D5.2 AGRICORE Land Market Module

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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 measures under and outside the framework of the Common Agricultural Policy (CAP).

This deliverable presents the results of *Task 5.2 - Land Market Module*, led by AKD. The objective of Task 5.2 is to design a module which considers the interaction between agents regarding the use and transfer of land. The land transfer is done through buying and selling depending on land price rules defined based on a comprehensive land characterization assessment. Further on, the interaction is performed through an auction system, in which the agents participating set their reservation price and offer price based on their financial optimisation and the average market price from the last time sample. Concerning the agent's participation in the land market, certain conditions are defined. Details on inputs/outputs are presented to ease further integration and interconnectivity of the land market module with other modules such as the ABMs,

For last, in order to endorse the strategy followed within the land market module to accomplish the land transfer between agents, a literature review on the subject and other models' approaches are presented within the deliverable.

Abbreviations

Abbreviation	Full name
ABM(s)	Agent Based Model(s)
ABM-e	Agent Based Model Simulation Engine
AC	Average Cost
ADAM	Agricultural Dynamics through Agent-based Modelling
AGRIPOLIS	Agricultural Policy Simulator
AMP	Average Market Price
AROPAj	European Agro-Economic Model
ARP	Average Rental Price
AVC	Average Variable Cost
CE	Certainty Equivalent
D	Deliverable
ESEU	Evaluated Soil Ecological Unit
EU	European Union
FPSBA	First Price Sealed Bid Auction
GM	Gross Margin
IAM	Impact Assessment Module
ICT	Information Communication Technologies
LARMA	Land Rental Market
LMM	Land Market Module
LP	Long Period
LP-LMM	Long Period-Land Market Module
LRP	Land Rental Price
MMM	Multi Market Model
MP-MAS	Mathematical Programming Based Multi Agent Systems
MVL	Marginal Value of Farmland
NPV	Net Present Value
NPVM	Net Present Value Model
P	Price
PMP	Positive Mathematical Programming
PR	Progress Rate
REGMAS	Regional Multi Agent Simulator
SMs	Small Medium(s)
SP	Short Period
SP-LMM	Short Period-Land Market Module
SwissLand	Switzerland Land Model
TC	Total Cost
TR	Total Revenue
WP	Work Package
WTA	Willingness to Accept
WTAP	Willingness to Accept Price
WTP	Willingness to Pay
WTPP	Willingness to Pay Price

List of Figures

List of Tables

Table of Contents

1 Introduction

The AGRICORE project (European Commission call RUR-04-2018) takes advantage of recent advances in modelling techniques and ICT to present a novel tool for increasing the current capacity to simulate agricultural policy. Such simulations will be conducted by modelling each farm as an independent decision-making entity that analyses its context and makes decisions based on its current status and future objectives. This modelling technique will also mimic interactions between farms and their context at regional and global scales, thereby allowing issues like the environment, rural integration, ecosystem services, land use and markets to be considered. Furthermore, the latest advancements in big data and artificial intelligence will help to:

- accelerate the lengthy parameterisation and calibration phase required to create realistic models
- improve farmers' behaviour and interactions, and
- accurately assess the effects of global events and EU policies with the consequence of improving policy design, impacts, evaluations and overall monitoring.

The objective of task 'T5.2 - Land Market Module' is to design a module which considers the interaction between agents regarding the use and transfer of land. The module will contain a land market that allows farmers to place bid/ask orders based on land pricing rules. The strategy to be followed will require a comprehensive land characterization assessment that considers factors that define a land plot, such as its geographical position, land cover, land quality, land use and landscape. Establishing connections with geo-referenced datasets will enable the initialisation and calibration of the land market module. As this task is responsible for revealing agent interactions in the land market, it requires an initial assignation of land to each agent (Agricultural Holding). This is performed during the synthetic population generation process, mimicking the distribution and characteristics of the real population of agricultural holdings that the researcher intents to analyse. In WP5 the AGRICORE tool will be enhanced to allow a thorough impact assessment of the agricultural policies, including those related to land, such as changes in land cover distribution, changes in average farm size, and accumulation of land by large landholders, etc.

2 An overview of the AGRICORE platform with respect to land market

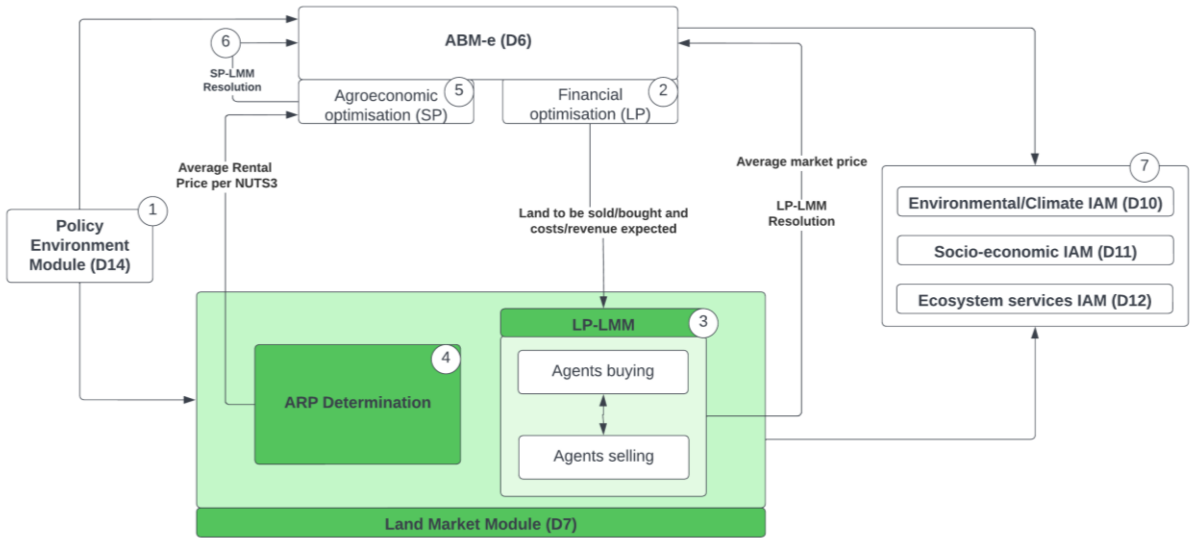

Figure 1 Land market module interconnections with other modules

Figure 1 depicts the schematic representation of the "land market module (LMM)", which is positioned within the "Multi-Market Module (MMM)" of AGRICORE modular architecture. The MMM consists of Land Market, Product Market and Production Factor Market modules. The LMM has bidirectional interaction with the Agent-Based Model Simulation Engine (ABM-e/D6). Policy instruments imported from the Policy Environment Module (D14) affect the agents in the ABM-e, but might also affect LMM specifically, e.g. through policies favouring land concentration ①. As highlighted in the diagram, there are two blocks in the LMM. The differentiation is made on the basis of the nature of the transfer (temporary rental vs. permanent transfer) and on the basis of the type of indicators of the agent (economic vs. financial) which are taken into account to determine its market behaviour. In the LP optimisation ②, the farm agent considers the financial and economic indicators presented in WP3 (current ratio, liquidity ratio, debt-equity ratio, solvency ratio and net profitability) to decide whether to invest in the farm (extending farm-scale) or to exit (full exit or downsizing). Then, in the long period land market module (LP-LMM), the buying and selling exchanges of land between agents are resolved ③. After that, the average rental price (ARP) needs to be computed at the regional (NUTS3) level ④, as it is then used on the agro-economic optimisation to decide if it is profitable to either rent in or rent-out land. In the SP optimisation ⑤, the farm agent evaluates their own economic situation and takes into account gross margin (or their equivalent counterpart marginal cost) for making land rental decisions. Then, the list of land exchanges due to rental interactions is passed also to the ABM-e ⑥ so that each agent can update its land availability status. Finally, there is also unidirectional interaction ⑦ between the LMM and Environmental/Climate IAM, Socioeconomic IAM and Ecosystem Service IAM, so that certain KPIs related to land use and land trading can be calculated.

3 Existing approaches for modelling Land Market Interactions in the ABM literature

The transfer of land actives in land markets can be divided into two main categories as farm transfers as a whole, and transfers of particular land plots or parcels. Both of these categories can be further divided into two subcategories such as sales contracts and rental contracts. Farm transfers as a whole can also be divided into other subcategories depending on whether the farm is kept as an independent unit or is going to be used as additional land for the other farms. The first mentioned category is usually referred to as generation transfers [1].

Farm exit and investment decisions depend on the farm holding economic and financial conditions as well as on the farmer's family demographics. Market exit and investment decisions, related to farm operations, are also based on different short and long period indicators. Table 1 presents a series of possible indicators and conditions for farm exit or investment based on farm typology. Key indicators such as economic, financial, demographic (age, existence/non-existence of successor), urban pressure (if relevant) and alternative land use possibilities (income-earning possibilities) are included in this table. Exit and investment decisions, differentiated by farm typology, are based on several conditions including profit and gross margin, retirement age, successor conditions, and income Net Present Value (NPV) obtained from agriculture versus the incomes obtained from alternative land uses.

The opportunity cost of capital and source of labour can be considered as the main decision rules for farm exit or investment decisions. This table can further be extended by adding or disaggregating indicators and conditionality for exit or investment decisions, differentiated by farm typology and rules. For instance, conditionality for exit or investment decisions can be differentiated according to short period and long period horizons. However, this basic form of the table, is sufficient to understand how land market agents act under several financial, economic and demographic conditions.

Table 1 Possible Indicators and Exit/Investment Conditions by Farm Typology

Indicators	Exit/investment conditions (sell/buy)	Farm typology	Decision rule	Who buys or rents
Net Profit (Long-Period)	TC>TR (TR includes policy support) or AC > P; sells the land	Large	Opportunity cost of capital	Profitable large farm in the vicinity
Gross Margin (Short-period)	AVC>P (including market price + policy support per unit of output) or MC > P; sells the land/parcel	SMs family owned	-Source of labour (if family labour is abundant)	Profitable large farms or SMs in the vicinity
Retirement Age	i.e (ADAM and SwissLand models); >65	SMs family owned	Institutional requirement	
Existence of Successor	Continue if the return from the farm business is satisfactory (Net Profit/GM) or otherwise stop; if NP/GM is not positive; a large farm sells the land/parcel, but SMs either sell the land/parcel or lease the land depending on income from capital gain (i.e. interest-earning) versus earnings from leased land	-Large - SMs family owned	- Opportunity cost of capital -Source of labour (if family labour is abundant)	Profitable large farm or SMs in vicinity

Nonexistence of Successor	Stop and sell/rent (if prevailing rent is attractive, i.e; annual rent earning > bank interest rate or stock return; lease the land/parcel	SMs family owned	Opportunity cost of capital obtained from selling land/parcel	Profitable large farm or SMs in vicinity
Urban Pressure	NPV income stream from agricultural production < NPV income stream from capital or real estate return; sells the land/parcel	Both large and SMs family owned	Opportunity cost of capital	Non-farm actors
Alternative use (tourism or recreational)	NPV of income stream agricultural < NPV of alternative use; sells the land/parcel or establish their own business	Both large and SMs family owned	Opportunity cost	Non-farm actors (if sells the rent)

Table 2 presents some basic characteristics of the land market in previous ABMs models. The ABMs listed in Table 2 do not allow land sell/buy but they only allow land rent/lease. The land exchange is generally achieved through auctions, but some specific constraints are also used for buyer types, for instance, similar farms or neighbours with maximum profit. The ABMs in the table, except ADAM, are used for evaluating land cover change in the agriculture policy analysis domain, land quality is restricted to either homogeneous or heterogeneous and land types are classified as mixed, land use types (arable, grassland, permanent crops, greenhouses, barn and non-agriculture) and also production system (conventional vs. organic). Generally, equal-sized space is assumed, and both heterogeneous and homogeneous land quality is assumed. Financial, economic and demographic indicators are the main indicators used for exit decisions.

Table 2 Land Market in Agricultural Policy-Oriented ABMs Models

Land Feature	AGRIPOLIS [2]	REGMAS [3]	MP-MAS [4]	SWISSLAND [5]	ADAM [6]	LARMA [7]
Cover/use change	Cover	cover	cover	cover	use	cover
Ownership	both farmer and non-farmer	farmer	farmer	not important	farmer	farmer
Sell/Buy	not allowed	not allowed	not allowed	not allowed	not allowed	not allowed
Rent/Lease	allowed	allowed	allowed	allowed	allowed	allowed
Types/ Quality	arable land, grassland, non-agriculture/ homogeneous in each group	mixed/ heterogeneous in each group	mixed/ heterogeneous in each group	product-based/both organic and conventional	barns, grassland, green-houses, permanent crops, or arable land	
Interaction	through 2 step auction/land shadow price	through auction; bidders are restricted by distance/land shadow price	through auction; bidders are restricted by distance	The neighbour with max. household income can rent land	priority is given to the same farmer type	endogenous land market through WTP/ WTA mechanism

			/ shadow price			
Space/ Quality	equal-sized plots/ heterogeneous	equal-sized plots/homogeneous	equal-sized plots/homogeneous	not important	unequal sized parcels/heterogeneous	unequal sized/ homogeneous
Exit/rules of exit	financial-economic, age	financial-economic	financial-economic, age	age/successor/household relative income	Age/successor/ mortality	financial-economic
Land price determination	Shadow Price (modified by transportation cost)	Shadow Price (modified by transportation cost)	Shadow Price (adjusted transaction cost)	average regional rent price from FADN data (modified by income increase due to the land plot)	Institutional rent price	WTA/WTP (based on expected return)

3.1 Farm exit/investment decision rules

3.1.1 Financial and Economic

As seen in Table 2, the existing ABMs do not contemplate agricultural agents' land sell/buy activities. The land title change is assumed to occur after the owner passes away, therefore, it can be said that the ABMs in Table 2 are generally used for short period-focused assessments.

Financial and economic rules used in existing agricultural and rural development policy-focused ABMs are varied, basically depending on household income and welfare or profit maximization. The agent in AgriPolis and RegMAS decides whether to exit or stay in the sector based on the expected returns for the next year. If the farm agent's equity capital is zero (the farm is illiquid) in RegMAS or if the off-farm income of the farm-owned production factors (land, family labour, and working capital) is higher than farm income (in AgriPolis and RegMAS) then it becomes rational for the agent to exit. In AgriPolis, an exit decision can be also taken if the farm agent has reached a certain age and there are no successors to take over. However, even if successors are present, their off-farm generated income should be lower than farm income, otherwise they are assumed not to take over. Opportunity costs of farm labour are quite decisive.

The household's expected income over the next few periods is an important consideration in deciding whether to exit or invest in AgriPolis. A farm agent's time horizon for planning is one period. Therefore, investment opportunities and farm employment opportunities in the next period are factored into the computation of expected household income. Assuming that a farm agent's land endowment remains constant, it is also essential to accurately estimate the expected household income. The opportunity costs of all on-farm inputs are compared to the resulting household income expectations to decide whether to exit or to continue production.

In RegMAS, a farmer takes an exit decision when the equity capital of the farmer is equal to zero or the farm is illiquid when the opportunity costs of off-farm activities exceed profit from production operation on the farm. In MPMAS the agent exits if the bankruptcy cannot be avoided. Based on the physical and economic outcomes of the production/investment decisions given in the first step of the simulation, the agent either sells assets to retain solvency and continue farming or leaves the agricultural sector. In MPMAS, for a farm to continue operating after its current manager retires or passes away, it is essential that a viable successor is in place. The presence of a potential successor, who is usually a member of the farm family, can have an outsize impact on investment and production decisions far in advance of the present farm manager's retirement. Thus, the birth rate and the willingness of children to take over the farm, as well as the retirement age and mortality rate of the farm manager, are crucial factors in determining the longevity of a farm. Despite the fact that some of these factors may be influenced by the farm's financial situation, they do not offer a full deterministic explanation and are modelled as stochastic processes in MPMAS. In ADAM, the same farm types in the region acquire the land title after the owner passed away.

In SWISSland, the agents are initially modelled by creating a spatially realistic municipality structure that incorporates neighbourhood characteristics throughout the farm locations and which are assigned to farm locations in the created municipalities. The model allows a plot-by-plot land lease of "exiting agents" to the remaining agents in the immediate vicinity. Four main criteria that have an impact on the agents' farm exit or farm takeover decision-making were identified for the model construction. These are i) heirless agents will retire from farming and lease out their land; ii) an agent at retirement age will make the farm exit decision if the household income is more than zero; iii) the farm exit decision will be made before the retirement age for scenarios where there is a drastic shift in policy and a correspondingly sharp decrease in revenue that would cause a negative household income over a 5 year period; iv) the decision of an agent on whether or not to take over will be based on the previous agents potential household income. The agent will only take over the farm from his predecessor if their household income is higher than an exogenously determined average regional minimum income (an average income for the second and third sectors in Switzerland is taken as a reference).

3.1.2 Demographics

As illustrated earlier in Table 2, the demographic indicator (retirement age threshold) is one of the main or only decision criteria for farm exit. Four out of six ABMs presented in table 2 use age as criteria for exit decision (rent out land). The retirement age threshold is only used for exit decisions in both ADAM and Swiss-land. In AGRIPOLIS, an exit decision can also be made if the farm agent has reached a certain age and there are no successors to take control. A desired feature in MP-MAS relates to successors being able to take over when household members die, retire or give birth. The agent is willing to forgo their own income if a major investment or farm expansion is necessary to employ their successors. In the SWISSLAND platform, agents reaching a certain age threshold (qualifying to receive direct income support) leave the farm business to possible successors (if there are any) and the successors take over if the farm income is above the average income level in the region. In ADAM, a similar process to SWISSLAND is implemented except the age threshold and farm profitability are the key criteria. The exit/stay decision of the agent in the LARMA platform is made based on whether the level of calculated working capital in each production cycle covers plantation and rental costs. In the study performed by Maes and Passel (2014) family, member succession is a crucial step even if the agent transforms into an elderly farm without significant growth, new investment, high efficiency or new innovations. The activity only ends when the owner passes away.

3.1.3 Short Period versus Long Period Decision

As previously mentioned, existing agriculture policy assessment ABMs only allow land renting/leasing, which infers that all of these models are interested in short period decisions. Decisions to buy or sell land are normally taken in a long period horizon, particularly where small and family farm structures are prevailing in a given spatial area. For these types of farms, operating economically above the shutdown point is sufficient to continue the business in a short period. On the contrary, net return from production activities such as net profit is particularly important for large-scale commercial farms in both the short and long periods, particularly since labour requirements and operations costs are high. While the number of large-scale farms is very limited in EU countries, the AGRICORE project assumed that land selling and buying is occurring in the long period because of the amortisation period of farm machinery (one of the major farm assets) and renewal of the EU agriculture and rural development policies. Furthermore, from an economic point of view, even if a large-scale farm experiences negative net profit in a short period, its immediate decision is most probably focused on restructuring the farm holding rather than exiting, with a possible restructuring model which includes renting parcels/plots of land to other firms.

3.2 Land Rent and Value Determination

3.2.1 Theoretical Background of Land Price and Valuation

The land is the fundamental input for agricultural production and also the main asset of farm holdings. The spatial nature of the land is another differentiating factor. Non-commodity output or services provided by land cannot be measured using monetary terms. Land rental value is not only an economic value; in addition to its production function, land has ecological, cultural, informative and educational, recreational, and social functions [1].

According to classical economic theory based on the fixity of land supply, the land value varies depending on land characteristics such as fertility (Ricardo, 1815) and location or distance to market (von Thünen, 1826). However, there are other factors that can affect the land use decision for a given plot. These include socioeconomic factors such as product prices and policy variables such as taxes or subsidies [8].

Apart from the fixity of land supply, classical economists also assume that land cannot be substituted in the production process. Therefore, the need for special treatment of land in economic analysis becomes clear. As a result, both the fixity and substitution assumptions have been relaxed, but the land is still a very scarce production factor and inelastic in terms of substitution. Even though the neo-classical theory considers land (as well as labour) and capital similar in terms of being a production factor, the special role and properties of land are widely recognised. As demonstrated by Miranowski and Cochran the fixed location of land means that it is also bound to a geo-climatic environment that influences soil characteristics and productivity. As such, the amount of land suitable for specific production processes is relatively limited. The special nature of land stems from the fact that land cannot be moved, more land cannot be produced, and land does not disappear [1].

3.2.2 Net Present Value Model (NPV Model)

According to the NPV model, the maximum price a farmer would be willing to pay for a particular piece of agricultural land at time **t** is equal to the summed and discounted expected future stream of earnings (income) from the associated land [9]. The NPV approach for farmland price computations is considered theoretically sound and is the most cited model in farmland price literature [10]. The farm value is the sum of the future net cash flows discounted at a particular rate. Following this method, one needs to accurately estimate future cash flows (investment and operating flows) as well as the discount rate, which can be viewed as the required rate of return [11]. Besides returns to land, other factors may influence the land price not included in the NPV model. One example is competing for demand for land for non-agricultural use, i.e. urban pressure. Another example is the structure of the market, e.g. market power of only a few land owners that are willing to sell [9]. An important remark in regard to the NPV model is that it basically reflects the willingness to pay and therefore the demand side of the price determination process [9].

3.2.3 Hedonic Price Model (HPM)

The hedonic pricing approach is based on consumer theory (Lancaster, 1966; Rosen, 1974) and assumes that the price of the good (i.e., land) can be explained by varying land characteristics [9]. The characteristics set include distance to market/or main infrastructure, lot size, crop yield (reflects soil quality, irrigation and climate-related variables), urban pressure proxies, population density in a location such as a municipality area, and amenities in location and so on. In the case of land value/rent determination, the hedonic price model is widely employed both with time series and also cross-section survey data. Slaboch and Malý (2022) argued that the official price of land in the Czech Republic is influenced by the evaluated soil ecological unit (ESEU) price. The ESEU price expresses the production potential of the land on the basis of soil quality indicators, which include the climatic region, the main soil unit, slope and exposure and, last but not least, the depth of the soil profile and skeletonisation. Climate change also means that the current values of the definition (e.g., for a climatic region, this refers to the average temperature or average precipitation) do not correspond to reality. The authors employed a hedonic method to determine shadow prices which reflect the intensity and direction of the effect of each input variable (detailed soil characteristics and climate change variables) on the price of an ESEU.

The Hedonic Price Model (HPM) can be considered an extension of the NPVM, and it is used extensively in the context of environmental and natural resource economics, as well as real estate economics. The HPM which was originally formalised by Rosen in 1974, is comprised of a price analysis of differentiated products depending on their attributes. The model involves disclosing the implicit prices for many characteristics of heterogeneous items.

The conducted literature review searched for studies using HPM as the methodology to reveal the variables which affect agricultural land values. The attributes represented in the models as explanatory variables can be split into two main groups. The first group can be categorised as the group of variables which describe the non-monetary properties of agricultural land including soil quality, lot size, climatic properties (temperature and precipitation), shares of forest land, grassland, building land and horticultural land in total land area, water source/supply, proximity to urban sites (distance to district city or municipality) and the future development potential of the location. The second group comprises the monetary properties of the agricultural land considering the different possible agricultural production choices of the farmers, such as the type of crops produced and animal husbandry operation, yield and net farm incomes. In addition to these two groups of variables, there are certain studies taking the types of agricultural land buyers (agricultural/non-agricultural/cooperative) into consideration and including them as explanatory variables within their models.

After examining the relevant literature, it is possible to observe the different types of theoretical models which have been developed to explain the value of agricultural land. Between 2000-2021 there were 31 studies with the aim of determining the drivers of farmland values which have subsequently been evaluated to represent the empirical literature. The structure of the reviewed econometric models in terms of their functional form are either linear (8), semi-logarithmic (15) or double logarithmic (8). The econometric model structure is important in terms of interpreting the statistically significant coefficients. If the econometric model follows a double logarithmic (log-log) functional form, then the coefficient estimated from the model is elasticities for each data point. However, the coefficients estimated from the studies that employed semi-logarithmic (log-lin) or linear (lin-lin) functional forms need to be converted into elasticities. The coefficient of hedonic properties in linear and log-lin models is converted into elasticities using the arithmetic averages of dependent and explanatory variables as stated in Gujarati (2009). The review spans 17 countries consisting of 10 studies from the European Union, 7 studies from the United States of America and 2 studies from Brazil. The review also encountered individual studies from countries including Turkey, Nigeria, Tanzania and Ukraine. Out of the 23 studies that included semi-logarithmic or linear models, 6 of the studies did not provide descriptive data statistics, hence the elasticities of variables representing the hedonic characteristics for farmland could not be calculated. The details of the reviewed hedonic farmland price estimates are included in Table 3. Table 4_reveals the elasticities of hedonic characteristics of farmland computed by hedonic land price/value model estimates of the reviewed studies.

Table 3 Hedonic Price Literature Revived on Land Value/Price Estimation

Author	Country	Source of Data	Model Structure	Variables with statistically significant coefficients
Takac et al. (2020) [12]	Slovakia	National official data	double log	distance to town
Merry et al. (2008) [13]	Brazil	Survey	double log	fraction of cropland, distance to town, share of forest land
Ma (2010) [14]	Michigan /USA	Official data	log linear	soil quality, distance to town, share of forest land, share of building land, lot size
Reydon et al. (2014) [15]	Brazil	National official data	double log	soil quality, share of building land, electricity
Kocur Bera (2016) [16]	Poland	National official data	log linear	soil quality, distance to municipality, share of forest land,
Patton and McErlean (2003) [17]	Ireland	National official data, Survey	double log	soil quality, distance to municipality, lot size, potential site
Hüttel et al. (2016) [18]	Germany	National official data	linear	soil quality, share of grassland, share of forest land, share of building land lot size, number of farms
Sills and Caviglia-Harris (2009) [19]	Brazil	National official data, Survey	log linear	soil quality, lot size, distance to town, share of horticultural land, lot size
Curtiss et al. (2013) [20]	Czechia	National official data	log linear	distance to town, lot size, number of farms
Ritter et al. (2020) [21]	Germany	National official data	log linear	soil quality, share of grassland, lot size,
Huang et al. (2006) [22]	Illinois/ USA	National official data	double log	soil quality, distance to municipality, distance to town, lot size, number of farms
Ma and Swinton (2012) [23]	Michigan/USA	National official data	log linear	soil quality, distance to town, share of forest land, share of grassland, lot size, share of building land
Feichtinger and Salhofer (2013) [24]	Germany	National official data	linear	soil quality, distance to town, potential site
Borchers et al. (2014) [25]	USA	National official data	double log	share of forest land, lot size, potential site
Wineman and S. Jayne (2018) [26]	Tanzania	National official data	log linear	soil quality, temperature and precipitation, distance to town, share of horticultural land, water source on lot
Sklenicka et al. (2013) [27]	Czech Republic	National official data, Survey	linear	distance to town, lot size, number of farms
Pyykkönen (2005) [28]	Finland	National official data	semi-log	temperature and precipitation, lot size, water source on lot, number of farms
Andriy (2016) [29]	Ukraine	National official data	log-linear	soil quality, lot size, water source on lot

Vasquez et al. (2002) [30]	Idaho / USA	National official data	linear	soil quality, lot size
Monaco et al. (2019) [31]	Milan / Italy	National official data	log-linear	temperature and precipitation, water source on lot
Bastian et al. (2002) [32]	Wyoming / USA	National official data	log-linear	soil quality, distance to town
Mallios et al. (2009) [33]	Chalkidiki / Greece	National official data	log-linear	distance to municipality, distance to town, lot size
Ehirim et al. (2017) [34]	Imo / Nigeria	Survey	double-Log	soil quality, lot size, water source on lot
Matthew Carl Stinn (2012) [35]	Iowa / USA	National official data	double-Log	lot size
Vural and Fidan (2009) [36]	Bursa / Turkey	Survey	linear	lot size

Table 4 The elasticities of hedonic characteristics of farmland computed from hedonic land price/value model estimates

Hedonic Characteristics of Land	Number of Studies including the Variable	Min	Max	Average
Yield	3/25	0.036	1.083	0.553
Soil quality	13/25	0.019	0.725	0.214
Temperature and precipitation	3/25	0.089	1.465	0.596
Share of cropland	1/25	0.066	0.066	0.066
Distance to a municipality (positive coefficients)	3/25	0.200	0.579	0,389
Distance to a municipality (negative coefficients)	2/25	-0.039	-0.519	-0.244
Distance to town (positive coefficients)	5/25	0.123	3.06	1.569
Distance to town (negative coefficients)	8/25	-0,020	-3.685	-0,605
Share of grassland	3/25	-0.004	-0.024	-0.009
Share of horticultural land	2/25	0.156	0.196	0.176
Share of forest land	4/25	-0.160	-0.647	-0.258
Share of building land	3/25	0.063	0.455	0.194
Lot size	15/25	0.0002	0.742	0.047
Water source on lot	4/25	0.007	0.370	0.157
Development potential of the site	2/25	0.115	0.459	0.287
Number of farms	4/25	0.044	0.275	0.001

Table 4 shows that the most included and statistically significant hedonic attribute variable from the studies conducted is lot size (15 studies out of 25). Soil quality and the distance of the farmland to town were other statistically significant variables being used in 13 studies respectively. According to the calculated elasticities, a 1% increase in soil quality for example will produce a 0.214% increase in farmland price. When the average of the elasticities is taken from double logarithmic models or calculated for the semi-logarithmic models for the "distance to town" variable, it is seen that the sign of the average elasticity is positive, normally anyone expects it to be negative as the farther a farm is from town (hence the market), the lower the value of the farmland. The unexpected negative average is due to two studies whose calculated elasticities were positive and extremely high when compared to the elasticities calculated for other studies. Hence, the studies revealing positive and negative elasticities have been separated in Table 3. When the average elasticities for variables that represent hedonic farmland characteristics are evaluated, it is noted that the highest impact on farmland values comes from the "distance to town" variable. For example, a 1% increase in the farmland distance to town will lead to a 1.519% increase in farmland value. According to the above elasticities, characteristics such as yield, soil quality, temperature, precipitation, shares of horticultural, building and croplands, lot size, presence of an on-site water source, future land development potential and the number of farms all produce a positive effect on farmland values. In contrast, the effect of being far from a municipality or town, shares of forest and grassland are found to be characteristics which decrease farmland values.

3.2.4 Shadow Price Approach

Ricardo's (1815) differential rent theory built on land fertility and von Thünen's (1826) spatial differential rent theory based on transportation costs to the central market provided the conceptual background for the relationship between land rent and farm-based return. According to the classical theories, the farmland value can be measured by net revenue minus production costs. This is usually referred to as the imputed residual farmland return or the imputed value of farmland. On the other hand, the Neo-classical economists solve the problem by incorporating the land factor into their capital theory for valuing the net farmland return and its rental price. This is known as the Marginal Value of farmland (MVL) or, in other words, the **shadow price of farmland** [10]. The shadow price corresponds to the marginal productivity of the land and is estimated using a mathematical programming model for agriculture and also production function estimates such as quadratic profit production [8] [10]. Shadow prices have typically been used as a proxy if the market rental price does not exist. An additional argument for using accounting or shadow prices is that market prices do not always represent the 'true' value to the economy of resources used or produced in a project. There may be several reasons which cause this. For example, some markets are small and monopolized, thereby possibly giving considerable power to some economic organisations to determine prices independently of any feasible alternative source of supply [37].

Chakir and Lungarskay [8] used land shadow price as a proxy for land rent in their ABM model (AROPAj). In this study, the shadow price of land was derived from the model of mathematical programming. An empirical dual production function estimated with FADN data in France demonstrated that the shadow prices of land and labour were persistently diverging from the observed price. The average shadow value of farmland was estimated at about 550€/ha/year which is five times higher than the average rental price of 112€/ha/year over the studied period [10]. The divergence from land market price from shadow price is generally justified by institutional regulation and hedonic characteristics. For example, the future development potential of the land area is not reflected in land market price statistics, therefore implicit (shadow) land prices are computed from hedonic model estimates that are usually higher than land market price statistics. In the case of France, the agricultural land market is regulated by public structures, and land market prices and land rents are upper bounded [9]. Arslan [38] argued that market prices may fail to explain farmers' land allocation behaviour if the relevant decision prices are "shadow prices" that deviate from market prices. This may be the case for farmers who attach significant non-market values to their crops. If, however, market prices fail to reflect the true value farmers attach to their output, conventional models based on market prices may yield wrong predictions, and farmers may not respond to price signals. Jeanneaux et al., (2020) criticized that the method based on the accounting (shadow price) /market value of the different farm assets does not consider the sociological point of view of intangible assets.

A summary of the land rental market processes used for MPMAS, AgriPoliS, RegMAS and SwissLand is provided below:

- MPMAS: Each plot as measured corresponds to one parcel and is independently treated on the land rental market in the original land market implementation. The potential plot suppliers and renters are based on shadow price in which each agent determines the price according to soil type and compares it against the average shadow price of all agents. If the shadow price is adjusted with a mark-up parameter less transport cost from the farmstead to the plot is lower than the average shadow price, then the agents will offer those plots for rent. The agents in a favourable shadow price position will try to rent the plots offered at the auction. The land market module in MPMAS screens all the offered plots and identifies the bidder with the highest bid. If this bid is higher than the minimum rent expected by the owner, a rental contract is prepared, and the rental payment is set to the average between the bid and the expected minimum rent. Subsequently, both the owner and tenant calculate their new shadow prices and decide whether to offer or bid for additional plots [39].
- AgriPolis: For each period the available land for rent is allocated in an iterative auction. The process starts when a farm agent is asked by the auctioneer to make a bid for a particular plot in the region. A farm agent aims to rent an available free plot which is close to the farmstead and next to other plots belonging to the same farm agent. The maximum land quality plot price or bid is a function of both transport costs from the farmstead to the plot and the number of adjacent plots. Therefore, similar to MPMAS, the shadow price in AgriPolis is adjusted by the distance and the number of adjacent plots, and then the adjusted shadow price is compared against the average of eight additional plots. This approach is followed because the shadow price for land derived from the optimization model may potentially change rapidly if calculated for more than one plot at a time. It can be an important computational issue if farm agents bid for more than one plot at a time. Accordingly, in addition to the shadow price for only one plot, the average shadow price for renting eight plots at a time is calculated. The maximum shadow price of one additional plot and the average shadow price of eight additional plots is then used as the basis for the bid. Similar considerations apply when a farm abandons rented land to increase its overall profit. In this case, a farm would abandon the rented plot if the shadow price does not cover the plot costs which include the rent and transportation costs. After giving up a plot, the farm recalculates the shadow price of land. The procedure is repeated until the shadow price of land is at least equal to the plot costs. Unless a farm agent withdraws from agriculture altogether, it is not possible to let owned land be rented by another farm agent. In AgriPoliS, the rent paid for a plot does not exactly correspond to the bid given in the land auction because of shadow prices. Therefore, rents can vary significantly between farms which do not correspond to reality. Most new rental contracts include a threshold that places rents in the context of average regional rent. For these reasons, the actual rent paid for a newly rented plot is calculated as the square root of the weighted geometric bid average given in the auction and the average regional rent [2].

The duration of the rental contract is an important point to be considered in the land rental market. In AgriPolis, it was assumed that a farm agent can terminate (sustain) the contract at the end of the planning period if the rented land return is unfavourable (favourable) such as a positive (negative) gross margin or profit. Accordingly, the rental land amount is available either because a farm agent withdraws entirely from agriculture or because rental contracts are terminated [2]. A similar assumption can be assumed in AGRICORE. In the MPMAS, the rental contract is normally one year, but it can be extended depending on the purposes of assessment. For instance, MPMAS had gone under a revision to run simulations of climate change adaptation in Germany and allowed long-period land rental contracts [39].

- REGMAS: This ABM assumes that the rental land market is working on fixed-term contracts whose duration is randomly chosen within a fixed interval. It does not allow direct farm-to-farm renting contracts. Farm agents can only rent from intermediary land pools. These pools consist of plots recently released by existing farms and previously listed plots for renting. Farmers are able to rent these available land plots through a bid process. The farm agent offering the higher rent price will acquire the plot. The farm agents base their rent price offer on the shadow land price for any plot which is on the market. When they are asked to bid he/she then offers a derivative of this shadow price to take into account the transaction costs. Any farmer can associate a shadow price to any plot for rent and when asked to bid he/she offers a fraction of this shadow price to take into account both fixed and variable transaction costs and overheads. The shadow price for any plot for renting is simply calculated by performing two MIP optimization problems, with and without the plot, and calculating the difference between the two profits [3].

- SwissLand: Income growth due to new land plots is what the agent considers while making a leasing decision with this model. The economic benefit from plots declines as the supply of plots increases because other production inputs, including labour, have a limiting effect. Agents who make exiting decisions according to the above-mentioned income criteria tend to give plots to the remaining agents in the immediate vicinity. The group of agents interested in an existing agent scheme is comprised of the five closest agents to the agent. The allocation of property to neighbouring agents and the lease prices are modelled as a plot-by-plot bidding procedure. The first lease price requested by an existing agent is determined by the average regional prices of the FADN farms for arable land and grassland in the base year. Each agent in the bidding process is optimized with the new plot to determine the increase in income for all neighbouring agents. The neighbouring agent takes possession of the plot that yields the highest profit at the lease's maximum price. If the maximum lease price exceeds the income increase of all local agents, the bidding process is repeated to include agents from areas further away. The assumption is that the existing agent will gradually lower the lease price if the upper limit is also too high for agents further away, hence a repeated bidding process will occur. In the scenario where a plot's lease price is greater than zero and no neighbouring agent can make a profit from the plot, the plot is considered to be fallow land. The model assumes that the existing agent will pass the plot to the neighbouring agent (rather than leaving it as fallow land) if the neighbouring agent only benefits from leasing when the lease price is zero.

3.2.5 Willingness to Pay (Accept) Approach

A land market model (LARMA) developed for the Pampas region in Argentina is an empirical example of the Willingness to Pay/Accept approach [7]. In this model, land rental price (LRP) is endogenously determined. This model is referred to be a hybrid model by its authors because it relies partly on Neo-classical economic theory, but it addressed drawbacks of the neo-classical approach by being integrated into an agent-based model. The LRP formation assumes economic equilibrium where the price-established supply of rental land area is equal to land demand. In the model, The LRP depends on (a) the "willingness to accept" prices (WTAP) of owners renting out land due to lack of capital or dissatisfaction with recent economic progress (a Minimum Progress Rate, (MPR) is targeted), and (b) the "willingness to pay" prices (WTPP) based on economic gross margin and working capital (WC) of potential tenants. Landowners base WTAP on the estimated profit they could achieve from operating their farms. Potential tenants base WTPP on their target gross margin from the upcoming production cycle. In the model, an economic Progress Rate (PR), defined as the relative increase in farmer's WC over the most recent cropping cycles-is calculated and compared to the MPR (defined arbitrarily for each farmer at initialization). If the farmer's PR ≥ MPR, they are satisfied and will continue farming. Conversely, if the farmer's PR < MPR, they will consider renting out their farm (despite having the WC to operate it) and, therefore, they need to form WTAP. This farmer will actually rent out his/her farm only if the formed LRP is larger than their WTAP. The second step in the LARMA model involves the formation of WTAP and WTPP. The WTAP is the minimum price that an owner is willing to accept to rent out their farm. The model assumed that an owner's WTAP is based on an estimation of the profit that could achieve from efficiently operating their farm. In the model, the inherent risk in agricultural production was also considered and it computed the expected utility of a range of production income (expressed as a certainty equivalent (CE) income, differentiated by the risk aversion of the owner). It was further assumed that the WTAP equals the CE. An initial simulation exercise with a simplified economic context (input and output prices) did not show significant differences in regional land tenure from LARMA vs. the use of an exogenous, fixed LRP. The simulated LRP trajectories reproduced the observed dynamics: prices followed the trajectories of conditions driving crop yields and profits [7].

3.3 Land Purchase and Sell - Auction-based Markets

3.3.1 Rule of Participation into Land Auction

All agents in a defined vicinity (i.e. municipality area) can participate in the renting/leasing auction in the short period and selling and buying auctions in the long period. Those agents who are approaching the retirement age threshold are not permitted to participate. In addition, agents who already have land size at the institutional upper bound are not allowed to participate. If the agent already has a tenant this priority to rent land according to institutional rules must also be taken into account. The minimum number of agents who are eligible to participate in the auction is another important decision to be considered if it is an institutionally binding requirement.

3.3.2 Bid Price Determination (Minimum Willingness to Accept/Pay)

The rules of determination for reservation prices or minimum (WTA)/maximum (WTP) bid/ask prices both for rent/lease in the short period and sell/buy in the long period are derived from the production function (subject to several technologies and regulation constraints) and solved by Positive Mathematical Programming (PMP). The shadow marginal cost of each agent is used as a proxy for reservation prices both for bid/ask in renting/leasing land market situations. Similarly, the shadow marginal revenue of each agent is used as a proxy for reservation prices both for bid/ask in selling /buying land market situations.

A small difference between minimum/maximum WTA and WTP prices can be allowed depending on who bears transaction costs, such as administrative costs, title fees and taxes (if relevant). As a matter of fact, the administrative cost and the tax for renting the plot are considered in AgriPolis [2].

3.3.3 Auction Finalisation Rules (Single vs. Multi-Stages)

Action finalisation is not unique in previous agricultural policy-oriented ABMs. As observed differences in exist/investment decision rules and bid/ask price determination rules, finalisation of the auction is also varied in the reviewed ABMs. A piece of brief information about auction market functioning in the agricultural-policy-oriented ABMs is given below.

In AGRIPOLIS, an auctioneer has a relatively low-level agent role, especially when compared to a farm agent. An auctioneer is responsible for coordinating the auction of free plots by collecting bids from farm agents, evaluating them, and allocating the plot to the highest bidder. An auctioneer may be appointed to collect rents on behalf of landowners who are not engaged in farming. During an auction first, the Manager class initiates a recursive auction of available plots, which the auctioneer then conducts. The auctioneer does this by requiring all farm agents who plan to lease additional farmland to submit bids for a single plot. The farm does this by looking for a free plot that is geographically close to itself. A bid is then determined for the desired plot by combining the shadow price of land, the number of nearby plots, and the costs of transportation. The auctioneer will then order the bids and give the plot to the highest bidder. Since only one plot can be offered by farm agents at a time, the bidding process will be repeated until all plots have been allocated or the highest bid has reached zero. The final phase in the auction process is for the auctioneer to set the rental price for the newly allocated plots. The auctioneer not only determines the starting rent for new leases but also adjusts the prices of already existing rental contracts by applying the procedure of rent adjustment.

In MPMAS, each plot represents a single parcel in the original land market implementation [40] and is exchanged independently in the land rental market. Each agent determines its own shadow price for each soil type and then compares it to all agents' average shadow price to find potential plot suppliers and renters. As a rule, agents will offer the plots for rent only when the shadow price multiplied by a mark-up parameter, less the cost of transportation from the farm to the plot, is less than the average shadow price across all agents. When each agent's individual shadow price multiplied by a markdown parameter and adjusted by internal transportation costs is bigger than the average shadow price, the agent will try to rent in the plots of that soil type instead of offering plots of a given soil type. After that, MPMAS examines each available plot and determines the highest bid. If this bid is greater than the owner's expected minimum rent, a rental contract is drafted with the rental payment set to be equal to the average between the bid and the expected minimum rent. When deciding whether to bid or make an offer on more plots, both the owner and the renter will take their new shadow pricing into account.

To be able to simulate adaptations to climate change in Germany, MPMAS land market implementation had undergone a complete revision. After the revision, rental contracts with terms of more than a year are allowed and the shadow price is evaluated via the investment choice problem. Furthermore, the model can be launched with already-in-place contracts. In addition, to reflect standard practice more accurately in Germany, parcels consisting of multiple neighbouring plots (pixels) of the same owner can now be exchanged as a whole, rather than plot by plot. Agents now take into consideration the possibility that they could find and rent another parcel that is cheaper or closer while deciding how much to bid. Presuming that another equivalent parcel can be hired for the average rental price observed with a fixed probability, the agent sets the bid for an offered parcel so that the expected value of renting this parcel is equal to the expected value of renting another equivalent parcel at the average rental price observed. The offering agent accepts the highest bid if the bid is above the reserve price, which is usually a percentage of the average rental price. The agreed-upon rental price between the agents is somewhere between the top and runner-up bids (or in the absence of a second bid, the reserve price of the landowner).

RegMAS uses real land-use data, so plots are heterogeneous even within soil types, which makes such algorithms very computationally demanding compared to AGRIPOLIS, where land heterogeneity consists only in different soil types and farmers are assured to place the highest bid for any certain soil type on the closest plot. This approach allows a more realistic land market functioning and limits the complexity of computations. RegMAS allows limiting the bidding process to the farmers at a given distance to the plots available for rent. When a farmer makes a bid on renting a new plot of land and determines the corresponding shadow price, plans a new investment, or determines production levels based on existing resources and assets, their objectives are maximizing their profits. Hence, the objective function of RegMAS is profit maximization, and it uses Mixed Integer Programming (MIP) methodology to derive the behaviours of farmers. The transportation costs are used as a calibration parameter to determine the precise number of bidders which determines the spatial range over which any farmer can rent land. Transportation costs have a negative correlation with the likelihood that a certain farm's bid will be accepted. The ability of a farm to rent new land and, thus, finance improved economic performance is impacted by factors such as distance and the costs arising from distance. On the other hand, the heterogeneity of land makes it possible to consider the effect of the local plot properties on the rental prices of plots hence on their rental status. When a rentable plot is awarded to the highest bidder, a new rental contract with a random (and then, fixed) duration that can be established by the RegMAS user is created, and the plot, along with the spatial objects associated with it, becomes a new resource in the farmer's optimization problem.

In SWISSland, neighbourly relationships are a prerequisite for land trading between agents. Since this relationship is based on farm locations within a municipality, land trade modelling is restricted to agents whose farm locations are within the same municipality. Exiting agents who have no farm successor to give over the farm to, or whose potential successor decides for economic reasons not to take over the farm, offer plots to the remaining agents in the immediate vicinity. The growth in the plot's income is what the agent considers while making a leasing decision. The economic benefit from plots declines as the supply of plots increases because other production inputs, including labour, have a limiting effect. Agents who take the exiting decisions tend to give plots to the remaining agents in the immediate vicinity. The group of agents interested in an existing agent's schemes is comprised of the five closest agents to the agent. The allocation of property to neighbouring agents and the pricing of leases are modelled as a plot-by-plot bidding procedure. The first lease price requested by an existing agent is determined by the average regional prices of the FADN farms for arable land and grassland in the base year. Each agent in the bidding process is optimized with the new plot to determine the increase in income for all neighbouring agents. The neighbouring agent takes possession of the plot that yields the highest profit at the lease's maximum price. If the maximum lease price exceeds the income increase of all local agents, the bidding process is repeated to include agents from further areas. The assumption is that the exiting agent will gradually lower the lease price if the upper limit is too high also for the agents in the wider vicinity, hence the bidding process will be repeated. In the scenario in which a plot's lease price is higher than zero and no neighbouring agent can make a profit from the plot, the plot is turned to be a fallow land. The model assumes that the exiting agent will pass the plot to the neighbouring agent instead of leaving it to be a fallow land if the neighbouring agent only benefits from leasing when the lease price is zero.

4 Structure of Land Markets in AGRICORE

4.1 Exit/investment decision rules

4.1.1 Short-period decisions

In the SP, differences between land market prices, average rental prices (ARP) and marginal costs will be used by the agents as guidance criteria and allow them to decide whether they will rent or lease land. A shadow marginal cost for the PMP-SP module is approximated from production function estimates under several constraints. A change in variable cost, as a result of one unit change in total output, is the same or equal to a change in marginal cost, as a result of one unit change in total output. However, in the competitive market, the guidance criteria are that each firm maximises its gross margin where its marginal cost is equal to the market price. Thus, the market supply curve is a summation of the individual firm supply curve (marginal cost curve) which represents the lowest price the producer would be willing to accept for each additional quantity or unit of a good. In order to avoid losing money, it is clear that the farmer would never intend to sell a unit of the good at a price lower than its marginal cost. To positively contribute to gross margin, it is convenient to sell a product only when the unit price of the good is higher than its firm marginal cost. Therefore, the marginal cost curve can be interpreted as the lowest price that sellers would accept for each quantity.

4.1.2 Long-period decisions

In the LP, the agent decides whether to sell or buy land taking into consideration economic conditions and financial performance indicators, such as net profit, liquidity ratio and solvency ratio. The economic condition is given by the shadow prices of land as the minimum prices offered to the market. The shadow price for an agent-owned land parcel is determined by measuring the change in total revenue due to one unit change in land input. The difference above this shadow price that an agent will bid/ask for, depends on the common hedonic characteristics of the land such as lot size, distance to main centres or infrastructure.

4.2 Land price determination rules

4.2.1 Rent/lease (Short-period)

The rent/lease land prices in a region (NUTS3) are uniform and are given by the ARP. Moreover, the ARP will determine the costs or revenues of the agent given the land rented-in or rented-out, which are essential for the gross margin optimisation. Concerning the ARP determination, it can be addressed by following different approaches:

- Exogenously picked. Based on an external data source (e.g. Eurostat) where a table can be found including the average rental price for each NUTS3 region considered in the simulation.
- Deriving it from the average market price resulting from the purchase and sale market executed in the current simulation step. In this case, the ARP could be calculated taking into account the time period considered for the amortization of land purchase transactions, modified by a certain factor that takes into account the different levels of risk faced by the farmer when renting versus buying.
- Averaging the individual rental reservation prices (WTA and WTP prices) of each agent from the same region. These prices would have to be determined in advance, either from the

reserve prices of each agent in the buying and selling market, or from its last known 'real' Gross Margin (i.e. the gross margin obtained in the immediately preceding simulation step).

- An external econometric model. The latter option would allow incorporating other effects produced by external factors (e.g. market pressure produced by non-agricultural agents acquiring farmland for other uses).

4.2.2 Purchase/sell (Long-period)

The agent decides whether to sell or buy land in the LP based on financial indicators or ratios. The indicators which assess the financial situation of an agent are reported in WP3. According to the financial performance ratios, the agent will decide to sell if it finds itself in threat of bankruptcy or will decide to buy if it possesses a positive net profit and favourable financial indicators.

The shadow prices of land are the minimum prices offered on the market. The shadow price for an agent-owned land parcel is determined by measuring the change in total revenue due to one unit change in land input. This rule is valid for both the agent willing to sell land or to buy land. The delta above this shadow price that an agent will bid/ask for, depends on the common hedonic characteristics of the land such as lot size, distance to main centres or infrastructure. The marginal revenue of each agent is different due to scale, management capacity, knowledge and so on. This situation causes the formation of different bid/ask prices. Theoretically, the number of bid/ask prices should be equal to the number of seller/buyer agents.

4.3 Land auction

4.3.1 Location and participation rules

All agents are allowed to participate in the LMM to either buy, sell, rent, lease operations or a combination of these options. The decision of one agent to engage in any of the aforementioned LMM operations is determined by the financial indicators or ratios as already explained in previous sections.

However, the participation by agents is contingent on their location, i.e., each of the agents can only buy, sell, rent or lease within the geographical limits of where they already own land plus some behavioural constraints such as: i) farms can exchange land within the agrarian regions; ii) the land price is uniform in the region; iii) farmers with more than 65 years and without successors cannot rent/sell land. This is because farmers are unlikely to perform any of the aforementioned operations for areas far away from their current possessions, let alone beyond a certain distance.

Such geographical limits can be established following several approaches which present different advantages and disadvantages. For instance, it is possible to use the already defined administrative boundaries at the level of the agrarian regions. Therefore, agents with land in an agrarian region would only be allowed to participate in auctions within the same region. Another option could include using a defined grid where the user can specify their desired spatial resolution. As stated in the previous case, the agents would only be allowed to participate if they already possess some land in the square delimited by the four closest points to such a land area.

Considering the three above approaches, the LMM will implement the one based on the agrarian region. While the circle-based approach is more methodologically consistent, the associated computational cost is relatively high as the relative position of the agent to each of the individual crops of the remaining agents needs to be computed. Nevertheless, the LMM will be prepared to support these two additional approaches in the event user requests are received. The three aforementioned approaches are shown in Figure 2 for greater clarity.

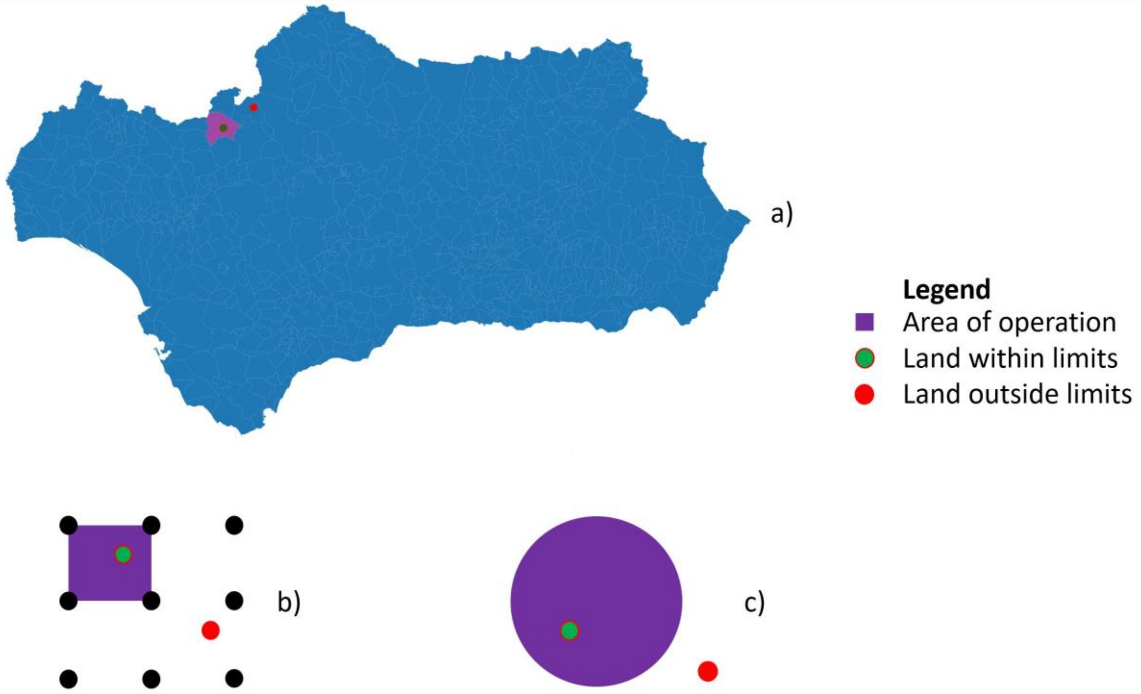

Figure 2 Geographical limits. a) By agrarian region, b) with a grid, c) circle-based

Once their area of operation is determined, the agents can participate in auctions for lands or crops within the limits of such an area. The auction follows the structure of a First Price Sealed Bid Auction (FPSBA), also known as a blind auction. This type of auction has been used in the past, for instance, to obtain the mineral rights to U.S. government-owned land [41], which is quite resemblant to the AGRICORE use case.

Each of the plots is auctioned following an FPSBA, i.e., there is a single seller (the owner of the plot) and multiple buyers (as many as interested in such a plot within the same geographical area). As the name implies, the buyers' bids are sealed, which means that such information is not known by the rest of the participants. Additionally, "First Price" stands for the fact that the highest bid is considered the winning bid. Given that there is only one round per auction, the bidders are encouraged to submit their best offer in order to be selected as the winner. The whole operation process is depicted in Figure 3.

The simplicity of this auction's structure has two direct implications for the implementation. On the one hand, since all bidders submit simultaneously and there is only one round, the time required to resolve an auction is significantly reduced compared to other auction models (e.g., English auction). On the other hand, the matching process is immediate (maximum price bid), making it computationally efficient and cheap.

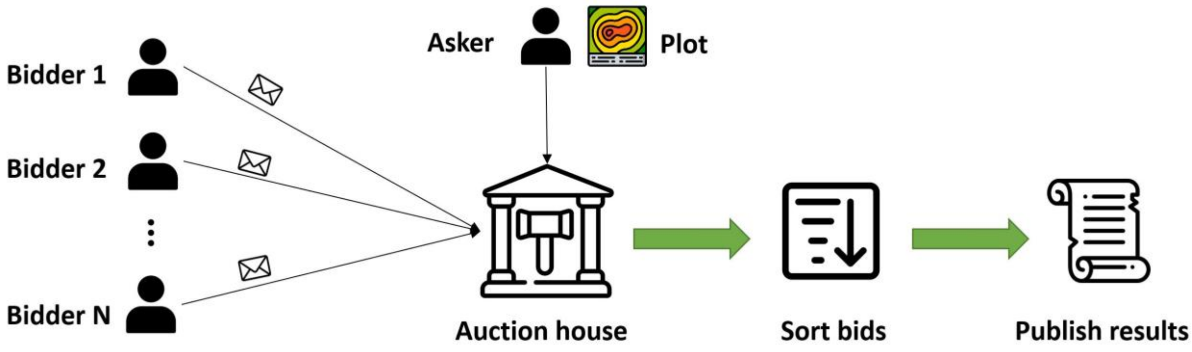

Figure 3 FPSBA operation

4.3.2 Ask/bid prices

Subsection 4.2 explains how the reservation prices of each participant, i.e., the minimum willing to accept/pay (WTA/WTP), are computed for the multiple operations available. However, these prices are considered to be the limits, and the agents are unlikely to bid or ask for these amounts. Instead of that, the agents will try to obtain some benefit from the transaction, for example, by offering a lower price than the WTP or a higher price than the WTA.

In the AGRICORE LMM, no agent will incur losses for buying or selling land. This entails that the bid and ask prices are always greater than the WTP and WTA prices, respectively, for buyers and sellers. If the previous statement is not fulfilled, the agent will just not participate in that specific auction.

The ask and bid prices are formulated following the assumption that the farmer interested in the land will prefer winning the auction, and thus such land, rather than making a profit out of the transaction. Therefore, ask and bid prices are close to the WTA and WTP prices. In order to compute these prices, the agents will use the average market price (AMP) from the past auction. Given that the results are public, and all agents have access to this information, they can easily calculate the average price per hectare of land.

The final bid or ask a price is a random number within the range of their WTP/WTA price and the middle point between the AMP and their WTP/WTA price. For instance, suppose the AMP from the past auction was 100 €/ha, and the agent is only interested in one hectare with a WTP price of 150 €. In this case, the bid price will be a random number within the range of 125 € (middle point) and 150 €. Analogously, for a seller with a WTA price of 80 €, the asking price will be a random number between 90 € (middle point) and 100 €.

In the event that the AMP is greater than the WTP price or lower than the WTA price, the bid and ask prices are computed as a random percentage of benefit over those WTP/WTA prices. Table 5 encompasses the aforementioned strategy

Table 5: LMM's bid/ask price strategy

Case	Bidder	Asker
AMP > WTA/WTP	Submit a random percentage lower than the WTP price	Submit ask between the middle point and the WTA price
AMP < WTA/WTP	Submit a bid between the middle point and the WTP price	Submit a random percentage greater than the WTA price

Analogously to the location strategy, the AGRICORE LMM will be prepared to support different bid/ask approaches according to the user's specific needs.

4.4 Finalisation of the auction: hypothetical examples

Within the defined auction system, different scenarios can occur depending on the matches between offers and demand. In the first place, scenarios from the **bidder's point of view are presented**. The simplest case is when the offer made is higher than the land price and there are no other higher offers. Consequently, the bidder wins the land. However, if there were other higher offers for the same land, then the bidder would not obtain the land. The same results will occur if the offer is smaller than the land price. From the **asker's point of view,** everything is simpler. Basically, if there is any offer higher than what is asked for the land, then the land will be sold. Figure 4 illustrates the whole process and the possible outcomes.

4.5 Graphical representation of the Land Market Module

Figure 4 presents a block diagram detailing the internal processes of the LMM in order to sum up graphically the concepts presented in the deliverable.

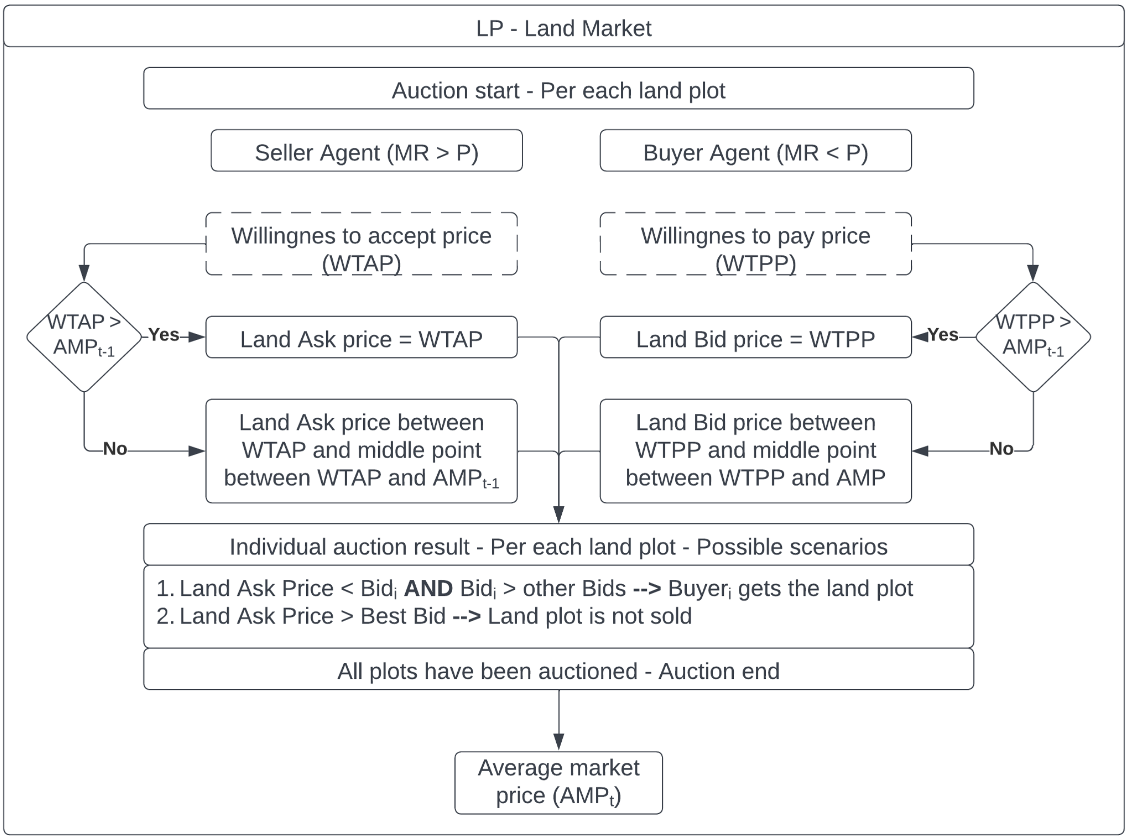

Figure 4 Land Market Module graphical representation

5 Conclusions, future works and recommended improvements

The ABMs in the literature relevant to the agricultural land market have been only interested in the land rental market. It has not encountered an ABMs that analysed land market from both short and long period perspectives. In other words, land title exchange has not been considered from the viewpoint of economic and financial decision rules in the literature. All the reviewed ABMs used either profit maximization or household income maximization for exiting/investment or renting out/in decision rules. In the literature, off-farm income is a very important role in the land rental market if household income is considered. Farm owners' age and having successors are also important land transfer decision rules considered. In the reviewed ABM literature, land transfers are generally realized via the auction market, but rules to participate auction market and finalisation are different in almost all the ABMs. The shadow price of land obtained from solving the maximization problem is used as reserve prices which are the minimum WTA price for the landlord and the maximum WTP price for a tenant. But land rental contract price is different than WTA or WTP price due to transaction cost or some hedonic characteristic of the land.

The agricultural land market module in AGRICORE is differentiated according to the SP and LP perspectives of farm managers. In the SP, land title exchange is not allowed and only land rent in/out is possible which is based on the gross margin indicator or its equivalent marginal cost-product price comparison. In the model, a farmland parcel is offered to renting-out if the marginal cost of production in that parcel is greater than the average farm-gate price of the product. In this situation, marginal cost is the minimum WTA price for a landlord. On the other hand, the maximum WTP price of the tenant for this land parcel is marginal revenue obtained when adding this parcel to the farm operation.

LP decision in AGRICORE starts at the end of seven years because of the renewal age of CAP and the amortization period of machines. The decision for whether to sell a parcel or buy is based on marginal revenue whether it is increasing or decreasing when adding a particular land parcel to a farm operation. This marginal revenue obtained as shadow revenue through solving the maximization problem by PMP is the minimum WTA price of the seller and maximum WTP price of the buyer of the land parcel at the auction market. The shadow price is differentiated with some common hedonic characteristics using elasticities.

This work can further be improved by adding an empirical hedonic land price/value model estimation using time series data (if available) or using cross-section survey data for a given location (i.e., Andalusia olive farming land). This empirical land price module can be substituted with shadow prices or used to check and adjust to shadow prices since shadow prices obtained from the production function is questionable.

The decisions to exit/invest considered in the land market module of the AGRICORE is related to land parcel rather than whole-farm exiting. In SP, renting out of land parcel is not mean that farm is closing, instead, it is downsizing. Decision rules for farm closing are very different from farm downsizing because the farm has other assets besides land assets and cultural linkages and perspectives to be considered. Therefore, the valuation of the whole farm is different than land parcels and whole-farm selling is different that land parcels selling/buying at the auction market. This is an important point to be analysed in a future versions of AGRICORE.

Statistical data gap in the land market is also important, the improved version of the Czech Republic practices with respect to agricultural land quality characteristics and price can be extended to other EU member countries.

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

Deliverable Number	Deliverable Title	Lead beneficiary	Type	Dissemination Level	Due date
D6.1	AGRICORE architecture and interfaces	IDE	Report	Public	M23
D6.6	Software Quality Assurance measures for AGRICORE	AAT	Report	Public	M15