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Growing resilient futures: agroforestry as a pathway towards climate resilient development for smallholder farmers

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Climate change is increasing pressure on communities that are already experiencing high levels of vulnerability and poverty, threatening their subsistence. Among the most vulnerable are smallholder farmers in the Global South, who rely on their yields for food and income. Smallholders need to adapt to changes in rainfall, temperature, and weather patterns and their knock-on effects, and at the same time, ensure that their on-farm climate adaptations do not make climate change worse by increasing greenhouse gas emissions. The Intergovernmental Panel on Climate Change (IPCC) emphasises the need for Climate Resilient Development Pathways (CRDPs) to support vulnerable communities, including smallholder farmers, in balancing climate adaptation, mitigation and development. CRDPs comprise reactive and/or preventive actions that key stakeholders (e.g., government, business, civil society and individuals, including smallholder farmers) can take to become more resilient in the context of a changing climate while not compromising their development or increasing emissions. The CRDP framework has so far remained conceptual, providing little information on how to actually create these pathways in practice. This paper addresses this gap, and with a focus on agroforestry projects and smallholders in the Global South, assesses how CRDPs can become more concrete and actionable through a focus on agroforestry: the voluntary combination of crop and/or pasture with trees and/or shrubs, considering its contribution to climate adaptation, mitigation and development. We draw on literature review and focus group data, analysed using Atlas.ti 23 and a coding process to present a tool relevant to project designers, policymakers and researchers to assess agroforestry projects according to different aspects of climate resilient development, with particular focus on smallholder farmers in the Global South. Evaluation of the tool found it is relevant and useful for project developers and funders to check that their projects follow the components of CRD, but the tool needs to be translated to the local context to better address local demands and reflect regional specificities, which focus group participants deemed possible.

KEYWORDS

sustainable agriculture, rural livelihoods, climate adaptation, climate mitigation, project development

1. Introduction

Temperatures have been rising globally, and extreme weather events have become more frequent and more devastating. These changes have emerged as a result of increased greenhouse gas (GHG) emissions, mostly linked to human activities, among which agriculture accounts for 25% of global emissions (Tubiello et al., 2022). As warming intensifies, more and more vulnerable communities will be further exposed to climate variabilities and extreme events (IPCC, 2022), increasing the risk of hunger, poverty and other development challenges. Such communities include smallholder farmers in the Global South, whose livelihoods directly depend on climate-sensitive natural resources.

Smallholder farmers represent c.70–80% of the world's farmers, producing 29% of global crops or 32% of world's food, on 24% of the available agricultural land (Ricciardi et al., 2018). The majority of smallholder farmers are currently located in the Global South, especially in Africa and Southeast-Asia (FAO, 2012). Two of the main characteristics of smallholder farmers is that they work on small plots of land (1–10 ha), with their direct family members, with whom they live on the land providing the farm labour (Chamberlin, 2008; Cousins, 2011). Due to their small plot sizes, smallholders often produce only enough to feed their family. Such subsistence farming means there is little opportunity for them to sell their products on the market or to a buyer to earn some money. Smallholders therefore commonly live on <$2 per person per day. Such low levels of income prevents them from meeting their basic social needs, investing in their farms, and shifting towards more sustainable farming practices under a changing climate.

Although economically deprived, smallholder farmers are not resource-less. They are often very well-connected to the land they cultivate and have practical knowledge and know-how about the specific conditions and practices for producing food on their land (e.g., local knowledge about which variety grows best, where and when to plant, when to harvest and so on, as well as farming practices such as traditional organic composting, crop rotation, or agroforestry; Singh and Singh, 2017). Local knowledge is nonetheless at risk of being lost. High numbers of the younger generation are leaving the family farm for cities, in the hope for a better future (Bisht et al., 2020), disrupting knowledge transmission. At worst, this could lead to a loss of local and indigenous knowledge, the successive abandonment of farms and an ensuing decrease in food production (de Scally and Doberstein, 2022). This is of particular concern considering that the world's population has recently exceeded 8 billion people, and is still increasing, all of whom need to eat (United Nations, 2022). Together, the issues of climate change, the precarious economic nature of smallholders, small plot sizes, and a growing human population, highlight the importance and urgency for transformation towards farming systems that can be climate resilient, addressing adaptation, mitigation, and development together, without exacerbating any of the pressures.

Agroforestry is one possible adaptation strategy that offers potential to open climate resilient development pathways. Agroforestry is an agricultural system involving the intentional mix of woody perennials (Somarriba, 1992), such as trees and shrubs, with crops and/or pasture (USDA, 2019) and has long been used in traditional smallholder systems. Agroforestry comes in different types (Brown et al., 2018; Lojka et al., 2022), of which the three most common are agrisilviculture (combining crops and trees), silvopastoralism (combining pasture and trees), and agro-silvo-pastoralism (combining crops and pasture with trees). Across the three types, agroforestry is characterised by the biological interaction between crops and trees (Somarriba, 1992) and can be customised and adapted to different and changing contexts with the use of different species. Gold et al. (2004) described agroforestry as a form of 'productive conservation'. While countries may perceive agroforestry as a tool to achieve nationally defined climate goals through carbon capture (Keur and Selin Norén, 2020; Waldén et al., 2020), it can also be viewed as a way to diversify production, leading to more diverse diets (Garrity et al., 2010) or enhanced profits with the sale of fruits. Evidence also suggests it can improve soil quality with the fixation of nutrients through the root network, with dead leaves and decomposing branches enriching the soil with biomass (Nyasimi et al., 2017). Trees in agroforestry may thus assume multiple functions:

- Economic functions: diversified crop production and associated increase in household income should crops be sold (Duffy et al., 2021), fodder (i.e., animal feed) reducing expenditure if it is grown on site (Brown et al., 2018).
- Social functions: time efficient on-farm firewood collection (Regmi, 2003), shade for animals/people (Meybeck et al., 2021), field boundary delimitation (Kalanzi et al., 2021).
- Environmental functions: windbreak for crops (Kalanzi et al., 2021), soil fertility and soil structural improvements, reduced erosion and improved water holding capacity (Franzel et al., 2014; Altieri et al., 2015; Nyasimi et al., 2017).

While agroforestry can help to reduce the impacts of more extreme climatic events (van Noordwijk et al., 2021), it also provides potential for mitigating climate change (Meybeck et al., 2021) with the capture of carbon (Salvini et al., 2016), while supporting development. Despite these benefits, agroforestry also presents challenges. The shift from monoculture to agroforestry involves major changes; one of which is investment in seedlings, plantlets, and small trees, requiring smallholder budgets to be adapted. Although often considered a low-level investment (Toensmeier, 2016; Ollinaho and Kröger, 2021), the initial outlay may, nonetheless, be a barrier to uptake. It also requires land to be taken out of production where the trees are planted which can have a negative impact on yields in the short term. In some regions, land tenure is not secure, but rather granted on a one-to-one basis. This can come as an extra barrier, especially when returns on investment are not immediately visible and take time. Farming practice change is also synonymous with knowledge acquisition and the learning of new skills, despite that different types of agroforestry have existed in traditional farming for centuries (Kansanga et al., 2021). A further drawback may be the competition between trees and crops, with one species impeding the development of another. As such, species need to be carefully chosen. Products from agroforestry may not have a market in the specific region or on a broader scale, limiting the potential for direct development and/or livelihood adaptation benefits. Finally, since agroforestry is tailorable to specific contexts (Mathez-Stiefel et al., 2016; Baker et al., 2023), it is not easily scalable. The form and the type of agroforestry may need to be re-assessed, and the tree species need to be adapted to context (Coe

et al., 2014). Given its benefits, and despite its drawbacks, agroforestry is considered a potential climate resilient development pathway for smallholder farmers, even if benefits do emerge over different time frames (Chandra et al., 2017).

Many tools have been developed to assess agroforestry projects previously, but they take rather narrow approaches. The farm-level agroecology criteria tool (F-ACT; Colbert, 2019) is more extensive in its approach building on the three principles of sustainable food systems: improve resource efficiency, strengthen resilience and secure social equity. However, the principle about strengthening resilience is largely based on biophysical characteristics (biodiversity, synergies, animal health, soil health), while social resilience is only seen through the lens of economic diversification. The scope of this tool is somewhat limited to the farm level. F-ACT (Colbert, 2019) nevertheless features qualitative questions and proposes to rate each response from 0 to 3, with a corresponding description of what the answer needs to be to fall into each category. This enables the scoring of the overall agroecology of the farm which can provide useful insights. Another tool, the FarmTree Tool (Farm Tree, 2022) displays more quantitative features with the outcome of the tool being presented through graphs. However, again, it largely focuses on farm level socio-economics in its assessment of the social side of agroforestry. The FarmTree Tool (Farm Tree, 2022) further guides on the design of land plots and a selection of species needs to be made in the model to get more tailored results. However, only four tree species are included, as well as only four crops. This may hinder the possibility of the model to adapt to different soil types. The Social Benefits from Carbon Forestry Guide (Hadju and Engström, 2019) offers more practical insight into the social side of agroforestry, and allows project developers, through qualitative questions, to reflect on the benefits and risks associated with their projects. However, this tool is limited to the scope of carbon capture related actions. As such, a gap remains among current tools to assess agroforestry as a pathway to climate resilient development.

The aim of this paper is to examine agroforestry as a way to operationalise climate resilient development. In doing so, we develop a new tool to scope and assess agroforestry projects for their climate resilient development potential. Two objectives support this aim using mixed methods. Objective 1 reviews the literature on climate resilient development pathways and agroforestry to gain insights into how the topics relate to one another. Objective 2 draws on this information and develops and evaluates a tool for use by agroforestry stakeholders to develop (scope and assess) agroforestry projects that foster climate resilient development. While many existing tools look at agroforestry from an agro-ecological or environmental perspective, we specifically include socio-economic and governance considerations. Overall, we shed light on the important qualitative questions to be taken into account while designing, implementing, and evaluating agroforestry projects in the Global South for their climate resilient development potential, with particular focus on smallholder farmers. To the best of our knowledge, this is the first attempt to operationalise climate resilient development pathways through a focus on agroforestry.

In section 2, we introduce the framework developed by the IPCC on climate resilient development pathways. After describing our research methodology in Section 3, we present the results of our analysis in Section 4. Section 5 discusses the main aspects emerging from the analysis and concludes by directly addressing our aim.

2. Climate resilient development pathways

This paper uses the IPCC framework on climate resilient development pathways (CRDPs; Schipper et al., 2022) as the starting point for the development of a tool for stakeholders who want to launch/fund agroforestry projects in the Global South. CRDPs are defined as reactive and/or preventive actions that key stakeholders (e.g., government, business, and civil society) can take to become more resilient in the context of a changing climate while not compromising their development or increasing emissions (IPCC, 2022). This dynamic process is highly context-specific, with actions and solutions tailored to suit particular local needs. CRDPs support systems to retain their overall functionality and productivity through change, even though this may materialise over different timeframes. The main difference between climate resilient development and CRDPs lies in that pathways define a deliberate context-specific set of actions developing over time against a certain supporting system (financial support, national support and targets, legislation, international agreements, institutional support and expertise) with specified results (climate resilient development). Climate actions are all the transformations/changes/adjustments happening in the system. Resilience is built from the multiple actions, enabling communities to keep on thriving over time, even when facing increased climatic variability. Development is a result of all the transformation and the built resilience, enabling communities to keep on thriving socially, economically and environmentally. The structure (supporting system and actors) is the necessary envelope keeping things on the agreed pathway, making sure that progress is made and that targets are reached according to a structured context-specific plan. Without the supporting structure, attaining climate resilient development would not be possible. CRDP also depends on the existing system. The existing system needs, therefore, to be both engaged in and support the transformation (Birkmann et al., 2022; IPCC, 2022; Schipper et al., 2022). Figure 1 presents an illustrative CRDP, using agroforestry in all its forms to indicate sets of context-specific actions.

Building on one of the most recent IPCC reports (IPCC, 2022), CRDP can be attained through specified pathways, whereby societal choices about adaptation, mitigation and sustainable development manifest themselves within multiple arenas, through interactions between key actors (civil society, private sector, and government). Those mentioned societal choices are referred to as 'enablers' encompassing knowledge diversity, equity and justice, inclusion, and ecosystem stewardship. These enablers manifest themselves across political, economic and financial, ecological, knowledge and technology, socio-cultural, and community 'arenas of engagement' (see Table 1) where actions and social interactions are performed in directions that support CRDP and the pursuit of sustainable outcomes (IPCC, 2022). This paper combines the four enablers and the six arenas of engagement, making them more concrete and actionable, through a focus on smallholder farmer agroforestry projects in the Global South.

3. Research methodology

This paper is an exploratory conceptual study that charts new ground by examining how smallholder farmer agroforestry projects

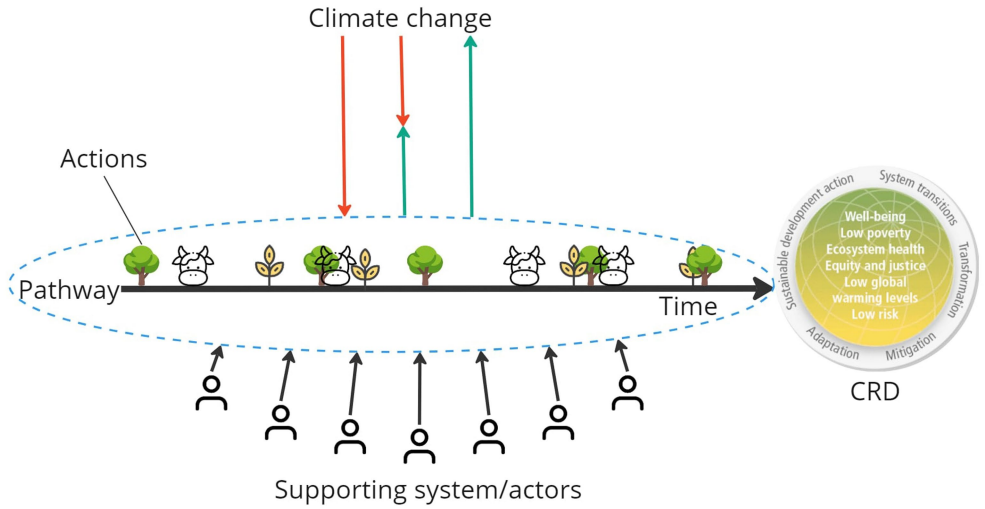

FIGURE 1
Visualisation of an indicative climate resilient development pathway. Black arrows represent support provided by different actors. The blue dotted line represents the decision-making space shaping the pathway. Actions for climate adaptation, mitigation, and development are represented by trees, hay stalks, and cows, showing how agroforestry can limit the impact of climate change on smallholder farmers (red arrows), while adapting to (interlinked green and red arrows) and mitigating the changing climate (green arrows).

TABLE 1 **Definitions of enablers and arenas of engagement (authors' own).**

	Enablers		Arenas of engagement
Knowledge diversity	Combining different types and forms of knowledge in a way that is acceptable, relevant and useful for stakeholders	Political	Power interplays between various levels of governance involving a wide array of actors
Equity and justice	Making sure that the process is fair and that the outcomes are fair [desirable] and good for humans and nature as a whole	Economic/ financial	Multi-level financial and resources fluxes and their use (investments, subsidies, loans, credits, taxes, incentives…)
Inclusivity	Ensuring that nature's and human's current and future stakes and interests are included in the process	Ecological	Environment in which a given society evolves and society's interaction with this given system (in face of climate change)
Ecosystem stewardship	Empowering communities to responsibly use and safeguard ecosystems through the uptake of sustainable practices	Knowledge/ technology	Existing/development/in-the-making knowledge and technology and their use
		Socio-cultural	Sets of norms and values shaping individual and group perceptions of the world (visions of the future, beliefs, attitudes, values, emotions, actions…)
		Community	Interactions between and among people sharing worldviews, values and behaviours at local, regional and global levels

in the Global South can operationalise CRDPs. The methods applied are mixed and largely qualitative, with the inclusion of descriptive statistics, as relevant (Figure 2).

3.1. Semi-systematic literature review

A comprehensive, semi-systematic literature review was conducted to understand how the enablers and arenas of engagement manifest themselves in publications on agroforestry and smallholder farmers in the Global South. As mentioned by Snyder (2019) 'The aim of a systematic review is to identify all empirical evidence that fits the pre-specified inclusion criteria to answer a particular research question or hypothesis'. In the context of our study, this was not possible since neither 'enablers' nor 'arenas of engagement' are explicitly addressed in the literature. Rather, we manually searched for more subtle references to 'arenas of engagement' and/or 'enablers', guided by our definitions. We therefore performed a semi-systematic literature review to allow more comprehensive analysis, which was not possible with only a keyword search. The publication time boundaries of the papers were defined between 2015 and 2022, the article language as English, and no specific spatial boundaries were set. The reason for selecting 2015 as starting date lies in the fact that in this year the Paris Agreement was agreed upon, whereby signatory nations agreed to

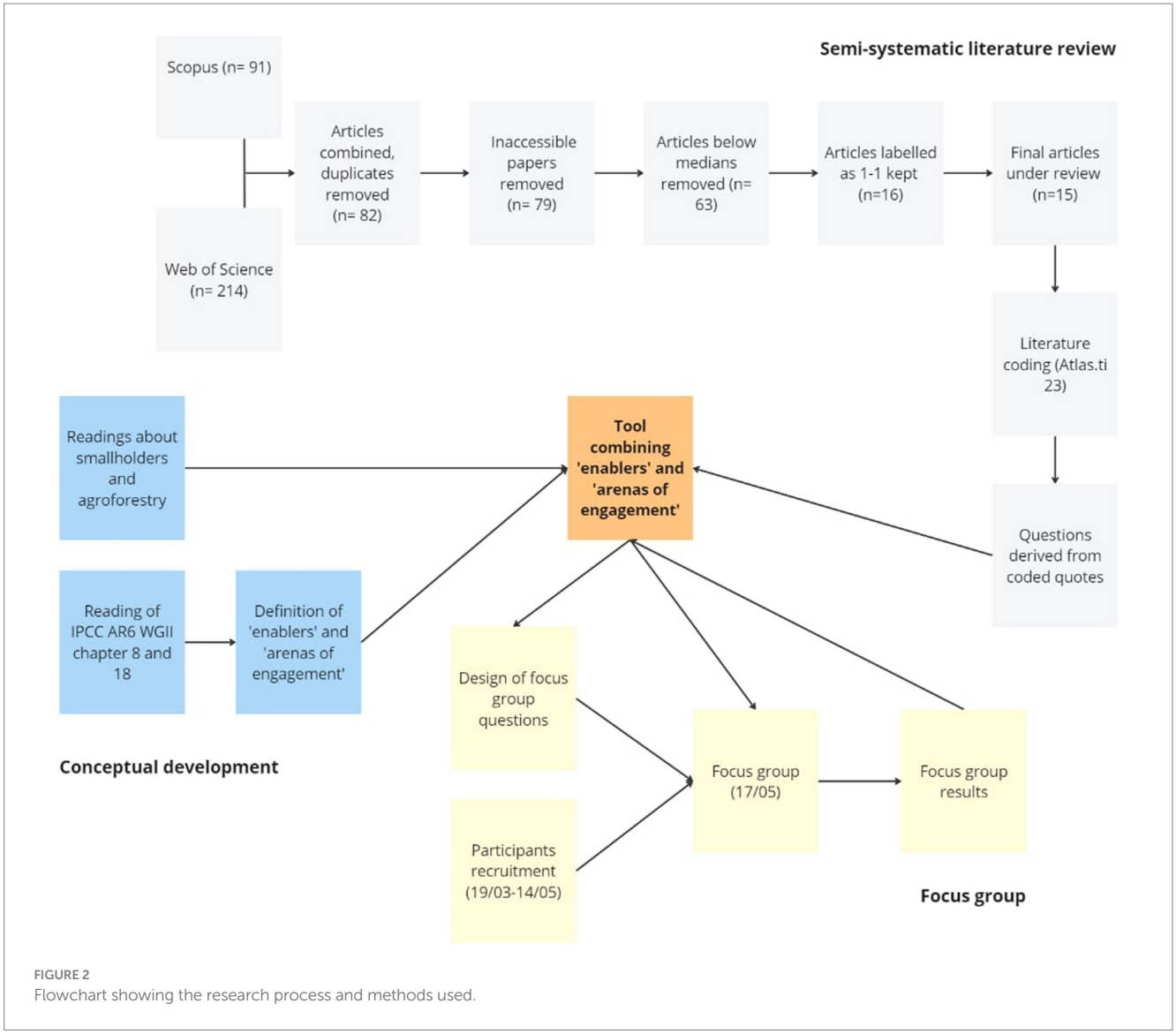

FIGURE 2
Flowchart showing the research process and methods used.

work towards climate resilient development. We deliberately chose to not set geographical boundaries so as to not exclude any articles from the Global South and to ensure the tool we developed can be broadly used across different geographical locations.

Next, we came up with the preliminary definition of search strings (see Appendix A1). The same search strings were used multiple times with 'community' replaced by each arena of engagement labelled as follows: 'political', 'economic and financial', 'ecological', 'knowledge and technology', and 'socio-cultural'. Considering the initial number of hits for each arena of engagement and for each enabler, some search strings were broadened, narrowed or changed accordingly (see Appendix A2). Finally, adjustments were realised after the second search round to be more encompassing (see Appendix A3). The following final search strings were used: agroforestry AND (1–6) AND (A-D) AND smallholder* (Table 2).

Search strings were then entered into Web of Science and Scopus. Because we wanted to see how the 'enablers' and 'arenas of engagement' were addressed in the literature, we considered it important to have only peer-reviewed articles in our analysis, thus ruling out the use of Google Scholar. Web of Science was chosen as an appropriate database in that it covers a wide range of subjects, which was needed for our research. Scopus was used to broaden the results, and enabled us to include articles that were not listed in Web of Science, while using the same search strings. Results from the two databases were combined in Excel (2016). Figure 2 presents the process of inclusion and exclusion of the literature. All article links were checked and a manual duplicate

TABLE 2 Final search strings (arenas of engagement and enablers).

	Arenas of engagement		Enablers
1	Poli*	A	Environment* empower*
2	Economic/financial	B	Fair*
3	Knowledge/technology	C	Knowledge diversity
4	Ecological	D	Inclusion*
5	Community*		
6	World-view*		

*as used in Boolean search, is a wildcard (i.e. Boolean operator) enabling the inclusion of other forms of the keyword to which it is appended.

check was carried out. Of the identified 83 papers, three were inaccessible and one was duplicated. The sample size was 79 papers at this point.

Papers were next screened using 'smallholder' and 'agroforestry' as search terms, allowing removal of papers that did not mention agroforestry. Frequency counts for these terms were indexed in Excel (2016). At this stage, no paper was removed. However, papers with a low number of mentions (between 1 and 4) of 'agroforestry' or 'smallholder*' mostly had those hits in the reference section, and not in the main text. This was addressed by calculating the median and quartiles of 'agroforestry' and 'smallholder*' mentions per article. This method was preferred to using the mean because of the extreme ranges of mentions (0–229 for 'smallholder*' and 0–349 for 'agroforestry'). Most papers included frequencies of mentions in 10 rather than 100. Also, the use of the median and quartiles was more objective than consciously altering the average when not taking into account the extremes. The obtained median for smallholder* was 11, while the median for 'agroforestry' was 16. Papers with frequencies of search terms less than or equal to the median (all papers ≤11 for smallholder* and all papers ≤16 for agroforestry) were labelled as follows:

- 1-1 = > median *2.
- 1-0 = > median smallholder.
- 0-1 = > median agroforestry.
- 0-0 = < median *2.

Papers marked 1–1, 1–0, and 0–1 were kept, and for the sake of not getting rid of relevant papers, the 22 papers labelled 0–0 were scanned through, of which six made it to the next step following further screening. The result was: 79−(22–6) = 63 papers.

All 63 papers were then imported into Atlas.ti 23. However, after reading through seven randomly selected papers from the sample, we realised some may still not be entirely relevant to our research because they did not clearly focus on agroforestry for smallholder farmers, with 'agroforestry' and/or 'smallholders' being mentioned only a few times throughout the papers. We, then focused on the 16 papers labelled as 1–1 (above median hits for both 'agroforestry' and 'smallholder*'). Of these 16 papers, 15 papers were reviewed through an in-depth semi-systematic analysis process. The 16th paper was excluded as it was out of scope following thorough reading: it addressed the correlation between bird species and population on land use variations (including land used for agroforestry). Coding of all the selected literature according to the enablers and arenas of engagement then ensued, with codes exported into Word (2016) for further analysis. The extended analysis entailed the formulation of questions raised by the papers which agroforestry projects could usefully consider. These were placed in a 24-cell table and formed the basis for development of the tool (Appendix C2).

3.2. Focus group

Potential participants for an online focus group (on Zoom) were contacted as early as 29 March 2023 for a session on 17 May. This was complemented by a snowballing approach whereby potential participants forwarded the invitation to other interested parties. We targeted between 6 and 12 participants from representing different types of stakeholders and perspectives. In total, 10 experts participated in the focus group, coming from six countries, four of which are in the Global South (Nigeria, Kenya, India, Indonesia), and two in Europe (Sweden, and France). Participants were mostly from academia (8/10), while two practitioners working from Kenya and Indonesia also took part in the discussions (see Appendix B1 for more information). Timing was sensitive to the time zones of the participants, to be as inclusive as possible and participants were given access to the draft tool 3 days ahead of the session (see Appendix C1).

The 2-h session opened with participant introductions. The draft tool was then briefly presented, followed by discussion of four open-ended questions (Appendix B2). Two people took notes in the discussions, while the session was also recorded, in line with ethical approvals granted by the lead author's institution which required free, prior informed consent to be given by participants. Focus group results were bundled by themes that emerged from the discussion, and the tool was revised in light of their comments.

3.3. Study limitations

Limitations of our study generally encompass the: (1) scope of the research, (2) limited representability, and (3) translatability. The scope of our research is limited to peer-reviewed articles, and does not include grey literature reflecting on regulations and or actions towards CRDP in agroforestry. In addition, search strings did not account for specific terminology used to describe the various forms of agroforestry. The papers we reviewed mostly covered agrisilviculture as a form of agroforestry. As such, the tool we developed may not cover agroforestry to its full extent. The final selection of articles under review was limited to 15 papers. We can assume that the literature on agroforestry and smallholder farmers, which touch upon components of CRDP may be broader. While we recruited participants for the focus group a long time in advance of the focus group itself and looked to have a diverse panel, most attendees were academics. This limited field-based insights in the discussion. Funders were also absent from the session, who may have helped us steer the tool more in the direction of topics funders would also see as prominent in the design of agroforestry projects for CRDP.

4. Results

4.1. Literature review

Figure 3 shows the breakdown of the sampled literature according to the year of publication. The majority of the papers from the reviewed literature were published in the past 5 years. Seven papers come from three journals: three in *Agriculture, Ecosystems and Environment*, two in *Forest Policy and Economics*, and two in *Land Use Policy*. The remainder of the sample papers were published in other journals.

Countries represented in the selected literature are fairly well spread throughout the Global South. Among the 15 papers, one focuses on Oceania (Melanesia), five on South Asia (India, Malaysia, two on Indonesia, and one comparing Indonesia with Bangladesh), three on Africa (Ethiopia, Sub-Saharan Africa, and Southern Africa), and four on Central and South America (Mexico, Nicaragua, and two

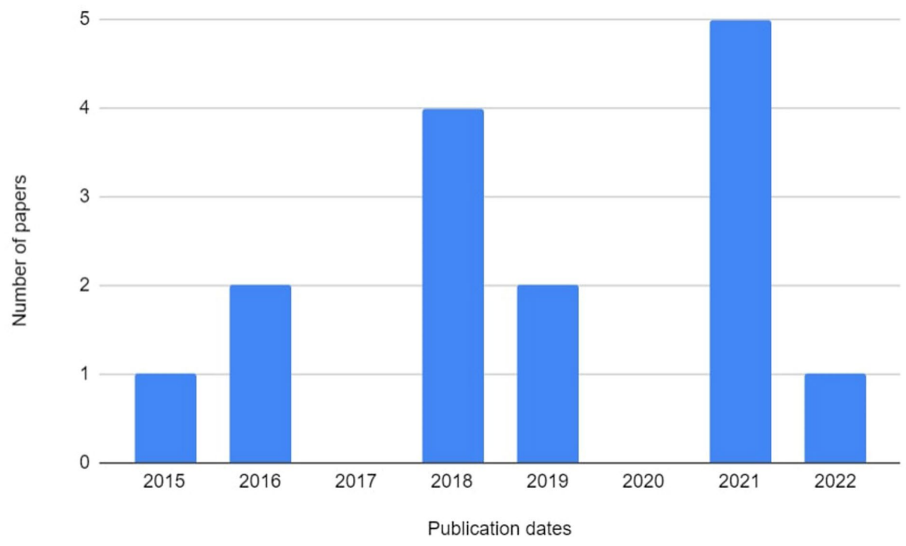

FIGURE 3
Number of papers per year since 2015.

on Peru). The last two papers have a more global focus, on low and middle income countries, and Meso-America and East Africa.

Based on the three major types of agroforestry (agrisilviculture, silvopastoralism, and agrosilvopastoralism; FAO, 2012), we examined which forms were most represented in the selected literature. The most common was agrisilviculture with 8/15 papers (53%) referring to this form of the practice (5, 6, 9, 10, 11, 13, 14, 15). This is followed by 3/15 papers (20%) tackling agroforestry more generally (1, 2, 7). Paper 7 discusses agroforestry in the wider agricultural system of climate-smart agriculture (CSA), therefore also taking other practices into account. Paper 4 is not categorised because of the limited information linked to the practice of agroforestry. Another mentioned both agrisilviculture and agrosilvopastoralism although later focused on agrisilviculture solely (3). Two papers did not fall so easily in the categories and focus on timber-agroforestry, which involves the felling of trees. These articles therefore differ from the rest of the reviewed literature for the business model they focus on, but also for the agroforestry benefits mentioned, with no focus on climate mitigation through carbon storage but rather on the sale or use of timber for local needs (8, 12).

The sampled literature concurs that smallholder farmers are vulnerable to food insecurity (5), whose vulnerability is increased by a changing climate, further marginalising this specific group (4). Shifting climate patterns put at risk smallholders' crops, which are often rain-fed and subject to little fertiliser (4, 7). Most smallholders rely on their crops to support their livelihoods (4, 5, 6, 12, 15). Moreover, their production is often limited (12) due to the small cultivable area they can access, but also due to the limited available labour, which is often limited to family members (15). Smallholder farms are often isolated (4, 6), with limited access to technology (4), and to the market (4, 5, 6). To access the global market more easily, farmers turn to high-demand commodities, such as cocoa, coffee, and palm oil (2, 8, 9, 10, 12). However, smallholders' income is often close to or below the poverty line (3, 4, 6), pushing them to look for off-farm work as a complement or replacement to farm labour (4, 6, 12). Although most definitions consider smallholders to farm landholdings of 1 to 10 ha (3, 4, 6, 7, 9, 11, 13), two articles, with a geographical focus on Peru, mentioned land holdings of up to between 200 and 400 ha (10, 12).

Appendix C2 presents the questions derived from the in-depth semi-systematic literature review. The number of questions per cell varies greatly, from 10 identified questions exploring the interaction of 'equity and justice' and 'economic/financial', to only one question for six of the other cells (economic/financial + ecosystem stewardship, ecological + inclusivity, ecological + knowledge diversity, ecological + ecosystem stewardship, socio-cultural + inclusivity, community + ecosystem stewardship). The sampled literature also focuses on certain arenas of engagement more than the others, with 'political', 'economic/financial', and 'knowledge/technology' receiving most coverage. The same can be said for 'equity and justice' as the most commonly addressed enabler. The following subsections zoom in to the main insights found in the literature, which guided the development of the questions and the drafting of the tool.

4.1.1. Barriers to the uptake of agroforestry by smallholders

One of the difficulties faced by smallholders is a lack of political support, which can take multiple forms. Barriers can take the form of new laws and regulations, binding smallholders to fulfil certain requirements (12), or exposing their constraints in complying with new requirements enforced by the government (3), disregarding challenges associated with smallholder farmers' capacity. Other reported barriers include a general lack of institutional support (1, 2) to make necessary investments or changes, and, in some places, absence of agroforestry policies supporting and regulating the practice (5). Finally, introduction of regulations on timber-agroforestry are seen as a further obstacle for farmers to adopt the practice because of the extensive, knowledge-intensive paperwork that farmers need to complete (12). One of the questions emerging from all the barriers associated with governments and institutions is that of the composition of the decisional agenda, as much for its content as for who influences it.

Another barrier to agroforestry adoption faced by smallholders is linked to funding, credit and financial capacity. Up-front costs are often associated with shifting farming practices to agroforestry with the purchase of seedlings, trees, and material, while at the same time, taking land out of agricultural production to plant the trees. The return on investment does not occur immediately, but after a few years (7, 8, 10), thus 'generating a negative flux of net benefits in the short-term' (7 p.12), which prevents smallholders from engaging in agroforestry. To cover for the yield losses while trees mature in the first years, smallholders would need to get access to credit, which is often difficult to obtain (1), not always culturally acceptable, and not all smallholders know about this possibility due to a lack of promotion of agroforestry linked to absence of policy support (1). In addition, some countries/institutions/organisations may not be completely ready for a massive investment in climate adaptation strategies, often viewing them as uncertain (2). This suggests that perceptions on climate adaptation need to evolve for new strategies to become socially acceptable and institutionally supported. A further issue is that while NGOs and other organisations have been investing in agroforestry through projects, they often have limited budgets, which once used up, result in termination of support to smallholder farmers. Discontinued funding is problematic in that it is not followed by long-term national funding, leaving smallholders to their own devices to maintain the trees. This has been found to limit the large-scale and long-term adoption of agroforestry (1).

One of the questions emerging from all the barriers related to financing and monetary capacity is whether funders/banks understand the situation of smallholders well before granting credits (i.e., acknowledging that the back payments may be delayed due to the temporality of agroforestry, as well as with fluctuating income of smallholders).

Contrary to other agricultural practices, agroforestry happens on a long time scale. Secure, continued land tenure is central to the uptake of the practice, as well as to its perpetuity, with one article (1) putting strong emphasis on secure tenure for agroforestry to develop: 'There are few agroforestry success stories in an uncertain land tenure context' (Borelli et al., 2019, p. 2 as cited in 1 p.3). Papers 8 and 12, which dive more in-depth into timber-agroforestry, also note that farmers are solely interested in changing their practices in a land secure context, and that the needed investments do not attract farmers who do not have secure tenure. Farmers often resist changing their practices to agroforestry when they do not own the land that they cultivate, an element which comes as an ancillary risk on top of the investment (6). To improve tenure security smallholders have also been found to join cooperatives as a means to by-pass this obstacle issue (13). One of the questions emerging from all the barriers linked to land tenure is that of whether smallholders are the tenants of the land on which they sustain their households.

Another barrier to the adoption of agroforestry as a main farming practice lies in the choice of species, which are often selected for their market prospects, rather than their adaptability to the local environment. This can lead to competition and incompatibility issues among and between species (9). Other issues may arise from the sole use of traded commodities from trees, with, for example, the degradation of local agrobiodiversity (10). Another issue may be the introduction of species largely promoted for benefits that they do not bring (5), which may, in turn, lead to misinformed ecosystem management, putting crops at risk of pests and diseases (14). To address newly emerging pests and diseases associated with climate change, hybrid species may be introduced (for example, an hybrid coffee species to combat coffee leaf rust in Mexico) (3), or other hybrids (4). Use of newly introduced species is often associated with the promotion of fertilisers (3), which may put a further burden on smallholders who not only have to change the species they are cultivating, but also invest in chemical inputs. This increases their dependence on external actors/inputs, reducing their autonomy and resilience (4). One of the questions emerging from all the barriers associated with species choice is that of whether the use of the new species or the farming technique poses a threat to the overall existing system in which they are introduced.

Agroforestry is described as a knowledge intensive practice, which requires multidisciplinary approaches (8), implying more than simple access to seeds or saplings (2). Successful agroforestry requires knowledge about nutrients and pruning (2), as well as seed quality, but smallholders are often unable to obtain information about the planting materials they can access (9). The literature also points to the need for farmers to know about the agro-ecological implications of planting certain species alongside others, to reduce the impacts of species competition (11). In addition, while information about mainstream commodities may be available to smallholder farmers, information about less mainstream species, which may be more appropriate to their farms, is largely absent, making the use of other species even more challenging (10). Another barrier is that smallholders often sell their products to middlemen, which they are at the mercy of, because farmers lack knowledge about fair pricing (1). One of the questions emerging from all these barriers linked to knowledge and information is that of whose responsibility it is to bridge these knowledge gaps.

4.2. Focus group

Focus group participants highlighted the suitability of our tool in including equity as one of the four enablers (FG1; FG2) noting the possibility to include everyone from a given community, including underrepresented groups, such as women and young people (FG3). Participants further suggested the need for gender to be considered more directly within equity concerns, as farm labour tends to be gender-specific (FG1), and rules and norms emerge from different genders (FG1; FG3). It was also suggested that gender dynamics should be taken into account in relation with trees (FG7) as the utility of the trees planted often differs according to gender. FG1 explained that a tool on gender equality and social inclusion was used in past research, but emphasised that tools need to consider equity, rather than equality. FG2 estimated that they unconsciously coupled equity ('how to make sure that smallholders can also feed their families') with the 'ecological' arena ('how to safeguard the environment and increase biodiversity') in one of his previous research projects, and concluded that it was essential to consider the two at the same time.

Questions about land tenure, land ownership, and land rights also came to the fore as another important topic to take into account when designing agroforestry projects (FG5; FG8; FG3), while participants suggested further consideration is needed of policy frameworks accompanying the adoption of agroforestry describing it as essential to understanding the contexts in which projects are taking place. Two experts (FG3; FG7) noted the absence of agroforestry policies in certain countries, while FG4 stated that even when policy frameworks

exist, they are not completely supportive, although they have been in the case of India, with an observed boost in the uptake of agroforestry.

Participants' experience also showed that enablers need to be integrated into the overall approach taken by researchers/project managers. One expert (FG8) considered knowledge and training can be usefully combined in the context of ecosystem stewardship, giving an example of how knowledge and training was offered to smallholder farmers, building their skills to measure carbon stocks in order to access the carbon market. This training was considered one of the essential requirements for farmers to be able to join the carbon market (FG8; FG5). It was further mentioned that measuring developments in agroforestry could not be achieved if the social dimension was not taken into account (FG2), therefore encouraging the use of our tool, which offers to combine different enablers to arenas of engagement.

Of the eight experts who orally took part in the discussion, five found the tool to be relevant, useful, and/or important (FG1, FG2, FG3, FG5, and FG7). FG9, who participated through the Zoom chat also mentioned that the 'tool is useful for monitoring and evaluating' projects. Usefulness was, however, qualified as an indirect usefulness to the experts, themselves. As most participants were academics, they did not see the tool could directly benefit/influence their research, but saw it as relevant to agroforestry project developers and funders, in the form of a 'checklist' (FG1; FG5). It was also perceived as a useful way of 'prioritising' (FG7) the social dimension of smallholder agroforestry through qualitative evaluation, instead of quantitatively measuring parameters, which is often difficult (FG5; FG7). In that sense, the tool we developed was considered potentially 'more receptive to the realities on the ground' (FG1) compared to other tools previously used in research projects, and as something that could be 'adapt[ed] to the local context' (FG3).

4.2.1. Critiques/concerns

Finally, while it may be a strength that our tool is not context-specific in its design, it may also be a weakness. Indeed, the limited context-specificness of the tool signifies that major interpretations and translations will be needed to adjust to the relevant local situation.

Critiques of the tool coalesced around: (1) concerns that the breadth of the questions leaves them open to misuse as a justification for implementing harming actions/projects, (2) concerns that the tool seems to solely account for project initiated agroforestry rather than that directly coming from the farmers, and (3) the tool has not yet been used in practice.

FG5 worried that the 'vagueness of the questions' makes it 'easy for the people who have the power to interpret the question in a way that is good for them'. While the same expert considered the tool useful to help agroforestry projects to formulate how they will take various parameters into account, they also voiced concerns over the manipulation of what is said, and how it is said. This highlights a potential risk to the use of the tool, which could benefit those already profiting from smallholders, leaving the latter group unaided.

The tool addresses agroforestry from a project-led initiative and the extent to which it could be useful to other groups was considered to be limited. In some countries, such as India and Indonesia, agroforestry is not always initiated through NGOs or funding agencies, but by farmers themselves, supported by policies encouraging agroforestry as the main farming practice (FG4; FG6). Another expert (FG8), suggested that in many cases in Indonesia, the land was owned by the government, and land access was granted to farmers. The tool was therefore seen as not reflecting/accounting for a sufficient variety of contexts (individual agroforestry projects, NGO-led projects, community-led projects, and so on).

Finally, the tool may lack direct usability in practice as it has not yet been field trialled by agroforestry project developers. As indicated by FG6, the tool also does not give an indication of when an agroforestry project is good to go, even if all questions have been addressed. There is no benchmarking through, e.g., numbers or colours to indicate whether the results from the pre-study at the design phase of a project would contribute to climate resilient development (FG6). FG6 reiterated twice that the tool was 'too big'. This can lead to misunderstandings about its purpose. For example, FG4 thought that market access was not taken into consideration into the tool, yet this is mentioned at the intersection of the 'economic' arena of engagement and 'inclusion' as an enabler. It is possible they got lost in the size of the tool, which demonstrates that it needs field-testing and further adapted to use more easily in practice.

Table 3 combines the results from our research and seeks to integrate as best as possible the critiques raised through the focus group.

5. Discussion and conclusion

5.1. Agroforestry and climate resilient development pathway

Agroforestry is presented here as a potential pathway, capable of adapting to and mitigating the effects of climate change, while promoting development. It offers ways of adapting to climate change through more diversified crops (Mbow et al., 2014) rather than monoculture. Mixed species, which is the case of agroforestry, are considered less risky than monoculture in the sense that if a pest appears, its spread may be limited to one species. Loss is thereby reduced, and other commodities than the failing crop sustain agricultural yield. This in turn enhances the adaptive capacity and reduces the vulnerability of smallholders, thus increasing their resilience to climate change (Quandt et al., 2023). Also, the diversified production of agroforestry offers important socio-economic prospects to smallholders. When a crop fails, farmers can still sell tree products for income, or consume their own products to sustain themselves. In addition, agroforestry has the potential to mitigate climate change as trees absorb carbon while growing. This is particularly relevant because limiting further warming through the uptake of carbon may limit the extent to which smallholders will be put at risk by extreme climatic events (such as prolonged or more frequent droughts, heavy rainfalls, …; Verchot et al., 2007). Reducing this risk is important as they already face the heavy burden of sustaining their household solely through the cultivation of their land and have very little income to buy extra food. Agroforestry would therefore positively impact two of the objectives of CRD: low global warming levels, and low risk (IPCC, 2022). Increasing the overall stability associated with the smallholding environment may therefore help farmers better cope with the already existing burden from climate change, whereas more diversified diets, diversified sources of income and other social benefits associated with agroforestry (e.g., on-farm wood gathering, more shadow, medicinal properties of the trees) will help them keep thriving and developing. The implementation of agroforestry bodes well for smallholders as it

TABLE 3 Revised tool integrating information from literature review and focus group data.

	Equity and justice	Inclusion	Knowledge diversity	Ecosystem stewardship
Political/ Decision-making	• What is on the agenda? • Who is benefiting from this decision/policy? • Is the policy/project a short term quick fix or is it meant as a long-term planning/resilience building? • Is this policy/project desirable for smallholders or harming/burdening them? • Is smallholder resilience valued? • Are laws supporting the implementation of agroforestry or limiting its generalisation? • What are the powers at play?	• What is on the agenda? • Who is benefiting from the project/policy? • Are farmers represented or are they directly participating? • How open to discussion is the decision-making forum (democracy, repressive power, dictatorship)?	• Is local knowledge weaved with scientific knowledge to help convince smallholders to transition to agroforestry? • Is external knowledge combined with local knowledge to guide farm decision-making? • Are agenda points justified by needs/demands from all or only fuelled by individual wills or power groups?	• Is this project/solution a quick fix or is it going to help with resilience building? (→ What is on the agenda) • Are legal texts helping the promotion of agroforestry or hampering its uptake altogether? • Who is taking action? • Is the project/policy/regulation empowering smallholder farmers to take care of the environment?
Economic/ financial	• How is money used? (→ What is funded and what is not? & What is the purpose of the investment?) • How accessible is the market? • Who is making profit? • Can farmers cover up for the up-front costs associated with the project? • Are the prices of material (seeds, trees, equipment) low enough that farmers can afford them? • Is there a market for smallholders' products? • Is the funding secured for a long time period or only destined for a short period of time? (→ What happens beyond the project when managers run out of money?) • Does the project/investment help smallholders make a living income or burdens them financially?	• Who has the money? (→ Who is investing and what are the motives behind the investment?) • What are the conditions/requirements to receive funding? • Can farmers afford the proposed solutions/technologies? • To what extent do smallholders have a say in the market? • Can farmers easily access the market to sell their products? • Are certain groups excluded from generating economic value? • Who is benefiting from the generated economic value?	• Do funders/banks understand the situation of smallholders well before granting credits (i.e., acknowledge that the back payments may be delayed due to fluctuating income)? • Do smallholders know about the available financial mechanisms they can have access to? • How is money invested (e.g., research and development, communication platforms, education, ...)?	• Are farmers equipped to protect the environment or are their investments making them more reliant on external input (chemicals) damaging the environment and reducing their autonomy? • Are investments targeting training farmers to safeguard the environment/promoting new (more sustainable practices)/new machinery, tools, and technology?
Knowledge/ technology	• To what extent is external information/scientific knowledge appropriate/fit to the local context? • How do farmers get the necessary skills to the proper realisation of agroforestry projects? • Is knowledge/technology physically and financially accessible? • Are there any threats associated with the introduction/use of this technology (species, equipment, planting material, chemicals, ...)? • How suitable/adapted is the technology to the local context? • Whose responsibility is it to bridge knowledge gaps when they are identified? • Who is providing for the material? • Are institutions promoting the use of new knowledge and technology?	• What are the conditions to join in the training activities? • Is the training integrating both local and scientific knowledge? • Under which condition is cultivating material, seedling, ... made available to farmers? • Do the farmers have sufficient pre-existing knowledge and enough financial capacity to access and use the technology? • Can all farmers access the necessary technology (e.g., smartphones) to obtain knowledge about the market? • Are institutions promoting the use of new knowledge and technology to all or to only to identified groups? • Are knowledge/technology intelligible/user-friendly to everyone or are they exclusive? • Who decides which technology to use?	• What is the place of local knowledge in the discourse farmers hear? • To what extent is local knowledge taken into consideration when external actors come? • Whose knowledge/know-how/skills are used in the projects? • Is the training weaving both local and scientific knowledge? • Does the introduced knowledge/technology build on pre-existing knowledge or introduces completely new knowledge and skills? • Is the introduction of new technology backed up by appropriate training?	• Does the introduction of this knowledge/technology cause any threats/dangers?/Do we know enough to apply the technology? • Is the species well adapted to the local context? • Are farmers empowered to protect the environment through the knowledge/technology they have access to? • Do farmers have enough leeway to experiment and adjust their practices, and develop new local knowledge?

(Continued)

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TABLE 3 (Continued)

	Equity and justice	Inclusion	Knowledge diversity	Ecosystem stewardship
Ecological	• Does everyone have access to the forest/land? • How easily accessible is the forest/land? • How can farmers benefit from forest products? • Are the best adapted species grown? • Which species are promoted? • Where does the benefit lie (global level, local level)? • Are the actions geared towards protecting the environment also good for people?	• Do all farmers have access to land? [Is land tenure secured?] • Is the project accessible to all or exclusive with selection criteria, investments, ...? • What are the means to deal with the barriers to land acquisition?	• Do farmers know about the nutritional requirements of the introduced species? • What is the state-of-the-art in terms of agro-ecological knowledge and local soil condition knowledge [overlaps or knowledge gaps]? • Do farmers need to receive training to plant and maintain trees better? • Is local knowledge about soil conditions taken into account in the design of the project?	• Are the introduced species further burdening the farmer through expenses (e.g., fertilisers, tree species with high maintenance costs)? • Is the land/forest handled sustainably (i.e., is it exploitation compatible with current and future conservation and use?)
Socio-cultural	• To what extent is smallholder resilience viewed as important? • What is valued and is this value shared or diverging among actors? • Are there crowd-out effects where organisations take a significant share of the responsibility to help smallholders, leading to more inaction from another actor? • Who is taking responsibility to help smallholder farmers?	• Is agroforestry acceptable to farmers or is it radically hindering their local agricultural identity (e.g., seasonal crops, garden farming, ...)? • Are smallholders' challenges and worldviews at the core of the project design? • Do existing cultural and social norms allow for equal participation in all forms of agroforestry?	• What is the story told to farmers when they are approached to join the project? [what is considered as important and whose values and perceptions are dominating?] • Are knowledge and experience about agroforestry shared to increase the perceived value of agroforestry?	• Which products/services are valued by the farmers in the trees? • Which tree species are valued by the farmers? • What motivates farmers to protect the environment and maintain the trees?
Community	• How beneficial/desirable is it for farmers to join a certification scheme/partnership through cooperative networks? • What is the role of local communities/networks in supporting smallholders? • Who is benefiting from the collaboration?	• Are there any conditions to join cooperatives/ partnerships? • Are cooperatives/farmer associations well integrated in the supply chain? • Are the interactions between actors benefiting the community as a whole or to specific groups only?	• What kind of information is shared between smallholders? • How is the information shared? • Whose perspective is considered important in the interaction?	• What is the common vision the community shares that encourages them to safeguard the environment? • Are farmers ready to adapt their practices to protect the environment better? • Are farmers empowered to change their practices to agroforestry?

The tool considers the enablers and arenas of engagement interactions in agroforestry projects, contributing towards the operationalisation of agroforestry as a climate resilient development pathway (This informative tool was designed to help project developers/ funders design and evaluate their agroforestry projects before its beginning, during the project, as an evaluation/monitoring tool, or at the end of the project to identify and learn from the project's successes and failures for future project development.).

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could offer the triple-win associated with CRD, that is climate change adaptation and mitigation, and development.

Agroforestry, however, also comes with challenges that should not be overlooked when pursuing CRD. For example, farmers may regard the years they lose while waiting for young trees to grow and produce as a net loss even though, over time, more diversified production will offer new potential sources of income (Lasco et al., 2016). The temporal and spatial aspects of agroforestry are therefore a challenge to the nutritional and economic stability of smallholder farmers. To avoid further burdening smallholders with the challenges inherent to the implementation of agroforestry, especially the net losses associated with the early implementation phase, it is essential to implement up front monetary compensation. This could take multiple forms such as governmental or organisational subsidies, bank loans, or delayed payback time for credits.

Another challenge agroforestry faces is that solely planting trees with high carbon storage capacity, which may be desirable to further mitigate climate change, may not be the best option, even though the new trees may improve local biodiversity (Jose, 2012). The ability of the selected species to adapt to the local context, including the climate variabilities it may experience, is also crucial. Coe et al. (2014) discuss the limited success of agroforestry projects which fail to account for local specificities. This is of major importance. When incompatible species are introduced, they may enter into competition with native species for nutrients, light (Ollinaho and Kröger, 2021), and water (Miller and Pallardy, 2001), leading some native species to die out or their yields to diminish (Santos et al., 2012 as cited in Ollinaho and Kröger, 2021). Not only can species misadaptation lead to environmental consequences, which undermine the health of local ecosystems, but it can also directly impact the capacity of smallholders to sustain their livelihoods. Because of diminished yields (competition for nutrients, introduction of pests) or increased expenses for chemicals, needed to compensate for the imbalance in nutrient distribution, smallholders may be at an increased risk of poverty, which would pose a direct challenge to the pursuit of CRD.

While agroforestry may provide climate mitigation through the uptake of carbon and may help farmers produce highly traded commodities (coffee, bananas, or mangos), the introduction of agroforestry needs, first and foremost, to reflect local needs and demands. If there is no local impetus to adapt practices or improve the agricultural system, the desirability and the fairness of the project may be significantly reduced. As Coe et al. (2014) discussed, the general local context must be taken into consideration, not solely the biophysical dimension, but also the social, economic and institutional conditions. Project designers and funders will therefore find it all the more important and relevant to pay attention to local aspirations as well as the context in which they exist. In some cases, for instance, smallholders have access to opportunities for funding such as subsidies from the government or NGOs, to practise agroforestry. As mentioned by FG4 and FG6, in other places, such as India and Indonesia, it is more common for individuals, supported by adequate policy frameworks, to initiate agroforestry projects. For example, in India, agroforestry is supported by a complete legislative framework, which encourages its implementation (*cf.* Government of India, 2014). In other contexts, however, financial help may not be available, leaving farmers to bear the costs associated with the initial investment. For CRD to be successfully pursued, these discrepancies need to be duly considered. Otherwise, the capacity of the project to reflect equity and justice at the local level where the project is implemented may be jeopardised. Our tool is holistic, rather than normative, and considers the multiple arenas of engagement, while allowing for particular enablers to be reflected more significantly, depending on the stakeholder preferences. FG7 suggested that our tool gives space for prioritisation instead of measurement, which may be more to the point when it comes to understanding how the components of CRDP play out in the local context. In addition, it is perceived as a tool that offers potential for social learning, whereby different stakeholders prioritise and discuss the different enablers in combination with the arenas of engagement. The process could offer a forum for smallholders to voice their expectations and concerns, helping project designers to explain how the different topics covered by the questions were taken into account in the project design. The tool was therefore seen as offering a means for project designers to explain what they intend to do in light of the local context (FG5).

Given these concerns, while agroforestry can be seen as a potential strategy through which climate resilient development could be operationalised, thereby contributing to climate adaptation, mitigation and development, its introduction is not without risks. Agroforestry as a farming practice calls for the careful consideration of species as well as more than the prime consideration of economic returns through selling agroforestry products, and also the consideration of potential social risks emerging from the practice. Overlooking the risks and trade-offs inherent in agroforestry may undermine the benefits it also brings about in terms of climate mitigation and adaptation, and development. As highlighted by Stringer et al. (2022), pursuing CRD is not a matter of whether or not trade-offs exist in the chosen pathway of action but rather a matter of acknowledging them to address them adequately. To do so, the chosen pathway needs to offer sufficient space for iterative discussion and decision-making between the different stakeholders, which will evolve throughout time to better reflect the local challenges. This is where we see that the support the pathway receives is crucial, both from the farmers and the project developers and funders, but also from the governmental and financial institutions as these challenges need to be addressed by all stakeholders through joint actions. This resonates with Eriksen et al. (2021), whose work emphasised that adaptation and development cannot be reached by non-targeted work engaging with one sole group of actors (e.g., smallholder farmers) while the system continues to go against the transformation initiated through projects and local actions; rather the whole system needs to support the action for it to successfully pursue CRD. We can imagine that our tool could be used as a communication platform between the various actors from the project, which could help build the supportive system on which the indicative pathway towards CRD relies.

5.2. Contribution to the literature

Our study contributes to the emerging body of literature on Climate Resilient Development Pathways (CRDP). We operationalised CRDP through agroforestry as a farming practice for smallholder farmers, and developed a tool for project developers and funders to use to check that their project is aligned with the goals pursued through CRD. Our tool takes the multiple objectives associated with

CRDP into consideration (climate adaptation and mitigation, and development) while also making sure that the trade-offs linked to agroforestry are duly taken into account to ensure that CRD is pursuable. In that sense, our tool has the potential to help developers and funders check that the project is suited to the needs of farmers, and that it will be benefiting them, without putting smallholders at further risk of nutritional and economic poverty, which would be contrary to the pursuit of CRD. Although our tool may be important to the literature, it was not without difficulty that we were able to build it. One of the biggest challenges was the current lack of CRDP language in the literature, with the literature not mentioning 'enablers' and 'arenas of engagement'. As such, our research contributes to expanding the current literature on CRDP, and may be used as an exploratory study upon which further studies may be built. We also developed a tool, which is potentially more advanced than other tools in taking the social dimension of agroforestry projects into consideration and which allows explicit consideration of the interactions between the enablers and arenas of engagement in pursuit of climate resilient development. Indeed, in comparison to other tools developed to assess agroforestry, our tool is more holistic, and can be adapted to various forms of agroforestry in different contexts. As such, our tool contributes to the body of literature around CRDP as, to the best of our knowledge, it is the first operationalisation of the concept.

5.3. Policy implications and future research

The CRDP, as developed by the IPCC, was incorporated in the summary for policymakers, but not delivered with adequate explanations enabling the conversion of scientific knowledge into actionable policy making. Additionally, considering that only the most central information is included in the summary for policymakers, the CRDP framework was therefore seen as an important concept to research. This study, therefore, serves as clarification of the framework through the definition of CRDP itself, enablers as a concept, arenas of engagement as a concept, as well as every single enablers and arenas of engagement. Our research also acts as an exemplification of the use of the CRDP framework through agroforestry as a potential pathway.

Although validated by researchers and practitioners during the focus group, and by the researchers team in a separate case study, the tool may be further applied for validation and reflections. Follow-up research may also involve the development of an evaluation grid that could help measure the extent to which projects actually strive towards CRDP according to the questions we developed. This could be achieved through a combination of comparative case studies of past and present agroforestry projects for smallholder farmers, in similar and varying climate regions. It may also be valuable to further inquire about the development of a supporting system for CRDP. Studies could, for example, focus on the role of governments and financial institutions in the development of the needed structure.

6. Conclusion

This paper has presented an exploration of the operationalisation of climate resilient development through agroforestry. We have seen that agroforestry projects require careful attention to multiple elements to ensure that its uptake is not harming the environment and not making smallholders more vulnerable (i.e., that it really is building climate resilience). Our study shows that attention needs to be paid to species selection, local biodiversity and soil composition to avoid any form of competition between trees and crops for nutrients, light, or water. In addition, we noted that the introduction of non-native species, when those are invasive to the place where they are introduced, can be detrimental to local ecosystems and food production. We highlighted the social challenges associated with agroforestry projects, where gender dynamics, labour division, social perceptions and fears need to be addressed. Our findings also emphasise the prominence of the local context and the need to consider social, economic and institutional conditions in the design of locally tailored agroforestry projects. In this respect, the tool we developed as a combination of enablers and arenas of engagement to pursue CRDP through agroforestry is useful. It provides a way for project developers to comprehensively check that their projects are taking the multiple dimensions of CRDP into account. It also allows project developers to explain how they intend to take CRDP components into consideration and how the project aims to align with local needs to maximise the potential benefits of agroforestry projects. Compared with other tools, ours provides features that permit greater reflection on the social dimension of agroforestry projects. Through the case of agroforestry, this study, therefore, contributes to the understanding and operationalisation of climate resilient development pathways as a farming practice for smallholder farmers.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

CT: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft. RC: Funding acquisition, Methodology, Supervision, Writing – review & editing, Conceptualization, Validation. LS: Funding acquisition, Methodology, Supervision, Writing – review & editing, Conceptualization, Validation.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2023.1260291/full#supplementary-material

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