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EFFECTIVENESS OF CLIMATE CHANGE MITIGATION INTERVENTIONS IN THE PRIVATE SECTOR IN DEVELOPING COUNTRIES - A SYNTHETIC REVIEW

Nathalie Doswald, Isabel Puche Marín, Jerónimo José Rocio Pérez, Martin Prowse, Emma De Roy, Luis Sanchez Torrente and Guido Fernández De Velasco

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Effectiveness of Climate Change Mitigation Interventions in the Private Sector in Developing Countries - A Synthetic Review

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About this IEU Learning Paper

This paper presents a synthetic review of causal evidence on the effectiveness of private sector mitigation interventions in the private sector in developing countries. It describes topics for which high-quality evidence exists and provides a critical assessment of the evidence base.

TABLE OF CONTENTS

TABLES

FIGURES

ACKNOWLEDGEMENTS

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ABSTRACT

This paper conducts a synthetic review of the available causal evidence on the effectiveness of climate change mitigation interventions in the private sector in developing countries. Based on an evidence gap map on the same topic, it provides a detailed description of the 32 studies that met the strict inclusion criteria, their different implementation modalities and the study designs applied in each case. More importantly, we systematically analyse the outcomes obtained in the studies and provide a critical appraisal of the quality of the evidence. The review's results show that the evidence on this topic is still limited and spread across various sectors and interventions, with most evidence in the energy, industrial and agricultural sectors. The role of the private sector in the assessed interventions consists, in most cases, of investments by households and smallholders in adopting alternative energy generation measures (e.g. domestic solar systems, biodigesters). Corporate investments include different forms, including energy efficiency services, GHG emissions treatment equipment or transportation fleet renewal. A significant proportion of the assessed interventions are embedded in or influenced by public policy initiatives that provide important elements of the enabling environment, such as financial, regulatory framework or tax incentives. The majority of the 32 reviewed studies found significant positive effects from the interventions regarding climate change mitigation and other co-impacts. However, the limited number of causal studies and the limited external validity in a significant number of papers pose significant challenges for drawing generalizable conclusions.

ABBREVIATIONS

ANOVA	Analysis of variance
CCM	Climate change mitigation
CER	Certified emission reduction
EGM	Evidence gap map
GCF	Green Climate Fund
GHG	Greenhouse gases
GLMM	Generalized linear mixed model
GMM	Generalized method of moments
IE	Impact evaluation
LCA	Life cycle assessment
OLS	Ordinary least squares
PICO	Population Intervention Comparator Outcome
PSM	Propensity score matching
SHS	Solar home system
SR	Synthetic review
USD	United States Dollar
WoS	Web of Science

A. INTRODUCTION

This synthetic review is part of the first research initiative to assess the evidence base on the effectiveness of climate change mitigation (CCM) interventions in the private sector in developing countries.[1] It is based on an associated evidence gap map[2] undertaken to understand existing quantitative evidence in terms of the types of mitigation interventions carried out by the private sector in developing countries and the outcome areas studied. The evidence gap map provided a graphical depiction of the existing evidence base but did not indicate the direction or magnitude of the impacts of interventions.

Based on the strict inclusion criteria, the evidence gap map (EGM) found a limited amount of relevant articles (32) with high dispersion across different sectors, outcomes and interventions (see Doswald and others, 2021). This precludes an in-depth analysis of a subset of papers, such as the meta-analysis of studies grouped in one cell of the EGM. Instead, this paper presents a synthetic review (SR) as the second best option to understand in detail the set of interventions and outcomes of climate change mitigation in the private sector in developing countries and their results in terms of effectiveness. The SR offers an in-depth analysis of the findings and approaches taken, including a critical appraisal of the methods used to establish the evidence. This synthesis can aid decision-making by private sector actors and highlight the role of the public sector and agencies in catalysing private sector investments in mitigation. It can also help identify research gaps within mitigation interventions and inform subsequent studies in this field.

This paper first presents a summary of the protocol and methodological approach used in the SR's development, including the criteria for the critical appraisal of studies. Second, it provides a synthesis of the results, emphasizing the outcome areas included in the studies and the particularities of the different interventions by the private sector. Finally, some conclusions and recommendations aimed at policymakers, financial institutions and the research community are derived from the results.

B. APPROACH

1. RESEARCH QUESTIONS

Similar to the EGM that preceded this work, the SR aims to address the following overarching question:

What evidence exists concerning the effectiveness and efficiency of CCM interventions in the private sector in low- and middle-income countries?

For our purposes, **effectiveness** refers to reducing greenhouse gas (GHG) in the atmosphere that is attributable to a particular intervention. **Efficiency** refers to the degree of GHG reductions that is attributable to a specific intervention relative to the resources utilized in its implementation.

Specifically, the SR responds to the following questions:

1) What kind of interventions have been most frequently adopted by the private sector, and how were they implemented?
2) Which interventions have proved to be more effective in leading to climate change mitigation and associated co-impacts?

[1] Developing countries in the context of this paper refer to low-to-middle income countries as defined by the World Bank.
[2] For further details on the underlying theory of change and background information of the research initiative, please see Bertzky and others (2020).

3) What kind of methods and approaches have been used to establish causal links between the interventions and the desired outcomes? Are these methods reliable and unbiased?

4) What different modalities of private sector participation are most frequently found in the evidence based literature?

We now turn to the search strategy that was conducted.

2. SEARCH STRATEGY

The articles to be included in the SR have been identified through the EGM on the same topic, conducted during the first stage of this research initiative. The search strategy of the EGM followed a systematic approach, including the use of a search protocol of academic literature in two different search engines and specialized searches of "grey" literature. The following table summarizes the main elements of the search strategy followed in the EGM and the output obtained at the end of the EGM process.

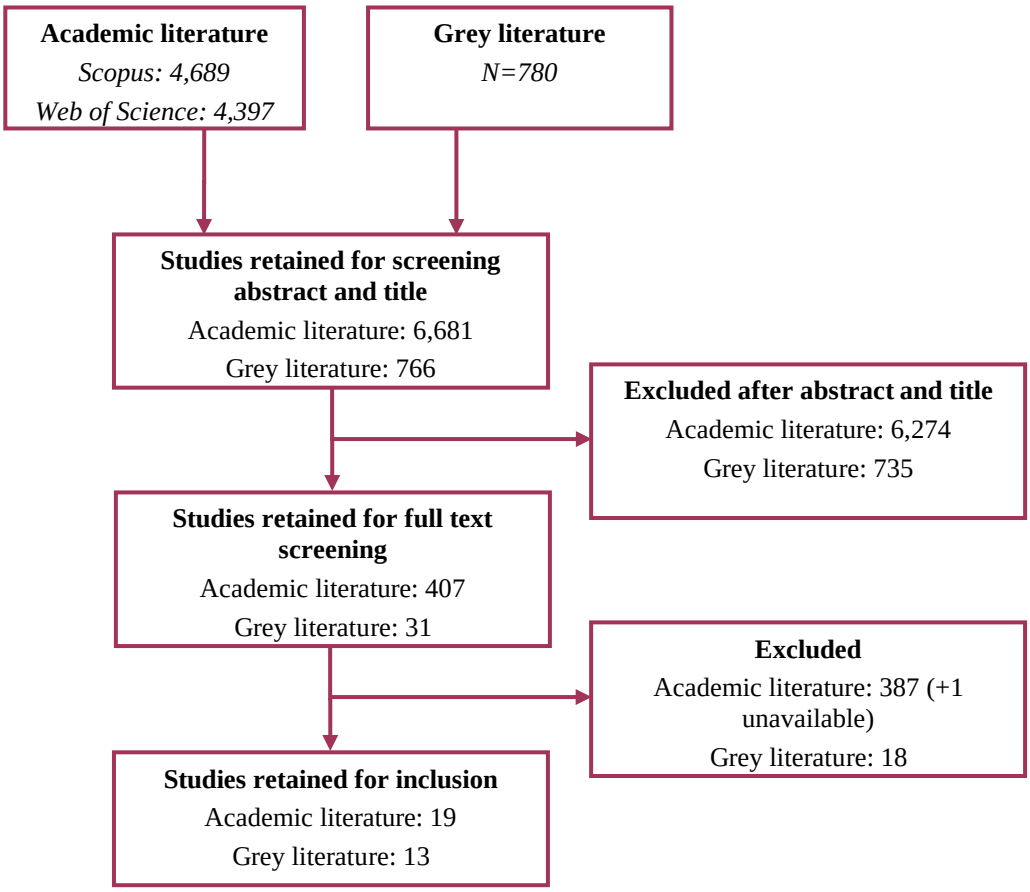
Table 1. Summary of the EGM search strategy

ELEMENT	DESCRIPTION
Time frame	The search was limited to articles published after 2005. The Kyoto Protocol was adopted on 11 December 1997 to operationalize the United Nations Framework Convention on Climate Change by committing industrialized countries and economies in transition to limit GHG emissions under agreed individual targets.
Language	The search was restricted to articles found in the primary publication databases written in English, Spanish, German and French.
Search terms	Four sets of search terms were used with individual terms (and wild card symbols (*) where appropriate) separated by Boolean "OR" operators and sets combined using "AND." A fifth set was used and combined with "AND NOT" (for exclusions). Appendix 1 contains the set of search terms.
Snowballing searches	This technique was applied for relevant systematic reviews identified through the above-presented search terms. Two additional benchmarking publications that examine impact evaluation (IE) studies in the transport and energy sectors were also examined under this methodology (Raitzer and others, 2019a and 2019b).
Publication database searches	Web of Science (WoS) and Scopus.
Specialist searches	A further limited selection of "grey" literature was identified by going directly to relevant organizations' websites. This search was expert informed according to the inclusion and exclusion criteria. To ensure replicability, a simple set of search terms was used and recorded (see Appendix 2 for a list of grey literature sources), as well as the date of the search and the number of articles downloaded.

The search strategy of the companion EGM found a total of 7,447 papers. Once duplicates had been removed, and after screening according to the strict inclusion and exclusion criteria,[3] 32 studies were included (see Figure 1 for a PRISMA diagram), out of which 19 correspond to academic papers and 13 to grey literature. In terms of the methodological approach, 17 publications provide evidence through solid causal analysis, including counterfactual analysis and causality tests. In contrast, the remaining 15 publications have adopted other quantitative approaches based on correlational analysis. The high diversity of outcomes, interventions and methods impedes the application of a meta-analysis of papers within a single cell of the EGM.

[3] See Bertzky and others (2020).

Figure 1. Inclusion exclusion diagram



3. THE EGM FRAMEWORK CATEGORIES

The companion EGM used an analytical framework to map the identified literature according to different sector, intervention and outcome categories. Some of these categories will also be used in the presentation of results for the SR. In particular, the evidence was grouped into eight sectoral categories:

1) Energy
2) Industry
3) Transport
4) Waste management
5) Building
6) Urban planning
7) Agriculture and livestock
8) Forestry and land management

For analysis of other EGM categories, including the geographical distribution of the evidence, intervention types and outcome groups/categories, please refer to the corresponding EGM report (Bertzky and others, 2020).

4. DATA EXTRACTION AND CODING STRATEGY

Studies included were given an identifier number and were coded according to the relevant intervention and outcome categories included in the EGM framework. The SR process required additional coding and information extraction for in-depth characterization of the PICO[4] elements

[4] PICO stands for Population Intervention Comparator Outcome.

and the analytical approach. Table 2 details the following aspects that were systematically recorded for each of the selected articles.

Table 2. Summary of the coding fields for SR

PICO ELEMENT	CODING FIELD
Population	Unit recipient of the intervention (factory, forest, homes, etc.)
	Role of the private sector (qualitative description)
Intervention	Brief qualitative description of the intervention
	Geographical scale of implementation (local, provincial, national, etc.)
	Time frame of implementation covered by the study
	The stage of development of the intervention (pilot, mature, well-developed intervention, etc.)
	Main implementing agent
	Other involved agents in the implementation
Outcome	Brief qualitative description of the outcome, as defined in the study
	Units of measurement (Kw/h, CO_2, etc.)
	Measurement method of the outcome variable (life cycle assessment (LCA), survey, remote sensing, etc.)
	Outcome quantification expressed in original units
	Time lapse between intervention and outcome measurement
	Main conclusion as reported by the author, summarizing the causal (or statistical) relationship between the intervention and the outcome
Study design	Brief description of the estimation methods
	Measurement methods, different from the outcome variable, used for variable construction
	Causality test used (if applicable)
	Comparison units (individuals, regions, companies, etc.)
	Level of comparison; cross section, time series, panel data
	Number of observations
	Possible study biases as identified by the author
	Other weaknesses/limitations as identified by the author

Three reviewers worked in parallel with two subsets of the papers to compile the information described above. They were the same reviewers as for the EGM process. Their Fleiss's kappa score during that process was 0.6, indicating an adequate amount of agreement. The data and information extraction were performed in two consecutive rounds. In the first round, qualitative information was extracted in the form of short statements, accordingly to the coding fields defined in Table 2. The three reviewers worked in parallel with regular coordination meetings to extract the information. In the second round, the reviewers refined the information. Where feasible, they grouped it into categories for each of the defined fields.[5] The reviewers worked jointly in the definition of

[5] Given the heterogeneity of studies, ex-ante definition of categories is not feasible.

categories, while a fourth reviewer provided quality control and supervision of the final output tables.[6]

5. CRITICAL APPRAISAL

The critical appraisal of each of the 32 studies was undertaken to determine the quality of the results. The critical appraisal was based on the following four components:

1) The relevance of the research question and how the general approach and conclusions address it.
2) The internal validity: the degree to which the study design, conduct, analysis and presentation have minimized or avoided biased assessments of the interventions under evaluation.
3) The external validity: the precision and extent to which it is possible to generalize the study's results to other settings. For consistency with our main research question, the generalizability of results is bound to the context of developing countries.
4) The appropriateness of data analysis and presentation: the extent to which authors provide transparent information of data-collection, variable definitions, population characterization and descriptive statistics.

Table 3 shows the checklist of questions used for the critical appraisal of the 32 articles identified in the EGM.

Table 3. Checklist of issues for the critical appraisal of papers

CRITICAL APPRAISAL ITEM	CHECKLIST QUESTIONS
Relevance	What is the research question as stated by the author?
	Are the methods used in the study the most relevant ones for answering the research question?
	Are the outcome measures used in the study the most relevant ones for answering the research question?
	Do the conclusions of the study address the research question?
Internal validity	Is the intervention clearly described, with details of who exactly received it?
	If two groups are being compared, are the two groups similar and subject to similar data-collection and analytical approaches?
	If not, was any attempt made to control for these differences, either statistically or by matching? Was it successful?
	Are there sufficient data points to enable reliable statistical inference?
	Is there evidence of multiple statistical testing (including causality test, alternative model formulation, etc.)?
	Are there any other possible sources of biases other than those identified by the author?
External validity	Does the study population appear to be representative of the population to which the results are applied?
	Have the interventions been replicated in several settings with different populations?
	Are the main findings and conclusions of the study bound to specific characteristics of the population?

[6] See Appendix 3 for further details on the data-collection process.

Critical appraisal item	Checklist questions
	Can the main findings and conclusions of the study be generalized to a broader population than the one described in the study?
Appropriateness	Does the study provide details of data-collection techniques?
	Is there an adequate description of the data (including tables and summary statistics describing the sample and adequate information on the results of any analyses)?

Based on the results of the first review of the critical appraisal, the reviewers worked jointly to assign each article on a three-part ordinal scale for each of the four assessed components. Table 4 summarizes the categories applied and their definition for each of the components.

Table 4. Categories for critical appraisal

Critical appraisal component	Quality categories		
	High	Intermediate	Low
Relevance	Research question is well defined and addressed through appropriate approach and methods. At least three checklist questions are adequately addressed.	Research question is stated but partial mismatch with approaches and methods to address it is identified. Between 2-3 checklist questions are adequately addressed.	Research question is not clearly stated or poorly defined. Evident mismatch between research question and methods is identified. Less than two checklist questions are adequately addressed.
Internal validity	The study design, conduct and analysis have minimized or avoided biased comparisons of the interventions. At least five checklist questions are adequately addressed.	The study design, conduct and analysis have partially minimized or avoided biased comparisons of the interventions. At least 3-4 checklist questions are adequately addressed.	The study design, conduct and analysis did not minimize or avoid biased comparisons of the interventions. Less than three checklist questions are adequately addressed.
External validity[7]	The study results can be generalized to other contexts and settings without or minimal adaptation of the intervention. At least three checklist questions are adequately addressed.	The study results can potentially be generalized to other contexts and settings, but partial adaptation of the intervention might be needed. Between 2-3 checklist questions are adequately addressed.	The study results cannot be generalized to other contexts and settings or may require substantial adjustment of the intervention. Less than two checklist questions are adequately addressed.
Appropriateness	Data and analysis are described and presented in detail or at least identified as an accessible external resource.	Data and analysis are partially described and presented. Information is sufficient, but additional details are needed for full transparency and understanding.	Substantial data description and analysis are missing or poorly presented. The lack of information impedes full understanding of the conclusions.

[7] A trade-off between internal and external validity may be common in some causal designs. For example, experiments may have very strong internal validity but limited external validity when bound to very specific characteristics of the population. This aspect has been taken into account when assessing the internal and external validity of the papers.

The following section provides the results of the SR. It includes a detailed analysis of the interventions and their implementation modalities, the studies' outcomes, and the corresponding study designs and their critical appraisal.

C. RESULTS

1. INTERVENTIONS, POPULATION AND THE ROLE OF THE PRIVATE SECTOR

This section presents a detailed account of the interventions assessed in the literature, including their target population, the agents involved in their implementation, and a description of the specific role of the private sector. The information is presented in three clusters of economic sectors, as specified in the corresponding SR protocol: a) energy, industry and waste management; b) forestry, agriculture and livestock; and c) buildings, transport and urban planning.

a. Energy, industry and waste management

The nature and scope of interventions in these three sectors show a wide variety depending on whether the investment is performed in the corporate or domestic domain, particularly regarding energy related interventions (Table 5). Out of the 12 papers identified in the energy sector, seven assessed interventions implemented at the household level, including solar home systems (SHS), improved stoves, efficient lighting systems and biogas generation equipment. In corporate investments, the nature of assets and services provided in the intervention ranged from large-scale generation projects (wind farms), environmental safeguards in the context of a large oil and gas project, and the provision of audit and consulting services for energy efficiency.

The interventions in the industrial sector (four articles) were implemented by corporate actors, although they differed in size and activity. Only one paper (Grimm and Peters, 2015) dealt with small companies (local beer breweries), whereas the remaining three dealt with larger industrial companies. Concerning the nature of the intervention, two articles assessed the effectiveness of different modalities of GHG treatment during industrial production processes. In contrast, the remaining two articles addressed the introduction of improved stoves and the provision of energy efficiency consulting services. In this last case (Ryan, 2017), the intervention was provided in an experimental setting, freely and randomly distributed among the participant industrial companies, although the subsequent investments, implemented as a consequence of consulting services, were performed under market conditions. In the waste management sector, a more prominent role of households and community-led interventions were also observed, all in the form of installed biodigesters.[8]

In general terms, the role of the private sector in these three sectors showed a wide range of modalities, with a prevalence of household-led initiatives. In these cases, the intervention was the result of a household private investment, whose main beneficiary was the household itself, mostly in terms of energy and financial savings. Nevertheless, it should be noted that such investments were commonly performed in the framework of wider initiatives that counted with the active role and support of the public sector or multilateral donors. This reflects the Green Climate Fund (GCF) business model in terms of providing public finance to catalyse private sector investment through interventions often aimed at household beneficiaries. In some cases, the support came in the form of subsidies and financial support. One case on waste management interventions illustrated how household and community investments fulfilled both domestic and productive functions (mostly in the framework of small farming activities). Two different types of private sector roles were present

[8] Biogas/biodigester types of interventions are classified within the energy or waste management sector depending on their main purpose as described in the narrative of the corresponding research article.

in the literature regarding corporate investments: those performed within the company´s activity (the most common case) and other financial investments and services outside the company´s main activity. In this latter case, we find financial investment in wind energy projects (Sabbaghi and others, 2018) and consulting/auditing companies providing energy efficiency services to industrial companies, eventually leading to subsequent investment within the activity of the recipient company (Fang and Miller, 2012; Fang and others, 2012; Ryan, 2017.)

b. Forestry, agriculture and livestock

The agriculture sector showed greater homogeneity in the type of interventions and the actors involved in their implementation. In most cases, the intervention responded to private investment initiatives by smallholder farmers, performed within their activities. All the agricultural interventions have been classified in Table 5 as sustainable agricultural practices and agroforestry, although a closer inspection allows identifying some specific practices. Thus, we find different cropping systems for rice, maize, lentils and other vegetables (Pokhrel and Soni, 2017), maintaining and planting a diverse array of tree species for various uses and benefits (Reppin and others, 2020), system rice intensification (Gathorne-Hardy and others, 2013) or the introduction of conventional tea, mini-terracing for tea and other climate-smart agriculture practices (Tran and others, 2018). The only article dealing with livestock-related interventions addressed, inter alia, smallholder dairy practices involving cattle management (feeding supplements and practices - Brandt and others, 2018). In the case of forestry, out of the three identified articles, two corresponded to corporate investments in forest protection and one community-driven initiative for land rehabilitation. The corporate investments consisted of voluntary transactions, which were conditional on maintaining an ecosystem that provided the desired environmental services (Sills and others, 2008), and private participation on park management (Blankespoor and others, 2014). However, it should be noted that in the latter case, the paper covered a wide sample of tropical protected areas in which both private and public management models were assessed. The community-driven initiative consisted of the establishment and construction of soil water conservation structures (Mekuria and others, 2015).

Except for the case of corporate participation in forest protection schemes, private CCM investments in these sectors were mostly led by farming households who adopted certain investments. Apart from their mitigation-related outcomes, these investments also provided adaptation benefits and other co-impacts (see the following section on outcomes). Contrary to what was observed in the energy sector, the role of public actors is less prominent in agriculture and forestry, as very few of the assessed initiatives were embedded in public programmes or initiatives. The most notable exception to this rule is found in Sills and others (2008) where the private transactions were embedded in a publicly-led programme.

c. Buildings, transport and urban planning

As no literature was identified in the building and urban planning sectors, all relevant interventions in this section referred to private initiatives within the transport sector. More precisely, two of the three identified papers dealt with the CCM effects of the fleet renewal in the aviation (Cabo and others, 2020) and maritime (Acciaro and McKinnon, 2015) industries, whereas Santos and others (2018) addressed the reduction in GHG emissions associated with the introduction of a new type of car fuel (ethanol and gasoline). Santos and others (2018) dealt with the aggregated effects of individual investments in private vehicles. In contrast, the former two fall into the category of corporate investments within the company's core business activity. The role of the public sector was identified in the papers as regulatory and as a policy facilitator; however, the interventions were not embedded in the framework of specific public programmes nor did they count explicit financial support from the government.

Table 5. Population and interventions of systematized fields

Study	Recipient of intervention	Private sector role	Intervention (description)	Geographical scale	Time frame	Main implementing agent	Other implementing agents
ENERGY							
Chun and Jiang, 2013	Households	Domestic investment	Energy-efficient lighting systems	National	2008-2009	Households	Government (subsidies)
Laramee and Davis, 2013	Households	Investment for domestic and farm use	Biogas/biodigesters systems	Seven communities	9 interventions before 1995 11 interventions after 2009	Households	Government (national programme)
Sabbaghi and others, 2018	Wind farms	Corporate investment (financial)	Wind energy	National	Since 2000	Private corporate investors	None
Somanathan and Bluffstone, 2015	Households	Domestic investment	Biogas/biodigesters systems	National	2010-2011	Households	None
Van Groenendaal and Gehua, 2010	Households	Community investment	Biogas/biodigesters systems	National	1985-2006	Households	Government (programme) and non-governmental organization
Bensch and Peters, 2011	Households	Domestic investment	Improved stoves	Two cities	2008-2011	Households	GIZ - PERACOD
Corral and others, 2018	Companies (large sized)	Corporate investment (within own activity)	Environmental safeguards	Regional	Pre-treatment (1992-2003) Treatment (2004)	Oil and gas companies	Government and Inter-American Development Bank

Study	Recipient of intervention	Private sector role	Intervention (description)	Geographical scale	Time frame	Main implementing agent	Other implementing agents
					Post-treatment (2005-2012)		
IOB, 2013	Multiple recipients	Multiple roles	Multiple, including improved cooking stoves, biogas digesters, SHS, etc.	Worldwide	2004-2012	Multiple	Multiple
Samad and others, 2013	Households	Domestic investment	Solar systems	National level (rural)	2004-2012	Households	Government (finance), local public agencies and World Bank
Wang and others, 2011	Households	Domestic investment	Solar systems	National level (rural)	2005	Households	Public utility, private service provider, microfinance institutions
Fang and Miller, 2012	Companies (unspecified)	Corporate investment (within own activity)	Energy audit and consulting services aimed at energy efficiency investments	Worldwide	1980-2007	Energy Service Companies	None
Fang and others, 2012	Companies (unspecified)	Corporate investment (within own activity)	Energy audit and consulting services aimed at energy efficiency investments	Worldwide	1980-2008	Energy Service Companies	None
INDUSTRY							

Study	Recipient of intervention	Private sector role	Intervention (description)	Geographical scale	Time frame	Main implementing agent	Other implementing agents
Sarwar, 2019	Companies (large sized)	Corporate investment (within own activity)	Industrial treatment of GHG	National	2005-2015	Undetermined number of companies	Government (regulations)
Teng and others, 2019	Companies (large sized)	Corporate investment (within own activity)	Industrial treatment of GHG	National	2011-2015	Industrial companies	Government (regulations)
Grimm and Peters, 2015	Companies (small sized)	Corporate investment (within own activity)	Improved stoves	Two cities	2010-2012	Local breweries	GIZ, Dutch-German energy partnership
Ryan, 2017	Companies (large sized)	Corporate investment (within own activity)	Energy audit and consulting services aimed at energy efficiency investments	Regional (subnational)	2011-2012	Industrial companies	Government, International official development assistance agencies and consulting companies
WASTE MANAGEMENT							
Hou and others, 2017	Households	Investment for domestic and farm use	Biogas/biodigesters systems	Four cities	Surveys in 2004 and 2009	Households (rural)	Government (finance) and service provider companies
Kelebe, 2018	Households	Investment for domestic and farm use	Biogas/biodigesters systems	Regional (subnational)	6 months	Households	Government (national programme)

Study	Recipient of intervention	Private sector role	Intervention (description)	Geographical scale	Time frame	Main implementing agent	Other implementing agents
Laramee and others, 2018	Communities	Investment for domestic and farm use	Biogas/biodigesters systems	Three communities	2008-2012	Households	Not specified
TRANSPORT							
Acciaro and McKinnon, 2015	Companies (large sized)	Corporate investment (within own activity)	Fleet renewal	Worldwide	Carrier's age from 1970	Freight carrier companies	Government (policy recommendations)
Cabo and others, 2020	Companies (large sized)	Corporate investment (within own activity)	Reduction of idle fleet capacity	National	2007 - 2016	Aviation companies	Government (tax policy)
Santos and others, 2018	General population	Domestic investment	Fuel substitution (transportation)	National	Since 2003	Companies and customers	Government
AGRICULTURE AND LIVESTOCK							
Brandt and others, 2018	Farms	Corporate investment (within own activity)	Sustainable husbandry	One forest	2010 - 2016	Farmers	Government (policy recommendations)
Pokhrel and Soni, 2017	Land plots	Farm investment	Sustainable agriculture and agroforestry	Regional (subnational)	Continuous (undefined)	Farmers	None

Study	Recipient of intervention	Private sector role	Intervention (description)	Geographical scale	Time frame	Main implementing agent	Other implementing agents
Reppin and others, 2020	Farms	Farm investment	Sustainable agriculture and agroforestry	Regional (subnational)	Continuous (undefined)	Farmers	None
Singh and others, 2016	Farms	Farm investment	Sustainable agriculture and agroforestry	Four villages	2012-2013	Farmers	None
Tran and others, 2018	Farms	Farm investment	Sustainable agriculture and agroforestry	Regional	2014	Farmers	None
Gathorne-Hardy and others, 2013	Farms	Farm investment	Sustainable agriculture and agroforestry	Regional	2011-2012	Farmers	None
Shimon and others, 2016	Farms	Farm investment	Sustainable agriculture and agroforestry	Regional (subnational)	September and October 2013	Farmers	Global Good Agricultural Practice
FORESTRY AND LAND MANAGEMENT							
Mekuria and others, 2015	Land plots	Community investment	Land management (rehabilitation)	Regional (subnational)	2006-2013	Communities	None
Blankespoor and others, 2014	National parks	Corporate investment in forest protection	Land management (forest protection)	4,028 parks in 64 tropical forest countries	Different time frames between 2001 - 2012	Government and private park management companies	Private companies (park management service providers)

Study	Recipient of intervention	Private sector role	Intervention (description)	Geographical scale	Time frame	Main implementing agent	Other implementing agents
Sills and others, 2008	Landowners	Corporate investment in forest protection	Direct payments for forest conservation	National	1997-2005	Landowners	Government, private companies

2. OUTCOMES

This section describes the results obtained in each study, focusing on the type of outcomes addressed and the results obtained in terms of the effectiveness of the interventions. The information is presented using the same sectoral structure as in the previous section.

a. Energy, industry and waste management

The CCM effectiveness of interventions in the energy, industry and waste management sectors were assessed across different outcome variables (Table 6). The direct measurement of GHG emission reductions attributable to the specific interventions was found in nine of the 19 identified articles (although the applied measurement method varied depending on the methodological approach). Thus, for cross-country studies (Fang and Miller, 2012; Fang and others, 2012) and macrolevel studies (Teng and others, 2019), GHG data was compiled from official emission inventories, whereas the emissions in the remaining studies were calculated through survey based data on energy consumption/generation patterns and subsequently transformed into GHG equivalents through standardized conversion parameters. Emission reductions were expressed only in one case (Sabbaghi and others, 2018) in terms of issued Certified Emission Reduction (CER). Energy efficiency measurement was the second most frequent outcome variable in this segment of the literature (seven articles), commonly expressed in energy/fuel unit per time unit. Energy expenditure, expressed in monetary terms and fuel substitution ratios were also commonly used outcome variables in the literature. In terms of co-impacts, several articles, particularly in the energy sector, included several welfare and economic measurements as outcome variables. These include crop productivity (Laramee and Davis, 2013; Kelebe, 2018), time savings, study time and safety (IOB, 2013), luminosity of economic development (Corral and others, 2018) and other multiple welfare measurements (Samad and others, 2013; Wang and others, 2011).

In general terms, all 19 articles found significant and positive effects of their respective interventions. The magnitude of the effects and potential contribution to global GHG accumulation is highly dependent on the nature and scale of the intervention. According to Table 5, these initiatives varied from community-driven activities (Laramee and Davis, 2013; Laramee and others, 2018) to worldwide cross-country evidence (Fang and Miller, 2012; Fang and others, 2012). Direct quantifications of GHG emission reductions, expressed in CO_2 equivalents, were provided in at least five articles. In contrast, in other cases, the effects were expressed in percentage reductions of energy and fuel consumption when comparing adopter and non-adopter groups. In other cases, particularly in non-experimental or quasi-experimental designs, the effects were expressed in terms of significant correlations between intervention and outcome variables, without an explicit quantification of energy of GHG reductions. Some particular cases worth mentioning: Corral and others (2018) found that safeguards and environmental mitigation measures applied to a large hydrocarbon project in Peru resulted in unaltered green cover in the affected area. Fang and Miller (2012) found that energy service companies significantly reduced CO_2 emissions; however, the magnitude of the decrease was not large relative to the effects of population, economic development and energy use.

Finally, for most of the outcomes related to the co-impacts of the interventions, the literature also found significant positive effects. These include crop productivity premia (Kelebe, 2018), time savings (IOB, 2013; Laramee and Davis, 2013) or lower incidence of respiratory diseases (IOB, 2013).

b. Forestry, agriculture and livestock

Outcome variables in the agricultural and forestry sectors were mostly expressed in terms of CO_2 reductions, relative to either surface measures (normally expressed in hectares) or to fixed quantities of crop outputs (e.g. per kg of grain). The emission estimations were performed through different methods. In some studies, household/farm surveys were used to collect primary data on inputs, cropping methods and yield outputs, and then converted into CO_2 equivalents through conversion parameters (Pokhrel and Soni, 2017; Singh and others, 2016). Direct sampling and analysis of land plots were utilized in some other cases (Mekuria and others, 2015; Reppin and others, 2020), whereas in other studies more complex approaches, using LCA approach, were applied to inventory emissions (Tran and others, 2018; Shimon and others, 2016). Most of the outcome results were expressed as net emissions savings, compared to a control group. Although in some other cases, the outcome was expressed in terms of total sequestered CO_2. Remote sensing for monitoring changes in land-use and forest cover was also used in studies related to forestry and the land management sector to construct the corresponding outcome variables (Sills and others, 2008; Blankespoor and others, 2014).

The most commonly investigated co-impact in this segment of the literature was change in crop productivity, which was included as an outcome variable in five of the seven articles in the agricultural sector. Some studies also addressed different measurements of land improvement and biodiversity as the target variable (Brandt and others, 2018; Mekuria and others, 2015).

The results of agricultural studies generally showed significant reductions in GHG emissions attributable to the implementation of the corresponding interventions. As seen in the previous sections, these include different cropping and rotation systems, sustainable husbandry practices and agroforestry measures associated with reductions in GHG emissions. Given the heterogeneity of outcome measurements (some of them expressed in correlational terms), direct comparisons across studies are nearly impossible to establish, except in the three cases in which outcomes were expressed in terms of $C0_2$ kg per hectare. The only study that described partial success of the intervention (agroforestry) is Reppin and others (2020), where aboveground carbon was associated with farm tree size but not to the species and land-use diversity. All three papers found significant effects in the interventions regarding forest cover, carbon sequestration and other outcome variables in the forestry sector. Only in Blankespoor and others (2014) were the results partially successful since the main intervention (establishment of national parks) was significantly associated with forest protection only in the Asia/Pacific region.

c. Buildings, transport and urban planning

All three articles found a positive relationship between the corresponding interventions and the outcome variables in the transport sector. In Acciaro and McKinnon (2015), fleet renewal (captured through several ship characteristics) was a significant element in improving fuel efficiency. Cabo and others (2020) found evidence on the relationship between fleet idle capacity in the aviation industry and different fuel efficiency measures. In contrast, the adoption of flex-fuel technology in the car industry was positively associated with GHG emissions reductions in Brazil (Laramee and others, 2018).

Table 6. Outcome of systematized fields

STUDY	OUTCOME (DESCRIPTION)	UNITS OF MEASUREMENT	OUTCOME QUANTIFICATION/CONCLUSIONS	TIME BETWEEN INTERVENTION AND MEASUREMENT
ENERGY				
Chun and Jiang, 2013	Energy efficiency	Watts/day; Watts/hour	Increases in energy efficiency with compact fluorescent light bulbs are reduced by as much as 34%.	Months
Laramee and Davis, 2013	GHG reduction; energy expenditure; fuel substitution; social benefits and crop productivity	(i) monetary terms, (ii) kg fuel/ year, (iii) kg CO_2 emissions	Compared to non-adopters, per year, adopters: (i) use 93% less firewood (5376 kg/year) and 98% less kerosene (48 L/year); (ii) spent on average USD 249 less per year on energy; (iii) spent an avg. of 1.4 fewer person-hours per day on energy procurement; (iv) generate on avg. 5203 kg less CO_2 per year per household and an avg. of 5825 kg CO_2 emissions are captured per year per sample	Between 2 and 16 years
Sabbaghi and others, 2018	GHG reduction	CER issuance	Positive correlation between investment scale and ex-post issuance of CER credits on the basis of power generation, after controlling for the economic scale and duration of the projects	Between five and 10 years
Somanathan and Bluffstone, 2015	Fuel substitution; GHG reduction	kg of firewood collected; t CO_2eq/kg of wood	1.1 tonnes of firewood reduction per year/household-1.6 tonnes of CO_2 eq per household per year	Unspecified
Van Groenendaal and Gehua, 2010	GHG reduction and energy efficiency	Standard Chinese coal equivalent (kgce)	The overall difference in primary energy use between non-users and users is 230.2 kgce	20 years
Bensch and Peters, 2011	Energy efficiency	(i) % of fuelwood savings per dish; (ii) % of total fuelwood savings/year	Charcoal consumption is 25% lower in improved cooking stoves than in traditional stoves (40% for lunch meals; in total, the savings rate at the national level amounts to around 1.2% - 1.4% (6.1% - 6.9% in the region of study)	Between less than one and three years
Corral and others, 2018	Forest cover change; improved livelihood	% of luminosity; % of change in forest cover	(i) Positive impact on local economic growth as measured by an annual gap of 27.9% in luminosity, or approximately 7.5% in local gross domestic product	Seven years

Study	Outcome (description)	Units of measurement	Outcome quantification/conclusions	Time between intervention and measurement
			between Cusco and its synthetic counterpart after 2004; (ii) no significant change in forest cover during the post-treatment period	
IOB, 2013	Energy efficiency (generation); Energy expenditure (domestic); welfare effects; GHG	SAVINGS, INCOME: € and %; HEALTH: CO and PM2.5 levels; TIME SAVINGS, STUDY TIME: hours, school performance; WELFARE: usage time (electricity), feeling of safety; MITIGATION: fuel and firewood savings (%), GHG emissions	Included studies reported savings of fuelwood, GHG reduction, as well as health, economic and social impacts (lower incidence of respiratory diseases, fuel savings, energy efficiency, time savings)	Not applicable
Samad and others, 2013	Fuel substitution; welfare effects	Duration of SHS use (years), kerosene consumption (litres/month), energy consumption (kWh/month) and multiple welfare co-benefits (health, etc.)	Adopters have lower consumption of kerosene (less than 1 litre per month versus almost 3 litres in non-adopter households). The overall consumption of energy does not differ significantly	Unclear
Wang and others, 2011	Fuel substitution; welfare effects	Litres of kerosene converted into kg of Co_2/year	2.2 litres of kerosene/month. 86Kg of CO_2 /year per purchased SHS	Four years
Fang and Miller, 2012	GHG reduction	kiloton CO_2 emissions	Energy service companies significantly reduce CO_2 emissions. The magnitude of the decrease proves important, although not large relative to the effects of population, economic development and energy use	27 years
Fang and others, 2012	Energy expenditure	kiloton of oil equivalent	Energy service companies significantly reduce energy use and the effect increases over time with the long-run effect exceeding 20%	28 years
INDUSTRY				
Sarwar, 2019	GHG reduction	Unspecified	Significant negative correlation between investment in treatment plants and CO_2 emissions	Unspecified
Teng and others, 2019	GHG reduction and energy efficiency	(i) trillion cubic metres (total emissions); (ii) tonnes of standard	The level of treatment intensity of key regions is higher than that of non-key regions, which generally leads to better performance of emission reduction	Not applicable

Study	Outcome (description)	Units of measurement	Outcome quantification/conclusions	Time between intervention and measurement
		coal equivalent (energy consumption)		
Grimm and Peters, 2015	Energy efficiency (industrial)	kg of firewood/litre of beer; CFA/litre of beer (CFA= local currency)	0.175 kg of firewood savings per litre of beer or 8.82 CFA F (local currency). As the average brewing is 240 kg, that means 42.3 kg per brewing or 2,117 CFA F (price of wood: 50 CFA F/kg)	Two years
Ryan, 2017	Energy efficiency (industrial); plant productivity	Expenditure in labour, capital and materials, and investment: USD; Electricity demand: MWh; Employment: number of hired workers and pay; Physical efficiency: index	The effect on monthly electricity demand is estimated to be negative 1,952 kWh (standard error 2,409 kWh), on an average monthly consumption of 56,716 kWh in the control	One year
WASTE MANAGEMENT				
Hou and others, 2017	GHG reduction	kg CO_2eq	Biogas systems increased farm household GHG emissions by 2668 kg·CO_2-eq·year−1 in northern China, but reduced farm household GHG emissions by 6336 kg·CO_2-eq·year−1 in southern China	Five years
Kelebe, 2018	Energy expenditure; waste recycling and crop productivity	(i) % reduction in energy expenditure; (ii) quintal/year/household; (iii) rate of substitution of fertilizers	(i) 20-26% in energy expenditure reduction; (ii) crop yield premium of 1.5 quintal/year/household	At least six months from construction completion to survey uptake
Laramee and others, 2018	Wastewater treatment efficiency, GHG reduction, fuel substitution	(i) kg CO_2eq; (ii) chemical oxygen demand (mg/L); (iii) fecal indicator bacteria (CFU/100 mL)	Reduction in annual emissions by 45-141 kg CO_2eq per inhabitant, representing a reduction of 4%-13% of the total estimated emissions produced per capita in Zambia	Between three and seven years
TRANSPORT				
Acciaro and McKinnon, 2015	GHG reduction and energy efficiency	Fuel kg/km	83% of the variability in heavy fuel oil (HFO) consumption per km and 57% of that per TEU/km are explained by speed, vessel size, vessel age, ownership and trade route	Various time frames

Study	Outcome (description)	Units of measurement	Outcome quantification/conclusions	Time between intervention and measurement
Cabo and others, 2020	Energy efficiency; fuel productivity	Tonne-km transported per litre of fuel	The elasticity of idle capacity (-0.94) indicates a negative impact over fuel productivity; the elasticity of aircraft size (0.48) indicates a positive impact	One year
Santos and others, 2018	GHG reduction	t CO_2eq	Negative correlation between the adoption of flex-fuel technology and GHG emissions; GHG emissions from ethanol combustion processing outweighed by their sequestration during sugarcane growth in rural areas	Ten years
AGRICULTURE AND LIVESTOCK				
Brandt and others, 2018	Forest cover, land improvement and biodiversity	% of forest disturbance	Higher on-farm cattle stocking and firewood collection were associated with 1%-10% reduced risk of forest disturbance. Higher milk yields, increased supplementation and more farm area allocated to fodder production were associated with 1%-7% reduced risk of forest disturbance	Not defined
Pokhrel and Soni, 2017	GHG reduction; crop productivity	GHG emissions: kg CO_2eq/ha. Energy analysis: MJ/kg and GJ/kg Yield: kg/ha	Lowest emissions achieved in the Rice Lentil-Mung bean system with 1109.1 ± 71.75 kg CO_2eq/ha	Measurements performed on working farms
Reppin and others, 2020	CO_2 sequestration; improved livelihood	Mg C/ha.	Farm C stocks significantly associated with farm size ($r = 0.453$), tree density ($r = -0.58$) and the average size of trees on-farm ($r = -0.42$), but not by the Shannon diversity index ($r = 0.36$), species richness ($r = -0.044$) or the number of land-use categories ($r = -0.192$).	Measurements performed on working farms
Singh and others, 2016	GHG reduction and energy efficiency; crop productivity	Kg CO_2eq/Kg grain	Maize-tomato crop rotation yielded 3 to 5 lesser carbon footprint than other crop rotations (0.019 Kg CO_2 eq./Kg grain)	At least five years
Tran and others, 2018	GHG reduction; crop productivity	t CO_2eq/ha/year	Net carbon capture from 70 to 90 t CO_2eq per ha and per year (conventional tea) and from 73 to 92 t CO_2eq per ha and per year (mini-terracing)	Not applicable
Gathorne-Hardy and others, 2013	GHG reduction and energy efficiency; crop productivity	kg CO_2eq/ha; kg CO_2eq/kg paddy	The emission savings are over 25%: 13,981 to 10,232 kg CO_2eq/ha from the control and system of rice intensification (SRI) fields, respectively ($p < 0.01$)	One year

Study	Outcome (description)	Units of measurement	Outcome quantification/conclusions	Time between intervention and measurement
Shimon and others, 2016	GHG reduction; crop productivity	t CO_2eq per farm	Complying farms had higher eco-efficiency (by 7%) compared to non-complying farms as a result of lower global warming potential intensities (by 7%) and a higher net farm income	Unclear
FOREST AND LAND MANAGEMENT				
Mekuria and others, 2015	Land improvement and biodiversity; CO_2 sequestration	Biodiversity: Sorensen's similarity index, Shannon-Wiener indexes of diversity and evenness. Aboveground biomass and C sequestration and storage: t C/ha. Net present value of revenues generated by storage: USD/ha	Significant differences in species diversity and considerable increases in aboveground carbon (ranged from 0.6 to 4.2 t C/ha), CO_2 storage (varied between 2.1 and 15.3 t CO_2/ha), woody species composition, and richness (ranged from 5 to 28) following the establishment of exclosures	Between one and seven years
Blankespoor and others, 2014	Forest cover change	Deforestation rate 10 km outside the park/deforestation rate 10 km inside the park (boundary zones)	Results expressed in terms of correlations. Positive, highly significant effect for park establishment only in Asia/Pacific	Yearly
Sills and others, 2008	Forest cover change	Ha of forest cover	10% increase of forest cover	Eight years

3. STUDY DESIGN

This section describes in detail the main elements of the methodological approach and estimation techniques used in the literature. It also provides an overview of the limitations and biases of the studies as described by the authors themselves. The same sector structure as in previous sections has been used to organize the results.

a. Energy, industry and waste management

Methodological approaches in this segment of the literature are diverse (Table 7). Out of the 19 selected articles, 10 used a causal approach in the estimation of the interventions´ effects. Among them, propensity score matching (PSM) was the most frequent estimation method. It was used in two energy related studies (Samad and others, 2013; Wang and others, 2011): one in the industrial sector (Grimm and Peters, 2015) and one in the waste management sector (Kelebe, 2018). The second most used causal approach, generalized method of moments (GMM), belongs to a branch of instrumental variable techniques designed to deal with potential endogeneity bias. In this instance, the bias was due to omitted variables in which exogenous variables are interdependent and jointly determined. Two variants of this approach were applied in the literature: difference GMM estimator (Fang and Miller, 2012; Fang and others, 2012) and system GMM (Sarwar, 2019). Other common approaches in impact evaluation are present in the literature, such as the use of difference-in-difference estimates (Grimm and Peters, 2015), synthetic control method (Corral and others, 2018) or one instrumental variable approach (Chun and Jiang, 2013). A randomized control trial is used in one study (Ryan, 2017). The lack of purely experimental approaches in our framework can be explained by applying the interventions under real life market conditions, according to our inclusion/exclusion criteria for the EGM. However, in this particular case, although the primary intervention is applied in an experimental setting (the provision of energy efficiency consulting services), the subsequent investments carried out by the recipient companies and their effects in terms of CCM are deployed under market conditions.

Among non-causal studies, the most frequent approach is ordinary least squares (OLS) regressions, applied in five different articles. However, in some cases, this approach was combined with other estimation methods, including causal ones (Wang and others, 2011; Grimm and Peters, 2015). Other authors opted for simple difference of means tests between adopter and non-adopter groups (Laramee and Davis, 2013; Van Groenendaal and Gehua, 2010; Laramee and others, 2018). In these cases, the evidence was not subject to formal causality tests. Thus, the possibility of omitted variable bias and unobserved differences between the comparison groups is expected to be significant. Some authors acknowledged these limitations in the body of their research (Laramee and Davis, 2013; Somanathan and Bluffstone, 2015; Bensch and Peters, 2011), and in some cases the potential bias was partially addressed through the inclusion of control variables.

The most common comparison unit across the study was the household, used in 10 of the 19 articles. Three other papers (Corral and others, 2018; Sarwar, 2019; Teng and others, 2019) used subnational geographical units as their comparison level, whereas two others (Fang and Miller, 2012; Fang and others, 2012) are cross-country studies. The comparison was performed across productive units, including industrial, wind farms and breweries only in three cases (Ryan, 2017; Grimm and Peters, 2015; Sabbaghi and others, 2018). A large majority of studies in these sectors used a cross section design, with the presence of a time series approach in one paper (Sabbaghi and others, 2018). Five cases used panel data.

b. Forestry, agriculture and livestock

Causal designs are less frequent in the agricultural and forestry sectors. Only three out of 10 papers made use of at least one causal approach, including the following: generalized linear mixed model (GLMM), including random and fixed effects (Brandt and others, 2018), PSM (Sills and others, 2008) and panel estimates by random effects and by fixed effects (Blankespoor and others, 2014). The remaining studies utilized standard correlational approaches such as OLS, or a difference of means test or an analysis of variance (ANOVA) across three or more groups. In some cases, these were combined with specific geographical estimation methods, such as allometric equations (Reppin and others, 2020) and geographical pre-matching (Sills and others, 2008). Although not considered an IE method, life cycle analysis is also present in the literature (Shimon and others, 2016; Tran and others, 2018; Gathorne-Hardy and others, 2013). LCA is a technique to assess the environmental aspects associated with a product or process over its life cycle, which in our framework is applied to inventory GHG in all the stages of a particular intervention. The exact estimation methods used to calculate emissions vary depending on the activity to be assessed. However, it normally relies on modelling assumptions and parameters that may challenge its appropriateness as a tool to obtain ex-post evidence. However, the LCA studies that met our inclusion criteria were selected because they were mostly reliant on post-intervention survey based data, or were used as a quantification technique in the framework of a broader methodological approach for IE. The lack of a counterfactual approach as a weakness in the study design was highlighted in the literature only in one case (Blankespoor and others, 2014). Other limitations acknowledged in other articles include uncertainties in variable construction, heterogeneity bias or the limited number of observations.

Comparison units in the agricultural and forestry studies were mostly farms, land plots or forest protected areas, which were assessed mostly in the framework of a cross-sectional design. The only exception was found in Blankespoor and others (2014), where panel data analysis was used.

c. Buildings, transport and urban planning

Out of the three articles identified in the transport sector, only one (Acciaro and McKinnon, 2015) did not adopt a methodological approach to control for endogeneity issues, solely relying on OLS correlational evidence. The other two articles used more advanced econometric techniques. Firstly, two stage least squares panel data with an instrumental variable (Cabo and others, 2020). And, secondly, full parametric and semiparametric estimations with fixed effects in panel data (Santos and others, 2018). With regard to limitations highlighted by the respective authors, Acciaro and McKinnon (2015) acknowledged possible non-linearities in their model formulations, whereas Santos and others (2018) pointed towards the possibility of omitted variable bias.

Table 7. Study type of systematized fields

Study	Estimation methods	Causality test used (if applicable)	Comparison units	Level of comparison	Number of observations	Bias (identified by author)
ENERGY						
Chun and Jiang, 2013	Uptake: probit model; Rebound effect: instrumental variables regression model	(i) adoption: maximum likelihood estimators; (ii) instrumental variable	Households	Cross section	3253	Recall bias; limited time frame
Laramee and Davis, 2013	Test of mean differences	None	Households	Cross section	20 (treated), 20 (control)	Limited sample; self-selection of treatment group; cross-sectional design
Sabbaghi and others, 2018	OLS applied in cross section and time series	None	Wind farms	Cross section and time series	14	
Somanathan and Bluffstone, 2015	OLS	(i) control for household-specific characteristics; (ii) methods to bound the omitted variable bias	Households	Cross section	4821 (model 1) and 2432 (model 2)	Omitted variable bias; sampling error
Van Groenendaal and Gehua, 2010	ANOVA (independent samples t-test)	Differences between the two groups are tested using five variables	Households	Cross section	239	
Bensch and Peters, 2011	OLS	None	Households	Cross section	624	Hawthorne effect; results depend on specific usage of the intervention; potential adjustments after the intervention; potential losses of positive effects due to lack of familiarity with the new stoves; heterogeneity of households; potential differences between treatment and non-treatment groups; dishes cooked might depend on which stove is used

Study	Estimation methods	Causality test used (if applicable)	Comparison units	Level of comparison	Number of observations	Bias (identified by author)
Corral and others, 2018	Synthetic control method (Abadie and Gardeazabal, 2003)	Synthetic control method	Districts within the Cusco region	Panel data	22	Possible noisy estimates (only one treatment unit and few comparison units)
IOB, 2013	Diverse methodologies (systematic review)	SR of difference approaches (randomized control trials, difference-in-differences, etc.)	Multiple	Cross section, panel data, etc.	Not applicable	Selection bias, self-reporting bias (recall and "courtesy bias")
Samad and others, 2013	Uptake: probit model; Welfare effects: Weighted (PSM) regression	PSM	Households	Cross section	1600(treatment), 2400 (control)	Selection bias
Wang and others, 2011	OLS and PSM	Matching	Households	Cross section	20914	Possible endogeneity bias
Fang and Miller, 2012	Difference GMM estimator	The Arellano-Bond (GMM) method	Countries	Panel Data	2936	
Fang and others, 2012	Difference GMM estimator	The Arellano-Bond (GMM) method	Countries	Panel Data	2937	
INDUSTRY						
Sarwar, 2019	System	The Arellano-Bond (GMM) method	Provinces	Panel data	330	
Teng and others, 2019	Non-radial directional distance function in the framework of the meta-frontier model	Not applicable	Provinces	Panel data	150	
Grimm and Peters, 2015	Uptake: probit model. Impact: OLS, PSM; difference-in-differences	Matching	Breweries	Cross section	236 (cross section); 66 (diff-in-diff)	Recall bias; unobserved characteristics that might influence adoption; possible self-selection bias/reverse causality
Ryan, 2017	Randomized control trial	Randomized control trial	Industrial plants	Cross section	435	Selection bias

Study	Estimation methods	Causality test used (if applicable)	Comparison units	Level of comparison	Number of observations	Bias (identified by author)
WASTE MANAGEMENT						
Hou and others, 2017	Consequential LCA, "cradle to grave"	Not applicable	Rural Household Biogas Systems	Cross section	95 (treated) 303 (control)	No proper counterfactual
Kelebe, 2018	PSM	(i) Regression (propensity), (ii) matching methods - ATT	Households	Cross section	200 (treated), 200 (control)	Self-selection bias (partially offset by PSM method)
Laramee and others, 2018	Cross section. T-test: 2-tailed test of means for households with versus without biogas	None	Households	Cross section	24 (treated); 96 (control)	Limited sample; limited timeframe, cross-sectional design; differences between treated and control groups
TRANSPORT						
Acciaro and McKinnon, 2015	Multiple regression model (OLS)	None	Shipping carriers on determined trade routes	Cross section	2291	Possible non-linearities
Cabo and others, 2020	2-stage least squares panel data with an instrumental variable	Statistical tests for fixed/random effects; Instrumental variable (endogeneity test)	Flight routes	Cross section	988	
Santos and others, 2018	Full parametric and semiparametric estimations; Fixed effects	None	States	Panel data	432	Estimation of variable of interest at aggregated level (omitted variable bias)
AGRICULTURE AND LIVESTOCK						
Brandt and others, 2018	(Binomial and Poisson) GLMM, including random and fixed effects	GLMM+Relative risk measure (Akobeng, 2015)	Farms and circular land samples	Cross section	216	Uncertainties in variable construction
Pokhrel and Soni, 2017	Mean differences: Tukey's honest significant difference	None	Farms	Cross section	210	

Study	Estimation methods	Causality test used (if applicable)	Comparison units	Level of comparison	Number of observations	Bias (identified by author)
	tests at probability level 0.05, in the context of Data Envelopment Analysis model					
Reppin and others, 2020	Allometric equations (biomass estimation); Correlation analysis; Multiple linear regression analysis; Associations (Kruskal–Walis, Mann–Whitney and Chi square) and ANOVA	None	Farms	Cross section	26	
Singh and others, 2016	ANOVA; Duncan multiple range test	None	Farmers	Cross section	100	
Tran and others, 2018	LCA	Not applicable	Farms	Cross section	Not reported.	Limited data
Gathorne-Hardy and others, 2013	Streamlined LCA and difference of mean test	None	Farms	Cross section	20 (treatment), 10 (control)	Evaluation of SRI practices not under strict controlled conditions
Shimon and others, 2016	Linear programming; LCA; OLS	Not applicable	Farms	Cross section	616	
FOREST AND LAND MANAGEMENT						
Mekuria and others, 2015	Tests for normality (Kolmogorov-Smirnov D statistic) and equality of variance (Levene statistic) of the variables tested; ANOVA	None	Communal Grazing Land; Land Exclosures	Cross section	6 (exclosures); 1 (grazing land)	Heterogeneity bias; possible negative effect of the intervention on the grazing land
Blankespoor and others, 2014	Panel estimates by random effects and by fixed effects	Fixed effects model	Parks	Panel data	4,028 / 726	No counterfactual (heterogeneity); variable time frame between intervention and study in different sites
Sills and others, 2008	Geographic pre-matching and PSM	Matching	Land owners	Cross section	184	

D. CRITICAL APPRAISAL

This section provides an assessment of the methods and results of the studies. The information is presented according to the four criteria defined in the methodological section: a) relevance, b) internal validity, c) external validity and d) appropriateness.

1. RELEVANCE

Although all the selected articles were assessed against our inclusion/exclusion criteria, which in principle would guarantee the relevance of the research topic in general terms, some specific aspects can be further evaluated in order to provide a more nuanced diagnosis. Thus, out of the 32 articles, eight were classified as "intermediate" in terms of their relevance. The most critical aspect referred to the observed divergence in some cases between the terms of the research question and the general approach of the study. More precisely, some studies claimed to serve the purpose of identifying and measuring impacts attributable to a particular intervention, whereas the type of evidence provided by their methods can only be described as correlational relationships. While some correlational papers were consistent in this approach (i.e. defining their research question in terms of relationships instead of impacts), others seemed to fail to properly bind their research question to the limitations of their approach. These included Laramee and Davis (2013), Laramee and others (2018), Reppin and others (2020), Teng and others (2019) and Van Groenendaal and Gehua (2010).

Other issues were identified regarding the relevance of the outcome variable. For example, in Laramee and Davis (2013) CCM aspects were assessed as a co-benefit and not as the central research topic of the articles, which focused on other environmental and economic impacts of biodigesters. In Sills and others (2008) the outcome variable was considered to be relevant (green cover), but the study failed to explicitly mention the linkage to CCM mitigation or the associated ecosystem services (e.g. carbon sequestration). In Laramee and others (2018), the outcome variable was also generally relevant; however, some improvements could have been made in its measurement, particularly regarding the measurement of energy use in different parts of the year.

2. INTERNAL VALIDITY

The assessment of the internal validity of the studies shows mixed results. Out of the 32 articles, only 10 were rated as "high," 13 as "intermediate" and nine as "low." Among those rated as having low internal validity, the most critical issue referred to the absence of comparable control and treated groups. In some cases, this is due to the total absence of discernible groups in the context of LCA studies (Hou and others, 2017; Tran and others, 2018), or to the lack of comparability among them. Partial attempts to control for differences between both groups were included in some cases. Examples include (i) the cross-selection of a control group (i.e. treated individuals help identify similar individuals not receiving the intervention) (Laramee and Davis, 2013); (ii) the inclusion of control variables in regression models (Reppin and others, 2020; Shimon and others, 2016); and (iii) a specific test of difference for some observable variables (Van Groenendaal and Gehua, 2010). Other articles, however, performed direct tests of mean differences without the provision of any technique to guarantee comparability between groups (Singh and others, 2016; Laramee and others, 2018). For all these cases, the possibility of omitted variable bias should be considered as a serious limitation. Another aspect identified in the assessment referred to the number of observations analysed in the studies. Five of the nine papers rated as "low" were found to be possibly insufficient in comparison to the potential target population of the corresponding interventions (Laramee and Davis, 2013; Laramee and others, 2018; Singh and others, 2016; Van Groenendaal and Gehua, 2010; Gathorne-Hardy and others, 2013). In most of these articles, the evidence was estimated by a

single approach, without the provision of multiple model formulations, sensitivity analysis or multiple tests, which also contributed to the low scores in terms of internal validity.

Articles classified as "high" had several characteristics in common: (i) they provided robust comparisons between at least two well defined groups, applying techniques and tests for their comparability, (ii) they adopted approaches and used specific tests to isolate causal effects, (iii) they were based on a representative sample with a sufficient number of observations, and (iv) they provided multiple model specifications or statistical tests under different conditions.

By sector, the highest percentage of articles having a low-level of internal validity were found in the agriculture (five out of seven) and waste management sectors (two out of three). The industrial sector received the highest rates at the other end of the scale, with two articles classified as high and two as intermediate.

3. EXTERNAL VALIDITY

The external validity of the literature also received mixed results during the critical appraisal process, with only six articles classified under the "high" category, 18 as "intermediate" and eight as "low." One of the key issues in assessing external validity is whether the main findings and conclusions of the study can be generalized to a broader population than the one described in the study. In this regard, the lowest rating articles showed some study designs elements that impede their generalization. In some cases, aspects related to the specific policy context and the specific characteristics of the intervention (Laramee and Davis, 2013; Tran and others, 2018; Corral and others, 2018) were behind the low rating, whereas in others, the generalization of the results could be plausible, but only to some extent and under certain conditions. Thus, in Grimm and Peters (2015), the results could be generalized to other cities of the country with firms of similar characteristics. By comparison, in Shimon and others (2016), the results could be extended only to similar crops and similar self-regulatory contexts. In other cases, the limitations in external validity were rooted in methodological aspects, such as the sample design (Singh and others, 2016).

In general terms, it should be noted that most of the articles provided findings and conclusions that were bound to specific characteristics of the target population (for example, geography, socioeconomic conditions, climate conditions or policy context). However, the results' external validity may be high when the same or similar conditions are frequently found outside the scope of the studied population. That would be the case for some of the articles rated as "high" in this field, such as Samad and others (2013), whose findings could be potentially applied to other developing countries where solar energy is a feasible alternative in rural areas. In Blankespoor and others (2014), the results can be potentially generalized to other tropical forests, whereas the implications of Ryan (2017) could be generalized to similar industries in the South Asian context. Other articles rating high in terms of external validity include Acciaro and McKinnon (2015), IOB (2013) and Chun and Jiang (2013).

By sector, the highest concentration of low rating articles in terms of external validity were found in agriculture (four out of seven) and energy (3 out of 12).

4. APPROPRIATENESS

The appropriateness of data analysis and presentation (i.e. the extent to which authors provide transparent information of data-collection, variable definitions) generally received a favourable assessment. Only four articles were classified under the "low" category (Gathorne-Hardy and others, 2013; Hou and others, 2017; Sarwar, 2019; Samad and others, 2013). The most common deficiencies found in these articles refer to the poor (or total lack of) data-collection description and variable construction process, as well as the corresponding descriptive statistics tables.

Table 8. Critical appraisal of the reviewed literature

Study	Relevance	Internal validity	External validity	Appropriateness
ENERGY				
Chun and Jiang, 2013	High	High	High	High
Laramee and Davis, 2013	Intermediate	Low	Low	High
Sabbaghi and others, 2018	High	Intermediate	Intermediate	High
Somanathan and Bluffstone, 2015	High	Intermediate	Intermediate	High
Van Groenendaal and Gehua, 2010	Intermediate	Low	Low	Intermediate
Bensch and Peters, 2011	High	Intermediate	Intermediate	High
Corral and others, 2018	Intermediate	High	Low	Intermediate
IOB, 2013	High	Intermediate	High	Intermediate
Samad and others, 2013	High	High	High	Intermediate
Wang and others, 2011	High	High	Intermediate	Intermediate
Fang and Miller, 2012	High	Intermediate	Intermediate	High
Fang and others, 2012	High	Intermediate	Intermediate	High
INDUSTRY				
Sarwar, 2019	High	Intermediate	Intermediate	Low
Teng and others, 2019	Intermediate	Intermediate	Intermediate	High
Grimm and Peters, 2015	High	High	Low	High
Ryan, 2017	High	High	High	High
WASTE MANAGEMENT				
Hou and others, 2017	High	Low	Intermediate	Low
Kelebe, 2018	High	High	Intermediate	High
Laramee and others, 2018	Intermediate	Low	Intermediate	High
TRANSPORT				
Acciaro and McKinnon, 2015	Intermediate	Intermediate	High	High
Cabo and others, 2020	High	Intermediate	Intermediate	High
Santos and others, 2018	High	High	Intermediate	High
AGRICULTURE AND LIVESTOCK				
Brandt and others, 2018	High	High	Intermediate	High
Pokhrel and Soni, 2017	High	Intermediate	Low	Intermediate
Reppin and others, 2020	Intermediate	Low	Intermediate	Intermediate
Singh and others, 2016	High	Low	Low	High
Tran and others, 2018	High	Low	Low	Intermediate
Gathorne-Hardy and others, 2013	High	Low	Intermediate	Low
Shimon and others, 2016	High	Low	Low	Low

Study	Relevance	Internal validity	External validity	Appropriateness
FORESTRY AND LAND MANAGEMENT				
Mekuria and others, 2015	High	Intermediate	Intermediate	High
Blankespoor and others, 2014	High	Intermediate	High	High
Sills and others, 2008	Intermediate	High	Intermediate	High

E. Conclusions

Evidence on the effectiveness and efficiency of CCM interventions in the private sector is generally scarce and scattered across different sectors and interventions. Private investment at the household and farm level were the most frequent interventions. These include adopting alternative energy sources, such as biodigesters, efficient stoves and solar panels. They also include implementing sustainable agricultural practices, for example, agroforestry and innovative cropping systems. Such interventions were commonly assessed in terms of multiple outcomes and co-benefits, including adaptation. Corporate investments were more commonly found in the industrial and energy sectors, mostly in investments within the core business activity. They encompass the installation of GHG treatment equipment and efficient industrial stoves in productive plants, the application of environmental safeguards policies in large generation projects and hiring energy efficiency consulting services as a preliminary stage before further CCM-related investments. Corporate investment was also found in forest protection activities, as part of the core business activity of the investor (through direct involvement in park management) or as a financial investment in ecosystem services (through participation in payment schemes for forest protection). Another example of corporate financial investment outside the core business activity was found in the wind energy sector.

Private initiatives assessed in the literature are commonly embedded in the framework of public initiatives, although the role of the public sector varied significantly across sectors and interventions. In some cases, public intervention came in facilitating regulatory frameworks. In contrast, in others, the public sector was more actively engaged in co-financing or providing direct incentives to investors (e.g. tax policy), particularly in the energy and industrial sectors. The role of international donors as a facilitator and co-financer was also present in a few cases.

The evidence points almost unanimously towards positive CCM effects of the assessed interventions, including net GHG emission reductions, intermediate outcomes (such as green cover, energy efficiency or energy expenditure), as well as in terms of most of the co-impacts investigated. In this sense, no distinction can be made by sectors or outcomes. Nevertheless, it should be noted that the internal validity of some of the studies should be regarded with caution since the isolation of impacts directly attributable to the intervention was not properly addressed through causal approaches. Only nine out of the 32 studies were assessed as “high” in terms of internal validity. The same could be said about the potential extrapolation of the results to other contexts and populations since the majority of the studies were bound to particular demographic and geographical circumstances that limited their external validity.

In light of these results, it is recommended that further research initiatives are undertaken to assess the effectiveness of CCM interventions in the private sector, particularly those involving corporate investment. The IE culture, traditionally rooted in the public policy domain, still seems to be in the early stages of development in private sector investments in mitigation, particularly in the topics addressed here. The adoption of rigorous counterfactual approaches should be encouraged against

study designs limited to correlational relationships. This way, impact quantifications can be reliably estimated and used as additional evidence for potential investment returns (including cost-benefit analysis), hence promoting further engagement of the private sector in CCM interventions in developing countries. From a policy perspective, private initiatives in CCM are promising in terms of their effectiveness. However, efforts to promote and facilitate private initiatives must be coupled with further research initiatives to obtain ex-post type of evidence that may help guide investment decisions towards key interventions and sectors.

REFERENCES

References included in the SR

Acciaro, Michele, and Alan McKinnon (2015). Carbon Emissions from Container Shipping: an analysis of Empirical Evidence. *International Journal of Transport Economics* 42(2): 211-228.

Bensch, Gunther, and Jörg Peters (2011). Combating Deforestation? - Impacts of Improved Stove Dissemination on Charcoal Consumption in Urban Senegal. Verein für Socialpolitik, Research Committee Development Economics.

Blankespoor, Brian; Susmita Dasgupta, and David Wheeler (2014). Protected Areas and Deforestation: New Results from High Resolution Panel Data. Policy Research Working Paper, No. 7091. Washington DC.: World Bank.

Brandt, Patric, and others (2018). Sustainable Intensification of Dairy Production can Reduce Forest Disturbance in Kenyan Montane Forests. *Agriculture Ecosystems & Environment* 265: 307-319.

Cabo, Manoela, and others (2020). Energy Effectiveness of Jet Fuel Utilization in Brazilian Air Transport. *Sustainability* 12(1): 16.

Chun, Natalie, and Yi Jiang (2013). How Households in Pakistan Take on Energy Efficient Lighting Technology. *Energy Economics* 40: 277-284.

Corral, Leonardo R., Maja Schiling, and Césa Montiel (2018). The Economic and Ecological Impact of Natural Resource Extraction: The Case of the Camisea Gas Project in Peru. IDB Working Paper (IDB-WP-00934). Inter-American Development Bank.

Fang, WenShwo, and Stephen Miller (2012). The Effect of ESCOs on Carbon Dioxide Emissions. Working paper. University of Connecticut, Department of Economics.

Fang, WenShwo, Stephen Miller, and Chih-Chuan Yeh (2012). The Effect of ECSOs on Energy Use. Working paper. University of Connecticut, Department of Economics.

Gathorne-Hardy, Alfrd, and others (2013). A Life Cycle Assessment (LCA) of Greenhouse Gas Emissions from SRI and Flooded Rice Production in SE India. *Taiwan Water Conservancy Journal*, Special Issue on SRI.

Grimm, Michael, and Jörg Peters (2015). Beer, Wood, and Welfare. *Ruhr Economic Papers* (538). RWI - Leibniz-Institut für Wirtschaftsforschung, Ruhr-University Bochum, TU Dortmund University, University of Duisburg-Essen.

Hou, Jun, and others (2017). Greenhouse Gas Mitigation of Rural Household Biogas Systems in China: A Life Cycle Assessment. *Energies* 10(2): 14.

Kelebe, Haftu E. (2018). Returns, Setbacks, and Future Prospects of Bio-energy Promotion in Northern Ethiopia: The Case of Family-sized Biogas Energy. *Energy Sustainability and Society* 8: 14.

Laramee, Jeannette and Jennifer Davis (2013). Economic and Environmental Impacts of Domestic Bio-digesters: Evidence from Arusha, Tanzania. *Energy for Sustainable Development* 17(3): 296-304.

Laramee, Jeannette, Sebastien Tilmans, and Jennifer Davis (2018). Costs and Benefits of Biogas Recovery from Communal Anaerobic Digesters Treating Domestic Wastewater: Evidence from Peri-urban Zambia. *Journal of Environmental Management* 210: 23-35.

Mekuria, Wolde., and others (2015). Restoring Aboveground Carbon and Biodiversity: A Case Study from the Nile Basin, *Ethiopia. Forest Science and Technology* 11(2): 86-96.

Netherlands, Ministry of Foreign Affairs, Policy and Operations Evaluation Department (2013). *Renewable Energy: Access and Impact*. IOB Study (376).

Pokhrel, Anil, and Peeyush Soni (2017). Performance Analysis of Different Rice-based Cropping Systems in Tropical Region of Nepal. *Journal of Environmental Management* 197: 70-79.

Reppin, Saskia, and others (2020). Contribution of Agroforestry to Climate Change Mitigation and Livelihoods in Western Kenya. *Agroforestry Systems* 94(1): 203-220.

Ryan, Nick (2017). Is there an Energy-Efficiency Gap? Experimental Evidence from Indian Manufacturing Plants. PEDL Research Papers. Private Enterprise Development in Low-Income Countries (PEDL).

Sabbaghi, Omid, Jing Li, and Navid Sabbaghi (2018). Certified Emission Reduction Credits and the Role of Investments: Evidence from Wind CDM Projects in China. *International Journal of Energy Sector Management* 12(3): 386-407.

Samad, Hussain A., and others (2013). The Benefits of Solar Home Systems: An Analysis from Bangladesh. Policy Research Working Paper (6724). Washington DC.: World Bank.

Santos, Augusto Seabra, and others (2018). Flexible-fuel Automobiles and CO2 Emissions in Brazil: Parametric and Semiparametric Analysis Using Panel Data. Habitat International 71: 147-155.

Sarwar, Suleman (2019). Role of Urban Income, Industrial Carbon Treatment Plants and Forests to Control the Carbon Emission in China. *Environmental Science and Pollution Research* 26(16): 16652-16661.

Shimon, Otieno Peter, and others (2016). Does Global-GAP Policy Reduce Smallholder Greenhouse Gas Emissions from French Bean Production in Central and Eastern Regions of Kenya? Conference paper. African Association of Agricultural Economists (AAAE).

Sills, Erin, and others (2008). Impact of Costa Rica's Program of Payments for Environmental Services on Land Use. Payments for Environmental Services (PES) learning paper. Washington DC.: World Bank.

Singh, Raman J., and others (2016). Economics, Energy, and Environmental Assessment of Diversified Crop Rotations in Sub-Himalayas of India. *Environmental Monitoring and Assessment* 188(2):1-13.

Somanathan, E. and Randall Bluffstone (2015). Biogas: Clean Energy Access with Low-Cost Mitigation of Climate Change. *Environmental and Resource Economics* 62(2):265-277.

Teng, Xiangyu, Danting Lu and Yung-ho Chiu (2019). Emission Reduction and Energy Performance Improvement with Different Regional Treatment Intensity in China. *Energies* 12(2):18.

Tran, Tuong The, Aslihan Arslan, Giacomo Branca and Mai Van Trinh (2018). Bio-Economic Assessment of Climate-Smart Tea Production in the Northern Mountainous Region of Vietnam. Asian Journal of Agriculture and Development 15 (2): 1-20.

Van Groenendaal, Willem, and Wang Gehua (2010). Microanalysis of the Benefits of China's Family-size Bio-digester. Energy 35(11): 4457-4466.

Wang, Limin, and others (2011). Quantifying Carbon and Distributional Benefits of Solar Home System Programs in Bangladesh. Policy Research Working Paper (5545). Washington DC.: World Bank.

Other references

Bertzky, Monika, and others (2020). *Climate change mitigation interventions in the private sector in developing countries*. Approach paper for an evidence gap map. Songdo, South Korea: Independent Evaluation Unit, Green Climate Fund. Available at: *https://ieu.greenclimate.fund/sites/default/files/page/201104-evidence-review-psim-approach-paper-top.pdf*

Bindoff, Nathaniel L., and others (2013). Detection and Attribution of Climate Change: From Global to Regional. In *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Stocker, T.F., Qin, D., Plattner, G.K., Tignor, M., Allen, S.K., Boschung, J., Nauels, A., Xia, Y., Bex, V. and Midgley, P.M. (eds.), pp. 867–952. Cambridge, United Kingdom: Cambridge University Press; New York, USA. doi:10.1017/CBO9781107415324.022.

Collaboration for Environmental Evidence. (2013). Guidelines for Systematic Review and Evidence Synthesis in Environmental Management. Version 4.2. Environmental Evidence. Available at *www.environmentalevidence.org/Documents/Guidelines/Guidelines4.2.pdf*.

Davies, Philip T. (2004). Is evidence-based government possible? Jerry Lee lecture to the 4th Annual Campbell Collaboration Colloquium, Washington, D.C., 19 February.

Doswald, Nathalie, and others (2014). Effectiveness of ecosystem-based approaches for adaptation: review of the evidence-base. *Climate and Development*, 6, 185-201.

Doswald, Nathalie, and others (2021). Evidence Gap and Intervention Heat Map of Climate Change Mitigation Interventions in the Private Sector in Developing Countries. IEU learning paper (July). Songdo, South Korea: Independent Evaluation Unit, Green Climate Fund.

Gupta Sujata, and others (2014). Cross-cutting investment and finance issues. In *Climate Change 2014: Mitigation of Climate Change*. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J. C. Minx (eds.)]. Cambridge, United Kingdom, Cambridge University Press; New York, USA.

Independent Evaluation Unit (2019). *Forward-Looking Performance Review of the Green Climate Fund*. Evaluation Report No. 3 (2nd ed.) (June). Songdo, South Korea: Independent Evaluation Unit, Green Climate Fund.

Intergovernmental Panel on Climate Change (2013). *Climate Change 2013: The Physical Science Basis*. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., Qin, D., Plattner, G.K., Tignor, M., Allen, S.K., Boschung, J., Nauels, A., Xia, Y., Bex, V. & Midgley, P.M. (eds.)], pp. 1535. Cambridge, United Kingdom: Cambridge University Press; New York, USA.

Intergovernmental Panel on Climate Change (2014). *Climate Change 2014: Mitigation of Climate Change*. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, United Kingdom: Cambridge University Press; New York, USA.

Intergovernmental Panel on Climate Change (2018). Summary for Policymakers. In *Global Warming of 1.5°C.* An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., Zhai, P., Pörtner, H.O., Roberts, D., Skea, J., Shukla, P.R., Pirani A., Moufouma-Okia, W., Péan, C., Pidcock, R., Connors, S., Matthews, J.B.R., Chen, Y., Zhou, X., Gomis, M.I., Lonnoy, E., Maycock, T., Tignor, M., and Waterfield, T. (eds.)], pp. 32. Geneva, Switzerland: World Meteorological Organization.

International Finance Corporation (2016). Climate investment opportunities in emerging markets. An IFC analysis. Washington DC.

Petticrew, M. and H. Roberts (2006). *Systematic reviews in the social sciences: A practical guide*. Blackwell Pub.

Prowse, Martin, and Birte Snielsveit (2010). Impact evaluation and interventions to address climate change: a scoping study. *Journal of Development Effectiveness*, 2(2), 228-262. *https://doi.org/10.1080/19439341003786729*.

Raitzer, David A., Nina Blöndal, and Jasmin Sibal (2019a). *Impact evaluation of transport interventions: A review of the evidence*. Manila: Asian Development Bank.

Sackett, David L. (1979). Bias in analytic research. *Journal of Chronic Diseases* 1979, 32(1-2): 51–63.

Saran, Ashrita, and Howard White (2018). Evidence and gap maps: a comparison of different approaches. *Campbell Systematic Reviews*, 14, 1-38.

United Nations Framework Convention on Climate Change (2015). *Paris Agreement*.

World Wide Fund for Nature (2018). Financial instruments used by governments for climate change mitigation. WWF policy brief. *https://dtnac4dfluyw8.cloudfront.net/downloads/wwf_2018_financial_instruments_used_by_governments_for_climate_change_mitigation.pdf*

APPENDICES

Appendix 1. Inclusion/Exclusion criteria

Inclusion criteria	Illustrative examples of included items	Exclusion criteria
1. POPULATION		
Private sector (households, private enterprises and companies) in low and middle-income countries as defined by the World Bank, who: • Hold full ownership of the main intervention assets, or • Hold ownership of the main intervention assets in the context of Public-Private arrangements, or • Provide financial intermediation in the form of equity	• Small- and medium-sized enterprises installing solar roofing in their facilities • Private office buildings installing insulation measures • Households investing in home solar generation equipment • Private and public banks taking part in an Infrastructure Equity Fund for the financing of a large wind energy project	• No private sector involved in the ownership of the intervention assets • Assets entirely owned by the public sector, even with the participation of private financial intermediation • Anecdotal participation of the private sector in mixed ownership structures • No description of the financial structure is provided • High income countries
2. INTERVENTION		
• CCM interventions: – Aimed at reducing energy consumption, decreasing GHG in the atmosphere or from being released in the atmosphere – Implemented through the purchase, replication or improvement of assets or items with the expectation that they will generate income or appreciate • Multifaceted interventions in which physical assets and regulatory components are combined • Pilot studies of innovations performed in real life context and/or market conditions • Interventions with both adaptation and mitigation outcomes	• Sustainable agriculture programme, for the improvement of soil management techniques for better adaptation and GHG soil capture • Pilot programme by a private social investor consisting in the provision of credit lines for small and medium enterprises (SME) for the acquisition of energy recovery equipment in small scale industrial processes • Institutional Public-Private Forest Fund to promote private investments in forest conservation in the context of REDD+	• Non-mitigation interventions. No mention of mitigation, energy-saving or emissions reduction or other mitigation or intervention search terms • Mitigation measure not implemented through an asset (e.g. consumption goods, grants, donations, subsidies) • Experimental settings in which the intervention assets are not distributed under usual market conditions • Financial instruments aimed at de-risking investments in CCM interventions (guarantees, insurance, etc.) • Investments into nuclear energy generation projects
3. COMPARATOR		
• Comparisons with a no-mitigation intervention scenario	• Comparison of insulated buildings and non-insulated ones	• No measure of success of the mitigation intervention is presented and

INCLUSION CRITERIA	ILLUSTRATIVE EXAMPLES OF INCLUDED ITEMS	EXCLUSION CRITERIA
• Different levels of intervention and comparisons between interventions • Time observation studies	• Comparison of land plot GHG capture by the level of tillage • Time series analysis of city GHG inventory	• compared with no-mitigation intervention or different levels of intervention
4. OUTCOME		
• Direct measurement of GHG reduction (avoided emissions, capture and storage, sequestration) • Outcomes that can potentially have a translation into GHG savings including: – Changes in energy consumption and generation patterns – Behavioural change (transportation, appliance use, consumption, etc. • Outcomes that capture positive and negative co-impacts (environmental, social, health and financial)	• Tonnes of yearly CO_2 emissions avoided through energy recovery equipment installed in manufacturing facilities • Increase in the number of yearly kms run by bicycle due to the construction of biking tracks in cities • Changes in respiratory disease prevalence ratios due to the implementation of clean production technologies in industrial districts	• No measure of effectiveness or efficiency of the mitigation intervention is presented • Studies addressing co-impacts exclusively • Cost-effectiveness studies
5. STUDY		
Quantitative or mixed-methods studies published as peer-review articles or as grey literature (documents published by organizations), including the following methodological approaches: • IE approach, which assesses the impact of an intervention using counterfactual analysis (experimental and quasi-experimental approaches) • Correlation analyses (e.g. using cross-sectional data, panel data or time series) • Systematic reviews of quantitative evidence studies	• Study combining a difference-in-difference approach and qualitative research to assess energy savings effects • Binary regression to assess the probability of behavioural change in the use of sustainable transport • Systematic review of the empirical evidence of GHG emission reduction in building renovation programmes	• Process-based evaluation reports (i.e. evaluation reports based on milestone indicators, stakeholder-based evidence and qualitative information) • Prospective and predictive analysis based on modelling • Cost-benefit and cost-effectiveness analysis • Books or book sections
6. LANGUAGE		
Language of article with English abstract: English, French, Spanish and German		Languages outside those in the inclusion criteria
7. PUBLICATION DATE: 1 January 2005- 1 September 2020		

Appendix 2. SEARCH

A. PUBLICATION DATABASE SEARCHES

- Web of Science (WoS)
- Scopus

The field codes "Topic (TS)" and "Abstract (ABS)" were used for WoS and Scopus respectively. A title exclusion (TI) was also included for biological terms instead of making exclusions based on journal or category, since we discovered that we had missed potentially useful evidence (during our trials?).

B. SPECIALIST SEARCHES

A selection of "grey" literature was identified by going directly to relevant organization websites, informed by the list of relevant sources determined by expert input. They include:

- 3ie impact evaluations: *https://www.3ieimpact.org/evidence-hub/impact-evaluation-repository*
- IDEAS-Repec: *https://ideas.repec.org/*
- EconLit: *https://www.aeaweb.org/econlit/*
- Environmental Evidence Library: *http://www.environmentalevidence.org/completed-reviews*
- CEEDER *https://environmentalevidence.shinyapps.io/CEEDER/*
- DFID research output: *https://www.gov.uk/dfid-research-outputs*
- SIDA *https://www.sida.se/English/publications/publicationsearch/*
- USAID Evaluations Clearinghouse: *http://dec.usaid.gov/*
- J-PAL *https://www.povertyactionlab.org/evaluations*
- World Economic Forum: *https://www.weforum.org/*
- OECD: *http://www.oecd.org/*
- UN Department of Economic and Social Affairs: *https://www.un.org/esa/ffd/index.html* (financing for development, ffd)
- UN Environment Programme (REDD+): *https://www.unenvironment.org/explore-topics/climate-change/what-we-do/mitigation*
- UN Framework Convention on Climate Change: *https://unfccc.int/*
- Green Finance Platform: *https://www.greenfinanceplatform.org/*
- Global Environment Facility: *https://www.thegef.org/topics/climate-change-mitigation* (also: *https://sgp.undp.org/areas-of-work-151/climate-change/climate-change-mitigation-176.html*)
- European Commission: *https://ec.europa.eu/europeaid/policies/financing-development/eip_en*
- European Environment Agency: *https://www.eea.europa.eu/*
- Development Finance Institutions:
  - Islamic Development Bank: *https://www.isdb.org/publications*
  - Eurasian Development Bank: *https://eabr.org/en/analytics/*
  - Council of Europe Development Bank: *https://coebank.org/en/*
  - Inter-American Development Bank: *https://www.iadb.org/en/topics-effectiveness-improving-lives/impact-evaluations-repository*

  - African Development Bank: *https://www.afdb.org/en/all-documents*
  - Asian Development Bank: *https://www.adb.org/publications*
  - World Bank- Open Knowledge Repository: *https://openknowledge.worldbank.org/*
  - World Bank (DIME): *https://www.worldbank.org/en/research/dime*
  - International Finance Corporation (IFC): *https://www.ifc.org/*
  - European Bank for Reconstruction and Development: *https://www.ebrd.com/home*
  - European Investment Bank: *https://www.eib.org/en/index.htm*
  - U.S. International Development Finance Corporation: *https://www.dfc.gov/media/reports/archived*
  - European Development Finance Institutions: *https://www.edfi.eu/*
- Individual pages of European Development Finance Institute members:
  - Belgium: *http://www.bio-invest.be*
  - Belgium: *http://www.bmi-sbi.be*
  - UK: *http://www.cdcgroup.com*
  - Spain: *http://www.cofides.es*
  - Germany: see also in below list *www.deginvest.de*
  - Finland: *http://www.finnfund.fi*
  - Netherlands: *http://www.fmo.nl*
  - Denmark: *http://www.ifu.dk*
  - Norway: *http://www.norfund.no*
  - Austria: *http://www.oe-eb.at*
  - France: *http://www.proparco.fr*
  - Switzerland: *http://www.sifem.ch*
  - Italy: *http://www.simest.it*
  - Portugal: *http://www.sofid.pt*
  - Sweden: *http://www.swedfund.se*
- German websites for grey literature search:
  - Bundesministerium fuer wirtschaftliche Zusammenarbeit und Entwicklung (BMZ): *http://www.bmz.de/de/index.html*
  - Deutsches Institut fuer Entwicklungspolitik: *https://www.die-gdi.de/*
  - Kreditanstalt fuer Wiederaufbau (KfW): *https://www.kfw.de/*
  - KfW DEG: *https://www.deginvest.de/*
  - Deutsche Bank: *https://www.cib.db.com*
  - Hub for sustainable finance Germany: *https://www.h4sf.de/*
  - Oesterreichische Forschungsstiftung fuer Internationale Entwicklung: *https://www.oefse.at/*
  - Schweizer EDA Entwicklung und Zusammenarbeit: *https://www.eda.admin.ch/deza/de/home.html*
- Spanish websites for grey literature search:

  - AECID: *http://www.aecid.es/ES*
  - Asociación Latinoamericana de Instituciones Financieras para el Desarrollo: *http://www.alide.org.pe/publicaciones-2/publicaciones-alide/*
  - Banco Centroamericano de Integración Económica: *https://www.bcie.org/*
  - Banco de Desarrollo de América Latina: *https://www.caf.com/*
  - Banco Interamericano de Desarrollo: *https://publications.iadb.org/en?field=type_view&locale-attribute=es*
  - Caribbean Development Bank (English): *https://www.caribank.org/our-work/evaluation*
  - CEPAL: *https://www.cepal.org/es/publications/list*
  - COFIDES: *https://www.cofides.es/*
  - Corporación Andina de Fomento: *https://www.caf.com/*
  - Fondo Internacional de Desarrollo Agrícola: *https://www.ifad.org/es/web/knowledge/publications*
- French websites for grey literature search:
  - Fondation pour les études et recherche sur le dévelopment internationale: *https://ferdi.fr/publications*
  - Agence Française de Dévelopment: *https://www.afd.fr/fr/ressources-accueil*
  - Comité Français pour la solidarité internationale: *https://www.cfsi.asso.fr/ressources-et-presse*

C. SEARCH STRATEGY

Grey literature: Different search terms used depending on the characteristics and search of options of the corresponding database. A list of specific search terms for each source is available upon request.

Web of Science and Scopus search:

1. Climate change mitigation

TS=("climate change mitigation" OR "mitigation of climat" OR "GHG emission*" OR "GHG abatement" OR "emission* reduc*" OR "reduc* emission*" OR "emission* abatement" OR "CO2 abatement" OR "CO2 emission*" OR "carbon emission*" OR "carbon abatement" OR "climate neutral" OR "carbon footprint" OR "greenhouse gas*" OR "energy- saving*" OR "energy expenditure" OR "energy access")*

2. Interventions

AND TS=("fossil fuel" OR "energy efficienc*" OR "energy generation" OR "energy consumption" OR "electrificat*" OR "renewable energ*" OR "clean energy" OR "solar" OR "clean technolog*" OR "clean product*" OR "recycle*" OR "circular econom*" OR "sustainable material*" OR "appliance*" OR "sustainable construct*" OR "sustainable infrastructure" OR "clean development mechanism" OR "carbon sink*" OR "forest protection" OR "reforestation" OR "afforestation" OR "avoided desertification" OR "sequest*" OR "carbon offset*" OR "thermal energ*" OR "geothermal energ*" OR "wind energ*" OR "hydropower" OR "low emission transport" OR "sustainable transport" OR "liquefied natural gas" OR "energy conservation" OR "fuel conversion" OR "carbon-neutral" OR "biofuel*" OR "biogas*" OR "biodiesel" OR "bioethanol" OR "carbon capture" OR "CO2 capture" OR "building insulation" OR "forest conservat*" OR "reforest*" OR*

"compost" OR "husbandr*" OR "soil manage*" OR "fertilizer manage*" OR "agroforestr*" OR "soil conserv*" OR "carbon intens*" OR "decarboniz*" OR "de-carboniz*" OR "carbon capture" OR "low-carbon" OR "lighting")*

3. Private sector

AND TS=("invest" OR "private" OR "compan*" OR "business*" OR "SME" OR "climate finance" OR "household*" OR "industr*" OR "purchas*" OR "loan*" OR "credit*" OR "bank*" OR "financial")*

4. Sector

AND TS=("transport" OR "energy*" OR "industr*" OR "agricultur*" OR "waste" OR "building*" OR "construct*" OR "urban" OR "forest*" OR "land use" OR "land manag*" OR "livestock" OR "farm")*

5. Method

AND TS= ("empirical evidence" OR empiric OR "impact evaluation" OR "systematic review" OR "statistical analysis" OR counterfactual OR experiment* OR "quasi-experiment*" OR "quasi experiment" OR "discontinu* design" OR "fixed effect*" OR regression OR "difference* in difference*" OR "double differenc*" OR "instrumental variable*" OR "propensity score" OR "matching" OR "propensity weight*" OR "time-series" OR "panel data" OR "double robust" OR "random* control*" OR randomization OR "random* trial*" OR "control group" OR "pipeline approach" OR "pipeline method" OR "pipeline comparison" OR "impact assessment" OR "econometric analys*" OR "cross-sectional data" OR "difference-in-difference" OR "random* control* trial*" OR "difference-in-difference*" OR "diff in diff" OR "diff-in-diff" OR "fixed effect*" OR "rapid evidence assessment*" OR "systematic literature review*" OR "systematic* review*" OR "control* treatment" OR "instrumental variable*" OR "heckman*" OR "counterfactual" OR "counter factual" OR "counter-factual" OR "control* evaluation" OR "randomized field" OR "household survey")*

6. Exclusion

NOT TI=(US OR USA OR "United states" OR "North America" OR Alabama OR Alaska OR Arizona OR Arkansas OR California OR Colorado OR Connecticut OR Delaware OR Florida OR Hawaii OR Idaho OR Illinois OR Indiana OR Iowa OR Kansas OR Kentucky OR Louisiana OR Maine OR Maryland OR Massachusetts OR Michigan OR Minnesota OR Mississippi OR Missouri OR Montana OR Nebraska OR Nevada OR "New Hampshire" OR "New Jersey" OR "New Mexico" OR "New York" OR "North Carolina" OR "North Dakota" OR Ohio OR Oklahoma OR Oregon OR Pennsylvania OR "Rhode Island" OR "South Carolina" OR "South Dakota" OR Tennesse OR Texas OR Utah OR Vermont OR Virginia OR Washington OR "West Virginia" OR Wisconsin OR Wyoming OR Canad* OR UK OR England OR Scotland OR Wales OR Ireland OR Irish OR Spain OR France OR Greece OR Ital* OR Portug* OR German* OR Switzerland OR Swiss OR "New Zeal*" OR Australia* OR Israel* OR Belgi* OR Netherland* OR "Dutch" OR Luxemb* OR Denmark OR Norway OR Sweden OR Finland OR Iceland* OR Poland OR Austria* OR Malta OR Hungar* OR Czech OR Slovak* OR Latvia OR Lithuania OR Estonia OR Russia* OR Romania* OR Bulgaria* OR Serbia OR Croatia OR Japan* OR Korea* OR "Hong Kong" OR Singapore OR "Saudi Arabia" OR Qatar OR Emirates) NOT TI=("Tax" OR "fiscal" OR "kuznets" OR "potential" OR "predict*" OR "mathematical" OR "modelling" OR "modeling" OR "simulat*" OR "politic*" OR "law" OR "growth" OR "FDI" OR "GDP" OR "population" OR "foreign direct investment")*

IDEAS/Re-PeEc search:

Search options
Whole record

Papers
From 2005 to 2020

use + for AND, | for | and ~ for NOT

("climate change mitigation" | "mitigation of climate" | "GHG emissions" | "GHG abatement" | "emissions reduction" | "reduced emissions" | "emissions abatement" | "CO2 abatement" | "CO2 emissions" | "carbon emissions" | "carbon abatement" | "climate neutral" | "carbon footprint" | "greenhouse gases" | "energy savings" | "energy expenditure" | "energy access") + ("investment" | "private" | "company" | "business" | "SME" | "climate finance" | "households" | "industry" | "purchase" | "loan" | "credit" | "bank" | "financial") + ("transport" | "energy" | "industry" | "agriculture" | "waste" | "building" | "construction" | "urban" | "forestry" | "land use" | "land management" | "livestock" | "farm") + ("empirical evidence" | empirical | "impact evaluation" | "systematic review" | "statistical analysis" | counterfactual | experimental | "quasi-experimental" | "quasi experiment" | "discontinuity design" | "fixed effects" | regression | "difference in differences" | "double difference" | "instrumental variable" | "propensity score" | "matching" | "propensity weight" | "time-series" | "panel data" | "double robust" | "random control" | randomization | "random trial" | "control group" | "pipeline approach" | "pipeline method" | "pipeline comparison" | "impact assessment" | "econometric analysis" | "cross-sectional data" | "difference-in-difference" | "random control trial*" | "difference-in-differences" | "diff in diff" | "diff-in-diff" | "fixed effects" | "rapid evidence assessment" | "systematic literature review*" | "systematic* review*" | "control* treatment" | "instrumental variable*" | "heckman" | "counterfactual" | "counter factual" | "counter-factual" | "control evaluation" | "randomized field" | "household survey")*

Appendix 3. DATA GATHERING AND CODING PROCESS

In the **first round**, reviewers worked in parallel with different subsets of academic papers and populated the table per entry (rows). Regular coordination meetings took place to clarify concepts, refine the information and, where feasible, group it into categories for comparison. More significantly, a common understanding for categories was agreed as follows.

Coding fields for SR

- Population:
  - The direct recipient of the intervention must be a natural or legal person.
  - The private sector role should be considered in connection to the intervention's physical asset and this includes asset ownership, service provider and financial assets investments, among others
- Intervention:
  - The intervention's description is related to its physical, procedural, financial and regulatory elements.
  - The geographical scale is limited to the intervention. Beyond its scope, the geographical scale is reported in the critical appraisal's external validity section.
  - The time frame is also bound to the intervention (and not to data-collection).
  - The intervention' stage of development refers to its implementation degree (planned, ongoing or finished) and its type (pilot, programme with a series of interventions, etc.).
  - The main implementing agent is the most notorious agent in the intervention's implementation. Public entities, if any, are normally categorized as other implementing agents. The main implementing agent is not necessarily the study comparison unit or the intervention recipient.
- Outcome:
  - The outcome describes the target variable of the intervention expressed in quantitative terms with a precise measurement method.
  - The outcome quantification expresses the target variable in quantitative terms.
  - The time between intervention and measurement refers to time elapsed between the beginning of the implementation and the moment of measurement.
  - The main conclusion contains the results of the study and its implications beyond the scope of the target variable (e.g., at policy level).
- Study design:
  - The estimation methods' category includes a short explanation of statistical methods used (to be distinguished from measurement methods).
  - Measurement methods used for variable construction refers to methods of aggregation or variables' measurement other than the target variable. These include different types of indicators, such as synthetic or official, factorized data or data stemming from surveys or LCA estimates.
  - Causality tests, if any, address endogeneity issues and double causality. The estimated method used (experimental or quasi-experimental) shall be mentioned.
  - Comparison units and number of observations are related to the statistical model.

  - The level comparison refers to the type of observational data: either cross section, time series or panel data.
  - The bias and other weaknesses and limitations to be reported here are those identified by the author.

Critical appraisal

- Relevance:
  - The research question alludes to the main (and relevant) research thesis.
  - The study methods' relevance is assessed in terms of the methodology's relevance in estimating either impacts or relations.
  - The relevance of outcome measures to answer the research question is assessed in light of declared bias or the use of proxies. Estimation methods are not analysed here.
  - Conclusions are analysed in terms of their coherence / relevance to answer the research question.
- Internal validity:
  - Clear description of the intervention in terms of technical implementation details, financing, time frame, involved agents, regulatory context.
  - Two groups if any, treated and control, are compared. Even the definition of a dummy variable in the framework of a quasi-experimental variable can be included.
  - In case of no similar groups, control methods should be detailed, namely quasi-experimental ones.
  - The assessment of a reliable statistical inference based on sufficient data points hinges on the number of sample observations and the size and heterogeneity of the target population. Public surveys are assumed to provide sufficient data points.
  - If evidence of multiple statistical testing exists, additional causality tests employed or alternative model formulations (under different assumptions) can be mentioned.
  - Other possible sources of biases, other than those identified by the author.
- External validity:
  - The assessment of study population representativeness of target population in terms of its characteristics, geographical scope, etc. is conducted. It goes beyond the number of observations used (internal validity).
  - The assessment of whether interventions have been replicated in several settings with different populations is conducted. This is deemed to be relevant if this variability in characteristics is key for the study results.
  - The assessment of whether the main findings and conclusions of the study are bound to specific characteristics of the population is also performed. That is, if the geographical and socioeconomic context of the study help validate study results.
  - As a consequence of the last two assessments, a conclusion should be reached in terms of the potential generalization of the main findings and conclusions of the study to a broader population. In such case, a rough mention to this broader population should be made (rest of the country, region, other developing countries?)
- Appropriateness:

  - In terms of collection data techniques, a formal assessment about details on survey design, sampling, database / sources, geographic information systems and satellite imagery analysis is to be expected.
  - The assessment of adequate description of the data relies on the inclusion of tables and summary statistics describing the sample (links and/or annex) and adequate information on the results of any analysis.

In the **second round**, reviewers conducted a column-wise revision per category building blocks to (i) allow for the consistency of statements within a single category and (ii) check the consistency of the critical appraisal based on the descriptive categories.

As for the second output, categories were homogenized to simplify subsequent analysis. As such, the team grouped different classes per category as stated below:

Coding fields for SR

- Population:
  - The recipient of the intervention can be frequently categorized as *companies, farms, households, communities* and *land plots.*
  - The private sector role tends to be of an investment nature, whose type differs in nature (*community, farm, corporate, etc.).*
- Intervention:
  - The intervention's description is varied and more precisely tackled in the SR.
  - The geographical scale is also very varied and more frequent at the *regional, regional, city level.*
  - The time frame spans from 1970 to the present, but more frequently from the early 2000s.
  - The intervention's stage of development includes *ongoing* and *finished projects* as well as *national initiatives*, among others
  - As main implementing agents, *companies, investors, farmers, households or landowners* count among the most frequent ones.
- Outcome:
  - The outcome can accept the following categories: *GHG reduction, energy efficiency, forest cover, land improvement and biodiversity, reduction in fuel consumption (kerosene / firewood), CO_2 sequestration* and *energy efficiency (domestic consumption / industrial consumption / generation / domestic or industrial).*
  - The outcome can be quantified in the following units: *CO_2 Kg/year, Kerosene l/month per household, % change in $/month per household, tonnes of sequestered CO_2.* For co-benefits, the *Biodiversity Index* can be used.
  - The time between intervention and measurement depends on each individual case and has been coded in a simple statement.
  - The main conclusion has been coded as a synthetic statement.
- Study design:
  - The estimation methods used have been most frequently *OLS, PSM, LCA, GMM, ANOVA,* etc.
  - The measurement methods may vary between *survey based, panel data, remote sensing, official statistics, sampling,* etc.

  - Causality tests most frequently used include the *Arellano-Bond (GMM) method, synthetic control method, quasi-experimental approach (matching), quasi-experimental approach (DiD)* and *inclusion/test of control variables in a non-causal framework.*
  - Comparison units used include *farms, households, parks*, any type of decentralized administrative units, *landowners, industrial plants*, etc.
  - The level comparison refers to either (i) *cross section* or (ii) *panel data.*
  - The bias (identified by the author) can be classified as *recall bias, self-selection bias, non-counterfactual approach, sampling error, omitted variable bias*, etc.
  - Other weaknesses and limitations are very varied but most frequently the assessment appears to be related to *limited sample, scope* or *data availability*, among others

Critical appraisal

- Relevance:
  - Research question is rewritten in an interrogative form.
  - Relevant methods could be answered by (i) *yes* and (ii) *partially* (in case, quasi-experimental studies are preferred over OLS or correlational studies are not adequate for assessing impacts).
  - Relevant outcome measures are answered by *yes* across the board except *partially* in two specific cases.
  - Conclusions can be considered adequate with a *yes*, and *partially* when either the outcome is addressed as a co-benefit or the results are questionable as a consequence of the methodological choice.
- Internal validity:
  - Description of the intervention can have three answers: (i) *yes* (details are provided), (ii) *partially* (some elements are missing), or (iii) *no* (intervention is inferred from explanatory variable).
  - Comparison of two groups also accepts three types of statements: (i) *yes* (with a mention to two groups; if any, also the dummy variable employed), (ii) *several groups*, or (iii) *no two groups are discernable.*
  - Methods for control of differences: (i) *yes* (mention the technique used, namely matching, random / fixed effects, control variable, test of differences, cross-selection sampling, etc.), and (ii) *no.*
  - Statistical inference based on number of observations may accept a judgment based on the following answers: (i) *sufficient* (very clearly in case of an official survey), (ii) *questionable*, or (iii) *unclear.*
  - Multiple statistical testing can be answered with two types of answers: (i) *yes* (alternative OLS model, several other model formulations, sensitivity tests and optimal weights), or (ii) *no additional model formulation or testing.*
  - Other possible sources of biases have a variety of answers stemming from (i) *none, apart from those identified by the author*, and (ii) *yes* (non-exhaustively, sampling error, omitted variable bias, self-reported bias, etc.).
- External validity:
  - On study population representativeness can accept the following: (i) *sample is representative* (in any case, for official statistics), or (ii) *sample representativeness is questionable* (either because the size of target population is unclear, there are no sufficient

observations for subsample categories and the relevant group is not covered in the sample).

  - Intervention replication in different settings and populations can accept answers of the like (i) *yes* or (ii) *no* and a mention to details.
  - Characteristic-bound findings and conclusions can accept answers of the like (i) *yes* or (ii) *no* and a mention to specific implementation details.
  - Findings and conclusions generalization can accept answers of the like (i) *yes* or (ii) *no* and a mention to details.

- Appropriateness:
  - Data techniques collection can be answered by *yes/partially/deficient/completely missing*, with some additional explanatory details.
  - Description of the data can also be answered by *yes/partially/deficient/completely missing*, with some additional explanatory details.

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