

Where s_m is the share of the population in class m (Train, 2012); M is the number of classes and J is the number of alternatives in each choice situation; δ_m is fixed to zero for one of the M classes for normalization. In the latent class framework consisting of choice attributes and latent variables, given that the observed component of the utility $V_{int} = \beta x_{int} + \Gamma z_n$, the probability of chosen alternative i by individual n is given by:

$$P_{ni} = \sum_{m=1}^{M} s_m \left(\frac{\exp(\delta_m + \beta'_m x_{ni} + \Gamma'_m z_n)}{\sum_{j=1}^{J} \exp(\delta_m + \beta'_m x_{nj} + \Gamma'_m z_n)} \right) \tag{5}$$

The methods and data utilized in the four studies are summarized in Table 5.

Table 5 A summary of the data and methods

Title	Data	Methods
Study 1: Investigating Rice Farmers' Preferences for an Agri-Environmental Scheme: Is an Eco-Label a Substitute for Payments?	Number of observations: 292 Target group: rice farmers Case study area: Taiwan	Discrete Choice Model - Mixed logit - Latent class model
Study 2: The Role of Rice Farmers' Attitude and Trust in Government in Decision-making for Participating in a Climate-related Agri-environmental Scheme	Number of observations: 292 Target group: rice farmers Case study area: Taiwan	Hybrid Choice Model - Discrete choice model - Structural equation model - Latent class model
Study 3: Explaining farmers' reluctance to adopt green manure crops planting for sustainable agriculture in Northwestern China	Number of observations: 276 Target group: grain farmers Case study area: Gansu/China	- Counting approach - Multinomial model - Mixed logit model - Tobit model - Latent class model
Study 4: Factors influencing the adoption of sustainable agricultural practices for rice cultivation in southeast Asia: A review	Number of studies: 39 Target group: rice farmers Study area: Southeast Asia	- Prisma flow diagram - Vote counting

In my dissertation, distinct methodological approaches were deliberately chosen to best suit the specific research objectives. In Study I, the Discrete Choice Model (DCM) was employed due to its alignment with the Random Utility Theory, enabling a realistic simulation of choice scenarios. This method was preferred over traditional Conjoint Analysis (CA), which is based on Conjoint Measurement (CM), primarily focusing on mathematical representations of preferences. Although CA is similar to DCE, it does not offer the same level of detail in capturing complex choice scenarios and trade-offs (Breidert et al., 2006; Louviere et al., 2010). Thus, CA method is unable to provide the depth of behavioural insights required for my dissertation. Thus, the selection of DCM for Study I was driven by its superior ability to model and interpret the intricate behavioural dynamics inherent in choice-based scenarios.

For study II, the Hybrid Choice Model (HCM) was employed, distinguished by its ability to simultaneous analysis of observable behaviours and underlying psychological factors. This approach enhances the explanatory power of choice model (Ben-Akiva et al., 2002). While Structural Equation Modeling (SEM) effectively analyzes the relationship between observed and latent variables, it does not directly connect these psychological factors to specific choices. HCM, on the other hand, combines the strengths of SEM with DCE, allowing us to explore how attitudes and perceptions influence decision-making within the context of AES. Furthermore, HCM addresses potential endogeneity issues that can arise when psychological factors are assessed separately from choice behaviour (Kim et al., 2014). Therefore, integrating DCE and SEM within HCM ensures a more comprehensive and holistic analysis, leading to more reliable and actionable insights for policy development. Consequently, HCM is identified as the most appropriate method for our research objectives in Study II.

For Study III, Best-worst Scaling (BWS) was chosen for its effectiveness in quantifying the relative importance of different attributes, a capability not as pronounced in alternative methods such as rating scales only allowing the expression of preference intensity. In Study IV, I opted for the vote counting method diverging from the more commonly used Meta-analysis for a systematic review. The Vote counting method was selected as it does not require the high homogeneity in data that Meta-analysis does, allowing for the inclusion of diverse study designs and data types.

The Laten Class Model (LCM) was employed in all three studies. As noted In Section 2.3, there are at least three approaches to model preference heterogeneity in stated choice data. The LCM was chosen because it allows for more effective interpretation of preference heterogeneity at a segment level rather than at an individual level (Colombo et al. 2009).

4 Summary of Empirical Studies

This chapter includes summaries of three individual publications, and one systematic review article. The complete articles have been attached in the appendix for further review.

4.1 Investigating Rice Farmers' Preferences for an Agri-Environmental Scheme: Is an Eco-Label a Substitute for Payments?

This study used a Discrete Choice Experiment (DCE) approach to explore how the AES should be designed and whether farmers would accept lower payments in exchange for an eco-label. This study begins by introducing the problem of excessive fertilizer use in Asian countries and highlights the negative environmental impacts of over-application of chemical fertilizers, such as biodiversity loss, climate change and water pollution. Taking Taiwan as a case study, we investigated the preferences of rice farmers in Taiwan for an Agri-Environmental Scheme (AES) – Chemical Fertilizer Reduction Scheme (CFRS) that aims to optimize fertilizer use and reduce adverse environmental impacts. The empirical analysis is based on data collected from 292 rice farmers in Taiwan.

Previous studies have explored farmers' preferences for AES factors, such as contract length, financial incentives and paperwork requirements. However, none have specifically addressed farmers' preferences for non-monetary rewards as incentives for complying with environmental regulations such as eco-labels. This study fills this research gap by offering farmers non-monetary incentives, and also, introduces the concept of a gradual reduction in agrochemical use within the scheme. The intermediate approach involves a step-by-step reduction of chemical fertilizer application and partial land enrollment in the scheme. By investigating the weighting of farmers' preferences for different attributes, policymakers can optimize scheme design before implementation.

The results reveal that farmers are willing to accept small incentive payments in exchange for receiving an eco-label. Partial land enrollment and gradual reduction of chemical fertilizer also emerge as important factors influencing farmers' decisions. The results of the latent class analysis suggested that farmers who already follow expert advice on gradual fertilizer reduction may represent a group with the lowest threshold for participation in CFRS. Therefore, the findings provide valuable insights for policymakers in developing effective schemes to promote more efficient fertilizer use in Taiwan.

Authors' contributions: Sheng-Han-Erin Chang developed the research questions, designed the questionnaire, organized the dataset, conducted the analysis and wrote the manuscript. David Wuepper reviewed the questionnaire and edited the manuscript. Alois Heissenhuber and Johannes Sauer supervised the study. The authors thank the editors of the Land Use Policy and two anonymous reviewers who provided helpful comments, as well as the colleagues in Taiwan for collecting the data and all participating farmers for their support.

Publication:

Chang, S.H.E., Wuepper, D. Heissenhuber, A., Sauer, J. (2017). Investigating rice farmers preferences for an agri-environmental scheme: Is an eco-label a substitute for payments? Land Use Policy. 64, 374-382, https://doi.org/10.1016/j.landusepol.2017.03.014

4.2 The Role of Rice Farmers' Attitude and Trust in Government in Decision-making for Participating in a Climate-related Agri-environmental Scheme

This study investigates the influence of attitude and trust in government on rice farmers' decision-making regarding the adoption of a climate-related agri-environmental scheme, namely, the Chemical Fertilizer Reduction Scheme (CFRS). A survey was conducted with 292 rice farmers in Taiwan and the data were analyzed using the Hybrid Choice Model (HCM). The research aims to provide insights into the psychological factors that shape farmer behaviour, considering the significance of both monetary and non-monetary incentives as well as social-demographic factors. The study also employs a latent class segmentation approach to identify preference heterogeneity among farmers.

The findings reveal that farmers with lower chemical fertilizer usage (Class-2) are interested in eco-labels, while those with greater usage (Class-1) prioritize higher entry payments. Additionally, Class-1 farmers prefer shorter contract lengths, while Class-2 farmers are more inclined to make longer commitments to CFRS. The findings underscore the need to consider preference heterogeneity and recommend the incorporation of diverse incentives, both monetary and non-monetary, for adopting agri-environmental schemes.

The study highlights the importance of tailoring contracts to cater to the preferences of different farmer groups, as this can enhance engagement and scheme efficiency. Furthermore, it suggests that addressing motivational aspects and establishing trustworthiness in institutional contract design can positively impact the uptake of CFRS. Overall, this study emphasizes the potential effectiveness of eco-labels and higher entry payments in addressing psychological barriers, such as low trust in government and negative attitudes towards SAP implementation, which often hinder farmer engagement.

Authors' contributions: Sheng-Han-Erin Chang developed the research questions, designed the questionnaire, organized the dataset, conducted the analysis and wrote the manuscript. Emmanuel O. Benjamin and Johannes Sauer provided supervisory support with the conceptual framework and commented on the manuscript. The authors thank the editors of the Journal of Environmental Planning and Management and three anonymous reviewers who provided helpful comments, as well as the colleagues in Taiwan for collecting the data and all participating farmers for their support.

Publication:
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4.3 Explaining farmers’ reluctance to adopt green manure crops planting for sustainable agriculture in Northwestern China

This study aimed to investigate the factors behind the low adoption rate of green manure cover crops (GMCCs) planting in Gansu Province, China. GMCCs have been identified as a potential solution for reducing synthetic fertilizer use, mitigating climate change effects, and contributing to achieving several Sustainable Development Goals (SDGs). However, their adoption rate, particularly in arid and semi-arid regions like Gansu, remains significantly low. Existing research has primarily concentrated on the effects of GMCCs on soil improvement and crop yields, but few have investigated farmers’ willingness to grow GMCCs. Moreover, previous studies have often focused on single conservation practice, making it challenge to compare the relative importance of different practices in a bundle.

To address these gaps, this study applied a best-worst scaling (BWS) approach, presenting farmers with hypothetical scenarios involving different bundles of conservation practices, including three GMCCs planting and six other conservation practices. The results indicate that low adoption may be influenced by farmers’ preference for alternative practices and a lack of understanding of the economic and ecological benefits of GMCCs.

The findings of this study hold significant implications for policymakers. Firstly, it emphasizes the importance of addressing the factors contributing to the low adoption rate of GMCCs, including farmers’ preferences, knowledge gaps, and inadequate financial support. Policymakers should consider alternative approaches beyond monetary incentives, such as providing improved irrigation facilities and promoting organic fertilizer use, to align with farmers’ existing preferences and priorities. Additionally, raising awareness about government policies on GMCCs and providing accessible training courses can help farmers overcome knowledge barriers and eventually increase adoption rates.

Authors’ contributions: Sheng-Han-Erin Chang conducted the statistical analysis and wrote the manuscript. Yi Xiao-yan designed the questionnaire, supported with data collection, and edited the

manuscript. Johannes Sauer reviewed and commented on the manuscript. Yin, Chang-bin and Li Fu-duo reviewed the manuscript. The authors thank the editors of the Journal of Integrative Agriculture and anonymous reviewers who provided helpful comments as well as the colleagues in China for collecting the data and all participating farmers for their support.

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4.4 Factors influencing the adoption of sustainable agricultural practices for rice cultivation in southeast Asia: A review

Rice cultivation is very important to the Southeast Asian (SEA) economy, but it also poses environmental issues, such as high greenhouse gas (GHG) emissions, soil degradation, and water pollution. Various sustainable agricultural practices (SAPs) for rice cultivation have been implemented in the SEA region to address these challenges. However, the adoption of these SAPs remains limited. This systematic review aims to investigate the available literature on SAPs for rice farming, with an emphasis on the factors influencing farmers' SAP adoption. A total of 39 manuscripts were identified.

The review highlights that organic farming is the most extensively studied SAP in SEA countries, followed by good agricultural practices/best management practices and climate smart agriculture/system of rice intensification. SAPs have demonstrated their potential in achieving multiple objectives such as food security, improved rice productivity, reduced agrochemical inputs, climate change mitigation, water consumption reduction, and enhanced farmer livelihoods. Several determinants influencing adoption were identified, including education level, farming experience, access to credit and extension services, participation in SAP training, and knowledge about SAPs.

The findings highlight the need for future research on understanding farmers' decision-making processes. This includes investigating the behavioural and psychological aspects that influence adoption decisions, exploring farmers' preferences and trade-offs between alternative SAPs, and identifying the incentives that can drive successful adoption. By delving into these aspects, researchers can uncover the underlying motivations and considerations that influence farmers' decisions regarding the adoption of specific SAPs. Policy interventions should aim to enhance institutional support, provide incentives, and improve access to credit, information, and training to facilitate the adoption.

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5 Discussion and Conclusions

Designing effective and efficient AESs requires a deep understanding of farmers' decision-making and the factors influencing their choices. This dissertation aims to contribute to this knowledge by investigating farmers' preferences for AES and identifying the key determinants of adoption by employing various approaches. This chapter discusses the results of the conducted studies, highlights their limitations, identifies areas that require further research, and offers valuable insights and policy implications.

5.1 Discussion of the studies

In Study I, it was revealed that rice farmers, who expressed a willingness to participate in the CFRS, displayed a preference for receiving an eco-label as a non-monetary incentive rather than a higher payment. This preference may stem from the eco-label's potential to offer better income opportunities or foster a conservationist identity. The eco-label could effectively incentivize farmers to adopt specifics SAPs, such as reducing chemical usage, while also providing profit and signaling benefits. Farmers tend to prefer an intermediate step involving less land enrollment and a shorter contract length, but they are reluctant to further reduce their reliance on chemical fertilizers. The findings hold relevance for Asian countries where consumers are willing to pay a premium for certified environmental-friendly products and governments are seeking more efficient designs for their AES.

Moreover, the findings of Tanaka (2022) align with the results of my Study I (2017), suggesting that combining eco-certification schemes with outcome-based payment for ecosystem services (PES) can lead Japanese farmers to be willing to accept lower payments from the government if higher crop prices are made possible through eco-certification. Their study highlights the potential of incorporating an eco-certification scheme to capitalize on the associated price premium, thereby reducing the monetary payments offered by the government and transferring some conservation costs from taxpayers to consumers. According to a systematic review conducted by Raina et al. (2021) on the attributes used in DCE studies of AES, the study found that contract attributes play a significant role in eliciting farmers' preferences. Their review identified 32 attributes classified into five typologies, namely, monetary (7 attributes such as payment), general (4 attributes, for instance, contract duration), flexibility (6 attributes, for example, contract cancellation), prescription (12 attributes such as monitoring, eco-label), and purpose (3 attributes, for example, reduction of chemicals). Raina et al. (2021), suggests that eco-labels could be considered as an alternative to greening in the post-2020 Common Agricultural Policy (CAP). From the policy-makers' perspective, the inclusion of an eco-label could possibly increase farmers' participation rates and enhance the likelihood of achieving the environmental objectives of the AES. However, it is crucial to acknowledge that integrating an eco-label introduces a certain level of income uncertainty for farmers. These findings, combined with our own research, emphasize the significance of integrating eco-labels with payment mechanisms in AES, regardless of whether the emphasis is on outcome-based or action-based approaches.

Study II emphasizes the importance of considering multiple factors simultaneously, including psychological factors, contract attributes, and socio-demographic factors, aiming to effectively encourage and promote the adoption of SAPs among farmers for climate mitigation strategies. These factors collectively play a significant role in influencing farmers' decision-making regarding their participation in AESs. Moreover, Study II reveals the heterogeneity in farmers' preferences and identifies two distinct groups based on their psychological factors and fertilizer use. In Study I, it was observed that when using the standard latent class model, all those farmers who expressed an interest in participating in the CFRS would prefer an eco-label. However, the results of Study II indicated that the eco-label remained positively statistically significant only for Class-2 farmers, who utilize fewer chemical fertilizers. Conversely, Class-1 farmers showed no interest in the eco-label. It was noted that Class-1 farmers, who use relatively higher amounts of chemical fertilizers, prefer higher entry payment, may be more concerned about potential yield loss. Consequently, a higher entry payment would be required to encourage Class-1 farmers' participation in the CFRS.

Furthermore, Study II also found Class-1 farmers and Class-2 farmers exhibit notably different preferences and attitudes toward percentage of land enrollment and contract length. Class-1 farmers, with their diminished trust in government and reservations about SAP, tend to prioritize short-term returns. They opt for a brief two-year contract and a full field enrollment, hoping to maximize short-term benefits from the scheme. Their lack of interest in eco-labels indicates a preference for immediate economic gains over long-term market positioning or environmental sustainability. In contrast, Class-2 farmers, who use less chemical fertilizer and have greater trust in government and a positive attitude towards SAP, lean towards longer-term engagement with a five-year contract. They value eco-labels, suggesting an appreciation of both environmental practices and potential market advantages. Surprisingly, they prefer partial field enrollment, possibly to maintain flexibility, test the waters with the new system, and ensure they have a diversified strategy that can adapt to unforeseen challenges. Their willingness to accept a lower payment in exchange for an eco-label further underscores their forward-looking approach. While Class-1 farmers seem driven by maximizing short-term gain, Class-2 farmers' decisions appear rooted in sustainable practices, market positioning, and a more strategic long-term vision.

These findings suggest that tailoring the contract for adopting the AES to suit the specific preferences of different farmer groups can enhance engagement and improve scheme efficiency. These results align with the findings of Broch and Vedel (2012), who employed the DCE method and confirmed the benefits of tailoring contracts, as well as with Yang et al. (2020), who emphasized the 'one-size fits all' policy should be avoided for chemical fertilizer reduction. Moreover, this study suggests that well-designed contracts and trust-building measures can effectively address farmers' lack of trust in the government and increase AES uptake.

Study III investigated farmers' preferences for arable land conservation practices using the Best-Worst Scaling (BWS) methods, specifically focusing on the adoption of green manure cover crops (GMCCs) in the northwest region of China. The findings revealed that farmers prioritize the improvement of irrigation facilities and the substitution of chemical fertilizers with organic alternatives over the planting of GMCCs. This preference can shed light on the reasons behind the low adoption rate. The fact that farmers have other preferred alternatives in mind and limited awareness and knowledge about GMCCs is a barrier to adoption, and emphasizes the need for increased training and extension services. The study also identifies variations in preferences based on farm location, with some areas showing a higher interest in intercropping with GMCCs. Study III concludes that understanding farmers' preferences and considering alternative conservation practices before implementing specific programs is crucial.

Study IV in chapter 5 reviewed 39 publications regarding the adoption of sustainable agricultural practices for rice cultivation in Southeast Asian Countries. The findings indicate that socio-demographic and farm management variables were frequently examined in these studies, with varying levels of significance. Our findings align with previous research conducted in developed countries (Thompson et al., 2023). Economic and institutional variables were moderately studied and tended to yield more significant results. However, there is a noticeable research gap regarding behavioural factors, highlighting the need for further investigation in SEA. In terms of SAPs, while organic farming adoption was the most studied in the region, it is worth mentioning the significance of best management practices (BMP)/good agricultural practices (GAP) as well. Unlike organic farming, BMP/GAP allows farmers to use agro-chemicals during specific stages of crop growth. However, these practices may not always prioritize environmental benefits or contribute to climate change mitigation. Nonetheless, they can serve as an entry point for promoting SAPs and reducing the negative impacts of agro-chemicals on the environment. Through proper implementation and monitoring, BMP/GAP can gradually shift farmers towards more sustainable practices, for instance, the reduction of agro-chemicals usage and adoption of climate-smart practices. However, the successful implementation of such measures can be hindered by a lack of political will and support. In many cases, there may be competing interests or priorities that take precedence over environmental considerations (Giles et al., 2021). This lack of political will can result in insufficient funding for incentive programs or inadequate enforcement of regulations, limiting the effectiveness of efforts to promote SAPs. Additionally, providing education and outreach programs that highlight the benefits of SAPs and the incentives available for adopting them could also help to encourage more farmers to participate. However, it is crucial to ensure that the incentives and rewards are designed in a fair and equitable manner, considering factors such as farm scale and location. This prevents unintended consequences or unfair advantages among farmers. Furthermore, ongoing monitoring and evaluation of the programs' effectiveness are necessary to make any needed adjustments or improvements over time. Table 9 lists the research studies and their key findings incorporated into this dissertation.

Table 6 Overview of studies in the dissertation and key findings

Study	Main research questions	Key findings
Study 1	Do rice farmers view eco-labels as a suitable substitute for payments in a chemical fertilizer reduction scheme?	Farmers demonstrate a cautious yet proactive approach towards joining the CFRS, showing willingness to accept lesser payment for eco-labels on their produce.
Study 2	How do the attitudes towards implementing sustainable practices and trust in government influence farmers' decision making in participating in a chemical fertilizer reduction scheme?	Farmers' negative views on SAPs and less trust in government decrease their willingness to participate in the CFRS. However, higher entry payment can act as an incentive, potentially offsetting their reservations towards the scheme. Those who have positive views on SAPs and more trust on government are more likely to participate in the CFRS and prefer an eco-label.
Study 3	Why farmers are reluctant to adopt green manure cover crops (GMCC) planting?	Farmers have other conservation practices they prefer over GMCCs, such as improving irrigation facilities and substituting CF with OF. There is also a significant lack of awareness and understanding about GMCCs and they have limited access to training courses. Additionally, the financial support and subsidies provided by the government are not sufficient to encourage GMCC adoption.
Study 4	What factors influence the adoption of SAP for rice cultivation in SEA, and what should policy interventions and future research do to promote a greater adoption of these practices?	The socio-demographic and farm management variables are common in studies, but their significance varies. Economic and institutional variables, though less studied, generally yield more significant findings. Noticeably, research on psychological factors is lacking in SEA, underlining the need for further research. Policy interventions should focus on enhancing institutional support and economic incentives and on improving access to credit, information and training.

5.2 Limitations and Recommendations for Future Research

This dissertation is subject to several limitations that should be taken into consideration. In Study I and II, firstly, due to the hypothetical nature of the choice scenario presented to respondents, there is a potential gap between stated preferences and actual behaviour. Although efforts were made to design realistic and meaningful scenarios, it is essential to recognize that individuals' choices in hypothetical situations may differ from their real-world decisions. Future research could consider incorporating real-life decision-making contexts to enhance the external validity of the findings. Secondly, a potential concern relates to the small number of farmers surveyed in Study I and Study II (n=292). However, it is worth noting that the DCE methodology enables multiple observations per farmer, effectively expanding the sample size beyond the approximately 300 farmers interviewed. By randomly sampling farmers from various regions across Taiwan, we are confident that the estimated preferences are representative of the larger population. Nevertheless, for future studies, we recommend the inclusion of a larger sample size to further enhance the accuracy and robustness of findings.

In Study II, there are three more limitations. Firstly, the measurement indicators are limited in number. The chosen indicators for this study may capture important aspects of the latent variables, however, it would be preferable to include more than three indicators for each latent variable to enhance measurement reliability and validity (Hair et al., 2017). Secondly, the exploration of psychological factors in this research is limited to trust in government and attitudes towards AES participation. However, there are other significant factors that could impact decision making, such as environmental concerns, risk attitudes, self-efficacy beliefs and social norms. Future research utilizing the HCM should consider including those factors to gain a more comprehensive understanding of their impact on AES adoption. Thirdly, this dissertation did not consider or investigate the underlying reasons why opt-out farmers were unwilling to participate in the scheme, primarily due to limitations in the number of variables examined. Previous studies have mostly focused on examining the endogenous determinants influencing farmers' adoption or non-adoption of PES (Falconer, 2000; Ma et al., 2010; Villanueva et al., 2017). While non-participating respondents were asked to give their reasons for non-participation, the validity of these reasons reflecting their true thoughts is questionable.

When conducting a choice experiment survey, a high rate of opting out in a choice experiment can signal various things – it might indicate that the presented alternatives are not attractive enough, or that the design of the experiment is too complex. It could also reflect a deep-seated preference for existing practices among participants. Careful analysis of the opt-out group can offer valuable insights for policymakers and researchers. To address this limitation, we recommend that future research explores and identifies the factors causing the opt-out group's reluctance to participate by incorporating psychometric data using HCM to acquire insights into their decision-making behaviour.

In Study III, we utilized the object case BWS method to allow farmers to rank their 'most preferred' and 'least preferred' conservation practices from a given set of options. However, due to time constraints, limited farmer knowledge of certain policies, as well as the inherent complexity of various conservation methods, we encountered challenges in conducting surveys using profile or multi-profile cases. Consequently, we were unable to calculate farmers' willingness to accept (WTA) specific measures or practices. Moreover, based on a systematic literature review conducted by Mühlbacher et al (2016), it has been demonstrated that BWS exhibits similar reliability to DCE, regardless of design and sample size. Specifically, the utilization of multi-profile case BWS can be considered as an enhancement of the traditional DCE, offering new possibilities in the field of agri-environmental research. Hence, building on the findings of our study, we recommend that future research endeavor to consider using the profile or multi-profile case BWS to further investigate farmers' preferences and decision-making regarding AES.

Study IV has two limitations that should be acknowledged. Firstly, the search was restricted to articles published in English, potentially excluding relevant literature published in other languages. Secondly, although measures were taken to ensure the inclusion of high-quality studies, there is a possibility of bias or error stemming from limitations in the study design or implementation. Furthermore, the findings of Study IV revealed that existing research primarily focused on the adoption of individual SAPs, highlighting the need for further investigations that explore farmers' trade-offs among different SAPs in rice cultivation. This can help determine the optimal combination for designing AES tailored to rice cultivation, thereby maximizing adoption among farmers. Secondly, the vote-counting method may not capture the full complexity of the studies, however, it can still provide a useful summary of the findings and offers insights for future research. Despite these limitations, this study serves as a valuable baseline for future research and offers insights for policymakers aiming to promote AES adoption and SAPs.

5.3 Policy Implications

The pressing need for designing effectives Agri-environmental schemes (AES) is evident in China, Taiwan and Southeast Asia. This region has a large population of smallholder farmers, who are highly vulnerable to the impacts of climate change. It is essential for the governments in these regions to establish mandatory schemes that support farmers in adopting SAPs, while simultaneously protecting the environmental and ensuring food security. Central to our understanding of farmer decision-making, as evidenced throughout the dissertation, lies the principle of random utility maximization. Farmers continuously evaluate the trade-offs between adopting a new practice and continuing with conventional methods. They assess an array of factors to make the most advantageous choice. Our findings also underscore the imperative of conducting a rigorous assessment of farmer preferences pertaining to SAPs prior to the formulation and implementation of conservation policies. Recognizing these preferences can ensure that policies are not only technically sound but also tailored to the specific needs, aspirations, and constraints, thereby increasing the likelihood of their acceptance and effective execution. Moreover, by tailoring interventions according to these preferences, policymakers can allocate resources more efficiently, foster greater trust in government within the farming community, and enhance the overall impact and longevity of conservation initiatives. Thus, an in-depth analysis of farmer perspectives and concerns should be a fundamental step in the design and implementation of any conservation policy.

In a recent study, Cortes-Capano et al. (2021) discovered that farmers expressed a preference for non-monetary incentives, such as access to training and technical support, over monetary payments. Similarly, Banerjee et al. (2021) demonstrated that incorporating non-monetary incentives, such as facilitation services and social rewards, can enhance ecological outcomes in voluntary green payment schemes while reducing costs by capitalizing on farmers' social preferences for a green social image. Taking these studies in conjunction with our own results, it becomes evident that a broad array of non-monetary incentives is important to effectively promote AES participation. Therefore, the combination of monetary and non-monetary incentives in policy interventions can address a broader spectrum of farmer motivations and preferences. While monetary incentives can provide immediate financial relief and offset initial implementation costs, non-monetary incentives, such as training, technical support and eco-label, can empower farmers with knowledge and foster a sense of pride and community engagement.

Moreover, the adoption of AES cannot rely solely on financial or non-monetary incentives, as psychological factors have been shown to pay a significant role in farmers' decision-making (Mills et al., 2017; Dessart et al., 2019). Thus, for a more holistic and effective policy framework, it is imperative to integrate an understanding of these psychological determinants. Psychological factors such as attitudes towards implementing SAPs, perceived risks and trust in government can all influence farmers' decision making. However, it is important not to overlook the influence of either psychological, economic, socio-demographic, farm management or institutional factors when examining farmers' adoption of AES. Neglecting any of these integral dimensions can lead to biased interpretations and policy recommendations.

This research also has implications for the structure and objectives of AES design. The emphasis on establishing a clear benchmark is the cornerstone of transitioning towards sustainable farming. It is paramount to set Best Management Practices (BMP) and Good Agricultural Practices (GAP) as a reference standard. However, setting standards alone is not enough, it is essential to incentivize farmers to go beyond these standards. These incentives can include financial support, such as tax credits or subsidies, or non-financial incentives, such as eco-labels or other awards. Recognizing and rewarding farmers who go beyond the minimum requirements can inspire other farmers to follow suit, ultimately driving greater adoption of SAPs and improving environmental outcomes.

Furthermore, an intermediate approach, allowing for partial or incremental land enrollment, or gradual reduction in the use of agro-chemicals, can be more effective than pressing immediate comprehensive changes. This gradual approach helps ensure a smoother transition for farmers, making it more approachable and feasible to adopt the changes. Our research indicates that a well-designed scheme can address and mitigate psychological barriers, such as low trust in government and negative attitudes towards implementing SAP, hindering farmers' participation.

Overall, this dissertation highlights that while the agri-environmental scheme can be instrumental in promoting specific SAPs and mitigating environmental impacts, its development must adopt a nuanced understanding of farmer preferences and motivations. Policymakers should consider a holistic approach, encompassing multiple dimensions to ensure broader acceptance, effective implementation, and long-term viability of these schemes.

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7 Appendix of surveys

Survey 1 Conducted in Taiwan (translated into English)

Survey 2 Conducted in China (translated into English)

Survey 1

Questionnaire for Rice Farmers in Taiwan

Nr.： _ _ _ _ Postcode：______________ Date：____DD____MM____YY

Part 1

I. General information	
1. Age: _______ years old	
2. Education ☐Primary ☐Junior high school ☐Senior high school ☐Agricultural college ☐University/above	
3. Household size (1)Younger than 15 years old：Male_________ ，Female_____ (2)Equal / Older than 15 years old：Male_____ ，Female______	
4. How many people work full time on the farm? ___ person. How many of them get a salary? ____ How many people work part time on the farm? ___ person. How many of them get a salary? ____	
5. Farming experience	________ years
6. Successor	☐Yes ☐No ☐maybe in the future
7. How important are the following income sources for you? (a) rice farming _______ (0-5, from not important at all to most important) (b) other farming _____ (0-5, from not important at all to most important) specify_______________ (c) off-farm income ____ (0-5, from not important at all to most important)	
8. Household income per year (include on-farm income) (Currency: NTD) ☐<200,000 ☐200,000~300,000 ☐300,000~400,000 ☐400,000~500,000 ☐500,000~600,000 ☐600,000~700,000 ☐700,000~800,000 ☐>800,0000	
9. On-farm income per year (Currency: NTD) ☐ <50,000 ☐50,000~100,000 ☐100,000~200,000 ☐200,000~300,000 ☐300,000~400,000 ☐400,000~500,000 ☐500,000~600,000 ☐>600,0000	

II. Farm Operation

10. Operation type ☐conventional farming ____% ☐Organic farming ____%

11. Farm size: ___________________ ha Number of land parcel: __________ pieces

Own cultivated land:__________ ha Fallow land __________ ha

Leased in: ___________________ ha Rental price: _________ NTD/ha

Leased out: __________________ ha Rental price: _________ NTD/ha

12. Certification of your products

☐None ☐GAP (Good Agricultural Practice) ☐TAP (Traceable Agriculture Product)

☐Organic Certification ☐Others _ _ _

13. Marketing channels

☐Farmers' association ☐Farmers market ☐Supermarket ☐Online-shop/Internet

☐Contract farming ☐Public grain purchasing program ☐Others _ _

III. Cropping practices

14. Main Crops/ Chemical fertilizer / Yield

Rice (first cultivation)____☐ paddy rice ☐ upland rice

Area:_____ ha

N:______ bag; ____kg/bag; Price: _____NTD/bag

P: ______ bag; ____kg/bag; Price: _____NTD/bag

K:______ bag; ____kg/bag; Price: _____NTD/bag

Compound fertilizer Number:______; ____ bags; _____ Kg/bag; Price: ____NTD/bag

Compound fertilizer Number:______; ____ bags; _____ Kg/bag; Price: ____NTD/bag

Yield: ___________ Kg/ha Price sold: ________NTD/Kg

Rice (second cultivation)____☐ paddy rice ☐ upland rice

Area:_____ ha

N:______ bag; ____kg/bag; Price: _____NTD/bag

P: ______ bag; ____kg/bag; Price: _____NTD/bag

K:______ bag; ____kg/bag; Price: _____NTD/bag

Compound fertilizer Number:______; ____ bags; _____ Kg/bag; Price: ____NTD/bag

Compound fertilizer Number:______; ____ bags; _____ Kg/bag; Price: ____NTD/bag

Yield: Kg/ha. Price sold: NTD/Kg

Other crops： _ _ _ _ _ growing period： _ _ _ _ _ _ Area:_____ ha N:______ bag; ____kg/bag; Price: _____NTD/bag P: ______ bag; ____kg/bag; Price: _____NTD/bag K:______ bag; ____kg/bag; Price: _____NTD/bag Compound fertilizer Number:______; ____ bags; _____ Kg/bag; Price: ____NTD/bag Compound fertilizer Number:______; ____ bags; _____ Kg/bag; Price: ____NTD/bag Yield: ___________ Kg/ha. Price sold: ________NTD/Kg
15. Which kind of fertilizer do you use? ☐Chemical Fertilizer _____% ☐ Organic Fertilizer___% ☐No Fertilizer
16. Since last decade, the fertilizer use per ha is gradually ☐increasing ☐decreasing ☐the same ☐neither
17. How expensive do you think is chemical fertilizer ___(1-5; 1 is very cheap, 5 is very
18. How expensive do you think is organic fertilizer____ (1-5; 1 is very cheap, 5 is very
19. Do you rotate your crops? ☐Yes, which crops? _____________________☐ No
20. Have you participated in any workshop on rational use of fertilizer which organized by the government? ☐Yes ☐ No. If yes, when and how often? _____________ How would you rate the training? ______________(from 1 - 5; 5 being the best)
21. How much do you follow the advice on fertilizers use by the extension agents? _____________ (from 0-4, 0 meaning not at all and 4 meaning fully)
22. Did you send the soil sample to the lab for soil fertility analysis? ☐Yes ☐No
23. Did you send the sample to the lab for the diagnosis of crop nutrition? ☐Yes ☐No
24. Do you make your own compost? ☐Yes ☐No
25. Amount of fertilizer applied according to ☐my own experience ☐other farmers’ experience
26. After harvest, what do you do with the rice straw residue? ☐open field burning ☐to chop the straw and leave them on the field ☐compost ☐feed ☐others

IV. Opinions about the future agri-envioronmental scheme

27. If the chemical fertilizer subsidy is terminated, the price of fertilizer will be increased, what would be your action? ☐reduce the amount of fertilizer application
☐ remain the same level of fertilizer application ☐switch to the other economic crops

28. what proportion of your are you willing to enrolled when the Fertilizer Reduction Scheme (FRS) when it is implemented in the near future:
☐ 100% of my farmland ☐ 50% of my farmland ☐25% of my farmland
☐0% please specify the reason:____

29. If your friends decided to participate the Fertilizer Reduction Scheme (FRS), your willingness of participating the scheme is:
☐ I will also participate the scheme with my friend
☐ I want to wait until I see the result of my friends' participation
☐ I don't want to participate at all. Please specify the reason:________________

30. The proportion of land you are willing to enrolled when the Pesticide Free Scheme (PFS) is implemented in the near future:
☐ 100% of my farmland ☐ 50% of my farmland ☐25% of my farmland
☐0% please specify the reason:____

31. How many farmers do you personally know, who already participated in an subsidy program? ___________ person

32. Do you think the farming activity have good contribution on the environment?
☐Yes. what is the contribution? ______________________ ☐ No

33. Have you ever heard about Rice-Duck farming? ☐Yes ☐ No

34. Would you be interested in trying Rice-Duck farming if extension assistance were available? ☐Yes ☐ No, why?________________________

V. Government support

35. Which subsidy program do you participate? (multiple choice)
☐Old farmers pension program ☐Public grain purchasing program ☐Set-aside payments
☐fallow land revival program ☐contract farming ☐subsidy for organic fertilizer

36. Are you satisfied with the general agricultural policies?
☐very dissatisfied ☐dissatisfied ☐neutral ☐satisfied ☐very satisfied

37. Which subsidy programs are you unsatisfied with? (multiple choice) ☐Old farmers pension program ☐Public grain purchasing program ☐Set-aside payments ☐fallow land revival program ☐contract farming ☐subsidy for organic fertilizer ☐Small landlords and big tenant-farmers project ☐subsidy for switching crops
38. How do you know the latest policy? ☐Farmers' association ☐Agricultural Research and Extension Station ☐Agricultural Research Institute ☐Township ☐Others：_____
39. Are the government supports sufficient for you? ☐Yes ☐No, what should be improved?__________________________
40. How much are you willing to take financial risk? _______ (from 1 to 5, 1 means not willing to take any risk, 5 means willing to take a lot of risk)
41. How patient are you when it comes to money? _______ (from 1 - 5, 1 means very impatient and 5 means very patient)
42. How much do you generally trust your government with paying the subsidy as agreed on? ____ (1-5, 1 means no trust at all and 5 means fully trusting)

Part 2

Assume the chemical fertilizer subsidy will be terminated. The Council of Agriculture will offer you the possibility to join a Chemical Fertilizer Reduction Scheme (CFRS). You will receive the reward payment when you join the program, but you must comply with a reference level of chemical fertilizer application. Once you reduce the quantity of chemical fertilizer application, you can save the costs of chemical fertilizer, and you can receive the reward/incentive payment according to the degree of reduction. We would like to ask you to make a choice from the following options. There are eight choice sets. Please choose the most preferred condition – only one from each choice set. Please answer carefully and honesty. These questions will contribute to future contract design.

Choice set 1			
	Condition 1 (ID-10)	Condition 2 (ID-14)	
Land enrolled in FRS	50%	100%	
Payment for entry level/reference level (ha/year)	NT$2,000/ha	NT$3,000/ha	
Additional reduction with corresponding payment	15% less than the reference level (+ NT$ 1,000/ha)	only reference level	
Contract length	5 years	5 years	I do not wish to participate in CFRS
Eco-label for FRS	Yes	Yes	
Please tick your preference	☐	☐	☐

Choice set 2			
	Condition 1 (ID-4)	Condition 2 (ID-11)	
Land enrolled in FRS	25%	25%	
Payment for entry level/reference level (ha/year)	NT$2,000/ha	NT$3,000/ha	
Additional reduction with corresponding payment	only reference level	30% less than the reference level (+ NT$ 2,000/ha)	
Contract length	2 years	5 years	I do not wish to participate in CFRS
Eco-label for FRS	Yes	No	
Please tick your preference	☐	☐	☐

Choice set 3			
	Condition 1 (ID-15)	Condition 2 (ID-16)	
Land enrolled in FRS	25%	25%	
Payment for entry level/reference level (ha/year)	NT$2,000/ha	NT$2,500/ha	
Additional reduction with corresponding payment	100% give up chemical fertilizer (+ NT$ 5,000)	30% less than the reference level (+ NT$ 2,000/ha)	
Contract length	5 years	5 years	I do not wish to participate in CFRS
Eco-label for FRS	Yes	Yes	
Please tick your preference	☐	☐	☐

Choice set 4			
	Condition 1 (ID-1)	Condition 2 (ID-12)	
Land enrolled in FRS	50%	50%	
Payment for entry level/reference level (ha/year)	NT$2,000/ha	NT$2,500/ha	
Additional reduction with corresponding payment	30% less than the reference level (+ NT$ 2,000/ha)	only reference level	
Contract length	2 years	5 years	I do not wish to participate in CFRS
Eco-label for FRS	Yes	No	
Please tick your preference	☐	☐	☐

Choice set 5			
	Condition 1 (ID-8)	Condition 2 (ID-16)	
Land enrolled in FRS	25%	25%	
Payment for entry level/reference level (ha/year)	NT$2,500/ha	NT$2,500/ha	
Additional reduction with corresponding payment	15% less than the reference level (+ NT$ 1,000)	30% less than the reference level (+ NT$ 2,000/ha)	
Contract length	2 years	5 years	I do not wish to participate in CFRS
Eco-label for FRS	No	Yes	
Please tick your preference	☐	☐	☐

Choice set 6			
	Condition 1 (ID-1)	Condition 2 (ID-14)	
Land enrolled in FRS	50%	100%	
Payment for entry level/reference level (ha/year)	NT$2,000/ha	NT$3,000/ha	
Additional reduction with corresponding payment	30% less than the reference level (+ NT$ 2,000/ha)	only reference level	
Contract length	2 years	5 years	I do not wish to participate in CFRS
Eco-label for FRS	Yes	Yes	
Please tick your preference	☐	☐	☐

Choice set 7			
	Condition 1 (ID-5)	Condition 2 (ID-7)	
Land enrolled in FRS	100%	100%	
Payment for entry level/reference level (ha/year)	NT$2,000/ha	NT$2,000/ha	
Additional reduction with corresponding payment	30% less than the reference level (+ NT$ 2,000/ha)	15% less than the reference level (+ NT$ 1,000)	
Contract length	2 years	5 years	I do not wish to participate in CFRS
Eco-label for FRS	No	No	
Please tick your preference	☐	☐	☐

Choice set 8			
	Condition 1 (ID-3)	Condition 2 (ID-13)	
Land enrolled in FRS	100%	25%	
Payment for entry level/reference level (ha/year)	NT$2,500/ha	NT$2,000/ha	
Additional reduction with corresponding payment	100% give up chemical fertilizer (+ NT$ 5,000)	100% give up chemical fertilizer (+ NT$ 5,000)	
Contract length	2 years	5 years	I do not wish to participate in CFRS
Eco-label for FRS	Yes	No	
Please tick your preference	☐	☐	☐

Survey 2

Survey on Green Manure Cover Crops Planting and Cultivated Land Protection & Utilization in Gansu Province, China

Part 1

I. General information	
Name	
City (County): ☐Wuwei City ☐ Zhangye City ☐ Pingliang City ☐ Linxia	
1. Household size: _______	
2. Number of members below 16 years old: _______	
3. Number of members above 60 years old: _______	
4. Age of the head of the household: _______	
5. Gender of the head of the household: _______	
6. Educational level of the head of the household? ☐Primary and und below ☐Junior high school ☐ High school ☐College and above	
7. Household income per year (include on-farm income) (Currency: RMB): _______	
8. On-farm income per year (Currency: RMB): _______	
9. Do you have an off-farm income? ☐Yes ☐ No	
II. Farm Operation	
10. Operation type ☐Crop Farming ☐Livestock Farming ☐Mixed type	
11. How many laborers work full time on the farm? _____ person. Salary RMB/year: _________	
12. How many laborers work part time on the farm? _____ person. Wage RMB/day: __________	
13. Number of farm machinery owned: _________units	

14. Farm size: __________________ mu Number of land parcel: __________ pieces Own cultivated land:__________ mu Fallow land __________ mu Leased in: __________________ mu Rental price: _________ RMB/mu Leased out: _________________ mu Rental price: _________ RMB/mu
15. Have you joined a cooperative? ☐Yes ☐ No
16. Do you collaborate with enterprises? ☐Yes ☐ No
III. Cropping practices
17. Main types of crops you grow ☐ Wheat ☐ Corn ☐ Mixed grains (sorghum, millet, oats, etc) ☐ Legumes (soybeans, adzuki beans, etc). ☐ Potatoes ☐ Oil crops e.g. rapeseed ☐ Greenhouse vegetables ☐ Open-field vegetables ☐ Fruit trees ☐ Medicinal herbs ☐Others
18. How much was spent on seed (in yuan): __________
19. How much was spent on chemical fertilizers (in yuan): __________
20. Amount of chemical fertilizer input (kg/mu): __________
21. Nitrogen fertilizers (urea, ammonium carbonate, etc.)(kg/mu): ____________
22. Phosphate fertilizers ((potassium chloride, potassium sulfate, etc.) (kg/mu):
23. Compound fertilizers (diammonium phosphate, NPK compound fertilizer.) (kg/mu):
24. Amount of commercial organic fertilizers used (including bio-organic fertilizers) (kg/mu):
25. Price of commercial organic fertilizer (yuan/kg):
26. Specialized fertilizers (like specialized corn fertilizer, specialized fruit tree fertilizer, etc.) (kg/mu):
27. Price of specialized fertilizer (yuan/kg):
28. Amount of farm-made fertilizer applied:
29. Price of farm-made fertilizer (yuan/ton):
30. Pesticide input (yuan/mu):
31. Number of pesticide applications (times):

32. Type of pesticide used: ☐ Insecticides ☐ Fungicides ☐Herbicides ☐ Plant growth regulators ☐ Others, please specify:________________
IV. Awareness of cultivated land protection and relevant land policies.
33. Which of the following cultivated land protection policies or measures have you heard of? [Multiple choices] ☐ Crop rotation and fallow system ☐ Replacing chemical fertilizers with organic fertilizers (reduced application of chemical fertilizers) ☐ Soil testing and formula-based fertilization ☐ Green manure planting for soil nourishment ☐ Returning
34. Which of the following cultivated land protection policies have you received training on? [Multiple choices] ☐ Crop rotation and fallow system ☐ Reduction of chemical fertilizers and pesticides (replacing with organic fertilizers) ☐ Soil testing and formula-based fertilization ☐ Planting green manure for soil nourishment ☐ Returning crushed
35. Is there a fee for the training? ☐Yes ☐ No
36. If there is a fee for the training, how much is it (in yuan): ___________
37. Where did you receive the cultivated land protection training? ☐ local authority ☐ agricultural companies ☐ dealers for agri-products ☐ Others, please specify:
38. Has your village carried out any promotions related to cultivated land protection? ☐Yes ☐ No
39. Do you think the protection of cultivated land is important? ☐ very important ☐ important, but not to be over-emphasized ☐ not important
40. Have you received training in other areas than cultivated land protection? ☐Yes ☐ No
41. If yes, in what areas? [Multiple choices allowed] ☐ Agricultural production techniques ☐Agricultural product sales ☐ Livestock pollution prevention and control ☐ Processing techniques ☐ E-commerce ☐ Others, please specify:
42. In your opinion, who is the primary responsible party for cultivated land protection? ☐ Central government ☐ Local government ☐ Village collective economic organizations ☐ Farmers (agricultural operators)

43. Are you concerned about changes in the quality of your cultivated land? ____ ☐ yes, very concerned ☐ Indifferent ☐ no, not concerned
44. As far as you are concerned, has there been any change in the quality of your cultivated land compared to the past? ☐ Yes, a decrease ☐ Yes, an increase ☐ the change is not obvious ☐ no change
45. What is your mean criterion for judging the soil quality of cultivated land? ☐ Thick soil layer, no compaction ☐ high yields ☐ I have no specific criteria/I am not sure
46. Do you agree that it is necessary to carry out fallow periods and crop rotation? _________ 1: strongly disagree, 2: disagree, 3: general, 4: agree, 5 strongly agree
47. Which of the following measures would you choose if given policy support? (multiple choice). ☐ crop rotation ☐ leaving the farmland fallow ☐ growing green manure cover crops ☐returning straw residue to the field after harvest ☐ reducing the application of chemical fertilizer ☐ reducing the use of pesticides. ☐ Crop-livestock combination ☐ following recommendations for the use of fertilizers after soil testing and analysis ☐ I do not choose any of the options
48. Which of the following cultivated land conservation practices do you currently adopt? (multiple choice) ☐ crop rotation ☐ leaving the farmland fallow ☐ growing green manure cover crops ☐returning straw residue to the field after harvest ☐ reducing the application of chemical fertilizer ☐ reducing the use of pesticides. ☐ Crop-livestock combination ☐ following recommendations for the use of fertilizers after soil testing and analysis ☐ none
V. Farmers' cognition of GMCC planting
49. It is easy to learn GMCCs planting techniques: ____________ 1: strongly disagree, 2: disagree, 3: general, 4: agree, 5 strongly agree
50. Planting GMCCs could conserve the environment: _________ 1: strongly disagree, 2: disagree, 3: general, 4: agree, 5 strongly agree
51. Planting GMCCs could improve soil quality: ________ 1: strongly disagree, 2: disagree, 3: general, 4: agree, 5 strongly agree
52. Planting GMCCs could reduce chemical fertilizer application: _________ 1: strongly disagree, 2: disagree, 3: general, 4: agree, 5 strongly agree

53. Planting GMCCs could diminish pesticide usage: ________ 1: strongly disagree, 2: disagree, 3: general, 4: agree, 5 strongly agree
54. Planting GMCCs could prevent soil erosion: ________ 1: strongly disagree, 2: disagree, 3: general, 4: agree, 5 strongly agree
55. Planting GMCCs could effectively cover bare soil: ________ 1: strongly disagree, 2: disagree, 3: general, 4: agree, 5 strongly agree
56. Planting GMCCs could enhance biodiversity in farmland ecosystems: ________ 1: strongly disagree, 2: disagree, 3: general, 4: agree, 5 strongly agree
57. I understand the government's policy on GMCC planting: _________ 1: strongly disagree, 2: disagree, 3: general, 4: agree, 5 strongly agree

Part 2

We would like to ask you six questions regarding your preference for arable land conservation practices. Each question is composed of six conservation practices. Which practice do you think is the best (most preferred) and which is the worst (least preferred)?

Block 1

MOST effective	Choice Set 1 (BWS-1)	LEAST effective
▢	Leaving fallow for a whole year	▢
▢	Applying biochar-based fertilizer	▢
▢	Halving chemical fertilizer and pesticide application	▢
▢	Interplanting leguminous green manure crops	▢
▢	Crop rotation with leguminous green manure crops	▢
▢	Returning residue or straw to the field after harvest	▢

MOST effective	Choice Set 2 ((BWS-3)	LEAST effective
▢	Leaving fallow for a whole year	▢
▢	Halving chemical fertilizer and pesticide application	▢
▢	Interplanting leguminous green manure crops	▢
▢	Returning residue or straw to the field after harvest	▢
▢	Improving irrigation facilities	▢
▢	Substituting chemical fertilizer (CF) with organic fertilizer (OF)	▢

MOST effective	Choice Set 3 (BWS-5)	LEAST effective
▢	Applying biochar-based fertilizer	▢
▢	Halving chemical fertilizer and pesticide application	▢
▢	Crop rotation with leguminous green manure crops	▢
▢	Growing green manure cover crops (GMCCs) on fallow farmland	▢
▢	Returning residue or straw to the field after harvest	▢
▢	Substituting chemical fertilizer (CF) with organic fertilizer (OF)	▢

MOST effective	Choice Set 4 (BWS-7)	LEAST effective
▢	Halving chemical fertilizer and pesticide application	▢
▢	Interplanting with green manure cover crops (GMCCs)	▢
▢	Crop rotation with leguminous green manure crops	▢
▢	Growing green manure cover crops (GMCCs) on fallow farmland	▢
▢	Returning residue or straw to the field after harvest	▢
▢	Improving irrigation facilities	▢

MOST effective	Choice Set 5 (BWS-9)	LEAST effective
▢	Leaving land fallow for a whole year	▢
▢	Applying biochar-based fertilizer	▢
▢	Halving chemical fertilizer and pesticide application	▢
▢	Interplanting with green manure cover crops (GMCCs)	▢
▢	Growing green manure cover crops (GMCCs) on fallow farmland	▢
▢	Substituting chemical fertilizer (CF) with organic fertilizer (OF)	▢

MOST effective	Choice Set 6 (BWS-11)	LEAST effective
▢	Leaving land fallow for a whole year	▢
▢	Applying biochar-based fertilizer	▢
▢	Interplanting with green manure cover crops (GMCCs)	▢
▢	Crop rotation with green manure cover crops (GMCCs)	▢
▢	Growing green manure cover crops (GMCCs) on fallow farmland	▢
▢	Improving irrigation facilities	▢

Block 2

MOST effective	Choice Set 1 (BWS-2)	LEAST effective
☐	Leaving land fallow for a whole year	☐
☐	Applying biochar-based fertilizer	☐
☐	Crop rotation with green manure cover crops (GMCCs)	☐
☐	Returning crop residues to the field	☐
☐	Improving irrigation facilities	☐
☐	Substituting chemical fertilizer (CF) with organic fertilizer (OF)	☐

MOST effective	Choice Set 2 (BWS-4)	LEAST effective
☐	Leaving land fallow for a whole year	☐
☐	Applying biochar-based fertilizer	☐
☐	Halving chemical fertilizer and pesticide input	☐
☐	Growing green manure cover crops (GMCCs) on fallow farmland	☐
☐	Returning crop residues to the field	☐
☐	Improving irrigation facilities	☐

MOST effective	Choice Set 3 (BWS-6)	LEAST effective
☐	Applying biochar-based fertilizer	☐
☐	Halving chemical fertilizer and pesticide input	☐
☐	Interplanting with green manure cover crops (GMCCs)	☐
☐	Crop rotation with green manure cover crops (GMCCs)	☐
☐	Improving irrigation facilities	☐
☐	Substituting chemical fertilizer (CF) with organic fertilizer (OF)	☐

MOST effective	Choice Set 4 (BWS-8)	LEAST effective
☐	Leaving land fallow for a whole year	☐
☐	Halving chemical fertilizer and pesticide input	☐
☐	Crop rotation with green manure cover crops (GMCCs)	☐
☐	Growing green manure cover crops (GMCCs) on fallow farmland	☐
☐	Improving irrigation facilities	☐
☐	Substituting chemical fertilizer (CF) with organic fertilizer (OF)	☐

MOST effective	Choice Set 5 (BWS-10)	LEAST effective
☐	Leaving land fallow for a whole year	☐
☐	Interplanting with green manure cover crops (GMCCs)	☐
☐	Crop rotation with green manure cover crops (GMCCs)	☐
☐	Growing green manure cover crops (GMCCs) on fallow farmland	☐
☐	Returning crop residues to the field	☐
☐	Substituting chemical fertilizer (CF) with organic fertilizer (OF)	☐

MOST effective	Choice Set 6 (BWS-12)	LEAST effective
☐	Applying biochar-based fertilizer	☐
☐	Interplanting with green manure cover crops (GMCCs)	☐
☐	Growing green manure cover crops (GMCCs) on fallow farmland	☐
☐	Returning crop residues to the field	☐
☐	Improving irrigation facilities	☐
☐	Substituting chemical fertilizer (CF) with organic fertilizer (OF)	☐

8 Appendix of Full Publications

Study I: Investigating rice farmers preferences for an agri-environmental scheme: Is an eco-label a substitute for payments?

Study II: The role of rice farmers' attitude and trust in government in decision-making for participating in a climate related agri-environmental scheme

Study III: Explaining farmers' reluctance to adopt green manure cover crops planting for sustainable agriculture in Northwestern China

Study IV: Factors influencing the adoption of sustainable agricultural practices for rice cultivation in Southeast Asia: a review

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