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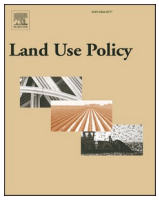

A comparative analysis of agri-environment schemes in China, Europe and US: Potential for improvement

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ABSTRACT

Due to severe environmental issues and the need for sustainable agriculture, the market-based policy tool of agri-environment schemes (AES) are in high demand in China. With the Grain-for-Green Program (GFGP) being a compelling example, China has shown its determination to implement AES nationwide. However, the government's efforts to address environmental impacts and efficient utilization of funds have faced massive criticisms, calling for urgent need to improve AES or AES-like programs in China. AES have been evolving progressively in developed regions like in Europe and US, where they first emerged. The goal of this paper is to compare the differences in the foundational basis of AES, design characteristics, explore examples of programs, policy and laws, and scientific basis of AES in China, Europe and US with an aim of providing directions for improvements in China. We review information from policies and existing AES studies which we analyze thematically and descriptively to draw insights. Findings show important gaps in governance and design mechanisms of AES programs in China, with its limited integration into the national agricultural policy and limited scientific guide compared to those in Europe and US. AES are an important concern in the Common Agricultural Policy (CAP) in Europe and the Farm Bill in the US. We recommend urgent attention to Chinese policy and scientific support to AES design to counter biodiversity loss, land degradation and climate change impacts in China.

1. Introduction

The increase in population in the past decades has threatened food security leading to the adoption of intensified agricultural production systems in China and many other parts of the world (Ickowitz et al., 2019). However, intensive agriculture has, in turn, led to complex negative externalities among them biodiversity loss, soil erosion, water pollution and climate change among others (Brussaard et al., 2010). These problems are not only difficult to resolve but have also led to broad and profound negative influence on both the agricultural production system and a wide range of ecosystem services. The resulting damages include negative effects on long-term sustainability of food production systems and its associated outcomes that range from economic losses, poor human health and disruption of agro-ecosystem functions (Elahi et al., 2019; Norse and Ju, 2015; Sandhu et al., 2010).

Reasons behind the difficulties to mitigate the negative externalities of intensified agriculture are characterized by the extensive nature of the agricultural land in use which acts as the control source, and its nature as a public environmental good. Methods of political regulations of command-and-control policies are limited in achieving the desired outcomes and are thus known to most likely result in resistance of farmers that would further induce ineffectiveness and high costs (Brouwer and van der Heide, 2009; Engel et al., 2008; Tang et al., 2020). This means that any potential efficient solutions must fully consider the role of farmers in the implementation of conservation measures (Uthes and Matzdorf, 2013).

Owing to the need for inclusion of farmers' opinions in the design of conservation strategies, there has been increased proposal of economic instruments that provide both environmentally effective and economically cost-effective response to the problems of agricultural externalities (Dowd et al., 2008; Sidemo-Holm et al., 2018). A common response is the instrument of agri-environment schemes (AES), which are a market-based tool that allows farmers to voluntarily implement conservation measures for payments. In an AES program, private landowners implement conservation measures on a voluntary basis under conservation payment policies (Vries and Hanley, 2016). Farmers are offered payments to compensate for associated income loss (Mack et al., 2020) when they undertake certain land management practices (Burton

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and Schwarz, 2013).

AES first appeared in Europe in the middle of 1980s and then spread fast in other parts of the world (Primdahl et al., 2003). From AES programs, great improvements of farmland quality, biodiversity benefits, and even poverty reduction and social welfare have been generated (Boatman et al., 2008; Mills, 2012; Zhu et al., 2018). As a promising approach, AES have been implemented worldwide, especially in Europe and US, where they were first promoted. In recent years several billions have been paid annually in these two regions to farmers as compensations for AES implementation to improve the environment (Armsworth et al., 2012; Donald and Evans, 2006; Feng et al., 2006).

From a regional perspective, AES are more applied in developed countries than developing ones. Developing countries are under immense environmental pressure. The Chinese government has been developing the concept and the practice of programs that are analogous to the mechanism of AES in Europe and US since the beginning of the 21st Century (Pan et al., 2017). China's efforts and decisions for pilot testing of AES programs have been internationally recognized with the Grain-for-Green Program (GFGP), which has both enormous amount of monetary investment (more than US$69 billion) and huge coverage of national area (32 million households, 15.31 million hectares) (Jin et al., 2017). The primary objective of GFGP is to promote soil and water conservation nationwide.

However, criticisms on the already implemented programs so far in China are far and wide particularly in various aspects, such as the top-down style with heavy intervention of government, unclear environmental targets, involuntary participation, lack of scientific identification of measures, under-compensation and unreasonable compensation without heterogeneity among others (Bennett, 2008; Shang et al., 2018; Yang et al., 2013). These problems have limited the performance of AES in both environmental improvement and the efficient utilization of program funds (Shang et al., 2018). Furthermore, they have also set obstacles for the favorable development of AES in China.

On the contrary, widespread and multidimensional environmental issues in China demand sound, practical and urgent AES implementation. An effective strategy to achieve the expected potentially significant improvement of AES implementation in China is to learn from successful AES in other parts of the world. AES in Europe and US, although not perfect, are comparatively much more developed with experienced modes in practice (e.g. Mack et al., 2020; Perrot-Maître, 2006; Vergamini et al., 2015) and insightful scientific discussions in theory (e.g. Baylis et al., 2008; Le Coënt, 2016; Simpson et al., 2023). Based on this, we consider a comparison of undeveloped AES in China with successful AES implementation in Europe and US as a novel way to figure out the improvement directions for Chinese AES in a concrete way. To be practical and specific, in this article, we compare and analyze AES in China, Europe and US based on four perspectives in the three different regions: (i) the foundational basis of AES emergence, (ii) the relevant policies and laws governing the design and implementation of AES, (iii) AES programs and their performance in practice, and finally, (iv) the existing scientific studies on AES development and modification. Through these comparisons, we give practical and step-based recommendations for the improvement of AES in China. We review information from policies and literature in respective countries and analyze them thematically and descriptively to meet our study objectives. This study is the first of its kind and it offers essential insights into the opportunity to strengthen the AES policy framework in China to avert environmental disasters and degradation.

Before this comparison, it is necessary to first clarify the scope, the mechanism and principles, as well as the characteristics of AES conceptually in order to set a clear boundary of this study. This is because there are many existing analogous terms related to AES, which have hindered the development of AES in China. Due to this, we intend to select and distinguish the most common analogous terms of payments for ecosystem services (PES) in the international world, as well as eco-compensation (EC) as the general conservation programs in China.

The rest of this article is organized as follows. Section 2 outlines the mechanism, characteristics and the scope of AES. Section 3 presents an overview of AES in China. Section 4 compares AES programs in China, Europe and US, from four different perspectives. Section 5 presents the discussion of our findings upon which we draw recommendations for AES improvement in China in Section 6. Finally, Section 7 presents conclusions and study limitations.

2. Clarification of AES

2.1. Distinction of AES, PES and EC

The terms of EC, PES and AES are interrelated and often used interchangeably, along with other analogous ones in both China and other countries (Shang et al., 2018; Yu et al., 2020). However, they refer to different conservation program categories along with different implementation principles. Distinguishing them is essential to reduce the confusion and to set the boundary for the discussions in this study (Fig. 1).

EC is a term commonly used in Chinese studies. There is no consistently accepted concept of it in China, with some researchers referring it as equivalent to PES (Pan et al., 2017), and some defining it as the combination of PES and punitive-based conservation programs (with polluter-pays principle) (Shang et al., 2018). A more recent report has pointed out that the concept of it has significantly broadened, including any conservation program involving fiscal transfers, transfers between the same level of governments, environmental trading platforms, green product and financial standards, among others (World Bank, 2021). It has vague definition (Shang et al., 2018) and has been continuously described loosely in the draft National Regulation and therefore has become increasingly challenging to pin down the exact meaning (World Bank, 2021). Based on this context, we conclude that EC is generally adopted as an umbrella term for basically all kinds of conservation programs in China.

The term PES is the most recognized one globally among EC, PES and AEC, and has a commonly accepted definition by Wonder (2005) (referring to Table 1). Also, the concept of EC and AES has evolved based on the core logic and mechanism of PES. It emphasizes the market-based voluntary principle for exchanging ecosystem services with economic incentives regarding a broad range of environmental issues. The so-called PES-like programs in China could be understood as programs involving compensation but not exactly conforming to the market-based principles of PES, like programs without the PES principle of voluntary participation (Pan et al., 2017; Yang et al., 2013).

The term AES emerged from Europe and has mainly existed also in European studies.[1] AES can be considered as a specific subset of PES, which target specifically at compensating farmers for conservation farming practices on agricultural land (Le Coënt, 2016; Ottaviani, 2011). The practical applications of it have been dominated in developed countries so far. Analogously to PES-like programs explained above, AES-like programs in China refer to the agricultural programs that do not exactly conform to the standard market-based principles of AES (Zhang et al., 2015).

2.2. Market principles of AES

As described above, AES are discussed as a specific group of PES, which implies that they have the same logic and principles underlying their meaning (Wynne-Jones, 2013). As a more globally well-known term, PES have the classic illustration for its market-based mechanism (Engel et al., 2008) as well as a typical definition (see Table 1) (Wonder, 2005). Here, we demonstrate the specific market operational rules and

[1] There are alternative terms in other countries for AES programs, like green payments in agricultural and environmental policies in US.

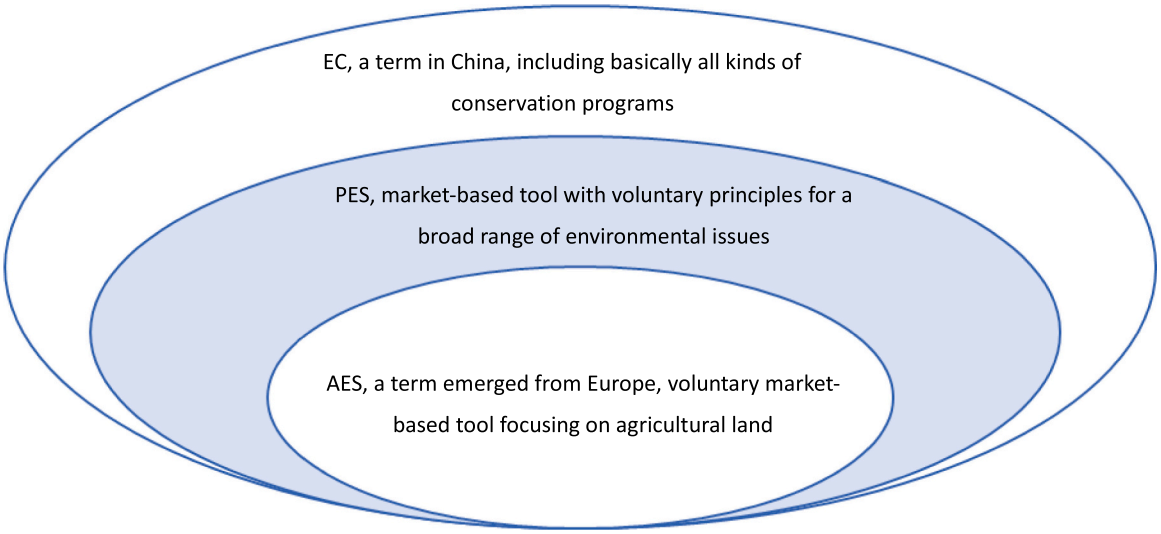

Fig. 1. Thematic scope of AES, PES and EC.

Table 1
Definition of PES and AES explanation.

PES definition (Wonder, 2005)	market elements	AES components
(1) a voluntary transaction	voluntarism	voluntarism for farmers to participate in AES programs
(2) where a well–defined ecosystem service (or a land-use likely to secure that service)	targeted commodity	land use change activities (i.e., conservation measures) or resulted environmental benefits
(3) being bought by a (minimum one) buyer	buyers	beneficiaries, or government, or the third parties
(4) from a (minimum one) provider	sellers	farmers
(5) if and only if the provider secures the ecosystem service provision	conditionality of exchange	payments are given only when required land use activities are completed or expected environmental benefits appear

market components of AES with the typical PES mechanism and definition as a basis.

The market-based mechanism of AES is illustrated in Fig. 2. Under business as usual (BAU) scenario, farmers are supposed to earn the best economic profit they can from their land, with the amount of profit being represented by the size of box-A in Fig. 2. However, conventional farming under BAU might cause negative externalities to other people or the public, like the water pollution from farming, the cost of which is indicated by the size of box-D in Fig. 2.

A way to prevent the negative externalities of BAU farming is that farmers adopt conservation measures with corresponding changed farming activities. However, conservation farming is generally less productive than BAU farming (De Ponti, et al., 2012). The size of box-B in Fig. 2 shows the amount of economic profits farmers can get from conservation farming.

Therefore, farmers have no willingness to adopt conservation farming without any compensation (Bartkowski, et al., 2023). The logic of AES is to give economic incentives through compensation payments to farmers in order for them to apply conservation farming, with the amount of compensation being shown by the size of box-E in Fig. 2. The notable thing is that the amount of compensation (the size of box-E in Fig. 2) should not be less than the losing profits from BAU farming to conservation farming (the size difference from box-A to box-B in Fig. 2), and should not be more than the cost of the original caused externalities (the size of box-D in Fig. 2).

From Fig. 2, it is noticeable that AES are an ingenious approach which is promising to satisfy both farmers and the public group affected by the negative externalities of farming, as well as to improve the societal welfare (Ward et al., 2021). With AES, farmers can obtain at least not less than the economic profit they can get under BAU farming (the summed size of box-C and box-E is not less than the size of box-A in Fig. 2). Meanwhile, the total welfare of the society can be increased as the compensation amount should be less than the cost of externalities (the size of box-E is smaller than that of box-E in Fig. 2).

However, the successful application of AES with these expected effects requires effective compliance of the market principles of AES. As a market-based approach, AES have five components reflecting the corresponding market elements, including buyers, sellers, targeted commodity, voluntarism and conditions for transaction (Table 1).

The first component (Table 1) indicates that farmers should voluntarily decide whether to participate in AES programs. Second, the targeted commodity in AES refers to either the performance of the required land use change activities implemented by farmers, or the results of final environmental benefits generated by farmers. Third, the market component of buyers in AES are usually either the beneficiaries of the land use changes and/or final environmental benefits, or the government or the related third parties; while sellers in AES are generally farmers who need to implement the land use change activities on their farmland. The conditionality for the transaction is that farmers will only get compensation payments when the expected land use change activities are successfully implemented (action-based payment) or the expected results of environmental benefits (result-based payment) appear.

2.3. *Design characteristics of AES programs*

In practice, AES programs differ with each other greatly from their design and implementation characteristics along with different features and mechanisms. The characteristics of an AES program are formed based on the design choices for each component of AES (Table 2). In AES, the component of sellers generally refers to farmers[2] who act as the providers of environmental benefits. However, farmers who can offer the same or higher environmental benefits at lower costs (and in turn lower compensation payment) are often the ones prioritized by AES designers as potential sellers (Engel et al., 2008). This aspect is important for the cost-effective design of AES (Claassen et al., 2008). The buyers in AES are expected to be the users of environmental benefits

[2] In this article, we adopt farmers as a term representing also farm landowners who adopt AES.

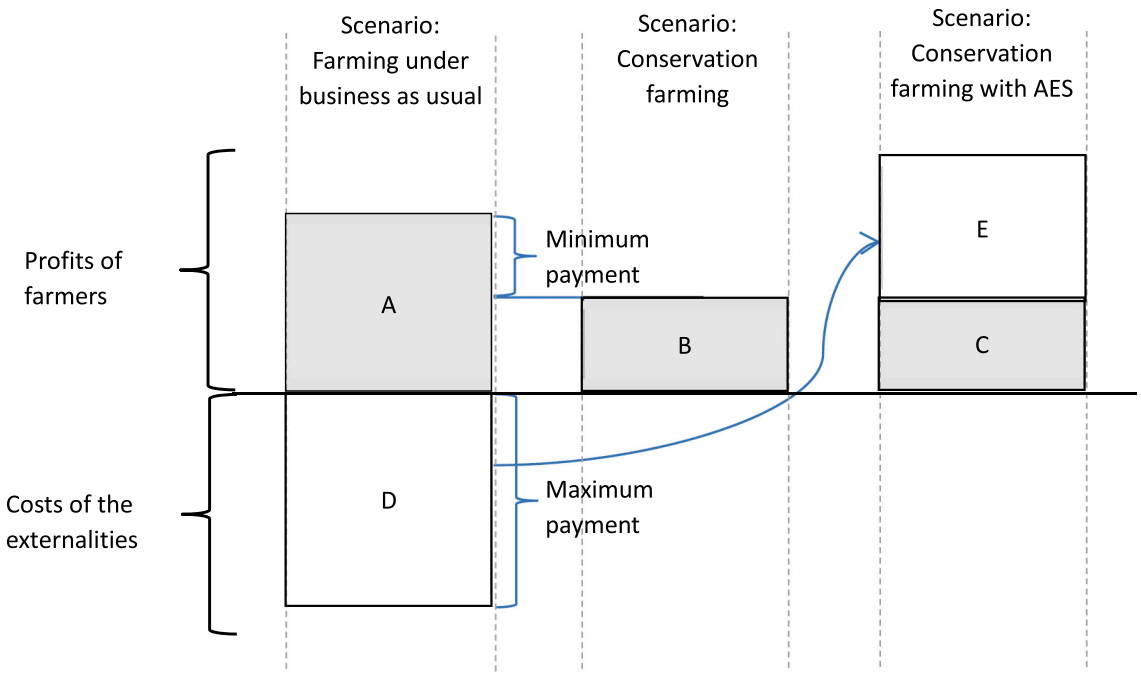

Fig. 2. Mechanism rules of AES (Source: Modified from Engel et al., 2008). Note: The size of the rectangular boxes indicates the amount of "profits of farmers" (above the line) or "costs of the externalities" (below the line). The grey boxes (box A, B and C) represent "profits of farmers" earned purely from farming under different scenarios, which are differed with the white boxes (box D and E) representing profits or costs not from farming. The arrow from box D to box E denotes that the amount of profits represented by box E should be from box D, i.e. "costs of the externalities". The size of box E should then be in the range of the difference of box A and B (minimum size for box E) and the whole box D (maximum size for box E).

Table 2
Design choices for AES components.

components of AES		design-choice	description
sellers		farmers	lower-cost farmers are pursued
buyers		user-financed government/agency-financed	buyers are actual users of the environmental benefits buyers are third parties
land use change activities		"activity creating" "activity reducing"	increase activates of land use reduce activities of land use
conditionality		result-based action-based	payment based on the provided environmental benefits payment based on the adoption of land use change activities
contract forms		traditional way auction-based	more like up-bottom style tend to be bottom-up way
payments	payment code	cash in-kind	monetary value items related to the measures
	payment standard	benefit-based cost-based in-mixed	value of environmental benefit provided costs of environmental benefit provision e.g., payment ability

provided by farmers/sellers. However, this is only true for a small number of AES programs (private programs). Most AES programs worldwide are public and government funded, and the government or a third party acts as the buyer (Ezzine-de-Blas et al., 2016).

Land use change activities (Table 2) refer to the conservation measures in AES, which can further be divided into two types. The first type is the increase in activities of land use, for instance the measure of cover crops; while the second type is to reduce the activities on land, like the no-till conservation measure. The "activity creating" type usually costs much more than the "activity reducing" type (Engel et al., 2008).

Conditionality in AES has also two types. The result-based AES payment type tends to be more cost-effective and is more desirable than action-based payment of AES (Molenaar, 2013). However, it is harder to implement in reality owing to the high monitoring and implementation costs, and risks of participation failure compared to the action-based AES (Simpson et al., 2023).

Furthermore, the AES contract between farmers and buyers can be offered in two forms: the traditional way in which farmers accept the terms and conditions of AES contract directly without bidding or via auction where farmers competitively bid payments which allow buyers to offer contracts more dynamically based on price and expected environmental targets. Auction-based AES give farmers more initiatives and also tend to achieve higher cost-effectiveness (Lewis and Polasky, 2018). The payment can be in the form of either cash or in-kind, and the payment amount should be defined within a certain scope (Fig. 2). In-kind payments are in form of subsidies or labor or donations (Carmona-Torres

et al., 2011; Del Corso et al., 2017; Kolinjivadi et al., 2019).

3. AES overview in China

In China, the implementation of AES did not happen regardless of the several continuous natural disasters affecting large areas with severe consequences, including the massive floods in 1998 and the unprecedented sandstorms between 2000 and 2002 (Pan et al., 2017; Sun and Zhou, 2008). Since then, the government has implemented a range of conservation projects, with less of them being either voluntary PES or AES programs but instead of government engineering conservation programs (i.e., EC). The objectives of these projects focus mainly on water and soil conservation issues, which are presumed to be the major contributors to natural disasters.

The program of GFGP, with its pilot testing starting in 1999 and being completed nationwide in 2002, is typically considered as the first and also the biggest AES program in China. However, there is also an existing debate that considers it as a partial AES-like program because its design does not conform to AES market-based principles (Shang et al., 2018). The design, implementation, and the means and amounts of compensation payments follow a top-down approach, with central government making decisions and lower levels of governments being delegated the responsibility of AES implementation (Wunder et al., 2008).

The similar top-down pattern, along with the corresponding shortages, also happens to other AES or AES-like programs in China, such as the Grassland Ecological Protection Subsidy and Reward Program (GEPSRP) nationwide and the cropland protection program of Farmland Protection Fund Program (FPFP) in Chengdu city. AES programs in China are implemented more in a way of performing government regulations than carrying out through the market-based voluntary mechanism. It is said that once the government in China designates a regional area for AES programs, the participation of farmers is mandatory instead of voluntary (Zhen et al., 2014). The details of programs which are decided by high levels of government often lack sufficient investigation to tailor them to local situations and determine where they are actually located (Benett and Carroll, 2014; Sun and Zhou, 2008). Participation of farmers is frequently mandatory when government has designated land for AES related programs, sometimes even when the payment levels are less than farmers' costs, which may cause resistance among farmers and further induce low environmental impacts and cost-effectiveness (Zhang et al., 2015; Zhen et al., 2014). Besides, the scheme design is focused generally on single conservation measure for one kind of land type in each program, and the contract is basically an action-based payment.

4. Comparison of AES in China, Europe and US

4.1. Foundational basis of AES emergence

AES emerged widely in many countries in 1980s and its origin was motivated by various reasons. Comparing with that in China was due to high environmental stress, the emergence of AES in both Europe and US were originally mainly due to the needs of controlling production surpluses as well as supporting farmers at the same time, with environmental conservation as a side benefit (Feng, 2007; Salt, 2016).

In Europe, AES are thought to have started in 1985 along with the Agricultural Structures Regulation (EU Regulation 797/85) (Batáry et al., 2015), with the first program being launched in the United Kingdom in 1986 (Dobbs and Pretty, 2008). In the same year of 1985, the Conservation Reserve Program (CRP) in the US is officially established in the Farm Bill, although the fore-runner of it had already started in 1930s (Hellerstein, 2017).

4.2. Policies and laws of AES

The Common Agricultural Policy (CAP) is a common policy for all European Union (EU) countries, which was first initiated in 1962 as a partnership between agriculture and society as well as between EU governments and farmers (European Commission, 2021). AES have been a component of CAP implementation in Europe since 1980s. CAP has been providing financial support for AES implementation in EU mainly under its pillar 2 of rural development, combined with the Member States' own additional expenditures. The legal guarantees of AES implementation in Europe include optional AES as part of European Community law in Council Regulation in 1985 (EEC 797/85) and mandatory AES for all member states in 1992 as part of MacSharry reforms (EEC 20178/92). It incorporates AES into Rural Development Regulation (pillar 2 of CAP) as part of the Agenda 2000 CAP reform (EEC 1257/99), and the continued Regulations afterwards (e.g. EEC 1698/2005) (Batáry et al., 2015; Zimmermann and Britz, 2016).

The Farm Bill in the US, originated in 1930s, as a package of legislation for guiding farming production and is updated roughly once every four to six years (National Sustainable Agriculture Coalition, 2018). As a component of Farm Bill since 1985, the AES related programs are authorized through the Conservation Titles of Farm Bills. Farm Bills provide both financial support and the legal guarantee for agri-environment payments in the US. Since the establishment of CRP in 1985 Farm Bill, the funding amount as well as the size and scope of the funded programs have substantially increased. For example, Environmental Quality Incentives Program (EQIP) was created in 1996, its expansion, and the increased Grassland Reserve Program and the Conservation Security Program in 2002, as well as the Agricultural Conservation Easement Program which emerged in 2014 (Baylis et al., 2008; Reimer, 2015).

AES are increasingly important components of environmental and agricultural policies in both Europe and US (Chabé-Ferret and Subervie, 2013). On the contrary, there is no policy or law, at least not one, that is specialized for the design and AES implementation in China. There are only some relevant policies and regulations for general PES and EC programs in China, with the related regulations being initiated relatively late and scattered in other relevant laws and legislations (Yang, 2018).

The first policy for agricultural protection in China was released in 1999 as "several opinions of the State Environmental Protection Administration on strengthening ecological and environmental protection in rural areas" (Han and Jin, 2016). The principles for developing EC mechanisms was first issued in 2005 in the fifth Plenary Session of the 16th Central Committee of the Chinese Communist Party (Zhang and Lin, 2010). In 2010, it was decided that EC would be regulated at the national level by the Chinese central government. By 2013, three national laws of the Forest Law, the Law on the Prevention and Control of Water Pollution, and the Water and Soil Conservation Law provided a legal basis for EC pilot projects (Asian Development Bank, 2016). In 2016, the State Council approved a paper entitled "several opinions on establishing a sound EC mechanism and the EC regulations".

4.3. Scientific AES studies

4.3.1. Studies in Europe and US

AES are a complex policy instrument, and the scientific studies for its design and implementation are also complicated and are explored from various aspects (Batáry et al., 2015). The majority of the relevant literature are case study based, with most of them involving more than one study aspect (Börner et al., 2017; Uthes and Matzdorf, 2013). According to studies with reviews, the most concerning aspects of AES studies in Europe and US include, but are not limited to, the environmental impact of AES, the farmer participation and acceptance of AES, the cost-effectiveness of AES programs and AES designs, the socio-economic effects of AES like poverty reductions, among others (Börner et al., 2017; Mennig and Sauer, 2020; Uthes and Matzdorf, 2013). Each of these aspects have been studied scientifically adopting different methods and focused on different perspectives, as illustrated in Fig. 3.

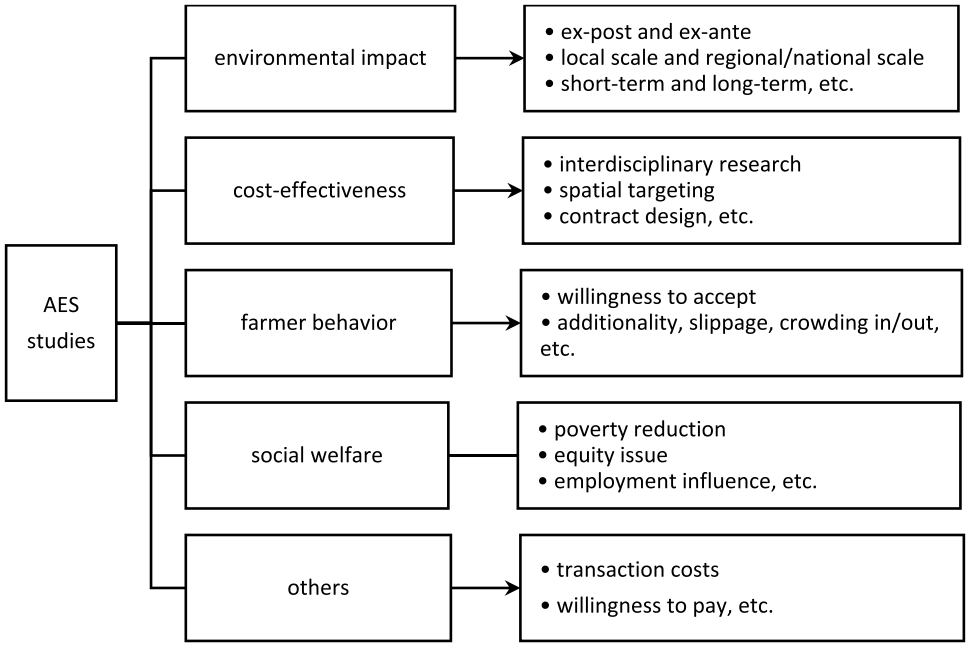

Fig. 3. Classified perspectives of AES studies. Note: It is a general and simplified classification for the different aspects and perspectives of AES, and these different aspects of AES are often intertwined both in the real world and in research studies.

For the environmental impact of AES, the quantitative evaluation for ex-post impacts generally refers to empirical analysis with all kinds of collected data and various statistical methods (Uthes and Matzdorf, 2013). The evaluation is easier at spatially small-scale and temporally in the short-term than that at large-scale and long-term scenarios (Princé et al., 2012). The majority of such study in Europe focus on the topic of biodiversity with less study for abiotic resources like water and soil quality (Mennig and Sauer, 2020; Uthes and Matzdorf, 2013). In contrast, for ex-ante evaluation of environmental impacts of AES, it is generally performed through modelled simulation, such as those performed in the national program of Conservation Effects Assessment Project (CEAP) in US which focuses initially on water issues (Johnson et al., 2015; Shields et al., 2006). However, the predicted environmental impacts most often lag behind in the expectation and may also be delayed (Börner et al., 2017; Marconi et al., 2015; Primdahl et al., 2003).

Increasing studies in Europe and US go for the cost-effectiveness of AES, which refers to either reaching the maximized environmental target under certain budget or achieving the minimized budget for a given set of environmental goals (Balana et al., 2011; Wätzold and Schwerdtner, 2005). To achieve the cost-effectiveness of AES, one promising emphasis is the integration of ecological and economic perspectives in a holistic and interdisciplinary research (Ansell et al., 2016; Wätzold and Schwerdtner, 2005). Another emphasis refers to the spatial targeting, as information of spatial heterogeneity of land for both environmental impacts and economic costs is important to reduce the producer surplus caused by asymmetric information (Baylis et al., 2008; Claassen et al., 2008; Guo et al., 2020). Some studies consider both interdisciplinary integration and spatial targeting with very technical and quantified methods for getting the cost-effectiveness of AES, including a few like Wätzold et al. (2016), Hao et al. (2023) and Simpson et al. (2023). In addition, another group of study attempts to reduce the information rents through the form of AES contract design, such as from perspectives of result-based payment, spatially differentiated payments, auctions, as well as the different combinations of them (Simpson et al., 2023; Börner et al., 2017; Uthes and Matzdorf, 2013).

Farmer behavior in AES programs has also attracted a lot of research attention. Many researchers have investigated farmers' "willingness to accept" to implement AES programs. They focused more on farmer-specific factors like gender, age and education among others that are difficulty to consider under pure economic rationality, adopting mostly econometric methods (Cullen et al., 2020; Defrancesco et al., 2007; Sattler and Nagel, 2010). Some other research cover farmer behavior responses and their impacts on AES outcomes, highlighting additionality, slippage, and crowding in and out (Claassen et al., 2008; Fleming et al., 2018).

Moreover, AES study may also refer to the socio-economic and other related aspects. These include the poverty reduction and equity issue, employment influences, transaction costs of AES, and the willingness to pay from stakeholders with mainly the method of choice experiments, etc. (Börner et al., 2017; Claassen et al., 2008; Schomers and Matzdorf, 2013; Uthes and Matzdorf, 2013).

4.3.2. *Studies in China*

Comparing to the studies in developed countries described above, AES research in China is limited (Zhu et al., 2018). AES studies in China are basically under the umbrella terms of either EC or PES instead of AES, with the exceptions of recent studies by Li et al. (2019), Zhang et al. (2015) and Zhu et al. (2018)[3]. According to the review study of Yang and Lu (2018), the majority of AES studies in China are descriptive without quantified analysis especially for the ones written in Chinese, with many case studies being about the GFGP which can only be described as AES-like program.

Based on the different aspects of AES study illustrated in Fig. 3, the cost-effectiveness of AES is the least concern so far in China, particularly the scientific design of cost-effective AES with sophisticated methods. Although there is increasing interest and demand for integration of biodiversity conservation goals into agricultural subsidies through AES in China, the majority of the studies are still qualitative.

However, there are quantitative studies in China on farmers' attitude towards AES (e.g. Li et al., 2019; Zhang et al., 2015) and farmers' willingness to accept AES program (e.g. Zhen et al., 2014; Zhu et al., 2018). However, factors influencing farmers' behaviour are limited to the characteristics of farmers such as age, education, attitudes and income among others, but do not draw more broadly from factors like the

[3] Many US relevant studies also refer to the terms of agricultural conservation programs, cost-sharing, green payments, etc.

neighboring farmers' behaviors and relationships as in Cullen et al. (2020) and Defrancesco et al. (2007). In addition, the possible results arising from farmers' behavior after participation in AES design and implementation, i.e., additionality, slippage, and crowding in and out, are also underexplored in China.

4.4. Programs

4.4.1. Overall situations

Over half of the European landscape is covered by agricultural activities, and about 25% of the EU farmland is under some form of AES contracts (Batáry et al., 2015; Science for Environment Policy, 2017). The expenditure for AES projects in EU from 2007 to 2013 is about 23 billion Euros, and since 2014 there has been increasing funds being transferred from CAP pillar 1 to pillar 2 to continue the enlargement and the ongoing reforms of AES in EU. Although there are a variety of AES implementation patterns among EU members, the majority of AES programs in Europe are aimed at biodiversity conservation and the payments are mostly action-based[4] (Baylis et al., 2008; Russi et al., 2016). Like in Europe, the area of coverage and expenditures for AES programs in both China and US are considerable. Compared with EU, AES programs in US and China are mostly targeted on issues of soil erosion and water pollution.

In Europe, preventing the abandonment of marginal land is considered as a protection for biodiversity, and AES are mainly implemented to generate positive externalities from traditional, high nature value farming and relatively less on the reduction of negative externalities of intensified farming (Baylis et al., 2008). In contrast, for mitigating soil erosion and water pollution, AES programs in US and China focus more on farmland retirement, which are targeted against the negative externalities of agricultural extensification (Baylis et al., 2005).

The application of AES programs in relation to their application scales differ when comparing the scale in Europe with that in US and China. In Europe there are a range of different AES programs with each program targeting a small spatial area, while the number of AES programs in both US and China is relatively small with each program covering a very large area. Overall, the number of AES programs implemented in Europe is the biggest, followed by those in US which are approximately twenty AES programs and finally, China with a very small number of AES programs (Zhu et al., 2018). This is mainly due to the small but many countries in Europe, with AES programs being tailored to each country's scope. In addition, it needs to be noticed that the AES policy and funding system in EU are different with that in China and US, with many AES programs in EU getting both a proportion of CAP funding and also country own funding. Along with this, the targets of these AES programs in EU should combine CAP overall targets with country specific concerns. Regarding the relatively even small number of programs in China, it can be mainly explained by the fact that AES policies and frameworks are still in conception stages (Li et al., 2019).

4.4.2. Specific features

To explore further the specific features of AES programs in Europe, US and China, we give three examples of implemented programs from each region respectively (Table 3) for demonstration purposes.[5] The rationale for comparing these specific programs is to identify the features and mechanisms of the schemes that could lead to their efficient (i.e., cost-effective) or inefficient performance, and to detect the concerned environmental issues. The relative consistent timing, application scale and funding size are not our concern here for comparison, as similar parameters for EU and US can be found in Biffi et al. (2021).

[4] For the existed resulted-based AES programs in Europe, one can refer to Burton and Schwarz (2013).

[5] We consider the representativeness and also the possible diversity of programs for each region for selection.

Table 3
Selected AES programs in Europe, US, and China.

Europe			
program and country	Vittel Watershed Protection program (VWP), France	Environmentally Sensitive Area (ESA), England	Northeim Model Project (NMP), Germany
targeted issue	water quality	landscape, biodiversity (wildlife), historic interest	biodiversity (plant species)
payment condition	conservation measures in dairy farms	conservation measures in grassland	conservation measures in grassland and arable land
payment method	cash payments with technical assistance; payments are differentiated on a farm-by-farm basis	cash payment with payments varying depending on management practices required under each tier	cash payment, result-based, with auctions to determine geographically different payments
funding source	Vittel company	EU and UK government	private foundation
description	begin in 1993; long-term contract of 18–30 years; covering 5100 ha Spring catchment, with 27 farmers involved; with careful scientific research basis	begin in 1987; contract of 10 years; national program covering 1.1 million ha with many ESAs in the country	pilot from 2000 to 2003, payments from 2004; contract of 10 years; covering 288 ha grassland with 28 farmers; coordinated by University of Göttingen
United States			
program	Conservation Reserve Program (CRP)	Environmental Quality Incentives Program (EQIP)	Conservation Stewardship Program (CSP)
targeted issue	water and soil quality, wildlife habitat, etc.	water and soil quality, wildlife protection, etc.	water and soil quality, wildlife protection, etc.
payment condition	land retirement of farms and ranches	conservation measures and land retirement	conservation measures
payment method	cash payment with technical assistance; spatially different payment with competitive auctions (based on local cash rental rates and productivity) and environmental index scores	cash payment with technical assistance; typically uniform payment in county level since 2002 (auction from 1997 to 2001)	cash payment with technical assistance; result-based payment, higher performances get higher payment
funding source	government	government	government
description	begin in 1985; contract typically 10–15 years; nationally largest and oldest program covering tens of millions of acres by now; originally targeted for highly erodible land; it assesses applications based on their score on the Environmental Benefits Index since 1990	begin in 1996; contract 1–10 years for working lands; covering more than 115 million acres with over 384,000 participants by 2018; including measures to improve tillage and nutrient management practices	begin in 2002; contract 5 years for working lands; covering more than 70 million acres by 2018; it consolidates existing conservation efforts while strengthening new operations
China			
program	Grain-for-Green Program (GFGP)	Grassland Ecological Protection Subsidy	Farmland Protection Fund

(continued on next page)

Table 3 (*continued*)

		and Reward Program (GEPSRP)	Program (FPFP), Chengdu
targeted issue	watershed protection (soil erosion and others)	grassland quality protection	quantity and quality of cultivated land
payment condition	cropland retirement to forest or grassland	abandoning grazing in severely degraded pasture area; reducing number of grazing sheep and doing rotational grazing in sustainable grazing area	arable land cannot be abandoned without cultivation or destroyed for other usages
payment method	cash and in-kind (grain, seedlings) payment; payment differs in Yangtze River Basin and Yellow River Basin	cash payment; payments differ between provinces along with different detailed requirements for payment conditions	payment as farmers' pension insurance, land transfer guarantee, and agricultural insurance; payments differ between two kinds of farmland
funding source	central government	central government	local government
description	pilot from 1999 to 2001, full scale since 2002; contract of 8 years for timber, 5 years for orchards, and 2 years for grassland; national largest program covering more than 34 million ha	pilot from 2009 to 2010 in Tibet; begin in 2011; contract of 5 years; national largest grassland program; targets at arid or semi-arid northern and northeastern area in China	begin in 2011; the first incentive-based farmland project in China for the protection of cultivated land area from decreasing

(Source: Wunder et al. 2008; Department for Environment Food and Rural Affairs 2011; Perrot-Maître 2006; Schwarz et al. 2008; National Sustainable Agriculture Coalition 2019; Khanna 2017; Zhu et al. 2018)

Private funded programs reflect the ideal market-based logic of AES that the buyers (or the financial providers, referring to Table 2) in AES are the actual users of the environmental benefits instead of the governments or the third parties. They are usually more market-oriented, precisely designed, and are more cost-effective than public funded programs, especially when supported with scientific design (Ezzine-de-Blas et al., 2016) that matches payments and environmental needs (Biffi et al., 2021). The Vittel Watershed Protection (VWP) in France is a true private AES example (Table 3), which has been used to illustrate a fictitious "perfect" AES scheme (Perrot-Maître, 2006; Molenaar, 2013). The primary reasons for the success of the program are not financial,[6] but are also as a result of the complex partnerships between technical, economic, social, legal, geographic, sociological and political issues, a good rapport resulting from a multidisciplinary research team building trust with farmers and the long-term contract ensuring farmers' income security among others (Perrot-Maître, 2006). It is hard to replicate successful private AES programs that are exclusively financed by ecosystem service users, as it is not only hard to identify the exact users who furthermore have the willingness and capacity for the financial burden (Molenaar, 2013) but also even harder to have the appropriate local cooperative context combined with different parties (Perrot-Maître, 2006). Blended-finances or cooperation could therefore be promising, like the Northeim Model Project (NMP) in Germany. Further, farmers' concerns and voluntary participations are critical in private schemes (Perrot-Maître, 2006), which is driven by social and economic factors but the spatial heterogeneity of land, costs and thus distribution of payments would require that the underlying socio-economic factors that moderate payment allocation are explored (Biffi et al., 2021).

Auctions, spatially heterogeneous payment and result-based payment scheme designs are considered generally a developing concept of advanced mechanisms of AES to better achieve the cost-effectiveness of programs (Schwarz et al., 2008). In the NMP project in Germany (Table 3), farmers were asked to submit a sealed bid with a corresponding bid price for the provision of the predefined environmental services (floristic biodiversity) on their fields (Ulber et al., 2011). It combined result-based payments with auctions for spatially heterogeneous payment schemes. The typical strategy that US conservation programs, including the largest land retirement program CRP as well as the two largest working land programs EQIP and Conservation Stewardship Program (CSP) in Table 3, have implemented cost-effectiveness by gathering information of farms/farmers through application forms and using benefit–cost indices (e.g., environmental index scores in CRP in Table 3) to rank and select participants[7] (Claassen et al., 2008). In this process, competitive bids were adopted to identify participating farmers, contract sites, and to decide the heterogenous payments for CRP since 1991 and for EQIP between 1997 and 2001. Furthermore, CSP in US has applied result-based payment with advanced benefit-cost indices, for maintaining and enhancing existing conservation systems as well as for adopting new additional conservation activities.

The mechanism of auction in AES is expected to make the program more cost-effective than fixed-rate payments due to its potential to reduce the information rent of farmers - the excessive payments caused by lack of information on farmers' heterogeneous compliance costs (Vergamini et al., 2020). However, auction cannot be a "silver bullet" to the information asymmetry problem, as bid prices are not only likely to reflect different costs but also farmers' expectations on the maximum payment they could accept (Molenaar, 2013). Result-based payment schemes are considered more advanced than action-based payments schemes because payments are attached to particular environmental benefits which gives farmers flexibility and opportunity to spur innovation and efficient usage of funding (Burton and Schwarz, 2013). However, disadvantages of result-based payment include the risk of discouraging the participation of farmers due to the fact that they cannot guarantee in advance on whether their efforts will pay off (considering also external risks like extreme weathers) or not, and the difficulties of developing monitoring indicators (biodiversity might be easier than other ecosystem services) (Molenaar, 2013; Burton and Schwarz, 2013). Spatially heterogeneous payment may not only be attached with auction or result-based payment, but can also be applied alone, like in VWP in France (Table 3) which has individual tailored plans for each farm. However, this demands much more transaction costs for elaborate design and communication.

Scientific basis is critical for the design and implementation of cost-effective AES programs. VMP in France and NMP in Germany (Table 3) collaborated with French National Agronomic Institute and University of Göttingen respectively for scientific designs of programs customized to the local conditions (Perrot-Maître, 2006; Ulber et al., 2011). The UK Environmentally Sensitive Area (ESA) program grew to a total of 43 designated ESA schemes, with different ESAs focusing on different environmental targets and measures tailored to suit the needs of each particular ESA. In shaping ESA program, different organizations partnered with the government for professional contributions and scientific lessons (Dobbs and Pretty, 2008). Regarding US programs (Table 3), scientific basis for program design mainly referred to the benefit-cost targeting, including the Environmental Benefits Index in CRP since 1990, the state-flexible benefit-cost ranking mechanism in EQIP, and the advanced result-based ranking mechanisms in CSP (Hansen, 2006; Claassen et al., 2008). Other than that, since 2004 the CEAP was

[6] Study has shown that complementing public funds with private money does not noticeably promote AES effectiveness (Molenaar, 2013).

[7] Because all current US programs are budget or acreage limited, program enrollment is competitive.

conducted for evaluating the environmental effectiveness of all USDA conservation programs, and a pilot national survey integration program CEAP-ARMS (Agricultural Resources Management Survey) was conducted between 2004 and 2005 for understanding farmers' motivation to adopt conservation practice (Schaible et al., 2015). In addition, with scientific support additionality and leakage issues during program implementation were investigated and quantified, like the NMP in Germany and CRP in US which were explicitly tested to determine their additionality rate and leakage rate respectively (Molenaar, 2013).

In China, the political top-down approach for the implementation of conservation program is generally applied. Programs are attached closely to political targets and pressures from different levels of governments especially in regard to the total land coverage area of program contracts. This makes farmer participation in these programs unlikely to be voluntary, especially due to lack land property rights in the country. From this perspective, all the three Chinese programs (see Table 3) should be AES-like programs instead of pure AES programs (Pan et al., 2017).

GFGP in China adopted one homogeneous payment level for the whole north area in China and the other homogeneous payment level for the whole south area in China. These two payment levels are decided by the government instead of either market-based auctions or scientific designs. GFGP attempted to get the maximum program contract covering area instead of selecting proper spatial sites with better environmental benefits.

In addition to the criticized issue of involuntary participation of farmers in many regions in the country, this top-down approach has also induced many other problems. They include the lack of investigation and consideration for various and heterogeneous local conditions, the neglect of local innovation and variation, and the obvious unreasonable and uniform compensation payment levels (Bennett, 2008; He and Sikor, 2015). Furthermore, in GEPSRP program (Table 3) it has additional issues of only weak enforcement of conditionality, dissatisfaction of farmers with the payment levels (as it is not totally voluntary participation), and thus the resistance and low performance of farmers in the programs (Wunder et al., 2008; Zhen et al., 2014). For FPFP program (Table 3), it is a small local program with less levels of governments involved, while the compensation payments are in the form of farmer pensions, which makes the program to act more like policy regulation than market-based tool.

Comparing with the political-task-like top-down approach in China, a more balanced top-down decision-making process with local autonomy is found in EQIP in US and ESA in UK (Table 3). With the general goals of EQIP being given by USDA as a federal agency, the states can designate local high-priority practices for increased payments, which is strengthened in the 2018 Farm Bill (Biffi et al., 2021). As an EU co-financed program, ESA program needs to follow the general goals of CAP Pillar II for the European Agricultural Fund for Rural Development (EAFRD), while it encourages member states to promote the development of local and sub-regional approaches via the Community Led Local Development.

For the aim of soil and water protection, in China, conservation measures in practice are monotonic, with land retirement being the single practice in GFGP. For the same targets, except the land retirement program of CRP, working land programs of EQIP and CSP are successively developed in US with almost 200 practices for voluntary farmer participation and are considered to be more cost-effective than land retirement (Feng et al., 2006).

In the spatial scale perspective, programs in US and China are generally nationwide and large, which also tend to have multiple environmental aims. Large scale programs are mostly poorly targeted and are hard to monitor, while small scales programs may have the concerns of disproportionally high cost and are disabling for solving environmental target covering big areas (like watershed problems). Therefore, Medium-sized geographical area of AES programs is recommended for better achieving the cost-effectiveness (Molenaar, 2013).

The participation and compliance of farmers is important for the successful performance of AES programs. Considering the participation of farmers, economic incentives are always important as the fundamental necessity and should not be ignored, while other non-monetary factors (e.g., socio and cultural influences) have been perceived impactful especially in the long-term (Schenk et al., 2007). So far, non-monetary factors are barely analyzed in practical programs in general (like those in Table 3), while technical assistance has been given along with cash payment in VWP in France and in all three programs in the US (Table 3) as one in-kind non-monetary consideration (Cortés-Capano et al., 2021). Even in theoretical research, non-monetary studies are rare and thus in high demand (Santangeli et al., 2016). On the other hand, some features from practical programs (Table 3) have been noted to impact farmers' participation. In VWP programs in France, an intermediary organization (Agrivair) created a rapport between farmers and the funding agency by taking care of paperwork and giving tailored advice to farmers thus building trust with farmers and encouraging participation. Besides, result-based payments and short-lasting AES contracts are considered to not encourage farmers' participation due to the risk of not paying off and income insecurity issues respectively (Molenaar, 2013).

Regarding the environmental topics concerning AES programs, Europe and US programs have covered more environmental issues than that in China. Biodiversity conservation is the main focus of most AES programs in Europe, like ESA in England and NMP in Germany (Table 3). Although programs in US are generally large and cover comprehensive environmental targets, wildlife conservation is also specifically one of the targets (Table 3). Besides, although not listed in Table 3, relatively small programs also exist in US that specifically target biodiversity conservation, such as the Wildlife Habitat Incentives Program (Reimer, 2015). Due to net-zero greenhouse gas emission target by 2050, climate measures in AES have been highly emphasized in the latest EU CAP reforms and other European countries[8] (Erekalo et al., 2024; OECD, 2024; Scottish Government, 2024). The US conservation programs have also included climate issues along with its new Farm Bill, with CRP starting the estimation of climate benefits for their contracts since 2021 (Joiner et al., 2023; USDA, 2021). In contrast, with the knowledge so far, we notice the limited emphasis on biodiversity conservation and climate benefits in AES programs in China (Table 3).

5. Discussion

5.1. Findings from comparison

First, AES in China appeared quite later compared to that in Europe and US, and the initiation was due to the severe and continued natural disasters instead of proactive prevention in China, although CRP in US was also due to poor environmental issues. Analogously, until now water and soil protection are the main concern of Chinese programs excluding other environmental issues.

Second, policies and laws in China are very vague and do not provide clear and strong support and guidance on AES implementation and development. The relatively sound development of AES in Europe and US cannot be separated from their explicit and straightforward policies and laws. These laws and policies are issued before the first AES programs in both regions and have been renewed and modified since then. In comparison, there are barely policies and laws in China directly targeted for AES, while the correlated ones are quite vague.

Third, the typical top-down manner of AES program implementation in China has induced various challenges, identified mostly by scholars and considered as the major reason for the poor performance of AES-like programs in China (Shang et al., 2018). It is even said that the

[8] New terms of "Agri-environment-climate Measures (AECM)" and "Agri-Environment Climate Scheme (AECS)" among others have emerged alongside.

conceptualization of Chinese programs "rather reflects a compensation mechanism for legal restrictions" (Schomers and Matzdorf, 2013). It has led to loss of the voluntary nature of AES programs, which is the key point for AES as a promising market-based tool. Along with the top-down and multiple levels of government regulation for the programs, other issues might result, leading to corruption, incomplete information, and delayed compensations (Shang et al., 2018).

Fourth, the current AES programs in China are quite monotonic in terms of the implementation practices and contract modes. Other than hundreds of developed (sometimes even tailored) measures, the European and US programs have been associated with various AES contract types with the aim of improving the environmental impacts and the cost-effectiveness of the programs, such as spatially heterogeneous payments, result-based payments and auctions among others, which are lacking in China. However, whether they are result-based or action-based payments the AES programs need to allow farmers voluntary participation as a main feature of them, which is lacking in China.

Fifth, China lacks AES scientific evidence, and it is expected that the AES program implementation in China should be guided by scientific evidence from locally implemented studies like in EU and US. The general study of AES in China demands more quantitative and technical methods (Yang and Lu, 2018). Many reputable AES programs that have been implemented so far in EU and US have been developed based on research carried out by scientists, which is one missing component of AES in China.

Sixth, the EU and US have structured funding which is also attractive to farmers to participate in AES which is lacking in China. The Chinese funding is mostly government-based while in EU we have AES that are privately funded which is a clear indication of better private-public partnerships in Europe compared to China. Although the geographical scales and the governance structures differ of the EU, China and US, the stable funding of AES and the involvement of stakeholders in EU and US has guaranteed more successful and cost-effective AES implementation compared to China.

5.2. *Challenges of AES design and implementation in China*

China is one of the major agricultural producers in the world in the urgent need to adopt environmentally friendly practices to preserve agricultural land, protect the environment and ensure food security (Cao and Solangi, 2023). However, farmers in China face obstacles that hinder the implementation of AES, including poor legislative frameworks, insufficient funding to boost investment in conservation agriculture and limited technological innovation (Cao and Solangi, 2023). More specifically, challenges to AES implementation are enumerated as follows.

First, the Chinese economy has been growing in an accelerated manner in the past few decades. Regardless of the economic growth, the government has not established a clear legislative framework upon which negative environmental externalities resulting from the growing economy can be resolved. China has been making significant efforts to promote its environmental initiatives. However, the building of completed foundations from all perspectives, including national policy and law, regulations in all levels of governance, funding sources and allocation, and even the social attitude changing towards environmental services, still needs more targeted efforts ahead. Right now, these foundation buildings are not supportive enough particularly for good functioning of AES as a market-based policy tool.

Second, AES are a market-based tool developed to internalize externalities due to common goods tragedy. Due to this, the government involvement for AES operation is unavoidable and necessary in some ways, while the voluntary mechanism of AES is also the key for the successful functioning of it. For a historically strict top-down governance country, applying both necessary governmental control and flexible market-operating AES is challenging and needs explorations based on the special governance modes and needs of China.

Third, in China farmers have no land property rights but only land-use rights for crop production. This means we cannot refer to them as landowners since land property rights belong to the government. This makes farmers hesitant and less emotionally bound to participate in improving the quality of agricultural land and protecting landscapes in rural areas, while instead they have more concerns on productions. The lack of property rights of Chinese farmers is analogous to that of tenant farmers in Europe and US, who have been shown to participate less in AES design and implementation than landowners (Biffi et al., 2021; Ranjan et al., 2019).

Fourth, the lessons, experience and advanced mechanisms of AES from Europe and US may not be feasible for direct application in China due to the different national conditions. For example, there are typical small-household farms in China with each family having scattered pieces of cropland inter-bordering with other families, and the total area of scattered cropland for each family is also small. This could make the operation of advanced AES mechanism complex and difficult to achieve. For example, if the AES design is payment for results, it is hard to say if the observed results are due to the neighbor efforts or individual farmer efforts. In addition, China may also need to develop further modes if considering to solve social issues together with AES, like poverty and inequity reduction (Zhu et al., 2018).

6. Recommendations of AES improvement in China

First, as a basic step, China needs to formulate systematic policies and legislations to support the design and implementation of AES in a similar manner like its counterparts in US and Europe. For example, the US Farm Bill is a policy framework that offers continuous and updated legislations for guiding the conservation directions of AES programs in the nation. Further, the CAP in the EU integrates environmental conservation goals into agricultural subsidies thus promoting biodiversity conservation and climate mitigation goals in the long-term. Besides, with Farm Bill in US and CAP in EU playing a leading role, US States and EU countries still have flexible designations on conservation specialty along with autonomy when necessary. The current AES policy and legislation in China are poor, and policy makers need to strengthen the limited existing policies and build new frameworks with clear transparent regulations and standards. For instance, building leading legislations for AES in China from the central government and designating local-level (like province- or city-level in China) the flexibility and autonomy for considering spatially ecological differences could be a good start.

Second, guaranteed funding sources and clear funding allocation formulas for explicit environmental targets for AES in China should be developed together with the legislation and policy building process. For example, the US Farm Bill has ensured consistent funding providing farmers with attractive financial incentives for long-term AES goals, and clear payment formulas for different goals. Further, CAP in the EU has been offering a proportion of overall funding and goals for AES programs, with allocation mechanisms being determined depending on the country. The Chinese AES goals could also be adjusted along with funding allocation, which cannot just be soil and water conservation but also biodiversity conservation and climate change mitigation. In addition, Chinese government should encourage more stakeholder participation where private- and public-partnerships and international collaborations could aid access to technology, markets and funding of AES implementation.

Third, AES design and implementation in China need to be guided by scientific evidence. On the one hand, the general theoretical research with China's special socio-political-economic-cultural context for AES deployment need to be more contextualized in detail to solve environmental and agricultural problems. The most concerning topics include environmental effectiveness, farmer participation considering both economic incentives and socio-cultural influences, cost-effectiveness design of AES from perspectives of contract length, spatial scale,

through action- or result-based payment schemes, different or fixed payment rates, auction or other enrollment modes, as well as trade-offs between cost-effectiveness and social welfare (reduction of poverty and inequalities) among others. On the other hand, the Chinese government needs to collaborate and fund local universities or research institutes for scientific support to design efficient localized AES tailored to local cultural and environmental needs, support monitoring and evaluation of implemented programs, give farmers' technical support and advance, and act as a good rapport between farmers and government for better communication.

Fourth, with policy, funding and scientific support, more practical programs need to be carried out that fit the localized experience, are more farmer-centered with voluntary participations based on feedback and lessons drawn from the US and Europe. In the process, international communications and knowledge exchanges through training, workshops and collaborations with counterparts in Europe and US among other countries could be very enlightening and helpful.

Fifth, along with all these anticipative developments, education and awareness for attitude and perception change among citizens is needed. Farmers should be educated to support AES in a similar manner to what happens in the US or through local community engagement like in Europe. It will help promote the understanding of the benefits and costs of AES between farmers and government. Policies and other supports need to be improved in an iterative manner like in the EU and the US, along with evidence drawn from practical AES programs.

7. Conclusion and limitations

The design and implementation of AES in China is still at the exploratory phase and an understanding of AES mechanisms in Europe and US is important. There is a big difference between the pure conservation engineering and ecological compensation programs in China, and the concept of AES in Europe and US. The fact that China does not primarily value farmers voluntary participation as the primary participants who are supposed to implement the AES, lacks a reliable policy framework and a strategy for stable dedicated funding is problematic. It reduces the success of the programs, the cost-effectiveness, and the ability to achieve environmental goals with measurable outcomes especially because the nature of agricultural land is scattered, and environmental challenges are complex. The AES implementation in US and Europe has led to substantial environmental improvements and although not perfect, there are valuable lessons for China particularly regarding environmental, policy and ecological effectiveness, and cost-efficiency.

Our study has several limitations. First, our comparisons from the four perspectives are broad although not conclusive, and comparisons based on scale and similar designs would be more appropriate. Second, our study assumes that AES implementation in Europe and US should be at per with that in China regardless of existing differences in economic development, program scales and environmental priorities. Third, our study findings are drawn from qualitative analysis without any primary data to quantitatively demonstrate the differences in opinions from stakeholders from the various regions.

CRediT authorship contribution statement

Mary Nthambi: Writing – review & editing, Formal analysis. **Zhengzheng Hao:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

References

Ansell, D., Freudenberger, D., Munro, N., Gibbons, P., 2016. The cost-effectiveness of agri-environment schemes for biodiversity conservation: a quantitative review. Agric. Ecosyst. Environ. 225, 184–191. https://doi.org/10.1016/j.agee.2016.04.008.

Armsworth, P.R., Acs, S., Dallimer, M., Gaston, K.J., Hanley, N., Wilson, P., 2012. The cost of policy simplification in conservation incentive programs. Ecol. Lett. 15, 406–414. https://doi.org/10.1111/j.1461-0248.2012.01747.x.

Asian Development Bank, 2016. Toward a national eco-compensation regulation in the people's republic of China. Asian Development Bank, Mandaluyong City, Metro Manila, Philippines.

Balana, B.B., Vinten, A., Slee, B., 2011. A review on cost-effectiveness analysis of agri-environmental measures related to the EU WFD: key issues, methods, and applications. Ecol. Econ. 70, 1021–1031. https://doi.org/10.1016/j.ecolecon.2010.12.020.

Bartkowski, B., Beckmann, M., Bednář, M., Biffi, S., Domingo-Marimon, C., Mesaroš, M., Wittstock, F., 2023. Adoption and potential of agri-environmental schemes in Europe: cross-regional evidence from interviews with farmers. People Nat. 5 (5), 1610–1621.

Batáry, P., Dicks, L.V., Kleijn, D., Sutherland, W.J., 2015. The role of agri-environment schemes in conservation and environmental management. Conserv. Biol. 29, 1006–1016. https://doi.org/10.1111/cobi.12536.

Baylis, K., Peplow, S., Rausser, G., Simon, L., 2008. Agri-environmental policies in the EU and United States: a comparison. Ecol. Econ. 65, 753–764. https://doi.org/10.1016/j.ecolecon.2007.07.034.

Baylis, K., Rausser, G.C., Simon, L.K., 2005. Including non-trade concerns: the environment in EU and US agricultural policy. Int. J. Agric. Resour. Gov. Ecol. 4, 262–276.

Benett, G., Carroll, N., 2014. Gaining depth: state of watershed investment 2014. Forest Trends, Washington, DC, USA.

Bennett, M.T., 2008. China's sloping land conversion program: institutional innovation or business as usual? Ecol. Econ. 65, 699–711. https://doi.org/10.1016/j.ecolecon.2007.09.017.

Biffi, S., Traldi, R., Crezee, B., Beckmann, M., Egli, L., Schmidt, D.E., Ziv, G., 2021. Aligning agri-environmental subsidies and environmental needs: a comparative analysis between the US and EU. Environ. Res. Lett. 16 (5), 054067.

Boatman, N., Ramwell, C., Parry, H.R., Jones, N., Bishop, J., Gaskell, P., Short, C.J., Mills, J., Dwyer, J.C., 2008. A review of environmental benefits supplied by agri-environment schemes. Report. Land Use Policy Group, London, UK.

Börner, J., Baylis, K., Corbera, E., Ezzine-de-Blas, D., Honey-Rosés, J., Persson, U.M., Wunder, S., 2017. The effectiveness of payments for environmental services. World Dev. 96, 359–374. https://doi.org/10.1016/j.worlddev.2017.03.020.

Brouwer, F., van der Heide, C.M., 2009. Multifunctional rural land management: economics and policies. Earthscan, London.

Brussaard, L., Caron, P., Campbell, B., Lipper, L., Mainka, S., Rabbinge, R., Babin, D., Pulleman, M., 2010. Reconciling biodiversity conservation and food security: scientific challenges for a new agriculture. Curr. Opin. Environ. Sustain. 2, 34–42. https://doi.org/10.1016/j.cosust.2010.03.007.

Burton, R.J.F., Schwarz, G., 2013. Result-oriented agri-environmental schemes in Europe and their potential for promoting behavioural change. Land Use Policy 30, 628–641.

Cao, J., Solangi, Y.A., 2023. Analyzing and prioritizing the barriers and solutions of sustainable agriculture for promoting sustainable development goals in China. Sustainability 15 (10), 8317. https://doi.org/10.3390/su15108317.

Carmona-Torres, C., Parra-López, C., Groot, J.C.J., Rossing, W.A.H., 2011. Collective action for multi-scale environmental management: achieving landscape policy objectives through cooperation of local resource managers. Landsc. Urban Plan. 103, 24–33.

Chabé-Ferret, S., Subervie, J., 2013. How much Green for the buck? Estimating additional and windfall effects of French agro-environmental schemes by DID-matching. J. Environ. Econ. Manag. 65, 12–27. https://doi.org/10.1016/j.jeem.2012.09.003.

Claassen, R., Cattaneo, A., Johansson, R., 2008. Cost-effective design of agri-environmental payment programs: U.S. Experience in theory and practice. Ecol. Econ. 65, 737–752. https://doi.org/10.1016/j.ecolecon.2007.07.032.

Cortés-Capano, G., Hanley, N., Sheremet, O., Hausmann, A., Toivonen, T., Garibotto-Carton, G., Di Minin, E., 2021. Assessing landowners' preferences to inform voluntary private land conservation: the role of non-monetary incentives. Land Use Policy 109, 105626.

Cullen, P., Ryan, M., O'Donoghue, C., Hynes, S., hUallacháin, D.Ó., Sheridan, H., 2020. Impact of farmer self-identity and attitudes on participation in agri-environment schemes. Land Use Policy 95, 104660. https://doi.org/10.1016/j.landusepol.2020.104660.

De Ponti, T., Rijk, B., Van Ittersum, M.K., 2012. The crop yield gap between organic and conventional agriculture. Agric. Syst. 108, 1–9.

Defrancesco, E., Gatto, P., Runge, F., Trestini, S., 2007. Factors affecting farmers' participation in agri-environmental measures: a Northern Italian perspective, 59, 114–131. https://doi.org/10.1111/j.1477-9552.2007.00134.x.

Del Corso, J.-P., Nguyen, Thi Dieu Phuong Geneviève, Kephaliacos, C., 2017. Acceptance of a payment for ecosystem services scheme: the decisive influence of collective action. Environ. Values 26, 177–202.
Department for Environment Food and Rural Affairs, 2011. ARCHIVE: England Rural Development Programme - The Environmentally Sensitive Areas (ESA) Scheme. http://adlib.everysite.co.uk/adlib/defra/content.aspx?doc=1922&id=1932 (accessed 29 June 2021).
Dobbs, T.L., Pretty, J., 2008. Case study of agri-environmental payments: the United Kingdom. Ecol. Econ. 65, 765–775. https://doi.org/10.1016/j.ecolecon.2007.07.030.
Donald, P.F., Evans, A.D., 2006. Habitat connectivity and matrix restoration: the wider implications of agri-environment schemes. J. Appl. Ecol. 43, 209–218. https://doi.org/10.1111/j.1365-2664.2006.01146.x.
Dowd, B., Press, D., Huertos, M., 2008. Agricultural nonpoint source water pollution policy: the case of california's central coast. Agric. Ecosyst. Environ. 128, 151–161. https://doi.org/10.1016/j.agee.2008.05.014.
Elahi, E., Weijun, C., Zhang, H., Nazeer, M., 2019. Agricultural intensification and damages to human health in relation to agrochemicals: application of artificial intelligence. Land Use Policy 83, 461–474. https://doi.org/10.1016/j.landusepol.2019.02.023.
Engel, S., Pagiola, S., Wunder, S., 2008. Designing payments for environmental services in theory and practice: an overview of the issues. Ecol. Econ. 65, 663–674. https://doi.org/10.1016/j.ecolecon.2008.03.011.
Erekalo, K.T., Pedersen, S.M., Christensen, T., Denver, S., Gemtou, M., Fountas, S., Isakhanyan, G., 2024. Review on the contribution of farming practices and technologies towards climate-smart agricultural outcomes in a european context. Smart Agric. Technol. 7, 100413.
European Commission, 2021. The common agricultural policy at a glance. https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/cap-glance_en (accessed 15 June 2021).
Ezzine-de-Blas, D., Wunder, S., Ruiz-Pérez, M., Del Moreno-Sanchez, R.P., 2016. Global patterns in the implementation of payments for environmental services. PLoS One 11, e0149847. https://doi.org/10.1371/journal.pone.0149847.
Feng, H., 2007. Green payments and dual policy goals. J. Environ. Econ. Manag. 54, 323–335. https://doi.org/10.1016/j.jeem.2007.03.003.
Feng, H., Kurkalova, L.A., Kling, C.L., Gassman, P.W., 2006. Environmental conservation in agriculture: land retirement vs. Changing practices on working land. J. Environ. Econ. Manag. 52, 600–614. https://doi.org/10.1016/j.jeem.2006.03.004.
Fleming, P., Lichtenberg, E., Newburn, D.A., 2018. Evaluating impacts of agricultural cost sharing on water quality: additionality, crowding in, and slippage. J. Environ. Econ. Manag. 92, 1–19. https://doi.org/10.1016/j.jeem.2018.08.007.
Guo, Y., Zheng, H., Wu, T., Wu, J., Robinson, B.E., 2020. A review of spatial targeting methods of payment for ecosystem services. Geogr. Sustain. 1, 132–140. https://doi.org/10.1016/j.geosus.2020.04.001.
Han, D., Jin, S., 2016. 40 years rural environmental protection in China: problem evolution, policy response and institutional change. J. Agric. Ext. Rural Dev. 8, 1–11.
Hansen, L., 2006. Better targeting, better outcomes (Vol. 2). USDA Economic Research Serv.
Hao, Z., Wätzold, F., Sturm, A., 2023. A spatially explicit Hydro-Economic modeling procedure to design Cost-Effective Agri-Environment schemes for mitigating water pollution from cropland. Water Econ. Policy 9.
He, J., Sikor, T., 2015. Notions of justice in payments for ecosystem services: insights from China's sloping land conversion program in yunnan province. Land Use Policy 43, 207–216. https://doi.org/10.1016/j.landusepol.2014.11.011.
Hellerstein, D.M., 2017. The US conservation reserve program: the evolution of an enrollment mechanism. Land Use Policy 63, 601–610. https://doi.org/10.1016/j.landusepol.2015.07.017.
Ickowitz, A., Powell, B., Rowland, D., Jones, A., Sunderland, T., 2019. Agricultural intensification, dietary diversity, and markets in the global food security narrative. Glob. Food Secur. 20, 9–16. https://doi.org/10.1016/j.gfs.2018.11.002.
Jin, L., Porras, I., Lopez, A., Kazis, P., 2017. Sloping lands conversion programme, People's republic of China. Conditional transfers, poverty and ecosystems: national programmes highlights. IIED, London.
Johnson, M.-V.V., Norfleet, M.L., Atwood, J.D., Behrman, K.D., Kiniry, J.R., Arnold, J.G., White, M.J., Williams, J., 2015. The conservation effects assessment project (CEAP): a national scale natural resources and conservation needs assessment and decision support tool. IOP Conference Series Earth Environmental Science 25, 12012. https://doi.org/10.1088/1755-1315/25/1/012012.
Joiner, E., Toman, M., Russo, S., 2023. How USDA Conservation Programs Mitigate Agricultural Greenhouse Gas Emissions. https://www.rff.org/publications/issue-briefs/how-usda-conservation-programs-mitigate-agricultural-greenhouse-gas-emissions/ (accessed 5 September 2024).
Khanna, M., 2017. Nexus between food, energy and ecosystem services in the Mississippi River basin: policy implications and challenges. Choices 32, 1–9.
Kolinjivadi, V., Charré, S., Adamowski, J., Kosoy, N., 2019. Economic experiments for collective action in the Kyrgyz republic: lessons for payments for ecosystem services (PES). Ecol. Econ. 156, 489–498.
Le Coënt, P., 2016. Agri-environmental schemes: behavorial insights and innovative designs. Doctoral dissertation.
Lewis, D.J., Polasky, S., 2018. An auction mechanism for the optimal provision of ecosystem services under climate change. J. Environ. Econ. Manag. 92, 20–34. https://doi.org/10.1016/j.jeem.2018.08.014.
Li, P., Chen, Y., Hu, W., Li, X., Yu, Z., Liu, Y., 2019. Possibilities and requirements for introducing agri-environment measures in land consolidation projects in China, evidence from ecosystem services and farmers' attitudes. Sci. Total Environ. 650, 3145–3155. https://doi.org/10.1016/j.scitotenv.2018.10.051.
Mack, G., Ritzel, C., Jan, P., 2020. Determinants for the implementation of action-, result-and multi-actor-oriented agri-environment schemes in Switzerland. Ecol. Econ. 176, 106715.
Marconi, V., Raggi, M., Viaggi, D., 2015. Assessing the impact of RDP agri-environment measures on the use of nitrogen-based mineral fertilizers through spatial econometrics: the case study of Emilia-Romagna (Italy). Ecol. Indic. 59, 27–40. https://doi.org/10.1016/j.ecolind.2015.02.037.
Mennig, P., Sauer, J., 2020. The impact of agri-environment schemes on farm productivity: a DID-matching approach. Eur. Rev. Agric. Econ. 47, 1045–1093. https://doi.org/10.1093/erae/jbz006.
Mills, J., 2012. Exploring the social benefits of agri-environment schemes in england. J. Rural Stud. 28, 612–621. https://doi.org/10.1016/j.jrurstud.2012.08.001.
Molenaar, K., 2013. Payments for ecosystem services (PES) design characteristics. Deltares publications, Netherlands.
National Sustainable Agriculture Coalition, 2018. What is the Farm Bill? - National Sustainable Agriculture Coalition. https://sustainableagriculture.net/our-work/campaigns/fbcampaign/what-is-the-farm-bill/ (accessed 21 June 2021).
National Sustainable Agriculture Coalition, 2019. Environmental Quality Incentives Program - National Sustainable Agriculture Coalition. https://sustainableagriculture.net/publications/grassrootsguide/conservation-environment/environmental-quality-incentives-program/#history (accessed 1 July 2021).
Norse, D., Ju, X., 2015. Environmental costs of China's food security. Agric. Ecosyst. Environ. 209, 5–14. https://doi.org/10.1016/j.agee.2015.02.014.
OECD, 2024. Agricultural policy monitoring and evaluation 2023: adapting agriculture to climate change. OECD iLibrary. ⟨https://www.oecd-ilibrary.org/sites/b14de474-en/1/3/3/10/index.html?itemId=/content/publication/b14de474-en&_csp_=a209f942fdf89c2476c9ec400d75ef2f&itemIGO=oecd&itemContentType=book⟩ (accessed 5 September 2024).
Ottaviani, D., 2011. The role of PES in agriculture. FAO, Payments for Ecosystem Services and Food Security, Rome, Rome, Italy.
Pan, X., Xu, L., Yang, Z., Yu, B., 2017. Payments for ecosystem services in China: policy, practice, and progress. J. Clean. Prod. 158, 200–208. https://doi.org/10.1016/j.jclepro.2017.04.127.
Perrot-Maître, D., 2006. The vittel payments for ecosystem services: a "perfect" PES case? International Institute for Environment and Development, London, UK.
Primdahl, J., Peco, B., Schramek, J., Andersen, E., Oñate, J.J., 2003. Environmental effects of agri-environmental schemes in Western Europe. J. Environ. Manag. 67, 129–138. https://doi.org/10.1016/S0301-4797(02)00192-5.
Princé, K., Moussus, J.-P., Jiguet, F., 2012. Mixed effectiveness of French agri-environment schemes for nationwide farmland bird conservation. Agric. Ecosyst. Environ. 149, 74–79. https://doi.org/10.1016/j.agee.2011.11.021.
Ranjan, P., Wardropper, C.B., Eanes, F.R., Reddy, S.M., Harden, S.C., Masuda, Y.J., Prokopy, L.S., 2019. Understanding barriers and opportunities for adoption of conservation practices on rented farmland in the US. Land Use Policy 80, 214–223.
Reimer, A., 2015. Ecological modernization in U.S. Agri-environmental programs: trends in the 2014 farm bill. Land Use Policy 47, 209–217. https://doi.org/10.1016/j.landusepol.2015.04.013.
Russi, D., Margue, H., Oppermann, R., Keenleyside, C., 2016. Result-based agri-environment measures: market-based instruments, incentives or rewards? The case of Baden-Württemberg. Land Use Policy 54, 69–77. https://doi.org/10.1016/j.landusepol.2016.01.012.
Salt, D., 2016. A brief history of agri-environment policy in Australia: from community-based NRM to market-based instruments. Canberra. ANU Press.
Sandhu, H.S., Wratten, S.D., Cullen, R., 2010. Organic agriculture and ecosystem services. Environ. Sci. Policy 13, 1–7. https://doi.org/10.1016/j.envsci.2009.11.002.
Santangeli, A., Arroyo, B., Dicks, L.V., Herzon, I., Kukkala, A.S., Sutherland, W.J., Moilanen, A., 2016. Voluntary non-monetary approaches for implementing conservation. Biol. Conserv. 197, 209–214.
Sattler, C., Nagel, U.J., 2010. Factors affecting farmers' acceptance of conservation measures—A case study from north-eastern Germany. Land Use Policy 27, 70–77. https://doi.org/10.1016/j.landusepol.2008.02.002.
Schaible, G.D., Mishra, A.K., Lambert, D.M., Panterov, G., 2015. Factors influencing environmental stewardship in US agriculture: conservation program participants vs. Non-participants. Land Use Policy 46, 125–141.
Schenk, A., Hunziker, M., Kienast, F., 2007. Factors influencing the acceptance of nature conservation measures—A qualitative study in Switzerland. J. Environ. Manag. 83 (1), 66–79.
Schomers, S., Matzdorf, B., 2013. Payments for ecosystem services: a review and comparison of developing and industrialized countries. Ecosyst. Serv. 6, 16–30. https://doi.org/10.1016/j.ecoser.2013.01.002.
Schwarz, G., Moxey, A., McCracken, D., Huband, S., Cummins, R., 2008. An analysis of the potential effectiveness of a Payment-by-Results approach to the delivery of environmental public goods and services supplied by Agri-Environment schemes. Land Use Policy Group, UK.
Science for Environment Policy, 2017. Agri-environmental schemes: how to enhance the agriculture-environment relationship. Issue produced for the European Commission DG Environment by the Science Communication Unit, UWE, Bristol, Issue 57.
Scottish Government, 2024. Agri-Environment Climate Scheme. OFFICIAL. https://www.ruralpayments.org/topics/all-schemes/agri-environment-climate-scheme/ (accessed 5 September 2024).
Shang, W., Gong, Y., Wang, Z., Stewardson, M.J., 2018. Eco-compensation in China: theory, practices and suggestions for the future. J. Environ. Manag. 210, 162–170. https://doi.org/10.1016/j.jenvman.2017.12.077.

Shields, F.D., Langendoen, E.J., Doyle, M.W., 2006. Adapting existing models to examine effects of agricultural conservation programs on stream habitat quality. JAWRA J. Am. Water Resour. Assoc. 42, 25–33. https://doi.org/10.1111/j.1752-1688.2006.tb03820.x.

Sidemo-Holm, W., Smith, H.G., Brady, M.V., 2018. Improving agricultural pollution abatement through result-based payment schemes. Land Use Policy 77, 209–219. https://doi.org/10.1016/j.landusepol.2018.05.017.

Simpson, K., Armsworth, P.R., Dallimer, M., Nthambi, M., Vries, F.P. de, Hanley, N., 2023. Improving the ecological and economic performance of agri-environment schemes: payment by modelled results versus payment for actions. Land Use Policy 130, 106688.

Sun, X., Zhou, H., 2008. Establishing eco-compensation system in China: practice, problems and strategies. China Popul. Resour. Environ. 18, 139–143. https://doi.org/10.1016/S1872-583X(09)60019-X.

Tang, H., Liu, J., Wu, J., 2020. The impact of command-and-control environmental regulation on enterprise total factor productivity: a quasi-natural experiment based on China's "Two control Zone" policy. J. Clean. Prod. 254, 120011. https://doi.org/10.1016/j.jclepro.2020.120011.

Ulber, L., Klimek, S., Steinmann, H.H., Isselstein, J., Groth, M., 2011. Implementing and evaluating the effectiveness of a payment scheme for environmental services from agricultural land. Environ. Conserv. 38 (4), 464–472.

USDA, 2021. USDA Announces New Initiative to Quantify Climate Benefits of Conservation Reserve Program. https://www.fsa.usda.gov/news-room/news-releases/2021/usda-announces-new-initiative-to-quantify-climate-benefits-of-conservation-reserve-program (accessed 5 September 2024).

Uthes, S., Matzdorf, B., 2013. Studies on agri-environmental measures: a survey of the literature. Environ. Manag. 51, 251–266. https://doi.org/10.1007/s00267-012-9959-6.

Vergamini, D., Viaggi, D., Raggi, M., 2020. Evaluating the potential contribution of multi-attribute auctions to achieve agri-environmental targets and efficient payment design. Ecol. Econ. 176, 106756.

Vergamini, D., White, B., Viaggi, D., 2015. Agri-Environmental payments design in Europe, USA and Australia: the potential of auctions and Self-Selecting contracts for designing better Agri-Environmental payments. Presentation at the 4th AIEAA Conference "Innovation, Productivity and Growth: Towards Sustainable Agri-Food Production.

Vries, F.P. de, Hanley, N., 2016. Incentive-based policy design for pollution control and biodiversity conservation: a review. Environ. Resour. Econ. 63, 687–702.

Ward, P.S., Mapemba, L., Bell, A.R., 2021. Smart subsidies for sustainable soils: evidence from a randomized controlled trial in Southern Malawi. J. Environ. Econ. Manag. 110, 102556. https://doi.org/10.1016/j.jeem.2021.102556.

Wätzold, F., Drechsler, M., Johst, K., Mewes, M., Sturm, A., 2016. A novel, spatiotemporally explicit Ecological-economic modeling procedure for the design of Cost-effective Agri-environment schemes to conserve biodiversity. Am. J. Agric. Econ. 98, 489–512. https://doi.org/10.1093/ajae/aav058.

Wätzold, F., Schwerdtner, K., 2005. Why be wasteful when preserving a valuable resource? A review article on the cost-effectiveness of european biodiversity conservation policy. Biol. Conserv. 123, 327–338. https://doi.org/10.1016/j.biocon.2004.12.001.

Wonder, S., 2005. Payments for environmental services: some nuts and bolts. CIFOR Occas. Pap. 42, 3–4.

World Bank, 2021. Ecological compensation in China: trends and opportunities for incentive-based policies towards a greener China. World Bank, Washington, DC.

Wunder, S., Engel, S., Pagiola, S., 2008. Taking stock: a comparative analysis of payments for environmental services programs in developed and developing countries. Ecol. Econ. 65, 834–852.

Wynne-Jones, S., 2013. Connecting payments for ecosystem services and agri-environment regulation: an analysis of the Welsh glastir scheme. J. Rural Stud. 31, 77–86. https://doi.org/10.1016/j.jrurstud.2013.01.004.

Yang, D., 2018. Study on the legal system of agricultural ecological compensation in China (in Chinese). Master's thesis.

Yang, W., Liu, W., Viña, A., Luo, J., He, G., Ouyang, Z., Zhang, H., Liu, J., 2013. Performance and prospects of payments for ecosystem services programs: evidence from China. J. Environ. Manag. 127, 86–95. https://doi.org/10.1016/j.jenvman.2013.04.019.

Yang, W., Lu, Q., 2018. Integrated evaluation of payments for ecosystem services programs in China: a systematic review. Ecosyst. Health Sustain. 4, 73–84. https://doi.org/10.1080/20964129.2018.1459867.

Yu, H., Xie, W., Yang, L., Du, A., Almeida, C.M.V.B., Wang, Y., 2020. From payments for ecosystem services to eco-compensation: conceptual change or paradigm shift? Sci. Total Environ. 700, 134627. https://doi.org/10.1016/j.scitotenv.2019.134627.

Zhang, Q., Lin, T., 2010. An eco-compensation policy framework for the People's republic of China: challenges and opportunities. Asian Development Bank, Mandaluyong City, Philippines.

Zhang, Q., Xiao, H., Duan, M., Zhang, X., Yu, Z., 2015. Farmers' attitudes towards the introduction of agri-environmental measures in agricultural infrastructure projects in China: evidence from Beijing and changsha. Land Use Policy 49, 92–103. https://doi.org/10.1016/j.landusepol.2015.07.021.

Zhen, L., Li, F., Yan, H.M., Liu, G.H., Liu, J.Y., Zhang, H.Y., Du, B.Z., Wu, R.Z., Sun, C.Z., Wang, C., 2014. Herders' willingness to accept versus the public sector's willingness to pay for grassland restoration in the xilingol league of inner Mongolia, China. Environ. Res. Lett. 9, 45003. https://doi.org/10.1088/1748-9326/9/4/045003.

Zhu, L., Zhang, C., Cai, Y., 2018. Varieties of agri-environmental schemes in China: a quantitative assessment. Land Use Policy 71, 505–517. https://doi.org/10.1016/j.landusepol.2017.11.014.

Zimmermann, A., Britz, W., 2016. European farms' participation in agri-environmental measures. Land Use Policy 50, 214–228.