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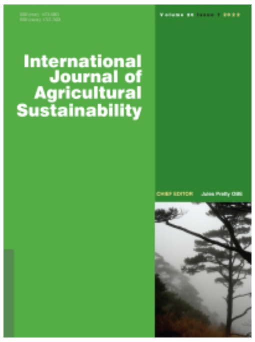


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# A systematic review on the impact of incentives on the adoption of conservation agriculture: new guidelines for policymakers and researchers

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**ABSTRACT**

Facing the new challenges of sustainable development in the agricultural sector requires transitioning toward sustainable systems, such as conservation agriculture (CA) practices. Despite several decades of work to diffuse CA technologies, the adoption rate remains below expectations in several countries. Different policy scenarios have been adopted to address this situation, mainly incentives. However, evidence of their effectiveness and possibilities of reinforcement are not clearly defined in the literature. The purpose of this systematic review is to examine the evidence of the impact of incentives on the adoption of conservation agriculture practices to help academics and politicians understand how to effectively spread sustainable innovations such as CA. Results show that four kinds of incentives are evaluated Agri-Environment Schemes (AES)/Payments for Ecosystem Services (PES), input subsidies, direct subsidies, and market-based incentives. The impact of PES and input subsidies was significant and positive for the diffusion of CA. However, the component of minimum tillage dissemination was not significantly affected by PES agglomeration payments or greater levels of direct subsidies, respectively. The incentives investigated are not sufficiently diversified in type, which consequently limits their usefulness. Three recommendations for the deployment of incentives were made in light of these findings.

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Subsidies; sustainable innovations; policies; diffusion; disincentives

## 1. Introduction

Conservation agriculture (CA) is considered an innovation that responds to both the concerns of increasing food security and lowering agricultural production's negative environmental impacts to achieve sustainable development (Knapp & van der Heijden, 2018). To distinguish CA from the other forms of sustainable agricultural production, it is necessary to note that CA is based on three complementary pillars: (1) Minimum disturbance of soil, (2) preservation of permanent cover cropping or mulching, and (3) crop diversification in time and space (Yigezu et al., 2021).

The first component, minimum disturbance, includes practices such as zero (no-) tillage, reduced tillage, broadcasting, or direct sowing (Ward et al., 2016). Maximum tillage leads to soil degradation by harming soil properties and causing problems such as compaction or cracks enlarging (Zulhaedar et al., 2023). No-till is then considered an efficient practice where farming is carried out without any plowing of the soil (Aboutayeb et al., 2023). Some studies have reported greater weed pressure under no-till conditions for specific soil types compared to plowed systems. Henceforth, reduced tillage or occasional

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tillage is argued and confirmed to ensure better weed management and increase of soil properties under specific conditions (Cordeau et al., 2020). In addition to no-tillage or reduced-tillage, the second component of mulching involves planting non-commercial crops on agricultural fields to provide soil cover between the growing seasons of primary crops (Deines et al., 2023). The third component of diversification refers to the variety of crops grown through intercropping or in rotation (Ward et al., 2016).

The diffusion and adoption of CA practices are facilitated by a set of policies mainly centred around incentives, extension services, and regulations, especially for the environmental aspect (Zhu & Chen, 2022). Regulations may be used to control the use of herbicides and market demand. Extension policies are adopted to increase farmers' knowledge and skills about CA practices and benefits. Government support through incentives remains an important factor in overcoming the initial investment costs required to purchase inputs of production and equipment for planting (Dev et al., 2023).

Focusing on incentives or subsidies, Rogers (2010) found that they are utilized to accelerate the rate of adoption and diffusion of innovations by increasing the degree of the relative advantage of the novelty. Incentives can take various forms, grouped into five categories. The first category is *Adopter versus diffuser incentives*, which differentiate between incentives paid directly to the adopter and those paid to another individual responsible for persuading an adopter. The second category is *individual versus system incentives*, which differentiate between incentives granted to the individual adopter (or change agent) and those granted to the system to which they belong. The third category is *positive versus negative incentives*, with positive incentives denoting payments offered to reward a desired change in behaviour and negative incentives describing penalties imposed in the case of non-adoption of an innovation. The fourth category is *monetary versus nonmonetary incentives*, which distinguish financial incentives from commodities or desired objects granted in some cases as incentives. The fifth category is *immediate versus delayed incentives*, with the former denoting payment given for adoption without delay and the latter awarded after a delay.

Despite all the forms of incentives that are adopted to enhance the diffusion of CA, the low rate of adoption remains an important drawback in several countries (Dev et al., 2023). If some countries in the world noted high levels of adoption and diffusion such as the US, Brazil, Canada, Paraguay, Argentina, Australia, Spain, South Africa, China, and Kazakhstan, in other contexts the diffusion experienced some delays (Kassam et al., 2022). The delay was reported in the Middle East and North Africa (MENA) countries, and inappropriate policy support figured between the main barriers to CA adoption in the region. The mismatch of policies is reflected in the context of incentives by the absence of system subsidies to encourage the distribution and maintenance of CA mechanization (Devkota et al., 2022). Countries of Sub-Saharan Africa (SSA) also display low values of adoption of CA practices and link it to the subsidization of fertilizer inputs (Rodenburg et al., 2021). In South Asia, low spread is also challenging as the rate of adoption is lower than 5 million hectares (Mha), and the absence of incentives for carbon credit or residue retention was reported as one of the causes of low scaling (Somasundaram et al., 2020).

The effectiveness of incentives on the diffusion of sustainable innovations depends mainly on the context of policies' history referring to the set of policies adopted to spread conventional technologies diffused before the introduction of sustainable innovations. We distinguish between two different contexts of policies' history; (1) highly subsidized context, and (2) highly taxed context. The selection of incentives and their impact after each context cannot be the same. In the first context, before the introduction of sustainable innovations, conventional innovations were subsidized. The effective choice in his case is the disincentivizing of conventional innovations and the adoption of new subsidies toward sustainable technologies. In the second context, taxes were originally applied to enhance conventional practices before the arrival of sustainable forms of production. In this context, the reduction of taxes and the implementation of incentives for sustainable innovations show better results (Tittonell et al., 2020). Nevertheless, these conditions of effectiveness are not respected in some contexts as the level of incentives or taxes formerly applied for conventional agriculture in the first context is maintained and not reduced, which limits the spread of sustainable practices (Grohmann & Feindt, 2023).

The studies on the impact of incentives on the adoption and diffusion of CA are varied. Nevertheless, evidence, and research gaps requiring more focus in incentives impact evaluation are not clearly defined in the literature.

Attempts of incentives' impact reviews are illustrated by the work of Rode et al. (2015) which reviewed eighteen empirical studies on the impact of economic incentives on motivation crowding out and crowding in effects to enhance biodiversity and ecosystem conservation. The authors confirmed that it was hard to extract evidence from studies as they were not comparable, the baseline information concerning former intrinsic motivations was lacking, and there was contextual heterogeneity and complexity associated with the culture. Later, Xie and Huang (2021) conducted a meta-analysis of 77 empirical studies to analyze the factors influencing farmers' adoption of pro-environmental technology in the agricultural sector. Five categories of factors were identified and analyzed; farm characteristics, family characteristics, householder characteristics, social factors, and informational factors. Government subsidies were identified in the category of social factors and the results confirm that they had a positive impact on raising the income of farmers and reducing their production costs, accelerating the adoption of pro-environmental agricultural technologies as a consequence.

Focusing directly on the impact of incentives on sustainable practices, Pineiro et al. (2020) studied how incentives granted to farmers influence their adoption of sustainable agricultural practices and the outcomes of that adoption using a scoping review. Three types of incentives were evaluated: (1) market and non-market incentives referring to the provision of incentives through market signals (such as input and output prices, income transfers, and subsidy compensation) or incentives that are not market-based (such as technical support, fiscal measures, and taxes) (2) regulations including environmental laws and standards or certifications, and (3) cross-compliance incentives compensating farmers for compliance with environmental standards. The results allowed the authors to extract evidence about the effectiveness of the studied incentives on sustainable agricultural practices adoption, productivity, and economic outcomes associated with adoption. However, little or no evidence was available on environmental outcomes. The decision to adopt in response to incentives is a continuum that depends on different variables including the incentive offered, programme conditions, personal and environmental perspectives, farmers' educational level, and previous experiences. Voluntary incentive programmes, such as certification schemes, market incentives, and non-market-based incentives are more uncertain as they are conditioned by farmers' decisions compared to compulsory incentives.

The aforementioned reviews did not match incentives' impact on conservation agriculture diffusion directly. Henceforth, to allow better extraction of evidence this paper aims to review the evidence about the evaluation of the impact of incentives on conservation agriculture adoption and diffusion, as well as the outcomes after adoption. The results of this study might be useful for researchers to identify the next research tracks requiring more focus and analysis. It is also of great interest for policymakers to increase the diffusion of CA pillars. In this sense, we attempt to answer the following questions through our review:

(1) What are the types of incentives adopted to enhance the adoption of conservation agriculture?
(2) Can evidence about the impact of incentives on the adoption of CA and its desired outcomes be extracted?
(3) What are the research gaps that require more focus in the evaluation of incentives' impact on CA and which may identify the new guidelines for incentives implementation?

## 2. Methodology

This systematic review was conducted following the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist (Page et al., 2021).

### 2.1. Information sources and search strategy

We conducted a comprehensive search strategy to identify all potentially relevant studies on the impact of incentives or subsidies on conservation agriculture. We used the following search sentence ((incentives OR subsid*) AND 'conservation agriculture') in Web of Science, Scopus, and Research4Life databases. The keywords were searched in the title, abstract, and keywords (if available) in the three databases. We limited the search to English papers without a limit on the publication year.

Results from database searches were then exported, combined, and deduplicated using Endnote software. The data were exported to an Excel spreadsheet to begin the screening and data extraction steps.

### 2.2. Screening and eligibility criteria

The selection of articles occurred in two phases; (1) title and abstract screening and (2) full-text screening. The second phase was applied to the articles in doubt from the first phase. The screening was done according to the following inclusion criteria:

(1) ***Being an empirical study and preferably research article***: review articles, books, and book chapters were eliminated.
(2) ***Explicitly focusing on conservation agriculture***: articles addressing sustainability practices, and environmental issues without a focus on CA were discarded.
(3) ***Studying the impact of incentives***: articles interested in incentives but not examining their effect on CA were not selected.

The resulting 191 articles were reduced to 147 articles after eliminating duplicates. This formed the basis of the screening process.

### 2.3. Data extraction process

For each selected paper, the following information was extracted using the data extraction model:

- Categorization of the type of incentives analyzed in the study.
- Identification of the type of impact evaluated, whether it was the adoption of CA or the outcomes of CA practices application
- The questions or hypotheses studied and their corresponding results
- The methodology used to assess the impact
- Limitations or recommendations for further studies

## 3. Results

After the first phase of the selection process, 25 articles were eliminated for not meeting the first eligibility criterion. Then, after the full-text screening of the questionable articles, 107 articles were discarded for not meeting the second and third inclusion criteria (Figure 1). Finally, 15 articles were selected for the extraction of results (see supplementary material).

The journals 'Land Use Policy' and 'Agricultural Systems' are the main journals that published in this area (see supplementary material). The investigated topic remains a recent subject in the literature as the first study recognized dates from 2009 (Figure 2). Geographical analysis shows the dominance of studies from Africa with nine papers, followed by three studies from Europe, two from Asia, and one from the USA. By country, findings indicate that Malawi is the most studied with six studies (Table 1).

### 3.1. The types of incentives adopted to enhance the adoption of conservation agriculture

The incentives evaluated depend on the programmes adopted by countries to scale up conservation agriculture (Figure 3). The main incentives analyzed are the Agri-Environment Schemes (AES) / Payment for Ecosystem Services (PES) programmes, which had been evaluated mainly in African countries (especially Mozambique, Malawi, and Kenya) as well as in Asian countries (Indonesia). PES programmes are defined as direct payments granted to enhance environmental conservation, where an ecosystem service (ES) is offered by an individual in return for compensation given by the beneficiary of the ES for the provision of the ES or the handling of the solicited land use (Ward et al., 2021). In Kenya, national policies provide agroforestry PES schemes that assist farmers to adopt CA and measure the carbon they sequestrate due to agroforestry (Benjamin & Sauer, 2018). Leimona and Carrasco (2017) studied conservation auctions for PES, which can be defined as the process by which a buyer of ES makes a call for bids (tenders) to the providers of ES for a determined contract and then can purchase the contracts with the lowest bids.

Another type of subsidy associated with PES is agglomeration payments, which are defined as a bonus payment awarded in exchange for the adoption of a neighbouring farm. These incentives are oriented toward enhancing technology diffusion as well as adoption (Bell et al., 2016; A. R. Bell, Benton, et al., 2018; Ward et al., 2021).

The second most studied type of incentives is input incentives, which were studied without specifying the subsidy type, as done by Khonje et al. (2022) who analyzed farm input subsidy programmes in many countries in sub-Saharan Africa. Input subsidies are offered to increase farmers' access to high-quality production inputs such as improved crop seeds or organic fertilizers. Subsidies in this case are given in

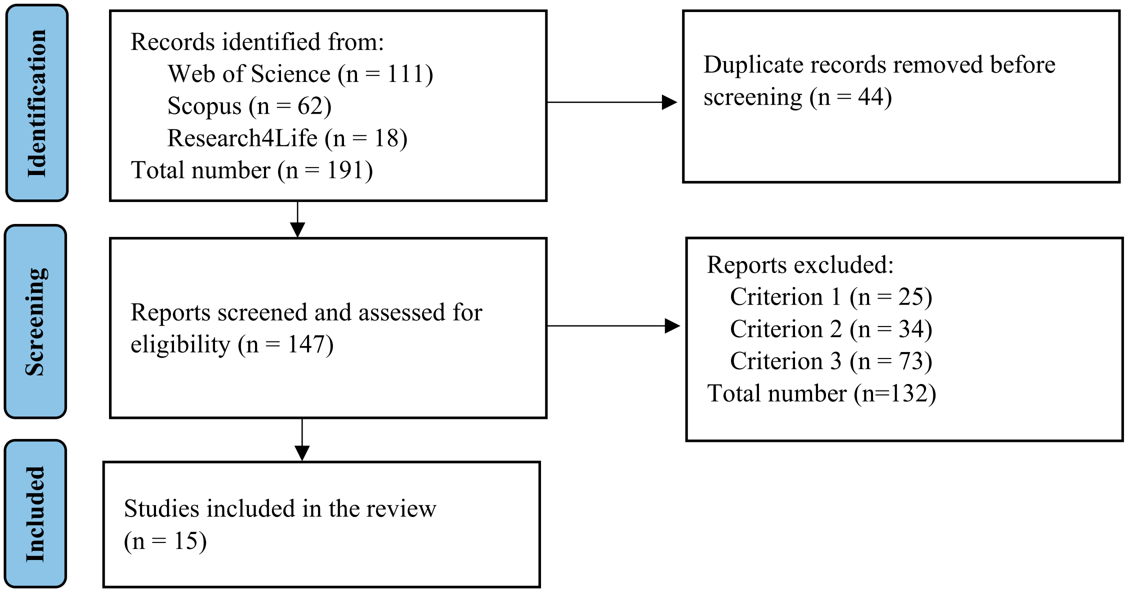


**Figure 1.** Flow diagram for the studies selection process.

the form of vouchers exchanged for a specified quantity of subsidized inputs at the subsidized rate. In addition to fertilizers and improved seeds subsidies, fertilizer transport subsidies were also evaluated in the same area (Marenya et al., 2017). Subsidized fertilizer was specifically studied in semi-arid Zimbabwe (Homann-Kee Tui et al., 2015).

Market-based incentives were also addressed such as the sale guarantee associated with a premium based on the quantity of humus present in the soil, explaining the strong impact of the sale guarantee on farmers' motivation (Targetti et al., 2021). De Leijster et al. (2020) simulated the impact of policy incentives being the level of the price premium above the normal market price which is solicited to compensate for the opportunity cost of potential externalities or benefit loss of alternative practices adoption compared to the conventional approach.

Direct subsidies which represent financial incentives granted to farmers in exchange for their adoption of CA were investigated in an ex-ante analysis conducted by Ward et al. (2016). The study assessed the impact of different scenarios of subsidy levels to offer to farmers subject to their adoption of CA practices and the interaction between the level of subsidy and the adoption of intercropping, zero tillage, and mulching either in combination or independently.

## 3.2. Evidence on the impact of incentives on the adoption of CA and its desired outcomes

Studies on incentives for enhancing CA have had a variety of objectives, including (1) assessing the impact of incentives and subsidies on the adoption of CA, (2) evaluating the influence of incentives on the outcomes of CA adoption, and (3) studying the modalities of accepting CA incentives.

### 3.2.1. Assessment of incentives and subsidies impact on CA adoption

Although not focusing directly on the impact of PES incentives on the adoption of CA practices, A. Bell, Zavaleta Cheek, et al. (2018) attempted to answer the question of what criteria, including PES incentives, influence the decision of farmers to adopt the trinity of practices forming conservation agriculture in Malawi. The study involved face-to-face interviews with 96 smallholder farmers to identify key factors impacting the decision to adopt the Trinity package of CA practices. The interviews led to 26 criteria analyzed using the ethnographic decision tree modelling (EDTM) model. Findings confirm that the decision to adopt is influenced primarily by two factors peer effect and incentives provision. Decisions within the treatment group about the practices to adopt and their results vary according to the presence or absence of incentives.

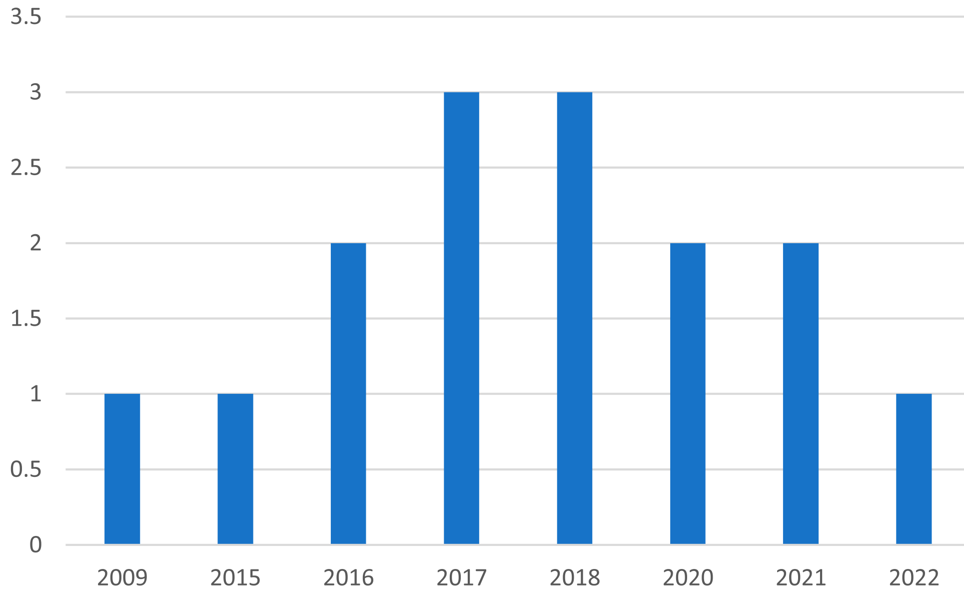


**Figure 2.** Evolution of reviewed papers per year.

Bell et al. (2016) used an agent-based model to analyze the impact of agglomeration payments associated with PES programmes on the level of CA practices. Results provide evidence of the positive impact of agglomeration payments on the improvement of conservation agriculture practices per programme dollar. This allows for reducing the expenditures on diffusion project monitoring and reinforcement.

Ward et al. (2021) analyzed the effectiveness of the PES programme adopted to enhance the adoption of CA by comparing agglomeration payment to conventional vouchers. They addressed four main questions: (1) the effectiveness of incentives in accelerating conservation agriculture adoption, (2) the robustness of the effects of conservation agriculture adoption, (3) the difference in effects between the two modalities of PES (conventional voucher and agglomeration payment), and (4) the impact of incentives on the three constituent practices of CA. Based on the results of a cluster randomized controlled trial conducted on a PES programme later analyzed with the difference-in-differences identification strategy, results confirm that the provision of calibrated financial incentives increases the intensity and extent of conservation agriculture adoption. The conventional subsidy is more effective for CA adoption, but the agglomeration payment appeared to be effective as well. New incentives that support the agglomeration of fragmented land in social systems may improve the extent of conservation agriculture.

**Table 1.** The incentives evaluated by the country.

| Types of incentives | Country of the study |
|---|---|
| Payments for ecosystem services | California – USA |
| | Indonesia |
| | Kenya |
| | Malawi (3) |
| | Monte Carlo-Monaco |
| | Mozambique |
| | Vietnam |
| Input subsidies | Ethiopia, Kenya, Tanzania and Malawi |
| | Malawi |
| | Zimbabwe |
| Market-based incentives | Spain |
| | Austria |
| Direct subsidies | Malawi |

The comparison yielded different results for A. R. Bell, Benton, et al. (2018), whose objective was to design and test the effectiveness of a PES scheme that allows for systemic transformation after the adoption of CA. The examination of incentive potential was based on a randomized control trial that compared a control group with a treatment group. The treatment group consisted of two categories of beneficiaries: (1) those who received a standard subsidy for the adoption of the three CA practices and (2) those who received an agglomeration payment granted as a bonus in addition to the standard subsidy for each adoption of adjacent neighbours. Then the difference-in-difference analysis was conducted between control and treatment measures.

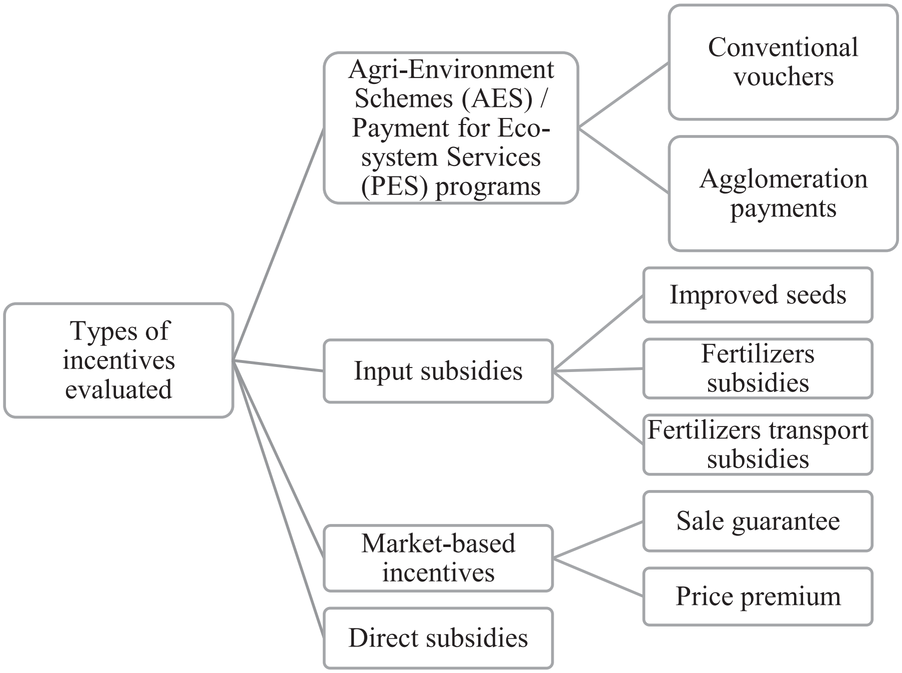


**Figure 3.** The types of incentives adopted to enhance the diffusion of conservation agriculture.

The study's results highlighted that incentives help increase the adoption of CA practices. However, the adoption of neighbours did not show a significant impact on the respondent's adoption.

For market-based incentives, Targetti et al. (2021) assessed the impact of different policy mechanisms such as sale guarantees and non-monetary initiatives on landscape governance in agriculture, especially the adoption of conservation agriculture. The Fuzzy Cognitive Mapping method was adopted in a participatory approach in a case study of Austria. Data were collected over two years through interviews with stakeholders, mind mapping, and focus groups. The analysis results showed that the combination of monetary incentives and non-monetary initiatives (such as farmers' partnerships, certification, and awareness increase) is effective for better agri-environmental governance. This efficiency is threatened in the case of a future context purely driven by the market.

Marenya et al. (2017) investigated the impact of input subsidies on minimum tillage and mulching (MTM) adoption in four African countries, aiming to identify farm-specific and country-specific variables that influence the adoption. The first hypothesis suggested that adoption is influenced by the variables characterizing the smallholder farms such as demographic, plot, market, and credit access, while the second hypothesis proposed that macro-level policy variables, including country and policy, also play a role. Using probit regression and post-estimation simulations, the authors found that policies that enhanced fertilizer subsidies predicted MTM adoption with a modest effect. Comparing the effect of subsidies to that of extension services, they observed that subsidies had a higher impact on MTM adoption.

Ward et al. (2016) analyzed the impact of direct subsidies on the willingness of smallholder farmers to adopt conservation agriculture. They used a discrete choice experiment to identify the variables that determine the willingness to adopt and found that the presence of incentives strongly influences adoption. However, the valuation of incentives varied among farmers, and the impact of incentives on different conservation agriculture practices varied. For example, an increase in subsidies enhanced intercropping and mulching but had a different impact on zero tillage.

#### *3.2.2. Assessment of incentives and subsidies impact on CA adoption outcomes*

The impact of incentives on the outputs of CA adoption was investigated just for two kinds of incentives: input subsidies and PES.

Concerning the impact of input subsidies on crop yields and farmers' consumption, Khonje et al. (2022) analyzed the effect of input subsidies and integrated soil fertility management technologies (ISFM) adoption on the productivity of farms and the nutrition of households in Malawi. The study was based on three models; (1) the multivariate probit, (2) the dynamic random effects probit, and (3) the multinomial endogenous treatment effects. Results confirm that the benefit from a farm input subsidy increases the probability of ISFM technologies (soil and water conservation, conservation agriculture, and organic fertilizer) adoption by 15% to 29%. The combination of ISFM technologies and input subsidies raises micronutrient consumption and crop income by more than 12%.

Homann-Kee Tui et al. (2015) evaluated the profitability of conservation agriculture with and without fertilizer subsidies using the Trade-Off Analysis Model for Multi-Dimensional Impact Assessment. The authors found that conservation agriculture without subsidized fertilizer prices was not financially viable, but with subsidies, it was profitable for half of the farm population.

The impact of PES programmes was dominated by profit variation evaluation. DeVincentis et al. (2020) investigated the limits to the adoption of winter cover crops as a practice associated with conservation agriculture by monetizing their agronomic and economic impacts, with a change in financial subsidies level, on the profitability of farms in the long-term in California. The study addresses the following two elements: (1) the identification of the advantages of winter cover cropping increase over time, and (2) the assessment of the response to the agricultural production context changes the profitability of winter cover crops at the economic level. Adopting a net present value model, findings reveal that winter cover crops may be profitable in California for the long term, Nevertheless, the level of profit changes according to the benefit from financial subsidies, cropping system, climate change, and the extent of irrigation savings.

In another study in Southern Spain, De Leijster et al. (2020) studied the impact of public greening payment and price premiums on the net present value of different agroecological practices like no-tillage, green manure, and compost in comparison with conventional tillage. Using a stochastic cash flow model, results confirm that compost can be applied without any financial support which is required for green manure and no-tillage. Public greening payments and price premiums allow compensation for opportunity costs. The adequate public greening payments and price premiums are supposed to be 5–7 times the current amount granted in agri-environmental schemes.

Evaluating the profit gained from carbon markets after CA adoption considering the benefit from PES, Simone et al. (2017) assumed that if the adopters gain from an exchange market due to PES, laggards may face negative returns if carbon prices decrease or remain stagnant in a project horizon of 20 years. A socioeconomic-biophysical model was used to confirm the results that there is an increase in smallholder income generated by PES, which enhances the adoption of conservation agriculture practices by decreasing the costs of adoption.

#### 3.2.3. Assessment of the modalities of acceptance of CA promotion incentives

This aspect was investigated solely for PES programmes. Jourdain et al. (2009) aimed to analyze the potential response of the poorest agricultural households in the upper catchments of Vietnam to a PES programme that compensates them for dedicating a portion of their land to the production of environmental services, including conservation agriculture. The recursive dynamic model adopted identified that the voluntary participation of farmers in the PES programme is only guaranteed if they are compensated for the loss in food production through transfers of in-kind grain or an increase in crop yields.

Talking about PES programmes an important question that needs to be answered is associated with determining the efficient level of compensation to provide in payments for ecosystem services schemes. Benjamin and Sauer (2018) attempted to answer this question by calculating the marginal cost of ecosystem services (ES) derived from the bioeconomic interactions at the farm level. The quantitative assessment was based on a flexible transformation function using cross-sectional data from 120 smallholder farmers with certification in agroforestry in Kenya. The results confirmed that the combined production between agricultural output and ecosystem services for a considerable number of smallholder farms does not have a complementary relationship but rather a supplementary product-product relationship. The biophysical linkage between marketed outputs and ecosystem services greatly impacts the marginal cost of ES. Consequently, an increase in the provision of ecosystem services is feasible without a decrease in the amount of agricultural output.

The winning conditions for conservation auctions in PES programmes were investigated by Leimona and Carrasco (2017). They used post-auction surveys as well as post-contract surveys and linear mixed-effects models. The results confirmed that farmers with larger plot areas were usually the winners of contracts. A short duration of land ownership, labour availability, and a lack of previous conservation applications were identified as constraints that affect the adoption of conservation agriculture. Final bids did not allow for predicting the capacity of auctions to provide the current level of incentive required by farmers.

## 4. Discussion

This systematic review investigated how incentives can motivate farmers to adopt conservation agriculture practices and whether they impact measurable outcomes of CA adoption.

Four main kinds of incentives were adopted and investigated: Agri-Environment Schemes (AES) / Payment for Ecosystem Services (PES) programmes, market-based incentives, direct subsidies, and input subsidies. For these kinds of incentives analyzed, we observed that they can be classified as adopter, individual, positive, monetary, and immediate incentives. The evaluation of diffuser, system, negative, non-monetary, and delayed incentives was absent.

Evoking the history of policies adopted during the diffusion of conventional agriculture phasis was also lacking which does not allow us to understand the adequacy of the adopted incentives and the necessity for complementary measures to accelerate the diffusion as recommended by Tittonell et al. (2020). The combination of conventional and sustainable policies without calibration leads to a misunderstanding of the design and perspectives of policies. This was confirmed in the case of the CAP policies facing a problem of low environmental effectiveness for the majority of instruments implemented to enhance environmental policy integration (EPI) (Grohmann & Feindt, 2023). Kelemen et al. (2023) indicated a disparity in farmer subsidy allocation between the CAP's two pillars. The subsidies of Pillar 1, which can harm the environment, outweigh the subsidies of Pillar 2, which can lead to environmental development.

Regarding the impact of incentives on CA adoption and based on the reviewed studies, for PES programmes, the impact assessment concerned conventional subsidies and agglomeration payments. Conventional subsidies were found to have a significant positive impact on CA adoption. However, for agglomeration payments, the impact was advanced significantly in some studies and not significant in others. After comparison, it was evident that conventional subsidies were more effective than agglomeration payments. Input subsidies were confirmed to have a higher significant and positive impact on CA adoption compared to extension services. For market-based incentives, especially sale guarantees, their combination with non-monetary initiatives like certification or awareness increase remains more effective.

One study aimed to analyze the detailed impact of incentives on each component of the three CA practices. Direct subsidies were found to have a positive impact on mulching and intercropping. However, if the level of subsidy increases, a significant negative impact is observed for the zero-tillage component. This can be explained by the complementarity relation between mulching and intercropping and the substitute relation between these components and zero tillage. This may contradict the results advanced by Xie and Huang (2021) assuming a positive impact of government subsidies on the adoption of pro-environmental technologies. This can be explained by the study's generality, which argues for the necessity of differentiation between the three CA pillars to measure the influence of incentives because those impacts may vary from one pillar to the next.

Regarding the impact of incentives on CA adoption outcomes, input subsidies were found to increase yields and micronutrient consumption. CA practices were not profitable without incentives, but with the presence of incentives, they became 50% profitable. PES programmes were also found to be profitable as they help compensate for opportunity costs. When it comes to factors influencing the acceptance of PES incentives, economic concerns prevail joining the results of Pineiro et al. (2020).

However, our review is limited by the number of studies identified in the three databases used for the analysis. Further studies should include more databases to enhance the evidence.

## 5. Conclusions

In our review, we identified the main types of incentives adopted to enhance CA practices investigated in the literature. Four kinds were identified among which the most studied are: Agri-Environment Schemes (AES) / Payments for Ecosystem Services (PES) and input subsidies. The various forms of incentives have a considerable and advantageous effect on the spread and results of CA, particularly the payments for ecosystem services (PES) and input subsidies. However, the PES agglomeration payments or higher levels of direct subsidies, respectively, did not have or may have a negative substantial impact on the component of minimum tillage distribution.

Based on the observed findings, we recommend three guidelines for incentives implementation to enhance CA adoption:

- **Assess the impact of further types of incentives**

The four kinds of incentives evaluated are considered adopter, individual, positive, monetary, and immediate incentives. The evaluation of incentives in the form of diffuser, system, negative, non-monetary, and delayed are required additionally. If these categories of policies are not existing in the actual designs of policies, it is argued to conduct an ex-ante assessment for these classes.

- **Take into consideration the history of policies formerly implemented to enhance conventional technologies and their changes after the introduction of sustainable innovations such as CA**

The choice of new categories to combine with the usual classes should take into consideration the historical context of policies. For example, if the former context was of high subsidies, combining the negative incentives category on conventional agriculture with the positive incentives class on sustainable practices is necessary. If the old context is of high taxes, reducing taxes associated with conventional agriculture with positive incentives for sustainable forms remains recommended. These contrasts should be evaluated simultaneously to understand the reasons for policies' effectiveness or ineffectiveness.

- **Distinguish between the distinctive impacts of incentives on each component of the CA Trinity package of practices**

It is recommended to analyze the impact of incentives on mulching, intercropping, and minimum soil disturbance separately and in combination. CA is composed of three pillars which are differently perceived by farmers. This perception leads to varied or contradictory impacts of incentives. Hence, the type of incentive to adopt and its effectiveness may vary with each pillar of CA.

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