D8.7 Conclusions towards better-supported policy making

agricore

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Executive Summary

The AGRICORE project introduces an innovative tool designed to enhance the existing capabilities for simulating the impact of agricultural policies using the latest advancements in agent-based modelling techniques. In this model, each farm is represented by an autonomous agent that makes decisions based on its context and expectations. By leveraging the FADN database, this approach enables the simulation of production decisions and interactions among farms at various geographic scales.

The AGRICORE tool is highly modular and customisable, characterised by its agent-based approach that employs synthetic populations to represent farmers and simulate their evolution over time. This method accurately reflects farm behaviour over both short and long periods, considering production planning and factor exchanges, which influence farm structure and regional environmental impact. Additionally, the tool features a user-friendly graphical interface for non-expert analysts.

This deliverable explores the AGRICORE project, focusing on its integration with agricultural policy as a strategic tool for planning food systems, rural development, and assessing environmental impacts. It provides also clear policy recommendations and conclusions derived from the project activities. The analysis targets two primary stakeholders: policymakers (at European, national, and regional levels) and farmers or their associations. The report emphasises the crucial role of data in agricultural policymaking, discussing the European strategy for agricultural statistics and how AGRICORE contributes to data generation for policy formulation.

The AGRICORE project underscores the importance of data and model-based policymaking in agriculture. While simulations are valuable for guiding policy, they should be complemented by expert feedback to address potential limitations. The CAP should leverage tools like AGRICORE and derived ones to ensure consistent analysis across European regions and member states, fostering more effective agricultural policies.

Abbreviations

Abbreviation	Full name
ABM	Agent-based Model
ARDIT	Agricultural Research Data Index Tool
CAP	Common Agricultural Policy
DEM	Data Extraction Module
DFM	Data Fusion Module
DH	Data Warehouse
EASS	European Agricultural Statistics System
EC	European Commission
ESAS	European Strategy for Agricultural Statistics
ESS	European Statistical System
FADN	Farm Accountancy Data Network
FAO	Food and Agricultural Organisation
FSS	Farm Structure Survey
GDP	Gross Domestic Product
GHG	Green House Gases
IACS	Integrated Administration and Control System
OECD	Organisation Economic Cooperation and Development
PDO	Protected Designation of Origin
RDP	Rural Development Plans
SP	Synthetic Populations
SPG	Synthetic Population Generator

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1 Introduction

This report highlights the link between the AGRICORE project and agricultural policy as a planning tool for food systems, rural development and the resulting environmental impacts. In this analysis, the deliverable aims to highlight the impact on two main actors dealing with agricultural policy: policymakers (European, national and regional) and farmers or their associations. The first stakeholder is addressed with topics that debate the importance of data in agricultural policymaking and the current state of agriculture data for policymaking, discussing the European strategy for agricultural statistics and the AGRICORE contribution to policymaking data generation. At the same time, the use cases consider the involvement of local stakeholders in the definition of different sectorial and territorial policies.

1.1 Background

The AGRICORE project provides a tool for modelling and simulating how public policies affect the agricultural sector at regional, national and EU levels. It also consider the wide diversity that exists between farms located in different geographical areas and/or dedicated to growing different crops. This is achieved by implementing an agent-based model and simulation environment populated by synthetic populations (SPs) of agricultural holdings, replicating the characteristics, distribution, and interactions of the real populations of interest. Within the SP, each agent represents an individual farm (Agricultural Holding) as an autonomous decision-making entity that individually assesses its own context and makes decisions based on its current situation and expectations.

1.2 Purpose of the Document

The document aims to introduce the objectives and activities of the AGRICORE project and to provide clear conclusions to support policy making. The project activities involved a thorough analysis of available data sources in Europe at regional, national, and EU levels, as well as an evaluation of their suitability for farm-level modelling and micro-policy impact assessment. The results of such analyses can be useful as valuable input for organisations involved in defining data acquisition initiatives in Europe. Indeed, actions derived from conclusions presented in the document "Strategy for Agricultural Statistics 2020 and beyond and subsequent potential legislative scenarios," presented by the European Commission (EC), have been processed. Accordingly, the goal of this document is to summarise the results of this project and share them with interested parties to contribute to a better definition of policies governing data collection in the agricultural sector.

1.3 Key Components

1. **AGRICORE Project Overview**: AGRICORE offers a tool to model and simulate the effects of public policies on the agricultural sector across regional, national, and EU levels. By using an agent-based model populated by synthetic populations of agricultural holdings, it replicates real-world farm structures and interactions. Each farm acts autonomously, making decisions based on its context and expectations.
2. **Data's Role in Policymaking**: Data is foundational for informed decision-making in agricultural policy, enabling resource allocation, policy effectiveness monitoring, and long-term planning. The report outlines different types of agricultural data, including geo-referenced datasets, and their relevance at supranational, national, and regional levels.

3. **European Strategy for Agricultural Statistics (ESAS):** ESAS aims to harmonize and integrate over 50 datasets to support coherent agricultural policy across the EU. This strategy prioritises collaboration among EU Directorates-General, National Statistical Institutes, and farmers, emphasising the importance of responsive governance and international cooperation.
4. **AGRICORE's Contribution**: AGRICORE supports policymakers by providing tools for data discovery, simulation, and impact assessment, including modules like the Agricultural Research Data Index Tool (ARDIT) and the Synthetic Population Generator (SPG) in addition to the ABM simulation. These tools enable evidence-based policy formulation and scenario testing, which is crucial for developing climate-resilient and sustainable agricultural policies.
5. **Use Cases**: The project features four use cases (Andalusian Olive Farming, Polish Agri-environment-climate Commitments, Greek Start-up Aid for Young Farmers, and CO2 Taxation in Emilia-Romagna), demonstrating how AGRICORE's tools can inform and refine policy decisions by integrating data-driven approaches with stakeholder engagement.
6. **Challenges and Benefits in Data Integration**: The report highlights challenges like data unavailability and the complexity of integrating diverse data sources. However, it also emphasises the benefits of comprehensive datasets that enhance simulation accuracy, leading to more informed policy decisions.
7. **Policy Recommendations**: The report suggests that policymakers should use ABM models (like AGRICORE's) for ex-ante evaluations to balance market, territorial, and environmental impacts. It stresses the need for bottom-up policymaking, incorporating regional and national insights, and recommends the use of benchmarks and KPIs to assess policy effectiveness. Additionally, it calls for user-friendly models that can guide both policymakers and farmers in aligning with CAP objectives.

1.4 Importance of Data in Agricultural Policy Making

A dataset is a collection of one or more tables, schemas, points, and/or objects that are grouped together either because they are stored in the same location or because they are related to the same subject.

The role of data in agricultural policymaking is fundamental, providing the essential framework for decision-making, policy formulation, and successful implementation in the agricultural sector. It serves as the cornerstone for informed decision-making, enabling policymakers to base their choices on real-world evidence rather than assumptions. In the complex landscape of agricultural policies, data unravels intricate issues related to production, trade, environmental impact, and rural development, facilitating the creation of targeted and well-designed policies. The efficient allocation of resources, crucial for policy success, relies on data to identify areas of need, assess intervention impacts, and allocate resources judiciously ([1]; [2]). Continuous monitoring and evaluation of policies, made possible by data, allow policymakers to measure effectiveness, identify areas for improvement, and make necessary adjustments. Data-driven policies not only anticipate and address challenges such as climate change and market fluctuations but also foster transparency and stakeholder engagement. Global comparisons enable benchmarking against international standards, fostering learning and adaptation of successful practices. Long-term planning for sustainability relies on historical data and trends, providing insights into future challenges. Lastly, data is indispensable for enforcing regulations, tracking compliance, and ensuring the overall success and sustainability of agricultural policies ([1]; [3]; [4]).

2 Current State of Agriculture data for policymaking

2.1 Definition and Types of Agricultural Data

Agricultural Data refers to information and statistics related to various aspects of agriculture, including but not limited to crop production, livestock, land use, environmental impact, market trends and rural development. The collection and analysis of these data is at the basis of the formulation of policies, like Common Agricultural Policy (CAP), environmental policies and climate change adaptation and mitigation policies. Moreover, Agricultural Data are used to verify the effectiveness of already implemented policies for the ex-post analysis.

Agricultural datasets play a pivotal role on various scales, encompassing supranational (EU and non-EU), national, and local levels. Additionally, datasets may be geo-referenced, providing spatial context. An EU statistical dataset captures socio-economic conditions across Europe, featuring economic variables like GDP and social variables such as age and gender. Euro indicators, produced mainly by Eurostat, cover diverse topics like balance of payments, labour market, and prices [5]. These datasets, forming the European Statistical System (ESS), aid policy analyses at both national and EU levels. Meanwhile, the Farm Accountancy Data Network (FADN) focuses on the economic situation of EU agriculture, serving as a basis for sector and policy analyses [6].

The AGRICORE project underscores the distinction between national and regional datasets. National datasets, governed by national statistical offices, follow rules valid at a national or supranational scale. Organised hierarchically, they ensure comparability at regional levels. Regional datasets serve either for inter-regional comparisons or present region-specific, non-comparable data relevant to local policymakers. Examples include OECD regional statistics and IACS databases, offering insights into farm holdings applying for payments under Rural Development Plans.

Geo-referenced datasets add a spatial dimension to information. They derive from raster datasets, allowing visualisation and analysis with other geographic data. Geo-referencing involves aligning data to a known coordinate system, facilitating ground coordinate display and measurement. In agriculture, geo-referenced datasets include information on land use, land cover, and soil properties. Such datasets contribute to comprehensive analyses, policy formulation, and decision-making, reflecting the evolving landscape of agricultural practices.

2.2 Overview of European strategy for Agricultural statistic

The European Strategy for Agricultural Statistics (ESAS) is a comprehensive framework designed to address the multifaceted challenges within the European Union’s agricultural landscape [7]. With over 50 datasets covering various aspects of agriculture, the strategy aims to streamline and integrate these datasets, ensuring coherence in concepts, definitions, and legislation. This strategic approach aligns with the Eurostat Vision 2020 and identifies eight key aims, including efficient statistical production, enhanced coherence, and a responsive governance structure. At the core of ESAS lies the European Agricultural Statistics System (EASS), a repository of more than 50 datasets across seven statistical domains. These domains, encompassing structural data, agri-monetary data, crop production data, organic farming data, permanent crop data, animal products and livestock data, and agri-environmental data, collectively provide a comprehensive understanding of European agriculture. Recognising the diverse stakeholder landscape, ESAS emphasises collaboration with the EU Directorates-General, National Statistical Institutes, and farmers. Stakeholder engagement is a key aspect, ensuring that the data needs of various entities, including DG AGRI, DG CLIMA, DG ENV, JRC, and DG SANTE, are addressed effectively. Addressing emerging challenges, ESAS acknowledges the evolving nature of policy priorities, particularly in environmental aspects. The strategy envisions the EASS as an integral part of the broader European Statistical System, promoting collaboration with domains such as forestry, environmental statistics, and energy statistics [8]. Agility, responsiveness, and international collaboration with entities like FAO and OECD are central to the future vision of EASS ([9]; [10]; [11]). Key principles underpinning ESAS include efficiency, reusability of existing data, integration of new technologies, common concepts and definitions, and proactive governance [12]. Regular performance assessments contribute to the strategy's effectiveness, ensuring a solid shared basis for linking statistical domains. The ESAS introduces an indicator pyramid, emphasising the importance of a reliable evidence base for policymaking. It recognises the interconnectedness of agriculture with various domains, exploring integration opportunities with the labour force, subsistence production, living conditions, and urban/rural status. Collaboration with trade, production, forestry, and land use statistics is prioritised. Efficient validation processes are central to ESAS, ensuring data conformity to specific criteria. The introduction of a Common Data Validation Policy across domains, with horizontal and vertical integration, aims to reduce inconsistencies and enhance the reliability of agricultural statistics.

To resume, the ESAS aims to enhance the relevance and reliability of agricultural data in the European Union. It focuses on harmonisation, efficiency, and integration with other statistical domains to meet evolving policy challenges.

3 The AGRICORE contribution to policymaking data generation

3.1 The AGRICORE support policymaking data uses

The AGRICORE project serves as a transformative initiative that significantly contributes to informing and supporting policymakers in the agriculture sector. Through a suite of advanced modules, AGRICORE facilitates evidence-based decision-making, offering a comprehensive toolkit for policy formulation, simulation, and impact assessment.

- The Agricultural Research Data Index Tool (ARDIT) enables researchers and policymakers to discover and access diverse agricultural data sources, laying the foundation for evidence-based policy development. It serves as an essential resource for policymakers involved in shaping agricultural policies, offering comprehensive access to data that can inform decision-making processes.
- The Data Warehouse (DWH) centralises data storage, providing comprehensive datasets for historical and real-time analysis. It also allows certain components or modules of the architecture to be supplied with information. Moreover, DWH is also be used to store data generated by the same or other components, generating a cyclical process of data storage and supply.
- The Data Extraction Module (DEM) simplifies data access and processing, empowering policymakers without advanced data engineering skills. DEM essentially acts as a bridge between the stored data in the DWH and the analytical tools or processes that policymakers may employ, contributing to the overall effectiveness and usability of the AGRICORE system in supporting informed decision-making in agriculture.
- The DFM is designed to enable the SPG to generate the (pseudo)random values assigned to each of the agents' attributes. To ensure the robustness of this process, DFM meticulously obtains the probability distributions of each variable, given the aggregation of data corresponding to the relevant variables extracted from the DWH by the DEM. The elaboration strategy integrates the process of obtaining probability functions within a broader process that seeks to obtain the Bayesian Network (BN) of the aggregate of variables. This comprehensive approach allows the detection of joint probability distributions and the sequence in which the values of those attributes that show interdependence must be generated.
- The Synthetic Population Generator (SPG) allows researchers and policymakers to create synthetic populations based on the extracted probability distributions, crucial for simulating policy effects, while the Agent-based Model Simulation Engine provides a platform for testing different scenarios before implementation.
- The Land Market Module offers insights into land use patterns, revealing agent interaction in the land market and suggesting the best way to play out land allocation policies.
- The Impact Assessment Modules assess environmental, socio-economic, and ecosystem service impacts as KPIs, aiding in the development of climate-resilient and sustainable agricultural policies.

The suite also includes and uses consultancy services, participatory research methodologies, and semantic APIs, offering a holistic approach to policymaking data utilisation.

From data discovery to impact assessment, AGRICORE empowers policymakers to navigate the complexities of the agricultural domain, fostering the development of sustainable and resilient policies.

3.2 The AGRICORE uses cases as examples of policymaking data generation

In the AGRICORE project, four use cases have been implemented that use the AGRICORE tool. Each of them focuses mainly on one type of policy impact assessment. These use cases illustrate how data-driven approaches, including Agent-Based Models (ABM) and Participatory Research, contribute to the formulation and assessment of policies. The ABM module enabled the simulation of the SP evolution under a specific policy context, while Participatory Research encompassed survey campaigns, search for public and non-public datasets and contact with relevant stakeholders to collect information and collaborate with project developments.

Use Case 1: Andalusian Olive Farming

The Andalusian use case focuses on evaluating the impact of the "M11: Ecologic agriculture" measure on the region's olive sector, particularly concerning environmental and climate effects in Andalusia. Through ABM, policymakers can evaluate the effectiveness of the policy, and Participatory Research ensures that the experiences and needs of local farmers are considered. Data on olive production, employment, environmental effects, and sustainability were collected through Participatory Research, contributing to a comprehensive understanding and aiding policymakers in refining and developing sustainable agricultural policies.

Use Case 2: Polish Agri-environment-climate Commitments

The Polish use case delves into the analysis of the impacts of national-level agri-environment-climate commitments (M10.1) on the overall agricultural system and the supply of ecosystem services. Utilising ABM, policymakers assess the policy's effectiveness in promoting practices that protect landscape diversity, natural habitats, and endangered species. Participatory Research provides real-time insights into the ecological and environmental challenges faced by Polish farmers. Data on land distribution, forest coverage, and specific environmental challenges contribute to informed decision-making, enabling policymakers to refine and adapt policies for better sustainability outcomes.

Use Case 3: Greek Start-up Aid for Young Farmers

The Greek use case analyses the impact of M6.1 (Start-up aid for young farmers) on the socio-economic aspects of Greek agriculture. It addresses the challenge of low youth participation in farming by providing financial aid and support for young farmers, differenced by the activity that will be carried out. ABM helps policymakers evaluate the economic implications of the policy, while Participatory Research ensures the inclusion of the perspectives and requirements of young farmers. Data on unemployment rates, education levels, and the success of the young farmers' scheme contribute to evidence-based policy design.

In these diverse use cases, the integration of ABM and Participatory Research emerges as a powerful approach to policy assessment. By combining computational simulations with real-world stakeholder engagement, policymakers gain a comprehensive understanding of the policies' socio-economic, environmental, and cultural implications. These analyses contribute to evidence-based decision-making, fostering more effective and responsive agricultural policies.

Use Case 4: The CO2 Taxation in Emilia-Romagna

UC#4 was initially not included in the AGRICORE Project and was added as a result of the collaboration with the projects within the AGRIMODELS cluster, in this case with MINDSTEP. The use case has the aim to assess the likelihood of dairy farmers accepting predefined policy scenarios that imply different levels of CO2 taxation on GHG emissions produced by the livestock sector in Emilia-Romagna. This Region accounted for 11.4% of Livestock Units bred in Italy and produces 16% of Italian milk. Emilia-Romagna is the second Italian Region for milk production after Lombardia (44%). Its milk production is mostly used for the production of cheese: 89.2% of the regional milk was allocated to the production of 140,000 tons of Parmigiano Reggiano PDO in the area between the Po and Reno rivers, while 325.700 tons of regional milk (0.016%) were used to produce 24,000 tons of Grana Padano PDO. For its milk specialisation, Emilia-Romagna is responsible for 10.4% of Italian livestock-related GHG emissions (2,059 thousand tonnes) and for 9 % of national ammonia emissions (23,114.78 tons of NH3). Considering the relevance of cheese production and the related CHG and ammonia emission, Emilia-Romagna was considered an ideal region to assess the impact of the introduction of CHG and ammonia taxation on the farmer's production choices.

In this use case, the Italian FADN data was used. The sample reflects the socio-economic structure of Emilia Romagna's agricultural system, considering the holder's age and the farm size as leading criteria. Considering these aspects, the FADN sample of Emilia-Romagna is characterised by a prevalence of farms smaller than 10 ha (44.8%). In terms of the holder's age and technical orientation, the largest categories are non-dairy farms, with farm holders aged 41–64 (44.1%) and 65 or above (41.9%). Young farmholders account for only 5.8%.

3.3 Challenges and Benefits in Data Integration

One of the reasons that make the AGRICORE tool stand out is the use of the most cutting-edge ICT techniques and methods to optimise the parametrisation and generation of synthetic populations that replicate the target ones. The efficient parametrisation and calibration process of the model is achieved by making use of the multiple information sources included in the EASS (that were defined in the second paragraph), such as FSS, FADN and IACS. These data sources can be used individually or by matching different data sources in relation to the research objective and the data content. Unfortunately, not all of these data sources are publicly available or do not have the data structure or level of detail needed to generate accurate synthetic populations. For this reason, during the AGRICORE project, it has been defined a systematic approach for identifying and filling information gaps (see D1.7 - Systematic approach for the Identification and filling of information gaps through participatory research actions). It involves generic guidelines delivered from experiences with the use cases. This approach aims to guide future users, emphasising the tool's modular and open-source nature. Users can modify or replace modules as needed, provided the outputs align with analysing the agricultural measure's impact.

The process involves assessing information inputs, consisting of agent attributes, target population data, and module initialisation. Identified information gaps trigger activities like public and non-public data searches, stakeholder engagement, and ad-hoc tasks, presented in order of resource consumption with an emphasis on efficient planning. The challenges in data integration arise from the dynamic nature of agricultural systems and the need for diverse, sometimes unavailable, data sources. The iterative process of identifying, filling, and monitoring information gaps demands significant effort and expertise. The survey campaigns, while resource-intensive, can provide crucial data but require careful planning and ongoing evaluation to prevent unnecessary resource wastage. The benefit lies in obtaining comprehensive datasets to enhance the accuracy and reliability of simulations, facilitating more informed policy decisions.

Furthermore, processing data from multiple sources complicates the generation of synthetic populations and initialisation of modules because there is no standardised format of the data (i.e., units of measurement, geographical scope and resolution, among others). This required extra effort to fit the information from different data sources in a useful way, establishing common criteria. This enabled data analysis to detect relationships between features of the agricultural holdings, using this information to create synthetic populations through Bayesian Networks. This showed some key points to be addressed in order to facilitate data integration in the agricultural sector.

Addressing potential tool users, especially policymakers, involves a standardised communication approach. While liaison with policymakers follows established processes, understanding organisational structures and approaching the most relevant contact person is crucial. Regular communication, including requests for information and promotion of the tool, is vital throughout the use case development. This ongoing contact allows for feedback incorporation, ensuring the use case aligns with policymakers' needs. The standardised approach, including cover letters and short opinion questionnaires, streamlines communication for effective collaboration.

3.4 Support for Farmers and Policymakers

The experiences from studying the Andalusian, Polish, Greek, and Italian Use Cases offer valuable insights that can support farmers and policymakers in several ways:

1. Targeted Policy Implementation

Andalusian Case: The "M11: Ecologic agriculture" measure's focus on enhancing ecological practices in olive farming provides a model for targeted policy implementation. The specific financial support for organic transition and maintenance underlines the importance of tailoring measures to the unique needs of different agricultural sectors. For policymakers, this case highlights the necessity of designing financial incentives that are tailored to the distinctive characteristics of crops and farming systems in their regions. For farmers, it demonstrates how targeted subsidies can facilitate the shift towards more sustainable practices, improving both environmental outcomes and farm viability.

Polish Case: The insights from the "M10" program indicate that streamlining administrative processes and improving communication can increase farmer participation in environmental measures. For policymakers, making programs more user-friendly and reducing bureaucratic barriers can lead to higher engagement. For farmers, it suggests that clearer, more accessible information about environmental programs and simplified application processes can make participating and benefiting from these initiatives easier.

2. Enhanced Data Utilisation

Andalusian Case: The comprehensive use of datasets like RECAN, SIPEA, and ESYRCE to evaluate M11 emphasises the importance of robust data collection and analysis in assessing policy effectiveness. For policymakers, this case demonstrates the value of integrating diverse data sources to comprehensively understand the impacts of farming measures. For farmers, it underscores the potential benefits of data-driven policies informed by detailed analyses, which can lead to more effective and tailored support.

Italian Case: Using simulation models based on agent behaviour to explore the impacts of CO2 taxation and ammonia regulation showcases the role of data-driven approaches in policy assessment. For policymakers, these models provide insights into how different scenarios might affect agricultural production, farming systems, farming practices, profitability, and environmental outcomes. This enables more informed decision-making. Understanding the potential impacts of policy changes through such models can help farmers better prepare and adapt their practices to comply with new regulations while managing economic pressures.

3. Encouraging Innovation and Sustainability

Polish Case: The evaluation of farmers' attitudes towards innovative farming and their investment in sustainable practices reveals the benefits of encouraging technological adoption.

Policymakers can use this information to design programs that support investments in new technologies and sustainable practices. For farmers, this means there could be more opportunities and incentives to adopt innovations that improve farm efficiency and environmental performance.

4. Supporting Young Farmers and Generational Renewal

Greek Case: The assessment of the Young Farmers Installation Support Measure highlights its effectiveness in supporting generational renewal and enhancing rural economies. For policymakers, the case provides a framework for developing similar programs encouraging younger citizens to enter and work in agriculture. This can help address issues related to an ageing farmer population and revitalise rural areas. For farmers, particularly young ones, it underscores the availability of support systems designed to help them start and sustain agricultural enterprises, thereby ensuring a more vibrant and dynamic farming community.

5. Balancing Economic and Environmental Goals

Italian Case: The simulation of CO2 and ammonia taxation impacts in Emilia-Romagna highlights the need to balance environmental objectives with economic impacts. For policymakers, it highlights the importance of considering how environmental regulations affect farm profitability and production decisions. This can lead to more balanced policies that achieve environmental goals without imposing excessive economic burdens. For farmers, it provides insights into how different policy scenarios might influence their operations, helping them to plan and adapt their practices in response to potential changes in regulations.

In summary, these use cases offer valuable lessons for both farmers and policymakers. By analysing targeted policies, data utilisation, innovation encouragement, support for young farmers, and the balance between economic and environmental goals, stakeholders can develop more effective and supportive agricultural policies. These insights can lead to better-designed programs under the EIP-AGRI that meet farmers' needs while advancing broader environmental and economic objectives.

4 Recap of Key Findings

4.1 Background and Objectives

The AGRICORE project, with its aim to model and simulate the impacts of public policies on the agricultural sector at regional, national, and EU levels, is a collaborative effort that values the role of Participatory Research. By utilising an agent-based model populated with synthetic populations of agricultural holdings, it reproduces real-world farm structure, production, distributions, and farm interactions. Each farm acts as an autonomous agent, making decisions based on its situation and expectations. The AGRICORE project has made it possible to highlight certain aspects that are central to the process of agricultural policy analysis and, in particular, the importance of having data that is useful for agricultural policy analysis and its management and organisation in models capable of representing the behaviour of individual farmers in their production environment. Participatory Research, which can encompass survey campaigns, searching for public and non-public datasets, and contacting relevant stakeholders involved in the rural development plan or managing regional value chains, is a key component of this collaborative approach. As an example of data generation and application, the use cases made it possible to verify the relationship between data, models, policy strategies and policy analysis in four production sectors and four different European Regions. One of the key achievements of the AGRICORE project is its ability to implement intelligent solutions that support policymakers' activities. By valorising individual farm information and using farm models that reproduce their behaviours, the project is able to consider the impacts of their decisions in both the short and long periods. This practical application of the project's findings demonstrates its potential to influence policy decisions and enhance the effectiveness of agricultural policies.

4.2 The challenges

The AGRICORE project has made it possible to highlight certain aspects that are central to the process of agricultural policy analysis and, in particular, the importance of having data that is useful for agricultural policy analysis and its management and organisation in models capable of representing the behaviour of individual farmers in their production environment. The use cases, as an example of data generation and application, made it possible to verify the relationship between data, models and policy analysis in four different production sectors and four different European regions.

The AGRICORE project verified that although research in the field of developing methodologies for policy analysis in agriculture has a long history, there are some critical aspects that need to be considered and further improved. These aspects can be traced back to the following types of elements:

- The availability of data for spatial analyses. In this context, the availability of individual information opens up new frontiers that lead to the representation of individual agents in their decisions and only then, through the aggregation of the variables that express their behaviour to, describe the impacts on food systems or rural territories.
- The organisation of data through computer tools that enable the construction of appropriate models for agricultural policy analyses.
- The definition of models using granular farm data (referring to each individual farm) for short- and long-term analyses taking into account the production and environmental context as realistically as possible.

On the whole, the IT procedures and ABM models developed in the AGRICORE project made it possible to verify the main challenges and benefits that can result from them, which include challenges: i) Data unavailability or inadequate detail; ii) Dynamic nature of agricultural systems requiring different data sources; iii) Significant effort and expertise needed for iterative data integration. On the other hand, the main advantages include: i) Comprehensive datasets enhancing simulation accuracy; ii) Improved policy decisions based on reliable data; iii) Standardised communication approaches with policymakers for effective collaboration.

4.3 Policy recommendations

Considering Regulation 2022/1475, and the new Delivery model, Member States must evaluate and monitor the achievements of the 10 CAP Specific Objectives through the Performance Monitoring and Evaluation Framework (PMEF) and conduct preliminary assessments of their Strategic Plans. In this context, the use of models for an ex-ante evaluation becomes paramount, and the results of the AGRICORE project suggest several issues that policymakers should consider in their actions.

This section outlines the main policy recommendations derived from the development of the AGRICORE project. Through the work done in project tasks and challenges encountered, the consortium partners have gained valuable knowledge on which basis several recommendations. They will improve the policymaking process by facilitating the data management process and including new practices. The sections below list the policy recommendations resulting from different project activities.

4.3.1 Participatory research activities

Participatory research encompasses all the activities carried out to search and collect information from public data sources and survey campaigns.

From the search for data sources, it was deduced the need for a way of centralising agricultural datasets. This is covered by the ARDIT tools to a large extent. In addition, it came to our attention the necessary homogenisation of agricultural datasets. One of the main challenges was the integration of data from different sources because they were measured in different units and referred to different geospatial and temporal resolutions. The specification of these aspects in future legislation would facilitate managing agricultural data.

Regarding the survey campaigns of each use case, several recommendations were extracted by interacting with farmers and analysing their answers. The further analysis from which those recommendations derive can be found in the scientific publications elaborated in each use case (see D7.4).

4.3.1.1 Andalusian use case

In the Andalusian use case, the first policy recommendation comes from an alarming discovery. Despite the fact that 98% of the olive farmers surveyed are in charge of the administrative and financial management of the farm, practically all of them were not aware of the costs of the exploitation. This key element for the accounting balance of any company may be related to the low profitability of agricultural activities claimed by farmers. Indeed, only 15% of the surveyed farmers has income from agricultural activities exclusively. The policy recommendation that emerges from this is that policymakers should promote awareness of the importance of farm management accounting. This could be done by offering free courses to farmers.

A second surprising finding was the low rate of farmers who know if their farms belong to a natural protected area. In M11, this information is essential to apply for the subsidy because those farms located in areas with environmental vulnerability have preference. As previously proposed, raising awareness campaigns about this issue should be promoted by policymakers. Moreover, control of agricultural practices should be intensified in those areas because farmers might be incurring severe environmental damage due to purely ignorance.

Finally, it is interesting to highlight that most of the organic farmers surveyed, almost 90%, do not consider abandoning organic olive farming. However, those who consider it is due to economic reasons followed by the high bureaucracy. Policymakers should take this into account because the reduction of requirements, which entails saving costs and time for farmers, might make M11 more attractive for those farmers who want to convert to organic farming.

4.3.1.2 Polish use case

Agricultural policy analysed in the Polish use case is generally positively perceived by farmers. However, most complain about the increased workload and higher costs associated with the programme's requirements. Furthermore, farmers who chose not to participate in the M10 often cited a lack of sufficient information about the programme, bureaucratic hurdles, and concerns about its profitability as the primary reasons for their decision. This highlights key barriers that may have deterred wider participation, so policymakers should implement changes to mitigate those negative effects. Based on the findings from the scientific publication "Impact assessment of the Agri-Environment-Climate Measure (M10) of RDP 2014-2020 on environmental and climatic policies implementation according to the perception of Polish farmers" (Krzyszczak et al., 2023), the following policies recommendations are formulated.

- Placing greater emphasis on streamlining administrative and legal processes at the national level, which could improve farmers' perception and increase participation.
- Prioritising enhancing farmers' knowledge of innovative methods and modern agricultural equipment, which could further support sustainable farming practices.
- Promoting more detailed studies using higher spatial resolution to better capture the nuances of farmers' attitudes toward pro-environmental programmes. Such studies would help identify specific regional factors that influence the acceptance or rejection of participation, enabling more targeted and effective policy interventions.
- Making bureaucratic processes plainer and improve transparency and communication regarding the program's benefits. Providing clear, accessible information and simplifying the application and compliance procedures could significantly increase participation rates. Additionally, tailoring the future program commitments to better match the diverse conditions of farms across Poland and the occurring climatic changes would help ensure that the program is more inclusive and effective.
- Implementing marketing strategies that promote the environmental and economic benefits of M10 participation, such as certification schemes and branding, could help enhance the reputation and market value of the goods produced at farms participating in the measure.

The findings from the AGRICORE's scientific publication "A Comprehensive Approach to Assess the Impact of Agricultural Production Factors on Selected Ecosystem Services in Poland" (Bojar et al., 2023) show a clear trend: the intensification of agricultural production tends to reduce the level of these services. Specifically, a higher share of agricultural land and increased investment subsidies correlated negatively with soil humus content and positively with gross nitrogen balance, indicating potential environmental degradation. In terms of cultural ES, agricultural production factors had a more limited effect. However, the study identified a positive impact of increased ecological land on cultural indicators. Conversely, the share of cereals in the sowing structure negatively affected these cultural indicators. A significant positive correlation was also observed between environmental subsidies under Measure 10 and increases in forestation and the number of natural monuments. These findings suggest that agricultural policies should aim to balance productivity with the provision of multiple ecosystem services, ensuring competitiveness both regionally and internationally while supporting environmental sustainability. The approach used in the study offers an integrated perspective that could help inform more effective agricultural and environmental policies that better align with sustainability goals.

4.3.1.3 Greek use case

The data collected through the participatory research activities of the Greek Use Case resulted in two already published scientific publications: a) "An Impact Assessment of the Young Farmers Scheme Policy on Regional Growth in Greece" (Gkatsikos et al., 2022) and b) "Assessing the Role of the Young Farmer Scheme in the Export Orientation of Greek Agriculture" (Staboulis et al., 2022), as well as two submitted and currently under review for publication studies titled: "Empowering Common Agricultural Policy Young Farmers Support Measure: The Case of Agricultural Biodiversity" and "Facilitating generational renewal in rural areas by responding to young farmers' voice".

The analysis perfomed in those publications identified certain characteristics of the young farmers' agricultural holdings as factors which could form farmers' attitudes and perceptions towards the young farmers measure. Therefore, at the policy level, the measure of young farmers should consider the presence of possible "obstacles or facilitators" that could be generated as a result of the different spatial and geographical allocation of agricultural holdings and influence the willingness of participation from young farmers, such as easiness to access land (land scape and rents), variation in biophysical factors (soil fertility, availability of water, climate, diseases etc.), or existence of supporting infrastructure. The derived policy recommendation from this is that policies for young farmers in Greece should adapt more to the variability of contexts, which makes them more attractive to new young farmers.

Additionally, the measure seems to succeed better at keeping farmers (e.g. members of a family-run agricultural holding) in the farming profession rather than attracting inflows of completely new entrants to the sector. According to the results, high percentages of participants stated that their agricultural holding pre-existed (obtained mainly by parental succession) before their participation in the relevant measure or they were previously occupied as farmers. From this, it follows that only those young farmers who have some basic resources can start farming, so the current policy could be improved by giving more benefits to those who do not have such resources. An example would be the exemption from paying taxes on the purchase of the first agricultural land and machinery.

Finally, the Greek Use Case study indicated that the generation renewal policies, as expressed through the young farmers measure, support rural economies notably for output production and employment increase, while income generation is benefited at a minor scale. In particular, for the rural areas in Greece, the indirect jobs created in rural economies due to payments from the measure equal to twenty percent of the number of new entrants (beneficiaries). Therefore, the young farmers' measure is a useful tool to create more jobs for regional, agriculturally oriented economies. It is suggested that an increased budget for the measure will bolster economic production, enhance regional employment, and revive rural populations.

4.3.2 FADN data analysis

FADN is the most comprehensive data source for agricultural data, so it is of paramount importance in current and future research in this field. FADN mitigates the lack of data to a large extent, as regional and national data sources are not updated yearly and consider so many crops. For this reason, access to those data should be facilitated as much as possible to boost those investigations. Based on the interaction with FADN, the following recommendations are proposed.

1. **Improvement of representativeness**. The holdings in the FADN are stratified according to region, type of specialisation and economic size. Economic size is the value of the

potential income that an economy could generate on the basis of its agricultural production in one year. This estimation means that only small farms whose economic size is above a certain threshold are considered. Consequently, the sample of small farms is not representative of all small farms in the EU. This is especially relevant for countries where most of the farms are small farms. Therefore, it is suggested that the method to select the FADN sample changes in order to include those small farms, increasing representativeness.

2. **Simplification of the EU-FADN data request process**. The authorisation of access to the FADN's metadata through national authorities is possible in some cases. If not, the EU-FADN data request process is the only alternative, but it is a time-consuming process. Although data privacy protocols must prevail, some steps, such as the manual selection of individual variables, could be simplified by offering predefined set of variables according to the type of application. This would boost research activities, resulting in valuable outputs that improve policymaking.
3. **Increasing geospatial resolution**. In FADN metadata, the geospatial resolution is according to the NUTS regions, so the highest level of resolution is NUTS3 regions. This limits the accuracy of the results of the data analysis because, generally, NUTS3 regions have large areas and are defined based on political and/or historical criteria. Therefore, there is a large heterogeneity between farms within NUTS3 regions, which makes it unfeasible to generalise conclusions across farms. To mitigate this, it is proposed to establish agronomic criteria to define regions with a higher level of resolution, that is, agricultural regions. They comprise municipalities, within or not the same NUTS3 region, that share features, such as the type of land (e.g., mountainous area, flatlands, etc.) and predominant crops.
4. **Use of synthetic populations as a base for disseminating fine**-grained FADN data. The potential adoption of synthetic populations by FADN could significantly benefit researchers across EU. By developing a peer-approved, automatic procedure to generate synthetic populations from the original data, FADN managers could provide a better way to access their data in a wider way, while removing existing privacy constraints. Moreover, the adoption of this methodology would allow exploiting the information-cascade capabilities of synthetic populations, where the original synthetic populations published by FADN could be further improved by other organisms by injecting further variables not usually in the scope of FADN (e.g. social-related variables, environmental data, etc.).

4.3.3 Stakeholders interactions

Participatory research and intensive dissemination and communication efforts allowed consortium partners to contact multiple stakeholders who provided feedback on the project developments and shared their concerns. From these conversations, some recommendations in terms of improvement of agricultural policies were received. In this line, the European agricultural policy must increasingly be conceived in a "bottom-up logic" to consider the opinion of regional and national governments in defining policies relevant to their territories.

Through contact with the Regional Ministry of Agriculture in Andalusia, CAAND was informed about the inequalities perceived at the regional level. Regional policymakers claimed that the mechanisms for the distribution of funds should be more flexible, evaluating the needs of the regions and crops.

The contacts established with key stakeholders of Polish Use Case, including members of the Association of Lease and Agricultural Owners, the Agricultural Advisory Center in Brwinów, the Association of Winners of the Farmer of the Year Competition, and industry associations of pig breeders and producers, alongside other prominent agricultural producers previously involved in projects with UTP and IAPAS, allowed to receive insights on critical aspects of policy relevance and adaptability. Stakeholders underscored several key areas for policy improvement:

- Policy Flexibility: Stakeholders from these groups emphasized that certain regulatory requirements, particularly those related to fertilization and sowing schedules, do not adequately reflect current climatic and economic conditions. They noted that, as climate variability and extreme weather events become more frequent, rigid schedules may hinder productivity and adaptability, reducing the effectiveness of these actions in practice. They recommended policies that are more adaptable to the specific environmental conditions and growing seasons of different regions.
- Economic Feasibility: Many farmers across contacted associations highlighted the need to readjust base payment rates to improve the competitiveness of those participating in the M10 action. They suggested that current rates may not adequately offset the opportunity costs for farmers, especially in comparison to other lucrative options, such as selling land for intensive or social-extensive farming enterprises or non-agrarian developments. These stakeholders recommended that payment structures consider the true economic pressures faced by agricultural producers today, to enhance long-term sustainability within the M10 framework.
- Fertilization Plans Restrictions: Some participants expressed reservations about the strict adherence to fertilization plans based on a single soil analysis, cautioning that this approach may overlook seasonal and localized soil variability. They proposed more frequent soil testing or flexible fertilization requirements that allow adjustments based on updated soil conditions. This would enable farmers to respond to dynamic soil health needs more accurately, which could lead to more efficient fertilizer use and improved crop outcomes.

4.3.4 Simulation results

Through the generation of synthetic populations and their simulations, policy recommendations have been formulated and are presented next.

4.3.4.1 Greek use case

In the Greek use case, a simulation on the synthetic populations generated for the NUTS2 level regions of Peloponissos and Central Macedonia for a five-year reduction of the mean age of farmers indicated clear policy conclusions for the agricultural sector in general. In the case of simulations for the Peloponissos region, a more than 60 per cent reduction in energy costs per farm was estimated signalling improved energy efficiency from the younger aged farmers. Moreover, in the case of Central Macedonia simulations, a two per cent increase in Average Working Unit (AWU) per farm was estimated with augmented annual hours of work per farm signalling potential for increased productivity and efficiency improvements from the younger aged farmers.

The primary objective of the Young Farmers installation support measure, in the Greek Use Case, is the stimulation of the competitiveness of agricultural holdings via age renewal. Although the young farmers' measure is a policy measure incorporated and integrated into the overall CAP objectives and aspirations, its inseparable effective character is more profoundly highlighted through the tracing of its indirect effects and results. In that direction, the study offered a positive assessment of the role of young farmer-related support in stimulating export orientation and agricultural holdings' export performance. Therefore, it is feasible that the combined approach of policy measures (young farmers support measure included) could lead to the creation of multiplier effects towards the direction of competitiveness enhancement and, by extension, to the augmentation of the sustainability of the agricultural sector.

In addition, the study of the use case attempted to investigate the effect of young farmers' measure on CAP biodiversity policies' objectives as reflected in agricultural biodiversity through crop diversification. The study indicated that as young farmers are trying to increase the output of their farms and to create a risk-free, effective portfolio of crops and activities, they seem to pursue conjointly the diversification of their crops at the farm level, augmenting by that way agricultural biodiversity and succeeding at the same time to fulfil inadvertently important environmental policy objectives. Therefore, a successfully, decades now, implemented political measure such as the young farmers' installation support measure that predominantly targets generational renewal can be augmented and utilised to pursue diversified political objectives and, in particular, environmental objectives in a synergistic attitude. That will contribute to a positive narrative for the environmentally related policy objectives of CAP as it will draw away from the "Polluter-Pays" or "Provider-Gets" principles and the political discourse that several environmental policies may cause due to their conformation character.

Furthermore, policy measures of proven effectiveness, such as the young farmers' measure, can be utilised by policymakers as valuable tools for policy intervention of limited risk at the national, regional or EU level. In this context, an evaluation of other socio-economic context agricultural policy measures of their added results, especially at an environmental level, can empower the effectiveness of the applied CAP's Strategic Plans by providing tools for the pursuit of a varied set of political objectives at all levels.

From these studies, the following policy recommendations are highlighted.

- Measure 6.1 is proposed to be maintained as an effective policy tool towards age renewal to future CAP landscapes supported and enriched with necessary reforms and environmental objectives.
- Young farmers' measure is assessed as effective at fulfilling objectives towards environmental protection and agricultural biodiversity augmentation. Therefore, its context can be enriched and adjusted by incorporating environmental and biodiversity dimensions.
- Synthetic Population Generation (SPG) simulation scenarios towards the fulfilment of a policy objective of decreasing the mean age of all farmers in the synthetic population for the Region of Central Macedonia in Greece by five years indicated an increase in the Average Working Units effort by more than two per cent indicating potentials for increased productivity and efficiency improvements assuming stable market conditions.

4.3.4.2 Italian use case

The Italian Use Case is related to the Emilia Romagna Region and is based on an Agent-Based Model (ABM) that uses regional FADN (Farm Accountancy Data Network) sample data directly, instead of synthetic population data. As described in other parts of the Deliverable, the AB Model aims to simulate the behaviour of individual agents—agricultural businesses, in this case—within their environmental context, taking into account the structural and productive characteristics of the family-owned farm and under conditions of stress due to changing agri-environmental policies.

The Italian Use Case is an addition to the other Use Cases analysed in the AGRICORE project, as it was developed with two specific objectives. The first is to test the potential of the short-term AB model within the structure of the AGRICORE project, particularly its ability to accurately describe the behaviour of agricultural businesses and provide useful information to regional policymakers and local stakeholders. The second objective is to provide a common benchmark for other models developed within the "AGRICLUSTER", which includes three Consortia managing the Agricore, Bestmap, and Mind-step projects, respectively.

In practice, the Italian Use Case, once the model was refined, went beyond a simple comparison of scenarios common to the Mind-Step project. It allowed an assessment of the potential of the AB approach and the model based on the use of PMP (Positive Mathematical Programming) in relation to a series of factors that become especially relevant when applying the CAP 2023-2030 Delivery Model, providing useful information to regional, national, and European policymakers.

The aspects characterizing the AB model in the simulated agri-environmental policy scenarios can be summarized as follows:

- Granularity of information at the farm level: Each farm represents a weighted group of FADN farms, ensuring representativeness at the regional level.
- Interaction potential among farms based on socio-structural and environmental characteristics of farm families: This considers the life cycle of the farm family, its structure, production orientation, and level of specialization. The interactions have considered the exchange of productive factors such as land (but other factors, like pollution and production rights, can also be considered) and technology among farms.
- Land use and technology: For each farm, all productive activities present on observed farms and their technological level are considered.
- Profitability of farms: Economic parameters are known and calculated for each farm, allowing the evaluation of economic productivity and income for both the farm and the family in their initial state and as individual policy and market scenarios vary.
- Territorial representation of the agricultural production system: The AB model's aggregation structure enables impact analysis from a micro (farm) to a macro (entire productive region) scale, and from a productive sector (based on production orientation and specialization level) to a productive system (based on the characteristics of farms across various territories).
- Link to agricultural policy: The characteristics of the cost function for each farm enable the simulation of interconnected agri-environmental policy and market scenarios, providing a realistic representation of development trajectories and intervention lines based on the actual needs of local policymakers. It is possible to simulate coupled, partially coupled, and decoupled agricultural policies, as well as the effects of production quotas, input taxation (e.g., nitrogen fertilizers), and output taxation (e.g., CO_2 and greenhouse gases), as well as the inclusion of agronomic measures like multi-year crop rotation.

Consequently, the model results span various dimensions useful for understanding the effects in terms of rural and market development. In detail, the following analyses can be developed:

- Structural changes: The potential for the exchange of productive factors, such as land, allows analysis of the concentration process, highlighting the type of “weak” or “marginal” farm families that would exit the market versus the “strong” or intramarginal farms that would strengthen their structure by achieving economies of scale. This analysis becomes particularly interesting when considering these flows by altitude band or agricultural region, enabling the evaluation of specific measures to slow the depopulation of rural areas. All analyses indicate a progressive concentration of production towards large farms, which, given their technological and economic efficiency, have lower transaction costs and higher marginal revenues, justifying their production expansion. The analyses conducted allow an assessment of how the hypothesized scenarios impact not only structural changes based on farm size but also on farm managers' ages, providing additional evaluation elements for regional and national policymakers (Baldi et al., 2023).

- Changes in land use: Different scenarios (simulating various changes in coupled and decoupled payments, market price variations, environmental taxes, and pollution rights) generated a productive recombination at the farm level, replacing less efficient crops with more efficient ones, which gradually disappear from the productive landscape of farms. This data is very significant as it allows the assessment of the effects related to the generation of public goods and both positive and negative externalities by farms. The granularity of information also allows the aggregated evaluation of how individual production types (by farm structure, production specialization, and manager's age) change according to the scenarios analyzed. Analyses have shown that the new European agricultural policy leads to a reduction in intensive crops, leaving space for extensive ones, mainly represented by cereals and annual forage crops. Conversely, measures aiming to reduce the environmental impact of livestock production through CO_2 taxation lead to farms exiting rather than reorganizing their production (Baldi et al., 2023).
- Supply variations: Similarly, the model provides indications on supply variation for the productions considered within the model. The Agent-Based Model is a supply model, highlighting how each type of production (by structure, age, and specialization) reacts differently to stimuli, showcasing the production impact generated by the different policy and market scenarios considered. This assessment is important, considering regional production specialization, to understand whether the proposed measures reinforce or reduce production relationships with downstream sectors in the region. A rather illustrative example is the analysis of the effects of GHG taxes on the Parmigiano-Reggiano PDO system (Baldi et al., 2023), as well as support for organic farming in Emilia Romagna (Baldi et al., 2024). Analyses have shown that smaller farms would need further economic support due to their lower efficiency, though they play a significant role in rural development.
- Economic changes: The impact of farms' productive choices is evidenced in the economic impact on the farm, measured through gross farm income, per hectare, and per Annual Working Unit (Baldi et al., 2023; Baldi et al., 2024a). This data is particularly relevant for regional and national policymakers who are tasked with evaluating agricultural policies included in the National Agricultural Plan for their effectiveness and efficiency. Analyses indicate that the income impact varies based on scenarios and the farms' adaptive capacities, developing their own strategies like economies of scale or production reorganization.
- Environmental impacts: Although not a bioeconomic model, the AB approach considers the environmental impact each scenario generates from the different production types in various territorial contexts, also providing elements for assessing impacts on the environment and the capacity of farms to generate ecosystem services that counteract climate change. Analyses of the AGRICORE project clearly highlight these aspects, leaving public decision-makers with the information needed to intervene and modify ongoing actions (Baldi et al., 2023; Baldi et al., 2024a; Baldi et al., 2024b).
- Impact on public spending efficiency and effectiveness: Finally, the AB model can provide aggregated evaluation elements for assessing the efficiency and effectiveness of agri-environmental policy measures concerning the objectives set in the rural development plan and the national agricultural plan. The granularity of farm-level information enables a comprehensive scenario evaluation, producing indicators functional for evaluation according to the guidelines provided by the European Commission (European Commission 2024). Analyses in the AGRICORE project through the AB model allowed a systemic assessment of the impact of the new CAP, considering effectiveness and

efficiency criteria from the new Delivery Model, evaluating the trade-offs between SO1 and SO5 (Baldi et al., 2024b).

- Policy recommendations represent an exercise to be developed according to the objectives of policymakers and stakeholders. In this case, without specific objectives, the policy recommendations have no particular meaning. However, the analyses clearly indicate the directions where rural development plans should focus to better direct policy action in achieving the expected objectives. Of course, the tools available are represented by the payments provided by the RDP

As previously mentioned, the Emilia Romagna Use Case within the AGRICORE project is based on a short-term AB model without interaction with the long-term model. This interaction would provide an additional perspective in terms of policy recommendations, as it would alter the effects on farms' productive structures.

4.4 Lessons learned

Through the project execution, multiple lessons have been learned. Many of them are reflected in the suggested policy modifications and improvements. The lessons from which a significant part of the aforementioned policy recommendations proceed are listed below.

- **Importance of ICT in modelling agricultural policy**: Modern computer technology and software endowments can significantly enhance the capacity to analyse regional and national agricultural systems, generating an ex-ante assessment of agent behaviours.
- **Use of the data**: FADN is the most critical and reliable data source, but it is incomplete since it represents only a part of the agricultural farming structure. Nonetheless, the integration of FADN with other data sources, such as IACS and FSS, is complex and somewhat difficult to implement. The use of a common approach and the development of synthetic populations is a key enabler to avoid privacy regulations hinder ABM simulations and derived policy impact assessments.
- **The representation of the behaviour of farmers as agents**: Considering farmers as agents allows for a careful consideration of farm production strategies, considering the socio-economic character of the farming family. Thus, it provides a more accurate representation of the reality of agricultural production.
- **The representation of agricultural agents by the PMP**: PMP is proposed to accurately represent agents' behaviour regarding production choices, technological innovations and structural farm development strategies within their productive environment.
- **The SP and LP representation of farm dynamics**: The representation of farms in the short and long term allows for the evaluation of business strategies in temporal logic, enabling the consideration of business investments (such as the purchase of technologies) as a productive choice of the agent.
- **Agent interactions**: In the model, agents' interactions, generating the exchange of technologies and factors of production (e.g., land), allow for a more realistic and policy-oriented representation of agricultural systems and policy scenarios. However, to have a correct representation of interactions, new technologies and criteria for carrying out factor exchange need to be defined a priori; in addition, information on the exchange price of factors is needed.
- **Model integration**: Integrating different methodologies, which have in common the analysis of farms, allows for a holistic evaluation of business behaviour encompassing the productive, economic, environmental, and social spheres.
- **Need for a CGE that accounts for regional limits**: Regional ex-ante analysis models, such as AGRICORE, would benefit from linking with regional CGE models to make short-

run and long-run analyses more current and realistic. However, information calibrated to regional characteristics would be needed.

- **The use of KPIs for the assessment of sustainable impacts**: ABMs require more data, which generates more complex analyses. KPIs simplify communication and allow a comparison between groups of agents. PMF Impact indicators are a very good example of the definition of indicators.
- **Computing power and development effort**: The use of sophisticated models and increasingly large and comprehensive databases are taking advantage of IT innovations in terms of hardware and software. However, maximising information potential requires a large investment in appropriate ICT and a transdisciplinary approach that combines diverse expertise.
- **Combination of ICT and agroeconomics expertise**: The implementation of useful ABM-based tools that can be used by different profiles (policymakers, agricultural researchers, potential farmers) is a highly challenging activity (as realised during the AGRICORE project). Putting in common all the required "languages" and expertise to transform script-based or specific scenario simulations into a general and flexible platform requires an enormous amount of work and collaboration between the participants, and therefore needs a considerable amount of time to be implemented.
- **Market and territorial impacts, as well as the rural development perspective and environmental impacts**. Policy impacts are not limited to the production sector alone, but in view of territorial specialisation, generate impacts that are both social and environmental, influencing and characterising rural development policies.
- **Contrasting objectives.** The agricultural system's heterogeneity and policy complexity may have contrasting objectives (e.g. SO1-SO5), hence multiple evaluation perspectives. The presence in the same production environments of heterogeneous farm systems in terms of structural and production characteristics can potentially generate impacts that benefit some production types to the detriment of others and some sectors to the detriment of others. In this sense, ABM models provide a significant contribution to defining spillovers by highlighting which production types and sectors would benefit the most by assessing multiple impacts that consider, for example, i) supply evolution, ii) added value for farmers, iii) environmental and social impact generated at the farm and agricultural region level.
- **The use of benchmarks through KPIs**. This approach enables comparisons between scenarios by assessing the effectiveness and efficiency of the agricultural policy measures that are proposed.
- **Use of tools by farmers**. Farmers could benefit from using ex-ante planning tools to identify efficient production plans that are in line with environmental and social sustainability objectives set by the CAP. Reusing the models and data to provide suggestions to farmers can be a very good way to capture information beyond the FADN /FSDN scope.
- **Limitations of model simulations.** The new policymaking needs to be model-based and data-driven. However, the models, even when using very detailed ABMs, have known and unknown limitations. Therefore, simulation results can be a factor in orienting new policies but cannot be the only one. Experts, stakeholders, and interested parties can provide valuable feedback that can help advance factors, such as low adoption rates or undesired side effects of the policies. The CAP should take action to achieve these objectives with appropriate tools for policymakers and regional stakeholders, aiming to bring all European Regions and Member States to the same level of analysis

5 Conclusions

Throughout the AGRICORE project, different tasks have provided valuable feedback and knowledge that can be used to better support policymaking. This is addressed to improve agricultural policy design, which directly involves policymakers (at European, national, and regional levels) and farmers or their associations. This document emphasises the paramount role of data in agricultural policymaking. The data management activities, project developments and interaction with stakeholders have derived into important lessons learned from which policy recommendations have been extracted.

All these recommendations are towards exploiting the enormous potential of agricultural data, leveraging the use of powerful tools such as big data and artificial intelligence. Through the deep analysis of those data, policymakers will be able to design policies based on real-world evidence, obtaining more precise policies. Many of those aspects are considered in ESAS, which aims to increase the efficiency of data management in the agricultural sector. This aspect requires appropriate tools that can capture complexity, but models must also be user-friendly and capable of producing credible information making possible the reproduction of policy results changing farm data.

Additionally, farmers should use ex-ante planning tools to identify efficient production plans that are in line with environmental and social sustainability objectives set by the CAP. Reusing the models and data to provide suggestions to farmers can be a very good way to capture information beyond the FADN /FSDN scope.

In the end, the new policymaking needs to be model-based and data-driven. However, the models, even when using very detailed ABMs, have known and unknown limitations. Therefore, simulation results can be a factor in orienting new policies but cannot be the only one. Experts, stakeholders, and interested parties can provide valuable feedback that can help advance factors, such as low adoption rates or undesired side effects of the policies. The CAP should take action to achieve these objectives with appropriate tools for policymakers and regional stakeholders, aiming to bring all European Regions and Member States to the same level of analysis.

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For preparing this report, the following deliverables have been taken into consideration:

Deliverable Number	Deliverable Title	Lead beneficiary	Type	Dissemination Level	Due date
D1.1	Standardised methodology and set of ontologies for the characterisation of data sources	UNIPR	Report	Public	M09
D1.7	Systematic approach for the identification and filling the information gaps through participatory research actions	AXIA	Report	Public	M29
D1.8	Use case participatory research actions	CAAND	Report	Public	M18
D2.4	Synthetic population generation model	AAT	Other	Public	M39
D7.7	AGRICORE use cases	IAPAS	Report	Public	M48