D7.7 AGRICORE use cases

agricore

Deliverable Number	D7.7
Lead Beneficiary	IAPAS
Authors	IAPAS, IDE, CAAND, AUTH, UTP
Work package	WP7
Delivery Date	M54
Dissemination Level	Public

www.agricore-project.eu

The Agricore project has received funding from the European Union's Horizon 2020 research and innovation programme under the Grant Agreement No. 816078

Document Information

Project title	Agent-based support tool for the development of agriculture policies
Project acronym	AGRICORE
Project call	H2020-RUR-04-2018-2019
Grant number	816078
Project duration	1.09.2019-31.8.2023 (48 months)

Version History

Version	Description	Organisation	Date
0.1	Table of content	IDE	12-jul-2024
0.2	First full draft	IDE, CAAND, UTP, IAPAS, AUTH	09-ago-2024
0.3	First revision	IDE	10-ago-2024
0.4	Second full draft	AAT	28-ago-2024
0.5	Final revision and content update	IDE	06-sep-2024
1.0	Final version	IDE	11-sep-2024
1.1	Final version after Review	IDE	10-feb-2025

Disclaimer

Executive Summary

AGRICORE is a research project funded by the European Commission under the RUR-04-2018 call, part of the H2020 programme, which proposes an innovative way to apply agent-based modelling to improve the capacity of policymakers to evaluate the impact of agricultural-related measurements under and outside the framework of the Common Agricultural Policy (CAP). The AGRICORE suite stands out for being highly modular and customisable. Thanks to its open-source nature AGRICORE can be applied to a multitude of use cases and easily upgraded as future needs arise.

This deliverable comprehensively outlines the preparation and execution of all the activities related to the project use cases, encompassing the data collection process through participatory research activities to the generation and simulation of synthetic populations. It provides a detailed overview of WP7, emphasising the efforts made to gather necessary information, address information gaps, engage stakeholders, analyse data, create synthetic populations, perform the corresponding simulations and realise the required impact assessments, whilst maintaining links with previous WP7 deliverables throughout. Section 2 of this document is divided in 4 sub-sections, one for each of the project use cases, each including a complete description of all use cases elements.

Abbreviations

Abbreviation	Full name
SPA	Area of special birds protection
GHG	Green Houses Gases
IAM	Impact assessment module
OCAs	Agricultural District Offices (by its Spanish acronym).
OPRACOL	Association of olive oil and table olive producers
POLSUS	Pig Breeders and Producers Association (Poland)
PR	Participatory research
RAMSAR	Convention on Wetlands of International Importance, especially as Waterfowl Habitats
RDP	Rural Development Programme
SIGPAC	Geographical Information System for Agricultural Plots (by its Spanish acronym)
SIPEA	Information System on Organic Production in Andalusia (by its Spanish acronym)

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1 Introduction

The AGRICORE project proposes a unique tool for boosting the existing capacity to simulate the impact of policies dealing with agriculture by utilising the most recent developments in agent-based modelling techniques. Each farm is represented by an agent, which is an autonomous decision-making entity that analyses its own context autonomously and makes decisions based on its expectations and current conditions. The AGRICORE project aims to offer policymakers a novel tool for improving their capacity to model agricultural policies by taking advantage of the latest progress in modelling approaches and ICT. Based on the FADN database, this modelling approach allows us to simulate production decisions and the interaction with other farms at several geographic scales.

The AGRICORE tool is highly modular and customisable. It is mainly characterised by its agent-based approach, which uses synthetic populations to represent farmers and simulate their evolution over the simulation.

This deliverable thoroughly describes the execution of the project use cases, from the data collection process through participatory research activities to the generation of synthetic population and their simulations. Thus, this document takes a tour through WP7, highlighting all the efforts made to collect the necessary information, cover the information gaps, contact stakeholders, analyse the information, and generate the synthetic populations. For this reason, the link with the previous WP7 deliverables (i.e., D7.1, D7.2, D7.3, D7.4, D7.5 and D7.6) is present along the document.

The deliverable is structured as follows. Section 2 comprises the complete description of all use cases (i.e., description of the situation of the sector, the analysed agricultural policies, the evolution of the participatory research activities and the contact with stakeholders). Moreover, those use cases with generated synthetic populations, such as the Andalusian use case and the Italian one, include a section that explains how those populations have been generated (further details can be found in D7.6). Finally, Section 3 gathers the simulation results of executing the simulation of those populations.

2 AGRICORE use cases

The AGRICORE use cases were originally three: i) UC#1 - Analysis of the impact achieved by the "M11 - Ecological Agriculture" measure defined in Andalusia's RDP, ii) UC#2 - Analysis of the impact achieved by the "M10.1 – Agri-environment-climate Commitments" measure defined in Poland's national RDP, and iii) UC#3 - Analysis of the impact achieved by the "M6.1 – Settlement of Young Farmers" measure defined in Greeks' National RDP National RDP. Furthermore, as a result of the involvement of UNIPR in the development of the ABM modelling approach, a fourth use case was designed to test the core of the AGRICORE modelling approach in the short-term period (agricultural year). This uses the FADN data of the Emilia-Romagna NUTS-2 region and analyses the impact of the introduction of an increasing carbon tax and quotas on the nitrogen from bovine manure, as well as farmers' responses in changing their production plans and resource allocation.

This section summarises the work done in the four use cases. Although all of them share common tasks, they have been carried out based on the particularities and limitations of each use case. Firstly, use case leaders conducted a deep analysis of the agricultural measures to be studied and the status of the agricultural sector in each region. In addition, as part of this analysis, a preliminary search for required data was performed, and some information gaps were detected. This was conditioned for the first approaches of the project solutions, such as a preliminary list of variables of the ABM model provided by WP3 (see D1.8 - Use Case Participatory Research Actions). This analysis phase was followed by several participatory research actions to collect the required data (a systematic approach for the identification and filling of information gaps was presented in D1.7), which also included the first information searches to identify some data sources. The main action was the preparation and execution of survey campaigns to the sample population of interest to collect relevant data for the development of the modules and execution of the simulations. This, which is described in the section below, aims to fill the detected information gaps as well as know the current situation of the agricultural sector according to the analysed measures. The analysis of the collected data also enabled the publication of scientific papers in each of the use cases. Moreover, although it is part of the survey campaign because it was another way of collecting data, the interaction and engagement with stakeholders are also described in an independent section. Finally, combining the data requested to FADN and national agencies, it was possible to generate the synthetic populations (SPs), which process is described for each use case.

2.1 UC#1 - Analysis of the impact achieved by the "M11 - Ecological Agriculture" measure defined in Andalusia's RDP

2.1.1 Analysis of the use case context

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. The relevance of the use case is because Andalusia has a significant agricultural area dedicated to olive farming and it is the world's leading olive oil producer. The M11 measure is part of the Rural Development Plan 2014-2020 and aims to bolster ecological farming practices, aligning with the national priority to enhance ecosystems linked to agriculture and forestry. This use case is particularly challenging due to the specificity of the geographical location and crop, as is the single mono-crop use case of the project.

2.1.1.1 Agricultural policy analysis

In the Andalusian use case, a deep study of Measure 11 - "Ecologic Agriculture" [1] (also referred to as "Organic Farming") was carried out at the beginning of the project. Given the regional character of the measure, it is part of the Rural Development Plan of Andalusia 2014-2020, which, in turn, is under the framework of the National Rural Development Plan of Spain 2014-2020 and the Royal Decree 1075/2014[2], which also, in turn, is under the EU Regulation 1305-2013[3], 1306-2013[4], 1307-2013[5] and 1308-2013[6]. Moreover, this measure commits to the regional regulation nº 834/2007 [7] that defines the controls and labelling of organic products. The measure aims to advance eco-friendly agricultural practices through the financial support of the transition to organic systems and the sustenance of efforts of existing organic operations. Its objectives include enhancing biodiversity, efficient water and soil management, and preventing soil erosion, with a specific focus on olive cultivation.

As part of M11, two sub-measures are considered in the use case:

- Sub-measure 11.1.2 - Conversion to organic olive grove practices (with a subsidy amount of 297,48 €/ha). The units committed must be certified in organic production as laid down in Regulation (EC) No 834/2007 and Regulation (EC) No 889/2008, thus laying down detailed rules for the application of Council Regulation (EC) No 834/2007 during the commitment period. This involves certification authorities that must check the compliance of those regulations. The standard duration of this conversion process is three years.
- Sub-measure 11.2.2 - Maintenance of organic farming practices and methods in olive groves (with a subsidy amount of 247,90 €/ha). The units committed must comply with the same regulations as sub-measure 11.1.2, but that have already been certified as organic production exploitations.

Among other requirements, eligible beneficiaries must be active farmers (legal or natural persons) who own their holdings, adhere to the specified organic regulations, be registered in the Information System on Organic Production in Andalusia (SIPEA) and have an olive grove area over 1 ha. The aid is conditional upon a five-year commitment to organic practices, with potential for extensions, and excludes operators with prior infringements or those not compliant with the established eligibility criteria and financial obligations to the Andalusian Regional Government.

Apart from applying to the measure and fulfilling the aforementioned requirements, the budget is distributed according to an order of priority. Thus, the group of appliers with an olive grove area below or equal to 40 ha will first receive 100% of the corresponding subsidy. Then, in the second level of priority, appliers with an olive grove area between 40 and 80 ha will receive 60% of the corresponding subsidy amount, and the last level of priority is for those with more than 80 ha of olive grove, who receives 30% of the subsidy. In addition, each group is ordered according to punctuation criteria based on the percentage of the land that belongs to environmentally protected zones (i.e., Natura 2000 Network, RAMSAR and Nitrate Vulnerable Zone) and the average slope of the olive grove.

The assessment of the performance of this measure is encompassed in the general evaluation of the RDP. This evaluation qualitatively analyses the situation in which the RDP has been developed and describes all the implemented activities in each measure. All the evaluation analysis is done through 21 evaluation questions, of which only 3 of them involve M11. However, there is no specific evaluation of the olive sector, so the questions that applied to M11 will be analysed from the perspective of the olive sector. As part of this analysis, the last evaluation in 2017 was studied to extract the main figures. The questions are presented below.

- To what extent have RDP interventions supported the restoration, preservation and enhancement of biodiversity, including in Natura 2000 areas, areas with natural and other specific constraints and high nature value farming systems, as well as the state of European landscapes?
- To what extent have RDP interventions supported water management improvement, including the management of fertilizers and pesticides?

- To what extent have RDP interventions supported the prevention of soil erosion and improved soil erosion management?

2.1.1.2 Situation of the agricultural sector in the framework of the use case

Olive farming in Andalusia is a key agricultural activity that has significantly shaped the region's landscape, economy, and culture. Andalusia leads the world in olive oil production and plays a vital role in table olive production as well [8]. The region is home to over 1.5 million hectares of olive orchards, which is about 14% of the global olive orchard area and accounts for 45% of Andalusia's total agricultural space [9][10].

Spain, with Andalusia at the forefront, is a major producer of olive products. It generates approximately 69% of the European Union's olive oil and 45% of the global supply. For table olives, Spain contributes to 77.5% of the EU production and 19% of the world production [11]. In recent campaigns (2018/2019 and 2019/2020), Andalusia's average olive production was 5.8 million tonnes, with 92.7% used for olive oil (yielding an average of 1,112,091 tonnes) and 7.3% for table olives (yielding an average of 428,740 tonnes). Andalusia dominates the Spanish market, producing 76.2% of the country's olive oil and 57% of its table olives [10][11].

The export market for Andalusian olive products is robust, with the region accounting for 75.8% of Spain's total exports. This includes 79.6% of its olive oil and 73.8% of its table olive production, which corresponds to a value of around 1,771 million euros for olive oil and 447 million euros for table olives [12]. Olive farming significantly contributes to Andalusia's economy, representing about 1.6% of its GDP [13].

The olive sector is also crucial from a social perspective, offering approximately 21.6 million days of agricultural labour in the 2020-2021 campaign, 90% of which is related to olive oil farming [14][14]. Women constitute 17% of the workforce in the olive sector. Farm ownership is predominantly by older individuals, with 74.6% of owners being over 44 years old, 25.3% over 64, and a mere 0.1% under 44. Men represent about 80% of farm owners, with women making up the remaining 20% [14][8].

2.1.1.3 Collection and characterisation of data sources and information of interest

Based on the initial approach of the different project developments and the parameters to evaluate the performance of M11, the first data requirements were detected. This motivated the search for datasets from which to extract those data requirements. In the case of the Andalusian use case, at least 26 datasets at the regional and national level were found (see D1.5 - Characterisation of national and regional data sources). These data sources were characterised for their inclusion in the ARDIT tool. Among them, some important datasets are highlighted:

- **Red Contable Agraria Nacional (RECAN) - Spanish branch of the FADN**. The National Farm Accountancy Network for Spain (RECAN, by its Spanish acronym) is an instrument for assessing the income of agricultural holdings and the impact of agricultural policy (reforms) on them, which registers the same variables as FADN, to which it transfers the collected data. The RECAN sample comprises an average of 8,500 farms, which have a set of weighting coefficients that allow the extrapolation of the data to the whole population. The anonymised microdata files of the RECAN are available upon request, and given its importance for the UC1, the application process was initiated by IDENER in M8. After several iterations with the Ministry of Agriculture, Fisheries and Alimentation (MAPA) and some delays due to the COVID-19 situation, the requested data were provided in February 2020 (M18).
- **Sistema de Información de la producción ecológica en Andalucía (SIPEA)**. The Information System for Organic Production in Andalusia (SIPEA, by its Spanish acronym) is a web portal where the certified organic producers in Andalusia (NUTS Code ES61) must be registered. Each producer is identified by a SIPEA code, and all information of his/her certified organic exploitation is associated with this code. This tool offers several

search filters, such as the name or the SIPEA code of the producer, the type of operator, the kind of activity, the type of product and the location of the exploitation. In M12, CAAND initiated the application process for the list of organic olive farmers registered in SIPEA. Thanks to the intermediation of Mr Jon Jáuregui, the list of olive farmers updated for November 2020 was provided in M15.

- **Encuesta sobre Superficies y Rendimientos Cultivos (ESYRCE) - Spanish Survey on Crop Areas and Yields**. The Survey on Crop Areas and Yields (ESYRCE, by its Spanish acronym) has been carried out annually since 1990. It is based on field research in which information is taken directly at the plot level in a georeferenced sample of the national territory. This survey aims to determine the crop area, estimate the average yield of the main crops and collect information on varieties and other characteristics of fruit trees. The anonymised microdata files of ESYRCE are available upon request, so IDE started the application process in M8. The process until the final delivery of the data took 8 days, requiring a second interaction in this period to specify the temporal and geographical scopes.
- **Olive production data in Andalusia**. The data on olive production in Andalusia are manually published by the Regional Government of Andalusia and other agricultural organisations and associations. These datasets distinguish between table and oil olive production and specify the type of production (conventional or organic). However, these data are at the NUTS3 level, and a higher geographical resolution was considered necessary, for example, at the municipality level or the agrarian region level. To this end, in M17, CAAND requested these data from the Regional Government of Andalusia, which provided the data some days later.

2.1.1.4 Detection of information gaps

The datasets mentioned above, together with other public data sources, were analysed to detect some information gaps based on the preliminary list of required data. In the Andalusian use case, several information gaps were detected, and a search in the literature was conducted to extract some available information (see D1.8 - Use Case Participatory Research Actions). Although some information could be found, some of the gaps had to be covered with the data obtained through a survey campaign, and others were finally omitted because they were considered at the economic level. For instance, the application of fertilisers was translated into the corresponding annual cost. The relevant, detected information gaps are briefly described below.

- **Innovativeness**. It is defined as the propensity to change agricultural tools and methods in order to improve the farm's production and save time, effort and money. This information was not found in any recent research.
- **Risk aversion**. It is understood as the farmer's tendency to get into debt to invest in machinery, farmlands or innovations. As for innovativeness, no recent research was found to extract this information.
- **Coordinates and areas of the parcels**. Due to anonymity reasons, both parameters are not included in public datasets and those that were requested. However, this information was included in SIGPAC and SIPEA portals from which the coordinates, areas and shapes of conventional and organic exploitations of olive groves can be obtained. Thanks to them, the geographical distribution of the parcels could be calculated.
- **Age.** The age of the olive grove is an important data to know the yield, but reports included a high-resolution of the age distribution in the Andalusian olive sector.

2.1.2 Participatory research: Survey campaign

2.1.2.1 Preparation of the participatory research

The survey campaign in the Andalusian use case was focused on the organic olive farmers. The target population was defined as organic olive farmers and those farmers who initiated the conversion between 2014 and 2017, which can be determined through SIPEA. From this population (around 2,000 farmers), 10% was set as the sample population. In addition, the same number of surveys was envisaged to be conducted to conventional olive farmers to compare the features of their exploitations and know their opinion about organic olive farming and M11. The latter was included in order to extract valuable information to determine the reasons for the acceptance and reluctance of this type of production.

In order to survey a representative sample of the target population, this was classified into four groups. These resulted from the readjustment of the six types of olive groves considered by the Regional Government based on the yield, slope and tree density because this third criterion cannot be processed due to lack of data. Thus, regions of Andalusia were identified with the estimated majoritarian type of olive grove, and proportional surveys will be conducted.

Regarding the questionnaire, IDENER and CAAND contacted Dr Carlos Parra-Lopez from the Institute for Agricultural and Fisheries Research and Training (IFAPA, by its Spanish acronym), who conducted similar studies in 2005 [15] and 2007 [16]. He provided us with the questionnaire they used in both studies. This was updated and adapted to the objectives and requirements of the Andalusian use case by removing and adding questions and modifying existing ones to become qualitative. Thus, a version of the questionnaire for organic farmers was created, which was also adapted to generate a version for conventional olive farmers. Both draft versions were presented in D1.8.

Since the original questionnaire was conducted in person, the original intention was to do the same in this case. However, the changeable COVID-19 situation at the beginning of 2021 made it unfeasible. For this reason, an electronic version of the questionnaire was tried to generate, but the available tools to conduct online surveys limited the replication of the initial version of the questionnaires due to the inclusion of tables. The solution was to conduct a pilot survey by telephone to assess the conduction of the survey campaign by this channel. To do that, the questionnaire was reviewed and adapted by ECOVALIA, a non-profit organisation with large experience in the organic farming sector. This entity was in charge of conducting the pilot survey between M19 and M20, detecting the following drawbacks:

- The questionnaires were too extensive to answer by phone, so they should be adapted or the channel changed.
- Some questions need visual support to be completely understood to avoid bias in the collected data.
- Many farmers are unaware of some of the asked data, such as the belonging to nature protection areas and the breakdown of the olive exploitation costs.

Based on this feedback, the questionnaires were modified to overcome these issues and the following decisions were taken.

- **In-person surveying**. Thanks to the improvement of Andalusia's COVID-19 situation, this alternative survey method was implemented because some questions required assistance.
- **Reduced questionnaire length**. Some questions were eliminated because their responses were irrelevant or could be extrapolated from others, and others were reorganised using tables.

- **Identifying ways to gather data not collected by surveys**. Since the pollster was an agricultural technician who knew the area well, this person usually checked unknown information and, if the farmer did not answer the corresponding questions, the technician could include this information in a prepared cell.

2.1.2.2 Execution of the participatory research

For the conduction of the survey, CAAND contacted OPRACOL, a farmer organisation with a significant presence in the Andalusian olive farming sector. This stakeholder participated in the revision and modification of the questionnaires after the pilot survey. Indeed, a workshop was organised to solve doubts and ensure that all technicians involved in the conduction of the survey campaign had the same understanding of the questionnaires. OPRACOL and CAAND agricultural technicians launched the survey campaign in September 2021, which lasted 10 months. The conduction of the survey of organic olive farmers was prioritised, and once the target number was approximately achieved, the surveys of conventional olive farmers started. This process was periodically monitored to check that the answered surveys were in line with the real population distribution. Finally, 189 surveys from organic olive farming and 106 from conventional olive farming were collected. Table 1 shows the evolution of the answered surveys.

Table 1 Evolution of the survey campaign in the Andalusian use case.

	Sep'21	Nov'21	Dec'21	Feb'22	Jun'22
Organic olive (type 1)	41	95	105	105	105
Organic olive (type 2)	2	22	22	22	22
Organic olive (type 3-4)	4	46	46	46	46
Organic olive (type 5-6)	1	16	16	16	16
Conventional olive	0	61	83	83	106

2.1.2.3 Analysis of the participatory research results

The data analysis was carried out on the basis of all completed questions in all questionnaires. The structure of the result analysis is based on collecting the information that is of most interest for completing the ABM modules of the AGRICORE tool, so aspects such as personal data and position distribution, cultivated crop, production, acceptance of the measure, farmer's knowledge and innovation and risk aversion, were considered.

The starting point was to examine the current dominant profile in the agricultural sector. The findings indicate that the average age of farmers is between 60-65 years, with over 35% being women. Educationally, there is an even split, with 50% having primary education and the other 50% having secondary education (Figure 1).

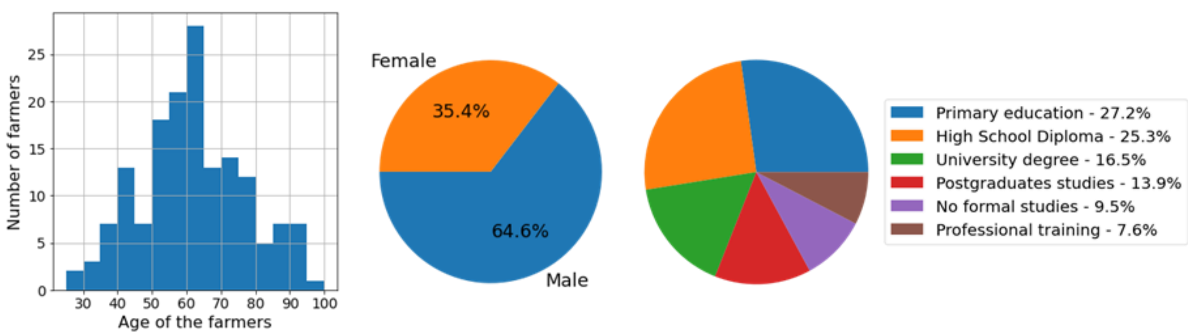


Figure 1 Profile of the surveyed farmers (Age - Gender - Educational level)

Additionally, the farmers' roles and activities on the farms were assessed. Over 80% of respondents own their farms, and more than 50% are involved in management, administration, and technical tasks on the farms (Figure 2).

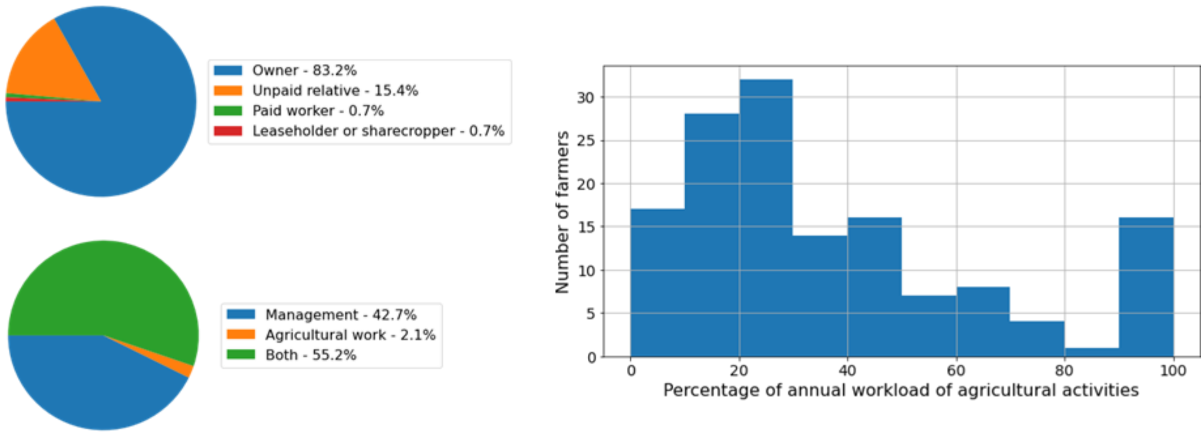


Figure 2 Farmer's roles and activities

To understand the state of the art and the position of olive groves on the farms analysed, the different types of olive groves found on these farms have been identified. The farms showed diverse territorial characteristics, with 74% dedicated to organic olive grove production (Figure 3). They were further categorised by irrigation type, tree age, land slope, and erosion levels. Nearly 95% of the farms were non-irrigated, and interestingly, 50% had centenarian trees (Figure 4). In terms of land slope, about 50% of the farms had a high slope, 37% had a medium slope, and the remainder had a low slope (Figure 5). Despite the high slope facilitating runoff and potential erosion, over 48% of the farms had low erosion levels, while 44% had medium erosion levels, correlating with 47% of the high-slope farms (Figure 6).

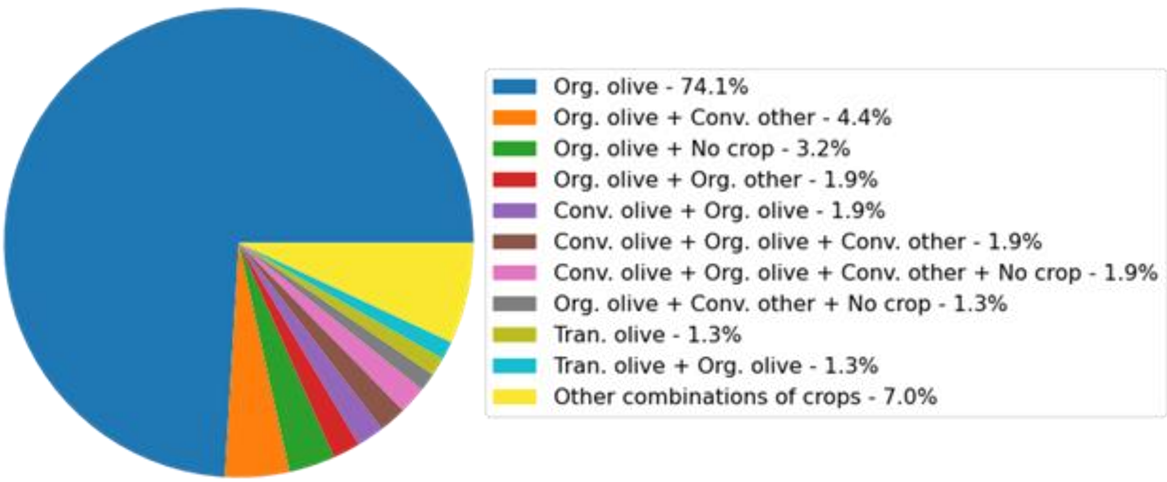


Figure 3 Analysis by territorial characteristics

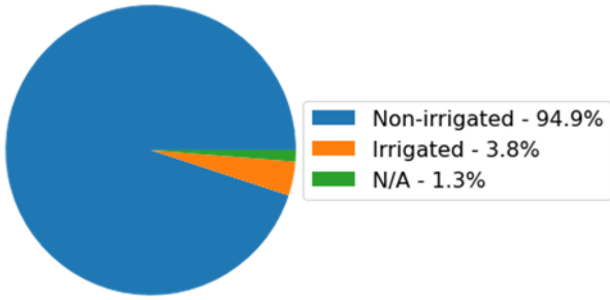


Figure 4 Analysis by type of irrigation.

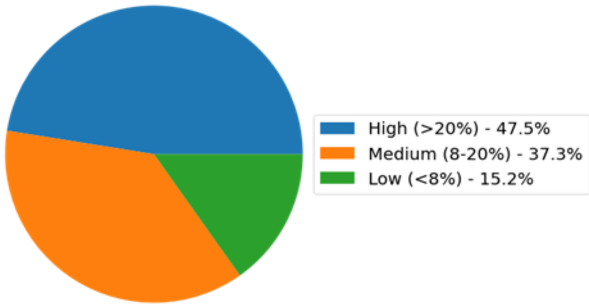


Figure 5 Analysis by land slope

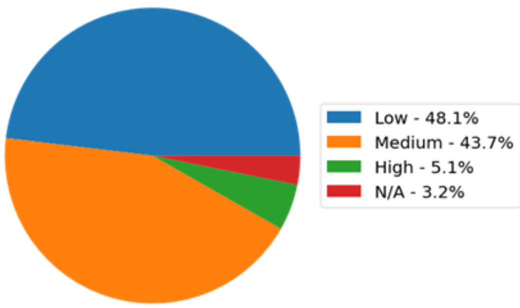


Figure 6 Analysis by level of erosion

On the other hand, the profitability of organic olive farms was assessed based on production volume and primary destination. It was found that most farms produced around 1000-2000 kg/ha. In terms of destination, it was found that the production is mainly destined for mill oil production. Only 10.3% of the farmers destinate their production for table olives (Figure 7).

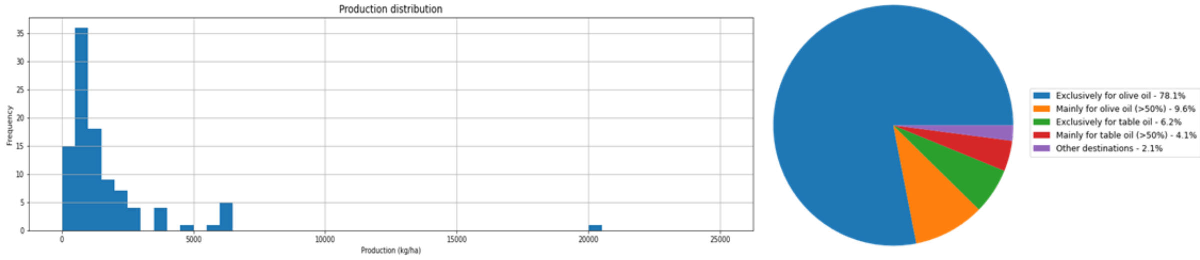


Figure 7 Production volume and primary destination

Another point of the study was to analyse whether there is a prediction of generational replacement, as the results would be interesting to take into account in the modelling of future agricultural policies. In this context, it was observed that there is a high percentage of generational replacement in the farms, or at least, they believe that it could exist, being around 76% of the farms (Figure 8). On the other hand, it was analysed whether they consider abandoning organic farming on their farm in the future, with a fairly high percentage, 87%, considering that they would not abandon organic farming (Figure 9). Among those considering abandoning it, 63% cited economic reasons, indicating that they do not find it a profitable venture (Figure 10).

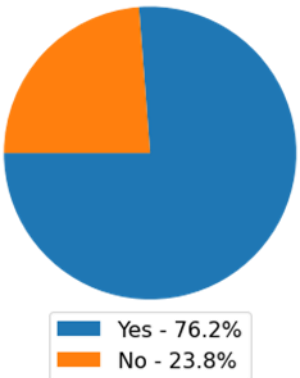


Figure 8 Prediction of generational replacement

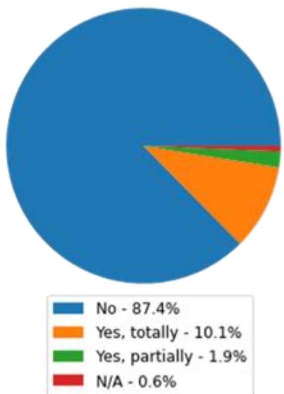


Figure 9 Farmer's consideration of abandoning organic farming

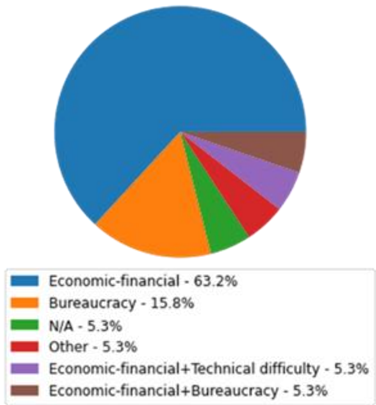


Figure 10 Reasons why farmers consider abandoning organic farming

The study also investigated farmers' knowledge about belonging to Natura 2000 areas, Ramsar areas, or nitrate risk areas, which are important for benefiting from the M11 measure. Results showed a significant lack of awareness among farm owners, with over 50% of responses coming from farm technicians or remaining unanswered. Only 30-40% of farm owners knew if their farm was part of these categories (Figure 11).

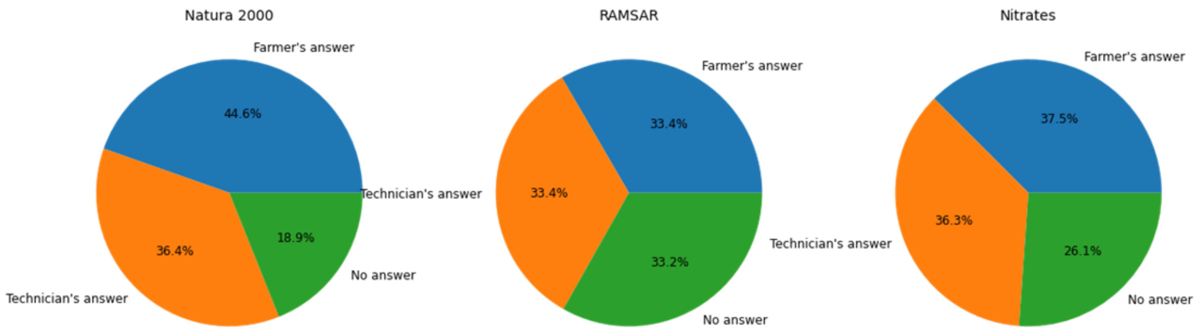


Figure 11 Farmers' knowledge about belonging to Natura 2000 areas, Ramsar areas, or nitrate risk areas

Farmers' innovation and risk aversion were evaluated using two "Multi-item" scales: one for innovations and the other for risk management strategies. For the first one, the following 10 innovation actions were considered:

- Inn1: Erosion control actions.
- Inn2: Use of deficit irrigation practices on water-scarce farms.
- Inn3: Olive orchard waste composting practices.
- Inn4: Disease and/or pest control by plant cover and/or antagonistic fungi.
- Inn5: Innovation in automatic and/or smart irrigation systems.
- Inn6: Use of integrated equipment for bunching, chopping and management of pruning residues.
- Inn7: Use a mobile app, including weather forecasting or machinery monitoring, as an aid to agronomic practices.

- Inn8: Use of drones and other equipment for precision farming.
- Inn9: Implementation of business lines that represent alternative sources of income (Ecotourism, Cosmetics, etc.)
- Inn10: Conducting training courses for all types of personnel.

The results showed that many farmers are interested in training courses, mobile applications, integrated equipment, erosion control, and pest or disease management. However, only 10% invested in innovations (Figure 12).

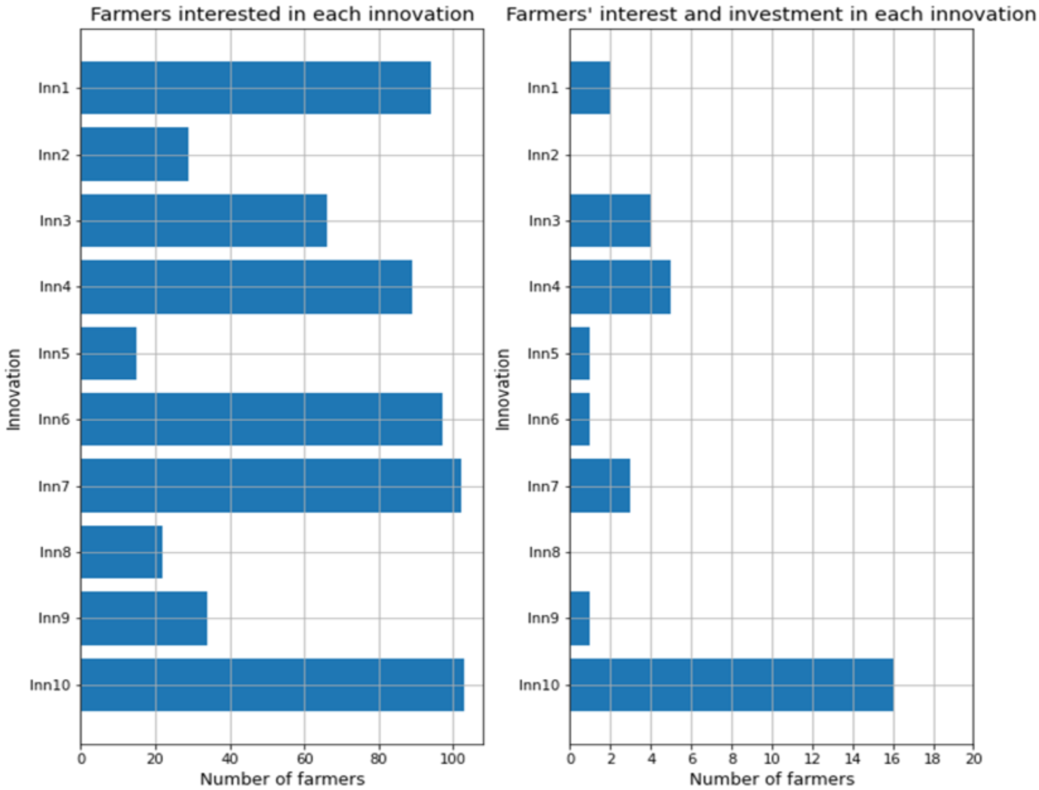


Figure 12 Analysis of farmers' interest in adopting and investing in innovations

Regarding the second multi-item scale, the following sixteen management strategies were taken into account:

- RA1: Liquidity-keep cash on hand.
- RA2: Prevent/reduce crop diseases and pets.
- RA3: Manage debt to ensure solvency.
- RA4: Buying farm business insurance.
- RA5: Producing at the lowest possible cost.
- RA6: Take off-farm work.
- RA7: Buying personal insurance.
- RA8: Renting machinery and/or land is safer than buying them.
- RA9: Hiring agronomical consultancies

- RA10: Diversifying agricultural holding activities not to depend only of agricultural holding activities not to depend only agricultural yield (rural tourism eco-cosmetic, etc)
- RA11: Sharing ownership of equipment or operating jointly with other farmers
- RA12: Buying productive factors (e.g. fertilisers) when they are cheap and storing them for future use.
- RA13: Hiring economic and or accounting consultancies
- RA14: Ensuring surplus of machinery capacity and/or stock of spare parts
- RA15: Investing part of the benefits off-farm (stock market, real state, etc.)
- RA16: Organizing the farm as a corporation to reduce exposure of personal equity.

The results showed that the most common strategies adopted in terms of risk management included off-farm work, cost-efficient production, and hiring agronomical consultants (Figure 13).

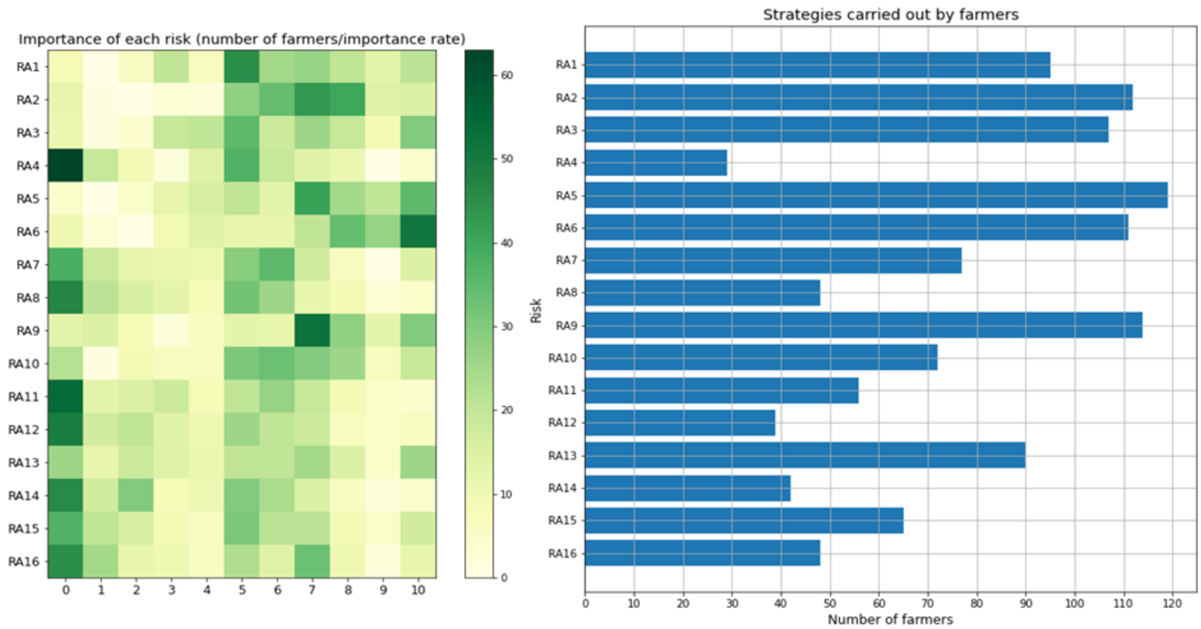


Figure 13 Analysis of risk management strategies most commonly adopted among farmers

These and further results were included in D7.4 and the resulting scientific publication "Characterisation of Organic Olive Farmers in the Framework of M11 of the Common Agricultural Policy". This provides an updated situation of olive farming in Andalusia, serving as a key instrument to design policies that adjust to the current situation of the sector.

2.1.3 Interaction and engagement with stakeholders

Interaction and engagement with stakeholders are key components for the success of the AGRICORE tool designed for this project.

The strategy to establish this connection with stakeholders started with identifying and categorising them according to their level of influence and interest in the project and its objectives. One of the fundamental pillars in the Andalusian use case has been to involve stakeholders from the earliest stages of the project, as these initial stages are the most relevant for considering external opinions.

In the process of interaction, communication and active collaboration actions have been carried out with private entities, associations, researchers and public administrations defined of important relevance for the use of the tool and help in decision-making. The subsequent commitment has been slowly forged until finally, after checking that everything works with the synthetic population, the necessary scenarios can be put forward to help decision-making.

On the one hand, one of the most important services offered by CAAND to its farmers members is the service of assistance and processing of subsidies under the Common Agricultural Policy. The federation processes more than 80,000 applications in the region of Andalusia, which represents more than 35% of these, so the department responsible for this purpose has a special interest in knowing in advance how the population can be expected to behave depending on the different scenarios set out in the bases of the legal calls for applications under the Common Agricultural Policy. Furthermore, as it has a direct link with farmers, this department reviews point by point the measures designed by Europe and is obliged to review them and provide the relevant public bodies with any errors or recommendations it considers appropriate, according to the convenience of the sectors involved.

In this sense, CAAND, as well as being a partner in the project, is one of the main stakeholders defined in it. Communication and collaboration have been active throughout the process of creating the tool and analysing the situation, contributing all the knowledge generated in this organisation about the CAP, with more than 10 years of experience, ensuring the commitment to use the AGRICORE tool when everything is available for it.

On the other hand, as mentioned above, the federation has a close relationship with public administration. The public bodies with competencies in agriculture and livestock farming are the focus of AGRICORE's objectives. These are the bodies that design the main strategy of action of the CAP and the AGRICORE tool is designed to help to know in advance the different scenarios that may occur in the population, helping to define this strategy in the following calls for proposals.

In this case, CAAND has communicated and collaborated with different profiles associated with the relevant public bodies, from technicians to general directors belonging to the Regional Ministry of Agriculture, Fisheries, Water and Rural Development. The contact has been physical and telematic from the beginning of the project until the end. The collaboration has been exceptional, not only showing interest in the use of the tool once it has been defined but also providing all the necessary information available in these administrations to help build the synthetic population of the tool. Their commitment has been present throughout the duration of the project and beyond, and they are still committed to testing the AGRICORE tool after the end of the project.

The main departments and contacts that have been actively and collaboratively involved in the project are the following:

- Coordinator responsible for Agriculture and Livestock (Mr Armando Martínez Vilela)
- Director of the Ecological Production Systems Service (Mr Jon Jáuregui)
- Director of the Department of Studies and Statistics (Mr Manuel Pino)
- Head of Services of Initiatives and Other Community Interventions (Mrs María Pilar Rojas)
- Technical adviser of the Department of Ecology, Agricultural and Fisheries Management Agency of Andalusia (Mr Juan Manuel Arcos)
- Director of the Agricultural Region Office of *Sierra Norte* (Mr Juan Antonio Cruz Martínez)

These aforementioned contacts have facilitated the conduct of the participatory research of the Spanish pilot, as well as providing all the necessary information to carry out this action.

Finally, as a public body, the JRC (Joint Research Centre) was contacted and the Adviser to the European Commission, Joint Research Center (Mr. Vincenzo Cardarelli), provided the federation with sufficient contacts to establish future synergies once the tool was completely ready for its use and testing.

Another group of stakeholders of great relevance for the study and analysis of the survey campaign carried out in the participatory research has been the connection established with researchers from different centres and universities, who have provided experience and knowledge in the areas of study of the Andalusian use case. The main researchers have been:

- Principal researcher of the Food Chain Economics Area (Mr Carlos Parra)
- Professor at the Higher Technical School of Agricultural Engineering, University of Seville. (Mrs María del Carmen Florido)

Alternatively, the farmers' associations have played an essential role in the implementation of the Andalusian use case. These associations have facilitated interviews with their members in order to carry out the survey campaign, which was aimed at the organic and conventional olive grove sector. More than twenty cooperatives took part in this study, although two of them are particularly relevant: the agricultural cooperative "Virgen del Robledo", led by Mrs Carmen Navarro Silván as President of the cooperative, and the Cooperativa Olivarera de los Pedroches, OLIPE, led by Mr Juan Antonio Caballero Jiménez, president of the cooperative.

Finally, it should be noted that private entities such as CERTIFOOD and non-profit organisations such as ECOVALIA have also shown their interest in the project and have provided all the information required by CAAND to properly conduct the participatory research of the Andalusian use case. CERTIFOOD is a private entity, an organic certifier, with a special interest in knowing what is going to be the near future trend of transforming currently conventional farms into organic and all those conventional farms that have tendencies to maintain this type of activity. This is the main reason why the project has generated interest in it and its possibilities throughout its life. In addition, as mentioned above, it has provided all the necessary knowledge about the platforms to be used for the selection of the study population to the technicians of CAAND. The NGO Ecological Value Association (ECOVALIA), through the Director of Innovation, Mrs Auxiliadora Vecina, has provided relevant information for the study.

In summary, the interaction and effective engagement of all stakeholders have been essential to the success of the Andalusian use case.

2.1.4 Generation of the synthetic population

The implementation of the Andalusian use case is grounded on the generation of a synthetic population that replicates the main economic, social, agricultural and environmental factors that characterise the region of study. This use case has required generating two synthetic populations, which correspond to the year 2014 and 2018. The process of generating the synthetic population for the Andalusian use case and for the years mentioned has been carried out by the synthetic population generation module.

This is an automated and containerised software module that can create synthetic populations from an original data sample in an automated way while maintaining the statistical interdependencies between variables. To achieve this, the generation component bases its performance on a Bayesian Network generation model. It begins by fitting a directed acyclic graph, which defines the generation sequence for the variables in the dataset and the interdependencies between them. Specifically, it focuses on determining which variables generate others. Then, it uses different generation methods, including Kernel Density Estimation and K-Nearest Neighbours, to generate the synthetic population according to the graph sequence.

The basic source of information for the building of this use case is the RECAN (Red Contable Agricola Nacional) dataset. This is a comprehensive dataset elaborated by the Ministry of Agriculture, Fisheries and Food from the Spanish Government. It covers a wide range of heterogeneous data at the farmer level, which makes it suitable to generate a context for the simulation of virtual agents in an agent-based simulation environment. The consequence of implementing such actions outcomes the generation of a synthetic population that mimics the actual agricultural landscape for a given year. Although the data sample does not represent the total number of farms available in the real world, extrapolation methods allow us to obtain such values while maintaining the macro indicators of production, cultivated areas and other economic values. The dataset utilised for the building of this use case contained a variable that included the weight of each farm, which made the extrapolation process straightforward, as the weight is the number of real farms that the farm in the data sample represents.

Although this dataset is quite complete, and a large number of agent parameters were covered, some information fields required for the simulations were not included. This fact forces us to obtain the information from alternative sources or to infer the values through mathematical or statistical methods. Specifically, the RECAN dataset did not contain some social factors related to the farmer's family composition. Alternatively, using the Eurostat database allowed for getting information about the number of family members composing the family of the farm holder or the statistics about the ages of the successors. Other not-included parameters were the geospatial location of the farm; in this case, the dataset contained up to NUTS 3 level, and the agent-based model works with another higher geospatial resolution level. This lack of information was filled with the utilisation of the INE (Instituto Nacional de Estadística) database, which contained a general distribution of farms for such geospatial level according to the crops managed, the availability of irrigated areas, etc. Finally, the specific crop costs were inferred through mathematical methods. The original dataset did contain the total expenses on crops, but these expenses were not referred to individual crops. To overcome this issue, a mathematical problem was formulated, and through the resolution of an optimisation problem, an approximation of the specific crop costs was obtained.

As other use cases later described, the Andalusian use case required a specific variable grouping for crops and livestock-related variables. The grouping is performed through the addition of homologous variables (surfaces, quantities, economic, number of animals,...) for different crop and livestock species according to a varied set of criteria. The idea is to reduce the computational cost when performing the simulations, simplify the agent model and focus on the most representative crops and animals according to the use case purpose. Accordingly, in this use case, the cultivation of olive groves stands out over all other crops, as it is the predominant crop in Andalucia in terms of cultivated area and economic indicators. Moreover, the use case is designed to observe the broader evolution of olive groves in general and to analyse the shift from conventional to organic production methods in particular according to a specific legal and subsidiary framework. Other product groups have been created according to the surface, economic or affinity indicators, with the aim of keeping the most representative crops and reducing the importance of the less representative ones under rational grouping criteria. Finally, a group named "OTHER" encompasses a varied number of minority crops that, although they have no individual weight on the overall farmer's accountancy, the aggregation of their values in the total economic and surface indicators have a considerable representation and cannot be neglected.

Following this approach, the built synthetic population already includes such considerations and it inherently contains such variable grouping. These are the product groups created for the Andalusian use case:

Table 2 Groups of crops in the Andalusian use case

#	Product Group	Abbreviation	Description
1	Olive	OLIV	Olive tree and all its varieties and derived products
2	Cereals	CER	All kinds of cereals, including maize, wheat, rice, rye, barley…
3	Vegetables	VEG	All vegetable species, fresh vegetables, tomatoes, lettuce, garlic carrots, and potatoes.
4	Grazing	GRAZ	All crops that can be used as fodder or as feed for livestock, including pasture, meadows, rough grazing, green maize and plants harvested green.
5	Citrus trees	CITRUS	Fruit trees dedicated to the cultivation of citrus fruit, including oranges, lemons, tangerines…
6	Fruit	FRUIT	All types of fruit-producing crops, fruit trees, melons, peaches, nectarines, and strawberries.
7	Protein crops	PROT	Agricultural plants that are cultivated for their high protein content including lentils, chickpeas, beans… Crops that serve as nitrogen-fixing.
8	Set aside	SET_ASIDE	Fallow land with or without subsidies.
9	Nuts	NUTS	Nuts cultivation
10	Sunflower	SUNFL	Sunflower cultivation
11	Cotton	COTTON	Cotton cultivation
12	Other	OTHER	Group of crops with low representativeness or without a relevant impact on the use case study. Grapes, wooded area, flowers,

The following figures are a sample of the set of graphs that compare the synthetic populations with the original data used to generate them. These graphs compare the cultivated area and production of cereals, among others, showing similar values between populations. From the total set of variables managed by the simulation model, a selection of variables has been made to illustrate the performance of the simulation model and the quality of the generated data in comparison to the original data characteristics. In this case, graphs include variables related to olive production and cultivation, along with other crop-related and categorical variables.

The complete results include a histogram of the non-zero values, the shape of the probability density function for each variable, and the cumulative distribution function. The histogram focuses on non-zero values to enable a more accurate comparison, given the high presence of zeros in the variables being analysed. All this is detailed in D7.6.

Figure 14. Andalusia use case: synthetic population comparison I

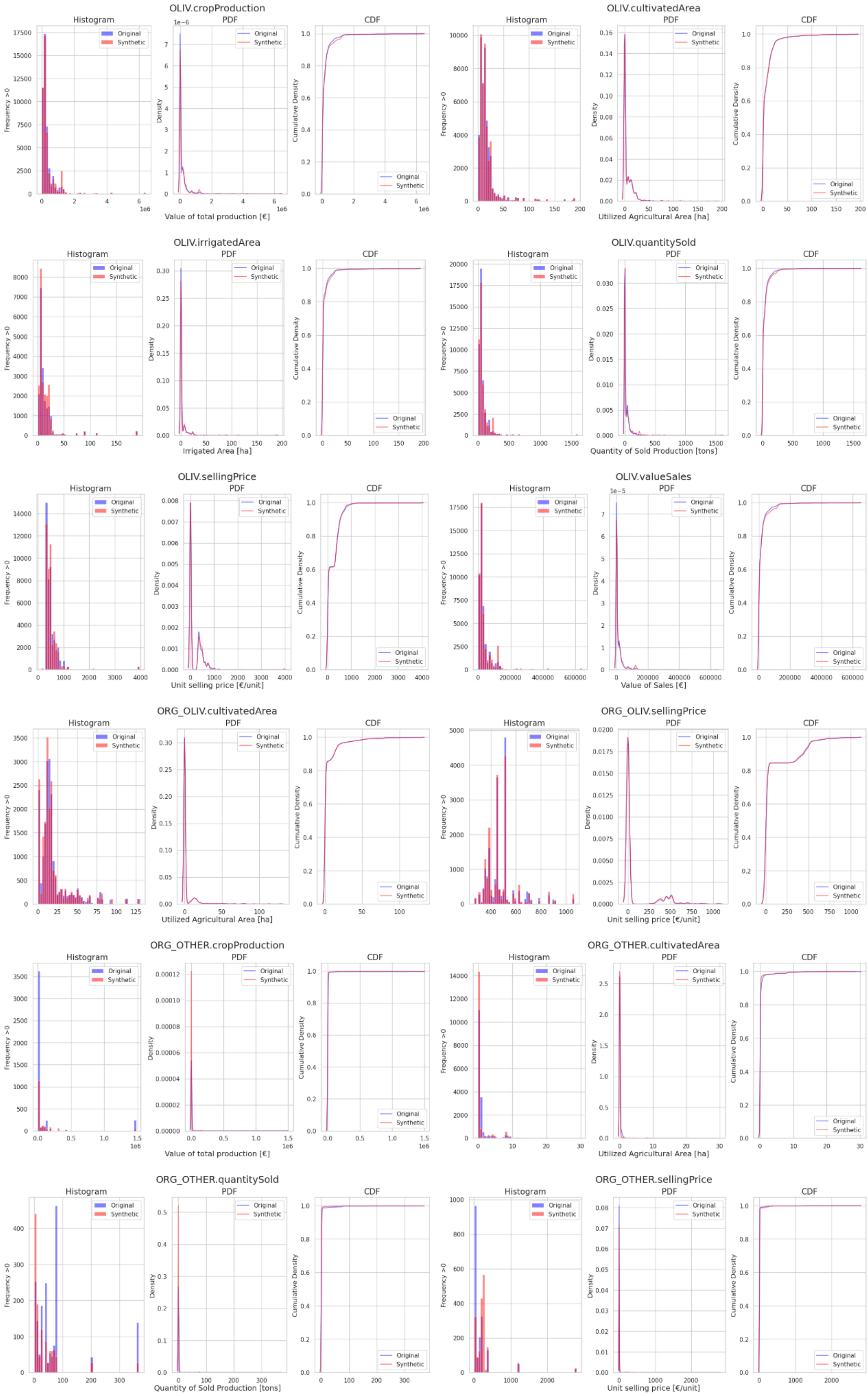


Figure 15. Andalusia use case: synthetic population comparison II

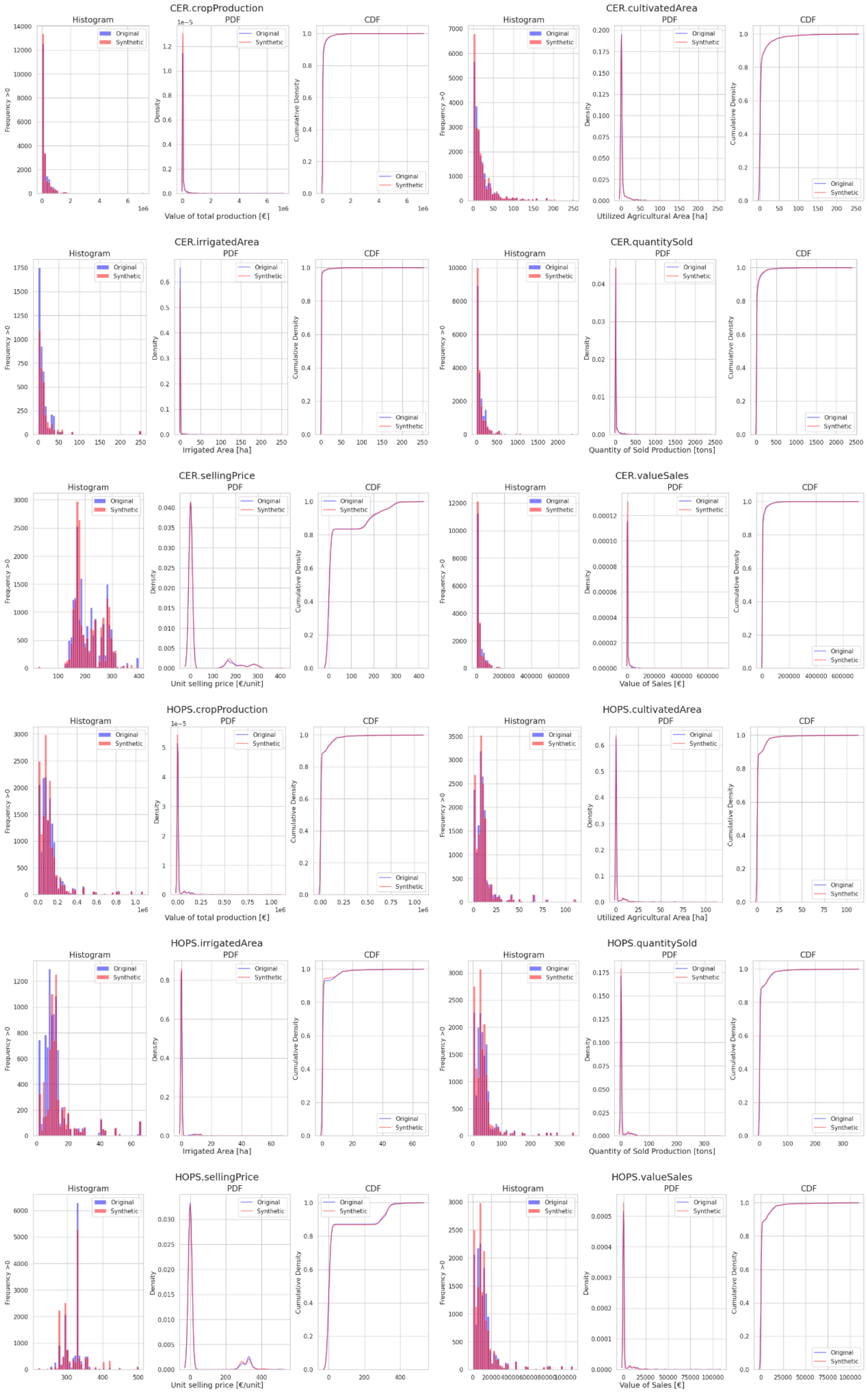


Figure 16. Andalusia use case: synthetic population comparison III

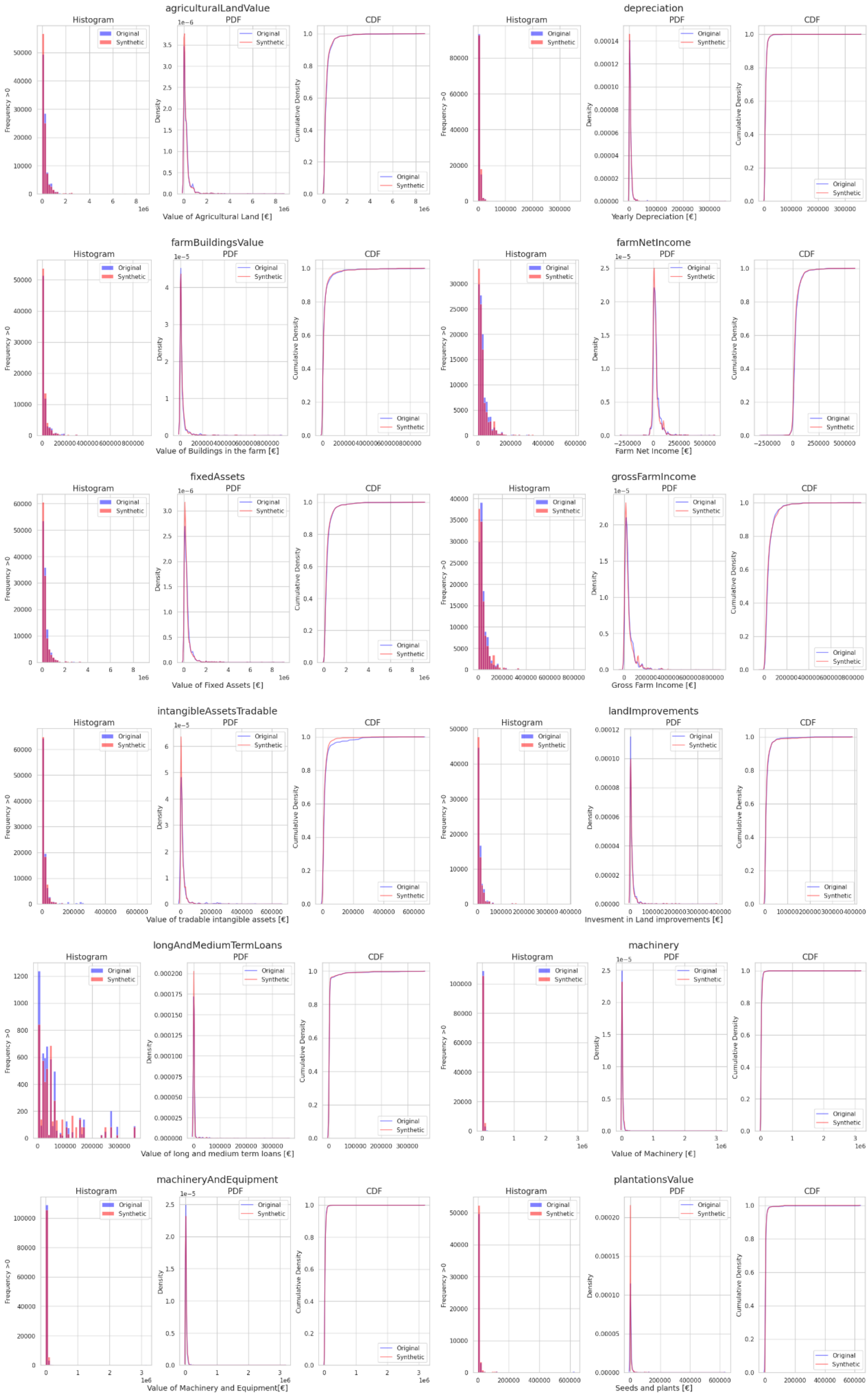


Figure 17. Andalusia use case: synthetic population comparison IV

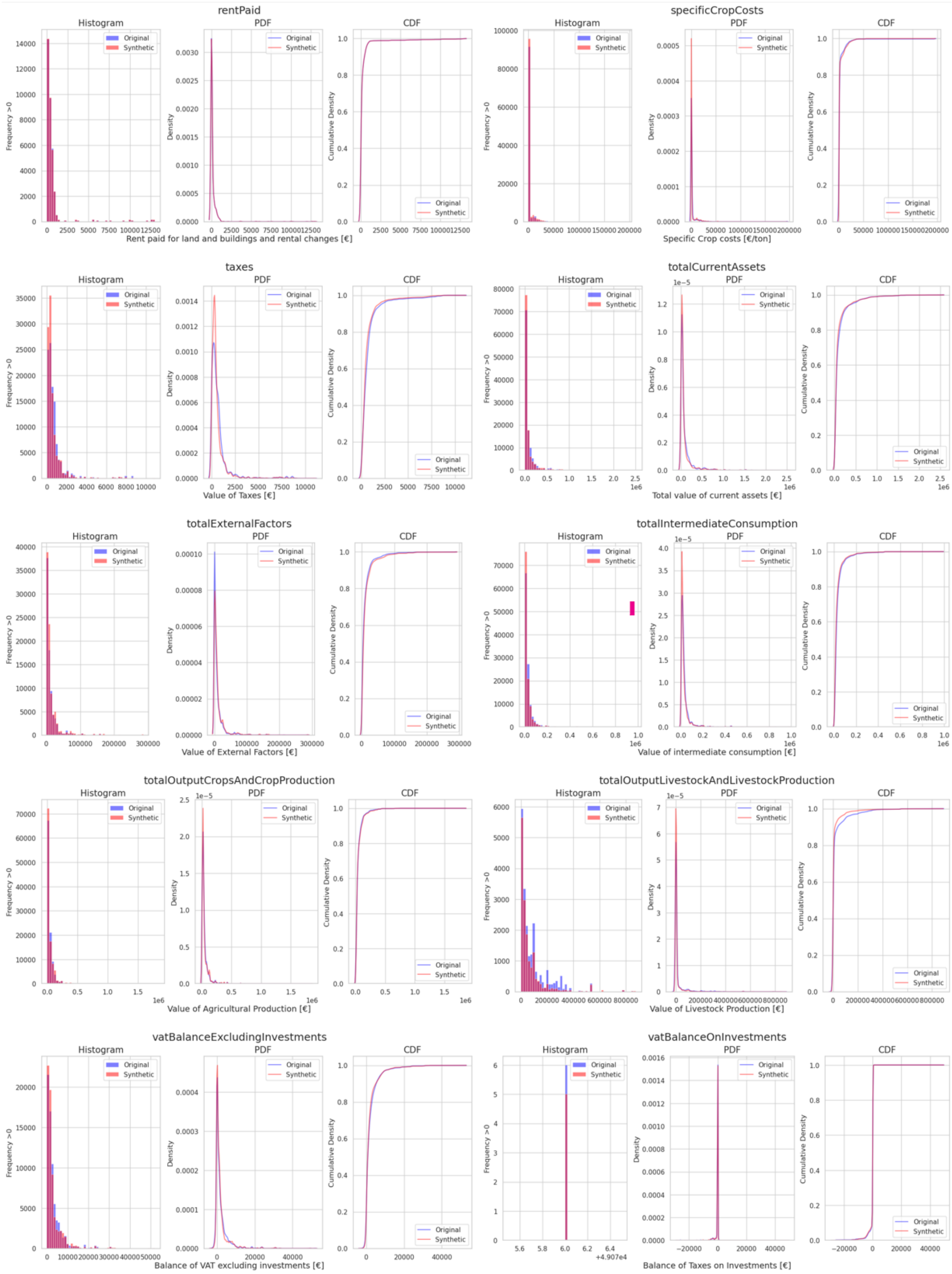
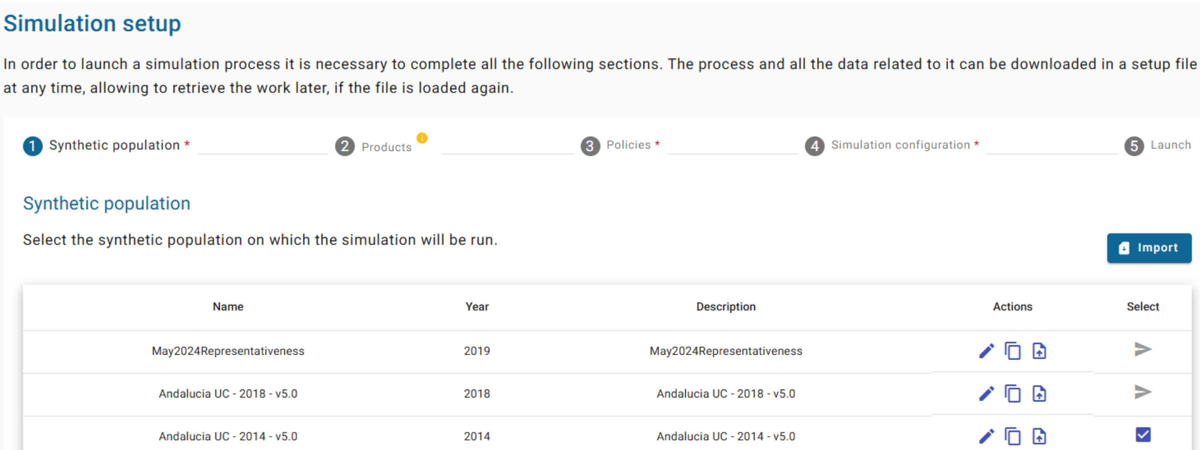


Figure 18. Andalusia use case: synthetic population comparison V

2.1.5 Simulation of the population

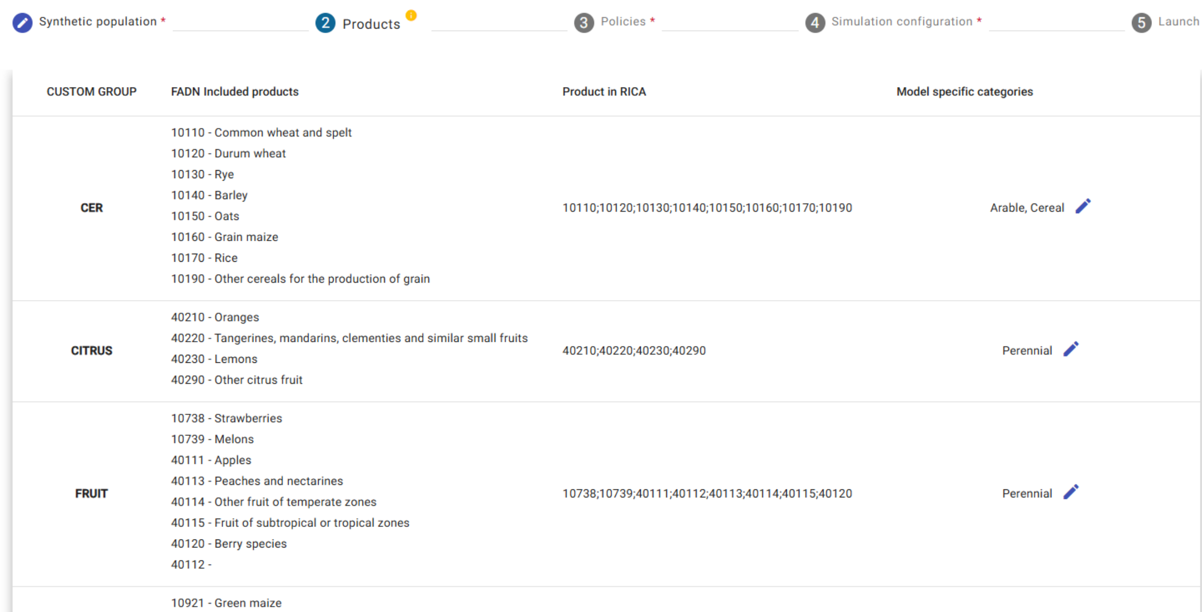
The synthetic population corresponding to the year 2014 obtained in the previous step wase used as a basis for performing the simulation of the Andalucian Use Case. The first step to simulate in the AGRICORE suite was to select it from the available synthetic populations, as shown in next Figure 19.



Name	Year	Description	Actions	Select
May2024Representativeness	2019	May2024Representativeness		
Andalucia UC - 2018 - v5.0	2018	Andalucia UC - 2018 - v5.0		
Andalucia UC - 2014 - v5.0	2014	Andalucia UC - 2014 - v5.0		

Figure 19: Selection of synthetic population for Andalucia 2014 SP

After the selection of the synthetic population, the grouping defined in the Synthetic population was verified across the uploaded data in the AGRICORE DWH. As shown in next Figure 20:



CUSTOM GROUP	FADN Included products	Product in RICA	Model specific categories
CER	10110 - Common wheat and spelt 10120 - Durum wheat 10130 - Rye 10140 - Barley 10150 - Oats 10160 - Grain maize 10170 - Rice 10190 - Other cereals for the production of grain	10110;10120;10130;10140;10150;10160;10170;10190	Arable, Cereal
CITRUS	40210 - Oranges 40220 - Tangerines, mandarins, clementines and similar small fruits 40230 - Lemons 40290 - Other citrus fruit	40210;40220;40230;40290	Perennial
FRUIT	10738 - Strawberries 10739 - Melons 40111 - Apples 40113 - Peaches and nectarines 40114 - Other fruit of temperate zones 40115 - Fruit of subtropical or tropical zones 40120 - Berry species 40112 -	10738;10739;40111;40112;40113;40114;40115;40120	Perennial
	10921 - Green maize		

Figure 20: Representation of the product grouping in the AGRICORE interface

Next, the simulation was configured in terms of the policies to be applied to the population. On a first instance, the subsidies that were already available in the data for year 2014 were reviewed, verifying that the data available in the original data sources and in the obtained synthetic population matched the one saved in the AGRICORE suite. The policies included are listed in next Figure 21. Next, the analysed policy measured (M11.1.2, M11.2.2) were included in the list of policies to apply.

Population Policies

Policy Identifier	Policy Description	Model Label	Economic Compensation	Start	End
1150	Basic payment scheme	Basic	13698.123	2015	2020
1400	Payment for agricultural practices beneficial for the climate and the environment	Greening	6608.3984	2015	2020
1600	Payment for young farmers		3981.5881	2015	2020
1700	Small farmers scheme		943.68964	2016	2020
23113	Protein crops		OTHER:56.90666;ORG_OTHER:56.90666	2015	2020
2313	Potatoes		VEG:831.85693;ORG_VEG:831.85693	2014	2020
2315	Vegetables		VEG:94.52105;OTHER:94.52105;FRUIT:94.52105;ORG_VEG:94.52105;ORG_OTHER:94.52105;ORG_FRUIT:94.52105	2015	2020
2317	Rice		CER:117.673874;ORG_CER:117.673874	2015	2020
2318	Grain legumes		OTHER:60.79841;ORG_OTHER:60.79841	2015	2020
2322	Crop specific payment for cotton		HOPS:938.46295;ORG_HOPS:938.46295	2015	2020
2323	National restructuring programme for the cotton sector		HOPS:966.6337;ORG_HOPS:966.6337	2015	2019
23312	Nuts		NUTS:78.910805;ORG_NUTS:78.910805	2015	2020
2333	Citrus plantations		CITRUS:35.41627	2017	2018
2334	Olive plantations		OLIV:10.812346;ORG_OLIV:10.812346	2014	2020
2335	Vineyards		OTHER:413.60464;ORG_OTHER:413.60464	2014	2017

Figure 21: Available policies in the SP for Andalucia 2014

Next, the simulation engine was configured to use the last version of the short term and long-term models available. The simulation horizon was set to 4 years that corresponded to the target period of 2014 to 2018. Moreover, the simulation was run including the long-term financial model (which can be disabled to use only the short-term one). The configuration of these parameters is shown in next Figure 22.

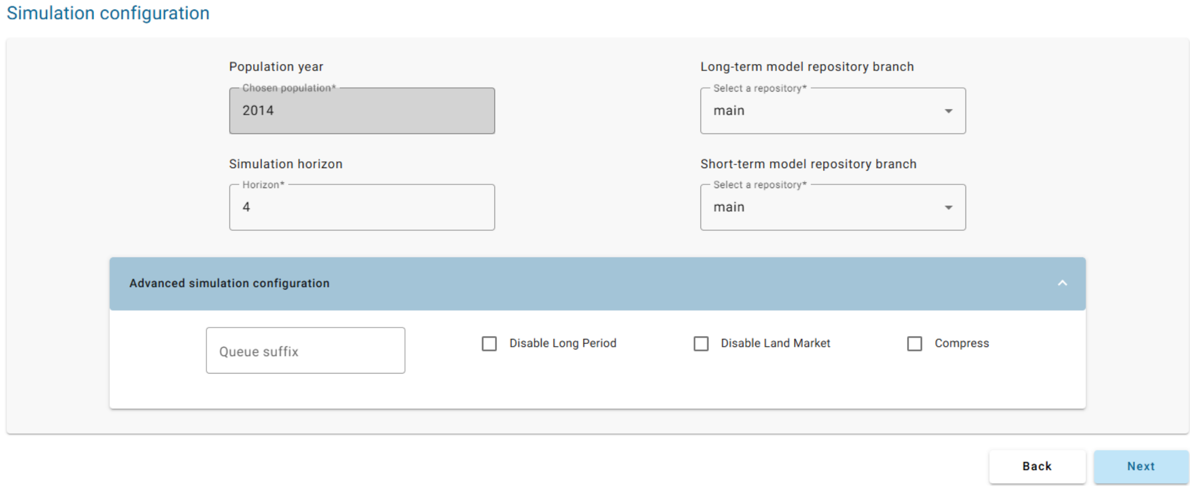


Figure 22: Configuration of the simulation for Andalucia 2014 SP

Finally, the simulation was launched using the AGRICORE interface (Figure 23):

Figure 23: Simulation launching process for Andalucia 2014 SP

The last simulation performed took ~21.5 h, which accounting for a total of ~115.000 simulated farms and 4 years of simulation gave a simulation rate of ~1.100 farms · year / hour. Considering the use of nonlinear models in the short-term model and the fact that the simulations were done with limited solver licenses (1 GAMS, 1 CPLEX) in a server with 16C / 32T and 128 GB of RAM, this figure is especially relevant and remark the work done in the speed up of the simulation through parallelisation techniques.

2.1.6 Results of the execution of the UC #1 – Andalucia

2.1.6.1 Ex-post impact assessment

The ex-post analysis of the performance and impact of M11.1.2 and M11.2.2 (organic olive) in Andalucia for the period 2014-2018 has been done based on the existing data published by the corresponding administrations (ESYRCE, RECAN, FADN), the results of the participatory research (presented in section 2.1.2 and D7.4 – Results on participatory research) and the findings acquired during its realisation, and the published publications [15, 16, 52]. The main conclusions are discussed next:

The majority (~88%) of the adopters of M11.1.2 and M11.2.2 regarding olive oil production have olive oil as the main destination of its production. Adopters of organic farming in olive farms generally (~87%) aim to maintain organic practices in the long term, with the potential main reasons that could led them to abandon it being economic and financial aspects. The farmers analysed seem to have a great lack of knowledge about the special land categories (Natura 2000, Ramsar areas, nitrate risk area), which is highly relevant as these aspects affect the access to M11.1.2 and M11.2.2 subsidies. A significant part of adopters (78.1%) had their farms exclusively dedicated to olive oil production.

The majority (65%) of adopters analysed (10% of the total) are veteran farmers (60 to 65 years old) with 35% being women. Only 15% of them have farming as its exclusive activity, which is generally common in the olive sector due to the low maintenance requirements of this cultivation. This also benefitted the potential of generational renovation between the families, with ~75% of the farmers believing it was possible in their cases.

Regarding adoption of the measure, M11.1.2 and M11.2.2 introduction has been quite positive towards the conversion to organic olive production:

- The number of farms that initiated the conversion in the period 2014-2017 was around 2000. According to the Spanish Agriculture census of 2009, in that moment 2.711 olive farms were producing using ecologic methods. In 2020, again according to the census, 5.633 farms were producing organic olive. Extrapolating data from RECAN and ESYRCE, we can estimate the intermediate values between these years, which shows a slower rate of growth of organic olive exploitations till 2014, which was increased with the introduction of M1.1.2 and M1.2.2. During this period, a rate of ~450 farms converting was observed. This shows a very positive impact of the measure in the increase of converting ratio from conventional to organic, one of the main goals of the measure.

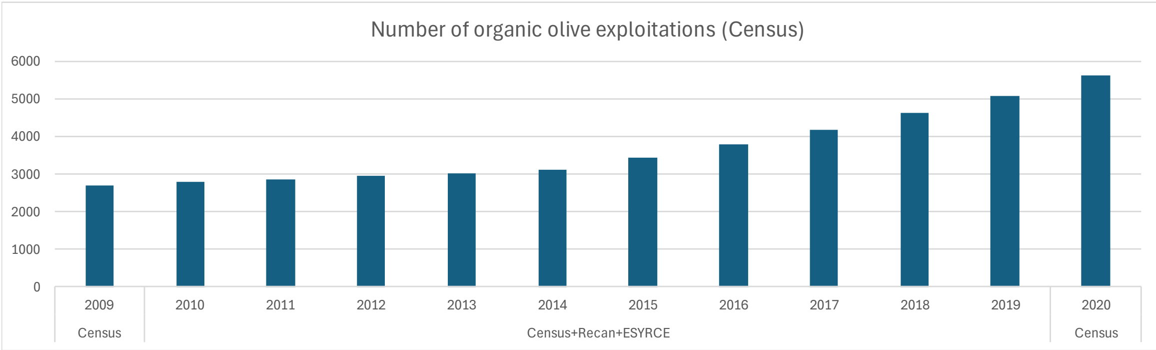


Figure 24: Comparison of the evolution of organic olive exploitations

- Regarding the number of total exploitations in the olive sector, the Spanish Agriculture census of 2009 shown 169.459 olive exploitations, which evolved to 196.166 farms in 2020. Extrapolating data from RECAN and ESYRCE, we can estimate the intermediate values between these years, shown in next Figure 28. The data shows a consistent growth of farms across the period. This indicates that the overall olive sector (not specifically to organic one) has kept the growing ratio but, given the low representative percentage of organic olive farms (5.26% in 2020), the impact of the specific measures M11.1.2 and M11.2.2 is limited.

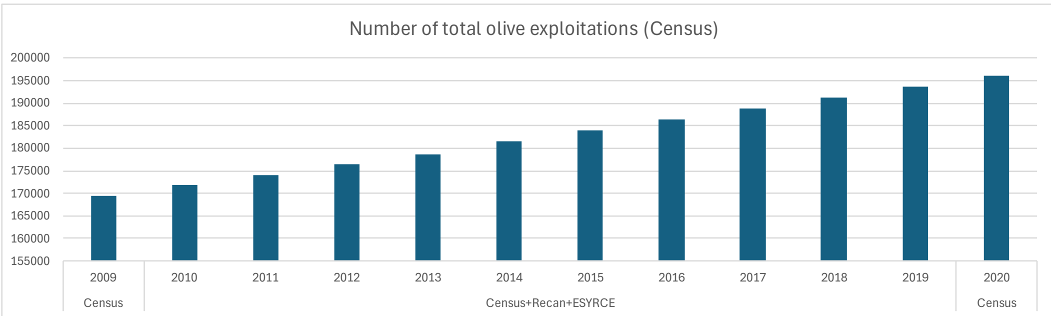


Figure 25: Comparison of the evolution of total olive exploitations

- Regarding the number of hectares dedicated to olive production, the census of 2009 indicated that 38.722 hectares were dedicated to organic olive from a total of 1.358.000. In the census of 2020, these figures evolved to 83.555 and 1.586.000 respectively. Extrapolating data from RECAN and ESYRCE, we can estimate the intermediate values between these years, shown in next Figure 29. The figures align with the two previous conclusions where the increase on total area used for olive production does not show a significant change in growth after the 2014 policies. In contraposition, the area used for organic olive production has significantly increased while M11.1.2 and M11.2.2 were active, which shows a very positive impact of the measure.

Figure 26: Comparison of the evolution of hectares dedicated to (organic) olive production

2.1.6.2 Ex-ante impact assessment

The ex-ante analysis of the performance and impact of M11.1.2 and M11.2.2 (organic olive) in Andalucia for the period 2014-2018 has been done based on the figures obtained during the build of the synthetic populations (based on RECAN data) for 2014 and 2018 and the results of the performed simulation. These figures are compared to the comparable findings presented in the previously presented ex-post analysis and the main conclusions are:

- As presented above, the number of farms that initiated the conversion in the period 2014-2017 was around 2000. According to the Spanish Agriculture census of 2009, in that moment 2.711 olive farms were producing using ecologic methods. In 2020, again according to the census, 5.633 farms were producing organic olive. In the Synthetic population of 2014, 3143 olive farms were identified as organic while in 2018, 5.102 were found. Analysing the number of olive organic farms in the simulation, the initial value of 3.143 (which matches the Synthetic population) evolved up to 5.327. This matches the trends identified in the data as shown in Figure 27, with an average growth of 546 farms converted per year in the simulation and ~500 following the census data:

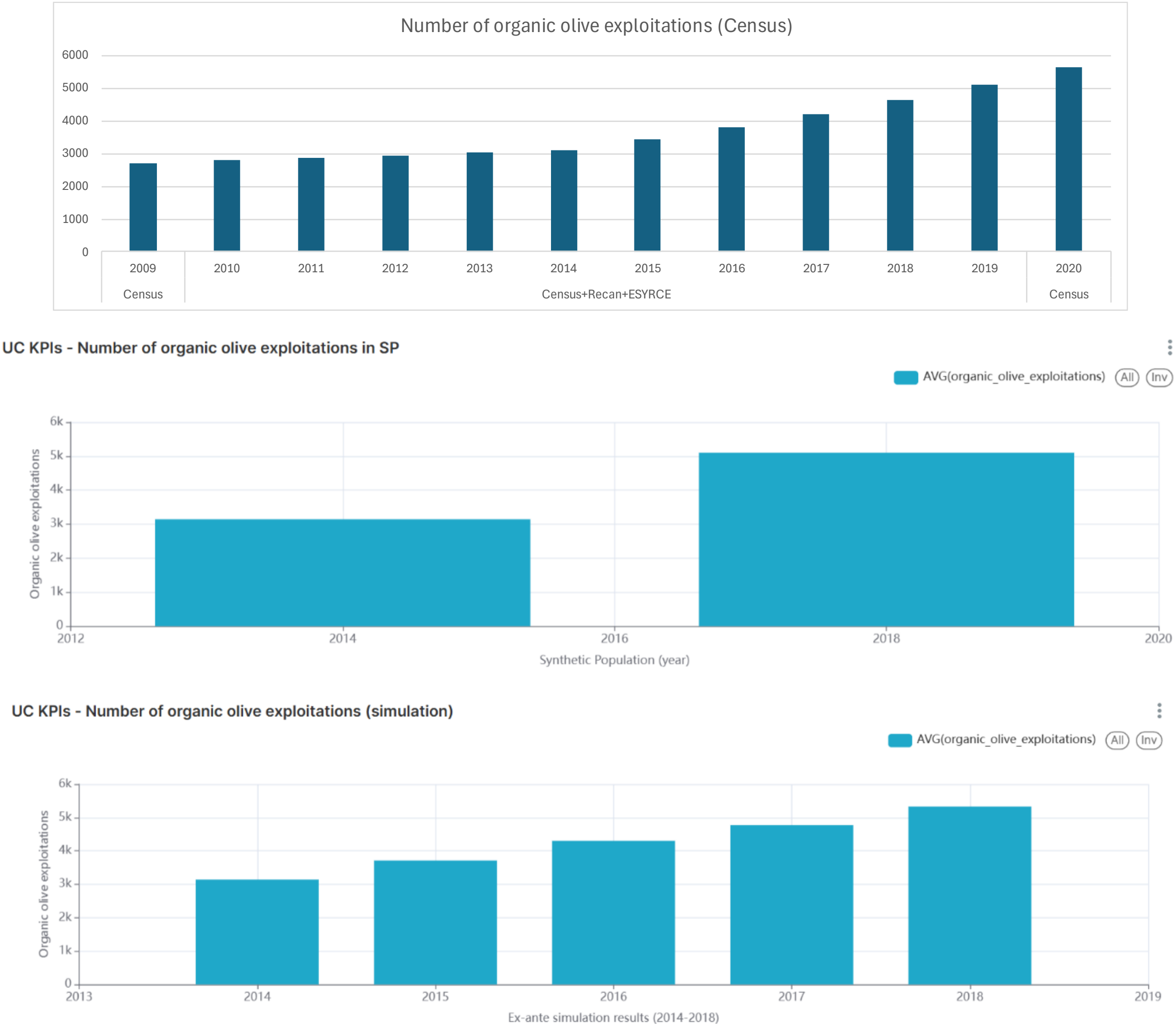


Figure 27: Comparison of the evolution of organic olive exploitations

- Regarding the number of total exploitations in the olive sector, the Spanish Agriculture census of 2009 shown 169.459 olive exploitations, which evolved to 196.166 farms in 2020. The Synthetic Population of 2014 show 45.596 farms and the one for 2018 show 63.012 ones. These figures differ significantly from the ones in the census, as census information represents all farms and the SP only represents the farms represented by the ones for which RECAN/FADN recovers data. The simulation for the period 2014-2018 (as shown in next Figure 28) shows a growth from the original 45.596 farms to 51.126, which is significantly lower than the observed figures in the Synthetic Population of 2018.

Figure 28: Comparison of the evolution of total olive exploitations

- Regarding the number of hectares dedicated to olive production, the census of 2009 indicated that 38.722 hectares were dedicated to organic olive from a total of 1.358.000. In the census of 2020, these figures evolved to 83.555 and 1.586.000 respectively. In the synthetic populations 67.221 hectares out of 1.147.819 were dedicated to organic olive, while in 2018 these figures growth to 102.447 out of 1.258.007. The performed simulation (Figure 29) shows a significant growth in the hectares dedicated to olive production in organic ways. However, the simulations shown a total growth of the hectares dedicated to olive production (organic and non-organic) significantly lower than the observed one in the Synthetic populations and in the extrapolated census data.

Figure 29: Comparison of the evolution of hectares dedicated to (organic) olive production

Conclusion

The ex-post impact assessment done during the project in parallel with the participatory research activities shown a positive impact of M11.1.2 and M11.2.2 towards the conversion to organic olive production. The performed simulations also indicate a positive impact of the introduction of these measures in the simulation, with an increase on the number of olive farms aligned with the observed values. However, the rest of the metrics related to olive production deviate significantly from the observed data. The simulation shown a very limited growth of the total area dedicated to olive production, while the census data and the synthetic population shown one significantly higher.

A potential explanation for this is due to an incorrect valuation of the sector profitability in the simulation. In this scenario, olive farms still opt for the conversion to organic production, due to the positive impact of the measure which renders it more profitable that staying in conventional production. However, the overall simulated profitability of the farm compared to other crops may not evolve as the census indicate, which renders the selection of olive production against other crops inefficient, explaining the low growth shown in the simulation. Indeed, when exploring the simulation results, the data seemed to indicate this was happening. Moreover, the reason may extend from issues on the calculation of the profitability of the olive sector, as other crops shown also abnormal profitability modifications (and therefore cause altered rates of crop replacement).

Overall, the authors conclude that further improvements need to be made to the AGRICORE platform and its models, in order to correct and improve the simulations and the reflection of the observed behaviour of the farmers, especially for multiple year analysis. The identified required upgrades are:

- Connection of the AGRICORE suite to a proper and fully fledged CGE market model (e.g. MAGNET) which can properly account for demand trends, prices evolution and imports and exports, as all these factors heavily influence the olive sector and in general, all agricultural activities.
- Further refine the tunning of weights and parameters of the AGRICORE models, to fix incongruent results identified in the simulation that may not be linked to market evolution aspects.
- Improve the management of different aspects in the model, mainly the management processed products and inter-year inventories.

2.2 UC#2 - Analysis of the impact achieved by the "M10.1 – Agri-environment-climate commitments" action defined in Polish RDP

2.2.1 Analysis of the use case context

The Polish use case focuses on the analysis of the impacts of the national-level agricultural measure, M10.1 - Agri-Environmental-Climate Commitments [17]. This measure, as part of the Rural Development Plan 2014-2020, aims to improve environmental and climate conditions, guaranteeing farmers a competitive advantage for their enterprises, towards the goals related to biodiversity and ecosystem services set in the RDP [18]. The importance of this use case lies in the high percentage of the Polish rural population and the high number of farms, most of which are family farms. This also entails a challenge related to the size of the target population.

2.2.1.1 Agricultural policy analysis

The AGRICORE Polish Use Case analyses the M10.1 measure (Agri-Environmental-Climate Commitments) influence on Poland, especially focusing on the enhancement of the ecosystem services and on the environmental and climate impacts. This sub-measure belongs to Measure 10 of the RDP 2014-2020 Agri-Environmental-Climate-Action designed by the Ministry of Agriculture and Rural Development and the Ministry of Environment. The action is part of the EU and national strategic legal framework. It was planned as one of the components implementing strategic EU and national environmental goals, taking into account the significant economic and social importance of agriculture. This measure obtained the 4th largest amount of money among all of the 17 different actions financed from the RDP budget, benefiting around a hundred thousand farmers, which corresponds to 7% of all farms in Poland [19][20][21][22].

Among the 23 packages considered in M10, M10.1 applies to 5 packages from which farmers can select. Each package has particular requirements and payment rates. However, there are common requirements that any farmer must comply to be a beneficiary [23]:

- Be an individual farmer/land manager or a group of them, understood as a natural or legal person,
- Have an agri-environmental activity plan,
- Keep a register of agri-environmental activities,
- Not transform existing permanent grassland on the farm,
- Keep on the farm elements agricultural landscape not used in agriculture, which are the mainstay of nature.

The packages included in M10.1, together with their specific requirements and payment rates, are gathered in Table 3.

Table 3 Measure 10.1: Agri-environment-climate commitments.

Package	Requirements	Payment distribution	Subsidy
1. Sustainable agriculture	• The use of a minimum of 4 crops in the main crop per year on the farm. • Double chemical soil analysis performed in the first (or preceding) and fifth (or preceding) year of the package implementation. • Obligation to develop and follow a fertilizer plan annually based on a	• 100% of the basic rate - for an area from 0.10 ha to 50 ha. • 75% of the basic rate - for an area above 50 ha up to 100 ha.	86 €/ha

	nitrogen balance and chemical soil analysis. • Obtain a positive balance of organic matter on an agricultural plot by applying a minimum of 3 crop groups in rotation within the 5-year commitment, using catch crops and ploughing in straw or manure. • Mowing or grazing on permanent grassland. • Use of sewage sludge is prohibited.	• 60% of the basic rate - for an area of more than 100 ha.	
2. Soil and water protection	• Sowing intercrop crops by the 15th of September. • Prohibition of resuming agrotechnical operations before the 1st of March. • Using as catch crops only a mixture composed of at least 3 plant species, prohibiting that the dominant plant species exceeds 70% and using a mixture consisting exclusively of different types of cereals. • Prohibition of fertilization • Prohibition of using pesticides and herbicides in catch crops • Prohibition of using sewage sludge • Ploughing of the biomass of the catch crop, excluding soil cultivation in a no-plough system • Prohibition of cultivating a mixture of the same plants in the main crop.	• 100% of the basic rate - for an area from 0.10 ha to 50 ha. • 75% of the basic rate - for an area above 50 ha up to 100 ha. • 60% of the basic rate - for an area of more than 100 ha.	97-140 €/ha
3. Preservation of orchards with traditional varieties of fruit trees	• Obligation to maintain an orchard of traditional varieties of fruit trees, including at least 12 trees. • Minimum height of the tree trunk of 1.20 m. • Prohibition of using herbicides. • Obligation to perform basic nursing treatments in the orchard. • Mowing and removing grass or grazing.	The payment is granted in full	423 €/ha
4. Valuable habitats and endangered species of birds in Natura 2000 areas	• Obligation to have documentation regarding nature prepared by an expert of nature (exception: extensive use in SPAs). • Prohibition of ploughing, rolling, application of sewage sludge, application of undersown and mechanical destruction of soil structure. • Prohibition of drifting in the period from 1st of April to 1st of September	The payment is granted in full, but the subsidy amount depends on some aspects.	129-280 €/ha

	in lowland areas (up to 300 m above sea level) and from 15th of April to 1st of September in upland and mountain areas (over 300 m above sea level). • Prohibition of applying plant protection products except for selective and local destruction of nuisance invasive species. • Prohibition of creating new, expanding and restoring the existing drainage systems. • Prohibition of storing biomass among clusters of trees and shrubs, in ditches, ravines and other depressions of the area.		
5. Valuable habitats outside Natura 2000 areas	• Obligation to have documentation regarding nature prepared by an expert in nature. • Prohibition of ploughing, rolling, application of sewage sludge, application of undersown and mechanical destruction of soil structure. • Prohibition of drifting in the period from 1st of April to 1st of September in lowland areas (up to 300 m above sea level) and from 15th of April to 1st of September in upland and mountain areas (over 300 m above sea level). • Prohibition of applying plant protection products except for selective and local destruction of nuisance invasive species. • Prohibition of creating new, expanding and restoring the existing drainage systems. • Prohibition of storing biomass among clusters of trees and shrubs, in ditches, ravines and other depressions of the area.	The amount depends on the type of habitat and it is distributed as follows: • 100% of the basic rate - for an area from 0.10 ha to 50 ha. • 75% of the basic rate - for an area above 50 ha up to 100 ha. • 60% of the basic rate - for an area of more than 100 ha.	129-280 €/ha

The assessment of the performance of agro-climate-agricultural policies in Poland is carried out by the Agency for Restructuring and Modernisation of Agriculture (ARMA). This agency prepares an annual report to evaluate the effectiveness of those policies and detect irregularities in the fulfilment of commitments. On the basis of this report, responsible Ministries can afford changes in the designed policies in order to achieve the goals. As part of M10.1, the most fully or partially unfulfilled requirements are the incompletion/non-compliant/inconsistency of the agri-environmental activity plan, the unfulfillment of dates for sowing catch crops and the minimum number of plants, the conversion of permanent grasslands and pastures and mowing wrongful agricultural plots. However, the criteria used in the official impact assessment plan could bot been obtained. Therefore, a rational set of indicators was selected to assess the impact on soil, water, air, biodiversity and farming levels of the agro-climate-environmental policy[24]. The selected indicators are:

- Fallow land area
- Soil pH - the share of very acidic and acidic soils
- Water intake
- Quality of surface water
- Aggregate GHG emissions
- Air temperature
- Farmland Bird Index (FBI)
- Other agricultural production indicators

2.2.1.2 Situation of the agricultural sector in the framework of the use case

Poland has a total area of 312 696 km^2 divided into six NUTS1 level regions, of which more than half of this area (51.2%) is rural. Consequently, an important part of the Polish population lives in rural areas, around 39%. All Poland administrative regions are considered as less developed under article 2014/99/EU definition. Moreover, the country is one of the member states eligible for funding from the Cohesion Fund.

The importance of the Polish rural area is shown in terms of area because 30% of the Polish territory is covered by forests and 46% is agricultural land, of which 70.4% is sown area. Indeed, Poland is one of the EU Member States with the largest number of farms, which amounts to 1428781 and an estimated 2,383 million persons working on farms[25]. The agricultural land area in good agricultural conditions is 14,55 million ha, and the average area of agricultural land in an agricultural holding is 10.42 ha, one of the lowest farm sizes in the EU. Most of these farms are family farms, which explains, together with Polish agriculture's socio-economic structure, the high share of the population working in agriculture. In 2019, the population age distribution in the rural area was 16.4% of people under 15, 68.6% of people between 15 and 64, and 15% of people over 64. Regarding the agricultural land, only half a million hectares are under organic farming and around 62% is under agricultural constraints (ANC). In addition, around 20% of arable land faces several environmental challenges, mainly the water and/or wind erosion (8.2%) and nitrates pollution (7.4% of Nitrate Vulnerable Zones), followed by the low level of humus.

By crop, the agricultural land is distributed as follows (based on data from 2019): 7.9 million hectares for cereals (wheat - 2.5 million ha, triticale - 1.3 million ha, barley - 1.0 million ha, maize for grain - 0.6 million ha, the remaining ones - 2,5 million ha (rye, oats, mixed cereals), 1.1 million hectares of industrial crops (rape and turnip rape – 1.0 million ha), 1.1 million hectares of feed crops (maize for feed - 0,6 million ha), 0.2 million hectares for vegetables [25]. As regards livestock in Poland, in 2019, around 1 million of livestock units (LSU) were registered, which were distributed as follows: 46,4% for cattle, 28% for pigs and 23,6% for poultry [25].

2.2.1.3 Collection and characterisation of data sources and information of interest

As in the Andalusian use case, the data requirements of the Polish use case were first drafted based on the initial approach of the project development and parameters needed to assess M10.1 performance. Thus, 11 datasets were found for the Polish use case (see D1.5 - Characterisation of national and regional data sources), which were characterised for their inclusion in the ARDIT tool. The most relevant datasets in the case of Poland are listed below.

- **Polish branch of the FADN**. In Poland, the Agricultural Accountancy Department is the entity in charge of collecting the FADN accounting data. The Polish FADN surveys 12 thousand farms on average classified according to the economic size and type of farming, representing more than seven hundred thousand farms. The anonymised microdata of the Polish FADN were requested several times to Dr Eng. Joanna Pawłowska-Tyszko, the Plenipotentiary Director for the FADN and Head of the Department of Accounting and Agricultural Farms, at the end of 2020, who asked for a special letter requiring the necessary use of those data for research purposes in the AGRICORE project. This letter was provided and the Polish FADN Deputy Head of the Department of Accounting and Agricultural Farms Manager, Dr Eng. Dariusz Osuch, was also contacted. However, at the end of 2022, the Agricultural Accountancy Department confirmed the impossibility of providing the Polish FADN microdata due to confidentiality issues. For this reason, the data were requested from the European FADN in 2023, whose procedure was very bureaucratic and time-consuming due to the fulfilment of several requirements, particularly related to cybersecurity, and the selection of the FADN variables one-by-one.

- **Agency for Restructuring and Modernisation of Agriculture (ARMA)**. ARMA is the accredited paying agency under the supervision of the Ministry of Agriculture and Rural Development and the Ministry of Finance. It is in charge of the implementation of instruments co-financed from the EU budget as well as providing aid from national funds. This entity collects several indicators related to biodiversity, pollution, environment and soil status. These data are available upon request, and UTP initiated the process for acquiring the data, which was delayed due to the Covid-19 situation at that moment.
- **National Chemical-Agricultural Station**. This organisation has several regional branches that cover the whole Polish territory and offer a range of agrochemical services for interested farms. Concretely, the database on mineral nitrogen content was of interest for the use case. This database covers 4925 farms and gathers information about soil characteristics (pH, C_{org}, granulometric composition), nutrients (N, P, K, Mg, S), fertilisation (type, rate, date of fertilisation), plants (forecrop, crop, yield) and farms (LSU, location). The entity was contacted two times to acquire the database, obtaining negative answers and redirecting to the Institute of Soil Science and Plant Cultivation (IUNG), which manages the data to assess agricultural policies.
- **Institute of Soil Science and Plant Cultivation (IUNG)**. IUNG is the National Research Institute in charge of creating cartographic and soil-agricultural maps on a scale of 1:25000 and 1:100000, with additional text and numerical data describing agricultural suitability. Following the recommendation of the National Chemical-Agricultural Station, IUNG was contacted to request soil databases for Poland. After several calls during 2021, it was concluded that obtaining data with the required spatial resolution was very expensive and accessing public data, such as SoilGrid, would be the best option.

2.2.1.4 Detection of information gaps

Based on the aforementioned databases and other public ones, such as Statistics Poland [26], some information gaps were detected. Some of the preliminary detected gaps were filled during the participatory research design process itself, through contact with stakeholders, bibliographic review or access to non-public databases through contacts with public administrations. Others were expected to be obtained during its execution because they were related to farmers' opinions and concerns. In addition to risk aversion and innovativeness described in the Andalusian use case, the following information gaps can be highlighted in the Polish use case:

- Previous experiences of farmers resulting from participation in M10 action
- Size of parcels
- The minimum size of plots
- Revenues obtained from agriculture guaranteeing farmer’s family maintenance

- Location of farms in relation to Natura 2000 areas
- Ecosystem components existing on the farm being friendly for M10 action participation
- Profitability of participation in M10 action
- Social/cultural impact being barriers/chances to access M10 action

2.2.2 Participatory research

2.2.2.1 Preparation of the participatory research

In the Polish use case, the participatory research was addressed to leading farmers from the whole territory of Poland due to being a reference for other farmers. Leading farms and/or those that carried out cooperation with advisory centres are characterised by outstanding economic results, high competitiveness, use of high technology, openness and development of sustainable practises. Within this target population, farms that have participated or not in the M10 measure or plan to participate in similar actions in future are included.

The first approach of IAPAS and UTP was to design an electronic survey, which was supported in the future due to the evolution of the Covid-19 situation in Poland. The Central Advisory Board of Brwinów was consulted on this approach, which, based on its experience, suggested distributing the survey via email to farmers from all voivodeships of Poland to ensure an unbiased sampling. Furthermore, the representativeness of the sample population was determined by comparing the features of the farms with existing statistical data, such as gender, age, geographical distribution and participation in M10 action. This determined that the minimal return of the survey campaign should be 300 to guarantee the representativeness.

The distribution of the survey was possible thanks to the email lists provided by several organisations, such as:

- **Association of Lease and Agricultural owners** (1000 farms in Poland in total and 90 in Kujawy & Pomorze Region).
- **Agricultural Advisory Center**. The cooperation with the Agricultural Advisory Center in Brwinów enabled sending the questionnaire to around 3000 farms.
- **Association of winners of the Farmer the Year competition.** Approximately between 200 and 350 emails were provided in total.
- **Industry associations of Pig Breeders and Producers**. Between 60 and 85 respondents were available.

Prior to launching the survey campign, a pilot survey was conducted among several of the biggest and leading farmers with which UTP and IAPAS previously cooperated within various other projects. This process enabled UTP and IAPAS to draw some preliminary conclusions that were used to review and improve the questionnaire. Among these medications, it must be highlighted the need to make some questions more visual, easier and quicker to answer and remove or reduce some questions that were not fully relevant to the use case. The main conclusions obtained from the pilot survey are listed below:

- Agricultural producers indicated that some action obligations are not sufficiently adjusted to current climatic and economic conditions, such as the fertilisation and sowing periods.
- Many farmers indicated that base rates of payments should be higher to enable the competitiveness of the farmers taking part in M10 action in relation to the other farmers or non-agrarian undertakings, e.g., the sale of plots to basic enterprises (intensive) and farms (social-extensive).

- Some respondents expressed doubts about the strict following of the fertilisation plan prepared based on only one chemical analysis of the soil performed.

2.2.2.2 Execution of the participatory research

Thanks to the emails provided by the associations of leading farmers, more than four thousand emails were acquired. Thus, the survey campaign in the Polish use case was organised with waves of electronic questionnaire mailings. These mailing waves were separated in time in order to fulfil the assumed minimal return level. Therefore, the first invitations to answer the survey were sent in the middle of October 2021, obtaining 63 answers in the recount on 9th November. After that, the questionnaire was resent two times more, at the beginning of December 2021 and February 2022. In these waves, the answered questionnaires increased to 115, recounted on 14th December 2021, and then increased to 260, recounted on 11th March 2022. To achieve the target number of responses, alternative measures were designed. Thus, Polish partners in the LIFT H2020 project (Krupin and Jendrzejewski, 2018) were contacted to obtain the e-mail addresses of the farmers who were surveyed in this project. In addition, it was decided to survey farmers directly during the AGROTECH agricultural fair in Kielce (18-20 March 2022). Several dozen responses were then gathered. Finally, 319 filled-in questionnaires were obtained, which means that the assumed minimum of returns was reached.

2.2.2.3 Analysis of the participatory research results

The participatory research activities among Polish farmers were intended to deliver a detailed view of the demographic structure and operational landscape of the agricultural sector. The analysis of the answers to survey questions allowed us to gain a deeper understanding of the challenges and opportunities farmers face in Poland. The analysis revealed some differences in farming practices and the adoption of sustainable methods, and also in willingness to take risks, distinguishing between those participating in agri-environmental measures (M10) and those who are not. The study covered all 16 regions in Poland and generated a representative sample, with respondent demographic data closely mirroring national data, which is supported by comparisons of the respondent's gender, age, and farm distribution to those coming from the Statistics Poland database. The largest proportion of survey responses came from the Lubelskie (18%) and Wielkopolskie (11%) regions, while the lowest were from Dolnośląskie (1%) and Opolskie (2%). It corresponds with the regional distribution of various agri-environmental and climatic measures under the Rural Development Program 2014-2020 presented in the figure below, which highlights areas with significant engagement in M10 activities, notably in Pomorskie, Kujawsko-Pomorskie, Wielkopolskie, and Lubelskie voivodships. The map also shows regions with dense implementations of sustainable agriculture and environmental protection activities, emphasizing Pomorskie, Zachodnio-Pomorskie, and Lubelskie, along with habitat protection in Podkarpackie, Małopolskie, and Dolnośląskie voivodships.

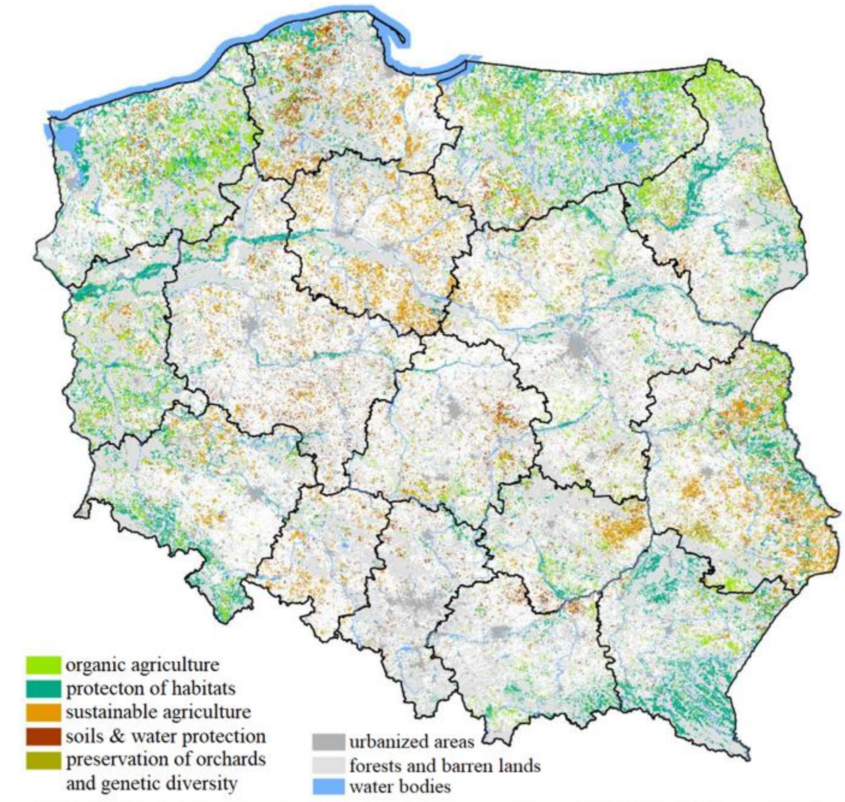


Figure 30 Regional distribution of M10 activities

A significant majority of respondents (83%) were farm owners, with 89% of these representing individual farms. Farm production was predominantly focused on cereals (57.4%), with smaller proportions involved in other sectors such as industrial plants (3.8%), vegetables (4.1%), fruits (6.9%), meat (7.5%), milk (5.6%), and others (14.7%). Most surveyed farms were family-owned, with 62% employing no workers, either permanently or seasonally. When asked about their farm's ability to achieve stable yields, 52.4% of respondents described conditions as moderate, 29.8% as difficult, 14.1% as good, and only 3.8% as poor or worse. Regarding income, 36% of respondents indicated that more than half of their budget came from farming, closely aligning with the 34% reported in the National Agricultural Census 2020 (GUS, 2022). The survey also revealed that 22.6% of respondents had never expanded their farm area, 24.1% did so more than 10 years ago, 27.0% between 5 to 10 years ago, and 26.3% less than 2 years ago.

An important aspect of the designed questionnaire was to obtain farmers' opinions on the effects and inconveniences they experienced during their participation in the M10 activities. The survey results indicate a generally positive reception, with 96% of respondents viewing the M10 program favourably. Among the 3.4% of respondents who gave negative feedback, it was not possible to pinpoint specific regions with higher dissatisfaction, as the negative responses were evenly distributed across different voivodeships. However, this generally positive assessment has been alleviated by observations regarding changes in workload and income during the program's implementation. Over half of the respondents (53.9%) reported an increase in workload, while 40.4% did not notice any change compared to the period before the program started. This response may stem from two main factors: variations in the number and intensity of obligations associated with different M10 packages, and disparities in the availability of agricultural machinery, tools, and resources among Polish farmers, which may have influenced the perception of the burdens of the program and the possibility of being able to fulfil the individual obligations. For example, Package 5, which focused on protecting valuable habitats outside the Natura 2000 areas, mostly involved passive obligations, such as prohibiting labour-intensive activities like ploughing, rolling, drainage system maintenance, sewage sludge application, mechanical soil disturbance, and the use of plant protection products. In contrast, some packages, like Package 1, required more laborious activities, such as maintaining a minimum of four crops per year, conducting double chemical soil analyses, developing and following a fertilizer plan, and ensuring a positive organic matter balance. On the other hand, 73% of respondents reported an improvement in income, highlighting the program's potential to align agricultural profitability with environmental goals, such as restoring and protecting ecosystems reliant on agriculture. Conversely, only 5.6% observed a decrease in income, while 21.3% saw no change. A substantial portion of respondents (64%) noted increased production costs associated with participating in M10, with only 4.5% experiencing a cost decrease and 31.5% not noticing any change. The main reasons for increased costs included changes in technological practices (24.1%), the necessity of using less productive plant species (11.4%), alterations in fertilization practices (9.5%), changes in plant protection measures (8.9%), and modifications in plant varieties (5.1%). All aforementioned statistics are gathered in the following figure.

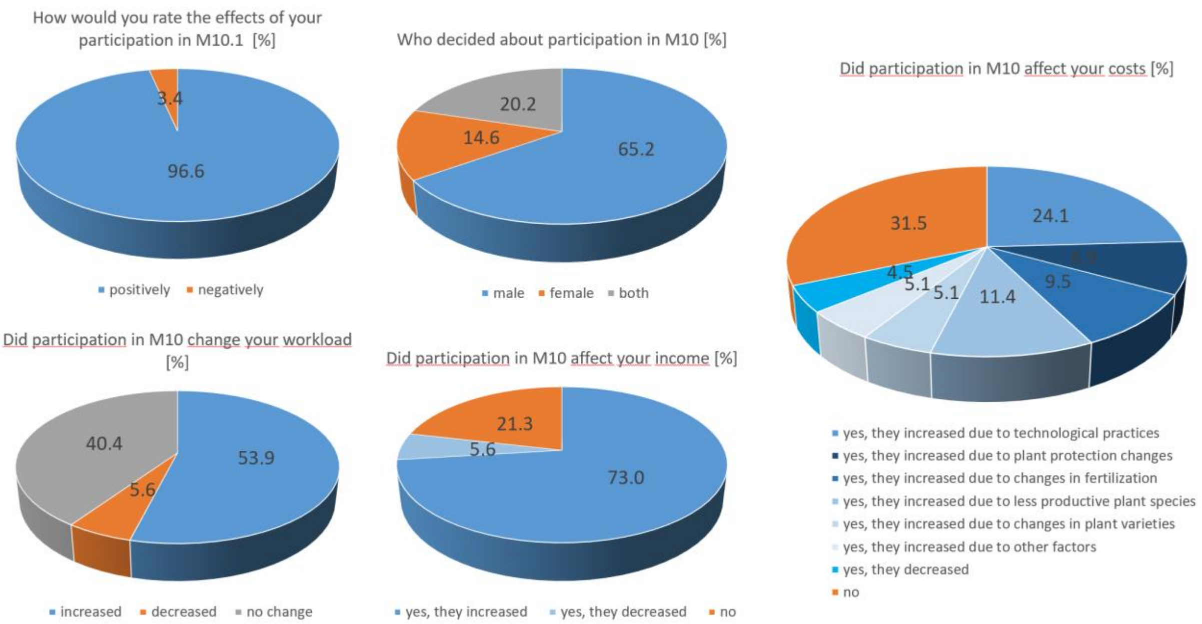


Figure 31 Survey results on farmers' opinions on the effects and inconveniences they experienced during their participation in the M10 activities

The generally positive evaluation of the M10 program's effects by farmers did not align with their views on its impact on the prestige, image, and market value of their products (see figure below). Most farmers indicated that participating in M10 did not enhance their prestige or increase the value of their products. When asked about specific concerns during the implementation of M10, only 39.8% of respondents reported having no uncertainties or worries. This suggests that previous experiences with EU and national institutions involved in subsidy programs were not always positive. Notably, there was a significant difference in trust levels: 21.6% of respondents expressed distrust towards national institutions, compared to only 4.5% who distrusted EU institutions. This lack of confidence, often attributed to complex procedures and unclear requirements, was a major factor behind the farmers' doubts. Additionally, a significant portion of respondents (31.8%) were worried about the possibility of having to repay funds in the event of a poor audit outcome.

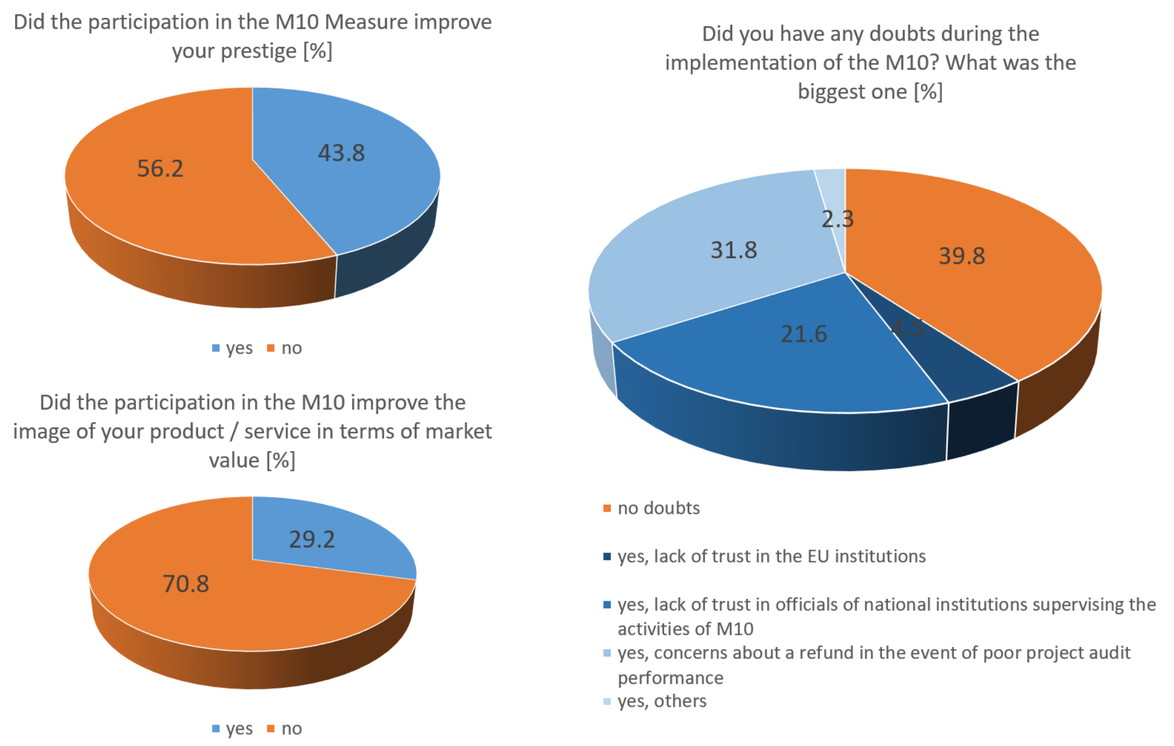


Figure 32 Survey results on farmers' views on its impact on the prestige, image, and market value of their products, and their specific concerns during the implementation of M10

A separate section of the survey targeted farmers who did not participate in the M10 program. The goal was to identify the main reasons for their non-participation. The responses, shown in the figure below, indicate three primary factors influencing their decision: a lack of information or incorrect/incomplete information about the program (24.3% combined), overly bureaucratic data registration procedures (23.3%), and anticipated lack of profitability due to high natural and business risks associated with making significant changes on the farm to meet M10 obligations (20.8%). Other factors mentioned by respondents included negative reports from neighbouring farmers about their experiences with subsidies (8.8%), inadequate support from agricultural advisors, ARMA officers, and other institutions in preparing applications (4.1%), and a general lack of trust and belief in potential positive outcomes, influenced by the negative attitudes of other farmers (8.2%). These findings suggest that significant improvements are needed to encourage broader participation in similar Rural Development Program (RDP) agri-environmental activities in the future. Improvements should focus on reducing bureaucratic hurdles, improving information dissemination, simplifying application procedures, and raising awareness among farmers about the environmental goals and benefits of these programs.

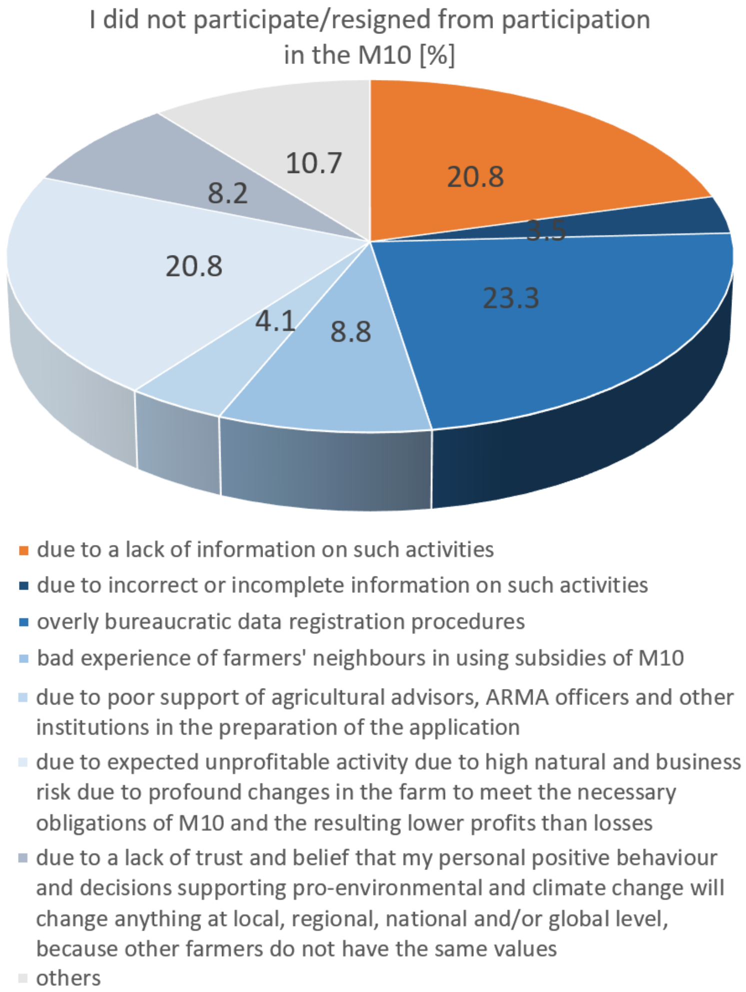


Figure 33 Survey results on farmers' main obstacles and reasons for their non-participation in the M10

The assessment of risk aversion levels among Polish farmers, comparing those participating in the M10 program with non-participants, was another aspect raised in the questionnaire. The data indicates that both groups generally exhibit high-risk aversion. However, there are subtle differences in certain areas. For M10 beneficiaries, minimizing production costs is slightly less of a priority compared to non-beneficiaries. This may be due to the financial support and incentives provided by the M10 program, which could reduce cost pressures on these farmers. Conversely, non-M10 participants place a somewhat greater emphasis on minimizing production costs and preventing/reducing crop diseases and pests, likely reflecting a more immediate concern with cost efficiency and risk mitigation without the additional support from the M10 program. The chart also shows that Polish farmers, regardless of M10 participation, tend to prioritize maintaining financial liquidity, preventing and reducing crop diseases and pests, purchasing farm business insurance (especially for natural risks), managing debt to ensure solvency, producing at the lowest possible costs, and buying productive inputs like fertilizers and pesticides when prices are low for future use. This suggests a generally conservative financial and risk management approach, potentially driven by perceived risks associated with environmental and sustainability standards. Overall, both groups of farmers demonstrate a high degree of caution in their farming practices. However, the M10 program appears to encourage participants to adopt a broader range of risk management strategies, possibly due to its specific requirements and the additional support it provides.

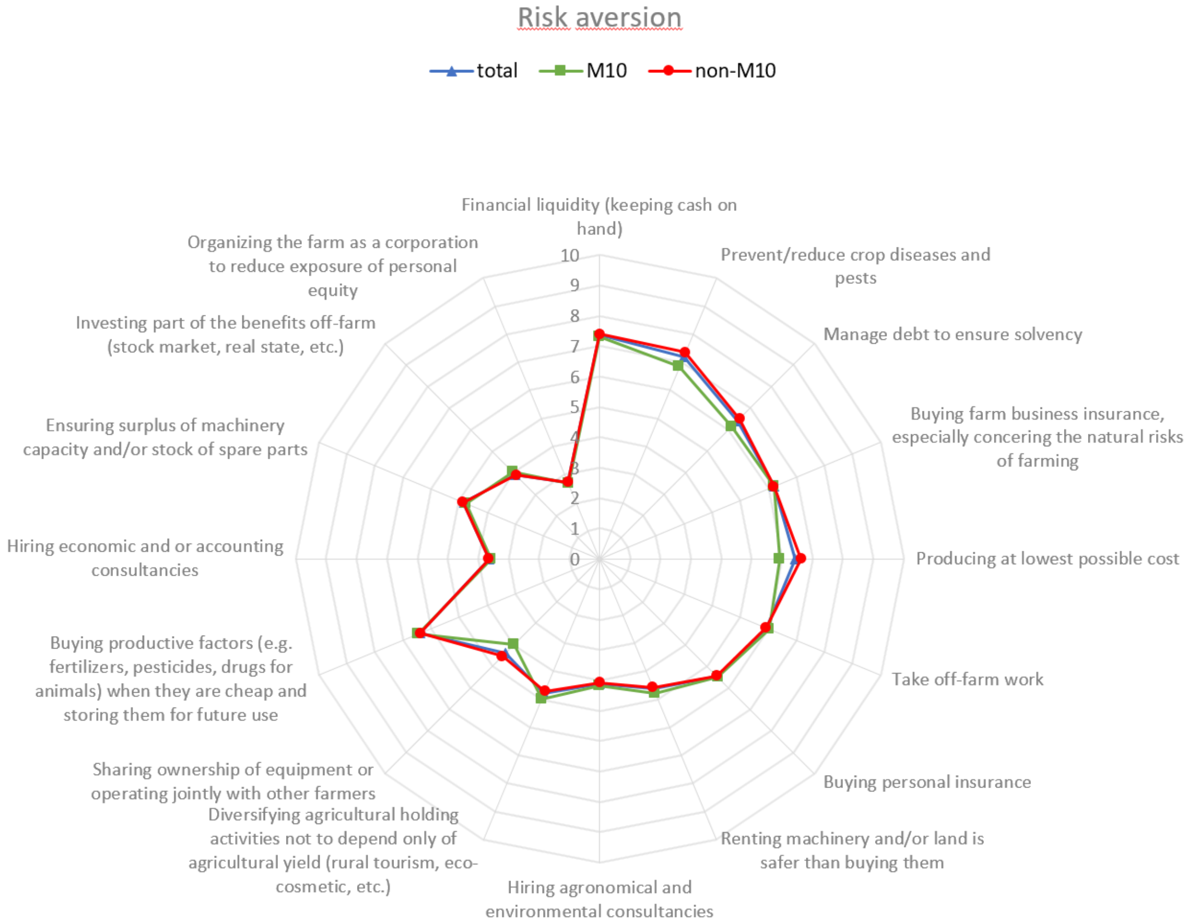


Figure 34 Assessment of the risk aversion among the Polish farmers

Lottery-choice scale also indicates no significant differences in risk aversion among Polish farmers, regardless of whether they participated in the M10 program. However, there is a trend where M10 beneficiaries appear slightly more willing to take risks compared to non-beneficiaries. This may suggest that participation in the M10 program can be perceived as a risk and only those farmers who are more willing to take risks in life decided to participate in it. This is evidenced by a higher percentage of M10 participants choosing riskier investment options, particularly around the midpoint (as indicated in charts III and IV) and higher-end investment choices (charts I and II) . This willingness to take risks may also be associated with the financial buffer provided by the program, which could alleviate some of the perceived risks of engaging in new or uncertain agricultural practices. Thus, while the general level of risk aversion is similar across both groups, it can be concluded that M10 participants display a marginally higher propensity to take financial risks.

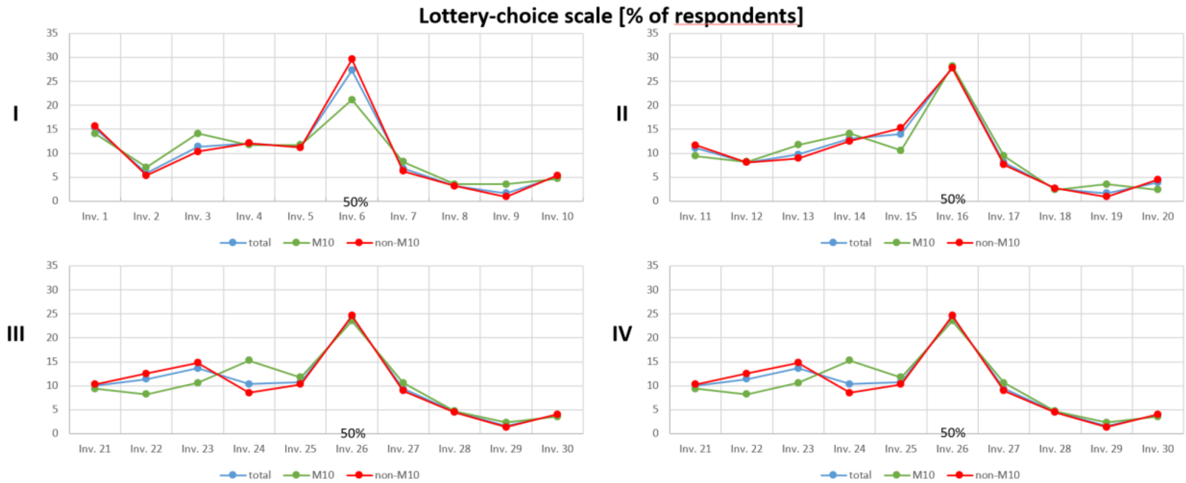


Figure 35 Polish farmers lottery-choice scale results

The survey included questions to evaluate their attitudes toward innovative farming solutions and their investment amounts in these activities over the past decade. The results presented in the figure below show the average amounts invested in various activities in the period of the last 10 years, and the percentage of the farmers who invested in these actions. The findings reveal significant differences in investment preferences between the M10 program participants and those, who decided not to participate in it. M10 participants generally invested more in sustainable agriculture practices. They made significant investments in irrigation practices on water-scarce farms and prioritized treatments preventing air and soil pollution by external factors. Additionally, they focused on measures to avoid soil degradation due to improper management. These farmers also showed a higher propensity to invest in eco-service-related activities, such as engaging in alternative income sources like eco-tourism and cosmetics. Furthermore, investments in precision agricultural equipment, including drones, were notably higher among M10 participants, indicating their commitment to leveraging advanced technology for sustainable farming. On the other hand, non-participants in the M10 program invested more in intensive agriculture practices. They favoured innovations in automatic and smart field operations and animal production systems. Investments in integrated equipment for postharvest residue management, such as bunching and chopping, were higher among this group. This indicates that non-participants prioritized efficiency and mechanization in their farming practices, focusing on immediate gains in productivity. Despite these focused areas, both groups showed a lack of investment in certain innovations. Conducting training courses for all types of personnel was underfunded by both groups, indicating a missed opportunity for enhancing knowledge and skills. There was also a notable reluctance to invest in mobile applications for weather forecasting and machinery monitoring, which are crucial aids for agronomic practices. Furthermore, both groups displayed scepticism towards investing in disease and pest control through plant cover and antagonistic fungi, possibly due to insufficient knowledge about these methods. In conclusion, the data indicates a clear divide in investment priorities between M10 participants, who lean towards sustainable practices, and non-participants, who focus more on intensive farming innovations. The potential of some innovation investments is being underestimated by both groups of respondents, especially those connected with knowledge improvement and monitoring systems. By addressing these gaps, farmers can better equip themselves to meet the challenges of modern agriculture.

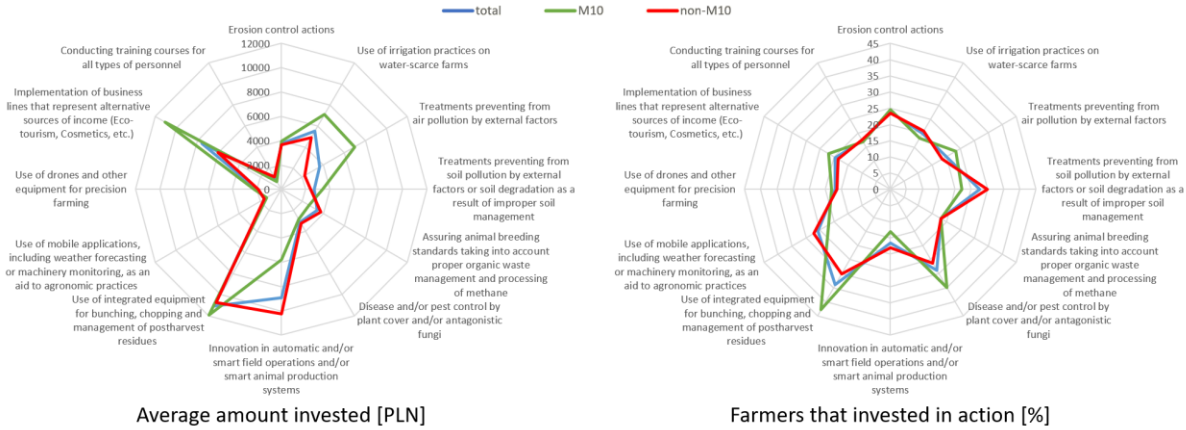


Figure 36 Investments in innovative activities on farms managed by M10 participants and non-participants

The survey conducted provided valuable insights into the various aspects of the M10 program implementation and its effects, revealing key areas of strength and concern. The findings allowed us to formulate a series of policy recommendations aimed at enhancing the program's effectiveness and perceptiveness. The study highlights a generally positive perception of the M10 program among Polish farmers, with 27.1% of participants noting increased profitability despite the additional burdens and costs involved. This positive feedback suggests that the program's financial incentives and support mechanisms are effective in helping farmers achieve better economic outcomes. **To capitalise on this positive perception, there should be efforts to expand the reach of future measures and provide even more targeted support. This could include personalized guidance and resources to help farmers manage the increased workload and costs associated with program compliance.** Non-participation in the M10 program is primarily attributed to bureaucratic complexities, a lack of trust in institutions, concerns about profitability, arising from complying with certain obligations such as the cropping plan, sowing dates, or catch crop use, commitments not being aligned with specific farm conditions, such as the type of production and specialization, and inadequate information about the program. This study underscores the importance of improving the administrative and legal frameworks at the national level to support the implementation of agri-environmental programs. Streamlining administrative procedures and ensuring that legal requirements are farmer-friendly can significantly improve the perception and acceptance of these programs. This is particularly important as the agricultural sector moves towards achieving national strategic goals by 2030, which will likely involve a range of activities aimed at stimulating sustainable farming practices. **To address these barriers, it is crucial to make 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.** This is especially important in the context of the actions to prevent nutrient leaching and reduce greenhouse gas emissions, which should be adapted to specific soil types and climatic conditions. However, the reconciliation of the intensification of agricultural production with the reduction of emissions requires both economic measures, especially those related to investments in innovations, and appropriate dissemination of ecological awareness among farmers. This dual approach can help farmers adopt more environmentally friendly practices without compromising their productivity and profitability. The study showed that the innovations appear to be of great interest among Polish farmers, with around 25% of them already investing in new technologies and methods. **To encourage the adoption of new**

technologies and reduce farmers' risk aversion, targeted programs should be launched to improve farmers' knowledge of innovative agricultural practices and equipment. These programs could include workshops, demonstrations, and training sessions aimed at showcasing the benefits and practical applications of new technologies. By equipping farmers with the necessary knowledge and tools, these initiatives can further encourage the adoption of innovations that enhance productivity and sustainability. At the same time, these actions would be helpful to provide farmers with knowledge about which of their practices and new technologies contribute more to production intensification while minimizing environmental impacts. Moreover, Polish coordinators of future EU pro-ecological programs should prioritize substantial efforts to promote and enhance the reputation and prestige of participants, as well as to increase the value of their products. The results of our study suggest that in the implementation of future EU agri-environmental measures, more care should be paid to promoting the prestige and market value associated with eco-friendly farming practices, which could be crucial for encouraging broader participation in programs like M10. Farmers need to see tangible benefits from their engagement in such initiatives, not just in terms of compliance but also in market recognition and financial returns. **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.** Public awareness campaigns can also play a vital role in highlighting the positive impacts of sustainable farming practices.

2.2.3 Interaction and engagement with stakeholders

The interactions with key stakeholders in the Polish Use Case of the AGRICORE project have been particularly relevant in terms of their importance and the significant assistance they provided. These stakeholders, encompassing academic institutions, agricultural organizations, advisory services, and policymakers, played a pivotal role in shaping and validating the project's outcomes. Their contributions ensured that the research was grounded in real-world agricultural practices and policy needs. This collaboration was instrumental in addressing contemporary challenges in agriculture and enhancing the effectiveness of agri-environment-climate policies.

One of the most crucial stakeholders was the Polish Ministry of Agriculture and Rural Areas Development. As a primary policy official, the Ministry's involvement is vital for the success and implementation of the AGRICORE project's outcomes at the national level. Initial contact was made by Prof. Cezary Sławiński, leading to two online meetings on June 23, 2021, and July 6, 2021. During these meetings, representatives of the Ministry expressed significant interest in the results of the AGRICORE project and the potential use of its tools. They declared their willingness to analyze and utilize the Polish Use Case study results, ensuring that research findings will be considered in improving agricultural policy management, particularly in socio-economic and environmental aspects. Subsequently, IAPAS representatives provided information to key figures at the Polish Ministry of Agriculture and Rural Areas Development, including General Director Monika Rzepecka, Chief Specialist of the Section of Water Management and Climate in the Department of Climate and Environment Małgorzata Ślusarczyk, Senior Specialist at the Department of Strategy and Analysis Zofia Giersz, and Head of Rural Development Plan Unit Anna Klisowska. During these meetings, the Ministry's representatives indicated that they could not directly provide data, sign a letter of support, or assist in accessing data held by subordinate agencies due to their non-membership in the Consortium and project implementation constraints. Agencies such as FADN Poland, KOBiZE, ARMA, and the National Chemical-Agricultural Station have independent rules regarding data sharing and GDPR compliance, which the Ministry cannot override. However, they shared valuable information about a 2022 amendment to the act on direct payments, which allows the free sharing of spatial data by ARMA. The Ministry also expressed interest in obtaining the final version of the AGRICORE tool for national agricultural policy problem-solving.

Another significant stakeholder was the Agricultural Advisory Center in Brwinów, which coordinates the work of several thousand agricultural advisors across Poland and maintains close relations with agricultural producers. The contact with the Agricultural Advisory Center (AAC) in Brwinów, represented by Head of Section for Innovation and Agriculture Janusz Dąbrowski, was established via email by IAPAS representatives. The ACC provided IAPAS with access to a database of 3,000 agricultural advisors for conducting the survey and expressed interest in participating in a workshop to discuss and interpret the project results. The Center also offered valuable suggestions for improving survey content and promised to publicize the survey, thereby enhancing farmer participation and data quality. Additionally, they expressed interest in participating in a workshop concerning the AGRICORE project results, further supporting the broad dissemination and application of the findings.

PBS representatives established contacts with the Association of Employers – Land Leases (ZPWiDR), represented by Office Director Łukasz Gapa, the Pig Breeders and Producers Association "POLSUS" Northern District, represented by Head of the Northern District Tomasz Kmuk, and the Association "Polish Club Farmer of the Year," represented by Chairman of the Competition Jury Teresa Kucharska. These organizations represent a significant group of farmers, facilitating direct contact and collaboration. PBS initiated contact via email and phone. Through email exchanges, phone calls, and direct meetings with farm managers, the AGRICORE project goals were described, and its potential impact on farmers in Poland was highlighted. We received support in creating and distributing the questionnaire for the Polish Use Case study. The association's involvement led to an improved description of the eco-services and environmental indicators within the framework of agri-climate-environment policy.

Contact with Piotr Gradziuk from the IRWIR PAS, Institute of Rural and Agricultural Development, was established by the IAPAS team by email, phone, and a direct meeting in Lublin. This contact aimed to discuss the AGRICORE project issues and helped us to evaluate, analyze, and modify the Participatory Research. It also resulted in the organization of the XXVI Workshop of Agricultural Economists in Krasnobrod between June 13 and 15, 2022. IAPAS representatives delivered a lecture on June 14, 2022, titled "Methods of assessing the impact of agriculture on the environment and climate in the AGRICORE project," and PBS representatives presented "Economic and social determinants of the effectiveness of agro-climate and environmental policy in light of the development of ecological services for agriculture in Poland.". This event facilitated discussions on the use of large spatial datasets and innovative methods useful in agriculture.

Representatives of IAPAS also established contact with Prof. Dr. Hab. Wiesław Oleszek, Director of the Institute of Soil Science and Plant Cultivation (IUNG) in Poland, to describe and present the AGRICORE project assumptions and actions. The Institute of Soil Science and Plant Cultivation (IUNG), a prominent research institution, ensures scientific validation and enhances the credibility of the AGRICORE project's findings. Contact was initiated by IAPAS Coordinator Prof. Cezary Sławiński, resulting in IUNG's initial agreement for active involvement in the AGRICORE project. Their scientific expertise contributes significantly to the analysis of policy impacts on the agricultural sector. IUNG expressed a willingness to be actively involved in the AGRICORE project, and their agricultural and environmental expertise was used to improve methods used in AGRICORE.

The Agency for Restructuring and Modernisation of Agriculture (ARMA), an executive organization responsible for payments and the implementation of Measure M.10, provided invaluable data and insights for the study. Contact was initiated by PBS to support the study through Participatory Research. ARMA expressed an initial willingness to analyze the results of the Polish Use Case study. Their analyses helped to interpret the results of the Participatory Research in the context of the implementation and effectiveness of M10 actions, and alignment of the policy goals with environmental aspects of agriculture.

The involvement of the National Centre for Emissions Management (KOBiZE) was crucial for understanding the environmental impact, particularly greenhouse gas emissions from agricultural activities. KOBiZE participated in an online meeting organized by the Ministry of Agriculture and Rural Development on July 6, 2021, where they expressed interest in the AGRICORE project results, especially in gas emission estimation. Their participation provided critical insights and comparative research capabilities on agricultural emissions, enhancing the environmental dimension of the AGRICORE project.

In the last months of the AGRICORE project realization, efforts were made to arrange a seminar for stakeholders and farmers in Bydgoszcz. It occurred on October 6, 2023, and was titled "Research results in the AGRICORE project in the light of improving the agri-environment-climate policy.". Academic representatives from the Institute of Agrophysics of the Polish Academy of Sciences in Lublin (IAPAS), and Bydgoszcz University of Science and Technology (PBS), met with the Production Engineering Committee of the Polish Academy of Sciences, the representatives of the Agency for Restructuring and Modernization of Agriculture (ARMA), and farmers. Presentations on the project's assumptions, goals, and biophysical module in the AGRICORE agent model were instrumental in providing a comprehensive understanding of the project's impact on agricultural policy. The ARMA representative, with extensive experience in agricultural policy, highlighted contemporary challenges and emphasized efforts for effective water management at the EU and national levels. This was crucial in contextualizing the project within broader policy initiatives like the "blue deal.". Moreover, discussions led by representatives from Bydgoszcz University on water resource management and ecosystem services development, as well as the ARDIT tool for data mining, were essential in addressing practical issues faced by farmers. These contributions underscored the importance of integrating academic research with real-world agricultural practices. Seminar participants stated that the presented solutions, combined with progress in the development of information technologies and expansion of data sources, create opportunities for more effective use of public funds to achieve the goals of the Common Agricultural Policy. Active participation from agricultural organizations, advisory services, and farmers, helped to validate the project's findings and suggested areas for future policy adaptation. This collaborative effort ensured that the seminar not only disseminated research results but also fostered a dialogue aimed at enhancing the competitiveness of farms and the need to adapt agricultural policy instruments to specific local conditions.

In conclusion, the interactions with these stakeholders have been instrumental in advancing the Polish Use Case of the AGRICORE project. Their significance lies in the provision of crucial data, broad outreach capabilities, scientific validation, and policy implementation support. These collaborations ensured that the project's outcomes were robust, scientifically validated, and relevant to both policymakers and practitioners in the agricultural sector.

2.2.4 Generation of the synthetic population

The AGRICORE team tried to gain access to the national statistics for Poland so they could be used for the synthetic population generation. The reason for this (instead of directly using FADN) is that the required variables for the generation of the synthetic populations was not completely at the moment of the request, and FADN service only provided access to the specifically requested variables, which is not the case for the national agencies (at least for Spain and Italy).

However, access to the national statistics was denied, the synthetic population for the Polish use case was generated using data from FADN.

The data obtained from FADN used to generate the synthetic population showed some characteristics inherited from the data request made for other use cases and a limitation in the number of variables that can be made in the request. These aspects had relevant implications regarding the potential utility of the synthetic population for the simulation of the Polish use case.

Firstly, there is a set of variables that are aligned with the Agricore purposes and that are cross-cutting to all use cases. These are variables are independent of the construction of the use case, and more specifically, variables that are common to all agents independently of the purpose of the study, as social and economic types. So far, there are no negative consequences of this approach. However, limitations arose when considering some categorical variables and crop-related variables.

Due to the limitation on the number of possible variables to be selected, some important and essential variables were omitted, underestimating their potential negative consequences for the construction of the synthetic populations. This action was not made arbitrarily but rather based on the assumption that other available variables would have more positive implications. Specifically, the lack of a request for representativeness or farm weights had severe negative consequences, as explained in deliverable D7.6.

Additionally, the selection was made considering the crops selection made for the Andalusian use case. Although this selection was considerable in size, it did not match the requirements of the Polish use case, as climatic, geographical conditions and agricultural cultures differ significantly, so farms in both regions cultivate different crops better suited to their specific conditions. This resulted in an imprecise representation of Poland's agricultural landscape, which included crops with a low representativeness while leaving out other crops that play a major role and account for the largest share in Poland's agricultural structure.

The synthetic population was generated considering the limitations and negative consequences of using data with the described characteristics and implications on the use case simulation for the Polish demonstrator. Once generated, populations were analysed, and the previous suspicion was confirmed: under these conditions, it was not possible to generate a reliable and suitable synthetic population for the simulation and analysis of the Polish case.

To rectify this problem, the team in charge of managing the data of the project, decided to make a new request to FADN with the proper set of variables and with the feedback of this prior wrong request. However, by that time, the project was in its final months, making it unfeasible to request, obtain and process data before the scheduled deadline. Therefore, all project efforts were focused on the proper execution of the two use cases for which enough data was received, Andalusia and Italy.

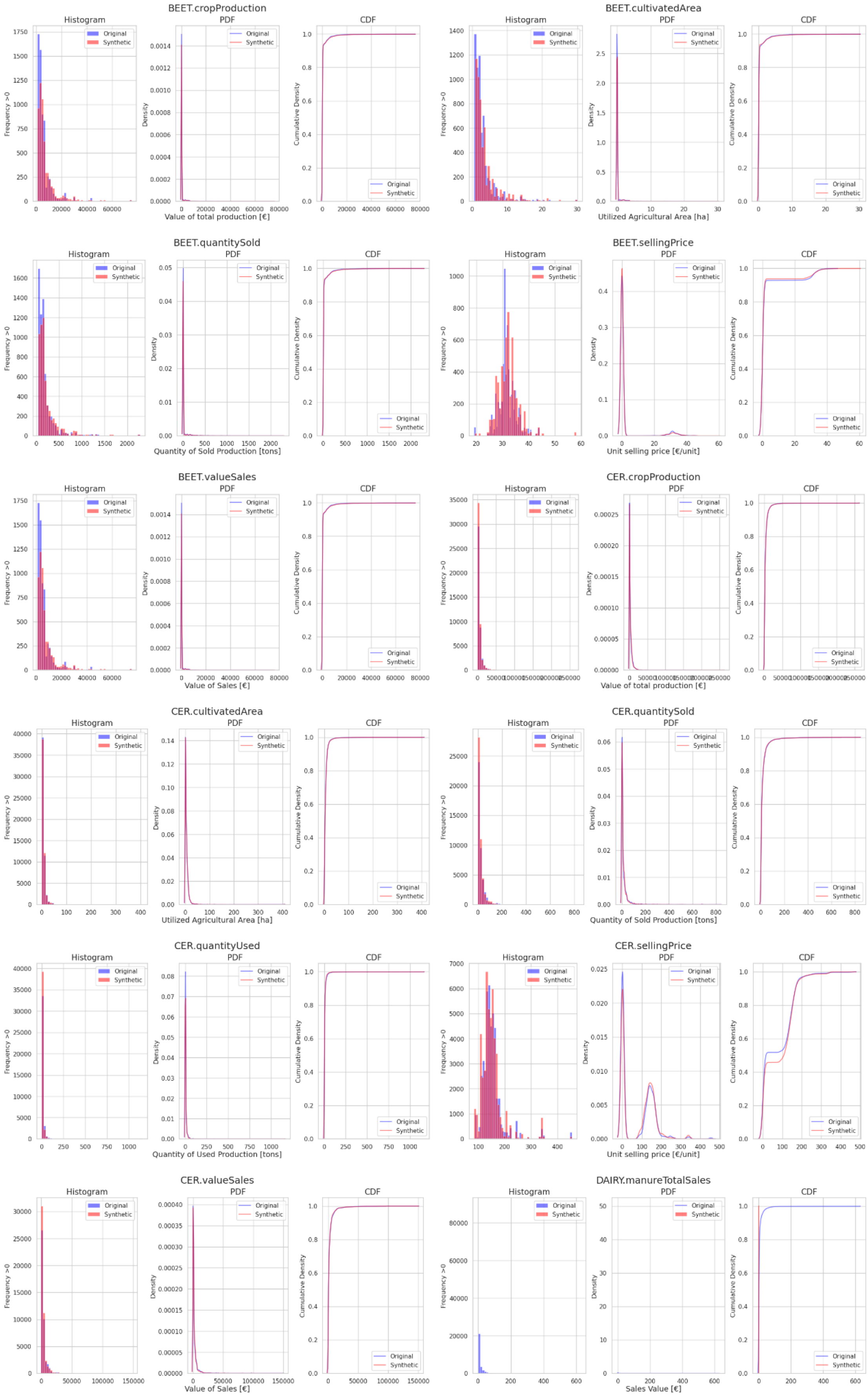


Figure 37. Poland use case: synthetic population comparison I

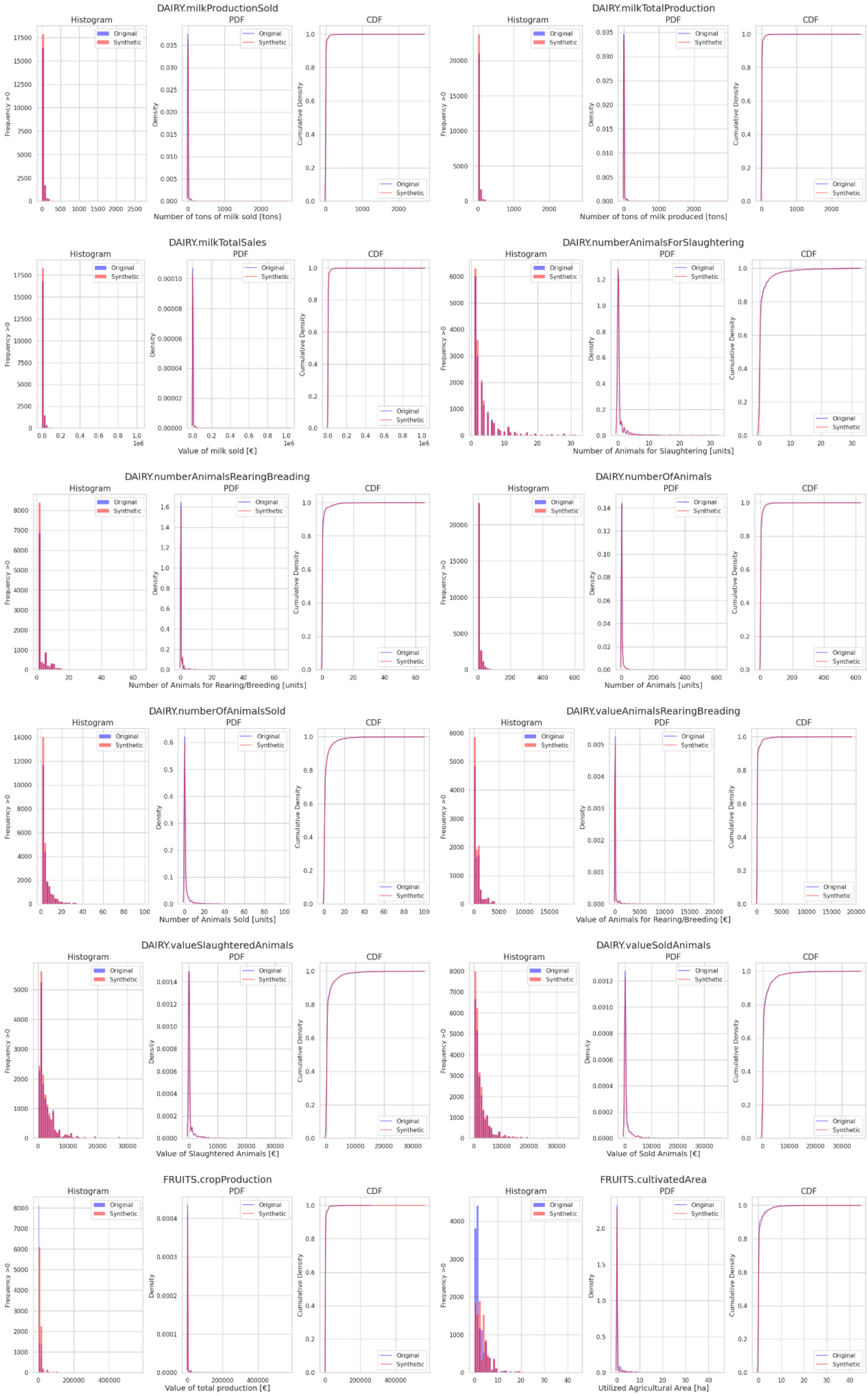


Figure 38. Poland use case: synthetic population comparison II

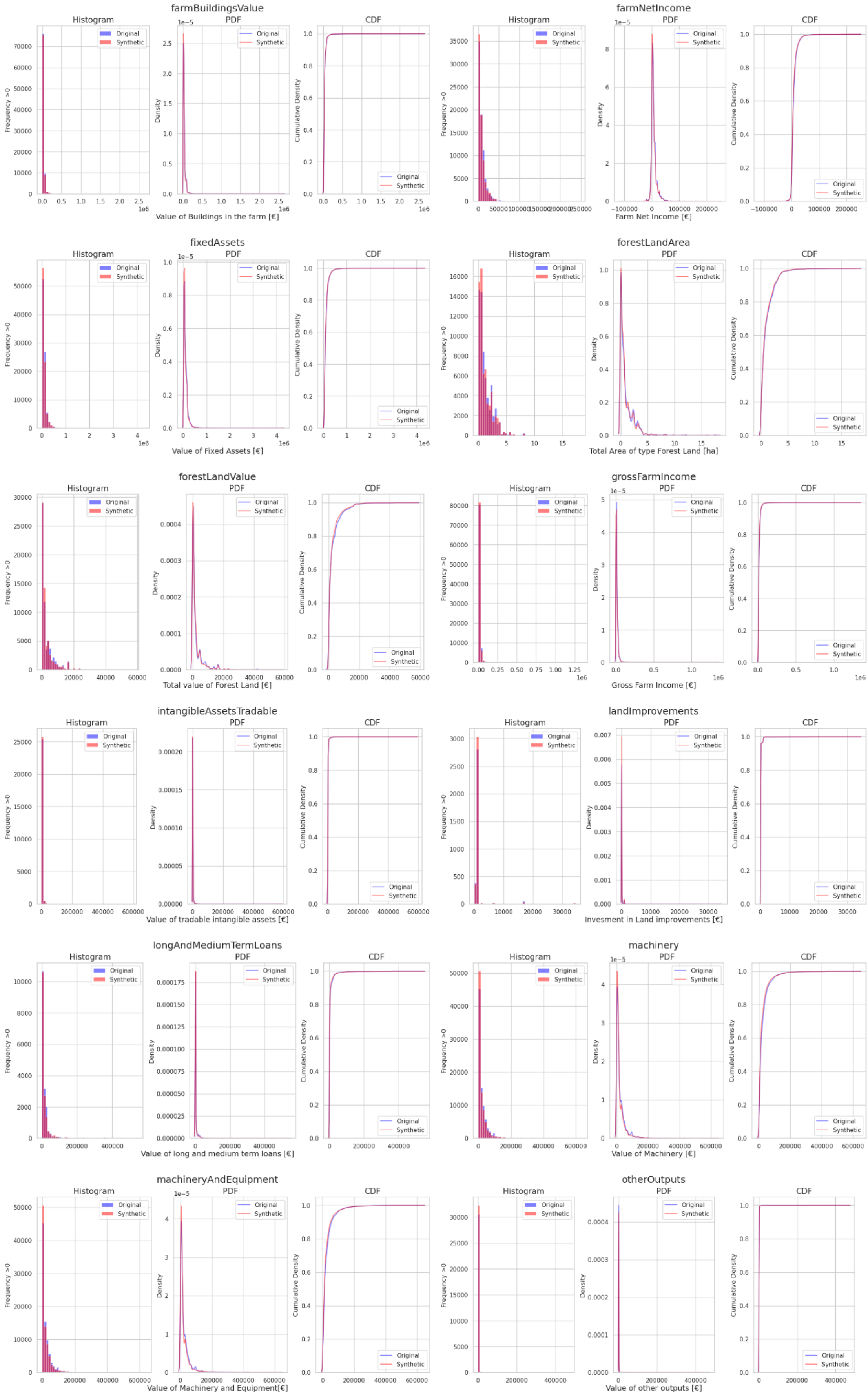


Figure 39. Poland use case: synthetic population comparison III

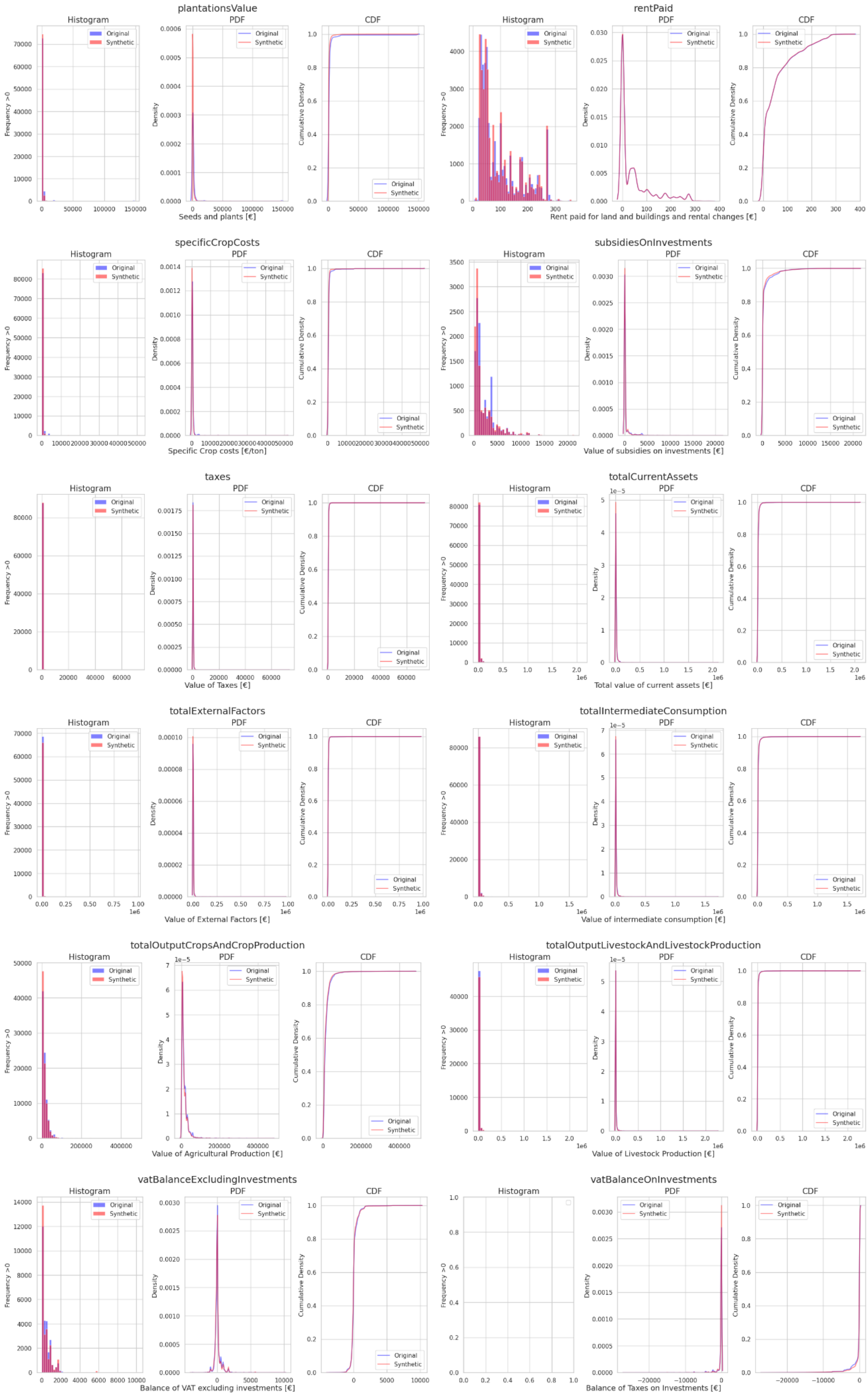
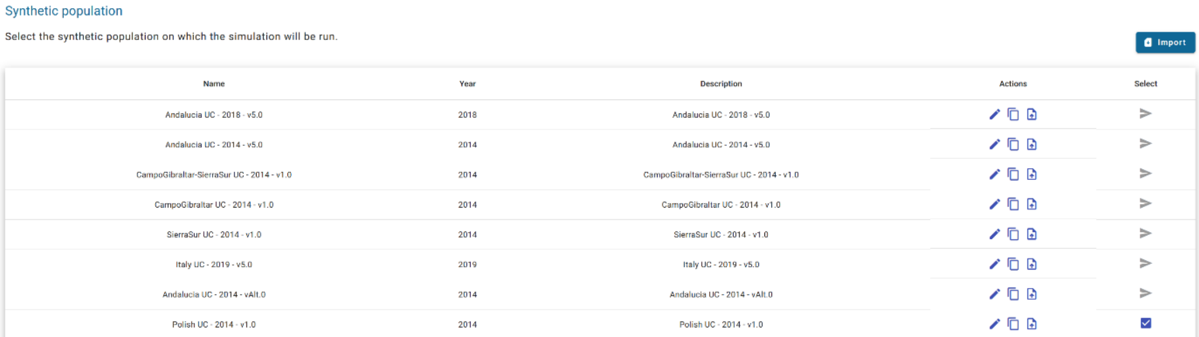


Figure 40. Poland use case: synthetic population comparison IV

2.2.5 Simulation of the population

The synthetic population corresponding to the year 2014 obtained in the previous step wase used as a basis for performing the simulation of the Polish Use Case. The simulation was executed mainly with the goal of identifying any potential gap that could appear in future simulations once a correct Synthetic Population could be instantiated.

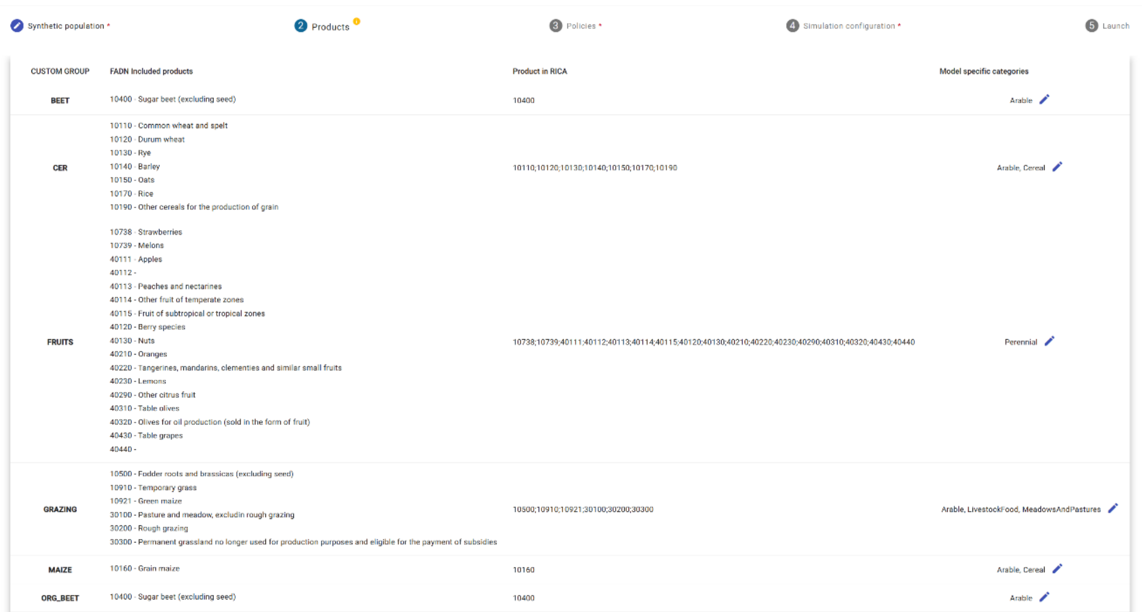
The first step to simulate in the AGRICORE suite was to select it from the available synthetic populations, as shown in next Figure 41Figure 19.



Name	Year	Description	Actions	Select
Andalucia UC - 2018 - v5.0	2018	Andalucia UC - 2018 - v5.0		
Andalucia UC - 2014 - v5.0	2014	Andalucia UC - 2014 - v5.0		
CampoGibraltar-SierraSur UC - 2014 - v1.0	2014	CampoGibraltar-SierraSur UC - 2014 - v1.0		
CampoGibraltar UC - 2014 - v1.0	2014	CampoGibraltar UC - 2014 - v1.0		
SierraSur UC - 2014 - v1.0	2014	SierraSur UC - 2014 - v1.0		
Italy UC - 2019 - v5.0	2019	Italy UC - 2019 - v5.0		
Andalucia UC - 2014 - vAlt.0	2014	Andalucia UC - 2014 - vAlt.0		
Polish UC - 2014 - v1.0	2014	Polish UC - 2014 - v1.0		

Figure 41: Selection of synthetic population for Poland 2014 SP

After the selection of the synthetic population, the grouping defined in the Synthetic population was verified across the uploaded data in the AGRICORE DWH. As shown in next Figure 42Figure 20:



CUSTOM GROUP	FADN Included products	Product in RICA	Model specific categories
BEET	10400 - Sugar beet (excluding seed)	10400	Arable
CER	10110 - Common wheat and spelt 10120 - Durum wheat 10130 - Rye 10140 - Barley 10150 - Oats 10170 - Rice 10190 - Other cereals for the production of grain	10110;10120;10130;10140;10150;10170;10190	Arable, Cereal
FRUITS	10738 - Strawberries 10739 - Melons 40111 - Apples 40112 - 40113 - Peaches and nectarines 40114 - Other fruit of temperate zones 40115 - Fruit of subtropical or tropical zones 40120 - Berry species 40130 - Nuts 40210 - Oranges 40220 - Tangerines, mandarins, clementies and similar small fruits 40230 - Lemons 40290 - Other citrus fruit 40310 - Table olives 40320 - Olives for oil production (sold in the form of fruit) 40430 - Table grapes 40440 -	10738;10739;40111;40112;40113;40114;40115;40120;40130;40210;40220;40230;40290;40310;40320;40430;40440	Perennial
GRAZING	10500 - Fodder roots and brassicas (excluding seed) 10910 - Temporary grass 10921 - Green maize 30100 - Pasture and meadow, excludin rough grazing 30200 - Rough grazing 30300 - Permanent grassland no longer used for production purposes and eligible for the payment of subsidies	10500;10910;10921;30100;30200;30300	Arable, LivestockFood, MeadowsAndPastures
MAIZE	10160 - Grain maize	10160	Arable, Cereal
ORG_BEET	10400 - Sugar beet (excluding seed)	10400	Arable

Figure 42: Representation of the product grouping in the AGRICORE interface

Next, the simulation was configured in terms of the policies to be applied to the population. On a first instance, the subsidies that were already available in the data for year 2014 were reviewed, verifying that the data available in the original data sources and in the obtained synthetic population matched the one saved in the AGRICORE suite. The policies included are listed in next Figure 43Figure 21. Next, three custom policies were included, one targeting the sustainable production (4 crops/year with a subsidy of 86€/ha – reduced for bigger farms up to 60%), soil and water protection (no use of fertilizer or pesticides, 97-140 €/ha) and the preservation of orchards (with up to 423€/ha).

Population Policies

Policy Identifier	Policy Description	Model Label	Economic Compensation	Start	End
1400	Payment for agricultural practices beneficial for the climate and the environment	Greening	3113.2673	2015	2020
1600	Payment for young farmers		1228.7723	2015	2020
1700	Small farmers scheme		726.8573	2015	2020
23113	Protein crops			2015	2020
2313	Potatoes		POTATO:8564.476;ORG_POTATO:8564.476	2015	2020
9900	Organic conversion of crops			2015	2020
9901	Organic olive conversion			2015	2020

Figure 43: Available policies in the SP for Poland 2014

Next, the simulation engine was configured to use the last version of the short term and long-term models available. The simulation horizon was set to 4 years that corresponded to the target period of 2014 to 2018. Moreover, the simulation was run including the long-term financial model (which can be disabled to use only the short-term one). The configuration of these parameters is shown in next Figure 44.

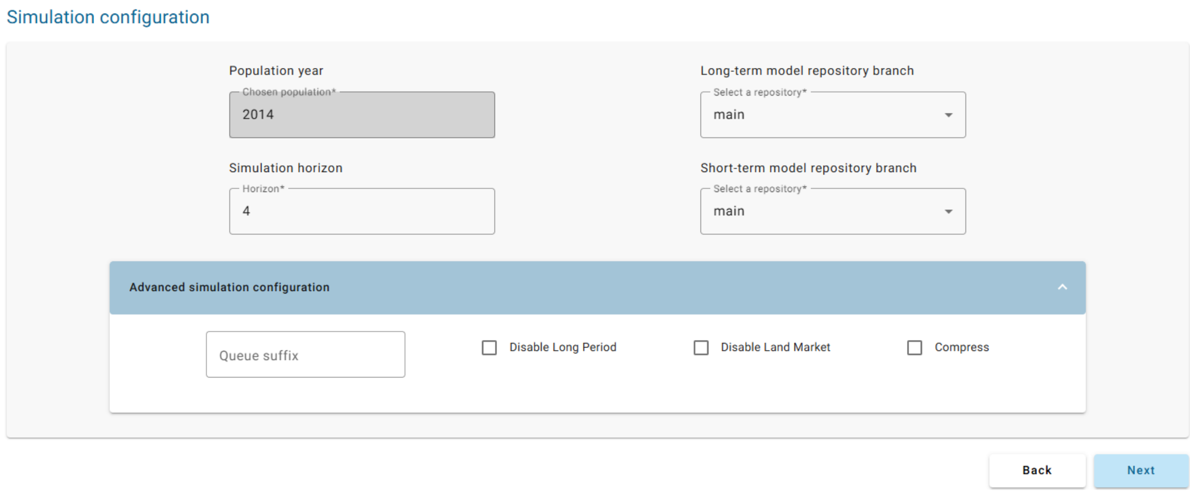


Figure 44: Configuration of the simulation for Poland 2014 SP

Finally, the simulation was launched using the AGRICORE interface (Figure 45)

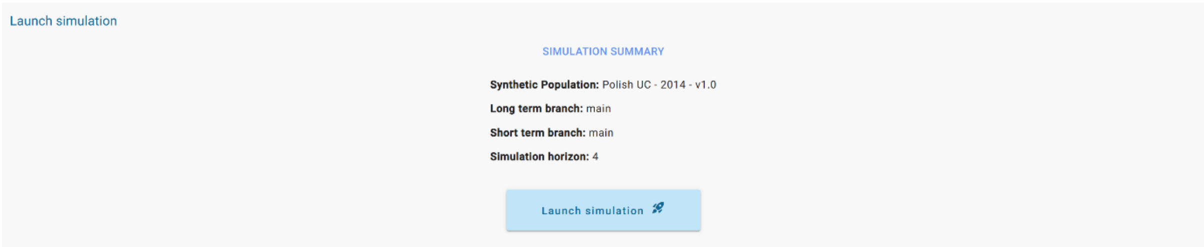


Figure 45: Simulation launching process for Poland 2014 SP

The last simulation performed took ~20 h, which accounting for a total of ~89.000 simulated farms and 4 years of simulation gave a simulation rate of ~1.100 farms · year / hour. Considering the use of nonlinear models in the short-term model and the fact that the simulations were done with limited solver licenses (1 GAMS, 1 CPLEX) in a server with 16C / 32T and 128 GB of RAM, this figure is especially relevant and remark the work done in the speed up of the simulation through parallelisation techniques. However, a correct synthetic population for Poland with complete FADN data should lead to a population of ~735.000 farms, which will require considerable more time to be simulated.

2.2.6 Results of the execution of the UC #2 – Poland

2.2.6.1 Ex-post impact assessment

The ex-post analysis of the performance and impact of *10.1 - Agri-environment-climate commitments* in Poland for the period 2014-2018 has been done based on the existing data published by the corresponding administrations (Agency for Restructuring and Modernisation of Agriculture (ARMA), FADN, National Chemical-Agricultural Station, Institute of Soil Science and Plant Cultivation), the results of the participatory research (presented in section 2.2.2 and D7.4 – Results on participatory research) and the findings acquired during its realisation. Please refer to such sections and to the complete impact assessment [57] published as peer-review publication for further analyses on the next main conclusions of the assessment.

Measure is positive seen although farmers perception is that it has led to increased costs but did not increase the value of the product. Special attention should be paid by the Polish coordinators of future EU pro-ecological programmes, to the prioritization of substantial efforts to promote and enhance the reputation and prestige of the participants, as well as increasing the value of their products.

A big adoption barrier is identified in the lack of trust to organisations, including the EU, national government and national organisations in charge of the follow up audits. In the implementation of future EU agri-environmental measures, more care should be paid to administrative and legal activity at a national level, which may improve the perception of these programmes among farmers.

Farmers perception is that some subpackages requires significantly more work (Packages 1-3) than others (Packages 4.5). This could be explained by the variations in the number and intensity of obligations associated with such M10 packages, and disparities in the availability of agricultural machinery, tools, and resources among Polish farmers, which may have influenced the perception of the burdens of the program and the possibility of being able to fulfil the individual obligations.

M10 seems to be applied and adopted more by less risk adverse farmers whom, at the same time adopt a broader range of risk management measurement to ensure investment.

Regarding key quantitative factors observable in the population:

- One of the main goals of package 1 of Measure 10.1 is to increase crop rotation to produce positive effects in the management of the soil. In Europe, a report from DG-AGRI recognized limited impact [53] in crop-rotation changes, with small farms finding difficulties to implement while larger ones already included it on their agricultural practices.
- In what regards to orchards (covered by package 3 of Measure 10.1), the measure seems to have been insufficient to palliate other factors that have affected the preference of farmers to other crops. Indeed, the area dedicated to orchards in Poland has decreased significantly over the last years [54]. FADN data shows almost a 20% reduction in the orchard used area for the years 2014 – 2018 in the sample. Eurostat indicates that, in 2017, 167.315 hectares were used for orchard production in Poland. The factors affecting this decrease are multiple [55]. First, the embargo of exportations to Russia strongly affected the Apple industry in Poland [56] causing a surplus and therefore a reduction of profitability. Second, extreme weather conditions have significantly affected fruit yields and seems to have influenced farmers to opt for lower risk-involved cultivations. Moreover, global factors as competing producers have also impacted farmers profitability and is forcing to expand to shift to other markets as Asia and middle east. Finally, the family-owned farms (which has a high representation in Poland) are showing higher levels of orchard reduction.

2.2.6.2 Ex-ante impact assessment

The ex-ante analysis of the performance and impact of M10.1 Agri-environment-climate commitments in Poland for the period 2014-2018 has been done based on the figures obtained during the build of the synthetic populations (based on FADN data) for 2014 and 2018 and the results of the performed simulation. However, due to the issues presented in previous sections in the obtention of the required data for a proper generation of a reliable and comprehensive synthetic population, the scope of this is limited, and the values obtained are not properly aligned to observed behaviour. However, the AGRICORE consortium performed the simulation of the available policy to verify that the policies included in the simulation affected the result and to identify potential additional required improvements.

The focus has been put in two KPIs, the number of farms which use more than 4 crops a year for rotation (linked to package 1) and the evolution of orchards presence in the population (linked to package 3). In both cases, the generated synthetic population did not contain the information regarding the subsidies for M10.1, nor in 2014 or 2018, which makes impossible the comparison to sampled data. Moreover, public information on M10 implementation by ARMA, does not break down M10 packages. The published figures are:

Region	Number of Submitted Applications	Number of Beneficiarie	Amount of Payments Made [PLN
Dolnośląskie	13,883	4,079	160,172,178.75
Kujawsko-pomorskie	21,079	6,735	206,630,573.01
Lubelskie	35,435	11,106	254,806,148.59
Lubuskie	9,947	2,951	173,788,291.16
Łódzkie	8,455	2,824	54,026,477.47
Małopolskie	13,649	4,046	97,881,716.03
Mazowieckie	25,068	7,855	185,324,729.62
Opolskie	3,838	1,383	47,903,877.65
Podkarpackie	31,451	9,089	197,752,131.33
Podlaskie	27,757	8,341	197,833,569.17
Pomorskie	20,679	6,370	218,957,980.57
Śląskie	3,306	1,099	32,996,280.58
Świętokrzyskie	13,929	4,487	62,401,266.72
Warmińsko-mazurskie	19,060	5,744	226,136,277.46
Wielkopolskie	26,004	8,348	237,378,328.25
Zachodniopomorskie	14,472	4,402	244,741,866.66
Total	**288,012**	**88,759**	**2,598,731,693.04**

- Regarding the package 1, the simulated population (Figure 46) shown a very limited adoption of M10.1 – Package 1, with 62 adopters in 4 years, representing only a 0.0007% of the synthetic population farmers. A potential explanation of this low level of simulated adoption can be rooted in the inconsistency of the synthetic population data, which does not include enough information on crops that can be considered for the crop rotation requirement of the policy.

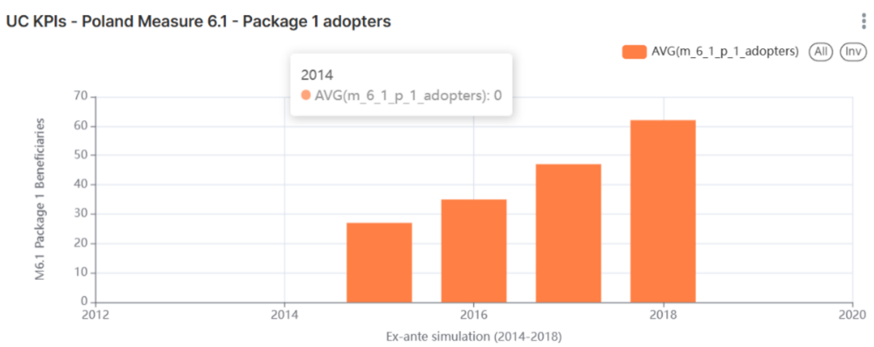


Figure 46: Simulated adoption of M6.1 Package 1

- Regarding the orchard area evolution (package 3), the synthetic population allowed to obtain values for 2014 and 2018 (although inaccurate as several orchard are not included). Indeed, the data follows the indications of the ex-post analysis above presented, with a significant reduction of the area used in orchards. However, the simulation results predicted a maintenance (even small increase) of the area used for orchards. This can be linked to two main factors: i) the generated synthetic population does not contain accurate economic data that can link orchard production to low profitability of the farms, allowing the model to consider it as profitable as other crops; and ii) the absence of the simulation of external factors (e.g. Russian embargo) does not reflect on a decrease of selling prices for the product, which reinforces the effect of the previous aspect.

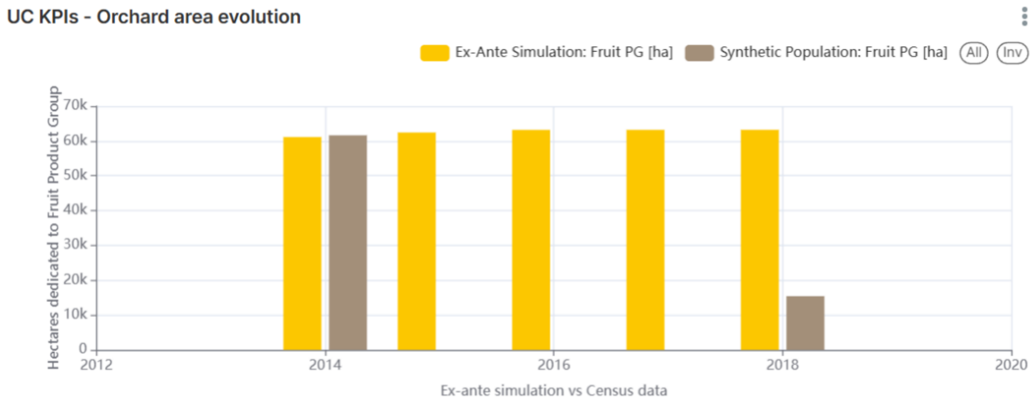


Figure 47: Simulated evolution of fruit used area

Based on the analysed metrics, the corresponding ex-ante assessment of the M10.1 in Poland shows a mildly positive effect on the targets of package 1 and package 3, providing theoretical positive effects in the conservation of orchards and in the increasement of crop rotation. However, as discussed next, these simulated results sensibly deviate from the observed impacts.

Conclusion

The ex-post impact assessment done during the project in parallel with the participatory research activities shown a positive impact of M10.1 towards the adoption of sustainable farming practices but failed to cover other areas. However, the measure has been insufficient to palliate external negative effects in some areas, especially regarding the conservation of orchards. The performed simulations seem to indicate a slightly positive impact of the introduction of these measures in the simulation but, in this case, does not reflect a significant reduction of the orchard sector (which clearly contrast to the observed data and presented in the ex-post analysis). Indeed, the inaccuracy and incompleteness of the used synthetic population does not allow to render final conclusions from the simulation results regarding adoption and impact of the targeted measure.

Overall, the authors conclude that further improvements need to be made to the AGRICORE platform, its populations and models, in order to allow for proper simulation and analysis of the Poland farming sector under Measure 10.1. The main identified required upgrades (in addition to those identified in the Andalucian Use Case) are:

- The elaboration of a proper synthetic population. This will require a properly requested FADN dataset or access to the national version of the FADN. Once a satisfactory synthetic population is built and used to simulate, a thorough analysis of the results should be done to identify any potential deviation in the simulation results.
- The embedded policy implementation in AGRICORE can receive additional upgrades to support the simulation of future complex measurements which may involve parameters and attributes of interest not currently covered by the current ABM model.

- Although already mentioned in the Andalucia's case, the coupling with a CGE (i.e. MAGNET) becomes especially relevant to the simulation of this scenario as some of the targeted KPI's (e.g. orchards used area) has been severely affected by factors not contemplated directly by the ABM (i.e. Ukrainian war / Russian Embargo) and can only be included by complete CGEs embracing global economy data.

2.3 UC#3 - Analysis of the impact achieved by the "M6.1 - Settlement of Young Farmers"

2.3.1 Analysis of the use case context

The Greek Use case studies impact of the Sub-Measure 6.1 "Start-up aid for young farmers". This sub-measure belongs to the Greek Rural Development Programme for the period 2014-2020, and its objective is to improve the competitiveness of Greek agriculture, focusing on age renewal and the creation of entrepreneurial farmers. Thus, Greece faces a demographical challenge in the rural area, the very low rate of young farmers and the high rate of elderly farmers, which complicate the future evolution of the sector. This is of paramount importance because of the considerable percentage of the Greek workforce that belongs to this sector, so the assessment of the socio-economic impact of M6.1 in the use case will be crucial.

2.3.1.1 Agricultural policy analysis

The Greek Use case studies the socioeconomic impact assessment of Sub-Measure 6.1 "Start-up aid for young farmers" of the Greek Rural Development Programme for the period 2014-2020 [27] [28]. This aims to unlock the access to finance, land, and knowledge that the new generations require when setting up their businesses, enhancing the age renewal and the creation of entrepreneurial farmers in the Greek agricultural sector. M6.1 is addressed to young farmers, which belongs to the group of new entrants (i.e., those who acquire farmland for the first time) but must be under 40 years old.

From 1985 until now, a set of chain regulations has been adopted, intending to support the renewal of the rural population and to create viable agricultural holdings by the new farmers. In general, these regulations have increased the subsidy amounts and the number of beneficiaries, being the M3.1 of RDP 2000-2006 the most successful one with almost forty thousand beneficiaries. M6.1, which is part of the Young Farmers Scheme of the Rural Development Plan, has had 16.900 beneficiaries until now. To this measure, natural and legal persons can apply. In the format case, they must be young farmers with legal capacity and permanent residence in the rural area for which the application is submitted. In the other case, the head of the holding must be a young farmer with at least a 51% share of the legal entity, which must have its headquarters in the same region as the permanent residence of the head and report agriculture as its main economic activity. Furthermore, natural and legal persons must comply with the following eligibility conditions to be beneficiaries [29]:

- Be the first establishment of the person or the head of the entity.
- Be registered to the Integrated system of Management and Control (IACS) of the Ministry.
- Be registered as professional farmers or new entrant farmers in the respective Registry.
- Have a different occupation other than agriculture the last 5 years prior to application for the call.
- Become professional farmers within 18 months of accession to the Measure.
- Have adequate skills or obtain them within 36 months since accession to the Measure. Middle education must be in a geotechnical major to become eligible for the scheme and according to the business plan of the application. For those with a University degree and above, no specialisation is required.
- Submit a business plan with economic goals and timelines to be implemented in a period not shorter than three and no longer than four years.

Beneficiaries receive a subsidy amount depending on his/her type of activity (i.e., crop, livestock or missed) and a bonus due to the type of residence. As a result, they may receive aid between 17.000€ and 22.000€.

The assessment of M6.1 is carried out by the competent Ministry based on common ad base indicators. The common indicators evaluate the performance, results and impact of the measure and they include the number of reinforced young farmers, the total amount of investments, the increase in gross value added on supported holdings, the economic growth, and labour productivity. Moreover, base indicators shape the age structure of the agricultural sector and the structure of agricultural holdings (i.e., number of holdings, used agricultural area (Ha), average size (ha/farm), the economic average size of holdings, and employed in agriculture in annual work units).

2.3.1.2 Situation of the agricultural sector in the framework of the use case

As indicated in the introduction of this section, the interest of this use case lies in the need for age renewal in the Greek agricultural sector. Greece has one of the lowest shares of young farmers in the total number of farm managers (3,7% aged up to 35 years old), in addition to which Greece has one of the lowest ratio of young managers to elderly in the EU [30]. This issue is emphasised due to the importance of the agricultural labour force in Greece, entailing a key factor for the survival of the sector [31]. Indeed, while 4.4% of the total labour force in the EU-28 is employed in agriculture, the corresponding percentage of Greeks stood at 11% in 2015 [32]. Moreover, the percentage of farm managers aged over 55 years old in Greece exceeds 55% of the total, while young farm managers aged <35 years old reach less than 6% of the total farmers.

According to the 2011 National Census [33], 2.260.401 persons aged 20-40 were eligible for the Young Farmers Scheme, with 57% being male and 43% female. Almost ten years later, their population is the same, but the youth suffer from unemployment. In 2019, the national average jobless rate was 17.3%, despite 53% of 20-44-year-olds having completed middle schooling and 34% having a university degree or above [34]. Younger groups had greater unemployment rates, ranging from 12.6% for 30-44 to 22.8% for 25-29 and a record 32.7% for 20-24. Measure 6.1 can boost entrepreneurship, create jobs, and help unemployed, disadvantaged people. Despite this, the agricultural sector employs 3.93% of the total workforce in Greece[35], ranking 7th. Furthermore, the relevance of the agricultural sector in Greece is also observed in economic terms, as it contributes 3.95% of Gross Value-Added (GVA)[36], ranking 9th among 64 sectors.

With regard to the environment, agriculture is a source-intensive sector that produces greenhouse gases like nitrous oxide and methane [37]. The impact of N2O on climate change is 298 times greater than CO2, with agriculture (using nitrate fertilisers) contributing 78.2% of total N2O emissions in 2017. Methane (CH4) is the second-largest emission component and 25 times more potent than CO2. In 2017, 45.2% of CH4 emissions came from agriculture, mostly livestock, and waste management.

2.3.1.3 Collection and characterisation of data sources and information of interest

In the Greek use case, the detected information gaps were focused on determining the features of the young farmers' population in the agricultural sector. Given the national geographical scope of the use case, 8 datasets were found and characterised for their inclusion in the ARDIT tool (see D1.5 - Characterisation of national and regional data sources). These data sources were necessary to assess the socioeconomic impact of M6.1. Among them, some important datasets are highlighted:

- **Greek branch of the FADN**. The FADN Department of the Ministry of Agricultural Development and Food and of the Greek government coordinates support and controls the programme at the national level. This department, together with the Hellenic Statistical Authority (ELSTAT), annually defines the features of the sample population to be surveyed, which is composed of 4.675 agricultural holdings from all over Greece. As in the other use cases, FADN microdata are key to setting the synthetic population, and they were requested. AUTH initiated the procedure through personal contact with the Unit of Agricultural Policy, Documentation and International Relations of the Ministry of Agricultural Development and Food. Dr Apostolos Polymeros, Policy Officer and Head of the Unit, was extensively briefed on the AGRICORE Project and its subsequent research activities. The AUTH team was granted access to the Greek FADN dataset early in 2021 for the years 2015, 2016, 2017 and 2018.

- **Young Farmers data**. Given the particular features of the population in the Greek use case, non-public data on the 13.905 applicants of M6.1 in the RDP 2014-2020 are key. These data are gathered and maintained by two public units: The Development Programs Management Organization Unit SA and the Special Management Service of the RDP 2014-2020. In November 2020, the AUTH team initiated the request procedure through contact with the Head of the Investment Unit in Agricultural Holdings of the Special Management Service of the RDP 2014-2020. This procedure included the specification of the requested variables, proving that no sensitive information was requested. Thus, after guaranteeing the anonymity of applicants, the values of the requested variables were provided. These data were divided into the personal data of applicants, farm holdings data for each piece of cultivated land, farm holdings data for each category of animal husbandry, specific commitments and specific objectives.

2.3.1.4 Detection of information gaps

Based on the initial approach of the project developments, especially the ABM and SPG modules, and the data of the aforementioned databases, a comparison was performed to detect the preliminary information gaps in the use case. In addition to the risk aversion and innovativeness, which are common to the three use cases, the available datasets did not include quantitative data related to the young farmers' concerns and opinions about the Young Farmers Scheme. These topics include:

1. Young farmer's motivation.
2. Beliefs about Young Farmers Scheme.
3. Beliefs about the farming sector in general.
4. Beliefs concerning Young Farmer's future in Agriculture.

2.3.2 Participatory research

2.3.2.1 Preparation of the participatory research

The Greek use case developed a methodology to fill in the detected information gaps through the execution of Participatory Research action. Firstly, a set of stakeholders composed of entities and associations was deeply interviewed in order to know how M6.1 was implemented and the level of satisfaction of young farmers. Secondly, a questionnaire was designed to directly survey the satisfaction and perfection of young farmers about M6.1.

For the survey campaign, the size of the target population was calculated based on the 2017 Labour Force Survey (LFS) and the 2013 ELSTAT dataset. The former determined that 24.8% of Greek farmers are under 39 years old, and the latter set the farmers' population in Greece at around 709.500. As a result, approximately 170.000 farmers constitute the target population, of which 13.905 are beneficiaries of Measure 6.1. From that population, 400 young farmers comprised the sample population, which was divided into beneficiaries and non-beneficiaries with a distribution of approximately 80/20, respectively. Although this distribution is not proportional, it was done in this way because it was thought that beneficiaries could provide a better substantiated opinion about M6.1. Additionally, the sample was geographically distributed among the 13 Greek NUTS2 regions in proportion to the number of beneficiaries of each region.

Thus, the percentage of beneficiaries in each region determined the number of beneficiaries and non-beneficiaries to be surveyed in that region.

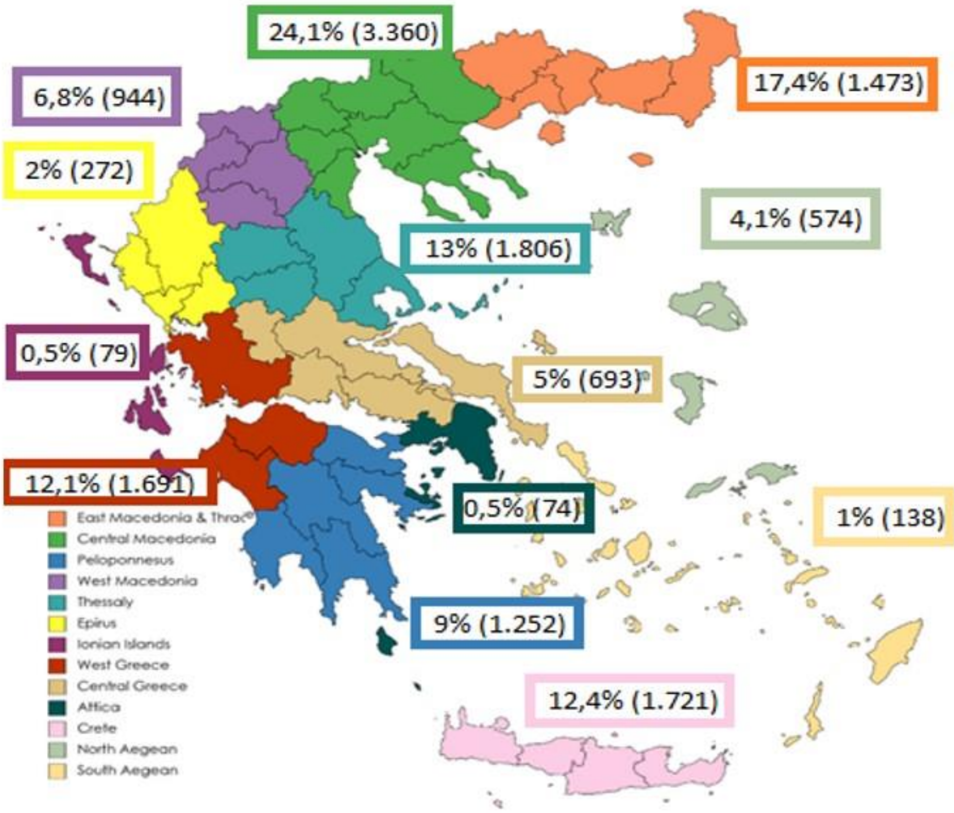


Figure 48 Spatial allocation of beneficiaries' population among the 13 Greek regions (NUTS II)

The designed questionnaire encompasses three sections to collect different types of data: demographic and socioeconomic data (section 1), financial and accounting aspects of agricultural holdings (section 2) and information about young farmers' evolution and agricultural holding improvement (section 3). The most significant part of the questionnaire was made up of structured questions with pre-programmed answers to guarantee that all questions were asked in the same way and to make it possible to analyse the data in a statistically sound manner. Some open questions were included in the questionnaire about the farmers' age and the mean hectares (ha) of owned and rented UAA (Utilised Agricultural Area). Moreover, in order to obtain quantitative data, a questionnaire based on the 5-point Likert scale was designed. The initial version was used to conduct the pilot survey, which led to modifications and adaptations of the questionnaire in order to clarify some questions.

2.3.2.2 Execution of the participatory research

For the execution of the survey campaign, the snowball sampling technique was chosen [38]. The sampling process starts when the researcher selects an initially small number of respondents referred to as seeds. After that, the seeds recruit others to participate in the study, and this process of existing sample members recruiting future respondent members continues until the size of the sample selected for the investigation is reached.

The survey campaign in the Greek use case was conducted in person from December 2021 to May 2022. At the end of this period, 445 farmers were surveyed, of which 433 were considered reliable because 12 questionnaires were excluded from the analysis due to missing or inconsistent answers issues. The surveyed sample was composed of 352 young farmers who were beneficiaries of Sub-Measure 6.1 and 81 young farmers who were not interested in participating or were interested in participating in Sub-measure 6.1 but somehow did not proceed even if they were eligible for it. The evolution of the completed questionnaire surveys was: 51 by December 2021, 171 by the middle of January 2022, 224 by March 2022 (collected exclusively from beneficiaries of Sub-measure 6.1) and 433 by the end of May of the same year.

2.3.2.3 Analysis of the participatory research results

The analysis of the data collected through the participatory research activities resulted in two scientific publications, "An Impact Assessment of the Young Farmers Scheme Policy on Regional Growth in Greece" [39] and "Assessing the Role of the Young Farmer Scheme in the Export Orientation of Greek Agriculture" [40]. This section highlights the most relevant results, but further details can be found in those publications.

The demographic profile of young farmers involved in the Greek Use Case is a significant output of this analysis. The majority of participants are male (76.2%), unmarried or divorced (53.3%), with an average age of 32. Regarding education, a significant portion (43.4%) have completed high school, followed by those with technical training (23.2%). A substantial number (61%) report an annual income below €18,000, with half (49.9%) deriving their income solely from agricultural activities. Prior to farming, participants were primarily unemployed (29.4%) or already engaged in agriculture (28.9%). A significant majority (67.5%) reside in rural areas.

Concerning agricultural holdings, participants cultivate an average of 14.9 hectares, including both owned and rented land. The majority (72.3%) acquired their owned land through inheritance. Notably, 77.1% of young farmers reported that their farms were established before their participation (or intended participation) in Sub-measure 6.1. Similarly, a considerable percentage stated that substantial machinery, including tractors, tractor accessories, and farm vehicles, were already present on their holdings prior to involvement in Sub-measure 6.1. It is worth noting that stakeholders believe the financial assistance provided to young farmers is less effective in cases where individuals must establish their agricultural holdings from scratch due to high initial costs, low profitability, and minimal return on investment. In general, descriptive statistics provide a non-encouraging assessment of the role of CAP incentives in general in attracting youth to work in agriculture. However, a considerable number of participants (44,9% cumulatively) believe in the ability of Sub-measure 6.1 in this direction. This contrast could be partially attributed to the fact that although the economic incentives to encourage participation in young farmers' schemes are useful, they are considered insufficient to achieve their overall aim, meaning the age restructuring of the agricultural sector.

The following figures show how attractive the CAP incentives and sub-measure 6.1 are for young farmers.

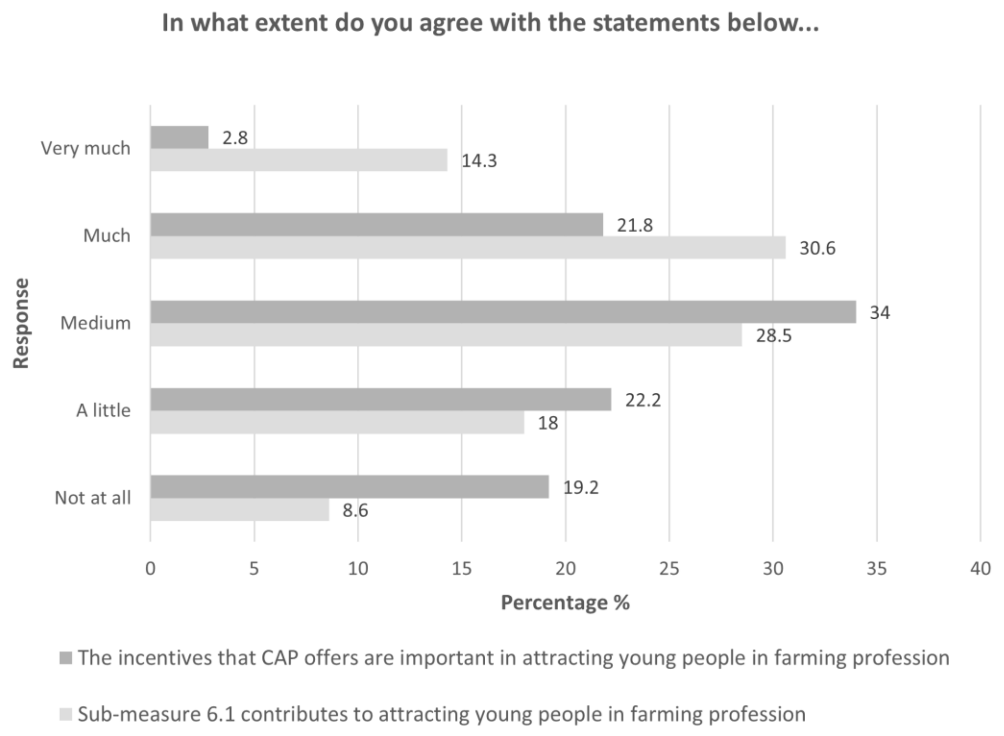


Figure 49 Attractiveness of CAP incentives and submeasure 6.1 for young farmers

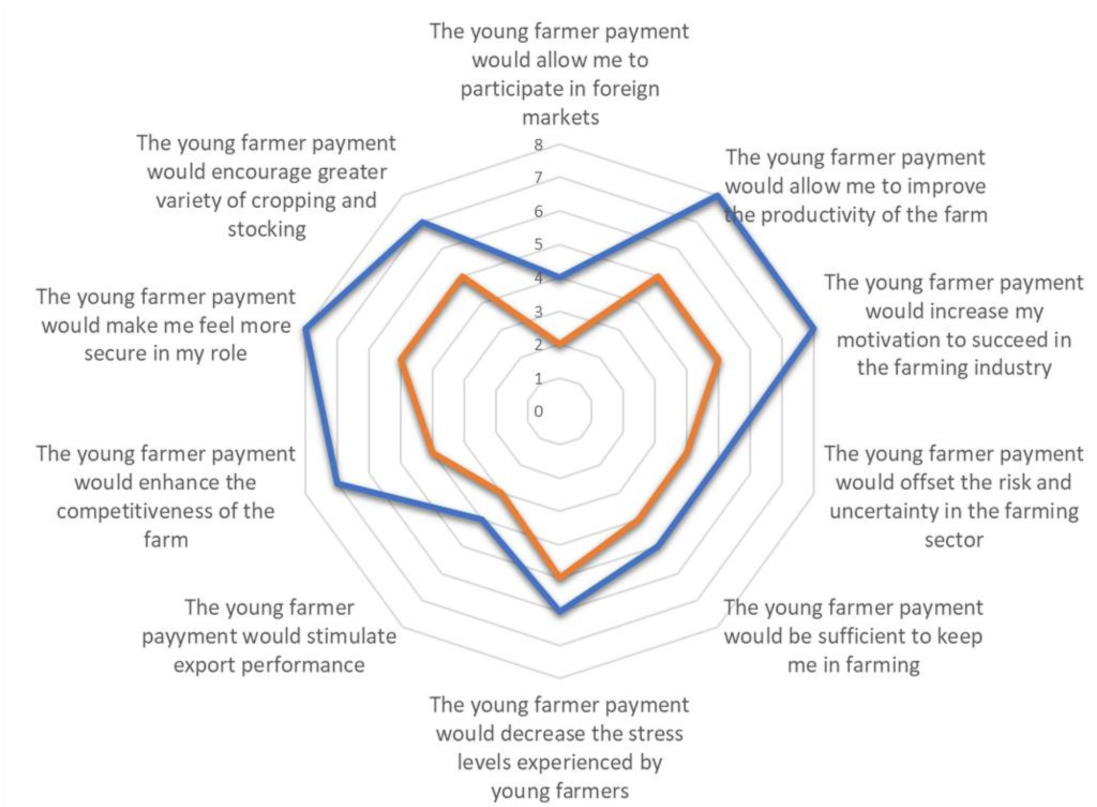


Figure 50 Farmers' beliefs and perceptions regarding Sub-Measure 6.1

In this line, the figures below reveals that the majority of respondents perceive the financial support offered by Sub-measure 6.1, "Start-up aid for young farmers," as an inadequate incentive to attract youth to the agricultural sector. The survey results also highlight bureaucracy as a significant obstacle. Moreover, delays in subsidy disbursement emerge as a critical factor influencing participation decisions in the measure. Interestingly, only a small fraction of participants views the measure's implementation requirements and the four-year commitment as disadvantages. This perspective may be partially explained by the fact that an overwhelming majority of young farmers (86.9%) expressed their intention to continue farming beyond the measure's commitment period.

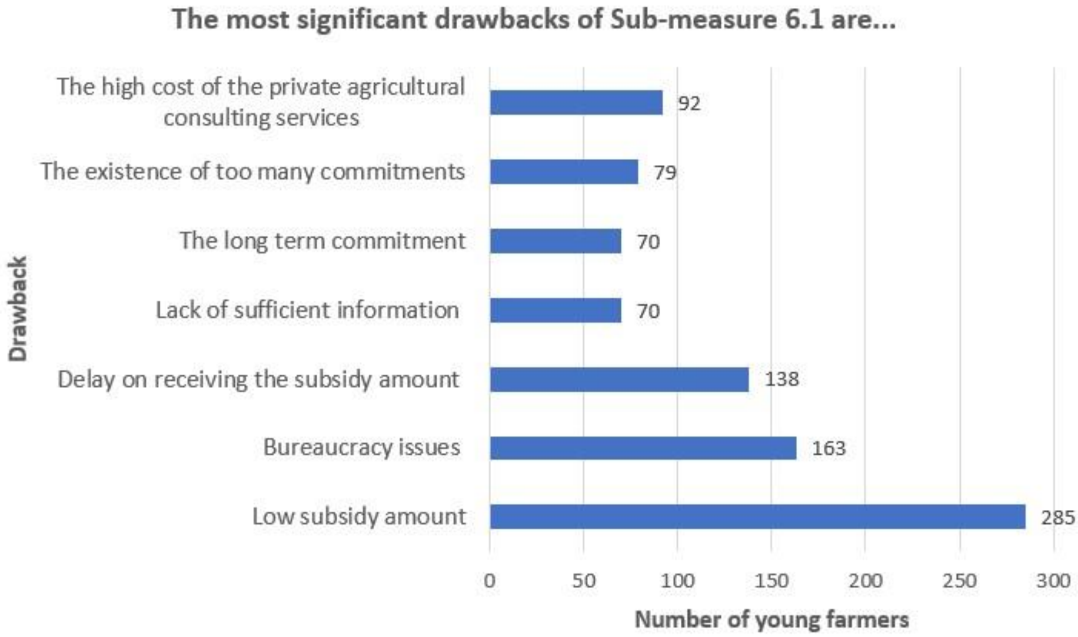


Figure 51 Major drawbacks of Sub-measure 6.1 according to young farmers' perceptions

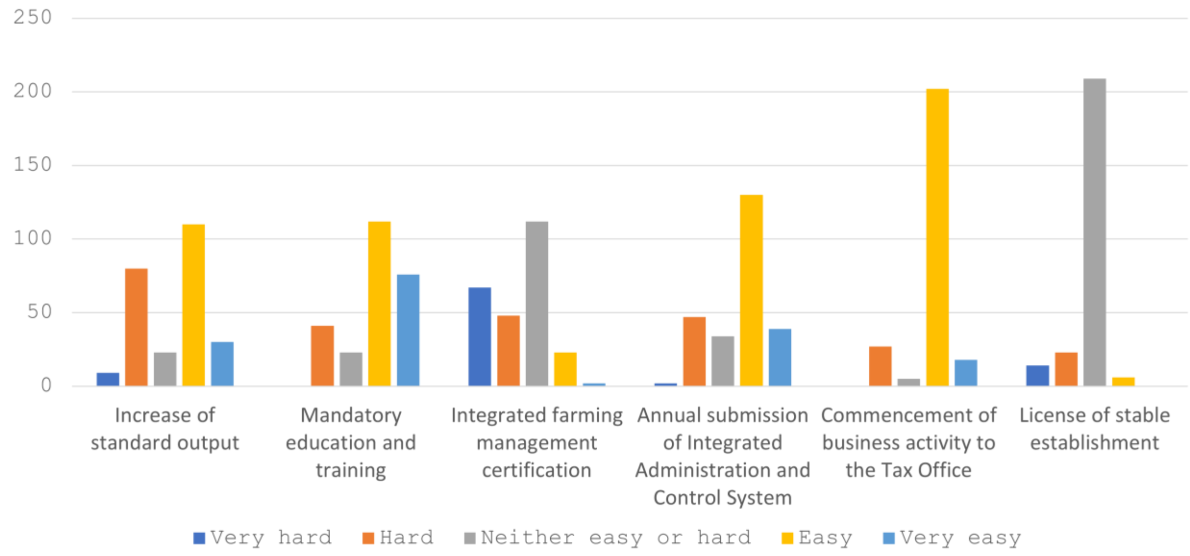


Figure 52 How easy or difficult was it for you to fulfil each one of the requirements of sub-measure 6.1

The figure below illustrates the primary motivations behind the respondents' decision to pursue farming as a profession. It is important to note that participants were allowed to select multiple answers for this question. As evident from the figure, the most prevalent reason is the pre-existence of family-owned agricultural holdings. This trend is largely attributed to the continuation of the family's farming tradition, which is considered a crucial factor in attracting young individuals to the agricultural sector. The second most significant motivation is the personal desire to become a professional farmer. Contrary to expectations, only 30.48% of participants (132 out of 433) cited Sub-measure 6.1 as a driving factor for their engagement in farming.

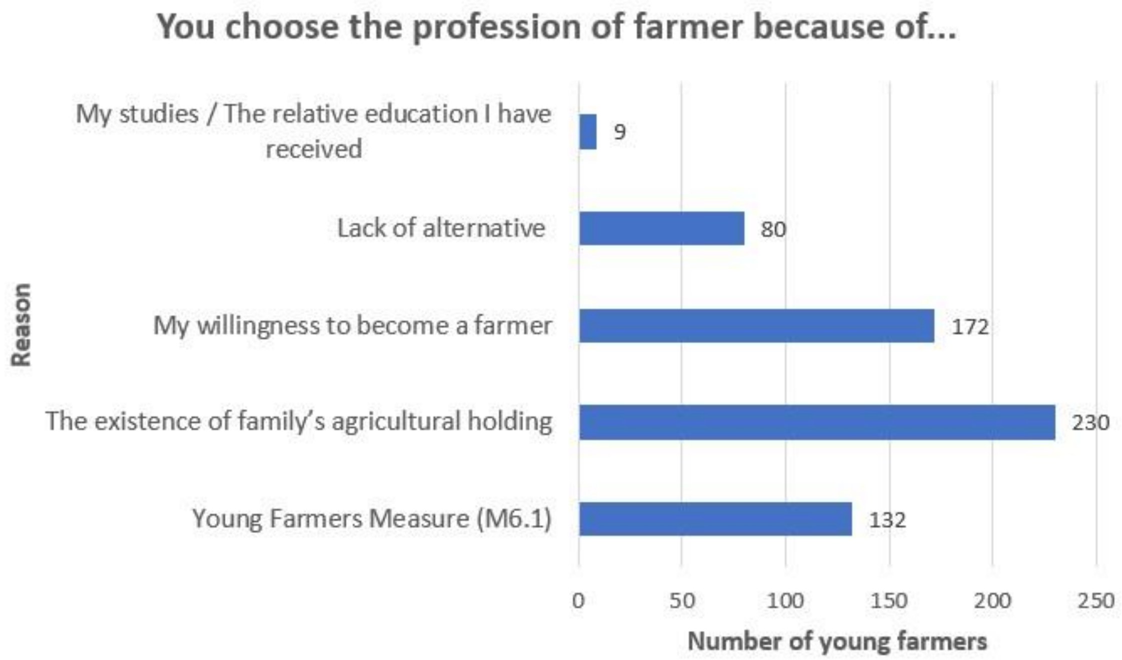


Figure 53 Reasons for participants to be engaged in farmer's profession

In conclusion, results indicate that although Sub-measure 6.1 acts as a useful instrument at the farm-level for a considerable percentage of young farmers to remain in the farming profession, it does not prove to be sufficient to create by itself actual inflows of new entrants in the agricultural sector. According to the results, the combination of the high percentages of participants who stated that their agricultural holding pre-existed before their participation in the relevant measure, the high percentages of participants who stated that they were previously occupied as farmers and simultaneously the low percentages of participants who chose the Sub-measure 6.1 as a reason to be engaged in the sector disputes if the relevant measure creates actual inflows of young farmers in farming profession. Thus, findings indicate the need for more intense policy interventions.

2.3.3 Interaction and engagement with stakeholders

The stakeholders' role has been crucial for the overall execution of the project research activities, especially in the Greek use case. Their engagement is particularly vital for conducting participatory research, not only due to their assistance in facilitating the process but also because of the valuable data they provide for policy evaluation. Given that the Greek use case focuses on the socio-economic assessment of an EU Common Agricultural Policy measure applied nationally—specifically, sub-measure 6.1 "Start-up aid for young farmers" of the Greek Rural Development Programme 2014-2020—special emphasis has been placed on including policymakers at national and regional levels, as well as relevant experts from the civil and private sectors in the stakeholder list.

In total, nine stakeholders are relevant to the Greek use case. These include: the Greek Ministry of Rural Development and Food (Policymaker), the Special Service for the Implementation of the Rural Development Program of the Greek Government (Policymaker), the Panhellenic Union of Young Farmers (Farmers), the Payment and Control Agency for Guidance and Guarantee Community Aid (Policymaker), the Greek National Rural Network (Policymaker), ELGO - DEMETER - Hellenic Agricultural Organization- Demeter (Consultancy and advisory agency), the

East Macedonia Regional Unit Administration (Policymaker), and a representative from a private consulting company specialised in agricultural advisory services (Consultancy and advisory services).

The majority of stakeholders are policymakers at either national or regional levels. Their inclusion underscores the importance of their contribution due to their i) provision of expert opinion to facilitate policy evaluation, ii) provision of crucial data regarding the implementation and progression of sub-measure 6.1, and iii) utilisation of valuable project outcomes (such as policy recommendations and knowledge) for designing future national CAP strategic plans. While a comprehensive list of contacted stakeholders was cited in D7.1, an updated list of contacted stakeholders for the Greek use case is provided in subsequent deliverables.

2.3.4 Generation of the synthetic population

The Greek use case was initially used for the initial work on the development of the synthetic population generator, quite successfully. The Greek partner AUTH had access to national data that showed suitable for the purpose of the population generator development.

Although the data used to validate the concept used to generate the synthetic population corresponded to Greece and certain regions under study, the variables presented in this dataset contained misalignments with the AGRICORE agent definition, thus leading to gaps in the data, and making it impossible to use to fully initialise the agents of the synthetic population. In addition, this dataset contained specific aggregations of variables that impeded a correct mapping between the data variables and agent parameters, leading to the conclusion that this dataset was not compatible with the overall AGRICORE approach. To solve this issue, a shift in the approach was made, and the synthetic population of the Greek use case was instead generated using the FADN data received.

As in the Polish use case, the dataset used to generate the Greek synthetic population contained some particularities taken from the Andalusian use case and key limitations regarding the number of variables permitted to be requested. Both constraints were crucial in the results obtained during the synthetic population generation process and the further analysis. More precisely, the issues led to missing key attributes during agent initialisation and a wrong representation of the agricultural landscape regarding the crop representativeness, resulting in a sparse presence of crops for the synthetic populations derived from using real data which led to an underrepresentation of the most relevant crops in the region. In general, the hindrances found were exactly the same as the ones explained in the Polish use case (2.2.4). This diagnosis led to the conclusion that the synthetic population was deficient and incomplete, and that further actions were required to overcome this situation.

The solution to fully obtain the set of variables used to fill the agent's parameters was to make a new request to FADN with an adequate selection of variables. However, by that date the project was in an advanced stage, very close to the deadline, and it was not feasible to perform such a request considering the timeframes that involve such a formal procedure and the approaching project deadline. For this reason, for this use case populations were generated, but their utility for simulation purposes was hindered by the limitations recently explained. Now, some of the results obtained during the generation process are shown to evaluate the results which, although not useful for practical purposes, is supported by a sound methodological approach.

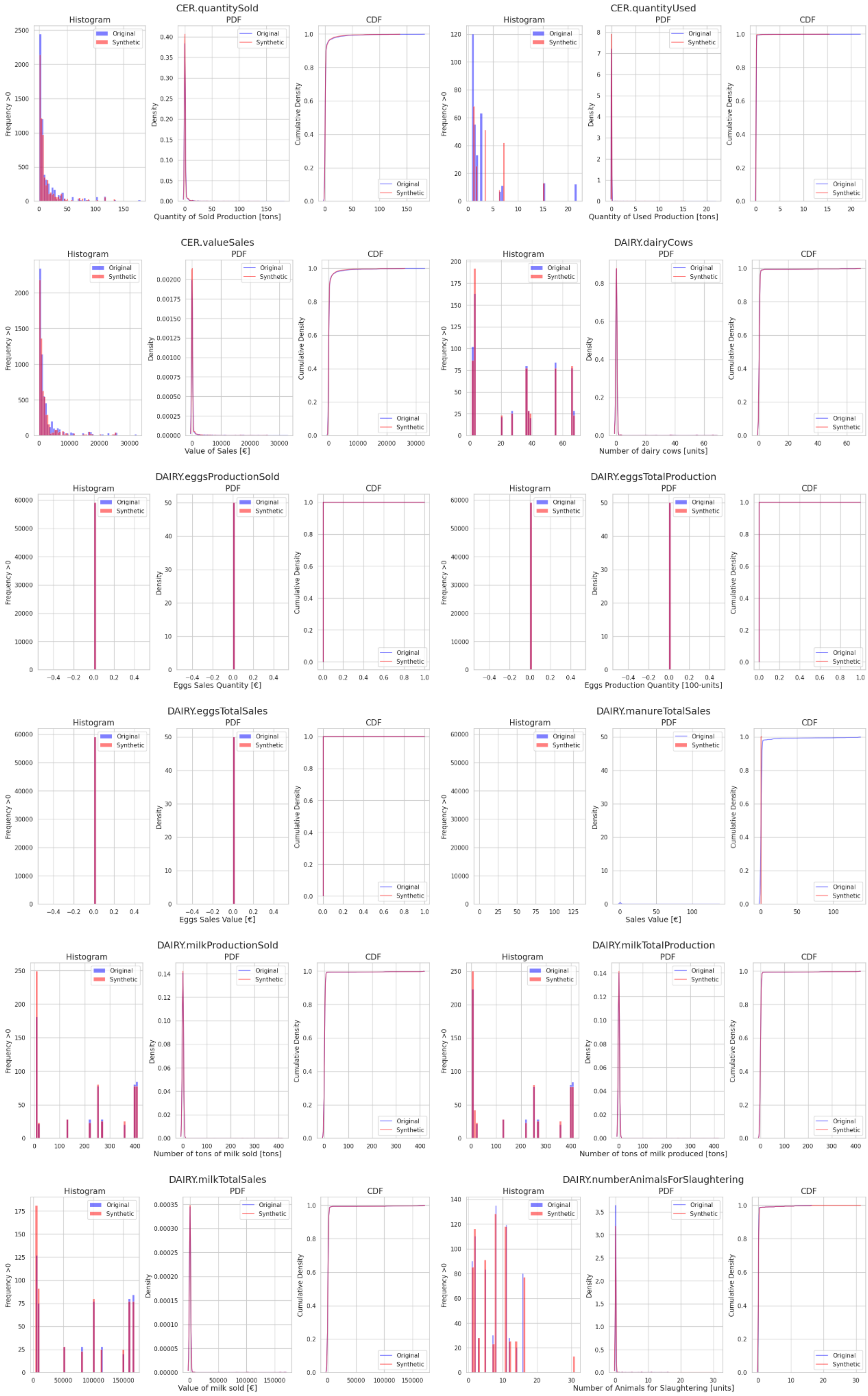


Figure 54. Greek use case: synthetic population comparison I

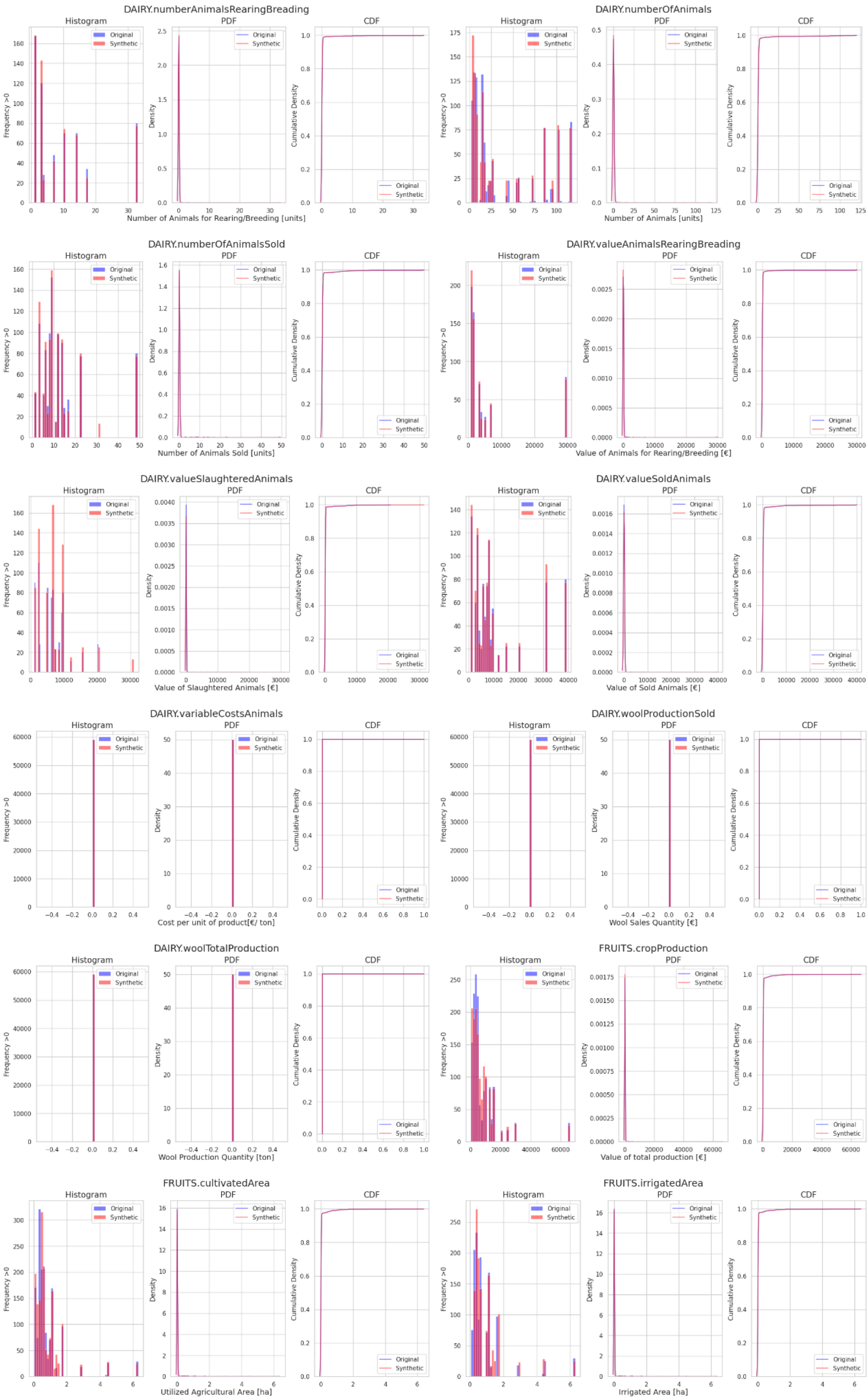


Figure 55. Greek use case: synthetic population comparison II

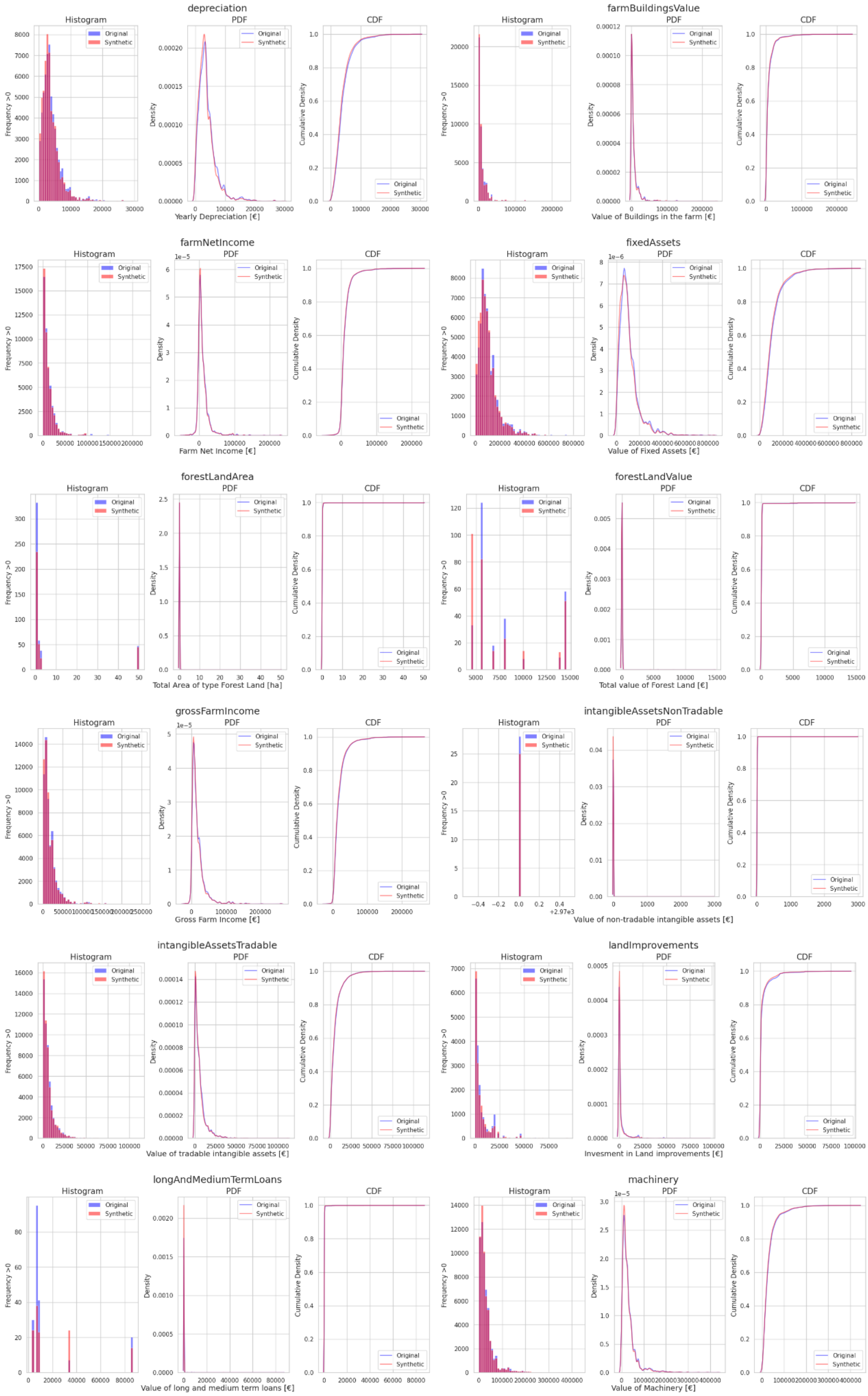


Figure 56. Greek use case: synthetic population comparison III

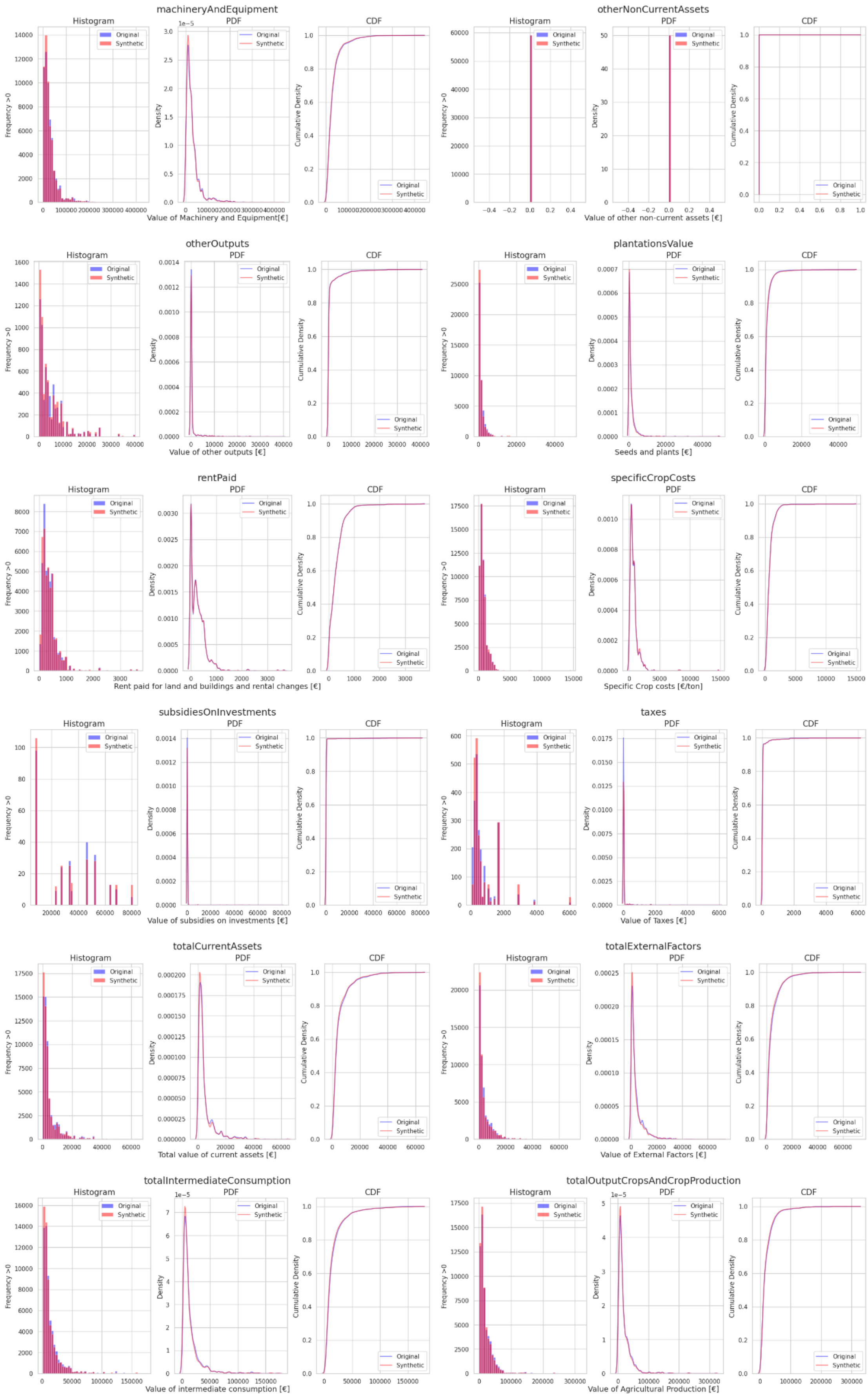


Figure 57. Greek use case: synthetic population comparison IV

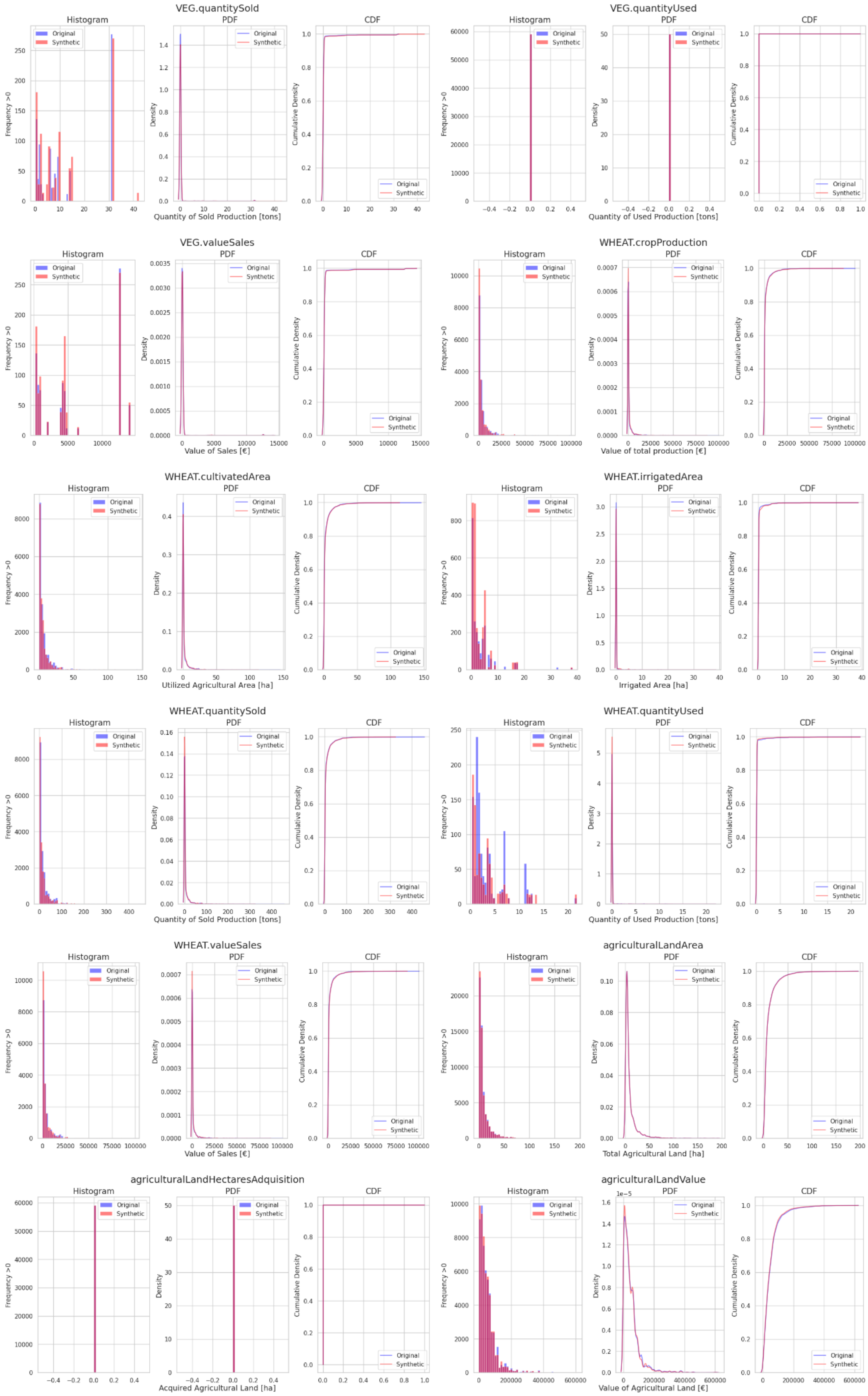


Figure 58. Greek use case: synthetic population comparison V

2.3.5 Simulation of the population

The synthetic population corresponding to the year 2014 obtained in the previous step wase used as a basis for performing the simulation of the Greece Use Case. The simulation was executed mainly with the goal of identifying any potential gap that could appear in future simulations once a correct Synthetic Population could be instantiated.

The first step to simulate in the AGRICORE suite was to select it from the available synthetic populations, as shown in next Figure 59.

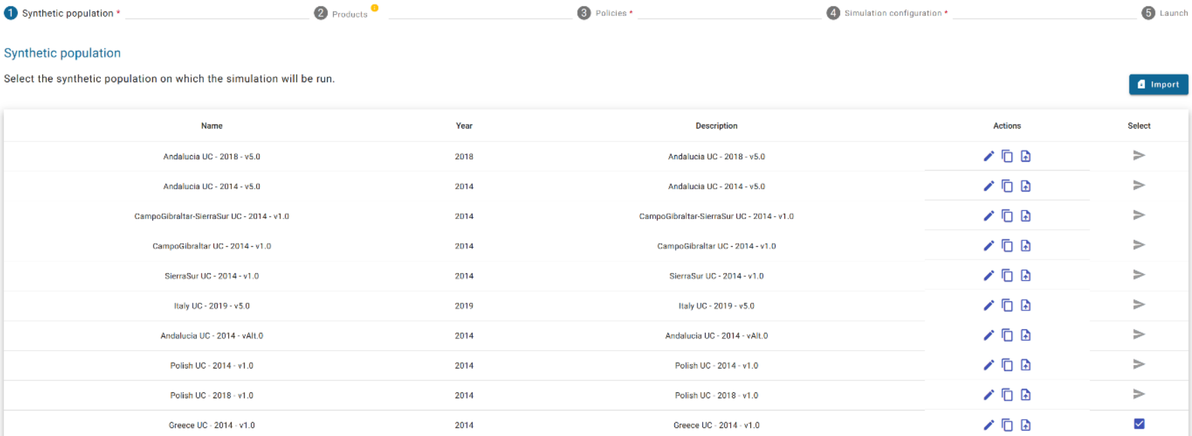


Figure 59: Selection of synthetic population for Greece 2014 SP

After the selection of the synthetic population, the grouping defined in the Synthetic population was verified across the uploaded data in the AGRICORE DWH. As shown in next Figure 60:

CUSTOM GROUP	FADN Included products	Product in RICA
CER	10130 - Rye 10140 - Barley 10150 - Oats 10170 - Rice 10190 - Other cereals for the production of grain	10130;10140;10150;10170;10190
FRUITS	10738 - Strawberries 10739 - Melons 40111 - Apples 40112 - 40113 - Peaches and nectarines 40114 - Other fruit of temperate zones 40115 - Fruit of subtropical or tropical zones 40120 - Berry species 40130 - Nuts 40210 - Oranges 40220 - Tangerines, mandarins, clementies and similar small fruits 40230 - Lemons 40290 - Other citrus fruit 40310 - Table olives 40320 - Olives for oil production (sold in the form of fruit) 40430 - Table grapes 40440 -	10738;10739;40111;40112;40113;40114;40115;40120;40130;40210;40220;40230;40290;40310;40320;40430;40440
GRAZING	10500 - Fodder roots and brassicas (excluding seed) 10910 - Temporary grass 30100 - Pasture and meadow, excludin rough grazing 30200 - Rough grazing 30300 - Permanent grassland no longer used for production purposes and eligible for the payment of subsidies	10500;10910;30100;30200;30300
MAIZE	10160 - Grain maize 10921 - Green maize	10160;10921

Figure 60: Representation of the product grouping in the Greece interface

Next, the simulation was configured in terms of the policies to be applied to the population. On a first instance, the subsidies that were already available in the data for year 2014 were reviewed, verifying that the data available in the original data sources and in the obtained synthetic population matched the one saved in the AGRICORE suite. The policies included are listed in next Figure 61. Next, a custom policy for Measure 6.1 was included in the long-term model (as it is the one that establish market entrance and successions).

Population Policies

Policy Identifier	Policy Description	Model Label	Economic Compensation	Start	End
1150	Basic payment scheme	Basic	4987.0874	2015	2030
1400	Payment for agricultural practices beneficial for the climate and the environment	Greening	2596.989	2015	2030
1600	Payment for young farmers		797.34503	2015	2030
1700	Small farmers scheme		923.66437	2018	2030
23111	Cereals		WHEAT:49.30091;CER:49.30091;MAIZE:49.30091;ORG_WHEAT:49.30091;ORG_CER:49.30091;ORG_MAIZE:49.30091	2015	2030
23113	Protein crops			2015	2030
2313	Potatoes		POTATO:1884.7697;ORG_POTATO:1884.7697	2015	2030
9900	Organic conversion of crops			2015	2020
9901	Organic olive conversion			2015	2020

Figure 61: Available policies in the SP for Greece 2014

Next, the simulation engine was configured to use the last version of the short term and long-term models available. The simulation horizon was set to 4 years that corresponded to the target period of 2014 to 2018. Moreover, the simulation was run including the long-term financial model (which can be disabled to use only the short-term one). The configuration of these parameters is shown in next Figure 62.

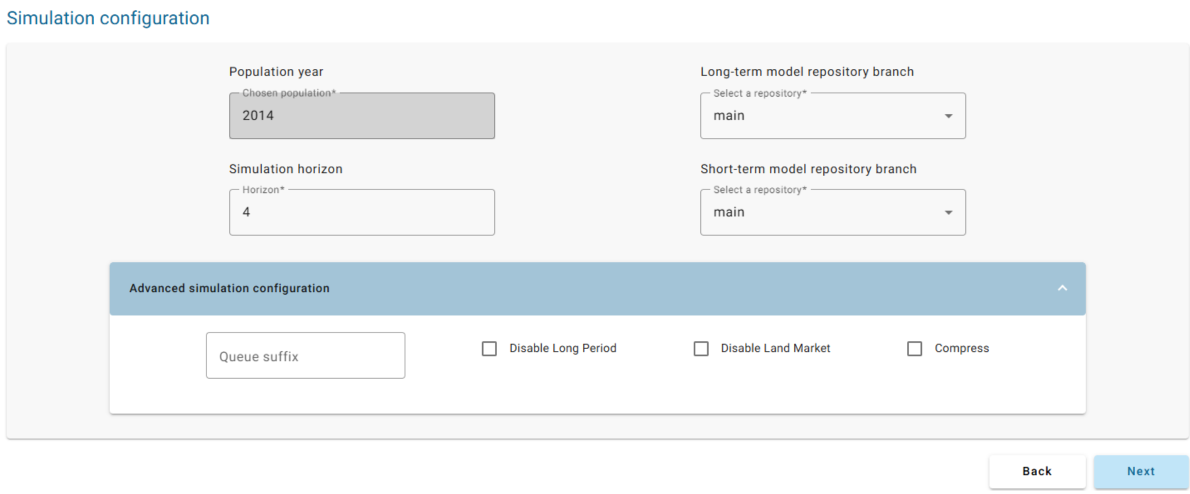


Figure 62: Configuration of the simulation for Greece 2014 SP

Finally, the simulation was launched using the AGRICORE interface (Figure 63Figure 45)

Figure 63: Simulation launching process for Greece 2014 SP

The last simulation performed took ~14 h, which accounting for a total of 59.049 simulated farms and 4 years of simulation gave a simulation rate of ~1.200 farms · year / hour. Considering the use of nonlinear models in the short-term model and the fact that the simulations were done with limited solver licenses (1 GAMS, 1 CPLEX) in a server with 16C / 32T and 128 GB of RAM, this figure is especially relevant and remark the work done in the speed up of the simulation through parallelisation techniques. However, a correct synthetic population for Greece with complete

FADN data should lead to a population of ~350.000 farms, which will require considerable more time to be simulated.

2.3.6 Results of the execution of the UC #3 – Greece

2.3.6.1 Ex-post impact assessment

The ex-post analysis of the performance and impact of *Measure 6.1 Settlement of Young Farmers* in Greece for the period 2014-2018 has been done based on the existing data published by the corresponding administrations (Greece National Census, FADN, ELSTAT), the results of the participatory research (presented in section 2.3.2 and D7.4 – Results on participatory research) and the findings acquired during its realisation. Please refer to such sections and the published paper - An Impact Assessment of the Young Farmers Scheme Policy on Regional Growth in Greece [39] for further details on the main conclusions of the assessment next presented

The introduction of Measure 6.1 has influenced positively the farming sector in Greece. Results indicate that regional output and employment are significantly benefited from the generation renewal policies while income generation is positive but at a lesser extent. Consequently, the Measure proves to stimulate regional output, refresh the agricultural population and enhance rural employment, and it can be a useful tool for policy makers to support rural welfare and maintain social and economic cohesion.

The major adoption factor of Measure 6.1 by young farmers is the presence of a farm in the family. Indeed, the majority (72.3%) of the analysed beneficiaries acquired their owned land through inheritance. Notably, 77.1% of young farmers reported that their farms were established before their participation (or intended participation) in Sub-measure 6.1. In this regard, it is worth noting that stakeholders believe the financial assistance provided to young farmers is less effective in cases where individuals must establish their agricultural holdings from scratch due to high initial costs, low profitability, and minimal return on investment. In general, descriptive statistics provide a non-encouraging assessment of the role of CAP incentives in general in attracting youth to work in agriculture beyond cases facilitated by inheritance and family ownership of the farms, and therefore are considered insufficient to achieve their overall aim, meaning the age restructuring of the agricultural sector.

The research indicates that, only 30.48% of participants cited Sub-measure 6.1 as the main driving factor for their engagement in farming. However, if the young farmers inheriting the family farm is discounted, the M6.1 payments represent the second main positive factor influencing the entrance on the sector, just after the pre-existent person desire to become a farmer. Overall, an overwhelming majority of young farmers (86.9%) expressed their intention to continue farming beyond the measure's commitment period. The main drawbacks identified by applicants of Measure 6.1 are the insufficient amount of subsidy, the complexity of the bureaucracy associated to the measure and the delays in payments by the government.

The results [39] of the current research imply that the Young Farmers Scheme is a critical contributor to regional growth, especially for output and employment. Payments from the Measure generated directly and indirectly €84,795,417.5 and 2287 new jobs for the Region of Thessaly and €167,746,774 and 4224 jobs for the Region of Central Macedonia. On average, Measure 6.1 "Establishment of Young Farmers" for the Rural Development Program 2014–2020 of Greece added 20% more jobs to the initial beneficiaries of the policy measure distributed to the rest of the economy and it has shown itself to be a significant tool for rural employment growth.

Regarding global quantitative indicators across Greece, the next main aspect can be analysed:

- As shown in next Figure 68, the number of beneficiaries of M6.1 in Greece by the end of 2018 was 15.585. Despite being a positive value, it seems insufficient to compensate the retirement ratio and to properly motivate a generation renewal. In 2016, 248,483 holders were aged over 65 in Greece according to ELSTAT, representing the 36% of the total. Measure 6.1 payments need to be coupled with additional measures that can alleviate other limiting factors, as existing financing gap and difficulties to access loans by young farmers (as the EAFRD financial instrument).

Sub-measure	Number of all submitted applications under the grant calls	Total support requested by all submitted applications (EUR million)	Number of approved and supported applications under the grant calls	Budget made available under the grant calls (EUR million)	Amount requested not being supported (EUR million)
4.1 Support for investments in agriculture holdings	15 364	933.4	8 182	316.0	617.4
6.1 Business start-up aid for young farmers	16 275	326.5	15 585	267.7	58.8

Figure 64: EAFRD Managing Authority 2019

2.3.6.2 Ex-ante impact assessment

The ex-ante analysis of the performance and impact of *Measure 6.1 Settlement of Young Farmers* in Greece for the period 2014-2018 has been done based on the figures obtained during the build of the synthetic populations (based on FADN data) for 2014 and 2018 and the results of the performed simulation. However, due to the issues presented in previous sections in the obtention of the required data for a proper generation of a reliable and comprehensive synthetic population, the scope of this is limited, and the values obtained are not properly aligned to observed behaviour. However, the AGRICORE consortium performed the simulation of the available policy to verify that the policies included in the simulation affected the result and to identify potential additional required improvements.

The focus has been put in the main quantitative KPI identified also in the ex-post analysis, this is the number of beneficiaries of M6.1: new farmers under 40 years becoming holders of farms:

- The sample data used to build the synthetic population did not contain information regarding the age of the holders. Moreover, the lack of key variables on it renders impossible to properly initialize the age of the holders using the data fusion techniques. Accordingly, the simulated data cannot be compared to the census information. However, the simulation still launches some insight on the potential positive impact of M6.1 in the penetration of young farmers (Figure 65). Indeed, simulation results indicate that around ~200 young farmers access the sector thanks to the subsidy incorporated in M6.1 which could be seen as a positive aspect. However, the comparison of this value with the population size (59.000 simulated farms) seems also insufficient. As a result, the ex-ante impact assessment in what regards to the successful adoption of M6.1 by farmers and the actual impact on the generation renewal is positive but very moderated.

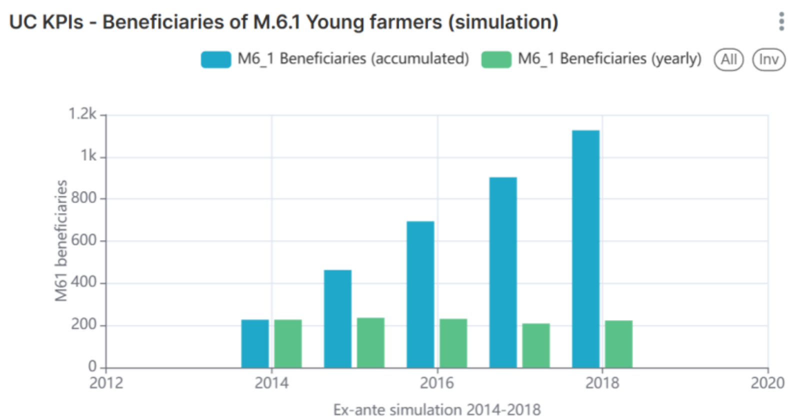


Figure 65: UC3 Simulation results on M61 beneficiaries

Nonetheless, the results should be considered with caution. The lack of relevance of the crops included in the synthetic population and the absence of key variables render the profitability of the farms instantiation an inter-year simulation completely inaccurate. Although the simulation results allow to verify the behaviour of the model, any derived figures (e.g. number of adopters) will be inaccurate, as in this case the profitability of the farm is a key aspect for the long-term model to determine farmers that retire and/or transfer their lands, key required elements to allow the entrance of new young farmers in the sector.

Conclusion

The ex-post impact assessment done during the project in parallel with the participatory research activities shown a positive impact of M6.1 towards the penetration of young farmers, although potentially insufficient to compensate normal ageing and retirement ratios. The performed simulations indicate a positive impact of the introduction of this measure in the simulation, but the inaccuracy and incompleteness of the used synthetic population does not allow to render final conclusions from the simulation results regarding adoption and impact of the targeted measure.

Overall, the authors conclude that further improvements need to be made in order to allow for proper simulation and analysis of the Poland farming sector under Measure 10.1. The main identified required upgrades are:

- The elaboration of a proper synthetic population. This will require a properly requested FADN dataset or access to the national version of the FADN. Once a satisfactory synthetic population is built and used to simulate, a thorough analysis of the results should be done to identify any potential deviation in the simulation results.
- Although already mentioned in the Andalucia's and Polish use case, the coupling with a CGE (i.e. MAGNET) is highly relevant to the simulation of employment related scenarios global effects can be better considered by the ABM when provided by a complete CGE embracing global economy data.
- The feasibility to access bank loans for agricultural initiatives could be improved in the long term and tailored to reflect the challenges of farmers when accessing the sector with no collateral.
- Additional KPI's could be added to estimate not only the direct impact of the new farmers penetration in the market but also the indirect ones.

2.4 UC#4 - An additional UC in Italy

2.4.1 Analysis of the use case context

The Italian use case has the particularity that was born during the execution of the project as an additional use case to test the ABM short-period model. It was possible due to the involvement of UNIPR, which had access to RICA microdata. This use case is at the regional level of Emilia-Romagna and studies the impact of introducing different levels of CO_2 taxation on GHG emissions produced by the livestock sector. For this reason, the use case aims to answer the two main research questions presented below by designing realistic policy scenarios under the European directives. Given the exceptionality of this use case, it is slightly different to the others because, for example, the conduction of a survey campaign was not envisaged. However, the participatory research was developed via other actions, such as contact with stakeholders and search for required non-public datasets.

2.4.1.1 Agricultural policy analysis

The Emilia-Romagna use case deals with a particularly relevant issue from a policy analysis point of view since the concentration of livestock activity in this region is such as to contribute significantly to water pollution and, more generally, to environmental sustainability. This issue, moreover, is common to other European regions and was considered useful for testing the ability of the several models developed in the BESTMAP and MINDSTEP projects to simulate GHG and ammonia taxation.Thus, the Italian use case does not address the impact of actual agricultural policies in the Emilia-Romagna regions. Instead, it tests the potential of the AGRICORE tool to simulate agricultural policies before its implementation as well as the environmental impact of those policies. The use case of Emilia-Romagna was therefore added to the three use cases foreseen to answer two main objectives underlying the following research questions:

- To what extent is the business model developed in the AGRICORE project able to simulate farmers' behaviour in a short-term perspective taking into account the context of the new CAP and the interactions with other farmers in their region?
- To what extent does the taxation of ammonia produced by dairy farming influence farmers' short-term choices with respect to: the definition of the production plan and land use, the profitability of farms, the strategy of varying the farm production size by leasing additional land and finally in the relationship with the environment? To better define the possible impacts, the following scenarios were considered:
    - The first scenario (s_cal) reproduces the farm decision observed at the time of model calibration.
    - The second scenario (s_land) gives the possibility to exchange arable land by renting or renting out land as a consequence of the possibility of determining an optimal use of farm resources. The cost of renting a hectare of arable land is set at 589 € according to [41]. This scenario is considered as baseline and provides the comparison term with the other six scenarios described below.
    - The third (s_em20), fourth (s_em50), fifth (s_em100), and sixth (s_em150) scenarios consider four different CO2 taxation levels (20, 50, 100, 150 €/tCO2eq).
    - The seventh scenario (s_Nitrogen) simulates the right to spread manure according to the EU Nitrate Directive 91/676/CEE [42], which aims at reducing and preventing nitrates water pollution from agricultural sources. The Nitrate Directive requires Member States to be responsible for identifying pollution sources, designating “Nitrate Vulnerable Zones” (NVZs) and designing appropriate action programs; moreover, it sets a limit of 170 kg of nitrogen from livestock manure that can be spread annually over one hectare. Farm holders

under the constraint of 170 kg of N/ha and based on (i) the quantity of nitrogen produced by their livestock and (ii) their Utilized Agricultural Area (UAA), can decide to either reduce the number of cows, or rent more land from non-livestock farms, to spread the exceeding manure. Dairy farmers can acquire rights to pollute to spread the exceeding manure from non-livestock farms that need nitrogen fertilizers, paying a cost of 150 €/ha. In addition, the distribution cost of exceeding manure is set to 69€/ton of nitrogen, based on the average price (80 €/hour) and capacity (4.5 tons of manure) of a manure tank, and the nitrogen content of dairy cow manure (0.42%). The economic convenience will drive the choice. Transportation cost is not considered, as farms are not geolocated within the FADN sample.

All the above scenarios include default policy measures of CAP 2023-2030, such as greening payment, single payment and crops coupled payment, funded through Pillar I, according to the 2014-2020 CAP reform. Moreover, it has been considered that farmers over 65 and no successors will receive a retirement pension of 1,000€/month. Besides carbon emissions and nitrogen production, also water consumption is evaluated using water footprint data.

2.4.1.2 Situation of the agricultural sector in the framework of the use case

According to the 2020 Census of Italian Agricultural Structure [43], in Emilia Romagna in 2020, there were 53,753 farms (4.7% of those in Italy), just under a third of the 170,000 farms recorded in 1982 (Figure 28). The greatest collapse occurred with the new millennium, although in the Region, this process had already begun to manifest itself since the 1990s. The maximum peak was reached in the first decade with a closure of about 30.8% of farms, and then subsided, at least partially, in the most recent decade (-26.8%). In Emilia-Romagna, the smaller reduction in the agricultural area compared to the decrease in the number of farms has led to a sharp increase in the average farm size, reaching almost 20 hectares of UAA, more than doubling those of 1982 (7.5 hectares). The increase in average size has been particularly remarkable in the new millennium, with an increase in UAA of as much as 10 hectares compared to 2000. The regional average sizes are among the highest at the national level, where they are significantly lower (11 hectares UAA).

The 2020 Census of Agriculture, confirming the profound structural change of regional farms in the new millennium, highlighted the concentration of areas in farms of increasingly larger widths. Over the last decade, the decline in holdings has affected all size classes below 50 hectares of UAA, with decreasing intensity as size increases. In fact, the reduction in holdings is -33.7% in those under 10 hectares UAA (-30.9% UAA), -22.9% in those between 10 and 20 hectares and finally -9.1% in those between 30 and 50 hectares. On the other hand, the number of farms with more than 50 hectares (+8.7%) and their UAA (+10.2%) are increasing, especially those larger than 100 hectares (+32.0% of farms and +34.9% of UAA) (Figure 29).

In 2020, therefore, there is a strong downsizing of holdings with less than 10 hectares of UAA; these are 32,418 holdings (more than two-thirds of the total), which manage 127,000 hectares, just over 12% of the regional UAA compared to 17% in 2010 and more than 23% in 2000. Holdings with a size between 10 and 20 hectares (9,102, 16.9% of the total), occupy 128 thousand hectares of UAA (-22.9% compared to 2010), representing 12.2% of the total, compared to 18.5% in 2000. Holdings with a size between 10 and 20 hectares (9,102, 16.9% of the total), occupy 128 thousand hectares of UAA (-22.9% compared to 2010), representing 12.2% of the total, compared to 18.5% in 2000. Holdings with a size between 20 and 50 hectares (7,521 and 14% of the total) manage 233 thousand hectares of UAA, decreasing both in number (-13.8%) and in their agricultural area (22.3% of the total compared to 25.2% in 2010). The set of farms with size classes from 10 to 50 hectares of UAA, albeit with their differentiations, still represents more than 30% of farms and almost 35% of the regional UAA, values that are almost similar to the national averages. The large farms, with at least 50 hectares of UAA, number 4,712 (less than 9% of the total), but manage 556 thousand hectares of UAA, more than half of the regional UAA (53.3%), a value well above the national average, second only to that of Lombardy. In 2010, these farms numbered 4,063 (5.5% of the total) and occupied 42% of the regional UAA, just over a third in 2000.

The distribution of UAA by size classes in Emilia-Romagna highlights the profound change that has taken place in the last 40 years (1982-2020). The role and importance of small-sized farms, with less than 10 hectares of UAA, have been completely overturned compared to that of farms larger than 50 hectares. Holdings with less than 10 hectares (12.2% of the regional UAA in 2020) managed 35% in 1982. Although their numerical importance remains prevalent, their incidence has decreased from 80% in 1982 to 60.3% in 2020. In contrast, holdings larger than 100 hectares, which occupied 13.1% of the UAA in 1982, now manage 33.3%. Even when considering holdings under and over 20 hectares, the results clearly show the concentration of UAA in the larger ones. In fact, holdings over 20 hectares (42.6% of the UAA in 1982) occupy 75.6% in 2020, while those under 20 hectares dropped from 57.4% to 24.4% of the UAA in the same period.

Years	Absolute Value		
	Farms #	UAA (Ha)	Average UAA /farm (Ha)
1982	171,482	1,290	7.5
1990	148,057	1,249,163	8.4
2000	106,102	1,129,279	10.6
2010	73,466	1,064,213	14.5
2020	53,753	1,044,820	19.4

Figure 66 Farms and UAA in Emilia Romagna - 1982 -2020

	Farms #		Distribution %		Variation %	UAA (,000 Ha)		Distribution %		Variation %
	2020	2010	2020	2010	2020/2010	2020	2010	2020	2010	2020/2010
< 0,99	4043	6799	8.2	9.3	-35.2	1.976	3.552	0.2	0.3	-44.4
1 - 1,99	4,909	8,764	9.1	11.9	-44	6.944	12.454	0.7	1.2	-44.2
2 - 2,99	4,473	7,017	8.3	9.6	-36.3	10.767	16.955	1.0	1.6	-36.5
3 - 4,99	7,542	10,756	14	14.6	-29.9	29.151	41.670	2.8	3.9	-30.0
5 - 9,99	11,091	15,539	20.6	21.2	-28.6	78.607	109.744	7.5	10.3	-28.4
10 - 19,99	9,102	11,807	16.9	16.1	-22.9	127.604	164.779	12.2	15.5	-22.6
20 - 29,99	3,799	4,628	7.1	6.3	-17.9	91.929	112.292	8.8	10.6	-18.1
30 - 49,99	3,722	4,093	6.9	5.6	-9.1	141.523	155.627	13.5	14.6	-9.1
50 - 99,99	3,036	2,793	5.6	3.8	8.7	208.679	189.415	20.0	17.8	10.2
> 100 ha	1,676	1,270	3.1	1.7	32	347.643	257.724	33.3	24.2	34.9
Total	53,753	73,466	100	100	-26.8	1,044.823	1,064.214	100.0	100.0	-1.8

Figure 67 Farms and UAA per farm-size 2010 -2020

According to the 2020 census of agriculture [43], in the last forty years, cattle breeding in Emilia-Romagna has consistently decreased both in the number of holdings (-88%) and in the number of head of cattle bred, going from 1 million in 1982 to almost 582 thousand in 2020 (-45%). The reduction was extreme in the nineties, both in the number of holdings (-50%) and in the number of heads (-28%), but in the new millennium, the drop in heads has lessened, recording a slight increase in the last decade (+4%). In 2020, the number of cattle farms was reduced to only 4,900, compared to 12,000 in 2000 and 41,000 in 1982. In the new millennium, the reduction in herds has continued (-60%), with a decrease of one-third (-33%) in the last decade as well. The smaller decline in the number of animals compared to the number of herds has led to a progressive increase in their average size, from just 26 animals forty years ago to 52 in 2000 and reaching 119 animals in 2020 (Figure 30).

Dairy cows comprise 47% of the regional cattle herd and 17% of the country's dairy cows, showing an even greater concentration process. In 2020, there are 271,000 dairy cows in the Region; the average size of the cowsheds is almost 95 head, compared to 58 in 2010, just over 36 in 2000 and 21 in 1990. The concentration process has been particularly relevant in the new millennium; in 2010, 44% of dairy farms, almost all of which were under 50 heads, had disappeared, with a 10% reduction in the number of heads, and 70% of heads were concentrated in farms with more than 50 heads.

	1982	1990	2000	2010	2020
Dairy Farms	41,109	24,361	12,183	7,357	4,900
Dairy Farms with Cows	31,050	18,223	7,688	4,272	2,876
Cattles (Heads)	1,067,713	878,064	627,964	557,231	581,811
Cows (Heads)	380,718	376,904	275,838	247,632	271,072
Cattles/Farm	26	36	52	76	119
Cows/Farm	12	21	36	58	94

Figure 68 Dairy farms, cattle, cows and dairy size 2010 - 2020

The Italian use case aims to assess the likelihood of dairy farmers accepting predefined policy scenarios that imply different levels of CO_2 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. Considering this 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 GHG and ammonia emissions, Emilia-Romagna was considered an ideal region to assess the impact of the introduction of GHG and ammonia taxation on the farmers' production choices.

2.4.1.3 Collection and characterisation of data sources and information of interest

For the Italian use case, the data collection process was limited to the FADN microdata. In the 2020 Italian FADN, the Emilia-Romagna agricultural system is described as a farm sample represented by 710 farms. It includes farms with different levels of specialisation which interact between them. Considering the “weighted factor”, which reproduces the representativity of each observed farm to the whole universe, the model reproduces the behaviour of the 35,459 farms settled in that region. Farms having more than 1,000 ha have been then removed from the sample as not statistically representative (see Figure 31). Moreover, the sample distinguishes between farms specialized in dairy cattle (dairy farms) and farms with other technical orientations (other farms).

Farm Technical Orientation	Type of Farming	Sample	Weighted Sample
Arable crops	1	310	15,351
Horticulture	2	8	411
Permanent crops	3	160	9084
Dairy cattle	450	91	3306
Other herbivores	460; 470; 481; 482; 484	24	2308
Granivores	5	30	677
Polyculture	6	67	3371
Mixed farming	7	2	33
Mixed (crop–livestock)	8	18	919
Total		710	35,459

Source: Emilia-Romagna 2020 FADN.

Figure 69 Number of farms in the Emilia-Romagna 2020 FADN by type of farming.

The sample also reflects the socio-economic structure of the Emilia-Romagna 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%. Most of the farms are located on flat lands (69%) (see Figure 32).

Technical Orientation	Dairy Farms			Other Farms			Total	%
Holder's Age	**≤40**	**41–64**	**≥65**	**≤40**	**41–64**	**≥65**		
<10 ha		289	68	593	7235	7696	15,879	44.8
10–20 ha	191	189	153	444	3248	4153	8379	23.6
20–50 ha	121	850	326	295	3161	2365	7120	20.1
50–100 ha	84	304	372	187	1404	380	2730	7.7
100–300	30	200	129	93	496	247	1196	3.4
>300 ha	0	0	0	31	109	15	155	0.4
Total	426	1831	1049	1644	15,654	14,856	35,459	
%	1.2	5.2	3.0	4.6	44.1	41.9		

Source: Emilia-Romagna 2020 FADN.

Figure 70 Emilia-Romagna 2020 FADN sample composition according to holder's age, type of farming and farm dimension.

2.4.1.4 Detection of information gaps

Given the particularity of this use case, there are no information gaps, as it was limited to the data included in the FADN. This meant that the use case was marked by the FADN's own limitations in terms of sample resolution and data. As a consequence, the participatory research actions were basically limited to presenting the progress and results of applying the ABM short-period model to the Emilia-Romagna region.

2.4.2 Short-period model in the Italian use case

For the use case of Emilia-Romagna, participatory research actions were limited, but rather, a short-period model was developed. This latter integrates the principles of agent-based models (ABM) with the Positive Mathematical Programming (PMP) approach. ABMs allow to evaluate agricultural policies and farmers' level of acceptance, simulating interaction between farmers taking territorial specificity and farm heterogeneity into account.

ABMs are models composed of a set of decision-makers (the agents) and an environment in which these agents interact with each other. They require rules to define the relationships between the agents and the relationships between the agents and their economic and bio-physical environments, as well as rules defining the sequence of actions occurring in the model. In agro-economics, they have been heavily used for simulating land-use choices based on an agent's utility derived from land and as a tool to explore the potential of landscapes to provide multiple ecosystem services. The acting agent, with pre-defined behavioural rules set at the individual farmers' level, seems to be the appropriate starting point for explaining or predicting the choices between different options.

Like mathematical programming (MP) farm models, ABMs can represent agents' behaviour regarding their production choices: what products to market, what technologies to adopt, what production factors to use (land, labour, water, etc.), and in what quantities. In the Emilia-Romagna model, the agents are represented by individual farm holders who exchange production factors, mainly land, but also rights to pollute (nitrate spreading). The model simultaneously optimises the use of land and rights to pollute for each sample agent. Thus, the decisions of each farmer, according to his/her economic advantage, impact the behaviour and decisions of the others. Some farmers will lease land and the right to pollute, while others will rent it, changing their production structure. The Emilia-Romagna model captures farms' heterogeneity in terms of farm structure and production strategies but also in terms of the interactions between farms in the use of scarce resources and evaluating structural changes under the assumption of not-fully rational production choices, maximising the utility function rather than than the profit function. Agents and the environment in which they operate are defined based on their characteristics. The agents' attributes considered are the age of the farmholder and the presence of heirs. As far as the environment is concerned, altitude and agrarian regions are considered. Individual attributes trigger behavioural rules, more precisely:

- Farmholders older than 65 and with no successor receive a monthly retirement pension and do not rent additional land.
- Farmers located in NVZ limit manure spreading to 170 kg per hectare, whereas elsewhere, this limit is set to 340 kg/ha, and in both cases, farmers are pushed to rent out their land if unused.

The model represents farmers not just as individual entrepreneurs but rather as farmhouse holders, with room in the decision-making process for mediation between family members, which may generate economic inefficiencies. Agents decide on the basis of endowment factors, technological knowledge, and individual perception of the economic and technical risks, and these decisions represent the agents' optimal economic choice. This representation is possible because agent-based farm models can, in sum:

- consider the individual farms and farm households' heterogeneity,
- reproduce production choices based on the observed activities,
- and depict the production specializations and the technologies used.

The literature counts some attempts to assess the effect of the CAP measures through ABMs, such as AgriPoliS, MP-MAS, LUDAS, RegMAS, and SWISSland [44] [45] [46] [47] [48]. Normative MP models, such as AROPAj, [49] are well suited to assess what production system changes are needed to reduce GHG emissions but are not appropriate to represent agents as described above, as they assume that farmer behaviour is fully rational and do not correctly estimate all of a farmer's explicit and implicit costs. Empirical evidence has shown that solutions obtained using the normative MP model calibration phase differ from the observed data [50].

Positive mathematical programming models, on the other hand, are based on the assumption that the observed production level, reproduced in the calibration phase, is the result of the optimal agent choices. Some examples of well-established models based on PMP and used for policy assessment are IFM-CAP [51], which links emissions factors directly to the more granular defined production activities, and FARMDYM, which incorporates detailed emission accounting for different GHGs.

However, one critical aspect of PMP is an estimation of the explicit variable costs per crop with only the total variable costs per farm available. The Generalized Least Square (LS) method, used in the Emilia-Romagna model to estimate the cost function, enables calibration by overcoming the criticisms of Paris's three-step approach. This LS method, based on two steps, has the advantage of avoiding the unsolved problems of the arbitrary use of support values needed in the Maximum Entropy procedure while using econometrics to correctly estimate the cost function, even in the absence of exogenous accounting costs. The cost function, estimated in this way, makes it possible to differentiate the total variable costs of each crop between the explicit and implicit costs, relating to the agent's choice of what to produce and how. The calibration phase is followed by the simulation phase, which reproduces farmer behaviour triggered by new market and agricultural policy scenarios. The possibility of estimating an unambiguous cost function for each agent makes it possible to show a representation of the farm heterogeneity.

The PMP approach, developed according to the seminal work of Paris and revised using the generalized LS method, introduces the following elements:

- Farmer heterogeneity is made possible by an individual cost function for each farm in the sample.
- Calibration is performed for each farm, reproducing its observed activities using "self-selection".

It can also reproduce an agent's "willingness" to adopt these activities that satisfy their family strategy while being aware of alternative available processes.

- The exchange of resources (land, labour, water, etc.) between agents is made possible by links between farms.
- Technology transfer between agents is simulated by using the common cost function matrix, which, in the event of changes in market or policy scenarios, provides farmers with the economic and technological information related to those activities not included in their production plan, but which could be added or could replace the existing one(s).

To simulate the effects on farmers' gross margins and structural changes caused by the introduction of carbon taxes, as well as other environmental constraints, agents (farmholders) are initialised with socio-economic characteristics (e.g., farmer age and family composition) and farm structure. The model considers the "short period" and runs in GAMS, with a two-stage structure: the calibration phase, which represents the "positive" component, and the simulation phase, which represents the "normative" component of the model. The short-period Emilia-Romagna Model represents the methodological base of the short-period AGRISP model with the use of the synthetic population derived from FADN data.

2.4.2.1 Analysis of short-period model test results on farm structure, land use and carbon emissions

Results from short period analysis show interesting indications in terms of impacts on the Emilia-Romagna agricultural system.

The exchange land scenario highlights how farmers opt for a more efficient combination of the limiting factor land. As described above, farmers can adopt a structural strategy of renting out all their land and abandoning the market or renting out just a part of their land and continuing farming. The impact of these strategies on the number of farms is depicted in Figure 33.

	Dairy farms		Other farms		Total	
Farm dimension	s_cal	s_land	s_cal	s_land	s_cal	s_land
<10 ha	6	7	237	199	243	206
10-20 ha	11	15	125	115	136	130
20-50 ha	39	42	151	147	190	189
50-100 ha	26	20	67	71	93	91
100-300 ha	9	6	34	37	43	43
> 300 ha	0	0	5	4	5	4
tot	91	90	619	573	710	663

Figure 71 Number of farms and class of size

Overall, with respect to the observed scenario (s_cal), the number of farms decreases from 710 to 663 (-6.6%), with a bigger impact on the non-dairy farms (-7.4%) than on the dairy ones (-1.1%). The number of farms decreases mostly in the size range <10 ha (-37 farms). This result demonstrates how the structural adaptation strategy leads farmers to find new forms of economic efficiency. Considering the land exchange scenario (s_land) as a baseline, the assessment of the policy scenarios on all the farms shows a net effect on farm structure (Figure 34).

Dairy farms	s_land	s_nitrogen	s_em20	s_em50	s_em100	s_em150
<10 ha	7	5	7	8	12	14
10-20 ha	15	19	18	14	16	10
20-50 ha	42	40	39	41	33	35
50-100 ha	20	20	20	19	23	23
100-300 ha	6	6	6	7	5	6
> 300 ha	0	0	0	0	0	0
TOT	90	90	90	89	89	88
Other farms	s_land	s_nitrogen	s_em20	s_em50	s_em100	s_em150
<10 ha	199	199	194	194	193	191
10-20 ha	115	115	116	116	117	115
20-50 ha	147	147	148	148	147	147
50-100 ha	71	71	71	71	70	70
100-300 ha	37	37	37	38	37	37
> 300 ha	4	4	4	3	5	5
TOT	573	573	570	570	569	565
all farms	663	663	660	659	658	653

Figure 72 Number of farms per policy scenario and class of size

Figure 34 shows a constant decrease in the number of farms (dairy and non-dairy), with 10 farms deciding to abandon the activities when the heaviest CO_2 tax (“s_em150”) is introduced. The ones leaving the market are mainly non-dairy farms, while in the dairy sector, the impact is limited. The number of smaller dairy farms (<10 ha) increases despite the introduction of the tax. This trend could be explained by the fact that as taxes rise, farmers rent out part of their land to cover their production costs but still manage to remain in business. The introduction of the Nitrate Directive (“s_nitrogen”) has no influence on the number of farms.

Figure 35 depicts the influence of policy scenarios on farms’ gross margins.

Regional Gross Margin	s_land	s_nitrogen	s_em20	s_em50	s_em100	s_em150
Million €	1050.0	1040.6	1005.1	944.74	860.31	788.36
% variation	-	-0.9	-4.3	-10.0	-18.1	-24.9
GM/ha	s_land	s_nitrogen	s_em20	s_em50	s_em100	s_em150
€/ha	1258	1246.9	1204.4	1132.0	1030.9	944.6

Figure 73 Influence of policy scenarios on farms' gross margin

Gross margin reduces slightly in scenario "s_nitrogen", but the reduction is substantial and increases along with the tax increase (from -4.3% with a tax of 20 €/tCO_2eq, up to -24.9% in "s_em150").

Figure 36 and Figure 37 describe farmers' production plans regarding land allocation and the variation considering "s_land" as the baseline scenario.

UAA (1000 ha)	s_land	s_nitrogen	s_em20	s_em50	s_em100	s_em150
CEREALS	194.44	195.66	199.36	200.96	206.51	210.73
FORAGES	324.38	326.03	349.76	366.23	377.98	384.29
MAIZE /SILAGE	77.44	74.18	67.62	53.93	40.30	31.15
PROTEIC/OILSEEDS	61.15	61.50	64.54	64.40	64.38	64.73
MEADOWS PASTURES	66.93	66.86	65.97	64.79	64.77	64.75
OTHER	107.15	107.26	84.22	81.10	77.43	75.38
GREENING	3.06	3.06	3.08	3.15	3.18	3.53

Figure 74 Land allocation by crop type

% variation	s_nitrogen	s_em20	s_em50	s_em100	s_em150
CEREALS	0.6	2.5	3.4	6.2	8.4
FORAGES	0.5	7.8	12.9	16.5	18.5
MAIZE /SILAGE	-4.2	-12.7	-30.4	-48.0	-59.8
PROTEIC/OILSEEDS	0.6	5.5	5.3	5.3	5.9
MEADOWS PASTURES	-0.1	-1.4	-3.2	-3.2	-3.3
OTHER	0.1	-21.4	-24.3	-27.7	-29.7
GREENING	0.0	0.5	2.7	3.8	15.2

Figure 75 Percentage variation in land allocation compared to s_land

The introduction of taxation also generates a significant effect on the farms' productive organisation by modifying land use. The "s-nitrogen" scenario, while not affecting the number of farms, modifies the production organisation by reducing the area allocated to silage for cows outside the Parmigiano Reggiano PDO area. On the other hand, the scenarios that foresee increasing taxation push farms towards more extensive management of crops with less environmental impact. In fact, the most penalized crops by taxation are maize-silage and industrial crops (others), which are reduced by 60% and 30%, respectively. Conversely, these crops would be replaced by fodder crops (+18.5%), cereals (+8.4%) and set-aside (+15.2%). All the policy scenarios introduced shown a decrease in the number of dairy cows (Figure 38).

LIVESTOCK UNTS	s_land	s_nitrogen	s_em20	s_em50	s_em100	s_em150
n. of dairy cows	228130	209050	202020	158510	109120	77914
% variation	-	-8.4	-11.4	-30.5	-52.2	-65.8

Figure 76 Variation in number of dairy cows

The decrease is due to the introduction of nitrogen pollution quotas in "s_nitrogen", both to the introduction of CO_2 taxation that impacts GHG emissions associated with milk production.

Figure 39 and Figure 40 show variations in carbon emission.

CO2 EMISSION (1000 tCO2eq)	s_land	s_nitrogen	s_em20	s_em50	s_em100	s_em150
CEREALS	334.6	337.8	326.0	318.7	313.4	305.5
FORAGES	164.9	165.9	180.7	189.2	195.4	198.4
MAIZE /SILAGE	227.4	217.3	194.5	156.2	113.9	85.4
PROTEIC/OILSEEDS	52.7	52.9	54.8	54.4	54.2	54.5
MEADOWS PASTURES	149.9	149.7	147.8	145.1	145.1	145.0
OTHER	175.0	173.5	138.5	132.1	124.9	121.2
DAIRY COWS	1254.7	1149.8	1111.1	871.8	600.2	428.5
TOTAL	**2359.3**	**2246.9**	**2153.5**	**1867.5**	**1547.0**	**1338.6**

Figure 77 Variation in carbon emission

% variation	s_nitrogen	s_em20	s_em50	s_em100	s_em150
CEREALS	0.9	-2.6	-4.8	-6.4	-8.7
FORAGES	0.6	9.6	14.8	18.5	20.3
MAIZE /SILAGE	-4.5	-14.5	-31.3	-49.9	-62.4
PROTEIC/OILSEEDS	0.4	4.0	3.2	2.8	3.4
MEADOWS PASTURES	-0.1	-1.4	-3.2	-3.2	-3.3
OTHER	-0.9	-20.8	-24.5	-28.6	-30.7
DAIRY COWS	-8.4	-11.4	-30.5	-52.2	-65.8
TOT	**-4.8**	**-8.7**	**-20.8**	**-34.4**	**-43.3**

Figure 78 Percentage variation in carbon emission compared to s_land

Compared to s_land, in s_nitrogen carbon emissions decrease by -4.8%. The products most impacted are dairy milk (-8.4%) and maize/silage (-4.5%). Emissions related to cereals and forages slightly increase. In the CO_2 taxation scenarios, overall CO_2 emissions drop down respectively by -8.7%, -20.8%; -34.4% and -43.3%. Decreasing in dairy products, maize and silage, other crops and cereals. Forage emissions increase.

The environmental policy tools developed through the post-2020 reform represent a new phase of the European Common Agricultural policy. The need for models capable of assessing policies' goals ex-ante by simulating agents' behaviours based on their socio-economic characteristics and their relationship with the geographical context becomes a must. These micro-based farm models can evaluate price-cost market dynamics, farmers' aptitude to change production plans under economic, market, technological and environmental scenarios, as well as the ability of farmers to deal with critical environmental variables.

Supply-side farm models, while accurately representing the entrepreneur's strategies, have the limitation of assuming the farm as a “close” production system whose decisions consider only the available production resources. In the real word, farmers exchange production factors, in particular land, as a possible strategy to adapt to changes in their marginal value. The effect is that some entrepreneurs rent out land to more productive farmers who instead expand their activity by pursuing economies of scale and scope. Thus, the assessment of the CAP’s impact on the environment must use new analytical tools capable of capturing the interactions between farmers, and the interaction between farmers and the surrounding socio-economic and natural environment. ABMs proved to be particularly effective in this context, also because they allow researchers to consider specific social farms households’ attributes.

The repercussion of CO_2 taxation on farms’ structure and rural regions, reveled through the use of agent-based models, is significant. If output prices are assumed to remain unvaried, CO_2 taxation will impact the most polluting processes (intensive crops and dairy cows) and the more intensive farms that will then opt for new production strategies to become more environmentally sustainable. Increased environmental sustainability is due to (i) reduced soil pressure (fewer animals per hectare), (ii) use of more sustainable fodder and (iii) the possibility of redistributing nitrate quotas to non-livestock farms. However, the possibility of exchanging land favours the most efficient farms, which increases their size to the detriment of inefficient farms, with consequent economic and social impact.

The Emilia Romagna case is emblematic as the wealth and welfare generated by PDO cheeses such as Parmigiano Reggiano, which led over time to increasing environmental pollution and creeping structural reform pushing small-scale farms to leave the market. While environmental pollution can be countered with targeted policies, such as effluent taxation, the effect on the socio-economic structure requires the use of a more complex set of interventions that the Rural Development Plan must address.

2.4.3 Interaction and engagement with stakeholders

The results of the model were presented and discussed with the managers of the Emilia Romagna Region's Department of Agriculture. The debate focused on the usefulness of these models for an ex-ante evaluation of the possible impacts that agricultural and environmental policies could have on local production systems. The complexity of the new CAP, together with the structure of the new Delivery model, in fact, requires an increasing ability to estimate and evaluate the effects that could be generated. Last but not least, there is considerable concern about the negative impacts on the agricultural system of the Parmigiano Reggiano PDO and the related consequences on the rural development process.

Table 4 Contacted stakeholders in the Italian use case

Affiliation	Role	Name
Assessorato Agricoltura Regione Emilia Romagna	Regional Minister of Agriculture	Dr. Alessio Mammi
Assessorato Agricoltura Regione Emilia Romagna	Department Director	Dr. Valitiero Mazzotti
Assessorato Agricoltura Regione Emilia Romagna	Officer	Dr. Paola Frontali
Assessorato Agricoltura Regione Emilia Romagna	Officer	Dr. Marco Vitale

Assessorato Agricoltura Regione Emilia Romagna	Officer	Dr. Barbara Bagolati
Assessorato Agricoltura Regione Emilia Romagna	Officer	Dr. Alessandra Nipoti
Assessorato Agricoltura Regione Emilia Romagna	Officier	Dr. Alessandra Falzone
Assessorato Agricoltura Regione Emilia Romagna	Officer	Dr. Nicola Nenatti
Assessorato Agricoltura Regione Emilia Romagna	Officer	Dr. Nicola Dall'Olio
CREA-PB	Unit Director	Dr. Luca Cesaro

2.4.4 Results of the execution of the UC #4

The Italian use case was born during the execution of the project as an additional use case to test the ABM short-period model. It was possible due to the involvement of UNIPR, which had access to RICA microdata. This use case is at the regional level of Emilia-Romagna and studies the effect of introducing different levels of CO2 taxation on GHG emissions produced by the livestock sector.

The results derived from the execution of this UC are described in previous section 2.4.2 and are published in [58, 59, 60]. The main outcome was the validation of the short-term approach and implementation of the AGRICORE short-term model.

In addition, the AGRICORE partners developed a synthetic population (described next) to validate the process and used the Italian case as a base to test the simulation during the development stages. In the last stage of the project, a simulation of the Italian scenario was run and this has paved the way for future collaborations on analysing new potential measures to be adopted not only at EU level, but also at regional ones.

2.4.4.1 Generation of the synthetic population

As mentioned, a single synthetic population for the 2019 accounting year was generated in relation to UC#4. In geospatial terms, the synthetic population was generated for the Emilia-Romagna region.

The creation of the synthetic population for this use case presented several advantages compared to other cases, as the base dataset obtained from RICA is highly comprehensive and aligns well with the parameters and variables required to define the agents composing the ABM model. Unlike other datasets used in the Agricore project, RICA contained rich fields of information with high granularity, avoiding the need to access alternative datasets to fill information gaps. For instance, it was the only data source that included all geospatial resolution levels for all farms, as well as all social-aspect parameters defined in the ABM entities.

The generation process was carried out by the SPG module, a Bayesian network-based approach that delivered excellent results in generating the synthetic population for the Italian use case, as will be shown later. The features of the SPG module allowed for a straightforward generation process with minimal user interaction; the user only needed to specify the use case and year to be generated. Additionally, the automated features enabled by the containerization of the module and the workflow orchestration efficiently managed the artifacts and modules involved in the generation process.

In line with Agricore's specifications, and to simplify the subsequent simulation process, a specific crop grouping was defined for this use case. This grouping was based on variables of interest and aligned with the use case's objectives, with frequency of appearance, total cultivated area, and production factors being key determinants in the grouping process.

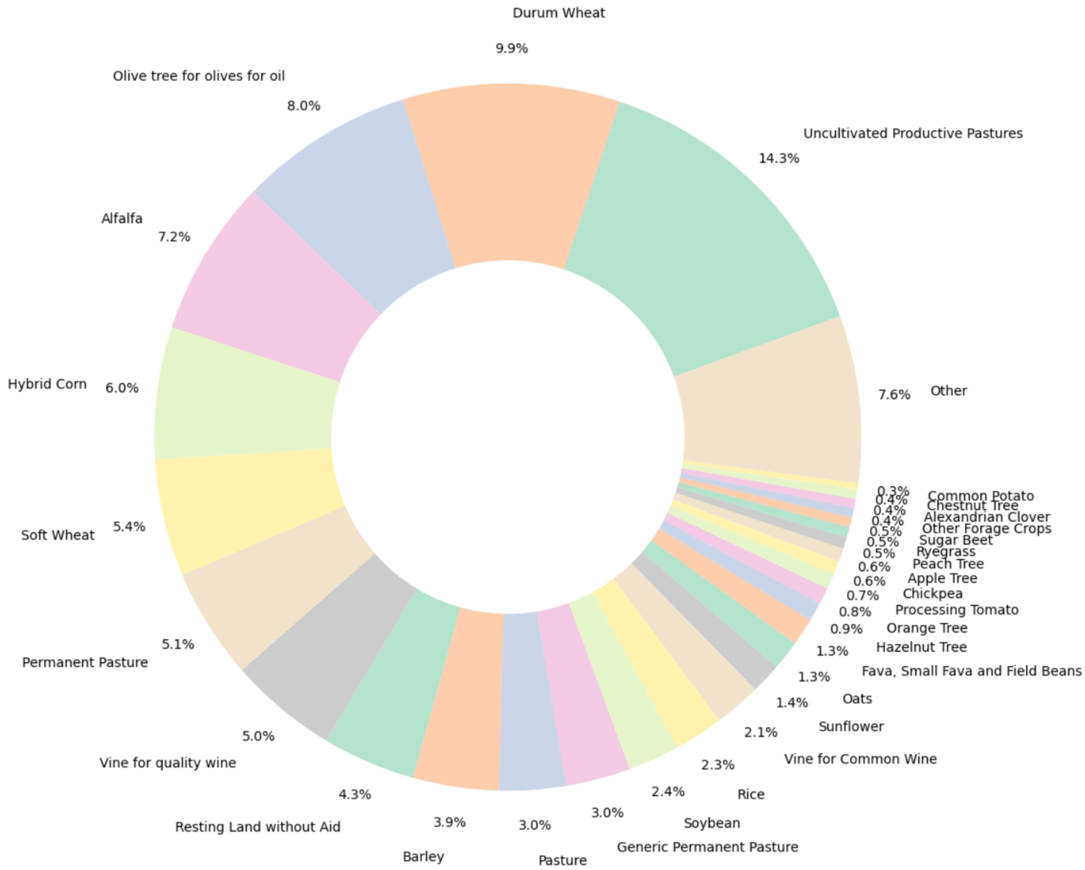


Figure 79 Crops representativeness in Italian use case

This figure shows the distribution of crops by cultivated area in the studied region. While several factors were considered in decision-making, this data primarily helped identify the most representative crops—those that are either most commonly grown by farmers or have the greatest impact on the regional economy. The result of this analysis is a link that related individual crops with product groups.

Groups of crops in the Italian use case

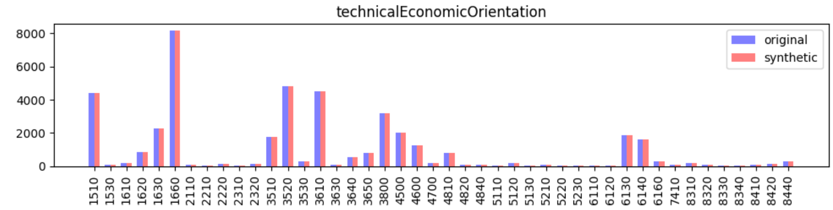
The following table contains the final grouping performed. It contains the product group created, its denomination in the use case and a brief description.

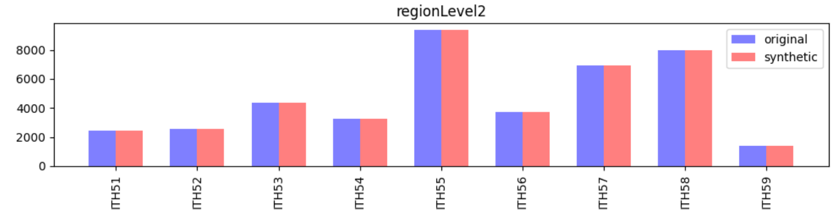
#	Product group	Abbreviation	Description
1	Olive	OLIV	Olive tree and all its varieties and derived products
2	Cereals	CER	All kind of cereals, including maize, wheat, rice, rye, barley…
3	Maize	MAIZE	Maize crop for different purposes, including the production of grain and livestock food as fodder
4	Grazing	GRAZ	All crops that can be used as fodder or as feed for livestock, including pasture, meadows, rough grazing, green maize and plants harvested green.
5	Alfalfa	ALFA	Alfalfa crop, which is commonly used as high-quality feed for livestock due to its high protein content.
6	Industrial	INDUSTRIAL	Crops grown for industrial uses.
7	Protein crops	PROT	Agricultural plants that are cultivated for their high protein content including lentils, chickpeas, beans… Crops that serve as nitrogen-fixing.

8	Forage	FRG	Crops grown specifically for grazing by livestock or for harvesting as hay or silage to feed animals
9	Other	OTHER	Group of crops with low representativeness or without a relevant impact on the use case study. Grapes, wooded area, flowers,

Table 5 Final crop grouping for the Italian use case

Finally, a comparison between the synthetic population variables and the original data used to capture data patterns is provided. Although the list of variables is extensive, only a subset has been included to present the results without overwhelming the document with excessive information. As shown, the synthetic population accurately reflects the patterns observed in the real data, with a good fit, particularly considering the analysis and tests conducted in D7.6.


technicalEconomicOrientation
original
synthetic
1510 1530 1610 1620 1630 1660 2110 2210 2220 2310 2320 3510 3520 3530 3610 3630 3640 3650 3800 4500 4600 4700 4810 4820 4840 5110 5120 5130 5210 5220 5230 6110 6120 6130 6140 6160 7410 8310 8320 8330 8340 8410 8420 8440


regionLevel2
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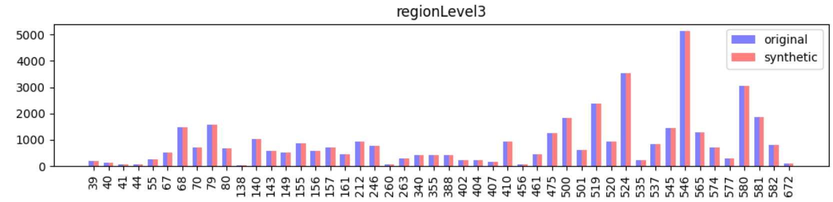
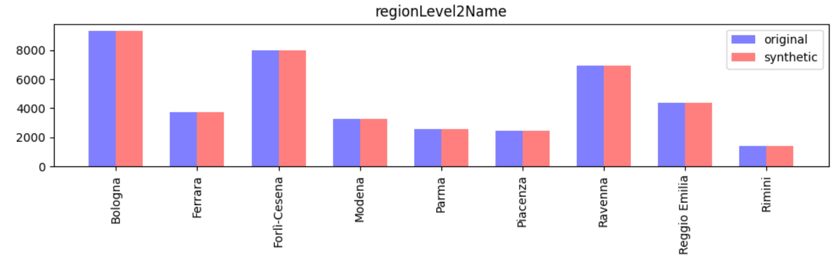
synthetic
ITH51 ITH52 ITH53 ITH54 ITH55 ITH56 ITH57 ITH58 ITH59


regionLevel3
original
synthetic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original
synthetic
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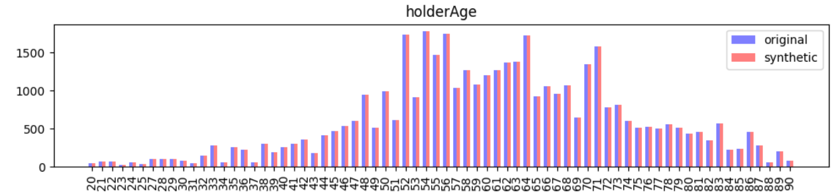
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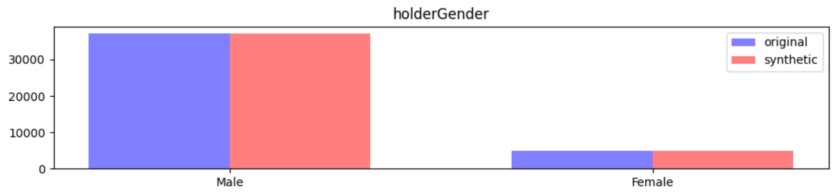
holderGender
original
synthetic
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Female

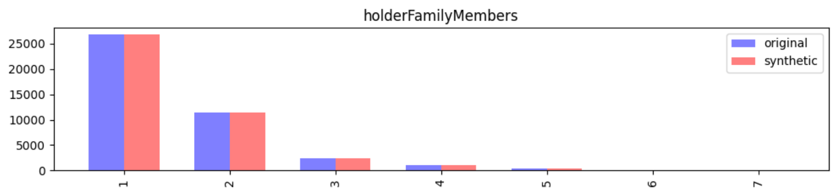
holderFamilyMembers
original
synthetic
1 2 3 4 5 6 7

Figure 80. Italian use case: synthetic population comparison I

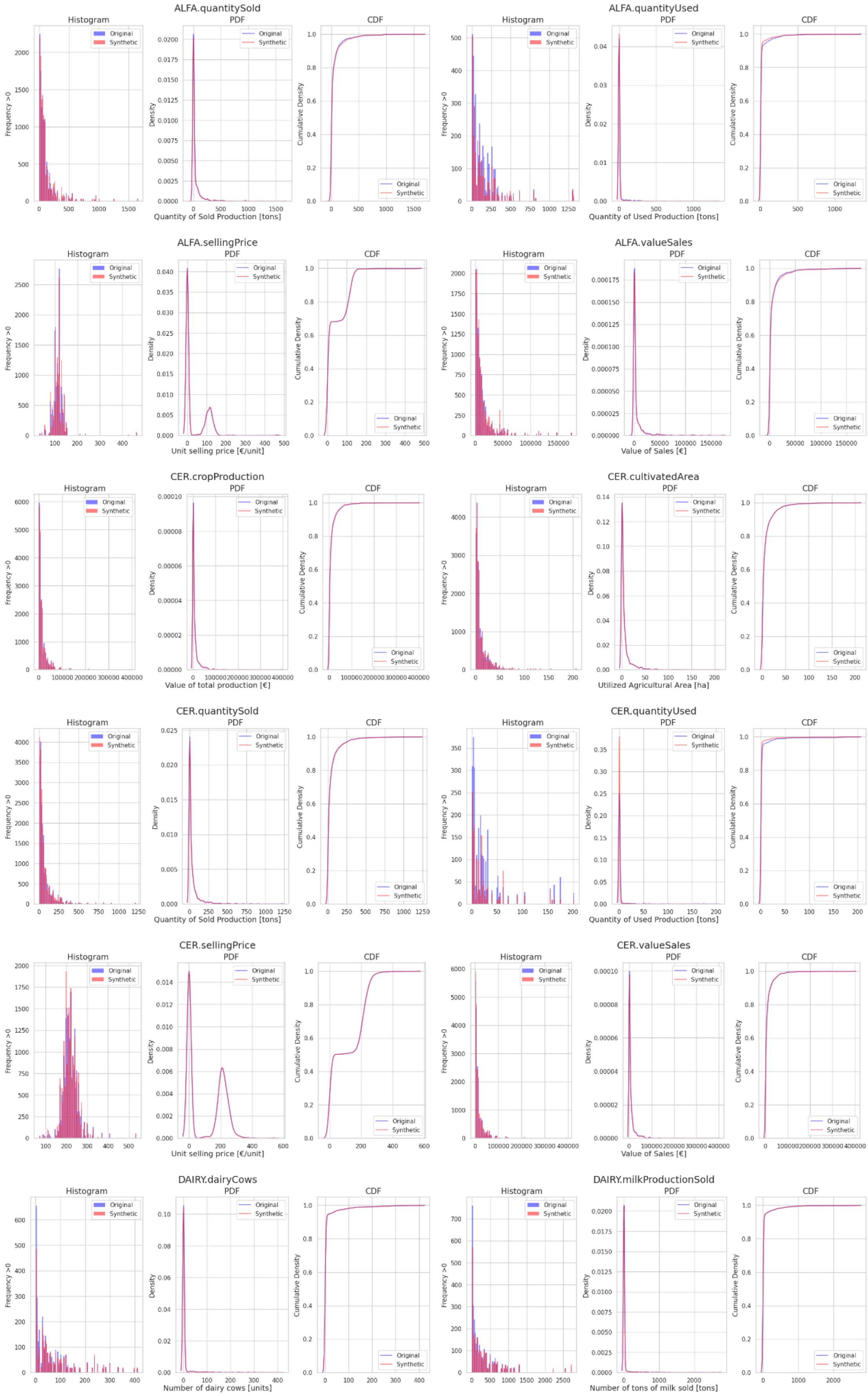

Figure 81. Italian use case: synthetic population comparison II

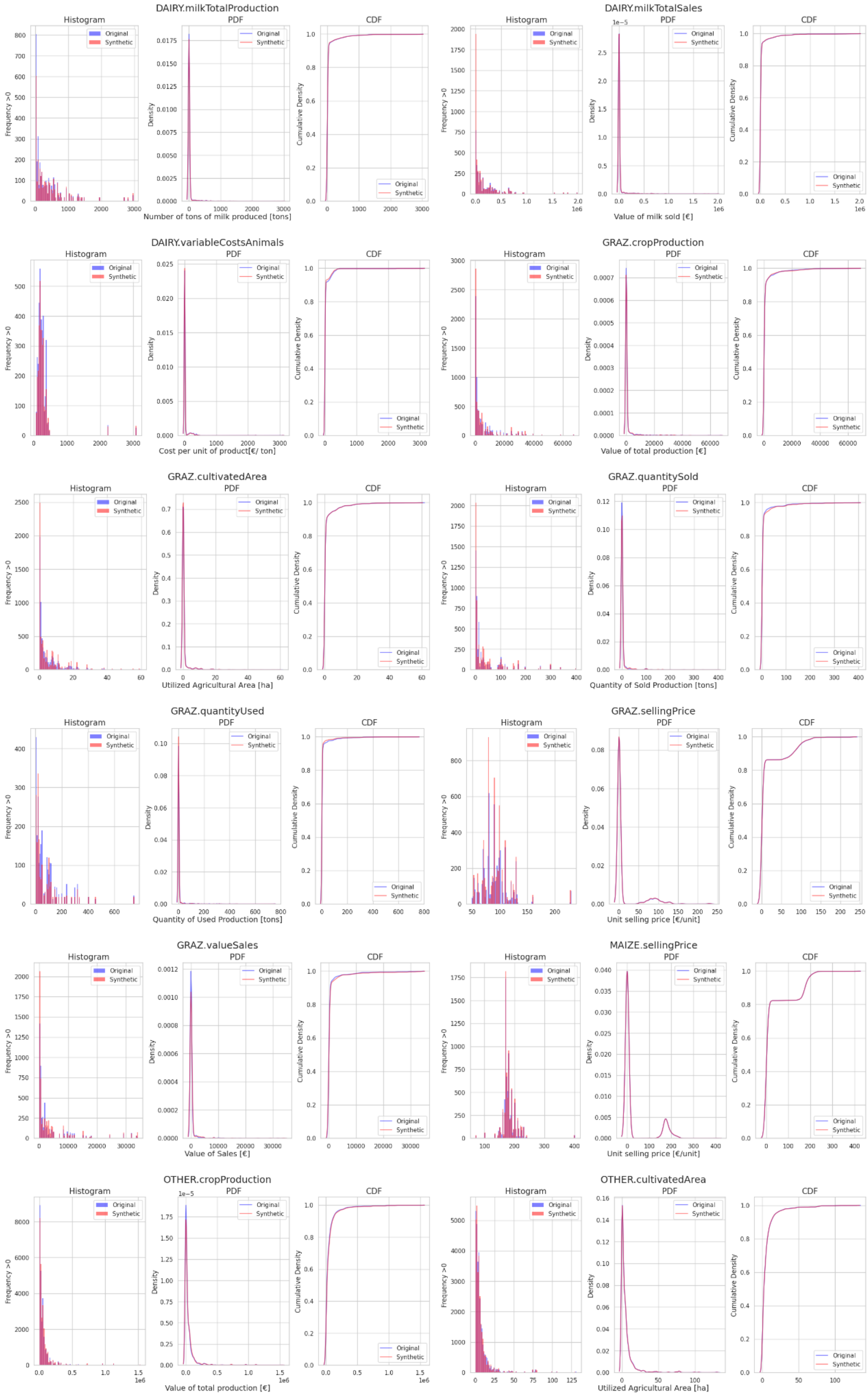

Figure 82. Italian use case: synthetic population comparison III

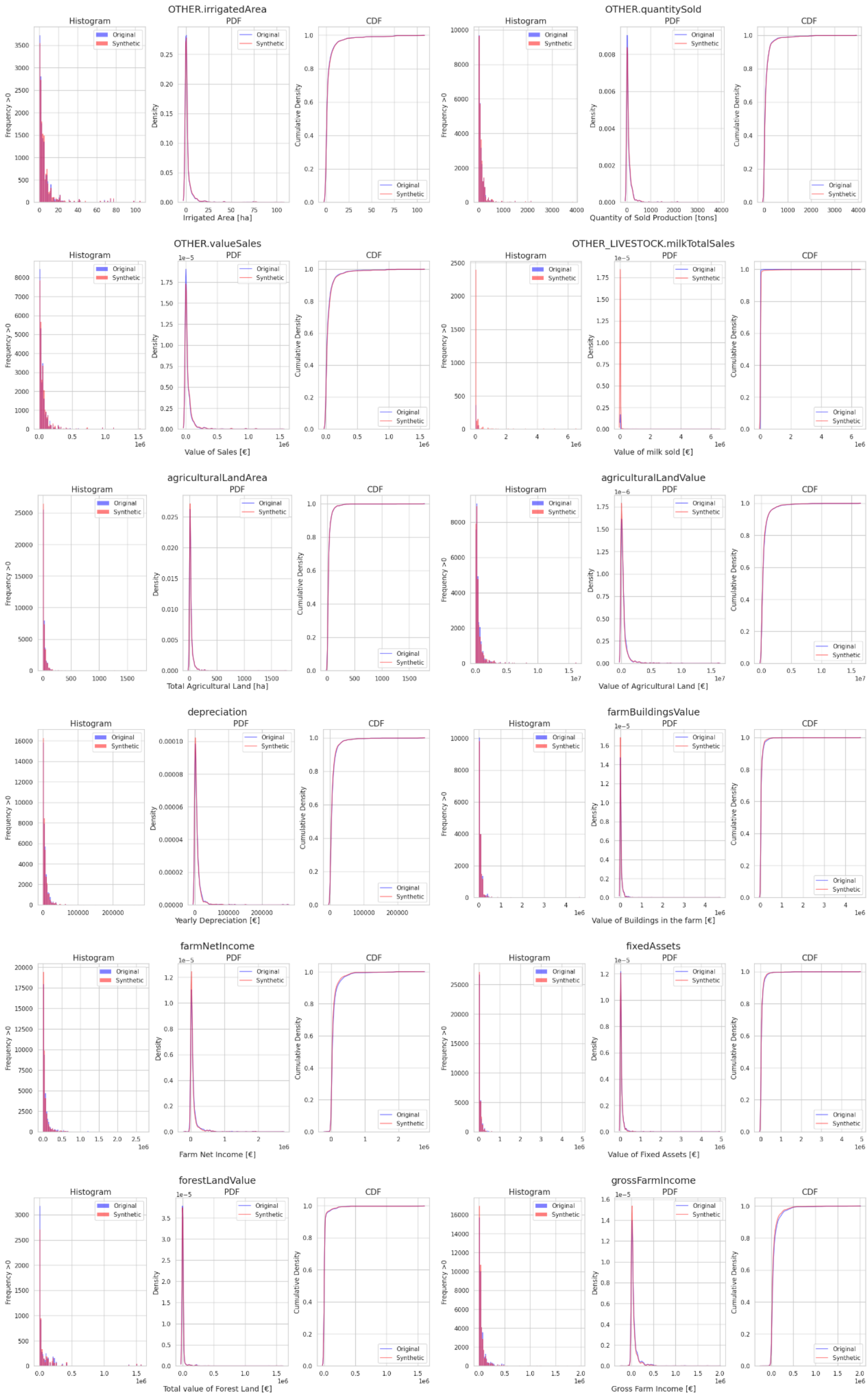

Figure 83. Italian use case: synthetic population comparison IV

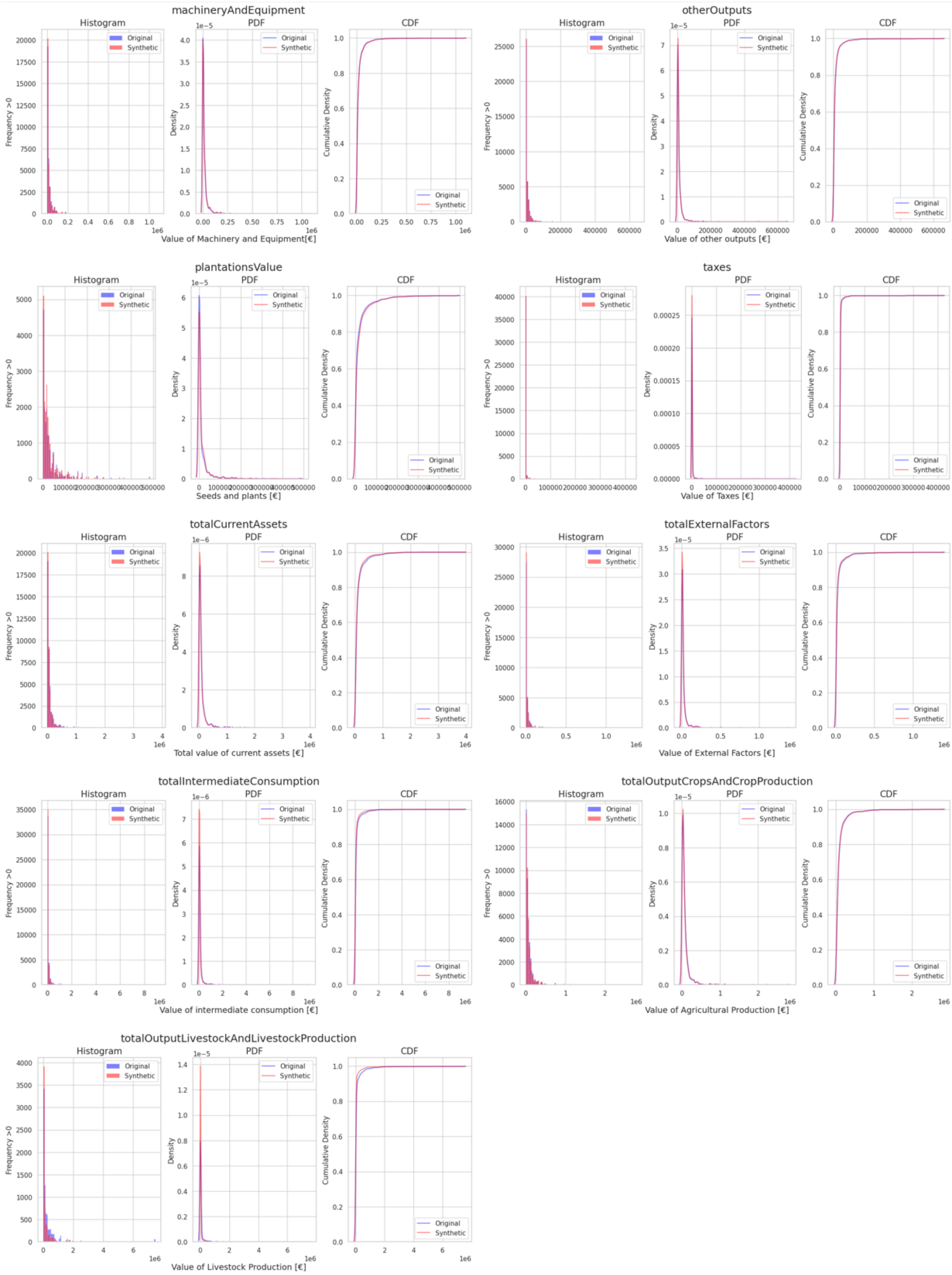

Figure 84. Italian use case: synthetic population comparison V

3 References

1. Consejeria de Agricultura, Ganaderia, Pesca y Desarrollo Sostenible, Texto Consolidado M11. Andalucia, España: CAGPDS, 2018.
2. M. de la Presidencia Relaciones con las cortes y Memoria democrática, “Pagos directos a la Agricultura y a la Ganaderia,” Gobierno de España, Gobierno de España, techreport, 2014.
3. D. oficial de la Union Europea, “Reglamento 1305 2013 del Parlamento Europeo,” Diario oficial de la Union Europea, Diario oficial de la Union Europea, techreport, 2013.
4. D. oficial de la Union Europea, “Reglamento 1306 2013 del Parlamento Europeo,” Diario oficial de la Union Europea, Diario oficial de la Union Europea, techreport, 2013.
5. D. oficial de la Union Europea, “Reglamento 1307 2013 del Parlamento Europeo,” Diario oficial de la Union Europea, Diario oficial de la Union Europea, techreport, 2013.
6. D. oficial de la Union Europea, “Reglamento 1308 2013 del Parlamento Europeo,” Diario oficial de la Union Europea, Diario oficial de la Union Europea, techreport, 2013.
7. D. oficial de la Union Europea, “Reglamento CE 834/2007 Produccion y etiquetado de productos ecologicos,” Diario oficial de la Union Europea, Diario oficial de la Union Europea, techreport, 2007.
8. C. de A. P. y D. Sostenible, Plan Director del Olivar Andaluz. 2015, p. 146. [Online]. Available: https://www.juntadeandalucia.es/organismos/agriculturaganaderiapescaydesarrollososteni ble/consejeria/sobre-consejeria/planes/detalle/59239.html
9. Pleguezuelo, “Organic olive farming in Andalusia, Spain. A review,” Springer, vol. 38, 2018, doi: 10.1007/s13593-018-0498-2.
10. P. y D. S. Consejeria de Agricultura Ganaderia, “Avance de Superficies y Producción.” [Online]. Available: https://www.juntadeandalucia.es/organismos/agriculturaganaderiapescaydesarrollososteni ble/servicios/estadistica-cartografia/estadisticas-agricolas/paginas/avance-superficie-producciones-agricolas.html
11. A. C. on Olive Oil and T. O. of the International Olive Council, “III Exchange of information on operational activities of the IOC Economy and Promotion.” [Online]. Available: https://www.internationaloliveoil.org/advisory-committee-55th-meeting-on-10-november-2020/?lang=es
12. Consejeria de Agricultura, Ganadería, Pesca y Desarrollo Sostenible, Aforo de Producción de Aceituna de Mesa en Andalucía, Campaña 2020-2021. https://www.juntadeandalucia.es/export/drupaljda/Presentaci%C3%B3n_ACEITUNA%20M ESA_2020-2021.pdf, 2020. [Online]. Available: https://www.juntadeandalucia.es/export/drupaljda/Presentaci%C3%B3n_ACEITUNA%20M ESA_2020-2021.pdf
13. L. G. Nogales, “Importancia económica y perspectivas empresariales del sector oleícola andaluz: el caso de Oleoestepa,” Universidad de Sevilla, Sevilla, España, 2018.
14. Consejeria de Agricultura, Ganadería, Pesca y Desarrollo Sostenible, Aforo de Producción del Olivar de Almazara en Andalucía, Campaña 2020-2021. https://www.juntadeandalucia.es/export/drupaljda/Presentaci%C3%B3n_ACEITUNA%20A CEITE_2020-2021.pdf, 2020. [Online]. Available: https://www.juntadeandalucia.es/export/drupaljda/Presentaci%C3%B3n_ACEITUNA%20A CEITE_2020-2021.pdf
15. C. Parra López and J. Calatrava Requena, “Factors related to the adoption of organic farming in Spanish olive orchards,” Spanish Journal of Agricultural Research, vol. 3, no. 1, p. 5, 2005, doi: 10.5424/sjar/2005031-119.

16. C. Parra-Lopez, T. De-Haro-Giménez, and J. Calatrava-Requena, "Diffusion and adoption of organic farming in the Southern Spanish olive groves," Journal of Sustainable Agriculture, vol. 30, no. 1, pp. 105–151, 2007, doi: 10.1300/J064v30n01_09.
17. Ministerstwa Rolnictwa i Rozwoju Wsi, Przewodnik po działaniu rolno-środowiskowo-klimatycznym PROW 2014-2020. 2018. [Online]. Available: https://www.gov.pl/attachment/b49226cd-5ae0-4561-bcd7-794c00391c7e
18. GUS, "STRATEG." Accessed: Feb. 14, 2021. [Online]. Available: https://strateg.stat.gov.pl/#/strategie/krajowe/1003
19. K. Giemza, "Wdrażanie funduszy europejskich w polskim rolnictwie na przykładzie Programu Rozwoju Obszarów Wiejskich na lata 2014-2020," Studia z Polityki Publicznej, vol. 15, no. 3, pp. 81–97, 2017, Accessed: Jan. 31, 2021. [Online]. Available: https://www.ceeol.com/search/article-detail?id=725622
20. PROW, Program Rozwoju Obszarów Wiejskich 2014-2020 (PROW 2014-2020). 2020. Accessed: Feb. 01, 2021. [Online]. Available: https://www.gov.pl/web/rolnictwo/-program-rozwoju-obszarow-wiejskich-2014-2020-prow-2014-2020
21. Agencja Restrukturyzacji i Modernizacji Rolnictwa, "Sprawozdania z działalności Agencji Restrukturyzacji i Modernizacji Rolnictwa," Warszawa, techreport, 2020. Accessed: Feb. 14, 2021. [Online]. Available: https://www.arimr.gov.pl/dla-beneficjenta/biblioteka/sprawozdania-z-dzialalnosci-agencji-restrukturyzacji-i-modernizacji-rolnictwa.html
22. GUS, "Rolnictwo w 2019 roku," stat.gov.pl. Accessed: Feb. 14, 2021. [Online]. Available: https://stat.gov.pl/obszary-tematyczne/rolnictwo-lesnictwo/rolnictwo/rolnictwo-w-2019-roku,3,16.html
23. Ministerstwo Rolnictwa i Rozwoju Wsi, PRZEWODNIK PO DZIAŁANIU ROLNO-ŚRODOWISKOWO-KLIMATYCZNYM PROW 2014–2020. 2019. Accessed: Feb. 17, 2021. [Online]. Available: https://www.gov.pl/attachment/b49226cd-5ae0-4561-bcd7-794c00391c7e
24. eurostat, "Agri-environmental indicators (AEIs) - Agriculture - Eurostat." Accessed: Feb. 14, 2021. [Online]. Available: https://ec.europa.eu/eurostat/web/agriculture/agri-environmental-indicators
25. GUS, Rocznik Statystyczny Rolnictwa 2019. Accessed: Feb. 09, 2021. [Online]. Available: https://stat.gov.pl/obszary-tematyczne/roczniki-statystyczne/roczniki-statystyczne/rocznik-statystyczny-rolnictwa-2019,6,13.html
26. GUS, "Agriculture. Forestry," stat.gov.pl. Accessed: Feb. 14, 2021. [Online]. Available: https://stat.gov.pl/en/topics/agriculture-forestry/
27. G. M. of Rural Development and Food, Rural Development Programme 2014-2020: Establishment of Young Farmers (in Greek). 2020.
28. E. Union, REGULATION (EU) No 1305/2013 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 17 december 2013 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD) and repealing Council Regulation (EC) No 1698/2005. 2013. 2013.
29. MRDF, Rural development programme 2007-2013. Athens, Greece, 2014. [Online]. Available: http://www.minagric.gr/index.php/el
30. E. Commission, "Analytical factsheet for Greece: Nine objectives for a future Common Agricultural Policy," European Commission, 2019. [Online]. Available: https://ec.europa.eu/info/sites/default/files/food-farming-fisheries/by_country/documents/analytical_factsheet_el.pdf

31. A. Kontogeorgos, A. Michailidis, F. Chatzitheodoridis, and E. Loizou, "'New Farmers' a Crucial Parameter for the Greek Primary Sector: Assessments and Perceptions," Procedia Economics and Finance, vol. 14, pp. 333–341, 2014, doi: 10.1016/s2212-5671(14)00721-7.
32. C. Coyette, H.; Schenk, "Agriculture, forestry and fishery statistics," p. 256, 2013, doi: 10.2785/570022.
33. ELSTAT, Economic characteristics of Greek Population. 2019. [Online]. Available: https://www.statistics.gr/el/statistics/-/publication/SAM04/-
34. ELSTAT, Labour force survey. 2019. [Online]. Available: https://www.statistics.gr/en/statistics/-/publication/SJO03/-
35. ELSTAT, Employment. 2019. [Online]. Available: https://www.statistics.gr/en/statistics/-/publication/SEL21/-
36. ELSTAT, Gross value added by Industry. 2019. [Online]. Available: https://www.statistics.gr/en/statistics/-/publication/SEL12/-
37. ELSTAT, "AIR EMISSION ACCOUNTS," Hellenic Statistical Authority, Athens, Greece, techreport, 2019. [Online]. Available: https://www.statistics.gr/en/statistics?p%7B%5C_%7Dp%7B%5C_%7Did=documents%7B%5C_%7DWAR%7B%5C_%7Dpublicationsportlet%7B%5C_%7DINSTANCE%7B%5C_%7DqDQ8fBKKo4lN%7B%5C&%7Dp%7B%5C_%7Dp%7B%5C_%7Dlifecycle=2%7B%5C&%7Dp%7B%5C_%7Dp%7B%5C_%7Dstate=normal%7B%5C&%7Dp%7B%5C_%7Dp%7B%5C_%7Dmode=view%7B%5C&%7Dp%7B%5C_%7Dp%7B%5C_%7Dcacheability=cacheLevelPage%7B%5C&%7Dp%7B%5C_%7Dp%7B%5C_%7Dcol%7B%5C_%7Did=column-2%7B%5C&%7Dp%7B%5C_%7Dp%7B%5C_%7Dcol%7B%5C_%7Dcount=4%7B%5C&%7Dp%7B%5C_%7Dp%7B%5C_%7Dcol%7B%5C_%7Dpos=1%7B%5C&%7D%7B%5C_%7Ddocuments%7B%5C_%7DWAR%7B%5C_%7Dpublicat
38. M. J. Salganik and D. D. Heckathorn, "Sampling and Estimation in Hidden Populations Using Respondent-Driven Sampling," Sociological Methodology, vol. 34, no. 1, pp. 193–240, 2004.
39. Gkatsikos, A.; Natos, D.; Staboulis, C.; Mattas, K.; Tsagris, M.; Polymeros, A. An Impact Assessment of the Young Farmers Scheme Policy on Regional Growth in Greece. Sustainability 2022, 14, 2882. https://doi.org/10.3390/su14052882
40. Staboulis, C.; Natos, D.; Gkatsikos, A.; Tsakiridou, E.; Mattas, K.; Bojar, W.; Baranowski, P.; Krzyszczak, J.; Rivero, O.P.; Roldán, Á.O. Assessing the Role of the Young Farmer Scheme in the Export Orientation of Greek Agriculture. Sustainability 2022, 14, 3287. https://doi.org/10.3390/su14063287
41. C.-R. C. for Agricultural Policies and Bioeconomy, Survey on the Land Market. Accessed: Aug. 23, 2024. [Online]. Available: https://www.crea.gov.it/en/web/politiche-e-bioeconomia/-/indagine-mercato-fondiario
42. C. of the European Union, "Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources," 1991. Accessed: Aug. 23, 2024. [Online]. Available: https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex%253A31991L0676
43. R. Fanfani, A. Davoli, A. Laghi, and F. Pecci, 7° Censimento generale dell'Agricoltura. La struttura delle aziende agricole in Emilia-Romagna. Regione Emilia-Romagna - Direzione generale risorse, europa, innovazione e istituzioni: Settore innovazione digitale, dati, tecnologia e polo archivistico - Direzione generale agricoltura, caccia e pesca: Settore programmazione, sviluppo del territorio e sostenibilità delle produzioni, 2023. Accessed: Aug. 23, 2024. [Online]. Available: https://agricoltura.regione.emilia-romagna.it/agricoltura-in-cifre/censimenti-generali-agricoltura/pubblicazioni/7-censimento-generale-agricoltura
44. W. Britz et al., "A design for a generic and modular bio-economic farm model," Agricultural Systems, vol. 191, p. 103133, 2021, doi: https://doi.org/10.1016/j.agsy.2021.103133.

45. AGROSCOPE, SWISSland - Structural Change Information System Switzerland. Accessed: Aug. 23, 2024. [Online]. Available: https://www.agroscope.admin.ch/agroscope/en/home/topics/economics-technology/economic-modelling-policy-analysis/swissland.html
46. P. Reidsma, S. Janssen, J. Jansen, and M. K. van Ittersum, "On the development and use of farm models for policy impact assessment in the European Union – A review," Agricultural Systems, vol. 159, pp. 111–125, 2018, doi: https://doi.org/10.1016/j.agsy.2017.10.012.
47. W. Britz, Overview of CAPRI in CAPRI model documentation 2011. 2011.
48. S. Janssen and M. K. van Ittersum, "Assessing farm innovations and responses to policies: A review of bio-economic farm models," Agricultural Systems, vol. 94, no. 3, pp. 622–636, 2007, doi: https://doi.org/10.1016/j.agsy.2007.03.001.
49. G. Flichman and F. Jacquet, "Le couplage des modèles agronomiques et économiques : intérêt pour l'analyse des politiques," Revue d'Études en Agriculture et Environnement, vol. 67, no. 1, pp. 51–69, 2003, doi: 10.3406/reae.2003.1715.
50. R. E. Howitt, "Positive Mathematical Programming," American Journal of Agricultural Economics, vol. 77, no. 2, pp. 329–342, 1995, doi: 10.2307/1243543.
51. S. Project, SUPREMA-Project - IFM-CAP. 2020. Accessed: Aug. 23, 2024. [Online]. Available: https://www.suprema-project.eu/project/solution/tools/ifm-cap
52. Parra Rivero, O.; Ojeda Roldán, Á.; González Álvarez-Ossorio, R.; Staboulis, C.; Natos, D.; Mattas, K.; Bojar, W.; Kuśmierek-Tomaszewska, R.; Baranowski, P.; Krzyszczak, J. Characterisation of Organic Olive Farmers in the Framework of M11 of the Common Agricultural Policy. Agronomy 2023, 13, 2630. https://doi.org/10.3390/agronomy13102630
53. Evaluation support study on the impact of the CAP on sustainable management of the soil, DG-AGRI, 2021
54. Kajtoch, Ł. Loss of Traditional Orchards and Its Impact on the Occurrence of Threatened Tree-Dwelling Bird Species. Agriculture 2023, 13, 2267. https://doi.org/10.3390/agriculture13122267
55. Żurawicz, E., Kubik, J., Lewandowski, M., Rutkowski, K.P. and Zmarlicki, K. (2019). The apple industry in Poland. Acta Hortic. 1261, 13-20 DOI: 10.17660/ActaHortic.2019.1261.3
56. Klepacka, A.M. and Florkowski, W.J. (2016). Poland's apple sector and the embargo on fruit exports to Russia. Acta Hortic. 1132, 31-38 DOI: 10.17660/ActaHortic.2016.1132.5
57. Krzyszczak, J., Baranowski, P., Lamorski, K., Sławiński, C., Siedliska, A., Bojar, W. ... Tkaczyk, P. (2023). 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. Int. Agrophys., 37(3), 311-323. https://doi.org/10.31545/intagr/168992
58. Baldi, L.; Arfini, F.; Calzolai, S.; Donati, M. An Impact Assessment of GHG Taxation on Emilia-Romagna Dairy Farms through an Agent-Based Model Based on PMP. Land 2023, 12, 1409. https://doi.org/10.3390/land12071409
59. Lisa Baldi & Arfini, Filippo & Calzolai, Sara & Donati, Michele, 2023. "CAP reform and GHG emissions: policy assessment using a PMP agent-based model," 97th Annual Conference, March 27-29, 2023, Warwick University, Coventry, UK 334520, Agricultural Economics Society - AES.
60. Baldi, L., Calzolai, S., Arfini, F., & Donati, M. (2024). Predicting the effect of the Common Agricultural Policy post-2020 using an agent-based model based on PMP methodology. Bio-Based and Applied Economics, 13(4), 333–351. https://doi.org/10.36253/bae-14592

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

Deliverable Number	Deliverable Title	Lead beneficiary	Type	Dissemination Level	Due date
1.2	Details and agreements for accessing selected data sources	UNIPR	Report	Public	M24
1.5	Characterisation of national and regional data sources	UNIPR	Report	Public	M29
1.8	Use Case Participatory Research Actions	CAAND	Report	Public	M18
2.4	Synthetic population generation module	AAT	Report	Public	M39
5.1	State of the art review of agricultural policy assessment models, tools and indicators	UNIPR	Report	Public	M12
5.4	Environmental and climate impact assessment module	IAPAS	Other	Public	M36

5.5	Socio-economic (integration of agriculture in rural society) impact assessment module	UNIPR	Other	Public	M42
5.6	Delivery of ecosystem services module	IAPAS	Other	Public	M36
5.7	Policy environment module	AUTH	Other	Public	M36
7.1	Use case planning and set of involved stakeholders	CAAND	Report	Public	M25
7.2	Report on use cases advances	CAAND	Report	Public	M48
7.3	Updated description of the AGRICORE use cases	AUTH	Report	Public	M42
7.4	Results on participatory research activities	CAAND	Report	Public	M48