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How agro-environmental and climate measures are affecting farming system performances in Guadeloupe?: Lessons for the design of effective climate change policies

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ABSTRACT
Relatively a few studies assess the impact of climate change (CC) policies on effective farmers' agronomic practices and associated agro-technical performance. This study aimed at characterizing how CC policies can help farmers to combine CC with other environmental issues to support the design of more effective policies at the farm level. It was conducted in Guadeloupe, where farming systems are highly vulnerable to CC. We analyzed the Agro-Environmental and Climate Measures (AECM) proposed by the European Union. We made surveys with 39 farmers and used an existing whole-farm simulation tool to assess practices promoted by the current AECM. The tool was also used to assess the new AECM under discussion by stakeholders. Structural characteristics allowed identifying various types of farms. These characteristics may affect farmers' capacity to implement the current AECM given that they are labour-intensive. New AECM focused on the decrease in pesticides and do not properly address CC since most of them lead to an increase in greenhouse gas emissions and are very different from the current farmers' CC adaptation strategies. Synergies can be found between the reduction of pesticide use and CC if the alternatives proposed also permit to decrease in the use of synthetic fertilizers.

KEYWORDS
Pesticide; insular areas; policy evaluation

1. Introduction

There is more and more evidence that human actions have warmed the atmosphere, ocean, and lands and that rapid changes are underway (IPCC, 2021). After the transportation and industrial sectors, the agricultural sector is pointed out as the highest contributor to greenhouse gas (GHG) emissions. For guiding adaptation and mitigation in the agricultural sector, international negotiations on climate change (CC) have triggered the development of various national and sub-national plans and strategies, including various instruments (Andrieu et al., 2020; Burton et al., 2006).

However, a few studies exist on the assessment of CC public policies at the farm level (Milhorance et al., 2021). Evaluating CC public policies is made much harder at the farm level because farmers are dealing with competing goals when implementing practices promoted by policies. Particularly, in vulnerable areas, farmers are exposed to various environmental concerns (e.g. CC and also water or soil eutrophication) and need to manage the trade-offs between them (Acosta-Alba et al., 2019).

Since the 2000s, the common agricultural policy (CAP) has evolved from a policy-oriented exclusively towards support to agricultural production through the inclusion of the multifunctional characteristics of agriculture and the expectations of society (Landel & Le Roy, 2012). Nowadays, the CAP is organized

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around two pillars, the first gathering direct support to the market and the second being oriented towards rural development, biodiversity, and CC adaptation and mitigation goals. Unlike the first pillar, the second one leaves more room for states and local groups to translate the EU directives. CAP's second pillar tools are locally adapted. The second pillar thus becomes a privileged place for regionalization (Trouve & Berriet-Solliec, 2010) and highlights the notion of territory (Trouve et al., 2007). In this process of regionalization, the challenge for policy-makers is consequently to articulate CC goals defined at European and national scales with other territorial development goals. Agro-environmental and climate measures are one of the policy instruments of this CAP's second pillar where local stakeholders link CC with their territorial goals when developing them. The aim of this study is to guide the policy process (Rogge & Reichardt, 2016) by analyzing the failures of implementation and effective outcomes of the AECM at the farm scale.

The study has been conducted in Guadeloupe a French overseas department located in the intertropical zone in the northern hemisphere. This insular department is highly vulnerable to CC (Orec, 2016). Guadeloupe also faces another huge environmental threat given the contamination of nearly one-third of the agricultural area and associated food chain by a remnant organochloride, called chlordecone used till 1992 to fight against banana weevils (Lesueur et al., 2016). An implicit assumption was made by local policy-makers that AECM promoting agroecological practices would easily articulate the objectives of tackling CC issues and local objectives oriented towards diminishing pesticides. We specifically informed the local representative of the state interministerial agricultural service in charge of AECM implementation, highlighting the constraints of the implementation of the first AECM at the farm scale and assessing the economic and environmental costs of the implementation of the forthcoming AECM (DAAF, 2021). We draw lessons for the policy design of more effective policies to tackle various environmental concerns.

2. Materials and methods

2.1. Description of the study site

In Guadeloupe, temperatures remain stable and mild throughout the year, from 20°C to 29°C on average, depending on the altitude. The distribution of rainfall is uneven: the island of Basse-Terre, volcanic and mountainous, collects most of the rainfall, up to 10,000 mm/year. Conversely, the island of Grande-Terre, a limestone plateau, with the southern islands and the leeward coast, collects an average of 1000 mm/year. These regions often face periods of drought and, every year, Guadeloupe can be affected by hurricanes during the hurricane season, from June 1 to November 30.

The average temperature in Guadeloupe had already increased by approximately 1.5°C from 1965 to 2009. The expected CC scenarios in the area include a temperature increase from 1.6°C to 4.3°C, an increase in the number of hot days, which would be three to six times higher, and more rapid and more frequent reaching extremes in temperature and rainfall. Drought episodes would be shorter but more intense and inclement weather such as rain showers and hurricanes would become more intense. These changes would be accompanied by rising humidity, sea levels, and the risk of flooding (Royer et al., 2017).

Agriculture, which employs 12% of the local population and represents 6% of the regional gross domestic product (DAAF Guadeloupe), is responsible for 5% of the total GHG emissions of Guadeloupe (CITEPA/Rapport Outre-mer, July 2013, IREP).

The expected impacts of CC on agriculture are a decline in cultivated area, weakening of crops with the development of diseases in rainy and humid weather, along with a drop in production yield, increase in losses, and decrease in exports, thus strongly affecting the local economy (daaf.guadeloupe.agriculture.gouv).

The total cropping area is 35,000 ha, which represents 18.2% of the area of the island. Sugarcane and bananas are the two major crops, mainly dedicated to the export market. The sugarcane area is 12,310 ha, mainly located in Grande-Terre. Banana production is located in Basse-Terre on approximately 2400 ha (Agreste, 2019). Almost 7000 ha of land in the south of Basse-Terre are polluted by chlordecone, making these lands unsuitable for the cultivation of certain foodstuffs such as tubers for several centuries (DAAF Guadeloupe).

2.2. The agro-environmental and climate measures in Guadeloupe

In Guadeloupe, two types of policy instruments dealing directly or indirectly with CC in the agricultural sector can be identified (Sabourin et al., 2019):

- Explicit climate instruments supporting changes of practices at the farm level: Agro-Environmental and Climate Measures (AECM). These measures were existing (agro-environmental measures) initially aimed at promoting practices with good economic and environmental performances. Their label changed to take into account the European Union's development priorities in terms of CC.
- Instruments created especially for adaptation, such as the Air, Climate, and Energy Plan. They support meetings, communication, information, and knowledge sharing around this theme for farmers and the general public. However, they do not include specific instruments permitting addressing CC at the farm level.

The AECM are consequently the unique CC-explicit policy instrument in Guadeloupe related to agriculture. AECM results from the Rural Development Plan (PDR). They were partly financed by the European Agricultural Fund for Rural Development (EAFRD). They began to be promoted in 2014. They aimed to 'support farmers who engage in the development of practices combining economic and environmental performances or in the maintenance of such practices when they are threatened with disappearance' (Ministère de l'agriculture et de la souveraineté alimentaire, 2022). The incentive associated with each measure was supposed to compensate for all or part of the 'additional costs and shortfalls' caused by their implementation compared with the conventional practices. Subscription of farmers to such measures is voluntary. The commitments are made for five years. A farmer cannot apply to various AECMs on the same plot and failure to comply with them implies a reimbursement of the whole incentive.

The region of Guadeloupe has identified the need to orient the PDR around three strategies organized into specific objectives. These strategies are to (1) foster a competitive economic environment favourable to innovation, (2) increase employment through measures permitting strengthening and adapting skills in part of the dynamics of territorial promotion, and (3) support an economy that cares about natural resources, low emissions of CO_2 through environmental innovation, and the transfer of new practices, based on the concept of adaptation to CC (European Union and Region of Guadeloupe, 2014).

AECM emerged from a bottom-up process in which the farmers' organizations proposed sets of alternative practices that were then discussed with decision-makers according to their cost and difficulty of implementation. Arbitration was then made by decision-makers according to their willingness to promote a more or less radical transformation at the farm level. With the number of targeted farmers and the budget allowance, 20 measures were proposed: five dedicated to market gardening systems, four to sugarcane systems, four to bananas systems, two for the promotion of beekeeping, two for the promotion of organic farming, one for the maintenance of the traditional creole diversified gardening, one for the maintenance of the local cattle breed, and one for citrus systems. Most of them were promoting standalone practices corresponding to various modalities to decrease the use of pesticides on cropping systems. Only two of them promoted the use of organic fertilizers or fallow. Four of them were promoting a systemic change at the crop level (e.g. sustainable management of the banana-cropping systems).

2.3. Overall methodological framework

We combined an ex-post assessment at the farm level of the first programming of AECM implemented in Guadeloupe based on farm surveys and an ex-ante assessment of the new AECM under negotiation with stakeholders of the agricultural sector using a simulation tool. The ex-post evaluation aimed to characterize the conditions of implementation of the policy at the farm level after its adoption by farmers based on on-farm surveys allowing the collection of data on these AECM, farmers' perception of CC, and structural data of the farm to build a typology of farms. The ex-ante evaluation consisted in analyzing the potential effects of the new version of the policy before its implementation based on a synthesis of the current knowledge of farming systems to inform the policy design.

2.3.1. Ex-post assessment of existing AECM

Farm surveys. The list of farmers accessing or not AECM is not publicly available for confidentiality issues. Consequently, using an existing list of 92 farmers from previous research, built to assess the level of agroecologization of Guadeloupian farms (Fanchone et al., 2020), we randomly selected 39 farms. Eighteen farmers were located in Basse-Terre and 21 in Grande-Terre.

In individual 2-hour face-to-face surveys, and using open-ended questions, two trained enumerators collected data on farm structural characteristics (areas of the various farm crops, types and the number of animals, use of irrigation, group membership), on farmers' perceptions of CC (do they believe that CC is threatening their farm functioning and, if yes, how?), and on their motivations for adoption or not of one of the AECM. Surveys were conducted in 2019.

Typology of farms. To build a typology based on the farm's structural characteristics, the use of AECM, and farmers' perception of CC, we transformed the qualitative and quantitative data collected during the surveys into discrete variables, then ran a multiple component analysis (MCA) followed by cluster analysis.

Farm size, level of mechanization, level of irrigation, reception of subsidies, vegetal diversification, presence of animals, and use of chemical inputs are classical structural data used to discriminate types of farms (Fanchone et al., 2020).

Farm size was transformed into three classes using the quantiles position for its mean. The reception of subsidies, presence of animals, use of chemical inputs, presence of banana, and presence of sugarcane were binary variables with the modality 'YES' if farmers use AECM, receive subsidies, have animals on their farm, or use chemical inputs, and the modality 'NO' if otherwise. Four levels of mechanization were considered: without mechanization, a low level of mechanization (material with a value of less than 10,000 €) a medium level of mechanization (material value comprised between 10,000 € and 50,000 €), and a high level of mechanization, (material with a value of more than 50,000 €). The level of irrigation was grouped into three classes depending on the amount of investment for irrigation (rainfed agriculture, sprinkler irrigation, and drip irrigation). The use of AECM was a binary variable. The perception of CC was decomposed into three classes: 'None' when farmers stated that they did not observe the effects of CC and did not modify their practices, 'Light' when farmers stated that they observed some modification of climate but did not modify their practices, and 'Strong' when farmers stated that they observed effects of CC and carried out some practices to manage it.

The data were processed using the FactoMineR package (Lê et al., 2007) of the R software suite (R Development Core Team, 2008). The Cattell (1966) scree test served to select the number of principal components needed for the MCA. According to Cattell (1966), the number of components was selected graphically using the bar plot of eigenvalues. The number of components to be retained corresponds to the last component before a drop in this bar plot. Cluster analysis was used on the relevant principal components of the MCA using the Cluster package (Maechler et al., 2016) of the R software suite. Ward's method was used to aggregate data. A dendrogram representing the hierarchy of individuals was built. This classification was used to group individuals into homogeneous classes. Given the within-class variability, we used the central farmer of each class to describe its main characteristics.

Analysis of farm performances. For the types adopting AECM, we assessed their outcomes at the farm scale, using an existing Excel tool that calculates various technical and environmental indicators for most of the crop and livestock systems found in Guadeloupe (Rasse et al., 2018). The indicators include gross value added and GHG emissions in CO_2 equivalent per ton produced. Gross value added (GVA) is an economic productivity metric that is the output of the farm less the value of the intermediate goods and services in production, before accounting for the consumption of fixed capital. It was used to estimate the cost of implementation per hectare of the set of practices promoted by the AECM and as a proxy for CC adaptation. Indeed, economic indicators as often used to assess the cost of adaptation or inaction (Stevanović et al., 2016).

GHG emissions were used as a proxy for maladaptation (Barnett & O'Neill, 2010). For these authors, one of the factors of maladaptation is when the adaptation strategy increases emissions of greenhouse gases, thereby increasing the likelihood that further adaptation to climate change will be required in future.

For the calculation of GVA and GHG emissions, we entered the amount and cost of the various inputs (synthetic and organic fertilizer, pesticide, and labour for each task of the technical itinerary) associated with each scenario described in Table 1. For labour cost, the tool considers the workload generated by the practice and the minimum wage level.

The calculation for the GVA is

$$\text{GVA/ha} = (\text{crop product sold X crop selling price} - \text{intermediate cost of the crop})/\text{duration of rotation}/\text{total area of the crop}$$

The calculation of GHG emissions in CO_2 equivalent is based on the equations suggested by the IPCC for tier 1 (the detailed equations are in IPCC, 2006, 2021). They gathered emissions associated with cattle enteric fermentation, emissions associated with cattle manure, direct and indirect emissions associated with the use of synthetic and organic fertilizer, emissions associated with synthetic fertilizer use, and emissions associated with the use of diesel.

We included the emissions associated with the production and transport of pesticides from France to Guadeloupe. For the production of pesticides, we used the emission factors of the various active ingredients contained in the pesticides (Ademe, 2021). For the transport of pesticides, we considered a trip from Marseille to Guadeloupe using a 3500 twenty-foot equivalent unit container vessel as classically used in the Guadeloupian context.

The input data for the calculations were the structural characteristics of the central farms of the types before and after the adoption of the AECM.

2.3.2. Ex-ante assessment of new AECM

Interviews with an expert from the state inter-ministerial agricultural service in charge of AECM implementation. An interview with an expert from the state inter-ministerial agricultural service in charge of AECM implementation in Guadeloupe allowed us to discuss the next AECM programming.

In 2021, discussions were underway between the local representative of the state agricultural service and farmers' organizations from the various parts of the agricultural sector of Guadeloupe to design the new AECM to be implemented in 2023. The main changes compared to the previous version of the AECM were the possibility of implementing a portfolio of agroecological practices in the same plot and the insertion of new crops. For example, a substitution of synthetic fertilizer for organic fertilizer can be associated with a decrease in herbicide use in the market gardening sector. However, the focus remained on the decrease in pesticides in the banana, sugarcane, and market gardening sectors.

Analysis of performance. Four scenarios were simulated (Table 1) and corresponded to various modes of implementation of the AECM for sugarcane and banana cropping systems to cover various potential cropping systems targeted by the new AECM (S1–S4). The cropping systems introducing the practices promoted in the new AECM were compared with their conventional cropping system (comparison of the two modes of implementation of the banana or cane AECM with the conventional mode of banana or cane production). The description of the conventional system was based on the surveys of Step 2.3.1 and on technical references published by the chamber of agriculture (Chambre d'agriculture, 2018). The potential effects of the practices promoted in the new AECM were first described according to surveys with research scientists who led research programmes on these practices and the associated literature (see Table 1 for the main modelling assumptions).

Proposition of new practices. Based on the results of the simulations conducted in Section 'Analysis of performance', we proposed practices able to potentially favour synergies between the decrease in pesticide use and the decline in CO2 equivalent (S5 and S6, see Section 3.3).

3. Results

3.1. Typology of farms adopting existing AECM

The results of the MCA indicated that the first three axes accumulate 46.3% of the total inertia. The classification of the farms according to these three dimensions allowed us to establish four types of farms (Figure 1).

Type 1 involved 18 farms, representing 46.2% of the sample. The central farm of this type had an area of 7 ha (an average area of 12 ha for whole farms of this type). It produced sugarcane like other farms of this type, had a small garden (like half of the other farms) and reared animals (like 11 out of 18 farms of the type). Like all of the farms of this type, the farmer used chemical inputs and had a low level of mechanization. The central farm of this type did not use AECM (five out of the 18 farms of type 1 used AECM, mainly dedicated to sugarcane production). As the majority of the farmers of this type (17/18), the representative farmer was aware of the effect of CC but had not modified his practices due to CC (only four have modified their practices due to CC).

Farmers of this type mentioned being constrained by the labour required to implement the practices promoted in AECM for the sugarcane sector. The five farmers adopting AECM selected the less constraining ones: the suppression of one post-

Table 1. New AECM under negotiation (S1–S4) and the proposed AECM by research (S5 and S6).

Item	Generic description	Observed conventional practice	Tested scenarios (S)	Main modelling assumption
Sugarcane	A unique herbicide is allowed	Use of one pre-emergence pesticide and two post-emergence pesticides	(S1) Substitution of the two post-emergence pesticides by mechanical weeding or (S2) manual weeding	S1 = mechanical weeding allows for saving 29% of labour compared to the conventional practice (surveys with farmers and Chambre d'agriculture, 2018). S2 = manual weeding leads to a 100% labour increase per hectare (S2) (surveys with farmers and Chambre d'agriculture, 2018).
Bananas	The use of herbicides is banned between rows and in surroundings Weekly removal of leaves to decrease cercosporiose (fungi) pressure	The use of herbicides in rows and weekly removal of leaves already practised (by farmers)	(S3) Substitution of herbicide use between rows by mechanical weeding or (S4) intercropping with a cover crop	S3 = mechanical weeding is done by a service provider nine times per hectare per year between rows (surveys with farmers). S4 = cover crops may lead to a 10% decrease in the banana crop yield linked to the competition with the cover crop and a 200% labour increase for planting, weeding, and maintenance of the cover crop (research scientists).
Alternative AECM: The use of bovine to control the fallow in the banana cropping systems	The use of herbicides is banned and bovines are used to destroy banana regrowth in fallow. Weekly removal of leaves to decrease cercosporiose (fungi) pressure	The use of herbicides in rows and weekly removal of leaves already practised (by farmers)	(S5) Substitution of herbicide use in fallow to destroy banana regrowth and weeds and of part of DAP fertilizer and (S6) of part of organic fertilizer	S5 = Three bovines per hectare permit to control weeds and banana regrowth in the fallow and restitution of 158 kg of organic nitrogen per year (research scientists, Stark et al., 2016). S6 = Three bovines per hectare permit to control weeds and banana regrowth in the fallow and restitution of 158 kg of organic nitrogen per year (research scientists, Stark et al., 2016).

emergence herbicide and its replacement by manual or mechanical weeding.

Type 2 gathered two farms, representing 5.1% of the sample. The median size of the farms was 7.5 ha. These farms produced only sugarcane and reared animals. They did not receive subsidies but used chemical inputs. They did not use AECM. One is aware of the effect of CC but the two have not modified their practices to account for CC.

Type 3 involved three farms, representing 7.7% of the sample. The median size of the farms was 5 ha. The three farms of the type were not diversified and only produced bananas; they were irrigated, received subsidies, used chemical inputs, and used AECM. All of these farms were aware of the effects of CC and two farms have modified their practices to account for CC.

Type 4 involved 16 farms representing 41.0% of the sample. The median size of the farms was 18 ha. The central farm, like all the farms of this type, produced bananas. It also produced sugarcane (5 out of 15 farms). It used a high or medium level of mechanization (as 13 out of 15 farmers of this type). Like all farmers of this type, the farmer received subsidies. He did not use synthetic inputs (only six farmers of this type used synthetic inputs). He was using AECM (Like 10 out of the 15 farms). He was aware of the effect of CC (Like 13 out of 15 farmers) and had modified his practices to account for CC (like 12 out of 15 farmers).

AECM were consequently mostly adopted by farmers of types 3 and 4 from the banana sector. The selected AECM correspond to the use of cover

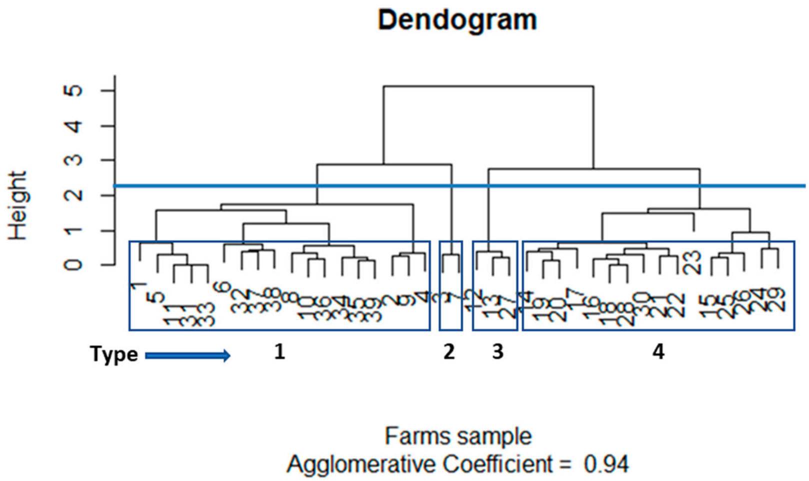

Figure 1. Dendrogram for the hierarchical cluster analysis of the 39 farms.

crops as an alternative to pesticide use and to the introduction of organic fertilizer. The surveyed farmers indicate that these practices were already implemented on their farms (before the incentive). These practices have been promoted by the banana sector since 2008. Farmers consequently used AECM to support practices that already exist on their farms. Only three farmers linked these practices (particularly the ones promoting cover crops) with their CC adaptation strategy. The majority of them were implementing additional practices to adapt to CC such as the change in the soil tillage mode, drains to evacuate water, decrease in banana planting density, the shortening of the crop cycle, or the development of agroforestry that provides shade to the banana and diversify the cropping system. Two other mentioned mitigation practices such as the use of organic fertilizers.

3.2. Assessment of the existing AECM

We simulated the effect of the practices promoted by the AECM for the central farmer of types 3 and 4 that we compared to their practices before their adoption in 2008. We considered in this case the conventional management practices of bananas. For the type 3 farmer who adopted cover crops, the use of herbicides was substituted by the introduction of cover crops in banana cropping systems. For the type 4 farmer who adopted organic fertilizers, synthetic fertilizers (320 kg per hectare of diammonium phosphate at 0.72 euro per kg, 320 kg per hectare of urea at 0.6 euro per kg, and 1250 kg per hectare of NPK fertilizer at 0.8 euro per kg) were substituted by 5.3 ton of organic fertilizers (nitrogen content of 7%) at 0.8 euro per kg.

The introduction of cover crops on type 3 farm led to a GVA of 17,500 euros per hectare, a value 8% lower than the GVA before 2008 mostly caused by the competition between the cover crop and the banana and to quasi no change of GHG emissions per hectare.

The introduction of organic fertilizers on type 4 farm led to a GVA of 7976 euros per hectare, a value 17% lower than the GVA before 2008 due to the cost of organic fertilizers and a decrease of 28 tons of CO_2 eq per hectare associated with the avoided emissions due to the production of synthetic fertilizers.

3.3. Assessment of the new AECM under negotiation

The new AECM under negotiation (S1–S4) led to a decrease in GVA compared to conventional practices (Figure 2). For these scenarios, despite a lower cost of herbicides, their cost of implementation is higher (e.g. labour for manual weeding, purchase cost of equipment such as brush cutter). For scenario 4 (banana with cover crop), these higher costs are associated with a decrease in yield (decrease in yield linked to competition with the associated crop) and lead to the maximum estimated decrease in value added of 3174 euros per hectare. These values allow us to estimate the amount of financial support needed to compensate for the cost of their implementation.

The relative value is the value of the scenario compared with the value of the conventional scenario for each crop.

These scenarios also have contrasting environmental performances. S1 and S3 lead to an increase in emissions of CO_2 eq per hectare (Figure 2). Indeed, the higher emissions due to the use of diesel for mechanical weeding and the importation of inputs (imports of diesel and brush cutter for mechanical weeding), are higher than the avoided emissions of pesticides. S1 and S4 lead to a decrease in emissions of CO_2 eq per hectare permitted in this case by the manual weeding or the yield decrease of the main crop associated with intercropping.

The detailed assessment of the emission spots (Figure 3) highlights that pesticide production and transport contribute slightly to total emissions at the crop level.

3.4. Which AECM favour a decrease in pesticide use while decreasing GHG emissions?

The assessment of the performances of the new AECM (S1–S4) under negotiation helped us to design two scenarios (S5 and S6) that could potentially favour synergies between a pesticide decrease and CC in banana cropping systems that were the ones mostly adopting AECM (types 3 and 4).

Based on Pissonnier et al. (2019) and Lenssen et al. (2013) highlighting the potential role of ruminants for weed control, we simulated two scenarios in which bovines would be used in substitution of the glyphosate used to destroy banana regrowth in fallow. The introduction of three bovines per hectare was simulated. The associated animal dejections on the grazed fields were considered as a fertilizer input for the banana crop. We also included the costs to fence the plot and the costs of acaricide and worm treatments. Two scenarios were compared: the animal permit to decrease both herbicide use in fallow and the supply of 2.25 tons per hectare of organic fertilizer in the subsequent year (S5), and the animal permit to decrease both herbicide use in fallow, the supply of 320 kg per hectare of diatomic phosphate and of 207 kg per hectare of urea (S6).

S6 allowed an increase in the GVA of 945 euros per hectare permitted by the decrease in both pesticide and synthetic fertilizer and S5 led to an increase of 2390 euros per hectare. Indeed, in this case, the cost of the organic fertilizer being higher than the cost of the synthetic fertilizer, the increase in GVA was higher than that observed with S6. For scenario 6 there was an increase in GHG emissions (15%) mostly linked to the enteric emissions of animals. For scenario 5, the avoided cost of emissions linked to the production of synthetic fertilizers permitted to compensate for the enteric emissions, a global decrease in GHG emissions (12%) compared to the conventional management (Figure 4).

4. Discussion

4.1. Adoption of AECM: which lessons for a better implementation?

Farmers adopting AECM were aware of the impacts of CC on their farms. However, the adoption of AECM was much more of a windfall effect, given that AECM were mostly adopted by farmers already implementing the promoted practices. Indeed, in the banana sector, similar agroecological practices such as the introduction of cover crops, of fallow, or the use of sanitized plants have been promoted by previous policy instruments such as the sustainable banana plan (Biabiany et al., 2021 in this issue; Risède et al., 2018). That explains why the proportion of banana farmers implementing AECM was higher than that of diversified farmers or sugarcane farmers. This may also highlight that the adoption of these practices is favoured when they are embedded in a systemic change at the crop level such as the one promoted by the sustainable banana plan. In the initial design of the AECM, they were taught as standalone practices that could not be combined at the crop level. The possibility to combine several practices on the same plot might favour the implementation of more sustainable cropping systems.

4.2. Can the policy instrument favour synergies between a decrease in pesticide use and CC?

The analysis of AECM mainly designed to decrease pesticide use highlighted that they can lead to an increase in GHG emissions given that the emissions associated with pesticide production and use are generally low compared with the emissions associated with the importation of the inputs and particularly the gas oil needed for the implementation of mechanical alternatives to pesticide use. In other terms, these

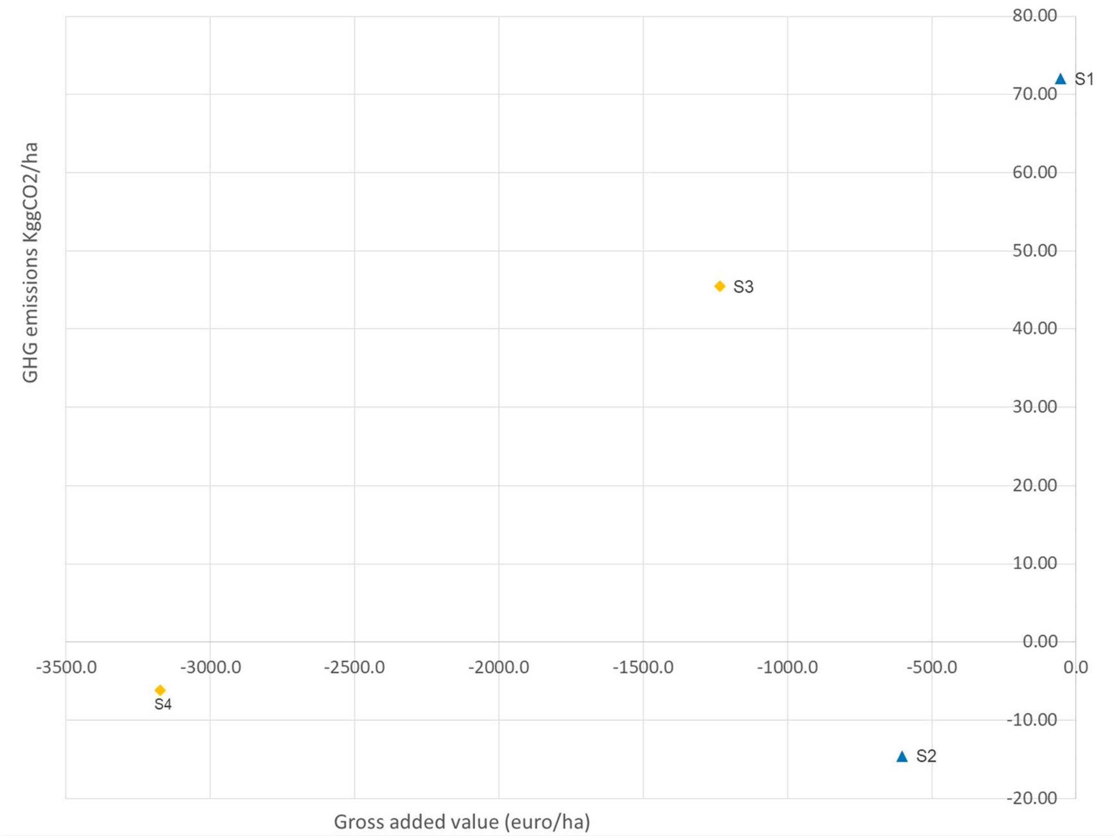

Figure 2. Relative emissions and gross added value of scenarios S1–S4.

practices may lead to maladaptation to CC change (Barnett & O'Neill, 2010).

We used simple metrics for assessing CC adaptation and maladaptation. Milhorance et al. (2021) assessed the contribution of policies to the various dimensions of farm resilience (Milhorance et al., 2021). However, in Guadeloupe, the link between AECM and CC adaptation was not straightforward given that only a few farmers linked the AECM to their CC adaptation strategies that mostly aimed to manage water for the banana crop.

A key to diminishing GHG emissions while decreasing the use of pesticides is to promote options that also decrease the use of synthetic fertilizers. Indeed, the latter is a higher source of GHG emissions than pesticides. Animals can be an opportunity for such synergies (Gourdine et al., 2021). Scenario 5 effectively permitted a decrease in intermediary cost and GHG emissions. However, the introduction of animals implies a transformation of the farm (Pissonnier et al., 2019) based on the integration of crop and livestock systems. Such transformative changes may be the ones allowing farmers to face multiple environmental problems (Duru et al., 2015).

4.3. Overall lessons for policy design

The participatory design of these instruments may have led to the preponderance of considering a local issue (pesticide and its impacts on local food chains) at the expense of the more global issue corresponding to CC. Howlett (2014) mentioned the low accountability of local decision-makers on CC. Hueting and Reijnders (2004) highlighted that the divergent needs and aspirations between stakeholders can lead to a soft compromise that does not match with the real environmental challenges that may require drastic decisions to be made. Some of the proposed practices under the AECM were already implemented by farmers, which leads to concluding that the AECM are soft changes. But, the balance is not easy between promoting drastic changes to deal with CC and pesticide use

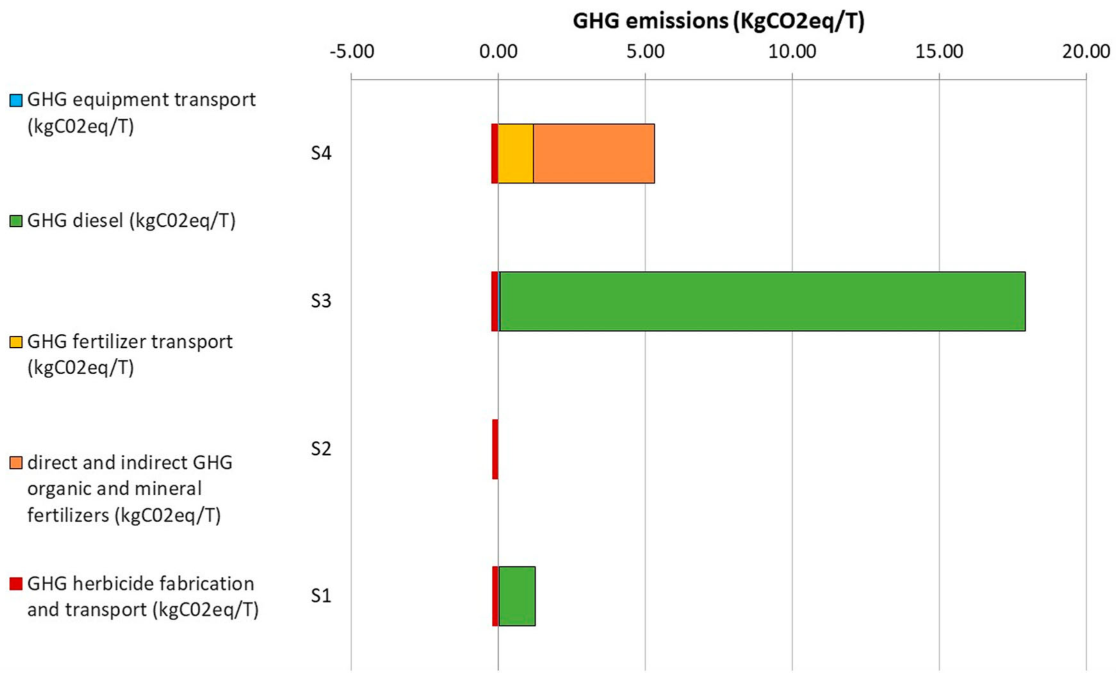

Figure 3. Spots of contribution to GHG emissions for the new AECM (scenarios 1–4).

issues and being sure that these changes are adopted. The amount of the financial incentive is a key to supporting a more or less transformative change. Our assessments highlighted that the same AECM can have various modes of implementation (the various scenarios we simulated for the same cropping system) whose specific costs are highly variable. Farmers should be informed of the specific cost of implementation of each of these modes to guide their decision-making.

5. Conclusions

The ex-post assessment of existing farming highlighted four types of farms according to their structural characteristics, the use of AECM, and farmers' perception of CC. We showed that the adoption of the former AECM was much more of a windfall effect promoted by the banana sector for farmers already implementing the promoted practices. The ex-ante assessment highlighted that the new AECM (S1–S4) tends to decrease the GVA and to increase GHG emissions particularly when they increase the use of diesel in farms. For the policy process, and when the promoted practices lead to additional costs for the farmers, the challenge is to calibrate the financial compensation to trigger changes for several farms than the ones currently adopting the practices. The challenge is also to include practices that can both allow the reduction of pesticide use, a crucial problem in the study site, and the reduction

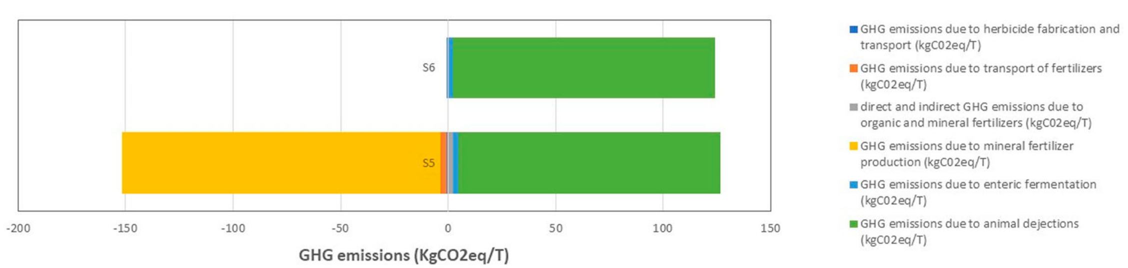

Figure 4. Spots of contribution to GHG emissions for cattle scenarios 5 and 6 in $kgCO_2eq/T$.

of GHG emissions. The use of animals in cropping systems (S5 and S6) can be an opportunity to address both challenges. Our conclusions were used to support the design of the new AECM by the state inter-ministerial agricultural service. At the time when the study was conducted the final selection of the practices of the new AECM was not yet finalized. The final decision will be key for helping farmers address the multiple environmental challenges that they face on their farms.

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