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Understanding the low uptake of agroforestry measures in Italy: evidence from CAP implementation and stakeholder perspectives

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Abstract Agroforestry systems represent a multifunctional land-use approach capable of enhancing numerous ecosystem services, including biodiversity, soil conservation, and climate resilience, as well as promoting farm income diversification by fostering sustainable quality production. However, despite active policy support since 2007 under the Common Agricultural Policy (CAP), their adoption in Italy remains limited. This study investigates the reasons behind the low uptake of agroforestry measures across three CAP programming periods through a sequential mixed-method design. It begins with a financial and policy analysis to delineate the implementation framework, followed by survey-based econometric modeling to explore behavioural and institutional factors involved.The financial analysis reveals a narrow implementation framework and low expenditure levels, with only a few regions effectively activating the agroforestry measures. The survey results further highlight the behavioural and institutional constraints shaping participation: awareness, technical capacity, and direct experience are associated with a higher willingness to apply, whereas limited knowledge, bureaucratic complexity, and perceived inadequacy of financial support are frequently reported as key barriers. Strengthening training, communication, and policy coherence could therefore promote agroforestry adoption in future CAP cycles.

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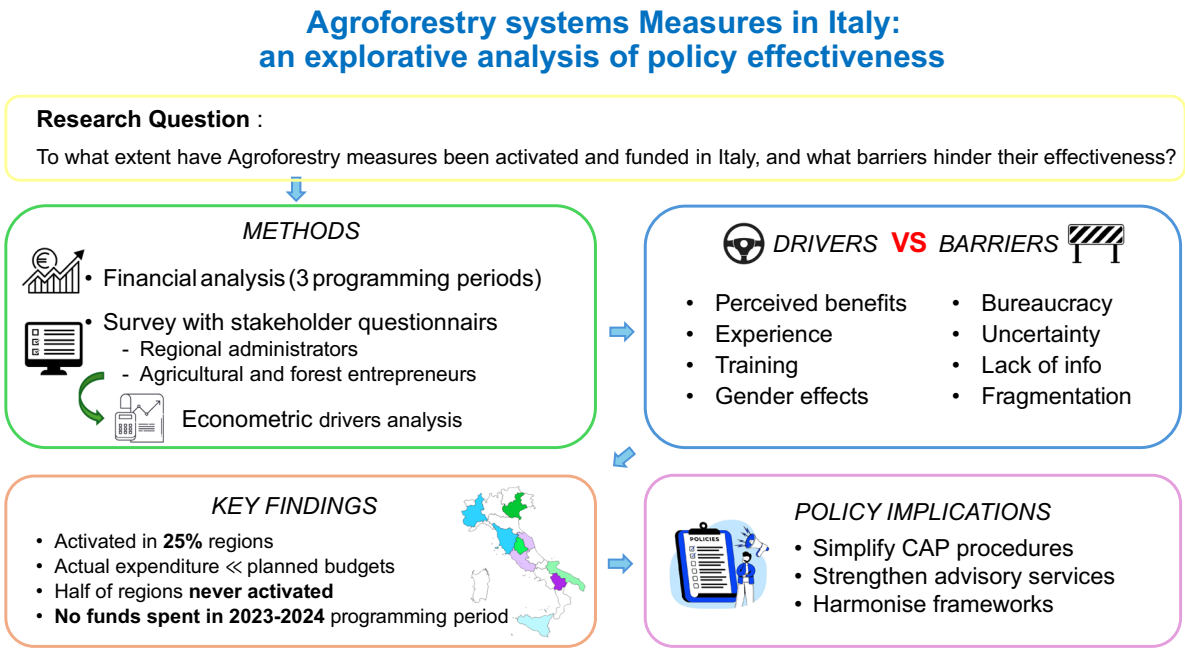
Graphical abstract



Keywords Agroforestry systems · Common agricultural policy · Policy implementation · Rural development · Italy

Introduction

Agroforestry (AF) is among the oldest land-use systems, originally practiced as a subsistence strategy integrating trees, crops, and livestock within the same landscape (Nair 1985).

Over time, the scientific community has systematically defined AF systems as diverse land-use configurations encompassing multiple typologies, whose structure and composition vary according to ecological, cultural, and socioeconomic contexts, as well as the specific tree and crop species cultivated across regions (Jose 2009; Mosquera-Losada et al. 2018).

Despite their long-standing tradition, AF systems have experienced a sharp decline in Europe since the early decades of the twentieth century, primarily driven by the spread of extensive agriculture, the Green Revolution, and the abandonment of marginal lands, which favored simplified and specialized agricultural systems aimed at maximizing crop yields (King 1987; Ferrario 2021; Varela et al. 2022; Watson et al. 2020). This shift contributed to significant territorial and social challenges, including the loss of biological and landscape diversity, increased vulnerability to erosion and hydrogeological instability, and the erosion of traditional knowledge and cultural heritage (Vang Rasmussen et al. 2024).

However, in recent decades, AF systems have regained prominence in research and policy agendas due to their capacity to deliver multiple ecosystem services, such as carbon sequestration, biodiversity conservation, soil protection and fertility, animal welfare, and the provision of diversified and aesthetically valuable rural landscapes (Paris et al. 2019; Hernandez-Morcillo et al. 2018; Mosquera-Losada et al. 2018; Torralba et al. 2016; Smith et al. 2022; Mele et al. 2019). AF systems are increasingly recognized as a pathway toward sustainable and resilient forms of intensive agriculture (Graves et al. 2017; Kay et al. 2019), playing a critical role in both climate change mitigation and adaptation. Their ability to withstand and recover from natural and anthropogenic disturbances (Viñals et al. 2023) and their contribution to

"sustainable intensification" make them a strategic land-use option for the future of agriculture (European Parliament 2020). Furthermore, AF systems can enhance the economic and cultural value of rural and inner areas by supporting high-quality local products and fostering territorial cohesion (EIP-AGRI 2017; FAO 2022). By diversifying farm income, they strengthen rural economies and improve farm resilience to yield variability, while promoting multifunctionality (Paris et al. 2019; Lin 2011).

For these many reasons, at the European level AF systems have gained renewed political relevance, being explicitly acknowledged in major policy frameworks such as the EU Biodiversity Strategy for 2030, the European Green Deal, and the Nature Restoration Law (European Commission 2019; 2020a, b). Within the Common Agricultural Policy (CAP), financial support for AF systems has been available since the 2007–2013 programming period and continues under the current CAP 2023–2027, which provides funding for both the establishment and maintenance of AF systems (Mosquera-Losada et al. 2018; EU CAP Network 2023). Nevertheless, this support has not achieved the expected success, both at the European level and in Italy (Lawson 2023; Rivieccio 2023).

In Italy, AF occupies a unique position at the intersection of historical tradition and innovation yet remains marginal within agricultural policy frameworks (Le et al. 2025). Current estimates indicate that AF systems cover approximately 12.90% out of the total Utilized Agricultural Area (UAA)[1] (Chiarabaglio et al. 2023).

Pioneering studies have highlighted the potential of silvoarable systems within the framework of the CAP, while also pointing to uncertainties related to management constraints, investment costs, and reductions in direct payments associated with tree presence on agricultural land (Pisanelli et al. 2012). Stakeholders acknowledge the broad productive and environmental benefits of AF systems but emphasize management complexity and bureaucratic burdens as major obstacles (Camilli et al. 2018). Paris et al. (2019) further note that CAP measures often favor monoculture systems at the expense of integrated practices such as AF.

[1] Equal to 1.6 million hectares out of 12.4 million hectares (ISTAT 2024).

Recent case studies on innovative systems -such as olive trees intercropped with wild asparagus- demonstrate advantages in terms of overall productivity and profitability, although they require higher labor inputs (Rezgui et al. 2024).

Overall, interest in AF as a tool for sustainable agriculture is growing, particularly in rural areas; however, its diffusion remains constrained by economic, administrative, and political barriers.

However, while CAP support for AF has formally been available across successive programming periods, a systematic and up-to-date assessment of how these measures have been implemented in Italy remains lacking. In particular, limited attention has been devoted to examining the degree of activation across regions, the financial resources effectively committed and spent, and the heterogeneity in design and support intensity resulting from regional implementation. Given the decentralized governance structure of the CAP in Italy, where Regions play a key role in measure activation and design, an updated and comparative overview is essential to determine whether limited uptake reflects insufficient policy deployment, restrictive eligibility criteria, or broader structural constraints.

A substantial body of literature has examined the adoption of sustainable agricultural practices and agri-environmental schemes, highlighting the role of structural farm characteristics, human capital, information access, transaction costs, social, cultural and behavioural factors shaping participation decisions (e.g., Pannell et al. 2006; Knowler & Bradshaw 2007; Prokopy et al. 2008; Dessart et al. 2019).

However, while a growing body of literature has examined the adoption of sustainable agricultural practices, evidence focusing on CAP AF measures in Italy remains limited, particularly from a behavioural and institutional perspective (Tranchina et al. 2024; Mosquera-Losada et al. 2023). Existing studies on AF in Italy have primarily emphasized ecological performance or farm-level profitability, whereas fewer contributions have jointly analysed policy implementation patterns and participation constraints within the Italian CAP governance setting.

This study contributes to the literature on AF policy and uptake in Italy in three main ways. First, it provides the first systematic and updated assessment of the activation, financial allocation, and budget execution of CAP AF measures across all

Italian Regions, highlighting the heterogeneity of implementation within a decentralized governance framework. Second, it complements this institutional analysis with survey-based evidence on farmers' willingness to apply for AF support, identifying the factors associated with participation. Third, by integrating these two perspectives, the study shows how the limited uptake of AF measures in Italy emerges from the interaction between regional policy design and farmer-level constraints, rather than from technical or ecological considerations alone.

Against this backdrop, the present study pursues two main objectives: (i) to provide an updated overview of the level of economic and financial support allocated to AF systems under the CAP and their implementation across the Italian territory; and (ii) to investigate, in light of the limited uptake recorded nationwide, the underlying reasons for the modest success of these support measures through surveys with two stakeholder groups, aiming to identify latent barriers and outline potential adjustments for future CAP programming.

The two components are designed to be complementary: the policy analysis provides the institutional and financial "diagnosis" of implementation, while the survey evidence helps explain the observed low uptake.

Materials and methods

The study adopts a two-stage empirical strategy based on a sequential multi-source research design where the second phase is explicitly used to interpret and explain the patterns observed in the first phase. In Phase 1, we compiled and analysed administrative and program-level data to provide an updated and systematic assessment of the economic and financial support allocated to AF under the CAP and its implementation across the Italian territory. In particular, this phase quantifies the amount of financial support, uptake levels, and their territorial distribution over time.

Building on these results, Phase 2 investigates the drivers of low uptake by collecting primary evidence from regional administrators and agricultural and forestry entrepreneurs through a structured survey complemented by semi-structured interviews. Quantitative and qualitative evidence is used to identify informational, institutional, and procedural constraints (e.g., latent barriers, implementation bottlenecks, and perception gaps) that can plausibly account for the limited participation documented in Phase 1.

Analysis of policy funding on agroforestry systems

This section provides a document-based policy analysis of the implementation of AF support measures in Italy under the CAP, focusing on official regional programming and implementation documents across three programming periods. The policy analysis covers the three CAP programming frameworks in which support for AF has been implemented in Italy: 2007–2013 and 2014–2022 and 2023–2027. In these programming periods are defined the legal basis, eligibility rules, and budget allocations for rural development Measures and, from 2023 onwards, the Interventions of CAP Strategic Plan, thereby shaping both the design and the actual activation of AF support at regional level.

The analysis is based on the regional official policy and implementation documents made available for each programming period, applying consistent criteria related to the regulatory framework, intervention design, financial architecture, and regional implementation choices. Specifically, we consider: (i) the 2007–2013 rural development programming period under Council Regulation (EC) No 1698/2005; (ii) the 2014–2020 period under Regulation (EU) No 1305/2013, including the 2021–2022 transitional extension established by Regulation (EU) 2020/2220; and (iii) the 2023–2027 Italian CAP Strategic Plan framework under Regulation (EU) 2021/2115, with financing, management and monitoring rules set by Regulation (EU) 2021/2116.

For the 2007–2013 and 2014–2022 periods, the analysis draws on the Annual Implementation Report (AIR). This dataset includes information on regional activation decisions, financial allocations, eligibility requirements, operational rules, and expenditure progress for AF measures.

For the 2023–2027 period, the analysis is based on the Italian CAP Strategic Plan, examining the intervention design, financial distribution, eligibility framework, and regionalisation mechanisms that shape the current configuration of AF support. All policy documents were collected at the regional level

for the 21 Italian Managing Authorities (19 Regions and 2 Autonomous Provinces) for the years in which AF support was available under the Rural Development Programme and CAP frameworks: Measure 2.2.2—first establishment of agroforestry systems on agricultural land (2007–2013), Sub-measure 8.2—support for establishment and maintenance of AF systems (2014–2020, including the 2021–2022 transitional period, with payments eligible until 2024), and Interventions SRA28.3 and SRD05.3 (2023–2027) which respectively support the maintenance and the establishment of AF systems on agricultural land. Specifically, the analysis includes: (i) regional calls for applications/tenders and their annexes (technical specifications, application forms, scoring grids), and (ii) Annual Implementation Reports (AIR), which were used to reconstruct financial execution and uptake across regions and programming periods.

Based on data from the AIR, the analysis examines variations in subsidy types and intensity, selection criteria, and eligibility requirements across regions, with the purpose of evaluating how regional authorities interpreted and operationalized EU guidelines in adapting them to local territorial, environmental, and socio-economic conditions.

Data collection for the survey

Considering the limited success of AF systems support measures, this study aimed to investigate more deeply the underlying reasons for the lack of participation, as well as the conditions that could foster greater future engagement. To this end, an empirical approach was developed based on two distinct questionnaires, addressed respectively to regional administrators (Regional Questionnaire, RQ) and to agricultural and forestry entrepreneurs (Entrepreneurs Questionnaire, EQ), with the aim of obtaining a multilevel understanding of the phenomenon.

The survey was carried out over the course of 2024 and resulted in a total of 121 completed questionnaires, including 28 responses from regional administrators and 93 responses from agricultural and forestry entrepreneurs.

The sample of agricultural and forestry entrepreneurs was obtained through voluntary participation using online distribution channels, institutional contacts, professional networks, and stakeholder mailing lists. As a consequence, the sample represents a convenience sample rather than a probabilistic one. Due to the absence of a predefined sampling frame, it is not possible to compute a response rate.

Given the voluntary nature of participation, the sample may be subject to self-selection bias, as respondents who are more interested in AF or environmental practices may have been more likely to participate in the survey.

Although it cannot be considered statistically representative of the entire population of Italian agricultural and forestry entrepreneurs, it includes respondents from different geographical areas and farm contexts. Consequently, the results should be interpreted as exploratory evidence providing insights into potential participation dynamics and perceived barriers, rather than as statistically generalizable estimates for the whole population.

Preliminarily, some exploratory qualitative semi-structured interviews with regional administrators, AF experts, and farmers were carried out in two different steps in order to design the questionnaires.

Following the approach provided by Graneheim and Lundman (2004), the interviews were registered upon the consent of the interviewees, transcribed, and content analysis was performed. The qualitative analysis was used in an exploratory phase to identify recurrent themes, perceived barriers, and key dimensions related to AF adoption and policy implementation, which informed the structure and wording of the survey questionnaires.

The two questionnaires share several common sections: information about personal details, AF knowledge, interest and actual presence, and future perspective for AF. Instead, the special part is different for the two targets, as described in the paragraph below.

Regional administrators questionnaire (RQ)

The branching and semi-structured questionnaire addressed to regional administration representatives was designed to collect both descriptive information (e.g., regional regulations, support instruments, the role of Rural Development programs) and subjective evaluations (e.g., perceived obstacles, strategic priorities, future opportunities).

The questions included both closed-ended items as well as open-ended questions aimed at gathering opinions and qualitative comments.

Table 1 Description of the variables included into econometric model

Variable name	Description	Variable type
Dependent variable		
Willing_to_apply_AF	Willingness to apply calls for AF measures	Dummy ("No" = 0; "Yes" = 1)
Explanatory variables		
Gender	Indicate the gender of the respondents	Dummy ("Male" = 0; "Female" = 1)
Training	Indicate if the respondent has participated in training/information activities on AF	Dummy ("No" = 0; "Yes" = 1)
Experience	The farm had or currently has land managed under AF systems	Dummy ("No" = 0; "Yes" = 1)
Association	Membership in a farmers' association	Dummy ("No" = 0; "Yes" = 1)
Perceived_benefits	Mean of responses to the 7 Likert-scale items on knowledge of AF benefits	Continuous (Likert scale 1—4)
Control variables		
Macroarea	Geographical area where the respondent from (North, Central, South)	Categorical (i.macroarea)
Morphology	Predominant territorial morphology of the area where farm managed by the respondents is located (Mountain, Hill, Plain)	Categorical (i.morphology)
Altitude	Mean altitude of the farm area, calculated as the average of the minimum and maximum elevations indicated by the respondents (m a.s.l.)	Continuous (numeric)

Regional authorities were asked to describe their approach to AF systems across the different CAP programming periods (I: 2007–2013, II: 2014–2022, III: 2023–2027) in order to better understand why and how each region acted to promote the diffusion of AF systems, and how these actions evolved over time. In particular, when AF measures had been activated in a given region, respondents were invited to provide details on the resources allocated, the perceived outcomes, and the main limitations encountered. Conversely, in cases where AF measures had not been activated, they were asked to explain the reasons underlying this decision.

Agricultural and forestry entrepreneurs questionnaire (EQ)

This questionnaire was administered to farm owners as well as to technicians, consultants, and collaborators of Italian agricultural and forestry enterprises. The objective was to investigate the factors influencing the willingness to apply for public calls under the current CAP programming period (2023–2027), with particular reference to measures supporting the establishment and management of AF systems.

The first section of the questionnaire included sociodemographic variables (gender, role within the enterprise), territorial variables (region, predominant territorial morphology, minimum and maximum altitude).

The second section focused on assessing the perceived benefits of AF, measured through questions concerning the restoration of traditional systems, production diversification, income diversification, climate change mitigation, biodiversity conservation, increased soil fertility, and erosion control. Additional questions explored previous experience with AF adoption, membership in professional associations, participation in training or information initiatives on AF, and opinions regarding the need for public intervention to support the sector.

Empirical strategy

Descriptive financial analysis

The financial analysis is descriptive in nature and is based on administrative data drawn from official policy and implementation documents, including Annual Implementation Reports (AIR) and regional programming documents. It focuses on the allocation and execution of public resources for AF measures, examining programmed and spent financial resources, the regional activation of measures, and their evolution across successive CAP programming periods.

This analysis is used to assess the degree of policy implementation and uptake at the regional and national levels, thereby providing the contextual framework within which the subsequent empirical analysis investigates the behavioural and institutional drivers of participation. In this sense, the financial assessment is not intended as an end in itself, but rather as a necessary step to document how AF support has been operationalised in practice and to frame the patterns of limited uptake observed across programming periods.

By outlining the level and evolution of financial allocations, the heterogeneity of regional implementation choices, and actual expenditure over time, the descriptive analysis provides an updated and systematic overview of the policy framework supporting AF systems under the CAP. This contextual evidence informs and supports the second research phase, which represents the core analytical contribution of the study, by allowing the observed implementation outcomes to be interpreted in light of stakeholders' perceptions, institutional settings, and decision-making processes.

Econometric analysis

For the analysis of farmers' data, we employed an econometric approach to identify the factors associated with potential future policy take-up for AF and, indirectly, with adoption under a subsidised scenario. Specifically, we estimated a binary Logit model (using STATA software) where the dependent variable captures the respondent's intention to apply for a regional CAP call supporting the establishment and/or management of AF systems in the 2023–2027 programming period.

The variable was constructed from the survey item: "*If, in the new 2023–2027 programming period, your Region were to activate measures supporting the establishment and management of agroforestry systems, would you consider applying for the calls?*".

Accordingly, the model explains the probability of being willing (vs. unwilling) to apply for such support as a function of a set of explanatory variables.

In the literature, similar approaches have been used by Neupane et al. (2002) and Tega and Bojago (2024), who investigated the determinants of AF practices adoption by farmers in Nepal and Ethiopia, respectively.

The description of the variables included in the econometric model and their descriptive statistics are presented in Tables 1 and 2, respectively. This analysis serves as an exploratory tool to identify the individual, farm-related, and experiential characteristics that could influence the likelihood of participation in AF systems support measures.

Indeed, given the relatively limited sample size, the estimated relationships by econometric approach should be interpreted with caution and primarily as exploratory associations rather than causal determinants of AF adoption.

With regard to the *Perceived_benefits* variable, it is a latent construct capturing the perceived benefits of AF. It was derived from seven Likert-scale items included in the questionnaire, each assessing the perception of respondents about a specific benefit of AF: restoration of traditional systems, diversification of production, diversification of income, climate mitigation, biodiversity conservation, improvement of soil fertility, and erosion control. The construct was calculated as the mean score across the seven items (Likert scale 1–4), thus providing a synthetic measure of the

Table 2 Descriptive statistics of the variables used in the econometric model

Variable	Mean	Std. dev
Gender	0.29	0.46
Training	0.39	0.49
Experience	0.65	0.48
Association	0.64	0.48
Perceived benefits		
Restoring traditional systems	2.38	1.20
Production diversification	2.62	1.16
Income diversification	2.46	1.17
Climate mitigation	2.40	1.22
Biodiversity conservation	2.85	1.08
Increase in fertility	2.54	1.24
Erosion defense	2.60	1.18
Macroarea		
North	0.28	0.45
Center	0.41	0.49
South	0.31	0.46
Morphology		
Mountain	0.28	0.45
Hill	0.48	0.50
Plain	0.24	0.43
Altitude	443.28	372.90

Table 3 Allocation of resources in agroforestry systems for the programming periods 2007–2013 (Measure 2.2.2.) and 2014–2022 (Measure 8.2). For the 2014–2022 period, four columns are reported to reflect budget reprogramming over time and the transitional extensions of the eligibility period. "Programmed" resources are shown at the beginning and at the end of the programming period, while "spent" resources refer to expenditure at the end of 2022 and after the transitional extensions (2024). Values are expressed in euros (€), rounded to the nearest unit. n.a. = not activated

Programming period	2007–2013			2014–2022 (2024)			
	Measure 2.2.2			Measure 8.2			
Resources (€)	Programmed		Spent	Programmed		Spent	Spent
Regions	2007	2013	2013	2014	2023	2022	2024
Basilicata	n.a	n.a	n.a	826,446	826,446	0	0
Latium	616,093	0	0	n.a	n.a	n.a	n.a
Marche	2,270,000	2,500	0	2,000,000	2,000,000	0	0
Apulia	n.a	n.a	n.a	5,000,000	3,169,402	1,280,196	1,886,826
Sicily	4,540,000	0	0	n.a	n.a	n.a	n.a
Umbria	760,068	0	0	1,000,000	187,400	0	86,563
Veneto	n.a	30,000	27,544	231,911	4,638	1,233	3,623
Total	8,186,161	32,500	27,544	9,058,357	6,187,886	1.281.429	1,977,012

overall perception of AF benefits, where higher values indicate a more positive perception.

The construct *Perceived_benefits* is conceptualized as a reflective latent variable, as the individual items represent different manifestations of the same underlying perception of AF benefits. To assess the internal consistency of the scale, a reliability test using Cronbach's alpha was conducted. The results show excellent internal consistency (Cronbach's $\alpha = 0.95$), supporting the aggregation of the seven Likert-scale items into a single composite index calculated as their mean value.

Let *Yi* be the binary dependent variable indicating the willingness to apply to future CAP 2023–2027 public calls for AF measures. The binary logit model is specified as follows:

$$\log it[P(Yi=1)] = \ln\left(P(Yi=1)/1 - P(Yi=1)\right) = \beta_0 + \beta_1 Perceived_benefits_i + \beta_2 Experience_i + \beta_3 Training_i + \beta_4 Gender_i + \beta_5 Association_i + \delta' X_i$$

The term $\delta' X_i$ represents a vector of control variables accounting for the *macroarea*, *morphology*, and *altitude*.

Results and discussion

The following sections examine the factors influencing uptake and participation, as well as the implementation of support measures.

Financial analysis

The promotion of AF systems under the CAP began in 2007, when Measure 2.2.2 was introduced within the Rural Development Programmes, providing grants exclusively for the establishment of AF systems. These grants supported farmers in creating systems that combine silviculture and extensive agriculture on the same land. During the 2007–2013 programming period, only planting costs were covered, with a co-financing rate of 70%, rising to 80% in disadvantaged areas. No subsidies were provided for maintenance.

This innovative measure remained largely unimplemented nationwide. Indeed, only four regions (Latium, Marche, Sicily, Umbria) activated the measure, while Veneto implemented it later during the period. Initially, Italy allocated €8.2 million under this measure to establish 6,737 hectares of AF

systems. However, these resources were significantly reallocated to other CAP measures. By the end of the period, only 0.3% of the planned resources had been spent, with Veneto being the sole region to support just two applications, covering a total of 20 hectares.

In the 2014–2022 programming period, AF systems support was reintroduced through Measure 8.2, which, unlike the previous measure, also covered maintenance costs by providing an annual premium for up to five years. Each region was required to specify in its Rural Development Programme the tree density, eligible species, and conditions for sustainable land use, with the aim of diversifying farm production and income. Implementation approaches, however, were heterogeneous: in some regions the measure was framed primarily with economic objectives, while in others environmental aims prevailed.

The degree of detail also varied considerably, ranging from generic provisions to specific prescriptions on tree species. Initially, five regions activated the measure (Basilicata, Marche, Apulia, Umbria, Veneto), allocating about €9 million-less than 1% of the total forestry resources under Measure 8. Implementation showed modest improvement compared to the previous period, although payments only started in 2020 due to mismatches between programming and local needs.

Overall, €1,281,429 were spent on 1,204 hectares, with only two regions (Apulia and Veneto) making use of the measure. Nevertheless, actual spending remained far below expectations: by the final year, expenditure corresponded to just 20% of planned resources in Apulia and 27% in Veneto, while at the national level only about 13% of allocated resources had been spent until 2022. Veneto eventually used nearly all its available resources to establish 1,201 hectares of AF systems, even increasing allocations during the period, while Apulia sharply reduced them in the last year. The application of the N + 3 rule-where N denotes the commitment year and + 3 refers to the additional three years granted for expenditure-extended the eligibility of payments for the 2014–2020 programming period (including 2021–2022 transitional period) until 2024. This allowed the Umbria region to absorb a portion of the reprogrammed funds, contributing to an increase in Italy's aggregate expenditure to 31.95% of the reprogrammed allocation after the 2023 adjustment.

Table 3 reports the amount of allocated funding (programmed and spent resources) for the 2007–2013 and 2014–2022 programming periods, including only regions where AF measures were activated. For the 2014–2022 programming period, four columns are reported to account for both budget reprogramming over time and the extended eligibility of payments under the transitional period. Specifically, the two "programmed" columns refer to the initial allocation at the beginning of the period and the revised allocation at the end of the period, reflecting reprogramming decisions adopted by regional authorities, while the two "spent" columns capture expenditure at the end of the original programming period (2022) and after the transitional extensions, which extended the eligibility of payments until 2024.

Programmed resources refer to the amounts allocated to AF measures within regional Rural Development Programmes. Under the CAP framework, these allocations are not fixed over time, as Regions may revise and reallocate programmed budgets during the programming period in response to observed or expected uptake. Spent resources refer to actual payments executed by the end of the eligibility period, including the transitional extensions where applicable.

Programmed resources refer to the amounts allocated to AF measures within regional Rural Development Programmes. Under the CAP framework, Regions may revise and reallocate programmed budgets during the programming period in response to observed or expected uptake. For this reason, Table 3 reports both the initial programmed allocation (at the beginning of the period) and the revised allocation at the end of the period. Spent resources refer to actual payments executed by the end of the eligibility period (including N + 3 extensions where applicable). By 2022, national expenditure corresponded to about 14% of the initial programmed allocation; however, this level of expenditure was largely driven by a single Region (Veneto). After the N + 3 extensions and reprogramming adjustments (2024), expenditure increased to about 32%, reflecting contributions from three Regions.

In the current programming period (2023–2027), according to the Italian CAP Strategic Plan (approved in November 2022, CCI 2023IT06AF SYSTEMSP001), AF systems support is delivered through two interventions: SRA28 – Support for the

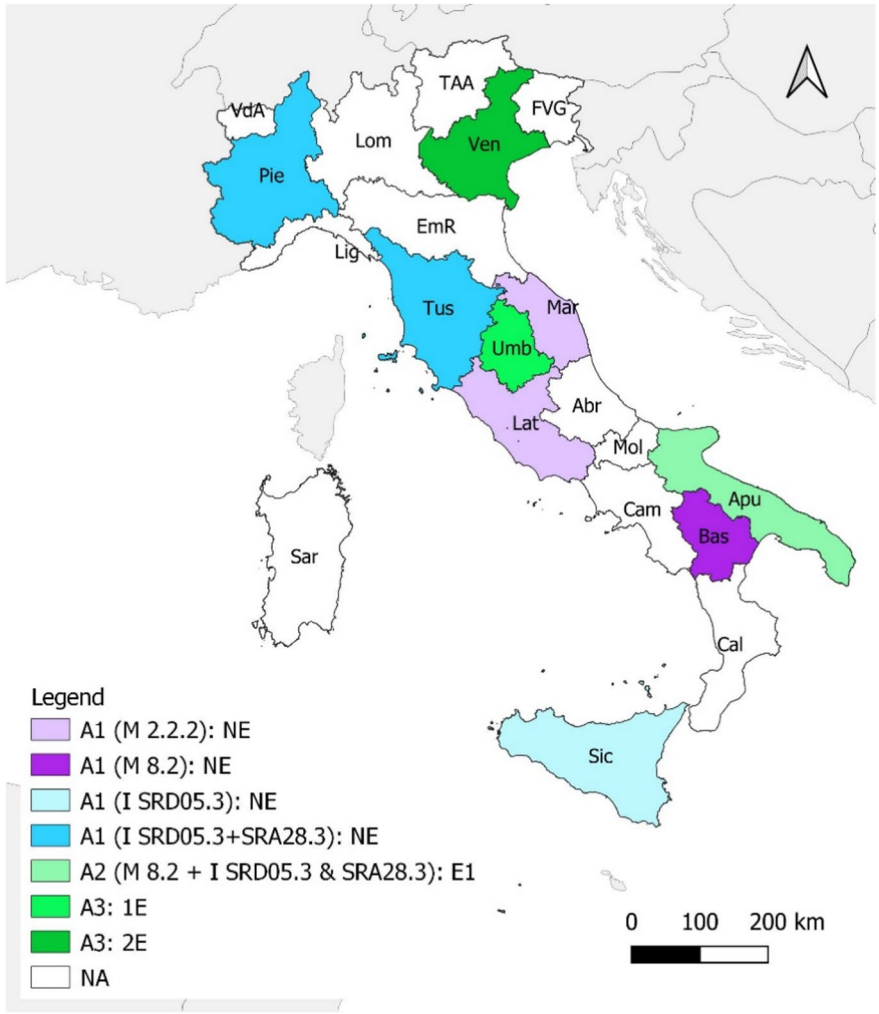


Fig. 1 Activation status and expenditure of forestry measures and interventions by Italian regions across the three CAP programming periods (2007–2013, 2014–2022, 2023–2027). Legend codes: A1–A3 denote the number of times a region activated the measures (once, twice, three times); NE, no expenditure; E1-E2 denote the number of expenditure recorded (once or twice); NA, never activated any measure or intervention

maintenance of afforestation/reforestation and agroforestry systems, SRD05 – Afforestation/reforestation and agroforestry systems on agricultural land. Both interventions include Action 3, which specifically targets AF systems: SRD05.3 – Establishment of agroforestry systems on agricultural land, funding plantation costs; SRA28.3 – Maintenance of agroforestry systems, covering maintenance costs for environmental purposes. Each Action 3 is further divided into two sub-actions: 3.1 silvoarable systems and 3.2 silvopastoral systems, designed to deliver multiple productive and environmental functions.

As of today, these two interventions remain only partially implemented. Approximately 25% of regional authorities have activated at least one AF related intervention, while about half of the regions have never activated any intervention. More specifically, SRA28.3 (maintenance) is currently operational in five regions, while SRD05.3 (establishment) is active in six regions. Among these, Piedmont, Apulia, Tuscany, Umbria and Veneto have activated both establishment and maintenance support, whereas Sicily has activated only SRD05.3 for establishment without the corresponding maintenance intervention.

At this stage, it is not possible to quantify the amount of resources specifically programmed for AF systems under the current programming period. In most of the Regions that have activated the interventions, financial allocations are defined at the level of the overall interventions (SRA28 and SRD05), without disaggregating resources by individual Actions (1, 2 and 3). As a result, the share of programmed resources attributable to Action 3, which specifically

targets AF systems, cannot be isolated. However, no region has reported any expenditure during the first two years (2023–2024) for either SRA28 and SRD05. Figure 1 summarizes the activation status of measures and interventions related to AF systems across the three programming periods, including regions that have activated them and those that have incurred expenditure. Despite the long-standing availability of CAP support, 11 Italian regions have never activated any AF-related measure or intervention across the three programming periods, highlighting a persistent gap in regional policy implementation.

Data collection for the survey

The analysis is based on the survey sample, described in "Data collection for the survey" Section, covering the two stakeholder groups.

The geographical distribution of responses was uneven across the Italian territory, with marked differences in the number of questionnaires collected by region. In particular, the highest number of responses was recorded in Tuscany (18), followed by Latium and Veneto (between 10 and 12 responses each). A second group of regions—including Basilicata, Emilia-Romagna, Campania, and Sardinia—reported a moderate number of responses (between 5 and 9). Lower participation levels (between 2 and 4 responses) were observed in Piedmont, Apulia, Umbria, Abruzzo, Calabria, Lombardy, Marche, and Molise, while only one response was received from Friuli-Venezia Giulia, Liguria, the Autonomous Province of Trento, and Sicily. Overall, the spatial distribution provides nationwide coverage; however, the limited and uneven sample size does not allow for robust conclusions regarding regional differences, and the results should therefore be interpreted with caution.

Regional administrators' questionnaire

The responses indicate that at least one officer from each Region completed the questionnaire, ensuring full national coverage. Overall, respondents reported good general knowledge of AF and acknowledged its relevance, especially for biodiversity conservation and climate change mitigation. However, they also identified several barriers to uptake. In particular, limited interest and insufficient technical know-how were frequently mentioned, together with poor access to clear information on the environmental and economic benefits of AF. Other barriers mentioned include the lack of available land and persistent preconceived ideas, often linked to perceptions of management complexityInstitutional intervention in AF systems is considered crucial by 86% of respondents, primarily for educational purposes. Knowledge is deemed essential to determine whether the grant is suitable for specific needs, for the territory and the farm, how to apply, and how to invest the subsidy. Respondents also called for increased financial support, not only to fund AF practices but also to recognize the ecosystem services they provide. Bureaucratic assistance is also needed, to better promote calls for applications and simplify administrative procedures. Those who considered institutional interventions unnecessary viewed AF systems as a niche and low-value sector, not warranting the use of public funds.

According to the descriptive financial analysis presented in "Financial analysis" Section, the implementation of AF measures under the CAP has been limited across programming periods (2007–2013 and 2014–2022). This limited implementation reflects both the low share of Regions that activated the measures (five regions out of twenty, i.e. around 25% of the total) and weak financial execution among activating Regions, as in most cases the allocated resources were only partially spent or not spent at all. In the 2007–2013 programming period, expenditure was recorded in only one out of five Regions that activated the measure, while in the 2014–2022 period spending occurred in two out of five.

In the first period, the shortcomings were attributed to the novelty of the intervention, with relatively large overall allocations but insufficient funding per grant. In the second period, they were attributed to the possibility of using AF measure funding to finance other types of works (e.g., windbreak barriers) rather than establishing AF plantations.

Looking ahead, the outlook appears more positive: although only a few regions have activated the two interventions (SRD05 and SRA28) in the 2023–2027 programming period, 11 regions plan to do so. According to regional programming documents, the 2023–2027 CAP framework foresees the establishment of new AF systems, with planned (earmarked) budgets ranging from €0.2 to €9.0 million per region. Importantly, however, this potential remains partly

uncertain, in line with the barriers identified by respondents, as the challenge goes beyond the limited activation of SRD05 and SRA28. The AF support architecture also relies on Action 3 and the two sub-actions (3.1 and 3.2 described in "Financial analysis" Section), whose activation is not automatic and may be excluded from regional implementation, thereby constraining the effective rollout of new AF systems.

Agricultural and forestry entrepreneurs questionnaire

The empirical analysis was conducted on a sample of 93 observations, which calls for caution in interpreting the results and limits the generalizability of the conclusions. Nevertheless, the findings provide valuable insights into the factors influencing farmers' propensity to adopt AF systems supported by CAP 2023–2027 measures.

Table 4 reports the logit estimates expressed as odds ratios, which are useful to assess the direction and statistical significance of the associations. To facilitate interpretation in terms of predicted probabilities, Table 5 reports average marginal effects, which are the main focus of the discussion below.

The results show that perceived benefits, previous experience with AF systems, participation in training activities, and female gender are positively associated with the willingness to apply for AF support measures. Macro-area, morphology, and altitude were included as control variables.

The logit estimates reported as odds ratios indicate that perceived benefits, previous experience with AF practices, participation in training activities, and gender are positively associated with farmers' willingness to apply for AF support measures. Higher perceived benefits are associated with substantially higher willingness to apply (OR = 2.17, $p < 0.05$). Prior experience with AF practices also shows a positive association (OR = 4.47, $p < 0.10$), consistent with the idea that direct experimentation may reduce uncertainty. Training exhibits the strongest association (OR = 7.44, $p < 0.01$), suggesting a key role for information and capacity-building initiatives. Gender is also significant (OR = 5.29, $p < 0.05$), with female respondents showing higher willingness to apply than male respondents, a result that warrants further investigation.

By contrast, membership in a farmers' association is not statistically significant.

The results in terms of average marginal effects (Table 5) indicate that participation in training activities is associated with an increase of approximately 18 percentage points in the predicted probability of applying for AF measures. Previous experience with AF practices is associated with an increase of about 13 percentage points, while a one-unit increase in the perceived benefits index is associated with an

Table 4 Logistic regression results (odds ratios)

Dependent variable: Willing_to_apply_AF (1 = Yes; 0 = No)			
	Odds ratio (OR)	Robust standard error (RSE)	95% Confidence interval (95% CI)
Perceived benefits	2.17 **	0.75	1.094–4.288
Experience	4.47 *	3.65	0.901–22.136
Training	7.44 ***	5.54	1.732 – 31.997
Gender (Female = 1)	5.29 **	4.19	1.117 – 25.026
Association	0.37	0.32	0.068 – 2.018
Macroarea: North	0.62	0.73	0.062 – 6.260
Macroarea: South	3.48	3.69	0.433 – 27.885
Morphology: Mountain	0.89	1.11	0.075 – 10.374
Morphology: Plain	4.02	4.43	0.462 – 34.897
Altitude	1.00	0.001	0.998 – 1.003

Significance codes: * $p < 0.10$, * * $p < 0.05$, * * * $p < 0.01$

Model statistics: N = 93 observations. Pseudo R^2: 0.2660. Wald $\chi^2 = 30.11$. Prob > $\chi^2 = 0.0008$

Reference categories: Macroarea = Central Italy; Morphology = Hill

Table 5 Average marginal effects from the logit model

Dependent variable: Willing_to_apply_AF		
	Average marginal effects	95% Confidence interval (95% CI)
Perceived benefits	0.069 ***	0.017–0.122
Experience	0.134 **	0.008–0.261
Training	0.180 **	0.032–0.329
Gender (Female = 1)	0.150 **	0.015–0.285
Association	− 0.089	− 0.232–0.054
Macroarea: North	− 0.053	− 0.310–0.204
Macroarea: South	0.094	− 0.077–0.266
Morphology: Mountain	− 0.012	− 0.267–0.242
Morphology: Plain	0.102	− 0.057–0.262
Altitude	0.000	− 0.0002–0.0003

increase of roughly 7 percentage points. Female respondents also display a higher predicted probability of participation, by approximately 15 percentage points, compared with male respondents.

Although some coefficients display relatively large robust standard errors—likely due to the limited sample size—the direction and statistical significance of the main effects remain broadly consistent with theoretical expectations.

However, given the observational nature of the data, the estimated relationships should be interpreted as associations rather than causal effects. Variables such as participation in training activities and perceived benefits may be jointly determined with farmers' willingness to apply for AF measures or correlated with unobserved characteristics such as innovativeness or environmental attitudes.

Moreover, the model does not include several structural farm characteristics commonly considered in adoption studies, such as farm size, enterprise specialization, income dependence on agriculture, access to advisory services, past participation in CAP measures, or financial constraints. The absence of these variables may lead to omitted variable bias and therefore the estimated coefficients should be interpreted with caution.

Therefore, it is preferable to focus on the direction of the effects rather than on their magnitude, which may be imprecise.

Overall, the model shows a moderate explanatory capacity (Pseudo $R^2 = 0.2660$) and is jointly significant (Prob $> \chi^2 = 0.0008$). However, given the small sample size, these goodness-of-fit indicators should be interpreted with caution and do not fully offset the uncertainty associated with limited statistical power.

These results should be interpreted in light of the limited statistical power associated with the small sample size and the non-probabilistic nature of the data. In particular, non-significant results may reflect insufficient power rather than the absence of underlying relationships, while self-selection bias may affect the representativeness of the findings. Consequently, the results are best viewed as exploratory and indicative of behavioural patterns rather than generalizable evidence.

These findings are broadly consistent with the existing literature on AF adoption. Previous studies have shown that farmers' decisions to adopt AF practices are influenced by a combination of socio-economic characteristics, resource endowments, market incentives, biophysical conditions, and risk-related considerations (Pattanayak et al. 2003). In the European context, qualitative and comparative research has also highlighted the importance of knowledge, awareness, and perceived management complexity in shaping farmers' attitudes towards AF systems (Rois-Díaz et al. 2018). In particular, limited familiarity with AF practices and uncertainty regarding their technical and economic performance have been identified as major constraints to uptake. Our results are consistent with this evidence, as training and previous experience with AF show a positive association with farmers' willingness to apply for AF support measures. These results are also in line with behavioural approaches to agricultural decision-making, which emphasize that farmers' intentions are shaped not only by economic incentives but also by psychological and cognitive factors. In this regard, Leduc and Hansson (2022) show that attitudes toward ecological practices, perceived behavioural control, and social norms can significantly influence farmers' intentions to adopt AF practices. Overall, these findings reinforce the view that improving access to information, training opportunities, and practical experience may play a key role in facilitating the uptake of AF systems.

It should be noted that European empirical evidence on the behavioural determinants of AF adoption remains relatively scarce (Leduc and Hansson 2022), particularly in the Italian context where

systematic analyses of participation in AF support measures are still limited.

Nevertheless, the results of the present study provide exploratory insights that may help inform future policy discussions on the promotion of AF systems in Italy, while acknowledging that the analysis is based on a limited and non-representative sample of agricultural and forestry entrepreneurs.

Conclusions

The findings of this study confirm that, despite the opportunities offered by the Common Agricultural Policy (CAP), the adoption of AF systems by Italian farms remains limited. In previous programming periods (2007–2013 and 2014–2022), measures designed to support the establishment and management of AF systems were only partially implemented and, even when available, recorded low participation rates among farmers. This limited uptake reflects structural and institutional challenges that have persisted over time, including fragmented policy frameworks and insufficient alignment between EU requirements and local farming conditions. The current CAP 2023–2027 programming period introduces higher financial allocations and new interventions specifically targeting AF systems. While this could represent an opportunity for revitalization, implementation remains uneven and slow. Regional disparities persist, with significant differences in capacity, awareness, and commitment.

Regional officers acknowledge the importance of AF for biodiversity conservation and climate change mitigation, yet they consistently point to limited technical expertise, lack of accessible information, and bureaucratic complexity as major obstacles to its implementation. These findings suggest that increasing financial allocations alone may not be sufficient to stimulate uptake, as respondents consistently highlight technical capacity, information gaps, and administrative complexity as relevant constraints.

Based on the perceived barriers identified, three areas emerge as potentially relevant for improving policy implementation and participation: (i) strengthening technical training and advisory services; (ii) simplifying administrative procedures to reduce transaction costs; and (iii) adjusting financial support mechanisms, including the possible recognition of ecosystem services.

Lessons learned from previous programming periods can play a crucial role in guiding the design and implementation of future measures, ensuring greater coherence and responsiveness to local needs.

From the perspective of agricultural and forestry entrepreneurs, the results indicate that perceived benefits of AF—such as improved soil fertility, biodiversity enhancement, and diversified income streams—represent a key factor in fostering adoption. However, this perception appears strongly linked to direct experience: farmers who have already experimented with AF practices tend to recognize their advantages more readily. This finding underscores the importance of targeted communication and awareness-raising initiatives to disseminate knowledge of AF benefits. Equally critical is the provision of clear and transparent information on initial investment costs, expected economic returns, and long-term profitability, enabling farmers to make informed decisions.

Future research should explore additional behavioural and contextual variables to deepen the understanding of the dynamics influencing adoption, while also relying on larger and probabilistic samples to improve statistical power and ensure greater representativeness, thereby allowing more robust inference on the determinants of AF adoption.

Such evidence would provide valuable guidance for policymakers in designing support schemes that are better targeted and more likely to increase participation. Moreover, integrating AF into broader value chains and fostering synergies with other CAP measures and forestry programs could enhance its socio-economic impact, particularly in marginal and inner rural areas affected by depopulation and land abandonment. In these contexts, appropriate land management and infrastructural support—such as road networks and water systems—are crucial to enabling the multifunctional benefits of AF.

Finally, awareness of the benefits of provided by AF systems remains limited among both farmers and the general public. Many farmers still perceive AF as a non-productive, environmentally oriented system with low profitability and limited mechanization potential. Overcoming these misconceptions requires a comprehensive approach that combines technical training, professional capacity building, and the recognition of the economic value of ecosystem services.

A more coordinated approach across institutional, technical, and communicative dimensions could facilitate a broader diffusion of AF systems within Italian agriculture.

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Declarations

Conflict of interest The authors declare no conflicts of interest.

Informed consent Informed consent was obtained from all subjects involved in the study. All subjects were anonymized, and no subject can be identified.

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