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What challenges impede the adoption of agroforestry practices? A global perspective through a systematic literature review

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Abstract Despite the extensive amount of evidence in the literature regarding the benefits of agroforestry systems including carbon sequestration, soil erosion reduction, climate change resilience, biodiversity conservation and other ecosystem services, the adoption of agroforestry practices presents several barriers for farmers and other stakeholders, thus requiring comprehensive examination from the scientific community. We performed a systematic literature review following the methodology described in the PRISMA framework, to provide a novel comprehensive and systematic overview of what is present in the literature regarding the obstacles stakeholders perceive with regards to agroforestry adoption, gathered through participatory research methods, which are methodologies that engage stakeholders in the research process. In this work, we highlighted and categorized 31 obstacles that stakeholders around the globe perceive according to the examined literature ($n=90$) with regards to agroforestry adoption, pertaining to i) technical-agronomic, ii) socio-economic and iii) policy-legislative aspects. We produced a consultable database of the examined literature presenting the extracted and categorized data including 1) Region of interest; 2) Investigated agroforestry system; 3) Methodologies utilized in the papers; 4) Number, gender ratio and type of stakeholders; 5) Main relevant obstacles found in the paper. We highlighted the five most frequently encountered issues i) the availability or quality of knowledge or experience on technical and agronomic matters, or knowledge diffusion necessary to implement or maintain agroforestry systems ii) the perceived socio-economic issue related to the market, marketing of agroforestry products, supply chain or jobs in agroforestry; iii) issues related to the amount of labor or time necessary to implement or maintain agroforestry systems; iv) issues related to the upfront economic investment necessary to establish an agroforestry system and availability of capital; and v) issues related to the availability of technical support necessary to implement or maintain agroforestry systems.

Keywords Farmers · Multi-stakeholder · Participatory · Sustainable · Policy · Economic · Technical

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Introduction

Climate change, unequivocally caused by the emission of greenhouse-gases from human activities, represents a hazard to human and planet health and affects vulnerable communities in a disproportionate manner (IPCC 2023). It was recently discovered that six out of the nine planetary boundaries (climate change, change in biosphere integrity, stratospheric ozone depletion, ocean acidification, biogeochemical flows, land-system and freshwater change, atmospheric aerosol loading, and introduction of novel entities) were crossed, indicating that humanity is currently operating in a space that is far beyond the safe boundaries of Earth (Richardson et al. 2023).

The Paris Agreement, a legally binding international treaty on climate change adopted by 196 Parties at the UN Climate Change Conference (COP21) in 2015, sets ambitious goals to limit global warming to well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the increase to 1.5 degrees Celsius. As part of the agreement, countries around the world have committed to taking increasingly ambitious climate actions, communicating them in their nationally determined contributions (NDCs) (UN 2015).

The IPCC mentions agroforestry among the effective adaptation options to reduce climate risk and improve the sustainability of food systems (IPCC 2022) as well as a mitigation option in the AFOLU (Agriculture, Forestry, and Other Land Use) sector, which together with improved and sustainable crop and livestock management, and carbon sequestration in agriculture, could contribute to a reduction between 1.8 and 4.1 $GtCO_{2\text{-eq}}$ per year (IPCC 2022). Other estimates indicate that by implementing agroforestry in the 10% of the area with the highest number of accumulated environmental pressures (related to soil health, water quality, biodiversity and climate change impacts), could lead to a carbon sequestration of 2.1 to 63.9 million t C per year (7.78 and 234.85 million t CO2 per year) depending on the type of agroforestry (Kay et al. 2019b).

Agroforestry can be defined as the set of land-use systems and practices in which woody perennials are deliberately used on the same land management unit with agricultural crops and/or animals where both ecological and economical interactions are present among the different components of the agroforestry systems (Ed. 1982). Although the definition of this practice might be recent, its origins are certainly not: already more than three decades ago, agroforestry was described in the literature as a novel name for an old practice (Nair 1991).

Agroforestry systems can be characterized in various ways depending on specific needs, such as based on the nature or arrangement of its components, or productive or protective function (Nair 1993), resulting in different categories including, but not limited to: silvoarable systems; silvopastoral systems; wood pastures; grazed orchards; hedgerows; windbreaks; grazed forests; forest farming (Fig. 1).

According to estimates made using LUCAS Land Use and Land Cover data, in the EU 27 the total area under agroforestry is estimated to be equal 15.4 million ha, corresponding to 8.8% of the utilized agricultural area (den Herder et al. 2017). It is also estimated that that the area of agroforestry in the EU23 decreased by 47% between 2009 and 2018 primarily due to a reduction in outdoor grazing (Rubio-Delgado et al. 2023), despite EU Member States having the opportunity to offer specific rural development programs support for establishing agroforestry on agricultural land since 2007, which has hardly been used (Martineau et al. 2016). Globally, the area under agroforestry has been estimated around 1023 million ha, but this estimate remains highly uncertain due to major methodological obstacles (Ramachandran Nair et al. 2009).

Despite the extensive amount of evidence in the literature regarding the multiple benefits of agroforestry such as carbon sequestration (Albrecht and Kandji 2003; Terasaki Hart et al. 2023), reduction of soil erosion (Palma et al. 2007), resilience to climate change from smallholder farmers (Verchot et al. 2007), conservation of biodiversity and generation of ecosystem services (Torralba et al. 2016), the adoption of agroforestry systems also presents its own set of challenges and barriers that require comprehensive examination and attention from the scientific community. Previous research has examined the adoption of agroforestry systems by conducting reviews, which have focused on specific types of agroforestry systems (Wienhold and Goulao 2023), particular geographical regions (Mercer 2004), and have employed a combination of review articles, theoretical research, and econometric studies (Amare and Darr 2020). The novelty of this work stands in its systematic approach and its focus on stakeholder perception in all regions and agroforestry

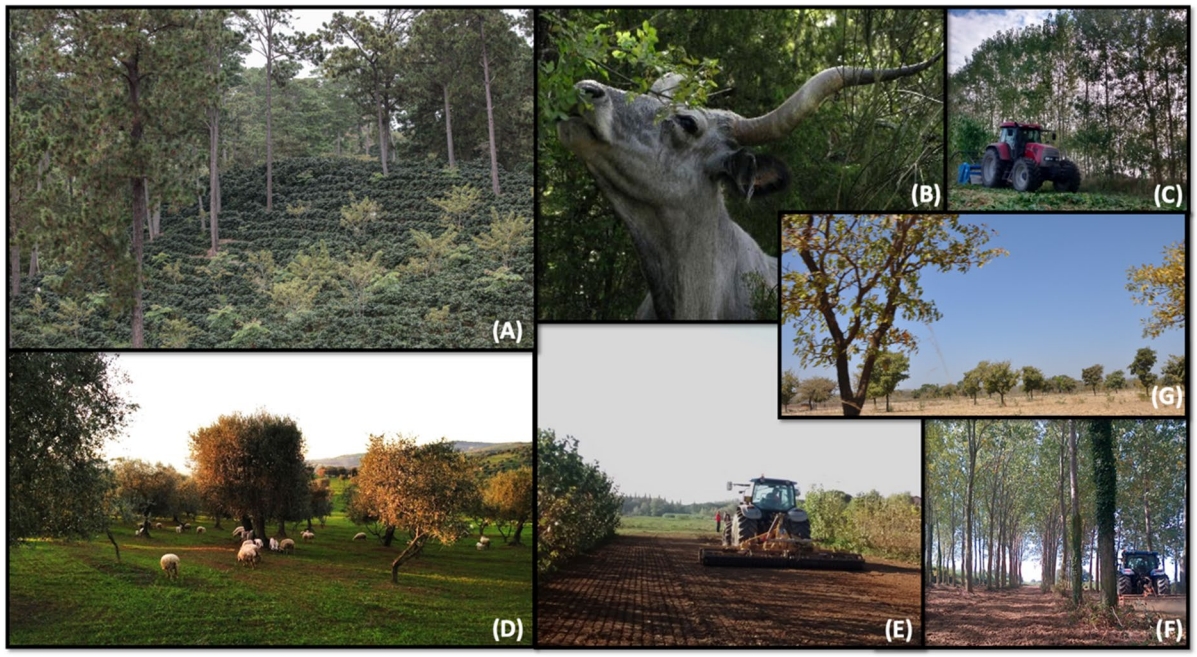

Fig. 1 A picture collection of agroforestry systems: (**A**) coffee agroforestry, (**B**) silvopastoral, (**C**) windbreaks, (**D**) agrosilvopastoral, (**E**) Alley cropping, (**F**) Forest farming, and (**G**) shea butter plantation. Photo **B**, **C**, **D**, **E**, and F by Alberto Mantino, A by Maren Barbee, and G by World Agroforestry (ICRAF)

systems rather than the investigation of factors affecting adoption or non-adoption with an external perspective. The goal of this work is to provide a comprehensive and systematic overview of what is present in the literature regarding the obstacles stakeholder perceive with regards to agroforestry adoption, gathered through participatory research methods. This work could serve as a starting point for future research to looking more in depth into time or region-specific challenges and finding solutions in line with stakeholders needs.

We chose to perform a systematic literature review consistent with the methodology described in the PRISMA framework (Page et al. 2021). This systematic literature review can be categorized as a descriptive textual narrative synthesis, as its aim is to describe the state of the literature pertaining to the research question but is also characterized by a standard data extraction process (Xiao and Watson 2019).

We aim to explore and analyze the existing research investigating the challenges of agroforestry globally as perceived by stakeholders of the agroforestry value chain, shedding light on key issues and drawbacks surrounding agroforestry. In doing so, we aim to contribute to a deeper understanding of the complexities surrounding agroforestry practices and their implications for promoting solutions to enable more sustainable and resilient agricultural future.

Moreover, this paper also produces a searchable database to easily retrieve information about perceived issues regarding agroforestry according to the literature published in specific geographical locations and/or agroforestry systems.

Review protocol development and validation

Research question and literature review framework

The first step of the review protocol development process was to define the research question, which can be summarized as follows: "*According to the literature, what do agroforestry stakeholders perceive to be the main challenges hindering the adoption of agroforestry practices, globally*?".

The systematic literature review as conducted following the PRISMA framework (Page et al. 2021) in the Scopus database and EndNote was used as the reference management tool.

All methodological processes and choices were described in a working document, which allowed to record and retrieve such information at a later stage for accurate description of the methodology despite the long time taken to screen records and full texts.

Query formulation

The query was constructed in an iterative manner by extracting the two primary concepts central to our research question, which represents the research objectives and the key themes under investigation. Subsequently, a structured query was developed to include various synonyms, related terms, alternative spellings, and variations of these core concepts including deriving nouns, adjectives and verbs. The query was finalized utilizing Boolean operators. This approach ensured the comprehensiveness of our literature search, enabling us to capture a wide array of relevant studies while maintaining the focus on the primary elements of our research inquiry. The key concepts were identified as I) "Agroforestry", and II) "Challenge".

TITLE-ABS-KEY (agroforest* OR agro-forest* OR silvopastur* OR silvo-pastur* OR silvopastor* OR silvo-pastor* OR silvoarabl* OR silvo-arabl* OR hedgerow* OR shelterbelt* OR "riparian buffer strip*") AND TITLE-ABS-KEY (obstacle* OR challeng* OR hinder* OR barrier* OR difficult* OR struggl* OR troubl*).

Endnote Importing and deduplication process

This query yielded a total of 2092 results in the Scopus database on 18.11.2022. The search result was then exported and imported into the EndNote software. The EndNote Built-in de-duplication tool was then used to eliminate as many duplicate records as possible. The deduplication function resulted in two duplicates being found. This was then complemented by manual deduplication, which excluded an additional 21 papers.

Relevant endnote groups and group sets were created for work organizations, creating duplicated working groups when needed. Labels were used to keep track of the screening and retrieval process.

In order to include addition research articles published the literature review after November 2022, the search was performed a second time on 28.11.2023 using the same query, which yielded an additional 208 papers. The same screening procedure was applied, and results were presented in aggregate form since the goal of this work is to provide a comprehensive synthesis of the literature as a whole.

Title and abstract screening

Titles and abstracts were screened and included or excluded according to the following criteria, excluding obviously irrelevant papers, papers not written in English and articles containing literature reviews. The exclusion and corresponding inclusion criteria are presented in Table 1.

At this stage, we chose to be rather generous when applying the exclusion criteria regarding the pertinence of each article. We included those articles that reasonably speaking, could provide information relevant to the research question. More papers where then excluded at a later stage during full-text screening.

The papers that were included for the full text retrieval were 668 for the first search and 37 for the second search, for a total of 705.

Full-text retrieval and screening

To screen the full text, the PDF file of the records had to be retrieved. A combination of the EndNote built-in function (with an efficiency of roughly 43%)

Table 1 Inclusion and corresponding exclusion criteria for the title and abstract screening process for a systematic literature review investigating the obstacles to the application of agroforestry practices following PRISMA guidelines

Exclusion criteria	Inclusion criteria
The article is in a language other than English	The article is in the English language
The article has nothing to do with AF systems and it is not plausible that it could provide information relevant to the RQ	The article has to do with AF systems and it plausible that it could provide information relevant to the RQ
The article is a literature review	The article is not a literature review

alongside a manual search for full text retrieval was used. Of the 705 records (considering both searches), 644 full-text papers were retrieved, while 61 full-text papers were not retrieved (57 during the initial search, 4 during the second search).

During full-text screening, the goal was to screen and find papers that could provide information relevant to the research question. Inclusion criteria (and corresponding exclusion criteria) are illustrated in Table 2. At this stage, three additional duplicates were found. After full-text screening, 90 papers were selected and fulfilled all the inclusion criteria and are therefore included in this systematic literature review.

Graphical representation of the Prisma SLR and time frame

The research question definition, query development, identification, screening and inclusion steps of this systematic literature review were conducted from November 2022 to July 2023, while the second search was conducted in November 2023.

The number of records and reports included and the reason for exclusion are illustrated in Fig. 2 as a PRISMA compliant flow diagram. All data extracted during the screening process was systematically recorded in an excel sheet, including the presence and source (bibliographic or original) of information relevant to the research question, exclusion or inclusion and its reason, additionally to the label to be assigned in EndNote to facilitate records and reports grouping and characterization. Results are presented in an aggregate form for the initial and second search.

Data extraction and obstacle categorization

After the selection of the 90 studies to be included in the review, the relevant data was extracted and categorized in an Excel sheet. The following data was extracted from each relevant paper and subsequently organized in homogeneous categories: 1) Region of interest; 2) Investigated agroforestry system (when multiple systems were investigated, it was categorized as "agroforestry"); 3) Methodologies utilized in the papers; 4) Number, gender ratio and type of stakeholders (when multiple stakeholders were present, it was categorized as multistakeholder) 5) Relevant obstacles found in the paper (which were then later initially categorized into i) technical and agronomic ii) socio-economic and iii) policy and legislative).

In the case of a multitude of issues being presented and especially in the case of close ended research format (I.E. large list of potential obstacles to be ranked by users), we chose to only include the obstacles clearly and openly deemed as most relevant by the authors when presenting the outcomes of their research. Furthermore, many research papers presented quantitative analysis and importance scores for such obstacles, which we chose not to include in this literature review at this stage.

Features of selected papers

Number of papers found per year

After the identification and screening phase of the systematic literature review, 90 papers were included.

Table 2 Inclusion and exclusion criteria for the full-text screening process for a systematic literature review investigating the obstacles to the application of agroforestry practices following PRISMA guidelines

Exclusion criteria	Inclusion criteria
The paper is not relevant to the RQ	The paper is relevant to the RQ, providing insight on stakeholder perception regarding the obstacles to the application of agroforestry practices
The paper is written in a language other than English	The paper is written in English
The pdf quality is not acceptable and doesn't allow the reader to comprehend the text. A better quality pdf was not retrieved	The pdf quality is acceptable and allows the reader to comprehend the text or a pdf of better quality was retrieved
The information relevant to the RQ is literature-based	The information relevant to the RQ is not literature-based but rather the product of original research

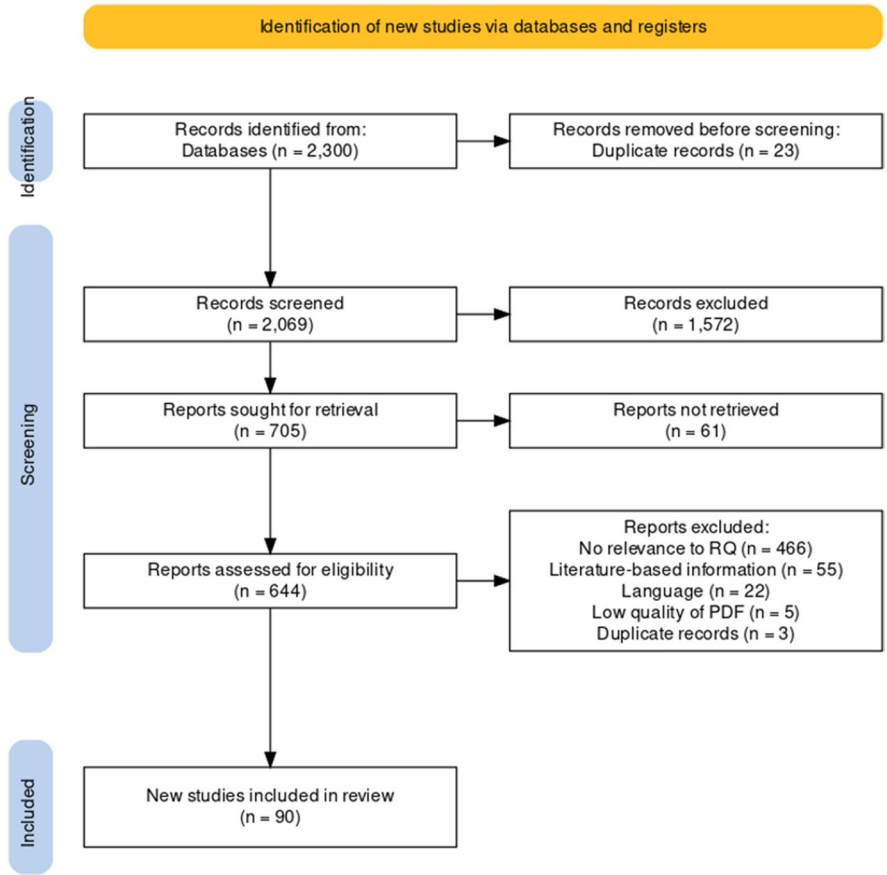

Fig. 2 PRISMA consistent flow diagram showing the identification screening and inclusion process of the systematic literature review (Haddaway et al. 2022)

Most papers were recent, with only 12 papers of the included papers being published prior to 2010.

Country of relevance

Of the 90 papers, only three of them referred to two or more countries. The 90 included papers covered 54 countries across all continents, as shown in Fig. 3. A full list of papers by country and other variables is available in Table A1.

Of the 90 papers included in this SLR, 27 were related to Africa, 14 to Asia, 19 to Europe, 11 to North America, one to Oceania, and 17 to South and Central America. One additional paper presented results from two countries, one in Europe and the other in South America.

Methodologies and stakeholders involved

The papers were classified based on the methodologies employed by their respective authors. While the majority of papers predominantly utilized a single methodology, we found that 19 out of the 90 papers incorporated a secondary methodology alongside the primary one. The utilized methodologies, combining main and secondary methodologies (n = number of papers where it was used) are as follows: Interviews ($n = 45$); Surveys ($n = 36$); Household surveys ($n = 12$); Focus group discussions ($n = 8$); participatory workshops ($n = 5$); Project field site visits ($n = 1$); Participatory game sessions ($n = 1$); participatory observations ($n = 1$).

Of the 90 papers, a vast majority concerns the category of farmers ($n = 44$), and smallholder farmers ($n = 9$), some of them involve a multi-stakeholder group ($n = 30$), landowners ($n = 3$); extension professionals ($n = 2$); practitioners ($n = 1$) and municipalities ($n = 1$). For further considerations regarding the occurrence of issues in papers according to stakeholder group, we chose to summarize the previous categories into I) (smallholder) farmers ($n = 54$) and II) multi-stakeholder

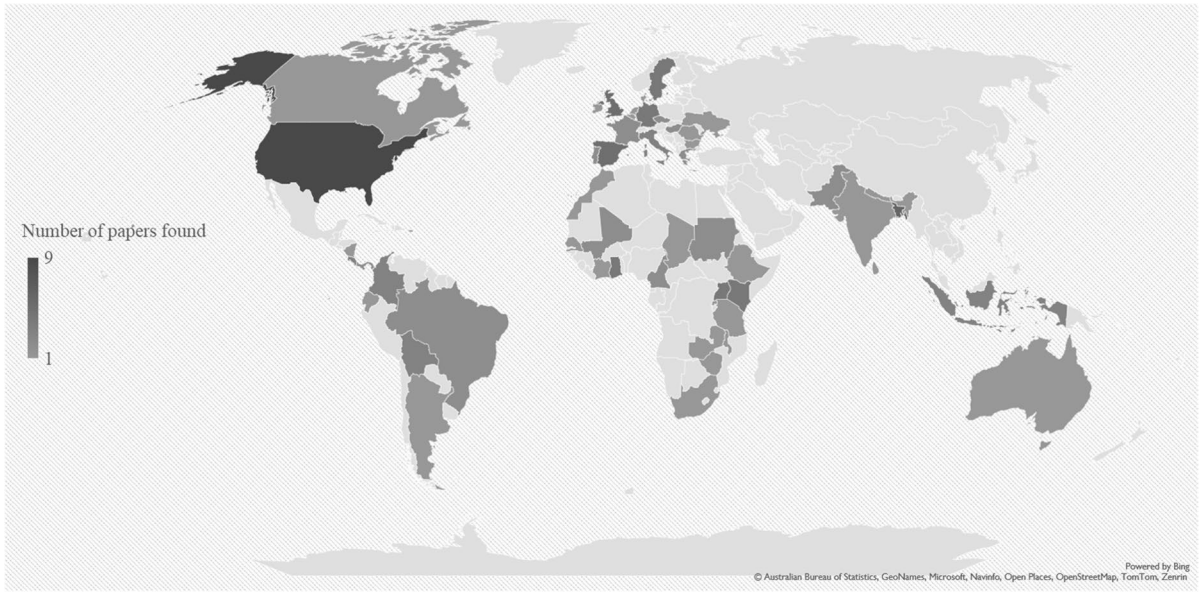

Fig. 3 Graphical representation of the number of papers found in each country in this systematic literature review on the perceived obstacles to the application of agroforestry

and others ($n=37$). By extracting the number of participants for each paper, we calculated the total number of participants in all methodologies in all 90 papers to be approximately 11.719, with 60% of the participants being in the "farmer/smallholder farmers" category and 40% being of the "multi-stakeholder + others" category.

In 55 of 90 papers (60%), the gender ratio of the investigated sample was not disclosed by the authors. In the remaining papers, females were on average 30.00% of the involved stakeholders. The average percentage of female participants per geographical region was as follows: 37% for Africa, 35% for Asia, 28% for North America, 23% for South and Central America and 6% for Europe, as shown in Fig. 4. Gender-related information is available for each paper in Table A1.

Investigated Agroforestry systems

Most papers referred to agroforestry in general or to multiple systems ($n=54$), while the rest referred to specific systems, namely: (agro)silvopastoral systems ($n=10$); cocoa agroforestry ($n=4$); forest farming ($n=4$); forest gardens ($n=3$); hedgerows/shelterbelts ($n=3$); Agroforestry systems of high nature and cultural value (HNCV) ($n=2$); improved tree fallow ($n=2$); modified taungya system (MTS) ($n=2$); coffee agroforestry ($n=1$); collaborative forest management ($n=1$); contour hedgerow intercropping agroforestry technology (CHIAT) ($n=1$); homegardens ($n=1$); oil palm agroforestry ($n=1$); silvoarable systems ($n=1$).

Conceptualizing barriers to agroforestry

Obstacles reported in the literature were extracted and categorized in macro-categories and subsequently in sub-categories in an iterative manner. In fact, the obstacles categorization presented in this study is not based on an existing framework but is rather original and was developed by the authors during the full-text screening process. The following categorizations made were mostly based on 1) how the issue was presented by the authors and 2) following similar criteria for categorization across publications in order to present the issues in a consistent manner.

The database and results should therefore not be interpreted as absolute categorization of issues across

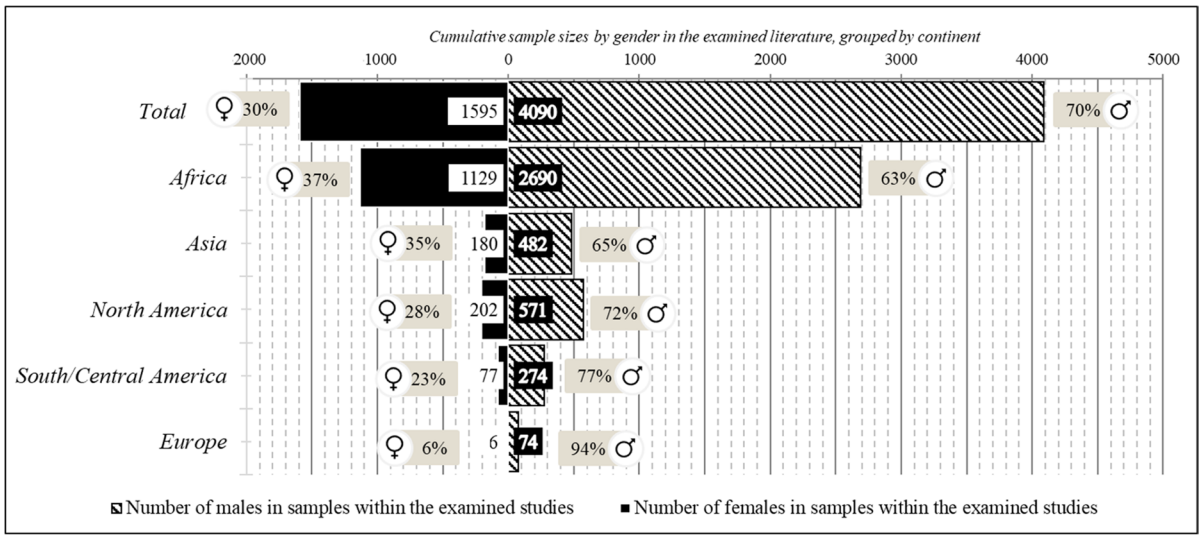

Fig. 4 Cumulative number of females and males and average gender composition in the samples taken in the selected literature by geographical region, when available (40% of the literature)

space and time, but rather as a starting point for readers to quickly retrieve articles that deal with perceived obstacles regarding agroforestry in a specific time region or country and have an overview of the findings of such article.

After data extraction, obstacles from each paper were categorized into:

- I: TECHNICAL, agronomic, environmental and climatic (including availability of inputs, lack of space, natural constraints, labor, technical knowledge)
- II: SOCIO-ECONOMIC, social, financial (including market related constraints, access to credit, investment, and social issues in the sense of relationships with neighbors or other stakeholders)
- III: POLICY, legislative or subsidy related (including land tenure, access to subsidies, legal definitions and project design)

Across the analyzed papers ($n=90$), we encountered issues pertaining to the category of technical issues in 86% of cases ($n=78$), followed by socio-economic issues in 76% of cases ($n=69$) and policy-related issues in 62% of cases ($n=56$).

Table 3 shows the breakdown of the occurrence of these different categories of issues per geographical region.

The following paragraph contains a breakdown of the specific obstacles and their occurrence across the literature. In Tables 4, 5 and 6 and across this research paper, issues codes are numbered from smallest to largest based on their occurrence in the literature (n: more frequently encountered; n + 1: less frequently encountered) within their macro-category.

Technical-agronomic issues

Within the category of technical issues preventing the adoption of agroforestry systems, we identified 13 sub-categories of obstacles. They are described in Table 4 alongside their unique code.

Socio-economic issues

Within the category of socio-economic issues preventing the adoption of agroforestry systems, we identified ten sub-categories of obstacles. They are described in Table 5, alongside their unique codes.

Policy-legislative related issues

Within the category of socio-economic issues preventing the adoption of agroforestry systems, we

Table 3 Occurrence of macro-categories of issues to the application of agroforestry in the examined literature ($n=90$) across geographical regions, expressed as the % of papers related to that area that reported one or more issues pertaining to such category

Geographical region	Occurrence of issues by macro category		
	I) Technical-agronomic	II) Socio-economic	II) Policy-legislative
Africa ($n=27$)	85.19%	66.67%	40.74%
Asia ($n=14$)	85.71%	78.57%	64.29%
Europe ($n=20$)	85.00%	75.00%	90.00%
North America ($n=11$)	90.91%	72.73%	27.27%
Oceania ($n=1$)	0.00%	100.00%	100.00%
South/Central America ($n=18$)	88.89%	88.89%	77.78%
Average	85.71%	75.82%	61.54%

identified six sub-categories of obstacles. They described Table 6, alongside their unique codes.

Barriers to the application agroforestry and their occurrence in the literature

In Table A1, we present the extensive results of the literature review, including year of publication, study location, number, type and gender of interested actors, methodology and agroforestry system, and finally a list of the sub-categories of issues emerging from each of the 90 papers included in the present study. Note that due to space limitations, we were only able to insert the label number, rather than the whole code. For the full explanation of the categorized obstacles, refer to the contents of Tables 4, 5 and 6.

Highlighting the necessary conditions to agroforestry adoption is not a novelty in the literature. An article published in 2001 by Byron summarized the author's three-decade long observations in dozens of failed and successful agroforestry in farm woodlots initiatives across Asia and Africa, as well as Australia, North America and Europe. The key obstacle to agroforestry in farm woodlots initiatives was identified as the failure to recognize the links between production, market and policies, with preconditions for success being: i) secure land access and product rights for farmers, ii) availability of viable production technology, knowledge and necessary inputs (fertilizer, credit, and germplasm), iii) confidence in protecting trees from various risks until maturity from risks (fire, insects, pests, diseases, theft, and expropriation), and iv) presence of market demand with attractive prices, and physical access to that market for small producers (Byron 2001). These general 'rules of thumb' deriving from experiences gathered throughout the 1970s'-2000s' align with many of the obstacles highlighted in our systematic literature review (namely P.03; T.03; T.01; T.14; E.07; T.06; T.10; T.09; E.07), suggesting that some of these problems might have been persisting globally more than two decades later (Byron 2001).

In Table 7, we present the sub-categories of perceived issues in the literature from most frequently encountered to least frequently encountered in the examined literature when analyzed globally. Note that as shown in Table A1, paper 87/87a refers to two different continents. In Table 7, we therefore chose to report it in both Europe and South America as results are presented in a clear and distinct manner for each studied country. The real total number of papers included in the literature review remains 90, although it was 91 for the purpose of regional considerations. Note also that in Table A1, issues that are encountered with the same rate are presented in no particular order. According to our analysis, the overall five most frequently encountered perceived issues in the examined literature regarding agroforestry adoption, globally, are: i) the availability or quality of knowledge or experience on technical and agronomic matters, or knowledge diffusion necessary to implement or maintain agroforestry systems, found in 33 articles (36.2%) [T.01.KNOWLEDGE.EXPERIENCE]; ii) the perceived socio-economic issue related to the market, marketing of agroforestry products, supply chain or jobs in agroforestry, in 33 articles (36.2%) [E.01. MARKET(ING).SUPPLY CHAIN]; iii) issues related to the amount of labor or time necessary to implement or maintain agroforestry systems, in 31 papers (34.1%) [T.02.LABOR.TIME]; iv)

Table 4 Codes and descriptions of all sub-categories of the technical-agronomic macro-category

Code identifying technical and agronomic issues	Brief explanation of the issue
T.01.KNOWLEDGE.EXPERIENCE	Issues related to the presence or quality of knowledge or experience on technical and agronomic matters or knowledge diffusion necessary to implement or maintain agroforestry systems
T.02.LABOR.TIME	Issues related to the additional amount of labor or time necessary to implement or maintain agroforestry systems
T.03.TECHNICAL.SUPPORT	Issues related to the availability or quality of technical support, assistance or technologies necessary to implement or maintain agroforestry systems
T.04.LAND.SPACE	Issues related to the availability of land or space necessary to implement or maintain agroforestry systems
T.05.SEEDS.SEEDLINGS.TREES	Issues related to the availability, health or state of seeds, seedling or trees on farm including low seedling survival, poor quality of seeds or seedling availability
T.06.INTERACTION.LIVESTOCK	Issues related to the interactions among the components of the agroforestry systems concerning livestock or wild animals. This includes livestock browsing, damages to trees and plants by animals due to lack of fences, as well as wildlife disturbances
T.07.COMPLEXITY	Issues related to the complexity of agroforestry systems, experiences as more difficult to manage, organize and perform work on, therefore requiring additional skills
T.08.INTERACTION.CROP	Issues related to the interactions among the components of the agroforestry systems concerning the main crops. This includes a perceived lack of benefit or disadvantages such as reduced yield or harvest delays
T.09.PEST.DISEASES.WEEDS	Issues related to the occurrence of pests, diseases of weeds in the agroforestry system. This is mainly related to the perception that the presence of trees possibly increases the occurrence of such elements
T.10.CLIMATE.NATURAL	Issues related to climate change, a lack of predictability or severity of weather events and climate disruptions, fire or natural constraints relating to agroforestry systems
T.11.MECHANIZATION	Issues related to mechanization and agricultural operations in the agroforestry system, including perceived issues with mechanization and harvesting operations due to tree presence in fields
T.12.WATER	Issues related to water quality of availability in/for the agroforestry system. This includes water scarcity and drought and perceived interactions with trees and water fluxes or diverse irrigation requirements
T.13.AF.SYSTEM.PLANNING	Issues specific to the planning of agroforestry systems. This includes species choice, crop-tree matching, tree placement, planting densities and system design
T.14.INPUTS.FARM	Issues related to the presence, availability or quality of inputs for farm operations in an agroforestry systems such as fertilizer, herbicide, fodder, and forage
T.15.SOIL	Issues related to the health, suitability or fertility of soil including soil erosion phenomena

issues related to the upfront economic investment necessary to establish an agroforestry system and availability of capital, in 30 papers (33%) [E.02. UPFRONT.INVESTMENT]; and v) issues related to the availability of technical support necessary to implement or maintain agroforestry systems, in 24 papers (26.37%) [T.03.TECHNICAL.SUPPORT]. Two additional technical-agronomic obstacles that emerged frequently are: issues related to the availability of space or land necessary to implement or maintain agroforestry systems, found in 23 papers (25.3%) [T.04.LAND.SPACE], and issues related to the availability or quality of seeds, seedling or specific tree-related issues, found in 21 papers (23.1%) [T.05.SEEDS.SEEDLINGS.TREES].

Additional frequently encountered socio-economic issues globally include: i) issues related to the increased costs associated with an agroforestry system, in 19 papers (20.9%) [E.03.INCREASED. COSTS]; ii) issues related to cashflow and the time

Table 5 Codes and descriptions of all sub-categories of the socio-economic macro-category

Code identifying socio-economic issues	Brief explanation of the issue
E.01.MARKET(ING).SUPPLY CHAIN	Issues related to the market, marketing of agroforestry products, supply chain or jobs in agroforestry. This includes limited, unfavorable or inaccessible markets, perceived market risk or presence of intermediaries
E.02.UPFRONT.INVESTMENT	Issues related to the upfront economic investment necessary to establish an agroforestry system and availability of capital
E.03.INCREASED.COSTS	Issues related to the increased costs associated with managing an agroforestry system
E.04.TIME.ECONOMIC.BENEFIT	Issues related to cashflow and the time necessary to have an economic return from the agroforestry system. This includes the concern with the lack of income until tree harvesting
E.05.PSYCHO.BEHAVIORAL	Issues related to psychological, behavioral and cultural factors. This includes perceived laziness, lack of motivation, lack of confidence, perceived risk or resistance to changing land use
E.06.FINANCING.CREDIT	Issues related to financing, limited access or inaccessibility to credit or credit facilities, limited or short-term financing, and taxes
E.07.RELATIONSHIP.STAKEHOLDERS	Issues related to the relationships with other stakeholders. This includes problematic collaboration, conflict over livestock or property boundaries with neighboring farmers, corruption among officials and lack of connections or supportive organizations
E.08.NOT.PROFITABLE	Issues related to the non-profitability, non-cost-effectiveness or lack of financial planning in agroforestry systems
E.09.FUNDING.INCENTIVES	Issues related to the availability of funding and incentives regarding agroforestry, either at government or wider (such as EU) level
E.10.POVERTY	Issues related to poverty or food insecurity. This includes inability the to adopt agroforestry for poorer and food-insecure farmers, which are prevented from long-term planning and risk-takin

Table 6 Codes and descriptions of all sub-categories of the policy-legislative macro-category

Code identifying policy-related issues	Brief explanation of the issue
P.01.INSUFFICIENT.LEGISLATION	Issues related to inconsistent or insufficient legislation, legislative restrictions or knowledge of the law regarding agroforestry. This includes perceive contradictions between agriculture and conservation frameworks, inconsistencies among regulations and a lack of legal recognition of agroforestry and restrictions of tree utilization on farmland
P.02.POLICY.SUBSIDY	Issues related to agroforestry policy, subsidies and incentives design or their implementation. This includes perceived limited incentives, flawed subsidy systems, fear of losing agricultural subsidies when planting trees on-farm, agroforestry-inapplicable eligibility criteria in tax-saving schemes
P.03.LAND.TENURE	Issues related to land tenure concerning agroforestry. This includes issues such as perceived lack of secure tree tenure, unfavorable land tenure arrangements, lack of formal land titles or legal obligation to not alter key features of the land when leased
P.04.ADMIN.BURDEN	Issues related to administrative burden, bureaucracy or legal obstacles regarding agroforestry. This includes administrative complexity and delays to initiate agroforestry programs or difficulty in being granted permission to plant trees on leased land
P.05.POLITICS.GOVERNMENT	Issues related to government trust or politics regarding agroforestry. This includes a perceived lack of political will, problematic collaboration with political leaders, or perceived conflicting interests and lack of recognition of agroforestry benefits from government officials
P.06.ILL PROJECT.DESIGN	Issues related to ill agroforestry project design or implementation or lack of fairness and transparency in agroforestry projects. This includes perceived lack of proper financial assistance or extension services within the project, lack of transparency in payments or complicated/ unfair processes in the selection of involved famers

Table 7 Occurrence of examined obstacle in the literature, from most frequently encountered (1) to least frequently encountered (31). Data is presented regionally both as the number and percentage of papers that reported such issue per geographical region

Nr	Name of the issue	Occurrence of issues by geographical area													
		Africa ($n=27$)		Asia ($n=14$)		Europe ($n=20$)		North America ($n=11$)		Oceania ($n=1$)		South/Central America ($n=18$)		Global ($n=90$)	
		nr	%	nr	%	nr	%	nr	%	nr	%	nr	%	nr	%
1	T.01.KNOWLEDGE.EXPERIENCE	6.00	22.22	7.00	50.00	8.00	40.00	7.00	63.64	0.00	0.00	5.00	27.78	33.00	36.26
2	E.01.MARKET(ING).SUPPLY CHAIN	7.00	25.93	6.00	42.86	6.00	30.00	7.00	63.64	0.00	0.00	7.00	38.89	33.00	36.26
3	T.02.LABOR.TIME	7.00	25.93	4.00	28.57	9.00	45.00	6.00	54.55	0.00	0.00	5.00	27.78	31.00	34.07
4	E.02.UPFRONT.INVESTMENT	5.00	18.52	6.00	42.86	6.00	30.00	5.00	45.45	1.00	100.00	7.00	38.89	30.00	32.97
5	T.03.TECHNICAL.SUPPORT	5.00	18.52	3.00	21.43	4.00	20.00	6.00	54.55	0.00	0.00	6.00	33.33	24.00	26.37
6	T.04.LAND.SPACE	13.00	48.15	3.00	21.43	1.00	5.00	3.00	27.27	0.00	0.00	3.00	16.67	23.00	25.27
7	T.05.SEEDS.SEEDLINGS.TREES	10.00	37.04	4.00	28.57	2.00	10.00	3.00	27.27	0.00	0.00	2.00	11.11	21.00	23.08
8	T.06.INTERACTION.LIVESTOCK	6.00	22.22	3.00	21.43	5.00	25.00	5.00	45.45	0.00	0.00	2.00	11.11	21.00	23.08
9	T.07.COMPLEXITY	1.00	3.70	3.00	21.43	9.00	45.00	5.00	45.45	0.00	0.00	1.00	5.56	19.00	20.88
10	T.08.INTERACTION.CROP	3.00	11.11	1.00	7.14	5.00	25.00	4.00	36.36	0.00	0.00	6.00	33.33	19.00	20.88
11	E.03.INCREASED.COSTS	4.00	14.81	1.00	7.14	6.00	30.00	4.00	36.36	0.00	0.00	4.00	22.22	19.00	20.88
12	T.09.PEST.DISEASES.WEEDS	9.00	33.33	2.00	14.29	4.00	20.00	1.00	9.09	0.00	0.00	2.00	11.11	18.00	19.78
13	P.01.INSUFFICIENT.LEGISLATION	5.00	18.52	1.00	7.14	5.00	25.00	1.00	9.09	1.00	100.00	3.00	16.67	16.00	17.58
14	T.10.CLIMATE.NATURAL	3.00	11.11	3.00	21.43	2.00	10.00	1.00	9.09	0.00	0.00	6.00	33.33	15.00	16.48
15	T.11.MECHANIZATION	0.00	0.00	0.00	0.00	8.00	40.00	6.00	54.55	0.00	0.00	1.00	5.56	15.00	16.48
16	E.04.TIME.ECONOMIC.BENEFIT	1.00	3.70	1.00	7.14	4.00	20.00	2.00	18.18	1.00	100.00	6.00	33.33	15.00	16.48
17	P.02.POLICY.SUBSIDY	3.00	11.11	2.00	14.29	6.00	30.00	2.00	18.18	0.00	0.00	2.00	11.11	15.00	16.48
18	T.12.WATER	10.00	37.04	0.00	0.00	3.00	15.00	1.00	9.09	0.00	0.00	0.00	0.00	14.00	15.38
19	E.05.PSYCHO.BEHAVIORAL	1.00	3.70	5.00	35.71	3.00	15.00	1.00	9.09	1.00	100.00	3.00	16.67	14.00	15.38
20	P.03.LAND.TENURE	6.00	22.22	2.00	14.29	4.00	20.00	0.00	0.00	0.00	0.00	2.00	11.11	14.00	15.38
21	E.06.FINANCING.CREDIT	5.00	18.52	2.00	14.29	1.00	5.00	2.00	18.18	0.00	0.00	3.00	16.67	13.00	14.29
22	E.07.RELATIONSHIP.STAKEHOLDERS	3.00	11.11	2.00	14.29	3.00	15.00	0.00	0.00	0.00	0.00	5.00	27.78	13.00	14.29
23	P.04.ADMIN.BURDEN	1.00	3.70	1.00	7.14	6.00	30.00	1.00	9.09	0.00	0.00	3.00	16.67	12.00	13.19
24	P.05.POLITICS.GOVERNMENT	2.00	7.41	3.00	21.43	2.00	10.00	0.00	0.00	1.00	100.00	3.00	16.67	11.00	12.09
25	T.13.AF.SYSTEM.PLANNING	1.00	3.70	3.00	21.43	3.00	15.00	1.00	9.09	0.00	0.00	2.00	11.11	10.00	10.99
26	E.08.NOT.PROFITABLE	1.00	3.70	3.00	21.43	3.00	15.00	2.00	18.18	0.00	0.00	0.00	0.00	9.00	9.89
27	E.09.FUNDING.INCENTIVES	1.00	3.70	0.00	0.00	3.00	15.00	1.00	9.09	0.00	0.00	3.00	16.67	8.00	8.79

Table 7 (continued)

Nr	Name of the issue	Occurrence of issues by geographical area													
		Africa ($n=27$)		Asia ($n=14$)		Europe ($n=20$)		North America ($n=11$)		Oceania ($n=1$)		South/Central America ($n=18$)		Global ($n=90$)	
		nr	%	nr	%	nr	%	nr	%	nr	%	nr	%	nr	%
28	P.06.ILL PROJECT.DESIGN	2.00	7.41	1.00	7.14	1.00	5.00	0.00	0.00	0.00	0.00	4.00	22.22	8.00	8.79
29	T.14.INPUTS.FARM	2.00	7.41	1.00	7.14	0.00	0.00	1.00	9.09	0.00	0.00	2.00	11.11	6.00	6.59
30	T.15.SOIL	1.00	3.70	2.00	14.29	0.00	0.00	1.00	9.09	0.00	0.00	0.00	0.00	4.00	4.40
31	E.10.POVERTY	3.00	11.11	1.00	7.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00	4.40

necessary to have an economic return from the agroforestry system, in 15 papers (16.5%) [E.04.TIME.ECONOMIC.BENEFIT]; and iii) issues related to psychological, behavioral and cultural factors, in 14 papers (15.4%) [E.05.PSYCHO.BEHAVIORAL].

According to our analysis, policy-related issues tend to emerge in the examined literature at a much lower rate. The five most frequently encountered policy-related issues globally are: i) issues related to inconsistent or insufficient legislation, legislative restrictions or knowledge of the law regarding agroforestry in 16 papers (or 17.6%) [P.01.INSUFFICIENT.LEGISLATION]; ii) issues related to agroforestry policy, subsidies and incentives design or their implementation, in 15 papers (16.5%) [P.02.POLICY.SUBSIDY]; iii) issues related to land tenure concerning agroforestry in 14 papers (15.38%) [P.03.LAND.TENURE]; iv) issues related to administrative burden, bureaucracy or legal obstacles regarding agroforestry in 12 papers (13.2%) [P.04.ADMIN.BURDEN]; and v) issues related to government trust or politics regarding agroforestry in 11 papers (12.1%) [P.05.POLITICS.GOVERNMENT]. The data indicating the occurrence of sub-categories of issues can be visualized in Fig. 5.

Prevalence of technical, socio-economic or policy-related issues in different stakeholder groups

As explained in previous paragraphs, across the literature included in this systematic literature review, issues pertaining to the category of technical and agronomic issues emerged in 86% of cases ($n=78$), followed by the category of socio-economic issues in 76% of cases ($n=69$) and the category of policy-related issues in 62% of cases ($n=56$). We then analyzed the occurrence of such macro-categories when comparing studies gathered in two groups: i) studies involving only farmers and smallholder farmers ($n=54$) and ii) studies involving a multitude of stakeholders and all other stakeholders ($n=37$).

We found that technical and economic issues tend to emerge more rather than the policy related ones in papers that involve farmers or smallholder farmers, while in papers involving multi-stakeholder groups and other stakeholders, all macro-category of issues

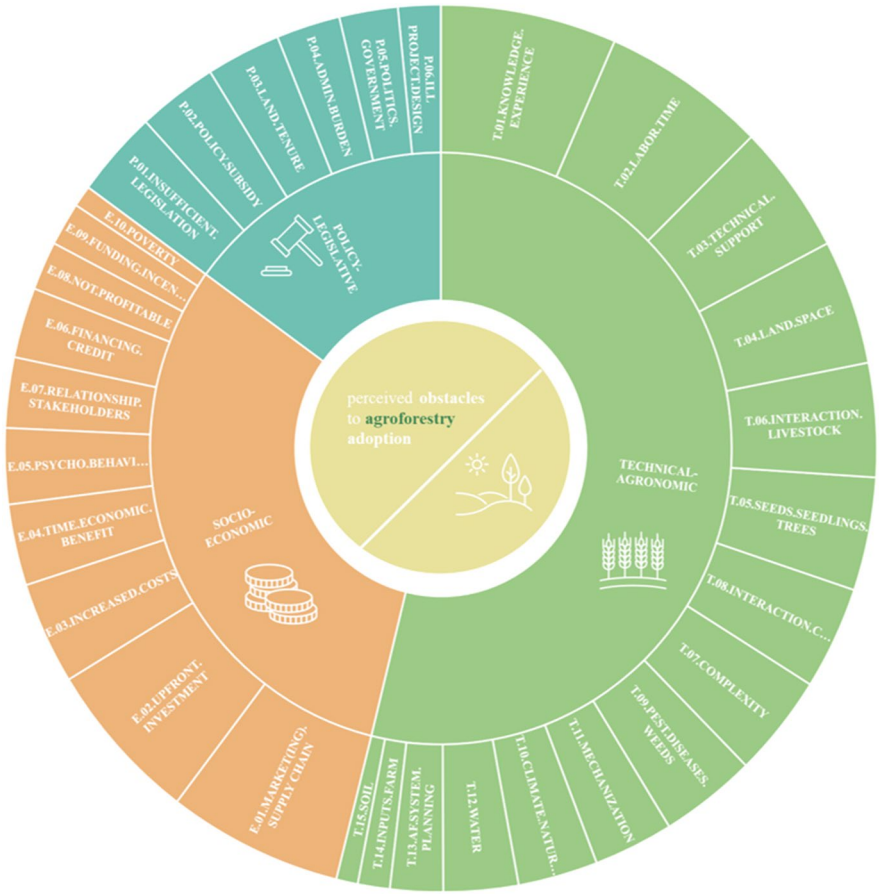

Fig. 5 Sunburst chart representing the perceived obstacles to agroforestry adoption according to stakeholders in the analyzed literature ($N=90$). Issues encountered: technical and agronomic (85% of cases), socio-economic (75% of cases = and policy-related (62% of cases)

tend to emerge at a similar rate. In group I (studies involving only farmers and smallholder farmers ($n=54$)) issues pertaining to the category of technical and agronomic issues emerged in 96% of cases, followed by the category of socio-economic issues in 77% of cases, and the category of policy-related issues in 53% of cases. In group II (studies involving a multitude of stakeholders and all other stakeholders ($n=37$)) issues pertaining to the category of socio-economic issues emerged in 78% of cases, followed by the category of policy-related issues in 76% of cases, and the category of technical and agronomic issues in 73% of cases. This does not mean that farmers perceive policy-related issues as less of an obstacle to the application of agroforestry practices, but it only illustrates that such issues tend to emerge less in scientific research that involves only groups farmers, perhaps because they are asked less frequently about such issues; because they are willing to speak about technical and economic topics with more confidence, or because they are more likely to be involved in research with a more sectorial approach (focused on technical obstacles) rather than multidisciplinary studies.

Prevalence and severity of perceived issues

While the previous sections did showcase numeric results regarding the occurrence of specific agroforestry-related perceived issues in the literature, this should not be interpreted as a measure of the severity of each issue in a specific geographical area. On the contrary, result should be interpreted as a measure of the amount of evidence in the literature in the Scopus database, in a specific area concerning perceived issues hindering the application of agroforestry.

In fact, this analysis does not take into consideration the severity of the constraint posed by the issues. For instance, an issue that occurs only in a specific

area (and therefore has a very low occurrence in the literature), or in a specific system or period may be significant enough to completely prevent the adoption of agroforestry in that same area or in a different one, should similar conditions arise/present themselves (extreme weather events, political instability, etc.). An example could be the labor related issues deriving from the HIV/AIDS epidemic in Kenya, which left many individuals unable to work either due to their sickness or due to them taking care of sick family members affected by the disease (Kiptot et al. 2007).

On the other hand, issues that are often found in the literature may be not severe enough to prevent the application of agroforestry as a sustainable practice or may be met with adequate support and tools from advisors or researchers.

Additionally, at this stage we were not able to differentiate among open- and closed-ended research formats, which is likely to affect results reflecting the more investigated or popular topics in participatory research.

Gender representation in agroforestry participatory research

As reported in the results section, gender ratio data of samples utilized in the participatory research studies was not available in 55 out of 90 papers (60%), while in the remaining papers, females were on average 30% of the involved stakeholders. The average percentage of female participants per geographical region was 37% for Africa, 35% for Asia, 28% for North America, 23% for South and Central America and 6% for Europe.

According to the FAO, women make up 43% of global agricultural labor, while facing enormous discrimination in the ownership of land and livestock, being significantly disadvantaged compared to men regarding land ownership, management, transfer and economic rights (Karia 2018). According to 2016 Eurostat data, 29% of farms across the EU have a female manager, varying greatly among countries (DG-AGRI 2021). On the other hand, agricultural landholders (the people making decisions regarding resource use and managing the agricultural holding) around the world are on average just 15%, while 85% are men.

In the included studies, one focuses on the participation of youth and women in agroforestry in Uganda, investigating the specific obstacles such groups of people face in agriculture (Galabuzi et al. 2021) and one highlighted unfavorable land tenure arrangements reducing women participation in Ghana (Apuri et al. 2018). One Bolivian agroforestry farmer reported that she had never seen an agroforestry project focusing on women and their home gardens but rather that projects were usually dominated by men and focused on marketable crops instead of household consumption (Jacobi et al. 2017).

In future research, more attention should be given to assuring gender representation in participatory studies investigating the adoption of agroforestry as a sustainable practice in order to fairly represent issues as perceived by all farmers or by a specific subgroup of them promoting equality in agriculture. Shedding light on the unique and perhaps different issues faced by women in agriculture could play a role in promoting their participation and uptake of managerial roles.

Proposed solutions and policy recommendations

Across the examined literature, the authors have presented potential solutions that are specific to the issues and context at hand, which cannot be explored in depth in the current paper due to the scope of this work and space constraints. In light of the complexity and intricacy of the challenges that actors in the value chain are faced with in relation to agroforestry adoption, authors in the examined literature consistently highlight the following aspects: i) the need for an integrated multidisciplinary approach to problem solving and collaboration among actors (Acheampong et al. 2016; Ajayi 2007; Akamani et al. 2015; Andreotti et al. 2020; Ashley et al. 2006; Ayisi et al. 2018; García de Jalón et al. 2018; Graves et al. 2017; Hauff 1998; Jerneck and Olsson 2014; Johansson et al. 2013; Kiptot et al. 2007; Krčmářová et al. 2021; Macke et al. 2021; Mahmood and Zubair 2020; Meijer et al. 2015; Powlen and Jones 2019; Rolo et al. 2020; Shennan-Farpón et al. 2022); ii) the involvement of farmers in policy design trough participatory processes to enable the sustainability transition (Barlagne et al. 2021; Brodt et al. 2020; Cavanagh et al. 2017; Fischer and Vasseur 2002; Gladkikh et al. 2020; Herbohn et al. 2005) iii) the need to take into account

regional peculiarities and local context (Björklund et al. 2019; Follis and Nair 1994; Rodríguez et al. 2022) and iv) the need for additional resources such as extension services and training (Alemagi et al. 2015; Camilli et al. 2018; Foundjem-Tita et al. 2021; Galabuzi et al. 2021; Hernández-Morcillo et al. 2018; Jahan et al. 2022; Schaffer et al. 2019), research (Borremans et al. 2018; Frey et al. 2012; Irwin et al. 2022) and additional funding (Bryan et al. 2013; López-Felices et al. 2022).Economic and market-related issues remain prevalent as perceived by stakeholders in the agroforestry value chain. Implementing a market system that takes into account ecosystem services an providing compensation for positive contributions could enable a transition towards the adoption of multifunctional agroforestry by making it a more economically viable and profitable choice (Kay et al. 2019a).

We formulate some recommendations according to the main findings of this work:

1. In light of the high amount and diversity of emerged challenges in the literature, we suggest that the adoption of agroforestry as a sustainable agricultural practice should be investigated in its complexity taking into account the various technical, economic and policy-related aspects, including but not limited to these frequently emerged issues related to i) the availability or quality of knowledge or experience on technical and agronomic matters; ii) the perceived socio-economic issue related to the market, marketing of agroforestry products, supply chain or jobs in agroforestry; iii) issues related to the amount of labor or time necessary to implement or maintain agroforestry systems; iv) issues related to the upfront economic investment necessary to establish an agroforestry system and availability of capital; and v) issues related to the availability of technical support necessary to implement or maintain agroforestry systems.
2. In light of the consideration that this study does not indicate the severity of different issues, but rather the frequency with which issues emerge in the available literature, we highlight the importance of continuing to fund participatory research projects, in order to further shed light on the existing and emerging issues that stakeholders face when striving to apply agroforestry practices and assess their context and country-specific severity in impeding agroforestry adoption. This could be done through a unified participatory research framework ensuring comparability among studies conducted in different regions of the world and on different agroforestry systems.
3. In light of systematic underrepresentation of women or lack of gender-related data regarding samples of stakeholders involved in participatory studies in most of the examined literature, we stress the need of ensuring fairness and equality in participatory research processes by constructing representative samples, collecting data in a stratified manner by providing gender-related information and striving to assess the specific challenges that women in agriculture face when trying to adopt agroforestry as a sustainable agricultural practice.
4. In line with the proposed solutions brought forward by the authors of the examined literature we highlight i) the need for an integrated multidisciplinary approach to problem solving and collaboration among actors; ii) the involvement of farmers in policy design trough participatory processes to enable the sustainability transition; iii) the need to take into account regional peculiarities and local context and iv) the need for additional resources such as extension services and training, research and additional funding.

Limits of the research

In this systematic literature, only one database was taken into consideration, therefore not completely exhausting the literature on agroforestry systems. At present, we did not take into account quantitative aspects in the subset of papers that did provide it. Due to space constraints, we could also not discuss the findings of each article in detail, but rather proposed a general overview of the issue occurrence patterns across publications. Future works could go more in depth by considering a geographical area or a set of issues individually.

Additionally, the categorization of the perceived issues is not to be taken as an absolute classification, as it fails to point out the multi-faceted and complex nature of the perceived issues, but rather an

instrument to facilitate the user into identifying relevant research in Table A1. Future development of this work could explore the interconnections between different categories of issues or create a more comprehensive classification system. Furthermore, the analysis focused on issues as perceived by the stakeholders, therefore referring to the subjective way in which facts are regarded, understood, or interpreted rather than being objective and unequivocable values or parameters. At this stage, the complex social and behavioral aspects emerged have not been addressed and analyzed in depth. Future studies addressing agroforestry adoption should include such aspects in collaboration with experts in behavioral science and human psychology.

The very nature of this systematic literature review and its research question resulted in a comprehensive but rather broad description of the current knowledge regarding perceived obstacles in agroforestry from participatory research. We provided a global overview without going in depth in region and context specific results and interpretations.

At this stage, we chose to exclude publications not written in the English language due to constraints in time and resources, therefore potentially excluding very valuable information. In this case, there is potential loss of valuable information deriving from studies in mainly Spanish and French-speaking countries. In fact, of the 22 articles excluded due to language, eight were in French, seven in Spanish, four in German, and three in Portuguese. Future research could focus on including these research papers and implementing their findings in the presented framework.

Further research could focus on comparing the perception of agroforestry adopters vs. non adopters in agricultural value chains according to the literature. Such considerations could be made analyzing a subset of the literature included in this systematic literature review or designing participatory studies to quantify differences. At this stage, we chose not to proceed to through a snowballing approach, which could have resulted in additional literature either from the included research papers or the ones excluded because the information relevant to the research question was bibliographic rather than originating from direct observation or experimentation. Future reviews, perhaps on specific geographical regions or agroforestry systems could follow a snowballing approach.

In this study, we did not make age-related considerations. This could be interesting in future research, given that different age groups might face different obstacles and might not adequately represented in sampled actors.

Conclusions

Through this systematic literature review, we highlighted and categorized 31 obstacles that stakeholders around the globe perceive according to the examined literature ($n=90$) with regards to agroforestry adoption, pertaining to i) technical-agronomic (T.01-T.15), ii) socio-economic (E.01-E.10) and iii) policy-legislative (P.01-P.06) aspects. We produced a consultable database of the examined literature presenting the extracted and categorized data including1) Region of interest; 2) Investigated agroforestry system; 3) Methodologies utilized in the papers; 4) Number, gender ratio and type of stakeholders; 5) Main relevant obstacles found in the paper.

We highlighted the five most frequently encountered issues i) the availability or quality of knowledge or experience on technical and agronomic matters, or knowledge diffusion necessary to implement or maintain agroforestry systems, found in 33 articles (36.2%) [T.01.KNOWLEDGE.EXPERIENCE]; ii) the perceived socio-economic issue related to the market, marketing of agroforestry products, supply chain or jobs in agroforestry, in 33 articles (36.2%) [E.01.MARKET(ING).SUPPLY CHAIN]; iii) issues related to the amount of labor or time necessary to implement or maintain agroforestry systems, in 31 papers (34.1%) [T.02.LABOR.TIME]; iv) issues related to the upfront economic investment necessary to establish an agroforestry system and availability of capital, in 30 papers (33%) [E.02.UPFRONT.INVESTMENT]; and v) issues related to the availability of technical support necessary to implement or maintain agroforestry systems, in 24 papers (26.37%) [T.03.TECHNICAL.SUPPORT].

Across the examined literature, in light of the complexity and intricacy of the challenges that actors in the value chain are faced with in relation to agroforestry adoption, authors consistently highlight the following aspects: i) the need for an integrated multidisciplinary approach to problem solving and

collaboration among actors; ii) the involvement of farmers in policy design trough participatory processes to enable the sustainability transition; iii) the need to take into account regional peculiarities and local context and iv) the need for additional resources such as extension services and training, research and additional funding. In addition to these considerations, in light of the findings of this work, we highlight the importance of: 1) investigating agroforestry adoption in its complex technical, socio-economic and policy-related components simultaneously, 2) continuing participatory research efforts to shed light on the severity of issues in different contexts, perhaps using a unified evaluation research framework; 3) ensuring gender representation in participatory research samples. In conclusion, we should continue to seek a deeper and more comprehensive understanding of stakeholder perceptions regarding the adoption of agroforestry as a sustainability practice through participatory research, enabling the development of realistic solutions on technical, economic, and policy-related matters, accounting for local features and stakeholder needs. When encouraging the transition towards more sustainable economies and decarbonized and resilient food systems, such obstacles and their potential solutions should be considered and prevented by governmental actors and policymakers during policy design and research funding allocation.

Authors' contributions The author Margherita Tranchina was responsible for the conceptualization, query construction, drafting of research objectives, search and screening process and manuscript drafting. The other authors participated in the query validation, supported the search, screening and manuscript drafting process as well as providing useful input for presenting and discussing results as well as critically revising the work. All authors read and approved the final manuscript.

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Data availability For this work, we used a combination of freely available articles as well as papers available through the author's institutional access. The main database generated from this work is fully available in Table A1.

Code availability Endnote was used as a reference management tool for the systematic literature to facilitate the review screening process. The license for this tool was purchased using IUSS Pavia PhD SDC research funds. No custom code was used for this research. To create the PRISMA flow diagram, we used the freely available PRISMA2022 R package and Shiny app for producing PRISMA 2020-compliant flow diagrams, with interactivity for optimized digital transparency and Open Synthesis Campbell Systematic Reviews.

Declarations

Ethics approval This work does not involve human participants, their data or biological material.

Consent for publication This work does not involve human participants, their data or biological material.

Consent to participate This work does not involve human participants, their data or biological material.

Competing interests The authors declare no competing interests.

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