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REVIEW ARTICLE

The socio-economic performance of agroecology. A review

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Abstract

Agroecology is identified as an important solution to increase the sustainability of agricultural and food systems. Despite the increasing number of publications assessing the socio-economic outcomes of agroecology, very few studies have consolidated the scattered results obtained on various case studies. This paper provides new insights by consolidating evidence on the varied socio-economic effects of agroecology across a large number of cases at a global level. To this purpose, we used a rapid review methodology, screening more than 13,000 publications to retrieve evidence on the socio-economic outcomes of the implementation of agroecological practices. The results of the review indicate that (1) agroecological practices are associated more often with positive socio-economic outcomes across the broad range of evaluated metrics (51% positive, 30% negative, 10% neutral, and 9% inconclusive outcomes); (2) the socio-economic metrics associated with financial capital represent the vast majority of evaluated metrics (83% of total) and are affected positively in a large share of cases (53%), due to favourable outcomes on income, revenues, productivity and efficiency; (3) human capital metrics (16%) are associated with a larger number of negative outcomes (46% versus 38% positive), due to higher labour requirements and costs that are however partly compensated by an overall greater number of positive outcomes on labour productivity (55%); and (4) the results vary depending on the agroecological practice assessed; e.g. for agroforestry, we identify 53% positive outcomes while for cropping system diversification 35%. These results indicate an overall favourable potential for farms to benefit from a positive socio-economic performance with the use of agroecological practices. Yet, the magnitude, temporal aspects, and success factors related to these outcomes, as well as the trade-offs between them, and the system-level effects of an agroecological transition are to be further assessed, since they can have an important influence on the performance of individual farms.

Keywords Agroecological practices · Socio-economic indicators · Sustainable livelihoods · Farm economic performance · Agroforestry · Intercropping

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1 Introduction

There is a growing consensus that agricultural and food systems need to be redesigned more sustainably in order to address food security, zero poverty, and environmental challenges such as climate change, biodiversity loss, and degrading land and water resources (United Nations 2021). Agroecology is perceived as a prominent solution to increase the sustainability of agricultural and food systems (HLPE 2019; Wezel et al. 2020). It is a dynamic concept that has gained importance and recognition in recent years in scientific, agricultural, and political discourses (IAASTD 2009; IPES-Food 2016). This is due to its varied potential benefits such as stabilisation of yields and productivity, enhanced resource use efficiency, reduced greenhouse gas emissions, and culturally sensitive and socially just approaches (Altieri 2002; Pretty et al. 2006; D'Annolfo et al. 2021).

Transitions to agroecological farming may be triggered by the need to mitigate negative environmental impacts generated by intensive approaches or from the need to improve food security for smallholder farmers in developing countries. Throughout Africa, Asia, and Latin America, agroecologically managed systems have demonstrated positive impacts on the livelihoods of rural farming communities enhancing food security with healthy local food, strengthening the natural resource base, preserving cultural heritage, and prompting resilience to climate change (Pretty 1995; Altieri and Nicholls 2008; Altieri and Holt-Giménez 2016). In more intensive agricultural systems, a general transition to agroecology aims at reducing negative environmental impacts and starts by improving resource use efficiency, substituting detrimental inputs, and more effectively implementing a substantial farm-scale redesign (Gliessman 2014; Bezner Kerr et al. 2021). The agroecological transition generally goes from the adoption of more environmentally friendly agroecological practices at the field and farm level (i.e. improving the ecological functioning of the soil-plant system) to a more comprehensive and complex landscape and food system redesign (Gliessman 2014; HLPE 2019; Bezner Kerr et al. 2021). This can imply, for example, incrementing interactions among different farm level components, increasing synergies among farms and across landscapes, and creating more diversity in the whole agroecosystem (Wezel et al. 2020). At the food system level, it involves strengthening the connection between producers and consumers, supporting the shift towards healthy diets, and revitalising local and regional agri-food systems (Francis et al. 2003; Lamine and Dawson 2018).

Despite the widely recognised benefits of agroecology for the environment (Nicholls and Altieri 2018) and food security and nutrition (Bezner Kerr et al. 2021), little is known on its socio-economic performance (D'Annolfo et al. 2017, 2021). van der Ploeg et al. (2019) offered some theoretical grounds for assuming that the economic returns of agroecology have the potential of being higher compared to conventional and industrial agriculture in Europe and provided some empirical examples confirming this assumption. D'Annolfo et al. (2017), after reviewing 17 articles to provide a framework and a quantitative overview of the social and economic effects of the adoption of agroecological practices at farm level, concluded that there is preliminary evidence that agroecology can have a positive contribution to improving financial capital while little meaningful information was found on human and social capital.

The topic has also raised interest and evaluations in non-academic circles. A recent report by Biovision (2019), which assessed the economic viability of agroecology considering aspects of profitability and resilience, argued that agroecological farming can be more profitable than so-called 'conventional farming', while strengthening the resilience of agricultural businesses to enhance long-term profitability. Another recent report by Grémillet and Fosse (2020) evaluated the profitability associated with 23 French specifications and reference frameworks linked to agroecological principles and practices (e.g. organic agriculture, agroenvironmental, and climatic measures). The study pointed to the finding that agroecology is profitable in the case of organic farming in the majority of cases, but not always under other cases such as high environmental value farming (French environmental certification HVE) or DEPHY farms (network aiming to reduce the use of plant protection products).

Thus, while these previous studies have shed some light on potentially positive socio-economic outcomes of the application of agroecological practices, the results remain fragmented, partial, or uncertain, pointing towards the need for a systematic large-scale assessment. As a wider uptake of agroecology can accelerate the achievement of sustainability targets such as those set by the European Green Deal, by the Sustainable Development Goals, and, more recently, by the UN Food System Summit via the Coalition for Food

Systems Transformation through Agroecology (UN Food Systems Summit 2021), it is now important to evaluate its socio-economic viability, which is a fundamental driver for its upscaling. A better understanding of whether agroecology enhances the socio-economic performance of farming systems is a key requisite to evaluate the efficiency of the conversion to agroecology and design policies to support it.

This study contributes to the literature on the evaluation of the socio-economic performance of agroecology by collecting evidence from an exhaustive number of studies and expanding the scope of in-so-far investigations in terms of the socio-economic indicators and the portfolio of agroecological practices considered. It contextualises the socio-economic research on agroecology into a more systematic framework based on a broad analysis of existing literature, trying to single out clear scientific evidence and hence increase confidence on the expected socio-economic outcomes of the adoption of agroecological practices. Using a rapid review methodology, the objective is to summarise systematically existing evidence at the global level with a focus on evaluating the socio-economic performance of the application of agroecological practices and on characterising the agroecological practices and socio-economic metrics associated to this evidence.

2 Materials and methods

2.1 Frameworks of agroecological practices and socio-economic indicators

This paper focuses on the socio-economic performance of agroecological practices, as opposed to the performance of systems associated with agroecological farming for which there was no specification or data on the underlying implemented practices (e.g. general papers on ecological intensification, biodiversity-based agriculture, or organic agriculture without details on the practices) or to food system elements. This choice was made with the intention of finding clear evidence based on a comparison with conventional practices. Packages of practices that were clearly identified and compared to conventional systems were also considered in the evaluation. We note that by 'conventional' agriculture, we refer to 'ordinary or commonplace agriculture' and/or 'agriculture that falls outside a clearly circumscribed category' (Sumberg and Giller 2022). Given the high diversity of systems that are labelled as 'conventional' or 'agroecological' and the variety of employed approaches ranging from industrialised to subsistence farming, the approach of focusing on concrete practices allows drawing conclusions that can be more easily interpreted by both farmers and policy-makers and associated with the present policy framework. The specific practices evaluated for each of the reviewed articles can be seen in the Supplementary Materials.

To structure the findings, and specifically to link individual agroecological practices to identified socio-economic indicators, we adopted two corresponding conceptual frameworks.

The first one, an agroecological practice framework, structures the portfolio of considered practices (Table 1). It is based on the list of practices presented in Wezel et al. (2014) complemented with additional practices from the WOCAT database (https://www.wocat.net/en/) to better reflect also situations outside Europe. Each practice is associated to one of eight management categories, with the clustering based on the categories of Wezel et al. (2014) and slightly modified during the review process to better reflect the number and types of identified practices.

The second one, a socio-economic indicator framework, assembles the diverse socio-economic effects related to agroecology (Table 2). The framework adopts as a starting point the categories of financial, human, and social capital presented in D'Annolfo et al. (2017) based on the sustainable livelihood framework (SLF) (DFID 1999). The SLF helps organizing the factors that constrain or enhance livelihood opportunities and how they relate to one another based on the premise that households have different livelihood assets of human, social, financial, natural, and physical capital (Serrat 2017). Here, we focused on financial as well as human and social capitals, to provide a broader perspective of socio-economic performance. In a next step, we screened the literature dealing with the socio-economic performance of agroecology (D'Annolfo et al. 2017; Biovision 2019; van der Ploeg et al. 2019; Grémillet and Fosse 2020), as well as the TAPE (FAO 2019) and OASIS (Peeters et al. 2021) agroecological indicator frameworks to identify socio-economic indicators related to financial, human, and social capitals. The identified indicators were clustered in the respective capital categories and, depending on their level of coarseness, attributed to 'themes' (aggregate categories), 'sub-themes' (sub-division of themes into more specific aspects), or 'metrics' (concrete measurable quantities) similarly to Mouratiadou et al. (2021). Given the diversity of metrics explored in the reviewed articles, we treated the framework as a 'living' one, with new metrics added when discovered in the course of the review and additional themes and sub-themes included as appropriate to cluster the identified metrics.

2.2 Literature review methodology

To collect evidence on the socio-economic performance of agroecology, we applied a rapid review methodology (Tricco et al. 2015; Bezner Kerr et al. 2021), recognised as a useful tool for evidence-based decision-making at the policy level (Yost et al. 2014). The review was based on PRISMA-RR protocol (Stevens et al. 2018) consisting of four phases: the literature identification phase, the abstract screening phase, the eligibility phase, and the final evidence retrieval phase (Fig. 1).

Table 1 Conceptual framework of agroecological practices. The agroecological practices refer to (1) Wezel et al. (2014), (2) WOCAT database, (3) found and added during the literature review.

Management category	Agroecological practices
Crop fertilisation management	Split fertilisation[1]
	Mixed organic fertilisation[3], balanced fertilisation[2]
	Biofertiliser[1], mycorrhizae inoculation[2], beneficial microbials and microorganisms[2]
	Organic fertilisation[1,2]: manure[1,2], compost[1,2], zai[3]/planting pit[2], biochar[2], biodigestate[2], biodynamic preparation[2], biofermentation[2]
Water management	Drip irrigation[1], micro-irrigation/drip irrigation/variable rate irrigation[2]
	Water harvesting[1,2]
	Raised bed/ridge cultivation[2]
	Contour bunds[3], contour farming[2], soil drainage[2]
Weed management	Ecological weed management[2], allelopathic plants[1]
Pest and disease management	Natural pesticides/botanical pesticides[1], pesticide reduction[2], antibiotic reduction[2]
	Beneficial arthropods/natural enemies, beneficial microbials and microorganisms[2]
	Push-pull strategies[3], allelopathic plants[1]
Crop choice, crop spatial distribution, and crop temporal successions	Crop residue application[2], coppice management[2]
	Multistorey cropping/syntropic agriculture[2]
	Stress-tolerant, disease-resistant crop/cultivar[1,2]
	Cover crop and mulching: green manure[1,2], cover crops[1,2], mulching[1,2], catch crop[2]
	Cropping system diversification[1]: variety/cultivar mixture[2], crop diversification[3], diversified crop rotation[1,2], improved fallow[3], crop-livestock integration[1,2] (i.e. pasture[3], grassland[2], grass-feeding[2], permanent grassland[2], rotational/controlled grazing[2], forest grazing[2], rice-fish system/rice-duck system[2], aquaculture/fish farming[2])
	Intercropping[1,2], alley cropping[2], relay cropping[2], living mulch[2], mixed cropping[2]
	Agroforestry[1,2]: silvoarable[1,2], silvopastoral[1,2], agro-silvo-pastoral[1,3], homegarden[2]
Tillage management	No tillage[1], reduced tillage[1], direct seeding[1], conservation tillage[2], controlled traffic[2]
Management of landscape elements	Integration of semi-natural landscape elements at field or farm scale[1]: hedgerows, windbreaks, and living fences[1,2], flower strips[2], field-margins and semi-natural patches[1], buffer/vegetative strips[2]
	Planting or managing landscape elements[1]: stone wall/terracing[2], paludiculture/wetland management[2], semi-natural areas[1,2], conservation headland[2]
	Dune stabilisation[2], erosion control[2], soil/land rehabilitation/restoration[2], afforestation[2]
Other—package of practices	Sustainable rice intensification[2], organic farming[1], climate change adaptation practices (e.g. adjusting planting dates)[3], agroecological farming[3], biodynamic farming[3]

2.2.1 Identification phase

To identify the literature sources utilised in the rapid review, we used a search string including terms relevant to agroecological systems and practices as well as to the evaluation of related socio-economic effects (Table 3). The terms used were selected according to relevant articles on the topic (Wezel et al. 2014; D'Annolfo et al. 2017; Chappell and Bernhart 2018; Stevens et al. 2018) and the expert knowledge of the researchers participating in this study. Wildcards, such as the asterisk (*), were added at the end of the root word to retrieve a larger number of relevant articles. For the identification of scientific literature, we screened the Clarivate Web of Science™ (13,532 articles retrieved) and the Elsevier Scopus™ (n =12,365 articles retrieved) databases and eventually kept the larger list of retrieved articles from Web of Science. For the identification of other published documents, we hand-searched the online repositories of several well-established institutes.

2.2.2 Screening phase

The abstracts of the identified articles were screened and either excluded from further analysis or kept for the evaluation phase. For this process, we predefined a list of inclusion and exclusion criteria with respect to publication dates, consideration of agroecological practices and socio-economic outcomes, and article quality, accessibility, and language (Table 4).

The first 6000 abstracts were hand-screened by two reviewers separately and concurrently. In cases where there was disagreement of inclusion between the two reviewers, a third reviewer took the final decision. In order to carry out the screening selection on the remaining abstracts in a more time-efficient way, we trained a machine-learning model to act as a secondary reviewer and replaced one of the two human reviewers. Currently, supervised machine learning is the primary technique for the automation of systematic reviews and is mostly

Table 2 Conceptual framework of socio-economic indicators used in the rapid review, broken down into its four elements: capital categories, themes, sub-themes and metrics. The definitions of financial, human, and social capital are based on D'Annolfo et al. (2017) and DFID (1999). The socio-economic elements refer to (1) D'Annolfo et al. (2017), (2) Biovision (2019), (3) Grémillet and Fosse (2020), (4) van der Ploeg et al. (2019), (5) Peeters et al. (2021), (6) FAO (2019), and (7) added by the authors to cluster the metrics. The metrics with no superscript are those identified during the review process (illustrative non-exhaustive list of examples).

Capital categories	Themes	Sub-themes	Metrics
Financial capital	Profitability[1,2]	Income[2]	Gross margin[3,4], direct margin[3], gross operating surplus[3], earnings before interest[3], satisfaction with economic benefits from farming activities (2.3.1)[5], similar or higher benefits compared to other farmers (2.3.2)[5], benefits per hectare per year after transition[3], outputs − inputs − operating expenses − depreciation + other income[6]
Financial resources to achieve farmers' livelihood objectives. The two main sources are available stocks and regular inflows of money.			Farm income, net income, net annual income, average yearly income, total annual income, cash income, crop income, livestock income, timber income
			Profit, net profit, profit per acre, farm profitability, land profitability
			Net balance, net present value, net benefit, net cash flow, value added
			Multidimensional poverty
		Revenue	Farm output value per hectare[6]
			Gross production value, total economic value of marketable services, monetary value, total production value, total value, total value of output, value of food crops
			Gross revenue, average revenue, total gross revenue, revenue from products, total revenue, revenue per acre, milk revenue, timber revenue, beef revenue
			Gross benefits, gross output, gross receipts, gross returns, total returns, total return from main product, total output, total outputs
		Efficiency and productivity[2*]	Yield[1,2], income per hour[4], income per dairy cow[4], gross value added/ewe[4], fossil energy consumption/ha[4]
			Benefit cost ratio, input-output ratio, financial efficiency, production efficiency, technical efficiency, financial productivity, land productivity, area productivity
		Product value[7]	Prices[2,3], value added over gross value of production[4], labour income/kg of milk[4], gross value added[4], product valorisation practices (2.2.1)[5], added value[6], price per unit
		Production costs[7]	Input costs[2], formal recognition of transition costs[1], level of transition costs[3], minimised fixed costs − investments (2.1.2)[5], costs per hectare per year after transition[3], variable costs and depreciation[4], decrease in machine costs[4], minimised variable costs (2.1.1)[5]
			Annual costs, variable costs, total variable costs, average variable costs, cost of cultivation, field crop inputs, total cost of input, input costs, total input costs, non-labour costs, operating costs, overhead costs, gross costs, total cash costs, total costs, total cost of production, intermediate costs, total production costs, total cost per acre, cost per kg, total expenses, average expenditure, total annual expenditure
			Capital costs, capital inputs, fixed costs
			Establishment costs, annuity establishment costs, initial establishment costs, initial investment costs, investment, total start-up costs, total initial investment costs
			Marketing and postharvest cost, processing costs
		Capital and investment[7]	Credit[7], total savings in a bank/credit association, total outstanding debit
			Return on investment, internal rate of return, cash flow, payback period, interest on circulating capital, returns on asset, returns on working capital
	Resilience[2]	Income diversification[7]	High level of diversification of activities/products (2.2.5/5.2.2)[5]
		Income stability[1]	Good temporal distribution of revenue (5.2.4)[5]
			Coefficient of variation of farm income, net present value under yield and discount rate changes, risk of net income levels, risk related to threshold yield, lowest expected maize yield, stochastic dominance criteria
		Autonomy[7]	Income according to the level of self-provisioning for feed and fodder[4], high proportion of locally or self-processed products (2.2.2)[5], high level of autonomy from commercial inputs (5.2.7)[5]
			Food crops produced on the farm, non-monetary income, intermediate consumption, month per year with enough grown food
			Dependency on subsidies[2,3,4], low share of subsidies in gross farm income (5.2.5)[5], number of households receiving subsidies from government, received subsidies

Table 2 (continued)

Capital categories	Themes	Sub-themes	Metrics
Human capital Skills, knowledge, ability to work, and good health together enable pursuing different livelihood strategies and achieving livelihood objectives.	Labour demand[1]	Labour requirements[7]	Investments in human capital[2], decrease in workload[4] Labour, labour days, total labour, labour requirements, annual labour requirements, labour required, average labour use, family labour, family labour days, labour demand, labour input use, labour use/ha, total labour hours, total labour input Labour costs, total cost of labour, total labour cost, labour costs per kilogram, hired labour costs
		Employment opportunities[7]	Employment generated at a given volume of production[4], employment per farm[4], large comparative contribution to job creation (3.1.4)[5], high ratio of employment of people at risk of poverty and social exclusion (3.1.5)[5], ability to attract and keep motivated workforce (5.2.6)[5], youth employment opportunity (access to jobs, training, education or migration)[6]
	Labour productivity[1]	Return to labour[7]	Gross value of production per labour unit[4], value added per labour unit[4], family income per family worker[4], farm output value per person[6] Labour productivity, discounted net present value of return to labour, gross margin labour per hour, gross margin per person for coffee and other products, own labour profitability, profit per family labour days, return to labour, returns to labour
	Labour conditions[7]	Working conditions[7]	Humane and safe working conditions (3.1.1)[5], fair wages, high job stability, solid provision of social protection (3.1.2)[5]
		Gender equity[7]	High level of gender equity (3.1.3)[5], women's empowerment (abbreviated women's empowerment in agriculture index)[6]
Social capital Social resources upon which farmers draw in pursuit of their livelihood objectives. These are developed through networks and connectedness, membership in formalised groups, relationships of trust, and reciprocity.	Value chains[7]	Market access[7]	Access to markets developed for products of agroecology[1]
		Marketing chain characteristics[7]	Consumer-producer linkages[2], short marketing chain (2.2.3)[5], local marketing chain (2.2.4)[5], short and local food marketing chains (5.2.1)[5], high level of diversification of clients (5.2.3)[5]
	Access to assets[7]	Infrastructure and resources[7]	Number of households sharing advice about agriculture, number of households borrowing farming equipment from each other, number of households borrowing money in times of need, number of households sharing crop seeds, number of households herding livestock together, number of households that share food in times of need

applied in the 'selection of primary studies' step, which is also the most time-consuming one (Goldfarb-Tarrant et al. 2020; van Dinter et al. 2021). The training, validation, and testing of the binary machine-learning classifier were based on the 6000 fully hand-screened articles. A logistic regression using two Bag-of-N-Grams representations (one on the abstract and another on the title of the screened article) with term frequency-inverse document frequency (TF-IDF) was implemented. The model was first trained and validated over 4800 examples of articles, using threefold cross-validation in order to obtain optimal hyperparameters. It was then tested over the 1200 remaining articles. The model obtained an accuracy of 83% on the test set. During the screening process for the remaining 7487 articles, the two reviewers hand-screened the abstracts (half of the abstracts per reviewer) and verified the disagreeing abstracts between the machine and the other reviewer. The reviewers did not have access to the machine learning results before making their selection, so they were not subject to bias. In cases where there was disagreement on the inclusion or exclusion of an article between the machine-learning model and the human reviewer, a second human reviewer took the final decision. With such a method, the machine cannot take decisions alone and is always subject to a human assessment, ensuring a transparent selection process. Following this screening procedure, 1610 abstracts (12%) were selected for full-text assessment.

2.2.3 Eligibility phase

The full texts of the selected articles were examined and the list of articles was further constrained using criteria on (i) the specification of agroecological practices, (ii) the evaluation of socio-economic outcomes, (iii) the assessment of the methodological approach, and (iv) the article quality evaluation.

(i) Specification of agroecological practices

Literature sources that did not refer to agroecological practices or misidentified agroecological practices (e.g. intercropping systems with genetically modified crops and/or high use of pesticides and herbicides) have been excluded. In addition, records referring to agroecological production methods, but where specific practices could not be clearly identified (e.g. papers referring to organic farming, biodynamic farming, or conservation agriculture without any detail on specific practices) were also excluded from further analysis. However, in line with Migliorini et al. (2020), specific practices with occasional/exceptional use of fertilisers/pesticides were retained. Although agroecological systems are generally expected to be free of synthetic agrochemicals

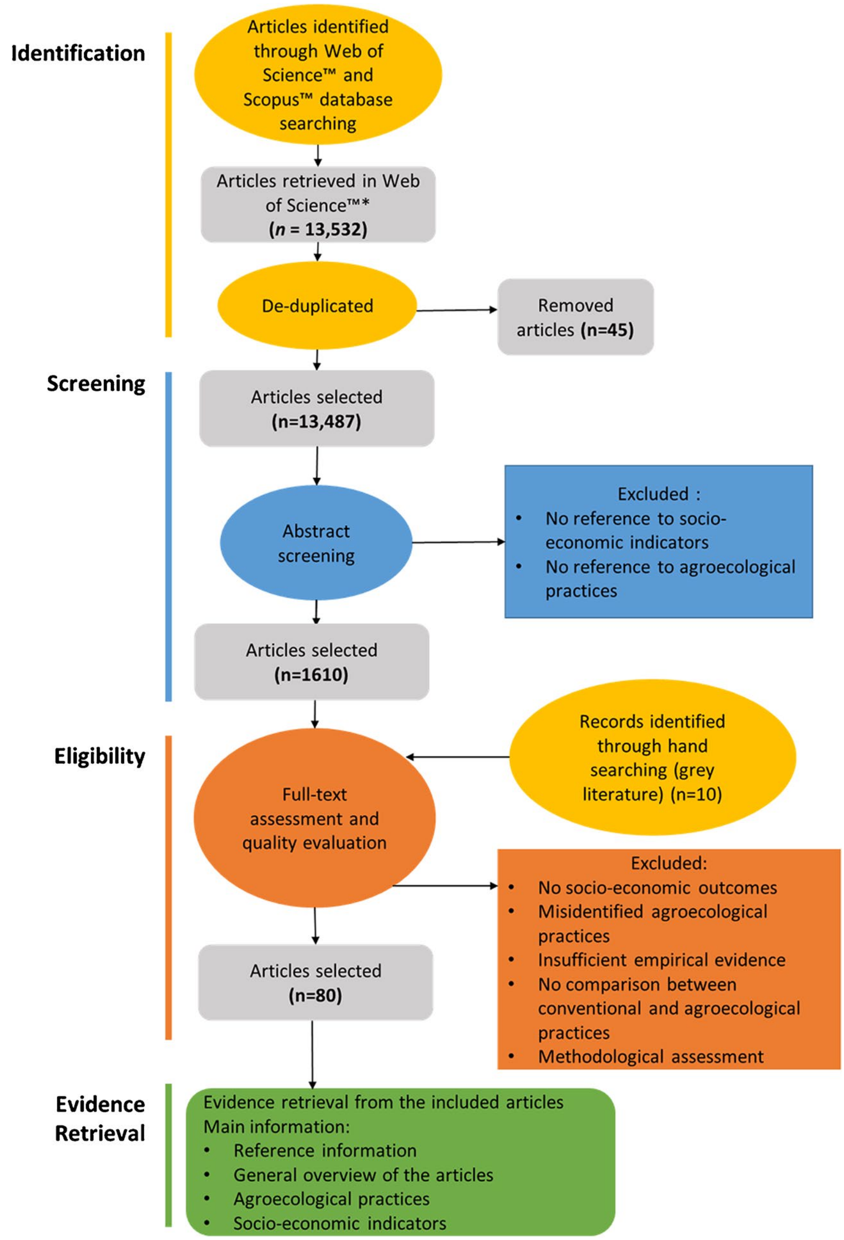

Fig. 1 PRISMA-RR flow diagram representing the stepwise process of the rapid review. The protocol is composed of the four main phases of literature identification, abstract screening, eligibility, and evidence retrieval.

Table 3 Search string and literature sources used for the rapid review.

Search string	Literature databases and online repositories searched
((agroecolog* OR agro-ecolog* OR 'diversified farming system' OR 'diversified cropping system' OR 'ecological agriculture' OR 'organic agriculture' OR agrobiodivers* OR agro-biodivers* OR 'regenerative agriculture' OR 'agroforestry' OR 'crop diversification' OR 'diversified crop rotation' OR 'intercropping' OR 'mixed farming' OR 'mixed cropping') AND ('income' OR cost* OR profit* OR econom* OR 'livelihood' OR 'employment' OR 'labour' OR 'labor' OR 'capital' OR 'investment' OR 'revenue'))	• Clarivate Web of Science™ Core Collection • Elsevier Scopus™ • Online repositories (websites), for example: - FAO - SOCLA - Agroecology Europe - Agroecology Fund - McKnight Foundation - IPES-Food - The 15 CGIAR institutes (e.g. Bioversity International-CIAT Alliance, ILRI, World Agroforestry Centre, IITA) - IDDRI

Table 4 Inclusion and exclusion criteria for the abstract screening phase.

Inclusion criteria	Exclusion criteria
Published between the year 2000 and March 2022	Not published between the year 2000 and March 2022
Includes agroecological practices	Does not include agroecological practices
Refers to socio-economic outcomes	Does not refer to socio-economic outcomes
Does not report only simple productivity indicators (i.e. yield) as main results	Reports only productivity indicators (i.e. yield) as main results
Peer-reviewed article or PhD dissertation/thesis or academic book or report from a nationally or internationally recognised institution (grey literature): (a) Institution has track record of research (b) Institution has expertise in subject area (c) Institution has no track record of falsified or dishonest research	Study is not peer-reviewed (e.g. conference proceedings) or it does not come from a nationally or internationally recognised institution (a) Institution has no track record of research (b) The institution has no expertise in subject area (c) Institution has track record of falsified or dishonest research
Full text accessible	Full text not accessible
Text in English, French, German, Spanish, or Portuguese	Text not in English, French, German, Spanish, or Portuguese

or organic contentious inputs, transitioning systems might still require a reduced use of agrochemicals, especially in case of farmers' perception of emergency such as unexpected pest outbreaks (Migliorini et al. 2020). In addition, it should be considered that in resource-limited zones where pedoclimatic conditions are particularly constraining, like many areas of sub-Saharan Africa, a regular application of reduced doses of synthetic fertilisers may be required to complement the role of agroecological practices in sustaining agricultural production (Falconnier et al. 2023). Details on the conventional and agroecological practices that have been compared can be seen in the Supplementary Materials.

(ii) Evaluation of socio-economic outcomes

We excluded articles that did not provide any indication on the socio-economic outcomes of the application of agroecological practices. In addition, we excluded articles where the socio-economic outcomes mentioned were not measured or quantitatively specified. Articles that contained a socio-economic analysis of the performance of agroecological practices but no identifiable comparison between the agroecological practices and a conventional counterpart were also excluded.

(iii) Relevance of the methodological approach

Here, we considered the methodology used to determine the socio-economic outcomes of agroecological practices. We classified the methods of data testing in the articles into a gradient ranging from 'real environment' to 'controlled environment'. Controlled environment articles, such as on-station experiments, on-farm experiments conducted by researchers only, and scenario modelling, were excluded. Instead, we included articles with on-farm actual implementation and on-farm intervention studies, because they involve the participation of the farmer on his/her actual farm and are, thus, closer to real-life farming situations.

(iv) Methodological clarity and sample size

In this phase, articles were excluded if the study design and research methods were not clearly described and/or the study sample was small (less than five farms).

The whole eligibility phase led to the selection of 80 relevant articles that were subjected to the evidence retrieval phase.

2.2.4 Evidence retrieval phase

This phase aimed at retrieving the relevant evidence on the socio-economic performance of the use of agroecological practices. First, all the selected articles were included in a synoptic table of a dedicated Excel database with the following information: reference information, a general overview of the context and scale of the articles (i.e. country, region, crops used, management system, the scale of the study), the agroecological practices applied, the socio-economic subthemes used, and the methodological approach. In terms of scale, considering the farmer as a central actor, we focused at farm-level analysis, but also included results at other levels identified during the course of the review.

The methodological approach specified the type of implementation of agroecological practices (on-farm actual implementation *vs* on-farm intervention study), as well as the approach of data collection (survey *vs* observations *vs* statistical data) and analysis (budgeting techniques *vs* econometric modelling). We classified studies for which the authors mentioned any intervention in the set-up and implementation of the practices as 'on-farm intervention' studies and all others as 'on-farm actual implementation'. Survey-based studies are those that rely mostly on the collection of primary data typically via interviews with farmers using semi-structured questionnaires. Studies relying on observations refer to those where the data were collected directly from researchers on the farm via own measurements and/or less structured exchange with the farmers (e.g. focus groups). Studies based on statistical data rely on large-scale existing databases of farm data (e.g. Farm Accountancy Data Network). Survey-based approaches may benefit from observations in addition to the data collected via the survey and all three approaches are often complemented by secondary data. Such supplementary approaches have not been noted explicitly in the evidence retrieval phase, where we focused on noting the core approach of data collection, but they are standard in many of the studies. Studies using budgeting techniques focus on the calculation of standard economic indicators (e.g. revenues, incomes, productivity), while the other category of studies uses econometric modelling approaches to investigate the effect of agroecological practice adoption on economic indicators.

Second, the socio-economic outcomes from the articles were entered into the database by noting the socio-economic metric(s) measured in the article. Each combination of country (in case articles referred to several countries), agroecological practice, and socio-economic metric referred to in an article was separately noted. In articles using mixed-method approaches, we only retrieved information that was produced by the methods described in Section 2.2.3 (iii) (i.e. on-farm actual implementation and on-farm intervention studies), as far as the description of the employed methods allowed us to distinguish. For example, in studies where results were produced via survey-based actual data collection and analysis, as well as simulation modelling, we retrieved only the results from the former type of analysis. The outcomes analysed in this review encompass both metrics that were statistically tested for significance and metrics that were not tested. For each individual socio-economic outcome, we specify whether the result has been subject to statistical significance tests or not.

These outcomes were then classified into ‘positive’, ‘negative’, ‘neutral’, or ‘inconclusive’. ‘Positive’ outcomes are those for which the agroecological practice resulted in a better outcome for the specific socio-economic metric in comparison to a conventional practice (e.g. higher revenue, lower costs). Not surprisingly, depending on the different setups of the individual studies, the reference for conventional practices varied, yet typically, we refer to practices representing the least diverse system and/or with the higher use of inorganic inputs (see the Supplementary Materials for details). Conversely, negative outcomes are those with worse socio-economic outcomes of the agroecological practice in comparison to a conventional one (e.g. lower revenue, higher costs). The ‘neutral’ outcomes are those for which no significant differences were observed between the agroecological practice and the conventional counterpart. These outcomes are frequent in the case of results that have been evaluated with statistical significance tests. An ‘inconclusive’ outcome is one where several contrasting results (positive, negative, and/or neutral) are reported between the agroecological practice performance and that of the conventional counterpart, due, for example, to year-to-year variations, contrasting results in different areas, and/or slight variations of agroecological practices (e.g. size of homegarden, degree of shade in shaded plantations). For cases that the outcome was always positive/negative but this result was not always statistically significant, these cases were still classified as positive/negative in order to avoid a large number of inconclusive outcomes.

3 Results

3.1 Characteristics of reviewed studies

In total, 80 articles have been included in the final review analysis, of which 79 are peer-reviewed scientific publications and one is a report. Nineteen percent of the articles were published between 2000 and 2010 and the remaining 81% between 2011 and March 2022. More than half of the articles (55%) were published from 2015 onwards, demonstrating the growing literature associated with the topic of this review. Regarding the geographical location, the vast majority of studies presented in the reviewed articles were conducted in countries of the Global South. Specifically, 43% of the studies took place in Asia, 41% in Africa, and 13% in central or South America. Only 3% of the studies were conducted in countries of the Global North (two studies in Europe and one study in the USA).

Regarding the typology of the implementation of agroecological practices, the majority of the 80 articles analysed were actual on-farm implementations (64%) and the rest (36%) were on-farm intervention studies conducted together with farmers. The economic data collection was in the vast majority of studies survey-based (70%), followed by studies relying on recordings of observations by farmers and researchers (28%) and a very small number of studies based entirely on secondary data (2%). Most studies used budgeting techniques for the estimation of economic metrics across practices (88%), while fewer studies used econometric modelling (7%) or both (5%).

Regarding the evaluated agroecological practices when an article evaluated more than one practice or crop or performed a study in more than one country, then each practice was counted separately, such that in total, we counted 125 cases of agroecological practices in the 80 articles. Almost half of the assessed cases are related to agroforestry (43%) (Table 5). Agroforestry practices represent a very broad group, in which the most common was silvoarable practices. Other agroforestry practices recorded were silvopastoral and homegardening. Intercropping practices are the second type of practices evaluated most often (19%). Cropping system diversification practices account for 10% of cases, including crop diversification, diversified crop rotations, improved fallow, and crop-livestock integration. Tillage practices, i.e. no-tillage and reduced tillage, correspond to 7% of cases. The management of landscape elements, including practices like hedgerows, windbreaks and living fences, stones walls, and terracing, accounts for 6% of cases. Organic fertilisation practices represent 4% of cases, including practices dealing with applications of manure, compost, zai pits, and mixed organic fertilisers. Cover crop and mulching practices are associated with fewer cases (3%), as do pest and disease management practices (2%) which focused on push-pull strategies. Finally, 6% of cases are associated with the application of packages of practices related to organic farming, sustainable rice intensification, agroecological farming, and climate change adaptation strategies. As mentioned above, the vast majority of the agroecological practices investigated are from studies in the Global South. The three studies conducted in the Global North are dealing with two cases in Europe investigating crop diversification and no tillage and one case in the USA on grassland management.

3.2 Socio-economic outcomes explored in the reviewed articles

Overall, we identified 577 outcomes corresponding to the 125 assessed cases in the 80 articles. The vast majority of socio-economic outcomes assessed are associated with metrics that belong to the financial capital category (83%) (Figure 2). A smaller proportion belongs to the human capital category (16%), whereas a marginal number of metrics belong to social capital (1%). Out of these metrics, 64% were not statistically tested for significance in the respective articles.

Out of the total metrics assessed under the financial capital category (477), most of the metrics refer to income (29%, e.g. net present value, net income, gross margin), production costs (23%, e.g. operating costs, input costs), efficiency and productivity (23%, e.g. yield, benefit-cost ratio), and revenue (15%, e.g. gross revenue, value of products). Fewer outcomes relate to capital and investment returns (6%), autonomy (2%), income stability (2%), and product value (< 1% with only one metric reported). Within the total metrics assessed under the human capital category (94), the great majority relates to labour requirements (65%, e.g. labour costs, hours of labour) followed by returns to labour (35%, e.g. labour productivity). The metrics assessed under the social capital category (6), relate to infrastructure and resources. No quantitative information was found on several sub-themes previously identified as relevant to the evaluation of the socio-economic performance of agroecology, i.e. employment opportunities, working conditions, gender equity, market access, and marketing chain characteristics.

The results indicate that 51% of the metrics analysed are associated with positive outcomes, 30% with negative outcomes, 10% with neutral outcomes, and 9% with inconclusive ones over the broad spectrum of evaluated themes.

Under the financial capital category, more than half of the outcomes (53%) are positive for agroecological practices in comparison to conventional ones. Negative outcomes are equal to 27%, neutral ones to 10%, and inconclusive ones to 10%. A large number of metrics indicate positive outcomes with respect to aspects of income and efficiency/productivity (60% and 56% of positive outcomes *vs* 20% and 18% of negative ones, respectively). Revenues and income stability are also mostly positively affected in a majority of cases (54% and 78% of positive outcomes *vs* 26% and 22% of negative ones, respectively). Production costs have a higher share of negative outcomes but with still higher positive outcomes over negative (46% *vs* 40%). Capital and investment returns and autonomy are associated with an equal number of positive and negative outcomes (45% and 13%, respectively). Autonomy, which is admittedly hard to quantify, is associated with a high share of neutral and inconclusive outcomes (50% and 25%, respectively). Finally, product value was hardly mentioned, but found to be associated with a neutral outcome in the only instance found.

In contrast to the financial capital category, within the human capital category, almost half of the outcomes for agroecological practices in comparison to conventional ones are negative (46%). Positive outcomes represent 38% of the total, neutral outcomes 7%, and inconclusive outcomes 9%. These results are explained mainly by higher labour requirements and costs, which is the only sub-theme for which negative outcomes are more than the positive ones (51% of negative *vs* 30% of positive outcomes). Return to labour showed higher positive outcomes compared to negative ones (55% and 36%, respectively).

Finally, under the social capital category representing infrastructure and resources, half of the outcomes (3 outcomes) were found neutral, 17% positive (1 outcome) and 33% negative (2 outcomes).

3.3 Socio-economic outcomes per agroecological practice

3.3.1 Overview across practices

The results on the socio-economic performance of agroecology vary significantly depending on the evaluated practice (Table 6). More than half of the outcomes are positive for the two most often evaluated management practices, i.e. agroforestry and intercropping. These practices are associated with 53% of positive outcomes versus 26% and 36% of negative outcomes, respectively. The outcomes are predominantly positive for tillage management (58% positive outcomes), cover crop and mulching (58% positive outcomes), and pest and disease management (67% positive

Table 5 Number of cases assessed per agroecological practice.

Type of management category	Agroecological practice	Number of cases
Agroforestry	Silvoarable	44
	Silvopastoral	3
	Homegarden	7
Intercropping	Intercropping	23
Cropping system diversification	Crop diversification	5
	Diversified crop rotation	4
	Improved fallow	2
	Crop-livestock integration, grassland management	2
Organic fertilisation	Mixed organic fertilisation	1
	Manure	1
	Zai/planting pits	2
	Compost	1
Pest and disease management	Push-pull strategies	3
Cover crop and mulching	Green manure	3
	Mulching	1
Tillage management	No tillage	7
	Reduced tillage	2
Management of landscape elements	Hedgerows, windbreaks, and living fences	6
	Stone wall/terracing	1
Package of practices	Sustainable rice intensification	3
	Organic farming	2
	Adaptation strategies	1
	Agroecological farming	1
Total		125

outcomes). For cropping system diversification, positive and negative outcomes are almost the same (35% vs 33%, respectively). A large share of neutral and inconclusive outcomes is observed for this category (32% for both combined). Negative outcomes are more frequent than positive ones in the case of organic fertilisation (51% negative *vs* 43% positive). The management of landscape elements and the package of practices are characterised by a large share of neutral and inconclusive outcomes (44% combined for the former practice and 53% for the package of practices). We note that for some of the practices, a limited number of metrics are evaluated rendering the associated results uncertain.

3.3.2 Agroforestry

Overall, 53% of the socio-economic outcomes evaluated for agroforestry are positive (118 outcomes), 26% are negative (59 outcomes), 11% are neutral (25 outcomes), and 10% inconclusive (22 outcomes) (Table 6).

Looking at the financial capital sub-themes, income is associated with 67% of positive outcomes, 19% negative, 9% neutral, and 5% inconclusive (Fig. 3). For example, in the Philippines, different agroforestry planting practices (hedgerow, block planting, and parkland) resulted in higher incomes compared to the usual annual cropping system with continuous maize, tomato or both, primarily due to the high input requirements of the conventional annual cropping systems (Magcale-Macandog et al. 2010). As another example, in China, agroforestry practices with *Coptis teeta* and *Toxicodendron vernicifluum* trees on different arable crop fields generated higher net annual income compared to the swidden practice (Huang and Long 2007). Efficiency and productivity outcomes are associated with 59% positive evaluations, 14% negative ones, 21% neutral, and 7% inconclusive. In an example from India, the teak-based agroforestry practice under irrigated ecosystems yielded higher benefit-cost ratios than the conventional control practice (Chittapur et al. 2020). Revenues are associated with a positive outcome in half of the cases (50%), a negative outcome in slightly more than a quarter of the cases (27%), and the other quarter spread between neutral and inconclusive outcomes (7% and 17%, respectively). Production costs are affected negatively in 43% of cases, positively in 40%, in a neutral way in 6% of cases, and in an inconclusive way in the remaining 11%. For example, the tree cropping and border cropping agroforestry practices in Pakistan had higher production costs for establishing trees compared to the conventional farming system (Abbas et al. 2021). Capital

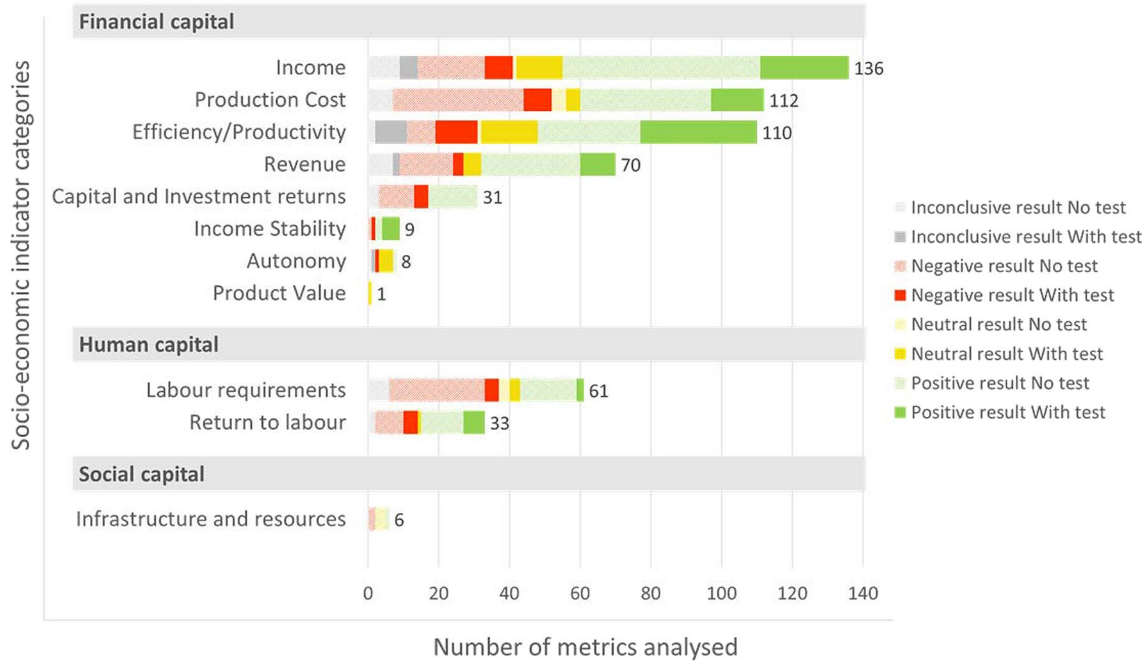

Fig. 2 Type of outcomes retrieved from the articles structured according to capital categories and socio-economic sub-themes. The numbers next to the bars indicate the total number of times we evaluated a metric grouped under the corresponding sub-theme. They include (i) identical metrics encountered across different studies (e.g. 'gross margin' encountered in two different studies is counted as two instances under 'income') and (ii) different metrics encountered in the same study or in several different studies (e.g. 'gross margin' in one study and 'net income' in the same or a different study are counted as two instances).

and investment returns have 61% positive outcomes; e.g. as reported by Owusu et al. (2021) and Nunoo and Owusu (2017), cacao under agroforestry (shaded cacao) had a higher internal rate of return and net cash flow over a cacao system without agroforestry.

With respect to the human capital sub-themes, labour requirements are related to 45% positive outcomes over 35% negative ones, while return to labour to 50% positive outcomes as opposed to 25% negative and 25% inconclusive ones (only 4 metrics reported in total). For instance, de Souza et al. (2012) report a higher number of workers and higher labour cost needed for managing coffee under agroforestry compared to conventional coffee grown under direct sun (sun-coffee) and an inconclusive outcome on the gross margin per person depending on the investigated farm. Finally, the few identified social capital metrics relating to infrastructure and resources correspond to one positive outcome, two negative outcomes, and three neutral ones.

Table 6 Socio-economic outcomes within each type of management category.

Type of management category or sub-category	Evaluated metrics	Related articles	Tested for significance	Positive	Neutral	Negative	Inconclusive
	Absolute numbers		% of outcomes				
Agroforestry*	224	38	17	53	11	26	10
Intercropping	126	18	55	53	6	36	5
Tillage management	60	8	42	58	2	28	12
Cropping system diversification	52	12	58	35	11	33	21
Organic fertilisation	35	4	29	43	6	51	0
Pest and disease management	15	3	73	67	13	20	0
Cover crop and mulching	24	2	4	58	13	29	0
Management of landscape elements	9	2	22	34	22	22	22
Package of practices	32	6	63	38	34	9	19

3.3.3 Intercropping

For intercropping, 53% of the socio-economic outcomes are reported as positive (67 outcomes), 36% negative (46 outcomes), 6% neutral (7 outcomes), and 5% inconclusive (6 outcomes) (Table 6).

Under the financial capital category, income is related to 68% positive outcomes, 16% negative, 8% neutral, and 8% inconclusive (Fig. 4). Revenue is associated with 62% positive outcomes, 23% negative ones, 8% neutral, and 8% inconclusive. For example, in Malawi, the intercropping practice with a maize-legume system generated a better gross margin (705 US$ over 344 US$), total revenue (1073 US$ over 689 US$), gross benefits (980 US$/ha over 529 US$/ha), and net returns (497 US$/ha over 131 US$/ha) compared to the conventional monocropping system (Ngwira et al. 2012). However, contrasting results were observed in Mozambique, where intercropping maize with watermelon had higher monetary value compared to sole maize but lower monetary value when compared to sole watermelon (Munisse et al. 2012). The productivity and efficiency sub-theme has slightly more than half (52%) of positive outcomes, 28% negative outcomes, 10% neutral, and 10% inconclusive. Regarding production costs, 61% of the outcomes are positive and 39% negative.

Considering the human capital sub-themes, we see that labour requirements are associated with a considerably large share of negative outcomes (82%). For example, Hougni et al. (2018) report that rubber and rice intercropping needs more family and total labour-day per hectare compared to the conventional monocropping system. Return to labour has 50% positive outcomes, 42% negative ones, and 8% neutral. In Vietnam, the intercropping of pepper produced higher profit per family labour compared to monocropping practices (Thuy et al. 2018), and in Malawi, it yielded a higher return to labour in two different areas of implementation (Ngwira et al. 2012).

3.3.4 Other agroecological management categories

For the remainder of agroecological practices, less than ten instances were found for the majority of sub-themes. These findings are therefore highly uncertain and not presented in detail here. Nevertheless, we present a summary of the breakdown of positive and negative metrics reporting the number of associated metrics as opposed to percentages. Figure S1 in the Supplementary Materials depicts the numbers of outcomes for the practices analysed in this section.

For tillage management, referring to non-inversion tillage practices, we identified 58% positive outcomes (35 metrics), 28% negative (17 metrics), 2% neutral (1 metric), and 12% inconclusive (7 metrics). The positive outcomes were mainly associated with efficiency and productivity (12 metrics), income (6 metrics), and revenue (5 metrics). For example, in Zimbabwe, the hand-hoe planting basins compared to conventional tillage resulted in higher revenue (441 US$ over 273 US$) and higher yields (1603 kg over 991 kg) (Nyamangara et al. 2014). Another example from Malawi showed higher yield and higher total revenues and gross margin for no-tillage maize cropping compared to the use of traditional tillage (Ngwira et al. 2012). Most negative incomes regarding tillage management were associated with production costs (8 metrics).

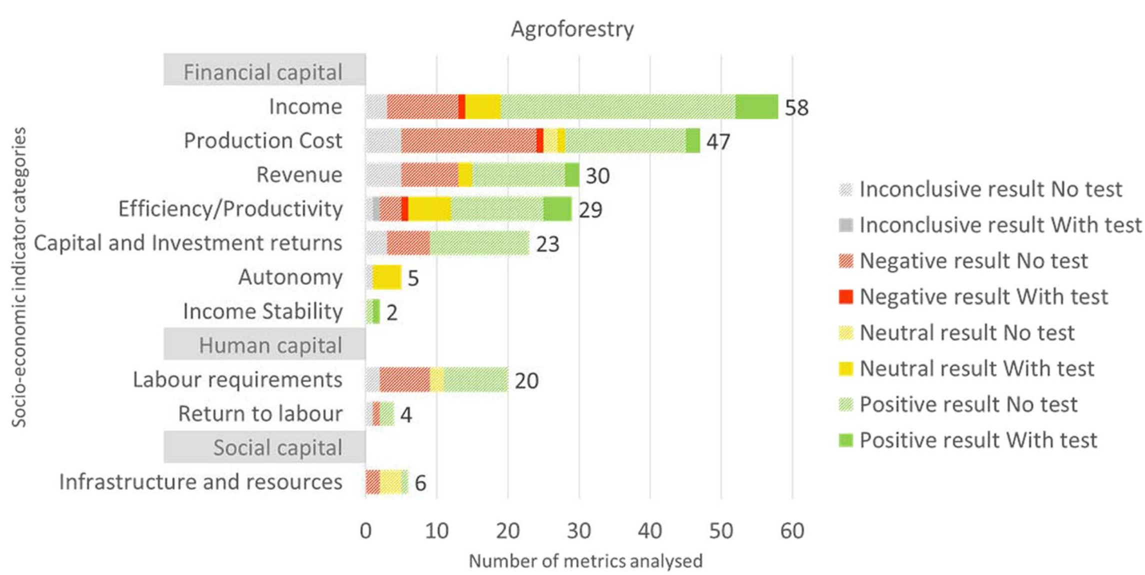

Fig. 3 Type of outcomes retrieved from the articles on agroforestry practices structured according to socio-economic sub-themes. The numbers indicate the total number of evaluated metrics per sub-theme.

The socio-economic outcomes of cropping system diversification practices show positive outcomes for 35% of the evaluations (18 outcomes), 33% negative (17 outcomes), 12% neutral (6 outcomes), and 21% inconclusive (11 outcomes). The positive outcomes relate mostly to production costs (6 metrics) and income (5 metrics), as well as efficiency and productivity (5 metrics). For example, in India, sustainable rice intensification combined with a rotation with pea generated higher net returns and benefit-cost ratio when compared to a rotation with fallow (Das et al. 2017). In Malawi, a diversified rotation with groundnut and pigeon pea in a maize-based system reported lower total input costs and total costs than continuous maize monocropping (John et al. 2021). The majority of negative outcomes were associated with income and capital and investment returns (4 metrics each).

Organic fertilisation practices showed more negative than positive outcomes (51% and 43% representing 18 and 15 metrics respectively) and 6% neutral (2 metrics). Most positive outcomes related to the human capital category, including return to labour (4 metrics) and labour requirements (3 metrics). Most negative impacts were related to efficiency and productivity (4 metrics). In an example in Kenya, using manure in indigenous vegetable farms generated lower gross output compared to using diammonium phosphate as fertiliser (Kurgat et al. 2018). Schuler et al. (2016) report that, in Burkina Faso, the use of zai pits offered higher yields and positive outcomes for gross production value, gross margins, and return to labour, whereas total variable production costs were negatively impacted.

Pest and disease management practices via push-pull strategies are related to 67% positive (10 metrics), 20% negative (3 metrics), and 13% neutral (2 metrics) outcomes. For example, in Nigeria, the push-pull strategy for *Striga hermonthica* control had higher yields and positive outcomes for gross margins, outputs, and purchased costs yet higher labour requirements compared to the monoculture maize system practiced among farmers (Kamara et al. 2008).

The socio-economic outcomes of cover crop and mulching practices (2 papers) showed 58% positive outcomes (14 metrics), 29% negative outcomes (7 metrics), and 13% neutral outcomes (3 metrics). Most positive outcomes were related to efficiency and productivity and production costs (4 metrics each) and most negative metrics related to labour requirements (3 metrics).

The management of landscape elements shows very similar results across positive (3 metrics), negative, neutral, and inconclusive metrics (2 metrics each). For instance, in a study in the Kyrgyz Republic, a windbreak system under different crops resulted in positive or negative outcomes for net present value compared to a system without windbreaks depending on the crop involved (Thevs et al. 2021), whereas in a study in Myanmar, the terracing system under different Wa-u cultivation methods compared to swidden agriculture resulted in higher production costs (Chan and Takeda 2019).

3.3.5 Packages of practices

Regarding the packages of practices, results are spread between 38% positive (12 metrics), 9% negative (3 metrics), 34% neutral (11 metrics), and 19% inconclusive (6 metrics) outcomes. As one example, Panneerselvam et al. (2010) report that, in India, input costs under organic farming practices performed positively over conventional practices for

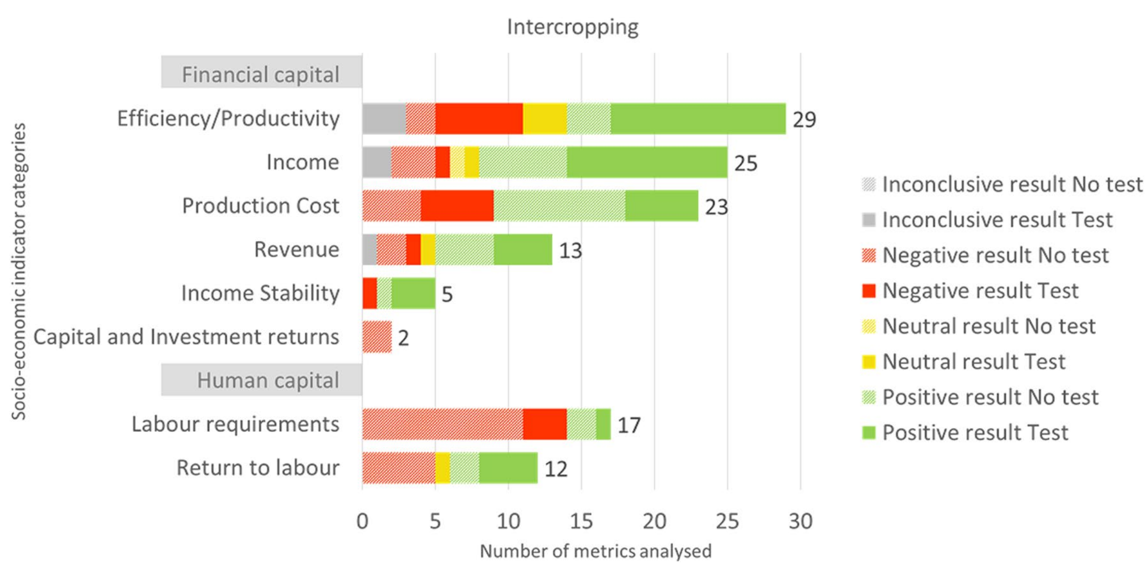

Fig. 4 Type of outcomes retrieved from the articles on agroforestry practices structured according to socio-economic sub-themes. The numbers indicate the total number of evaluated metrics per sub-theme.

different crops whereas yields, net margin, and gross margin were reported with neutral or inconclusive outcomes because of no significant difference with conventional practices or contrasting results between states. Under sustainable rice intensification, for example, in India, yield, gross returns, and net returns were all reported with positive outcomes, whereas total production costs as a negative outcome (Balamatti and Uphoff 2017). Similar results were found by (Das et al. 2018). Under climate change adaptation strategies, farmers in Ethiopia applied combined practices (intercropping, adjusted date planting, changing crop varieties, crop rotation, and minimum tillage), which resulted in a positive net present value compared to non-adopters (Tilahun 2021).

4 Discussion

4.1 Socio-economic outcomes and further research

This review provides important insights on the socio-economic performance of agroecology at the global level, by focusing on agroecological practices across a large number of case studies and socio-economic indicators. Our finding that agroecological practices are more often associated with positive socio-economic outcomes (51% positive outcomes, 30% negative, 10% neutral, 9% inconclusive) is supported by previous studies (D'Annolfo et al. 2015; Paracchini et al. 2020; Stratton et al. 2021; Paracchini et al. 2022) that suggest potential win-win outcomes from agroecological farming measured by ecological and socio-economic indicators.

With respect to the different capital categories, we observed that the financial capital category was by far the most assessed one (83% of the total number of metrics), followed by the human and social capital categories (16% and 1%, respectively). No metrics were identified for several socio-economic indicators considered relevant such as market access, marketing chains, employment opportunities, working conditions, and gender equity. These findings are in line with previous studies which show that social and human capital indicators are likely to be less investigated (D'Annolfo et al. 2017) and that most papers considering socio-economic benefits focus on evaluating productivity while results seldom include quantified information on social aspects (Paracchini et al. 2020). The above imply that in studies evaluating the performance of agroecological practices, important indicators are often omitted if they are hard to quantify and/or they pertain to social science research. In consequence, we highlight the need for further research to embed the knowledge generated from social science research on a large set of concepts related to the agroecological transition (Ong and Liao 2020) and to embark on wider systemic studies which require longer research periods and more intensive data collection (D'Annolfo et al. 2017).

Our results related to the financial capital category indicate, similarly to Altieri (1999) and Chappell and Bernhart (2018), that higher productivity and efficiency are often mirrored by improvements in income (56% and 60% positive outcomes for these sub-themes, respectively). Further, we found that agroecological practices are often associated with higher production costs (40% negative *vs* 46% positive outcomes). This is often due to additional establishment costs as, for example, in the case of agroforestry (e.g. Rahman et al. 2007) or additional crop production costs as in the case of intercrops (e.g. Ijaz et al. 2014). The study of Chappell and Bernhart (2018) also demonstrate higher production costs for agroecological practices, adding that conventional farmers' expenses relate mostly to seeds, fertilisers, and pesticides but that agroecological farmers may face more important expenses for commercialisation and marketing due to an increased effort of multiplying sales networks and marketing channels (Dumont et al. 2016). Despite those efforts, better valorisation of agroecological products on markets could translate into higher economic benefits (van der Ploeg et al. 2019).

In the human capital category, our results suggest that agroecological practices tend to be more labour demanding (51% of negative *vs* 30% of positive outcomes). For example, homegarden farming does not require intensive labour input at a specific time; however, it involves continuous maintenance and monitoring all year round (Ali 2005). This perspective is also discussed in previous studies, which suggest that although agroecological practices often need more labour, they also relate to more job opportunities and development in rural areas (van der Ploeg et al. 2019). Transforming the labour demand under agroecological innovation into attractive jobs and sufficient livelihoods remains a challenge that calls for integration with social programmes (Tittonell et al. 2020). With respect to return to labour, outcomes showed a better performance compared to labour requirements (55% of positive vs 36% of negative outcomes). This is in agreement with the observation of Sánchez et al. (2022) that diversified farming systems, strongly promoted under agroecology, are associated with higher labour costs but also higher gross income, thus resulting in farm profits equivalent to those of simplified systems.

An important issue is that the socio-economic effects of agroecological practices aiming at improving ecosystem functionality (e.g. providing nesting sites for pollinators, enhancing soil functionality) are typically not measured and accounted for. Yet, such practices show positive effects by creating an optimal environment to maximize ecosystem services and biodiversity conservation with minimal cost for farmers (Segre et al. 2019). Further, the findings with neutral outcomes can be seen favourably since the socio-economic performance of these practices is not significantly different from conventional ones, while they potentially provide positive effects in terms of environmental benefits and well-being (Milheiras et al. 2022). Internalising in economic terms the benefits provided by agroecological practices via the provision of ecosystem services, biodiversity, and overall improvement of agroecosystem health would further accentuate the prevalence of positive outcomes.

This review is focusing on summarising the direction of change when comparing agroecological practices to non-agroecological ones. However, other information such as the magnitude and certainty associated with this change is also important. This is a promising research avenue to support individual households in identifying the transition pathway that is most suitable to the socio-economic reality in which they are embedded. Inconclusive socio-economic outcomes indicate, in fact, that the effect of the implementation of the same agroecological practice can differ across different locations (e.g. Ali 2005) or years (e.g. TerAvest et al. 2019). Also, the exact implementation of a practice and the structural and institutional contexts of a farm matter. For example, Nunoo and Owusu (2017) find that the effects of shaded cocoa agroforestry systems on income and costs can be positive or negative depending on the shade level. Frey et al. (2012) show different effects of silvopastoral systems on revenues and labour requirements depending on the size of the enterprise. Lojka et al. (2007) show that labour requirements are higher in the years of establishing a practice but lower for the following years. Consequently, a better understanding of the diversity of conditions and contexts under which agroecology enhances the socio-economic performance of farming systems is required. Relevant aspects to be investigated are the sign and magnitude of the socio-economic effect depending on the location or structural characteristics of farms, the temporal dimension of the transition, the level of participation of the farmer in its design and implementation, and the anticipated effects of spatial and temporal variability.

4.2 Balancing trade-offs between socio-economic indicators

In our study, the trade-offs between socio-economic indicators were not systematically analysed, mainly due to the difficulty in comparing different metrics and measurement approaches across studies and the limited information on trade-offs within the individual studies. Other studies also report that the trade-offs in the socio-economic performance of agroecological practices have been poorly studied (Garibaldi et al. 2016; D'Annolfo et al. 2017). Nevertheless, some common trends emerged.

A trade-off often observed was between the negative outcome related to production costs despite a positive final net return (e.g. Kamara et al. 2008; Mekonnen et al. 2021). Production costs were associated with more positive, as opposed to negative, outcomes, but this was not the case for several of the explored cases and the effects are not uniform across the different phases of the transition. For example, establishing ecological infrastructure on the farm (e.g. living fences, hedges, grass strips, insect habitats) tends to be costly in the first 3–5 years during the redesign phase, but after the key ecological services and processes are in motion, the need for external inputs is reduced due to the increase of functional biodiversity in the farm and maintenance costs also decrease (Nicholls and Altieri 2016). Also, despite observed higher costs for certain agroecological practices, higher productivity and higher valuation of products under agroecological practices often result in more profitable practices (Grémillet and Fosse 2020). Nevertheless, depending on the farming context in different parts of the world, higher costs at the beginning of the growing period (e.g. for seeds, organic fertilisers, or other inputs) or significant establishment costs (e.g. for agroforestry systems or landscape elements) may render the uptake of associated agroecological practices infeasible for farmers with no access to cash or credit.

Another trade-off observed in the articles is the contrasting result between productivity and the capital and investment returns. Although the overall result within both showed higher positive outcomes, some papers reported contrasting results. For example, in Bangladesh, agroforestry generated higher yields and a higher benefit-cost ratio, yet a lower internal rate of return and a longer payback period (Rahman et al. 2007). Moreover, the organic fertilisation practice compared to inorganic fertilisation in another study in Bangladesh resulted in the same contrasting outcomes of higher output expressed in physical terms (kg/ha) yet lower farm capital expressed in monetary terms (Taka/ha) (Salam et al. 2021).

A further example is an increase in yields and land productivity at the field level, accompanied by improved farm incomes and labour productivity but also higher labour requirements at the farm level. For instance, Schuler et al. (2016) report a case where the zaï farming practice for millet production in northern Burkina Faso results in increased millet yields, higher gross margins, higher labour productivity, and even lower production costs, but is associated with higher labour requirements. Ultimately, despite several positive outcomes in a number of metrics, the feasibility of adopting this practice may depend on the labour endowments of individual households.

Hence, balancing trade-offs across temporal and spatial scales and considering farmers' objectives and conditions are important conditions for ensuring practices are economically sustainable and feasible. As the agroecological transformation can be a lengthy process, it comes as no surprise that farms in transition may struggle to manage the temporal mismatch between costs and benefits and to deal with multiple dimensions of ecological complexity on the farm. The struggle during transition can lead to work difficulties and reduced profits (Stratton et al. 2021). It is therefore evident that to reduce risks, the transition period needs to be supported. Despite the fact that many countries consider agroecology as promising in theory, support actions via large policy shifts, and national or multinational policy frameworks remain rare (Ewert et al. 2023). Given the wide variety of departing farming and farm household conditions, policy support may cover different aspects including an efficient network of extension services, increased farmer-to-farmer exchanges, responsible governance mechanisms at different scales, contributions from science, and an enabling policy environment providing subsidies to assist farmers to cover extra-costs and losses in the transition period.

An in-depth analysis of socio-economic metrics can improve the targeting of policy measures. For example, the analysis of negative outcomes may identify potential bottlenecks towards a wider adoption of agroecological practices and directly point to the need for tailored support. Since there is a high share of case specificities, only general recommendations can be drawn and the most evident concerns labour requirements. A potential solution, and an interesting future research direction, is based on the evaluation of supporting mechanisation and digitalisation in reducing labour requirements in agroecological settings. Another avenue is to support farmers with payments in the early years of the transition if there is evidence of income forgone associated with lower productivity and yields and/or the need for upfront investments. In a Global South context, positive outcomes of agroecological practices enhancing soil productivity may call for a direct support of such practices. Another example is indicators describing the value chain, which may point to the need to support farmers through public food procurement programmes (Nicholls and Altieri 2018) or improving access to markets, which are critical nodes in enhancing viability of agroecological farming.

Analysis of the trade-offs between socio-economic and environmental indicators is beyond the scope of this study; however, we can expect that these situations exist and may not be rare. Systemic assessment of the pros and cons of agroecological *vs* conventional cropping and farming systems as seen from the lenses of all three sustainability pillars is seldom done, due to the complexity of such studies (Affholder et al. 2019), yet such an approach would be important to fully understand upon which conditions agroecology can fully unravel its potential.

4.3 Challenges in evaluating socio-economic outcomes

In course of this review, we identified recurring challenges in comparing socio-economic aspects of agroecological and conventional practices. First, the socio-economic evaluation methodologies and the agroecological practices varied considerably depending on the specific objective and focus of the different articles. The objectives ranged from e.g. determining the profitability of the farm-level transition by using crop residues as fodder and manure as fertilisers (Kurgat et al. 2018) to comparing the feasibility of different agroforestry systems such as hedgerows and scattered or field border planting (Magcale-Macandog et al. 2010). These aspects emphasise the diversity and multiple goals of agroecological practice management, yet pose challenges in covering and comparing the implementation and development of different practices (Martinelli et al. 2019). In addition, some articles have clearly shown how different management aspects, particularly the selection of crop species/varieties or the planting date, can affect final socio-economic results (Kuntashula et al. 2004; Srinivasa Rao et al. 2012; Sogoba et al. 2020; Severini et al. 2021).

The socio-economic evaluation methodologies also differed substantially regarding the metrics assessed, the units of measurement, and the quantification approaches. Themes of investigation included varied topics from the assessment of the feasibility of subsistence products (Kuntashula et al. 2004) to the evaluation of income from marketable products for improving food security within households (Cerda et al. 2014). Methodological choices such as the selected discount rate, the type of costs accounted for, the timeframe of the analysis, the consideration of opportunity costs of family labour, and whether subsidies are considered can strongly influence the results of different studies and thus hamper their comparability. For example, Ajayi et al. (2009) showed that under soil fertility management practices, subsidised fertilised maize was the most financially profitable under a 50% subsidy on fertiliser cost, but without the subsidy, the difference between fertilised maize and agroforestry practices was reduced sharply. Some standardisation on the reporting of socio-economic outcomes of agroecological practices would allow a better comparison between studies.

In addition, we note that for some practices, the results are based on a limited number of observations. Additionally, several other practices (see Table 1 for a list of practices) did not appear at all in the analysed articles. A previous review by Bezner Kerr et al. (2021) also emphasizes the existence of fewer studies on certain agroecological practices such as livestock integration and management or landscape-level practices. Lastly and importantly, an unbalanced retrieval of documents for these practices may have partly been influenced by the selection of terms used in the study search string that referred explicitly to terms like ‘agroforestry’, ‘crop diversification’, or ‘intercropping’.

Finally, aspects such as equity, co-creation of knowledge, or consideration of culture and food traditions were not analysed in the course of this review. These elements are pertinent to the assessment of the socio-economic performance of agroecology, but they are difficult to quantify, often go beyond the farm-level context that was the focus of this study, and tend to manifest themselves in the long-term. As indicated by our results, as well as D'Annolfo et al. (2017), there is a lack of quantitative evidence on indicators associated to social capital. This points to the need for longer investigations and social science research approaches to determine long-term social effects at the community and food system levels.

5 Conclusion

This review examined scientific evidence to gain insights into the socio-economic performance of agroecology by focusing on either individual agroecological practices or combinations thereof across a large number of cases at a global level and different socio-economic metrics.

The results indicate that overall agroecological practices are more often associated with positive socio-economic outcomes than negative or neutral ones. This finding holds for most agroecological practices, including those most frequently assessed, i.e. agroforestry and intercropping. The financial capital socio-economic metrics, representing the vast majority of evaluated metrics, are affected positively in most cases due to favourable outcomes on income, revenues, productivity and efficiency, and to some extent production costs. However, agroecological practices are found to be associated with higher labour requirements and costs in many of the evaluated cases, but also potentially higher returns to labour compared to conventional practices. Further enriching the perspective with qualitative findings from social science research and considering a larger and different range of articles (e.g. ex ante evaluations, on-station experiments, systemic approaches) can enlarge understanding of these trends.

The results of this study provide evidence on the socio-economic performance of agroecological practices, contributing to the evaluation of the effects of agroecology at the global level. This review may support evidence-based decision-making for policymakers and strengthen the socio-economic benefits rationale of the agroecological transition. Evaluating the magnitude of positive or negative outcomes and the conditions under which these emerge is identified as a further research priority to provide additional support to farmers and policy makers to take decisions about the transition pathway that is most suitable to their specific reality.

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