D3.4 Biophysical models linking capabilities for the ABM

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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).

This deliverable presents the linking functionalities of the AGRICORE ABM with external climatic and biophysical models. Connectivity with the climate module allows the extraction of historical observations or future predictions, as appropriate, on the meteorological conditions affecting the agricultural holdings represented by the agents. These data are important on their own because they are used to extract the regression models relating weather conditions and regional productivity of each agricultural activity. The extracted productivity matrices can substitute the biophysical models to compute the current productivity of each activity of each agent. Information on climatic conditions is equally relevant in the case that links to external biophysical models are available, as they are one of the inputs required by these models.

Connectivity with external biophysical models allows adding a further level of complexity to the calculation of the climate-yield relationship, incorporating the effect of different technologies. In this way, the relationship becomes climate-technology-yield, condensed into a series of matrices containing the average productivity values for each agricultural activity (represented by a crop or livestock type and the corresponding agricultural technology) as a function of the climatic type of year and the geographical region.

Finally, biophysical models, when connectors are available, make it possible to simulate the performance of each agricultural season under certain climatic conditions. The result of this simulation is, for each agent, the productivity of each of its activities (and therefore its total production) and the effect of these activities on the state of its agricultural soil.

Abbreviations

Abbreviation	Full name
ABM	Agent-based model
AGRICORE	Agent-based support tool for the development of agriculture policies
CMIP6	Coupled Model Intercomparison Project Phase 6
DNDC	DeNitrification-DeComposition model
ED	Extremely dry
EW	Extremely wet
IAM	Impact Assessment Module
KPI	Key Performance Indicator
LP	long period
M-CYFS	Mars Crop Yield Forecasting System
MD	Moderately dry
MERRA2	Modern-Era Retrospective Analysis for Research and Applications
MW	Moderately wet
NN	Near normal
NUTS3	Nomenclature of territorial units for statistics level 3
PDSI	Palmer Drought Severity Index
SD	Severely dry
SP	short period
SPEI	The Standardised Precipitation-Evapotranspiration Index
SPI	Standarized Precipitation Index
STICS	Simulateur mulTIdisciplinaire pour les Cultures Standard
VW	Very wet
WOFOST	the WOrld FOod STudies simulation model

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1 Introduction

Biophysical modelling is the best tool for predicting the impact of various factors on plant growth and development. The deterministic models, which are based on the physical description of the processes occurring in the soil-plant-atmosphere system [1][2][3], can directly assess the effects of the changes in climate or management practices used by the farmer. This is their advantage over the statistical methods [4][5], which do not allow for assessing the course of the complex processes at a specific time scale. The four most important factors that influence crop yield are soil fertility, availability of water, climate, and diseases or pests. The AGRICORE proposal establishes, within the links with biophysical models (B.5), the existence of a link that should provide algorithms related to the computation of some of these variables that influence crop growth. This requirement is articulated by tasks T3.5 and T6.3. The objective of T3.5 is to incorporate information from external biophysical models that is potentially useful for decision-making by agents. To this end, the initial phase is to define those parameters that affect production performance factors (e.g. yield as a function of crop and soil type, yield as a function of crop and amount of fertiliser used, yield as a function of crop and climatic conditions, etc.). The objective of T6.3 is to build software connectors that allow communication with external bio-climatic models and the bidirectional exchange of information between the agent-based simulation engine and these external models.

In order to simulate the productive performance of the agents in each agricultural season, it is necessary to define specific weather conditions to which the agricultural holdings are subjected during the time period of that season. If the impact analysis being carried out is ex-post, it is possible that the exact weather conditions of the simulated year (daily temperatures, precipitation, hydrometeors, etc.) are known; in this case, the simulation is carried out by applying real past weather conditions. If the impact analysis being performed is ex-ante, the weather conditions that will occur in future years are not yet known; in this case, the simulation is performed using predicted weather conditions. In both cases, the meteorological conditions to be used throughout the simulation are defined during the Initialisation phase of the simulation. For this, use is made of connectors with external climate models that allow obtaining historical weather observations that can be applied directly or from which future predictions can be generated.

These meteorological conditions are then used by the biophysical models in a two-fold manner. Firstly, they will be used to calculate the weather-technology-yield dependence, based on typical weather scenarios and contemplated technology alternatives. The implemented procedure will be launched prior to ABM simulations, and the obtained results will inform the Agricultural Decision Optimisation. Secondly, biophysical modelling will be employed to obtain the actual production and to update the soil state based on detailed weather data. Therefore, a pre-condition for the biophysical models linking capabilities for the ABM is to provide a methodology to determine meteorological conditions of the agents, both to calculate the weather-technology-yield dependence, as well as to obtain the actual production and to update the land state, and to provide the technological alternatives for crop activities.

2 Using Climatic Models to determine meteorological conditions of the agents

Within the current AGRICORE implementation diagram, climate information is incorporated at several points:

- For the *agro-economic optimisation* (SP): each agent (agricultural holding) generates a prediction about how the next campaign is going to be climatically. This assumption is partly based on the current performance and usage of the Mars Crop Yield Forecasting System (M-CYFS) [6], in which the main idea is that weather conditions have a significant effect on crop yields, determining most of the inter-annual variability. The time lag of the forecast is typically one year, which means that the system forecasts crop yields at harvest during the current agricultural season. In the current design of the system, the weather conditions observed "in practice" determine the crop yield at harvest. At the moment, it is assumed that agents might presume three possible predictions (standard weather year, worse than a standard year, or better than a standard year) and that each agent assumes only one. In future model versions, a different probability of occurrence could be determined for each of the scenarios, thus incorporating some stochasticity to the optimisation. The weather forecast is not incorporated into the optimisation process directly, but through the average expected yield, which depends on the predicted climate scenario. Therefore, what each agent receives as input is a matrix of average expected yields in its NUTS3 (according to the assumed meteorological conditions) for each of the crop-technology combinations predefined in the model.
- For *simulating the actual agricultural season*: to determine the actual yield of each crop/activity in each region (NUTS3) it is necessary to incorporate certain weather conditions for the crop season. There are two possibilities here:

  - Use an external biophysical model to calculate the yield: the weather conditions of the cropping season must be provided according to the input requirements of the biophysical model (temporal resolution, spatial resolution, and units). In this case, it may well be necessary to connect to a meteorological database to download the data and further transform them according to the input format imposed by the biophysical model. If the impact assessment being carried out is *ex-post*, it is very likely that the actual meteorological conditions, that occurred in the area and period under study, are known. If the impact assessment is *ex-ante*, the external database (i.e. CMIP6 [7]) with weather predictions can be used, or, in case the data is unavailable, it is necessary to generate a prediction of conditions based on existing historical data and/or external trends.

  - An external biophysical model is not available (or not recommended) for the detailed yield calculation. In this case, the same yield-climate matrices previously generated are used to simulate the yield. The climate scenario that "actually occurred" in the campaign (which may or may not coincide with the prediction made by the agents) is determined, and the corresponding yields for that scenario, taken from the matrix corresponding to each NUTS3, are returned.

It follows from the above that for the use of AGRICORE it is necessary to generate at least these expected yield matrices for each crop-technology alternative in each NUTS3 region. This is done by deriving the regression model between pre-defined climate scenarios (independent variable) with annual production data (dependent variable) for each of the production technology alternatives considered. The climate scenarios should consist of one or more weather indicators that have been proven to influence the growth rate and total biomass of the different crops under consideration.

2.1 State of the art - common indexes used to measure water availability

Weather conditions affect a wide range of socio-economic activities: energy, logistics, industrial production, tourism, and of course agriculture.

For centuries there has been an understandable interest in finding out how climate influences agricultural productivity, so that crop yields can be accurately predicted as a function of past and present climate. In recent years, with awareness of climate change, this interest has extended to understanding how the climate of the future might affect the survival and profitability of some agricultural and livestock activities. Nowadays, in addition to the farmers' own interest in knowing as soon as possible the amount of product they can make profitable, an accurate prediction of crop yields in different geographical areas is critical for the security of supply (food autonomy), for price control, for the elaboration of public policies and agricultural plans, or for the management of water resources.

Agricultural activity is influenced by external factors beyond human control, including weather conditions. They determine the scheduling of tasks and influence the performance of tillage, yields obtained, and potentially more profitable crop selection by location. Especially water availability is the main affecting factor on agriculture. This circumstance even characterises the typology of farms according to their geographical location.

Agricultural activity has progressively adapted to the climatic conditions and the availability of water in each region. But at the same time, there is high variability between successive periods of time that can condition the performance of the agricultural activity and can pose a risk to its proper functioning. Mainly, the water balance is of particular interest to analyse whether the water needs of the crops are met. Water supply and water consumption can occur in different ways and at different rates depending on the conditions in each area. External factors such as air temperature, lack of rainfall, soil moisture evolution or the existence of a previous drought can significantly affect the development of water balance, and all these factors are inherent to weather conditions.

The measurements of water availability and water balances have been linked to the concept of drought. Several indexes have been developed to characterise and evaluate droughts, their duration, intensity, and cause. Taking advantage of the work and indicators used to measure the drought it is possible to establish a characterisation of time periods to be used to create possible simulation scenarios and to establish the relationship between weather behaviour and crop yield.

As mentioned above, there are several indexes used to capture drought episodes and their features. For their computation, it is possible to use past weather measurements, or it is possible to extract them directly from public databases. They have in common that have associated numeric values expressing the severity of the drought. In turn, each scale has categories to characterise temporal episodes.

Each index will be assessed to find the most suitable and specific for the purpose of the task, analysing their capabilities and drawbacks.

2.1.1 The Palmer Drought Severity Index (PDSI)

The PDSI was one of the first indexes used to measure the intensity of droughts in a standardised way. It is based on a soil moisture balance model that incorporates rainfall values to compare predicted rainfall with the rainfall needed to maintain moisture balance under normal conditions. Other factors such as temperature which affect moisture loss are considered. Its computation can be adapted to the conditions of each zone through the use of weighting factors [8]. The PDSI has a defined categorization with 11 classes that characterize the intensity of a drought for a defined period, from extreme humidity sequence to extreme drought. It does not allow capturing the multiscalar characteristic of the drought and hence it does not allow for differentiation among the class of the drought [9].

It has a long-term memory and is therefore strongly influenced by past climatic conditions [10]. This is a disadvantage, as agricultural seasons are usually less than a year-long (and presumably the model incorporates this feature), and crop development and yields are particularly influenced by short-term past conditions (usually crops with growing seasons of less than a year).

2.1.2 Standarized Precipitation Index (SPI)

The SPI is defined as a numerical value representing the number of standard deviations of the rainfall in the cumulative period treated with respect to the mean, once the original distribution has been transformed into a normal distribution [11]. SPI was developed by the American researcher Mc Kee in 1993 to be able to quantify the precipitation deficit for different time scales and, on this basis, to be able to assess the impact of precipitation deficit on the availability of different types of water resources.

It allows for quantifying and comparing the intensity of the deficits in rainfall for different climates and locations. The freedom to use different time scales enables for identification of different drought types. Specifically, short-duration droughts affecting agricultural performance may be recognized by this index but with certain particularities. The most important variable affecting drought for this index is the precipitation measured. It considers that the effect of other variables is stationary and can be neglected.

The criteria used to characterise drought periods are the magnitude and sign of the SPI. A dry period is produced when SPI presents a continuous sequence of values equal to or lower than -1. To finish such a dry period, the SPI should reach a positive value. In this way, the index allows to characterize of the drought period in duration, intensity, and magnitude. There is a defined scale relating SPI values to 7 wet-drought classes.

Some authors remark on the lack of information used to compute this index. Specifically, the temperature is a variable affecting evapotranspiration which has a strong impact on water removal from soil [12]. The calculation of SPI requires a large amount of data. This can be a drawback if the meteorological information in the biophysical models is provided on an annual basis. The weather conditions may not correspond to the desired category and would lead to a wrong approach. Some studies support the non-use of this index for short periods of time since it may provide wrong values [13].

2.1.3 SPEI

To understand the SPEI index evapotranspiration should be defined. It is the process by which water moves from the surface of the earth into the atmosphere either by evaporation of water or by transpiration phenomena through vegetation [14][20]. Evaporation is the physical phenomenon by which liquid water passes from soil, plant, and water surfaces into the atmosphere as vapour. Transpiration is the biological phenomenon by which plants drain water into the atmosphere. It is part of the water taken up by the roots for their growth.

This index combines the influence of temperature and precipitation on the evaluation of the drought. For the calculation of the SPEI precipitation referred to a month or week, and potential evapotranspiration are used. Their difference represents a basic water balance for the analysed period of time. It combines the strengths of the PDSI and the SPI, incorporating the multi-temporal nature of the SPI to measure the drought severity in duration and also a variety of variables used inherited from the PDSI to track changes in evaporation demand. The use of evapotranspiration implies the incorporation of physical variables according to the methodology applied, such as changes in available energy, wind speed, relative humidity, and temperature [15].

2.2 Studies relating drought and crop yield

Several research studies have focused on assessing the relationship between drought and yield variation in agriculture. This study [16] assesses the impact of drought on the yield of a set of crops. It reflects that some crops, especially maize and spring wheat, are susceptible to varying their yield according to weather conditions given in the season. In this work, SPEI and crop yield data were categorised to search for associations between anomalous events. The method used was a contingency approach to measure the frequency of the associations. The results show that there was a high explainability of crop yields by water stress.

[17] evaluates the impact of drought on the production of maize and wheat in Hungary. Both SPI and SPEI are used to monitor the draught alongside the country. The study tries to emphasise the impact of the drought on crop yield at different SPI time intervals. Biases inherent from non-climatic factors such as agriculture modernisation or enhancement of fertilisers have been removed. The analysis highlights the sensitivity of crop yields to drought events, showing a high correlation between the two variables that is accentuated during certain stages of the growing cycle. Thus, the study reinforces the approach to the effect of water stress on crop production.

A study to assess the impact of drought on crop yield in tropical climates was done by Jo & Eo (2022) [18]. In this case, the analysis duration encompasses 10 years and uses SPEI-6 to characterise the drought. The list of crops analysed is extensive and includes cereals, vegetables, and legumes.

The characterisation of the years is based on standardised categories for the SPEI index, and reflects the negative increasing impact of drought on crop yield especially in. The results of the study show that the higher the degree of drought, the greater the reduction in crop production. In addition, it shows that production peaks are obtained in periods where it is near normal and mild wet.

2.3 Selection of the most suitable index

Among the indices defined to measure the drought, the SPEI seems to be the more suitable based on its features and the amount of information gathered. The fact of considering temperature and resulting evapotranspiration is an advantage over the other indexes.

Different studies have made a comparative analysis to evaluate the more suitable index for agriculture applications.

This analysis [19] focuses on crop yields and analyses a wide range of indices. The most prominent are SPI and SPEI. It is noted that in general, the SPEI gives better results shown through higher Pearson correlations with crop yields and for variable temporal scales during the crop development periods.

In the *Effectiveness of drought indices in identifying impacts on major crops across the USA* [20], PDSI, SPI and SPEI are analysed. The methodology applied uses the Pearson correlation coefficient, and for those multi-scalar indices, different timescales were applied (from 1 to 12 months). Production data of crops with high representativeness is used. In this case, non-climatic factors' influence has been removed through a de-trend process. The study showed a good performance of both the SPI and SPEI, but the SPEI slightly improved correlation indicators. In principle, this small improvement is caused by the role of the atmospheric evaporative demand on drought reflected in the SPEI.

The report *The impact of drought on the productivity of two rainfed crops in Spain* assesses the correlation of different drought indices with the winter wheat and barley yields at two spatial scales in the Spanish territory.

Among the indexes analysed are the SPDI, the SPI and the SPEI. Data regarding crop yields were provided at the provincial level (NUTS3) and agricultural districts level. In line with other studies, production data was also detrended to remove bias introduced by non-climatic factors using standardized yield residuals series. To obtain the relationship between standardized yields and the evaluated indices polynomial correlation coefficients were used.

Unlike the studies mentioned above, this one uses a non-linear relationship to analyse the correlations. The time span of the analyses covers the period from sowing to harvest.

In summary, SPEI values again stand out from the rest. Stronger correlations have been found at different levels of spatial resolution and in different locations across the territory for this index. This demonstrates its ability to adapt to different territorial and meteorological conditions and its sensitivity to climate. The SPI has also good results but always with slightly worse performance. The results of the uni-scalar indices are less able to relate the effects of drought on crop yields.

The results of these studies have shown that the SPEI index is better suited to reflect climate impacts on crop yields. The SPI does not reach the levels of correlation shown by the SPEI although generally performing well for the case studies analysed.

2.4 SPEI classification

SPEI value can be classified into 7 categories according to the literature [21]. They are the same as those used for the SPI and arrange from extremely wet to extremely dry to characterise drought periods. The following table summarises the categories and associated SPEI values:

Table 1: SPEI drought index categories [21]

Moisture category	SPEI
Extremely wet (EW)	2.00 and above
Very wet (VW)	1.50 to 1.99
Moderately wet (MW)	1.00 to 1.49
Near normal (NN)	-0.99 to 0.99
Moderately dry (MD)	-1.00 to -1.49
Severely dry (SD)	-1.50 to -1.99
Extremely dry (ED)	-2.00 and less

This classification of SPEI values can serve as a reference to establish the boundaries between dry, normal, and wet years. The classification into three categories of climatic conditions is done to establish the three possible simulation scenarios. Consequently, it will be necessary to set the SPEI values corresponding to a bad, normal or good scenario for the production of each crop given the difference between the number of categories and the number of scenarios.

If sufficient climate and performance data are available for the regions covered by the project, this classification will be very useful for characterising the exercise years. Otherwise, other non-standardised classification methods should be explored based on the data available. In any case, the adoption of the boundaries shall be subject to prior analysis of data.

2.5 Data used

The SPEI value can be extracted directly from the Global SPEI database, SPEIbase [22]. It contains data about SPEI index for more than 100 years and on a global scale. It has already computed SPEI indexes through the monthly precipitation and potential evapotranspiration values extracted from the Climatic Research Unit of the University of East Anglia. In Table 2. a preview of the SPEI database is presented.

Table 2: SPEI database example

Time	Latitude	Longitude	SPEI12
2019-12-31	70.875	27.875	0.508895
		28.125	0.512309
		28.375	0.526519
		28.875	0.536696
	71.125	25.625	0.759034

Data is indexed to a geo-located grid with a 0.5 degrees spatial and monthly resolution. This resolution is too high, so data should be mapped to another geo-spatial distribution in line with the simulation tool. To resolve this question, access has been gained to the Eurostat database [23] which includes data on the coordinates of the NUTS3 enclosures in Europe in geojson format. Through python programming and making use of pandas, geopandas, and shapely libraries, it is possible to check to which NUTS3 each pair of coordinates belongs. Further on, there is calculated the mean SPEI value per NUTS3 and month.

2.6 Determination of the meteorological conditions of the agents

From the downloaded SPEI values from the Global SPEI database, the yearly means of SPEI are calculated for each grid point of the analyzed region for the period from 1995 to 2021. Based on the classification presented In Table 1, the category is assigned to each year as:

- yearly SPEI below -1 indicate that the year was dry,
- yearly SPEI from -1 to 1 that the year was standard
- yearly SPEI above 1 means that the year was wet.

To obtain the scenarios of the meteorological conditions of the agents, the minimal, maximal, and yearly SPEI closest to 0.0 has to be found from the assessed period. The year with minimal yearly SPEI will be assumed as the year with the least favourable conditions for crop growth (worse than the standard year), the year with yearly SPEI closest to 0.0 will be assumed as the standard year, whereas the year with maximal yearly SPEI will be assumed as the year with most favorable conditions for crop growth (better than standard year). After identifying which year is dry, wet, and standard for each grid point of the SPEI database, the daily meteorological time series for the whole year for these specific years will be collected from the ARDIT (e.g. using the MERRA2 database) to serve as an input to the biophysical modelling for the agro-economic optimisation (SP). The determination procedure of the meteorological conditions of the agents for simulations of the actual agricultural season will depend on whether the impact assessment is ex-post or ex-ante. In the case of ex-post, the actual meteorological conditions for the analysed past years will be obtained from the ARDIT (e.g. using the MERRA2 database). When it comes to ex-ante analyzes, the most convenient data source for biophysical modeling would be the daily meteorological data prediction taking into account the IPCC climate change scenarios (e.g. CMIP6 from https://cds.climate.copernicus.eu/cdsapp#!/dataset/projections-cmip6?tab=form) obtained directly from the ARDIT database. If these data will not be available, the ex-ante analysis will be performed by the reanalysis of the pattern of the dry, wet, and standard years occurring in the yearly means of SPEI time series from the period 1995-2021 for each grid point. The same pattern will be assumed for the period assessed in the ex-ante analysis. Additionally, the number of the years X_n belonging to a specific category for each grid point will be determined, and the numbers from 1 to X_n assigned to each year from the specific category. For each year of ex-ante analysis with a specific category assigned, a random number generator will be run to draw a number from 1 to X_n, which will allow for an assignment of a specific historical year having the same category from the period 1995-2021 to this year. Such a procedure will allow determining which data from the ARDIT (e.g. MERRA2 database) has to be downloaded for the ex-ante analysis.

To conclude, the meteorological scenarios are defined through an analysis of the distribution of the values in each region.

3 Using Biophysical Models to determine technological alternatives for crop and livestock activities

Three external biophysical models can be used, through appropriate linking connectors, by the AGRICORE platform, namely DNDC [24], STICS [25], and WOFOST [26]. Selected models result from different approaches to modelling the potential and actual crop yield (they belong to various model families), and each of them put the main focus on a specific process determining plant development.

The Denitrification-Decomposition (DNDC) model is a process-oriented model focused mainly on carbon and nitrogen biogeochemistry in agroecosystems. The crop growth and decomposition sub-models of DNDC are able to predict soil temperature, moisture, pH, redox potential, and substrate concentration profiles, while the nitrification, denitrification, and fermentation sub-models, aim to predict emissions of carbon dioxide, methane, ammonia, nitric oxide nitrous oxide and dinitrogen from the plant-soil systems.

STICS model simulates crop growth and additionally calculates soil water and nitrogen balances from daily climatic data. It predicts agricultural variables (yield, input consumption) and environmental variables (water and nitrogen losses). A very important feature of the STICS model is its adaptability to various crops, both annual and perennial.

WOFOST model explains crop growth based mainly on photosynthesis, and respiration and how these processes are influenced by environmental conditions. It calculates attainable crop production, biomass, and water use, given knowledge about soil, crop, weather, and crop management.

They also significantly differ with respect to the complexity of the input data needed for their initialization. The inputs and outputs of these models were described in Deliverable 6.3. The choice of the three biophysical models was determined by the wish of taking into account several technological alternatives (each model allows modifications of different specific management practices), but also to enable simulations in case of limited input data.

In the DNDC model, the management technologies include information on crop types, planting/harvest dates, tillage, fertilization, manure amendment, irrigation, flooding, plastic film use, grazing, and grass cutting. The tillage input consists of the information on a number of tilling applications in the year, the dates of each tillage application, and the tillage method (no-till, or ploughing). The fertilization and irrigation inputs need the applied amounts, besides the information about the number of applications, their dates, and the method used (for fertilization the type of fertilizer). Flooding practice is usually applied for paddy rice or other wetland crops. Plastic film can be utilized to construct greenhouses or mulch the ground. The practices can substantially alter the temperature-moisture regimes in the soil, and hence affect the crop growth as well as all the microbial activities in the ecosystems. Grazing is usually applied to grassland or pasture. Grazing practice is defined by specifying the livestock type, heads, and grazing duration, which will be used to quantify feeding intensity and waste deposition of the livestock when they stay in the field.

The WOFOST model does not allow the direct inclusion of any agricultural practices, but only the crop types and planting/harvest dates are taken into account. However, there is a possibility to include fertilization and irrigation indirectly. Irrigation can be included by adding the amount of water to the daily sum of the rainfall in the weather file, so only the dates and amounts are taken into account, not the method used (or, in other words, there is one method included, which can be treated as sprinkler). Fertilization can be included by adding the amount of NPK to the basic supply of nitrogen, phosphorus, and potassium by the unfertilized soil variables, therefore only the amounts are taken into account.

In the STICS model the agrotechnical practices consist of defining the crop type, the dates of sowing and harvesting, planting (interrow, row orientation), and harvest type (once or several times) using various criteria (physiological maturity, water, nitrogen, sugar or lipid contents), day of fruits removal, fertilization, irrigation, tillage, source of residue in the soil, use of plant or plastic mulching, thinning, cutting (forage). For fertilization and irrigation the type, amount applied, the number of applications, and their dates can be modified. The tillage operations are defined by specifying the numbers of tillage practices and their dates while the type of the tillage is defined by sources of residues in the soil.

As the selected models take into account specific agricultural practices, or the same practices are defined differently (i.e. tillage in DNDC vs STICS), the technological alternatives to be used in the AGRICORE platform had to be defined. The technological alternatives that are taken into account in the biophysical modelling cover two groups of methods related to conventional and ecological agriculture. Besides conventional and ecological, they are differentiated based on 2 irrigation levels, 3 fertilization levels, and 2 tillage practice options. For ecological technologies only methods with no tillage were considered. Finally, all the possible combinations of practices lead to 30 variants of technologies (T1-T30) which are included in the weather-technology-yield dependence computation phase. Detailed information on agricultural practices performed in each technological alternative is provided in Table 3. The selected biophysical models were not able to simulate the effects of the diseases on the plant growth and yield and health protection techniques such as pesticides and herbicides application. However, the pesticides and herbicides amounts and types are included in the Table 3 to differentiate economic input to the crop production between conventional and ecological farming, being the framework for the financial decision optimisation.

Table 3: The technological alternatives to be used for the biophysical modelling in the AGRICORE platform

CONVENTIONAL TECHNOLOGY ALTERNATIVES (T1-T6)					
· No-till · extensive mineral fertilization · with irrigation	· No-till · extensive mineral fertilization · rainfed	· No-till · standard mineral fertilization · with irrigation	· No-till · standard mineral fertilization · rainfed	· No-till · intensive mineral fertilization · with irrigation	· No-till · intensive mineral fertilization · rainfed
- standard planting date (depending on the crop species and climatic zone) - standard harvest date (depending on the crop species and climatic zone) - no-till (mulching only) - the standard type of three irrigation applications (depending on the climatic zone - drip for the Mediterranean, sprinkler for temperate) - standard dates of three irrigation applications (depending on the crop species and climatic zone) - standard amounts of three irrigation applications (depending on the crop species and climatic zone) - standard date of urea application (depending on the crop species and climatic zone) - 70% of the standard amount of urea application (depending on the crop species and climatic zone) - the standard amount of pesticide and herbicide application (depending on the crop species and climatic zone, not taken into account in biophysical modelling, but important for Agricultural Decision Optimalization)	- standard planting date (depending on the crop species and climatic zone) - standard harvest date (depending on the crop species and climatic zone) - no-till (mulching only) - no irrigation - standard amounts of three irrigation applications (depending on the crop species and climatic zone) - standard date of urea application (depending on the crop species and climatic zone) - 70% of the standard amount of urea application (depending on the crop species and climatic zone) - the standard amount of pesticide and herbicide application (depending on the crop species and climatic zone, not taken into account in biophysical modelling, but important for Agricultural Decision Optimalization)	- standard planting date (depending on the crop species and climatic zone) - standard harvest date (depending on the crop species and climatic zone) - no-till (mulching only) - the standard type of three irrigation applications (depending on the climatic zone - drip for the Mediterranean, sprinkler for temperate) - standard dates of three irrigation applications (depending on the crop species and climatic zone) - standard amounts of three irrigation applications (depending on the crop species and climatic zone) - standard date of urea application (depending on the crop species and climatic zone) - the standard amount of urea application (depending on the crop species and climatic zone) - the standard amount of pesticide and herbicide application (depending on the crop species and climatic zone, not taken into account in biophysical modelling, but important for Agricultural Decision Optimalization)	- standard planting date (depending on the crop species and climatic zone) - standard harvest date (depending on the crop species and climatic zone) - no-till (mulching only) - no irrigation - standard date of urea application (depending on the crop species and climatic zone) - the standard amount of urea application (depending on the crop species and climatic zone) - the standard amount of pesticide and herbicide application (depending on the crop species and climatic zone, not taken into account in biophysical modelling, but important for Agricultural Decision Optimalization)	- standard planting date (depending on the crop species and climatic zone) - standard harvest date (depending on the crop species and climatic zone) - no-till (mulching only) - the standard type of three irrigation applications (depending on the climatic zone - drip for the Mediterranean, sprinkler for temperate) - standard dates of three irrigation applications (depending on the crop species and climatic zone) - standard amounts of three irrigation applications (depending on the crop species and climatic zone) - standard date of urea application (depending on the crop species and climatic zone) - 130% of the standard amount of urea application (depending on the crop species and climatic zone) - the standard amount of pesticide and herbicide application (depending on the crop species and climatic zone, not taken into account in biophysical modelling, but important for Agricultural Decision Optimalization)	- standard planting date (depending on the crop species and climatic zone) - standard harvest date (depending on the crop species and climatic zone) - no-till (mulching only) - no irrigation - standard date of urea application (depending on the crop species and climatic zone) - 130% of the standard amount of urea application (depending on the crop species and climatic zone) - the standard amount of pesticide and herbicide application (depending on the crop species and climatic zone, not taken into account in biophysical modelling, but important for Agricultural Decision Optimalization)

CONVENTIONAL TECHNOLOGY ALTERNATIVES (T7-T12)					
· Till · extensive mineral fertilization · with irrigation	· Till · extensive mineral fertilization · rainfed	· Till · standard mineral fertilization · with irrigation	· Till · standard mineral fertilization · rainfed	· Till · intensive mineral fertilization · with irrigation	· Till · intensive mineral fertilization · rainfed
- standard planting date (depending on the crop species and climatic zone) - standard harvest date (depending on the crop species and climatic zone) - standard date of tillage (deep ploughing 30cm, date depending on the crop species and climatic zone) - the standard type of three irrigation applications (depending on the climatic zone - drip for the Mediterranean, sprinkler for temperate) - standard dates of three irrigation applications (depending on the crop species and climatic zone) - standard amounts of three irrigation applications (depending on the crop species and climatic zone) - standard date of urea application (depending on the crop species and climatic zone) - 70% of the standard amount of urea application (depending on the crop species and climatic zone) - the standard amount of pesticide and herbicide application (depending on the crop species and climatic zone, not taken into account in biophysical modelling, but important for Agricultural Decision Optimalization)	- standard planting date (depending on the crop species and climatic zone) - standard harvest date (depending on the crop species and climatic zone) - standard date of tillage (deep ploughing 30cm, date depending on the crop species and climatic zone) - no irrigation - standard date of urea application (depending on the crop species and climatic zone) - 70% of the standard amount of urea application (depending on the crop species and climatic zone) - the standard amount of pesticide and herbicide application (depending on the crop species and climatic zone, not taken into account in biophysical modelling, but important for Agricultural Decision Optimalization)	- standard planting date (depending on the crop species and climatic zone) - standard harvest date (depending on the crop species and climatic zone) - standard date of tillage (deep ploughing 30cm, date depending on the crop species and climatic zone) - the standard type of three irrigation applications (depending on the climatic zone - drip for the Mediterranean, sprinkler for temperate) - standard dates of three irrigation applications (depending on the crop species and climatic zone) - standard amounts of three irrigation applications (depending on the crop species and climatic zone) - standard date of urea application (depending on the crop species and climatic zone) - the standard amount of urea application (depending on the crop species and climatic zone) - the standard amount of pesticide and herbicide application (depending on the crop species and climatic zone, not taken into account in biophysical modelling, but important for Agricultural Decision Optimalization)	- standard planting date (depending on the crop species and climatic zone) - standard harvest date (depending on the crop species and climatic zone) - standard date of tillage (deep ploughing 30cm, date depending on the crop species and climatic zone) - no irrigation - standard date of urea application (depending on the crop species and climatic zone) - the standard amount of urea application (depending on the crop species and climatic zone) - the standard amount of pesticide and herbicide application (depending on the crop species and climatic zone, not taken into account in biophysical modelling, but important for Agricultural Decision Optimalization)	- standard planting date (depending on the crop species and climatic zone) - standard harvest date (depending on the crop species and climatic zone) - standard date of tillage (deep ploughing 30cm, date depending on the crop species and climatic zone) - the standard type of three irrigation applications (depending on the climatic zone - drip for the Mediterranean, sprinkler for temperate) - standard dates of three irrigation applications (depending on the crop species and climatic zone) - standard amounts of three irrigation applications (depending on the crop species and climatic zone) - standard date of urea application (depending on the crop species and climatic zone) - 130% of the standard amount of urea application (depending on the crop species and climatic zone) - the standard amount of pesticide and herbicide application (depending on the crop species and climatic zone, not taken into account in biophysical modelling, but important for Agricultural Decision Optimalization)	- standard planting date (depending on the crop species and climatic zone) - standard harvest date (depending on the crop species and climatic zone) - standard date of tillage (deep ploughing 30cm, date depending on the crop species and climatic zone) - no irrigation - standard date of urea application (depending on the crop species and climatic zone) - 130% of the standard amount of urea application (depending on the crop species and climatic zone) - the standard amount of pesticide and herbicide application (depending on the crop species and climatic zone, not taken into account in biophysical modelling, but important for Agricultural Decision Optimalization)

CONVENTIONAL TECHNOLOGY ALTERNATIVES (T13-T18)					
· No-till · extensive organic fertilization · with irrigation	· No-till · extensive · organic fertilization · rainfed	· No-till · standard organic fertilization · with irrigation	· No-till · standard organic fertilization · rainfed	· No-till · intensive · organic fertilization · with irrigation	· No-till · intensive · organic fertilization · rainfed
- standard planting date (depending on the crop species and climatic zone) - standard harvest date (depending on the crop species and climatic zone) - no-till (mulching only) - the standard type of three irrigation applications (depending on the climatic zone - drip for the Mediterranean, sprinkler for temperate) - standard dates of three irrigation applications (depending on the crop species and climatic zone) - standard amounts of three irrigation applications (depending on the crop species and climatic zone) - standard date of manure application (depending on the crop species and climatic zone) - 70% of the standard amount of manure application (depending on the crop species and climatic zone) - the standard amount of pesticide and herbicide application (depending on the crop species and climatic zone, not taken into account in biophysical modelling, but important for Agricultural Decision Optimalization)	- standard planting date (depending on the crop species and climatic zone) - standard harvest date (depending on the crop species and climatic zone) - no-till (mulching only) - no irrigation - standard amounts of three irrigation applications (depending on the crop species and climatic zone) - standard date of manure application (depending on the crop species and climatic zone) - 70% of the standard amount of manure application (depending on the crop species and climatic zone) - the standard amount of pesticide and herbicide application (depending on the crop species and climatic zone, not taken into account in biophysical modelling, but important for Agricultural Decision Optimalization)	- standard planting date (depending on the crop species and climatic zone) - standard harvest date (depending on the crop species and climatic zone) - no-till (mulching only) - the standard type of three irrigation applications (depending on the climatic zone - drip for the Mediterranean, sprinkler for temperate) - standard dates of three irrigation applications (depending on the crop species and climatic zone) - standard amounts of three irrigation applications (depending on the crop species and climatic zone) - standard date of manure application (depending on the crop species and climatic zone) - the standard amount of manure application (depending on the crop species and climatic zone) - the standard amount of pesticide and herbicide application (depending on the crop species and climatic zone, not taken into account in biophysical modelling, but important for Agricultural Decision Optimalization)	- standard planting date (depending on the crop species and climatic zone) - standard harvest date (depending on the crop species and climatic zone) - no-till (mulching only) - no irrigation - standard date of manure application (depending on the crop species and climatic zone) - the standard amount of manure application (depending on the crop species and climatic zone) - the standard amount of pesticide and herbicide application (depending on the crop species and climatic zone, not taken into account in biophysical modelling, but important for Agricultural Decision Optimalization)	- standard planting date (depending on the crop species and climatic zone) - standard harvest date (depending on the crop species and climatic zone) - no-till (mulching only) - the standard type of three irrigation applications (depending on the climatic zone - drip for the Mediterranean, sprinkler for temperate) - standard dates of three irrigation applications (depending on the crop species and climatic zone) - standard amounts of three irrigation applications (depending on the crop species and climatic zone) - standard date of manure application (depending on the crop species and climatic zone) - 130% of the standard amount of manure application (depending on the crop species and climatic zone) - the standard amount of pesticide and herbicide application (depending on the crop species and climatic zone, not taken into account in biophysical modelling, but important for Agricultural Decision Optimalization)	- standard planting date (depending on the crop species and climatic zone) - standard harvest date (depending on the crop species and climatic zone) - no-till (mulching only) - no irrigation - standard date of manure application (depending on the crop species and climatic zone) - 130% of the standard amount of manure application (depending on the crop species and climatic zone) - the standard amount of pesticide and herbicide application (depending on the crop species and climatic zone, not taken into account in biophysical modelling, but important for Agricultural Decision Optimalization)

CONVENTIONAL TECHNOLOGY ALTERNATIVES (T19-T24)					
▪ Till ▪ extensive ▪ organic fertilization ▪ with irrigation	▪ Till ▪ extensive organic fertilization ▪ rainfed	▪ Till ▪ standard organic ▪ fertilization ▪ with irrigation	▪ Till ▪ standard organic ▪ fertilization ▪ rainfed	▪ Till ▪ intensive organic fertilization ▪ with irrigation	▪ Till ▪ intensive ▪ organic fertilization ▪ rainfed
- standard planting date (depending on the crop species and climatic zone) - standard harvest date (depending on the crop species and climatic zone) - standard date of tillage (deep ploughing 30cm, date depending on the crop species and climatic zone) - the standard type of three irrigation applications (depending on the climatic zone - drip for the Mediterranean, sprinkler for temperate) - standard dates of three irrigation applications (depending on the crop species and climatic zone) - standard amounts of three irrigation applications (depending on the crop species and climatic zone) - standard date of manure application (depending on the crop species and climatic zone) - 70% of the standard amount of manure application (depending on the crop species and climatic zone) - the standard amount of pesticide and herbicide application (depending on the crop species and climatic zone, not taken into account in biophysical modelling, but important for Agricultural Decision Optimalization)	- standard planting date (depending on the crop species and climatic zone) - standard harvest date (depending on the crop species and climatic zone) - standard date of tillage (deep ploughing 30cm, date depending on the crop species and climatic zone) - no irrigation - standard date of manure application (depending on the crop species and climatic zone) - 70% of the standard amount of manure application (depending on the crop species and climatic zone) - the standard amount of pesticide and herbicide application (depending on the crop species and climatic zone, not taken into account in biophysical modelling, but important for Agricultural Decision Optimalization)	- standard planting date (depending on the crop species and climatic zone) - standard harvest date (depending on the crop species and climatic zone) - standard date of tillage (deep ploughing 30cm, date depending on the crop species and climatic zone) - the standard type of three irrigation applications (depending on the climatic zone - drip for the Mediterranean, sprinkler for temperate) - standard dates of three irrigation applications (depending on the crop species and climatic zone) - standard amounts of three irrigation applications (depending on the crop species and climatic zone) - standard date of manure application (depending on the crop species and climatic zone) - the standard amount of manure application (depending on the crop species and climatic zone) - the standard amount of pesticide and herbicide application (depending on the crop species and climatic zone, not taken into account in biophysical modelling, but important for Agricultural Decision Optimalization)	- standard planting date (depending on the crop species and climatic zone) - standard harvest date (depending on the crop species and climatic zone) - standard date of tillage (deep ploughing 30cm, date depending on the crop species and climatic zone) - no irrigation - standard date of manure application (depending on the crop species and climatic zone) - the standard amount of manure application (depending on the crop species and climatic zone) - the standard amount of pesticide and herbicide application (depending on the crop species and climatic zone, not taken into account in biophysical modelling, but important for Agricultural Decision Optimalization)	- standard planting date (depending on the crop species and climatic zone) - standard harvest date (depending on the crop species and climatic zone) - standard date of tillage (deep ploughing 30cm, date depending on the crop species and climatic zone) - the standard type of three irrigation applications (depending on the climatic zone - drip for the Mediterranean, sprinkler for temperate) - standard dates of three irrigation applications (depending on the crop species and climatic zone) - standard amounts of three irrigation applications (depending on the crop species and climatic zone) - standard date of manure application (depending on the crop species and climatic zone) - 130% of the standard amount of manure application (depending on the crop species and climatic zone) - the standard amount of pesticide and herbicide application (depending on the crop species and climatic zone, not taken into account in biophysical modelling, but important for Agricultural Decision Optimalization)	- standard planting date (depending on the crop species and climatic zone) - standard harvest date (depending on the crop species and climatic zone) - standard date of tillage (deep ploughing 30cm, date depending on the crop species and climatic zone) - no irrigation - standard date of manure application (depending on the crop species and climatic zone) - 130% of the standard amount of manure application (depending on the crop species and climatic zone) - the standard amount of pesticide and herbicide application (depending on the crop species and climatic zone, not taken into account in biophysical modelling, but important for Agricultural Decision Optimalization)

ORGANIC TECHNOLOGY ALTERNATIVES (T25-T30)					
· No-till · extensive ecological · with irrigation	· No-till · extensive ecological · rainfed	· No-till · standard ecological · with irrigation	· No-till · standard ecological · rainfed	· No-till · intensive ecological · with irrigation	· No-till · intensive ecological · rainfed
- standard planting date (depending on the crop species and climatic zone) - standard harvest date (depending on the crop species and climatic zone) - no-till (mulching only) - the standard type of three irrigation applications (depending on the climatic zone - drip for the Mediterranean, sprinkler for temperate) - standard dates of three irrigation applications (depending on the crop species and climatic zone) - standard amounts of three irrigation applications (depending on the crop species and climatic zone) - standard date of manure application (depending on the crop species and climatic zone) - 70% of the standard amount of manure application (depending on the crop species and climatic zone) - no pesticide and herbicide application (to include the effect of pests and diseases, the yield obtained from the biophysical model has to be reduced by 15%)	- standard planting date (depending on the crop species and climatic zone) - standard harvest date (depending on the crop species and climatic zone) - no-till (mulching only) - no irrigation - standard amounts of three irrigation applications (depending on the crop species and climatic zone) - standard date of manure application (depending on the crop species and climatic zone) - 70% of the standard amount of manure application (depending on the crop species and climatic zone) - no pesticide and herbicide application (to include the effect of pests and diseases, the yield obtained from the biophysical model has to be reduced by 15%)	- standard planting date (depending on the crop species and climatic zone) - standard harvest date (depending on the crop species and climatic zone) - no-till (mulching only) - the standard type of three irrigation applications (depending on the climatic zone - drip for the Mediterranean, sprinkler for temperate) - standard dates of three irrigation applications (depending on the crop species and climatic zone) - standard amounts of three irrigation applications (depending on the crop species and climatic zone) - standard date of manure application (depending on the crop species and climatic zone) - the standard amount of manure application (depending on the crop species and climatic zone) - no pesticide and herbicide application (to include the effect of pests and diseases, the yield obtained from the biophysical model has to be reduced by 15%)	- standard planting date (depending on the crop species and climatic zone) - standard harvest date (depending on the crop species and climatic zone) - no-till (mulching only) - no irrigation - standard date of manure application (depending on the crop species and climatic zone) - the standard amount of manure application (depending on the crop species and climatic zone) - no pesticide and herbicide application (to include the effect of pests and diseases, the yield obtained from the biophysical model has to be reduced by 15%)	- standard planting date (depending on the crop species and climatic zone) - standard harvest date (depending on the crop species and climatic zone) - no-till (mulching only) - the standard type of three irrigation applications (depending on the climatic zone - drip for the Mediterranean, sprinkler for temperate) - standard dates of three irrigation applications (depending on the crop species and climatic zone) - standard amounts of three irrigation applications (depending on the crop species and climatic zone) - standard date of manure application (depending on the crop species and climatic zone) - 130% of the standard amount of manure application (depending on the crop species and climatic zone) - no pesticide and herbicide application (to include the effect of pests and diseases, the yield obtained from the biophysical model has to be reduced by 15%)	- standard planting date (depending on the crop species and climatic zone) - standard harvest date (depending on the crop species and climatic zone) - no-till (mulching only) - no irrigation - standard date of manure application (depending on the crop species and climatic zone) - 130% of the standard amount of manure application (depending on the crop species and climatic zone) - no pesticide and herbicide application (to include the effect of pests and diseases, the yield obtained from the biophysical model has to be reduced by 15%)

4 Using Biophysical and Climatic Models to generate production scenarios for agents' optimisation

Based on the determined scenarios of the meteorological conditions of the agents and the defined technological alternatives for crop activities, production scenarios for agents' agro-economic optimisation are generated. For three defined weather scenarios (standard weather year, worse than a standard year, or better than a standard year) and the chosen technological alternatives, which take into account conventional and ecological production variants, the simulations of crop yield will be conducted with the use of the adequate biophysical model (e.g. DNDC), and ultimately, an ensemble of outputs from the three models is gathered into the AGRICORE platform. The meteorological input to the biophysical modelling consists of the daily whole-year time series of the meteorological variables obtained through ARDIT (e.g. from MERRA2 database).

The daily whole-year meteorological time series for specific year, being the representative of defined weather scenario, are selected on the base of SPEI classification, as explained in the previous section. This has to be done for all the representative regions (NUTS3 or other arbitrary geo-defined regional shape). Biophysical modelling has to be performed individually for each defined region and for each of the plant species included in the generated synthetic population at the ABM simulation preparation and for all the defined technological activities. As a result of performed biophysical model computations (3 x 30 = 90 executions per region and per crop) a matrix of average expected yields will be obtained. As the spatial resolution (precision) of the meteorological data and the data on soil status is lower than the resolution of the agent's spatial coordinates, the same weather-technology-yield matrix can affect a group of agents located in the a 'nearest' geographical vicinity (represented by the same NUTS3 or other arbitrary geo-shape). In Table 4 exemplary matrix is presented for illustrative purposes.

Table 4: Sample matrix of average expected yields for each of the crop-technology combinations predefined in the model for one agent for one crop species.

	No-till extensive mineral fertilization with irrigation	No-till extensive mineral fertilization rainfed	No-till standard mineral fertilization with irrigation	No-till standard mineral fertilization rainfed	No-till intensive mineral fertilization with irrigation	No-till intensive mineral fertilization rainfed	...	Till standard mineral fertilization rainfed	...	No-till intensive ecological rainfed
wet	$X^w{}_1$	$X^w{}_2$	$X^w{}_3$	$X^w{}_4$	$X^w{}_5$	$X^w{}_6$	...	$X^w{}_{10}$	...	$X^w{}_{30}$
standard	$X^s{}_1$	$X^s{}_2$	$X^s{}_3$	$X^s{}_4$	$X^s{}_5$	$X^s{}_6$	...	$X^s{}_{10}$	...	$X^s{}_{30}$
dry	$X^d{}_1$	$X^d{}_2$	$X^d{}_3$	$X^d{}_4$	$X^d{}_5$	$X^d{}_6$	...	$X^d{}_{10}$	...	$X^d{}_{30}$

*X is the yield in tons/ha obtained for the specific weather-technology combination (expressed by indices)

This matrix serves as input to the Agricultural Decision Optimisation, informing the decision of each agent about the expected performance of its available alternative activities for the following agricultural year/campaign (please refer to D3.2 for further details on how agents plan their agricultural operation in the short-term).

5 Using Biophysical and Climatic Models to compute the actual production of agents

At the beginning of each of the simulated agricultural annuities, each agent (each agricultural holding) re-adapts its financial planning (its assets and liabilities structure) and replans its agricultural operation (optimal allocation of assets to productive activities). If the manager of each farm could see into the future, she would be able to know exactly what the weather conditions are going to be during the immediately following agricultural campaign. She could also anticipate with her decisions other disturbances external to the AH (pests, implementation of new policies, variations in costs or product prices, etc.). Unfortunately, this does not happen in reality, and therefore there is always a difference between what the farm manager believes will happen (the effect that the management decisions will have on the financial-agronomic state of the farm) and what actually ends up happening (the state to which the farm is actually driven as a joint effect of the management decisions AND the external constraints and disturbances)

In the multiyear simulations realised through AGRICORE, this is modelled by clearly differentiating, at each simulation timestep (year/campaign) the Optimisation phase from the Campaign Realisation phase. In the latter, the following is simulated:

1. What is the 'actual' productivity of each activity as a function of given climatic-meteorological conditions.
2. What is the 'actual' cost of the agricultural campaign for each agent, based on the realisation of point 1 and on the 'real' price of the productive factors. For this purpose, use is made of the link with the Production Factor Market Modules.
3. What income each producer obtains as a result of his agricultural activity, based on the total production given by the realisation of point 1 and the 'actual' price he receives for it. For this purpose, the connection to the Product Market Module is used.

In the above enumeration, the word 'actual' refers to the values obtained as a result of simulating the realisation of the campaign, as opposed to the values 'predicted' as part and result of the optimisation phase in each iteration of the global simulation of the period under analysis. These 'actual' values may coincide with the 'real' values that occurred in the crop year in question (in case an ex post analysis is being done and such data are already known) or be fully simulated values that reproduce the 'real' values that the agents will face (as in the case of an ex-ante impact assessment). This functionality is particularly useful to be able to assess the impact of the same policy under different climate, cost or market scenarios.

Focusing only on item 1, the agricultural inputs and states for each agent (and its crop/livestock activities), together with its specific soil conditions and actual climatic conditions, are used as input for the biophysical models to compute the actual output production of each agent. After each agent makes its decisions on crop-technology mix selection, only one simulation is needed per each agent-activity element. However, the input data coming from the climatic module differs depending on whether the impact assessment is ex-post or ex-ante. In the case of ex-post already recorded data can be used, whereas ex-ante assessments require either a daily meteorological data prediction taking into account the climate change scenarios, or the presented procedure assigning historical data to each assessed year based on its predicted SPEI category. In any case, the actual climatic data for each simulated year is defined a priori during the initialisation phase and not done online during the simulation phase. The modelling will be performed after the gRPC request is passed to the Biophysical models connectors module from the ABM Simulation Engine to translate the inputs to the format recognisable by the specific biophysical model. After the calculation is performed, the output information on actual production and updated soil status coming from the biophysical model is delivered via the gRPC response to the ABM simulation engine. The output on the actual production of each agent given by the biophysical modelling, once aggregated for all of them located in the same region/country, will be then further used in the Product Market Module.

6 Conclusions

The linking capabilities of biophysical models for the ABM have been defined and described in this report. The methodology for the determination of the meteorological conditions of the agents has been elaborated both for the agro-economic optimisation (SP), as well as for simulating the actual agricultural season production levels. The meteorological conditions of the agents for the agro-economic optimisation (SP) are obtained based on the SPEI index. The procedure of meteorological conditions determination was elaborated separately for ex-post and ex-ante impact assessment, with two possible options available for ex-ante (either prediction coming directly from the CMIP6 database taking into account IPCC climate change scenarios, or from the procedure utilizing the SPEI categories pattern reconstruction). The technological alternatives for crop activities have been defined. They are divided into two groups of methods related to conventional and ecological agriculture, differing in terms of irrigation, fertilization, and tillage practices. The main source of the information from the biophysical models, which will be delivered to the ABM simulation engine is the crop yield related to various weather-technology scenarios, however, it is also planned to use their outputs in the IAM to calculate various KPIs.

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

Deliverable Number	Deliverable Title	Lead beneficiary	Type	Dissemination Level	Due date
D3.5	Positive-normative configurations	IDENER	Report	Public	M37
D6.3	Biophysical model connection modules	IAPAS	Report	Public	M34
D1.9	Agricultural Research Data Index Tool (ARDIT)	AAT	Report	Public	M31