UKRAINIAN CATHOLIC UNIVERSITY

MASTER THESIS

Investment modeling of agricultural land valuation in Ukraine

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A thesis submitted in fulfillment of the requirements for the degree of Master of Science

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Declaration of Authorship

I, Nataliia NOVOSAD, declare that this thesis titled, "Investment modeling of agricultural land valuation in Ukraine" and the work presented in it are my own. I confirm that:

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- Where I have consulted the published work of others, this is always clearly attributed.
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"At its heart, engineering is about using science to find creative, practical solutions. It is a noble profession."

Queen Elizabeth II

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Abstract

Evaluating the fair market value of land is a complicated and expensive process carried out by experts. The final valuation is the main factor for investment decision-making. The asset valuation has to include many components, particularly the estimation of the future net income, risks, and opportunities.

The objective of this study is to find the fair value of the agricultural land and compare the different approaches. We consider planting four crops: wheat, maize, soybeans, and sunflower. In this project, we estimated future crop prices, yields, and expenses to predict income. We started with the simple income method and showed how the value changes when complicating the method and considering new real options like crop rotation, optimizing crop portfolio, and installing an irrigation system. Moreover, we analyze the sensitivity of the estimated value to the economic situation (discount rate and price growth rate).

The data we are considering is the land in Ukraine, specifically in the Kherson region. Due to the land moratorium, the free market does not exist, and the farmland in Ukraine is usually underestimated. Thus, this causes the impossibility of direct comparison of the proposed valuation and the absence of needed open data. Therefore, we rely on expert opinion in different aspects of the project.

Acknowledgements

First of all, I want to thank Yevhen Pentsak, the Professor at Kyiv-Mohyla Business School, who directed me during the research of this thesis, for consulting and bringing value to the research.

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List of Abbreviations

NMV	**N**ormative **M**onetary **V**aluation
UAH	Ukrainian hryvnia
USD	United States dollar
AR of Crimea	**A**utonomous **R**epublic of Crimea
DCF	**D**iscounted **C**ash **F**lows
CF	**C**ash **F**lows
PV	**P**resent **V**alue
EBITDA	**E**arnings **B**efore **I**nterest **T**axes **D**epreciation and **A**mortization
EBT	**E**arnings **B**efore **T**axes
TFP	**T**otal **F**actor **P**roductivity
KOATUU	Classification of objects of the administrative-territorial system of Ukraine
ha	hectare
AR(k)	**A**uto**R**egressive process with lag **k**
MSE	**M**ean **S**quared **E**rror

To my beloved father. Thanks for believing in me.

Chapter 1

Introduction

1.1 Motivation

The land is one of the most crucial assets for the country. The policy of land management impacts the country's growth and development. Here we consider farmland as it is the key factor for production and economy. The existence of a farmland market ensures the optimal use of the asset. The land belongs to the farmers and investors that are interested in the productive usage of the asset. It causes business growth and, therefore, the country's growth.

Since 1992, the farmland market in Ukraine is closed. The moratorium was first signed in 2001 and has been continued ten times. It limits the development of the country and generates significant losses. In 2000, agriculture formed 14.5% of GDP, and in 2019, only 9% (due to The World Bank[1]). Even though the quality of land in Ukraine is high, the production (and therefore the prices) is low (Fig. 1.2,1.1). However, in March 2020, the government signed a new law about the land market[2]. Due to this law, from July 2021, the moratorium will be lifted, and citizens of Ukraine will be able to sell agricultural land freely.

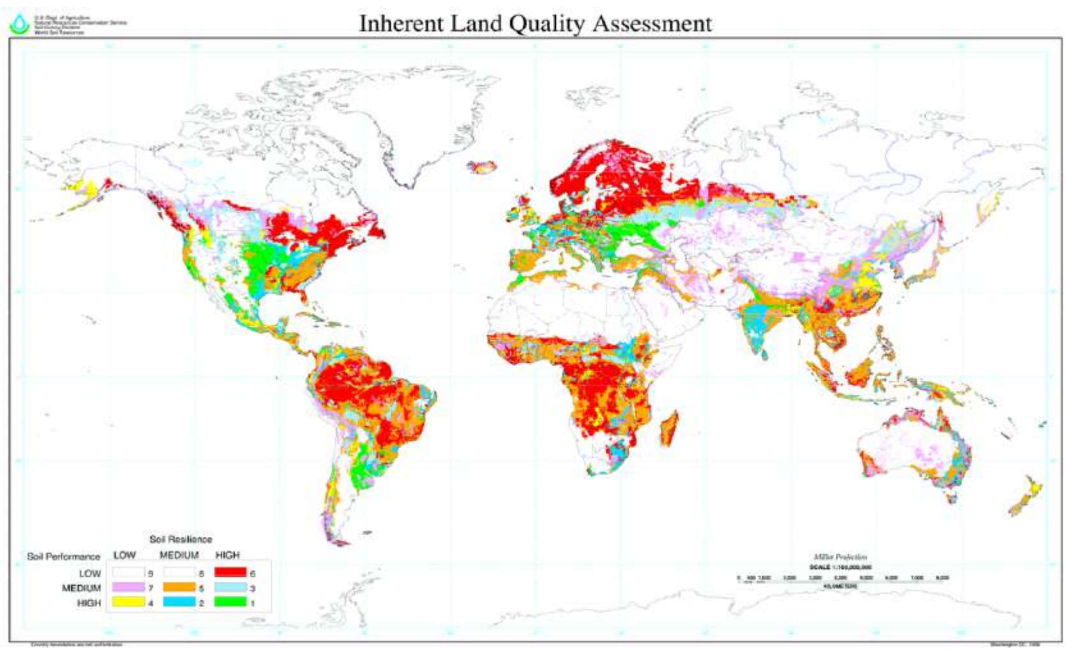


FIGURE 1.1: World soil performance
Source: Natural Resource Conservation Service, USDA

[1]https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS?locations=UA
[2]https://zakon.rada.gov.ua/laws/show/552-20?lang=enText

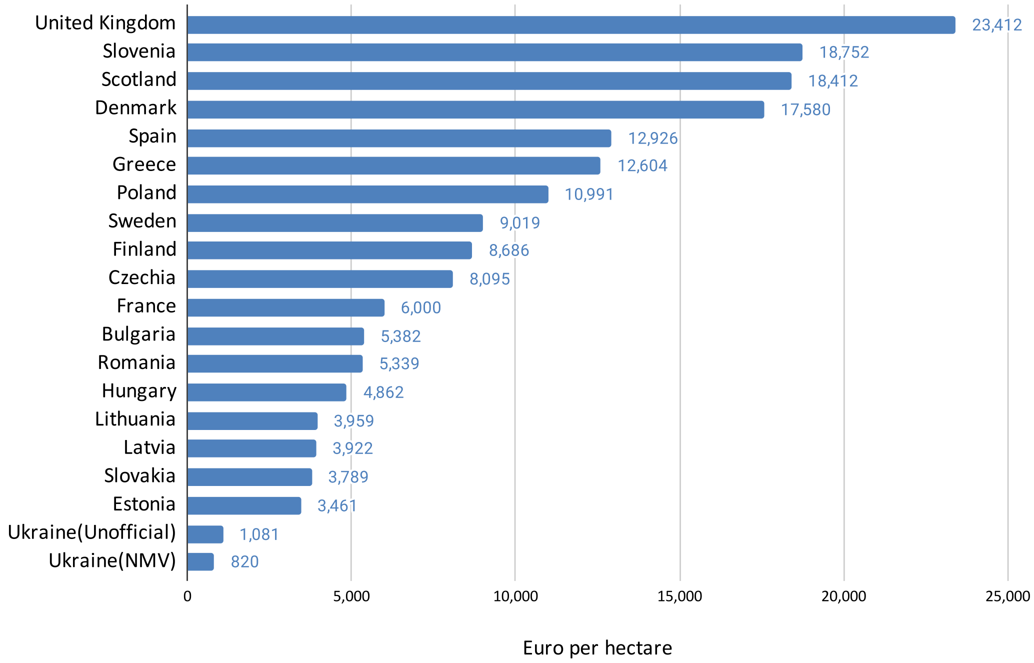


FIGURE 1.2: Agricultural land prices in different countries, 2018-2019
Source: Own calculations based on data from Eurostat, Report by VoxUkraine of unofficial land price (in Ukrainian), Government of Ukraine, 2020

The main challenge that will come up is the land valuation. As was said before, the farmland now has low prices compared to other countries. So we need to apply advanced methods to find its fair value. Developing a fair land evaluation system will help landowners earn more and manage their assets consciously and wisely.

It is appropriate to outline how the land price changed after free-market opening in neighboring countries. Due to Agropolit[3], the land price in Poland, Czechia, Lithuania, Latvia, Slovakia, Estonia, Bulgaria, Romania, and Hungary rose 2.5 times in five years after free-market opening on average. Furthermore, it is expected that the land price in Ukraine will rise by 76.7% in two years. However, according to Halytsia, 2019, the successful start of liberalization depends on the country's politics and other conditions. For example, Moldova and Russia face such obstacles as urban migration processes and bureaucracy.

Since we consider the Kherson region in this thesis, we outline the role of this region in agriculture. According to the State Statistics Service of Ukraine[4], the Kherson region contains 1969 thousand hectares of agricultural land. In 2020, the principal crops were wheat (489 thousand ha), barley (197 thousand ha), maize (45 thousand ha), soybeans (72 thousand ha), sunflower (331 thousand ha). The share of the region in the total agricultural production in 2018 was 4.2%. 320 thousand ha of land has an irrigation system, one of the highest numbers in Ukraine.

[3] https://agropolit.com/blog/231-tsina-silskogospodarskoyi-zemli-dva-stsenariyi
[4] http://www.ukrstat.gov.ua

1.2 Goals of the master thesis

This paper aims to find the value of the agricultural land in the Kherson region, Ukraine, and compare used methods. The central hypothesis is that the price of the land is underestimated, and its value is much higher. Also, we show how the value changes when model assumptions close to the real one and account for additional factors. Therefore, the goals are the following:

- investigate the existing approaches for land valuation
- modeling of the essential components such as crop price, yield, and expenses
- develop the model based on income method and make it more complex with the real options
- compare developed methods with the NMV and rent price

This thesis introduces and compares the following approaches:

- valuation based on rent payments
- income method for monocropping farming
- income method for monoculture farming (account for the crop rotation)
- income method for polyculture farming (consider crop portfolio optimization)
- valuation of the option to install an irrigation system
- valuation combining polyculture farming and installing an irrigation system

1.3 Thesis structure

Firstly, we review the related work in chapter 2. In chapter 3, we describe the data. We outline used approaches and methods in chapter 4 and evaluate the results in chapter 5. Finally, chapter 6 concludes the results.

Chapter 2

Related work

2.1 Normative monetary valuation methodology in Ukraine

Since the farmland in Ukraine has no market price, the government set a normative farmland valuation methodology. It is used to determine land tax, state duty, inheritance and donation of land, and others. The actual methodology is the following (Government of Ukraine, 2020):

$$NV = PA \times RA \times K1 \times K2 \times K3 \times K4 \times Kp \times Ku \times Ki \tag{2.1}$$

where:
NV – normative farmland valuation (UAH)
PA – area of agricultural soils (hectare)
RA – standardized rental income of agricultural land (UAH/hectare)
$K1$ – coefficient that takes into account distance to big cities
$K2$ – coefficient that takes into account the resort and recreational value of settlements
$K3$ – coefficient that takes into account distance to zones of radiation pollution
$K4$ – coefficient that takes into account the location
Kp – coefficient that takes into account the purpose of the land
Ku – coefficient that takes into account the specifics of land usage
Ki – indexation coefficient

The average NMV of the regions are shown in Fig. 2.1. We see that the methodology includes a lot of pre-calculated coefficients and is based on multiplication. Therefore, the errors of the coefficient estimates are multiplied as well, which makes the valuation inaccurate. Even if the indexes are calculated correctly, they contain only the baseline scenario and data at the moment of calculation. Therefore, this methodology is not adaptive to the situation. Furthermore, it is too generalized and does not consider the specifics of land.

2.2 Methods of land valuation

2.2.1 Comparative method using regression

The idea of this method is to evaluate the land based on the value of similar land. The similarity is measured with different properties: the area and shape, the quality of soils, the location, sociodemographic factors, climate, and others. So the straightforward way here is to use the mean value of the k similar lands. In Choi et al., 2019, the authors calculated the Euclidean distance on 40 features and used the mean of 3 closest cases as a final valuation.

However, this evaluation has disadvantages: choosing the number of land plots to take the mean of, what factors take into account, and what similarity measure to choose. Therefore, another approach is to use regression analysis. This method is

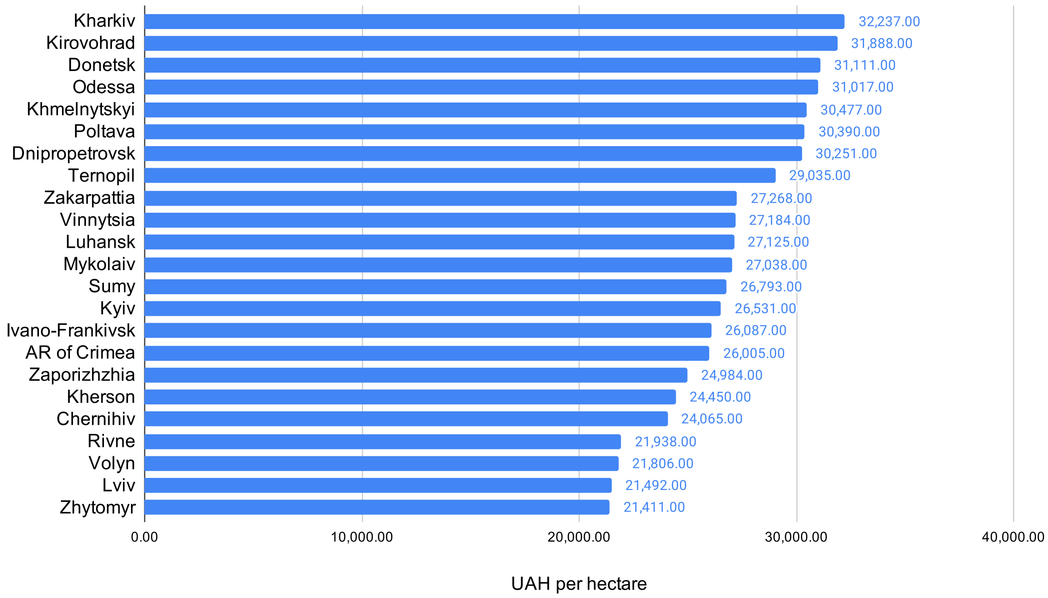


FIGURE 2.1: Average NMV by regions
Source: Author

commonly used in real-estate valuation (Masías et al., 2016; Sampathkumar, Santhi, and Vanjinathan, 2015). Such models include different factors as population, water quality, area, land type, and others. The models for regression can be the following: Linear Regression (Sampathkumar, Santhi, and Vanjinathan, 2015), Neural Network (Sampathkumar, Santhi, and Vanjinathan, 2015; Masías et al., 2016), Random Forest (Masías et al., 2016) and Support Vector Machine (Masías et al., 2016).

2.2.2 Income method

In this method, we consider the land as any common asset. We estimate the potential income that the land can produce for a buyer during some period. The sequence of the incomes through time is called the cash flows. The sum of discounted cash flows (DCF) is called present value (PV), and it can be used as a valuation of the asset (Brealey, Myers, and Allen, 2017). The source of income can be different: the rent payments, the selling of harvest, building the infrastructure, and selling it. In Nivievskyi and Kandul, 2015, the authors used the rental price of land in Ukraine as a source of income.

2.2.3 Real option method

Real options are used to estimate the value of future opportunities. This method has an advantage over the income method because it considers the active management (Brealey, Myers, and Allen, 2017). An example is the deferral option: the option to wait for a better economic situation and then build the construction and sell it; the abandon option: the option to sell the asset immediately; the expand option: to improve or develop the current asset. In Čirjevskis and Tatevosjans, 2015, the authors consider all three options to choose the best investing strategy.

To estimate the real option, we can use the same methods as for common options. In Čirjevskis and Tatevosjans, 2015, the authors used the Black-Scholes formula, the

Binomial model, and the option space matrix “Tomato Garden”. The land price can be estimated as a put option using Monte Carlo simulation of the future crop prices (Moreno Fuentes, Todeschini, and Navas, 2009). Also, according to Moreno Fuentes, Todeschini, and Navas, 2009, we can apply the option to stop crop production, the option to switch crops, or the option to transform the land into urban development in agricultural land valuation.

2.2.4 Crop portfolios and crop rotation

In agriculture, the uncertainty in the crop price and yield causes additional risks in revenue. The optimization of a multi-crop portfolio mitigates the risks. According to Guariso and Recanati, 2016, the choice of a mixed crop portfolio can guarantee the minimum risk. The authors used Modern Theory Portfolio that Markowitz proposed in 1952. In Lee et al., 2016, the minimization of the Sharpe ratio showed that revenue becomes the most stable.

Machine learning algorithms for portfolio optimization showed promising results in the area of high-frequency trading (Snow, 2019). Hence, it makes sense to apply the same methods for crop portfolio optimization.

According to Ball et al., 2005, crop rotation has a great influence on yields because it plays an important role in soil quality, helps to keep a sufficient level of nutrients, and suppresses possible diseases. Since yields generate revenue, crop rotation is an essential factor to introduce in land valuation.

2.3 Approaches to land valuation in Ukraine

In this section, we want to discuss the related work that deals with data in Ukraine. Firstly, the research was done on crop production. According to Halytsia, 2019, the land moratorium had a negative effect on technical efficiency and productivity growth in crop production. It decreased crop producers’ efficiency by 0.11%, and the annual TFP growth decreased by 0.06 points. In Deininger et al., 2020, the authors used satellite images and showed that crop rotation has a significant impact on crop production.

There are two papers on land valuation based on comparative methods. In Popovych, 2016, the authors made a regression of such factors like size, distance to a regional center, soil quality, and others on the land prices from ads. One of the possible ways to sign the rental contract in Ukraine is to use public auctions. In Kvartiuk et al., 2020, the authors made the regression into such rent prices. From mentioned papers, we can see what factors impact the price and how.

The income method was considered based on perpetuity formula with rent prices (Vitaliy V. Humenyuk, 2020; Nivievskyi and Kandul, 2015). Additionally, the authors did the regression of rent price and deposit interest on land price abroad.

All the authors mentioned the difficulty of data search and the necessity of alternative data sources. Also, due to cited papers, the fair land price is underestimated and bigger than NMV. Finally, the negative impact of the moratorium was confirmed.

Chapter 3

Data

3.1 Crop prices

For crop prices, we used two sources: www.macrotrends.net[1] for wheat, maize, and soybeans and USDA[2] for sunflower seed prices. Since the prices are in US dollars, we used the exchange rate from the National Bank of Ukraine[3] to transform the data into Ukrainian hryvnia (Fig. 3.1).

Also, the original data is measured in bushel[4] and hundredweight(cwt)[5], but we will use centners[6] for experiments. Table 3.1 shows the conversion between those measures.

Crop	bushel	cwt	centners
Wheat	1	-	0.27216
Maize	1	-	0.2540
Soybeans	1	-	0.27216
Sunflower seeds	-	1	0.4535

TABLE 3.1: Measure conversion for crops

For experiments, we aggregated daily data by mean to get the average yearly price. For the 2021 year, we had daily data only for three months (January-April).

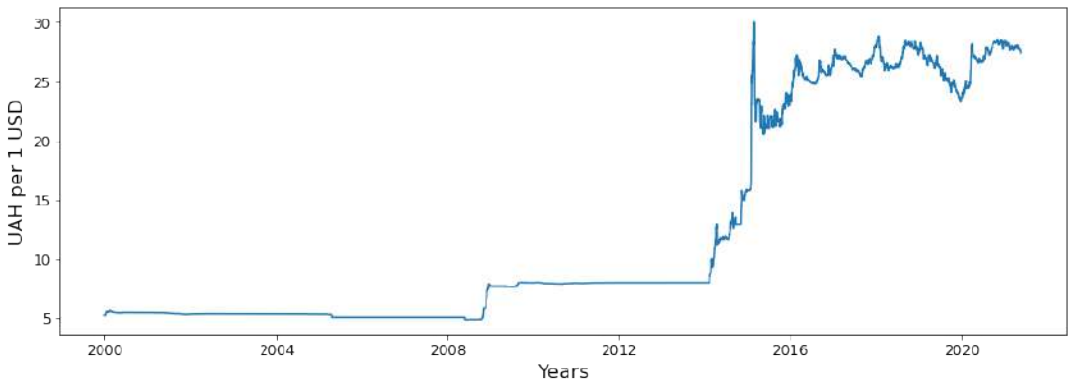


FIGURE 3.1: USD to UAH exchange rate
Source: Author

[1] https://www.macrotrends.net/
[2] https://usda.library.cornell.edu/concern/publications/c534fn92g?locale=en
[3] https://bank.gov.ua/en/markets/exchangerate-chart
[4] 1 bushel = 35.239 liters
[5] 1 cwt = 100 pounds = 45.35 kg
[6] 1 centner = 100 kg

Fig. 3.2 shows the original and converted price data and table 3.2 shows the standard deviations of the prices. Before calculating the standard deviation, we removed the trend from the time series. We used moving average with window size 5 to find the trend.

Crop	std
Wheat	46.62
Maize	48.79
Soybeans	118.19
Sunflower seeds	117.34

TABLE 3.2: Standard deviation of crop price (UAH per centner)

3.2 Crop yield

3.2.1 Country and regional crop yield

To analyze the yield dynamics in time, we used country and Kherson regional average yields from the State Statistics Service of Ukraine[7]. It includes the data from the 1985 year for wheat, from the 2000 year for maize, soybeans, and sunflower. The regional average yield of soybeans is from 2014, so we cannot rely on its dynamics and suggest using the average country yield of soybeans. The measure we use here and in the future for the yield is centners per ha. Fig 3.3 shows the country and regional average yields. Table 3.3 shows the main statistics like mean and standard deviation.

crop	type	mean	std
maize	Kherson region	51.266667	17.242805
	country	50.290476	13.894528
soybeans	Kherson region	32.528571	2.198268
	country	19.353846	4.015722
sunflower	Kherson region	13.076923	3.350660
	country	19.646154	4.531301
wheat	Kherson region	27.783333	7.282837
	country	31.830556	6.686995

TABLE 3.3: Mean and standard deviation of country and Kherson regional average yields

3.2.2 Crop yield by KOATUU

KOATUU is the system that classifies the territory of Ukraine. It contains ten digits which are divided into four groups. The first group (two digits) corresponds to regions or regional centers. The next group describes smaller parts of Ukraine.

We obtained crop yield data from the cooperation of NSAU-NASU Space Research Institute[8], The World Bank[9] and State Statistics Service of Ukraine. The data

[7] http://www.ukrstat.gov.ua
[8] http://www.ikd.kiev.ua
[9] https://www.worldbank.org

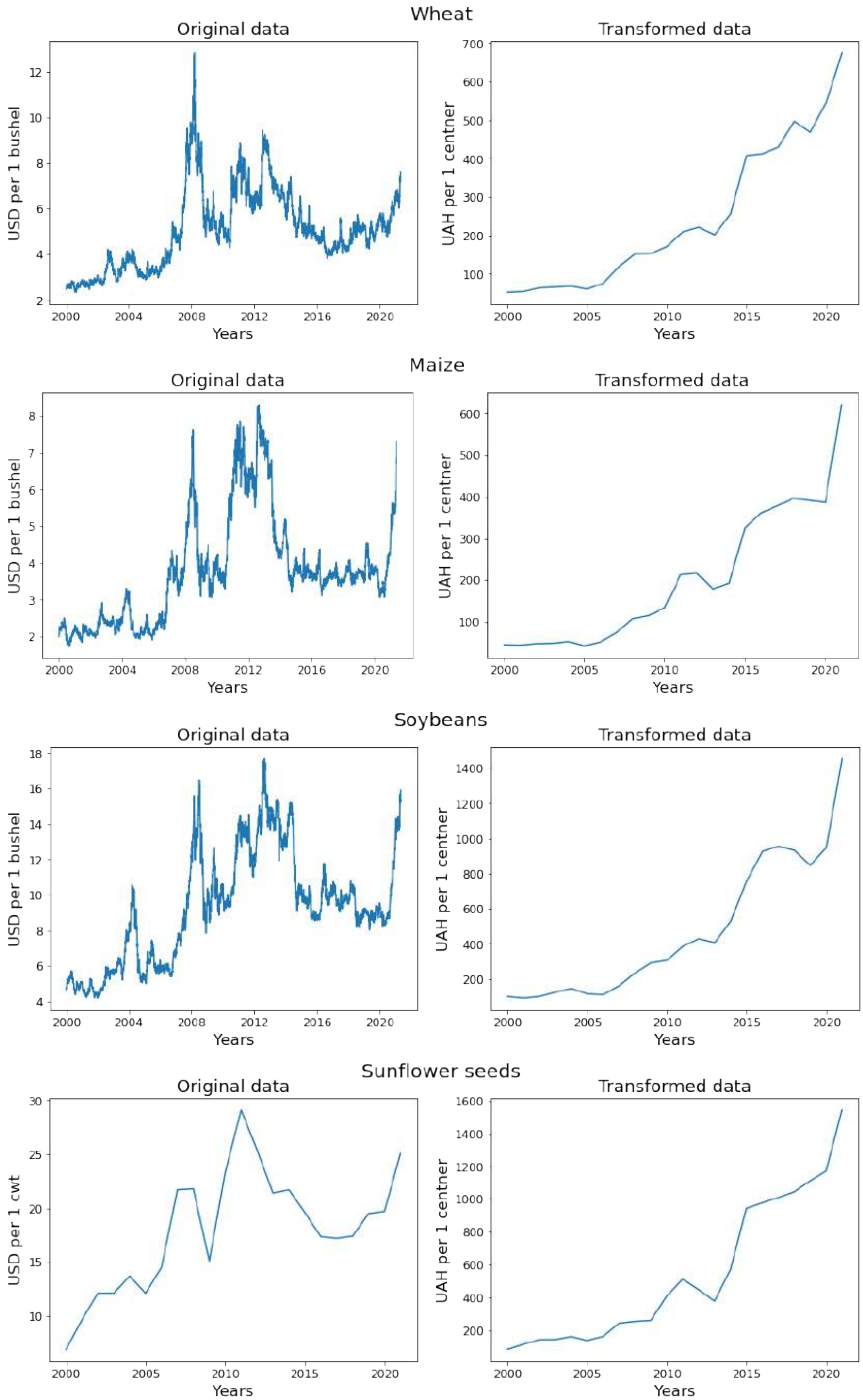


FIGURE 3.2: Crop price
Source: Author

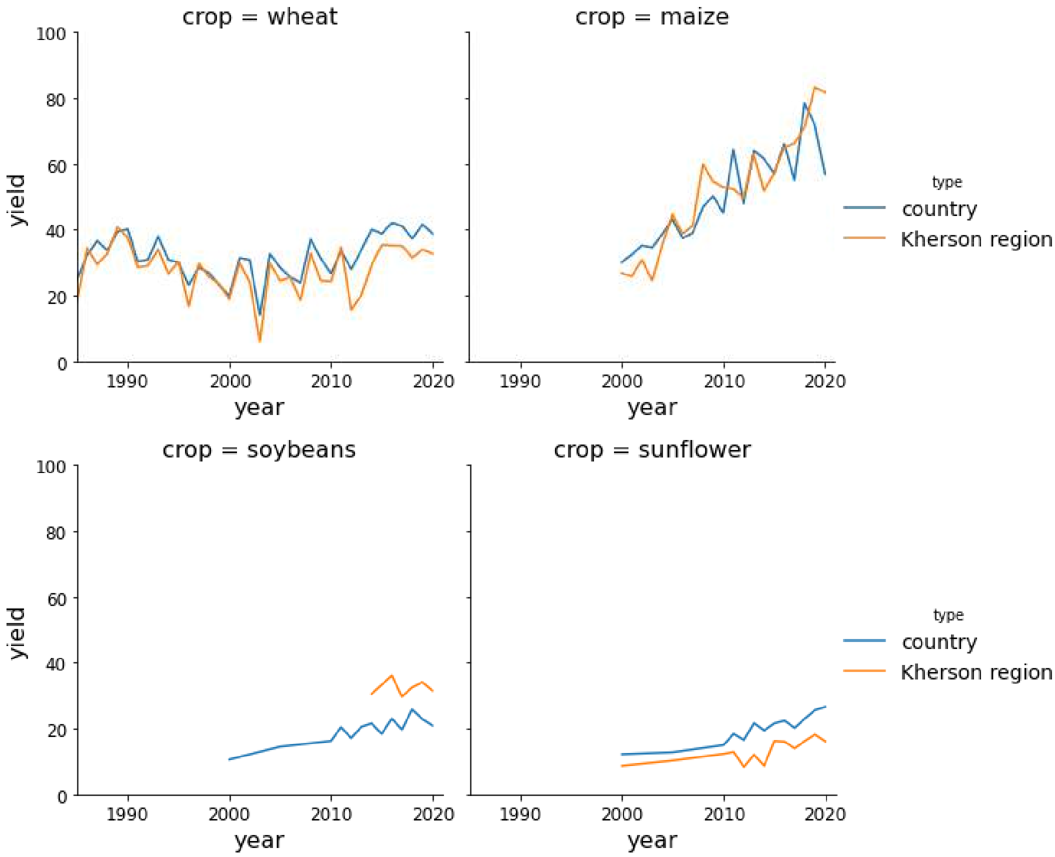


FIGURE 3.3: Country and Kherson regional average yields
Source: Author

are aggregated by the third group of KOATUU (mainly village councils) in the Kherson region (KOATUU starts with 65 and ends with 00).

The data contain information about wheat, maize, soybeans, and sunflower yields for 281 KOATUU during 2016-2019. Unlike regional crop yield data, these data include a shorter period but are more accurate because they are aggregated over smaller areas like KOATUU rather than the entire region. We delete the data with anomaly yields: more than 150 centners per ha for maize, 100 centners per ha for soybeans and 60 centners per ha for sunflower. Table 3.4 shows the detailed statistics. Figure 3.4 shows the histograms of KOATUU yields. We can see that the wheat, sunflower, and soybean yields have a nearly normal or lognormal distribution, but the maize yields differ. It can be explained by the fact that maize depends a lot on rainfall. Therefore, in case of drought, the farmland without an irrigation system will suffer from crop failure, while at the same time, the farmland with an irrigation system will have a higher yield even in standard years. Also, we can see that soybeans and maize are less popular crops in the Kherson region than sunflower and wheat.

3.3 Rent prices

The transfer of rights on state-owned land is carried out based on auctions. We use the average rent price of the state-owned agricultural land and the results of the land

crop_name	year	mean	min	max
Maize	2016	60.445203	0.000000	145.192917
	2017	73.059463	4.571429	150.000000
	2018	75.983931	0.000000	144.000000
Soybeans	2016	34.299186	0.500000	57.003204
	2017	27.717633	0.000000	54.299999
	2018	30.473430	8.181818	51.118114
Sunflower	2016	16.125679	2.000000	55.984482
	2017	14.383146	0.000000	47.505592
	2018	15.995071	0.000000	57.500000
Wheat	2016	32.862033	2.600000	71.414749
	2017	33.277127	7.436941	70.999718
	2018	30.301586	5.932710	80.923683

TABLE 3.4: Main statistics of data yields by crop and year (centners per ha)

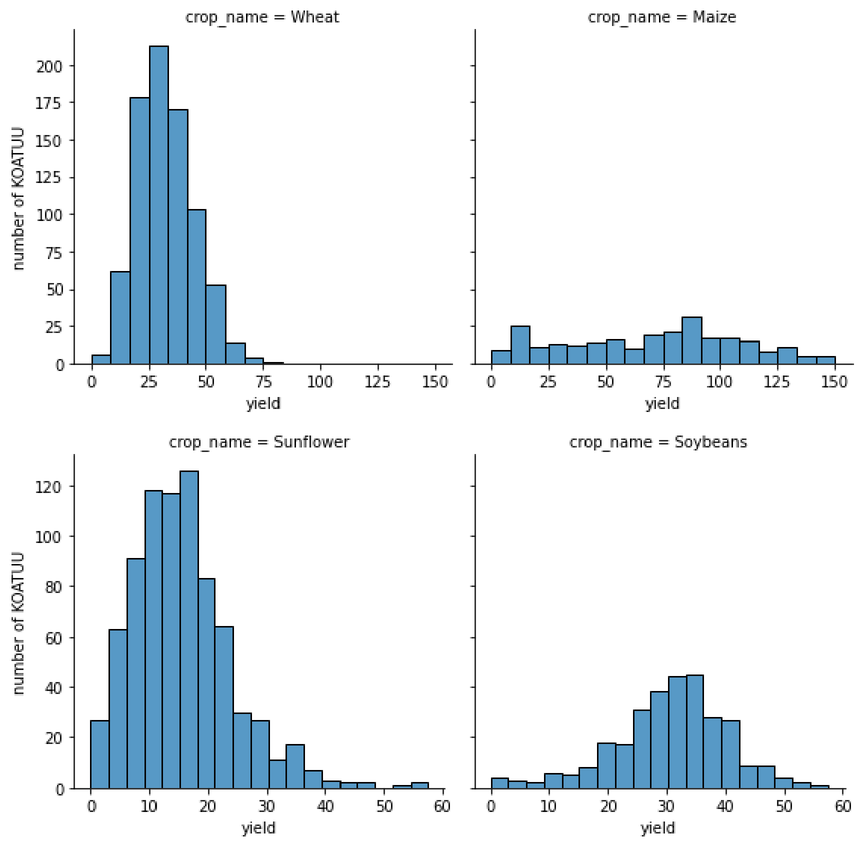


FIGURE 3.4: Yield distribution by crop for different KOATUU
Source: Author

auctions obtained from StateGeoCadastre[10]. The data is shown in Fig. 3.5. In 2020, the mean country rent price was 3671 UAH per ha, while in the Kherson region, it is 1783 UAH per ha. We observe that the mean region rent price is almost twice cheaper than the mean country rent price since 2017.

[10]https://land.gov.ua/old/en/

Furthermore, we collected the auction results in the Kherson region from 2016 till February 2021 from the StateGeoCadastre[11]. We removed the fields that were not for conducting commodity agricultural production and farming. Also, we filter only those that have both: the NMV and final rent price. Finally, we got 527 fields in 153 KOATUU.

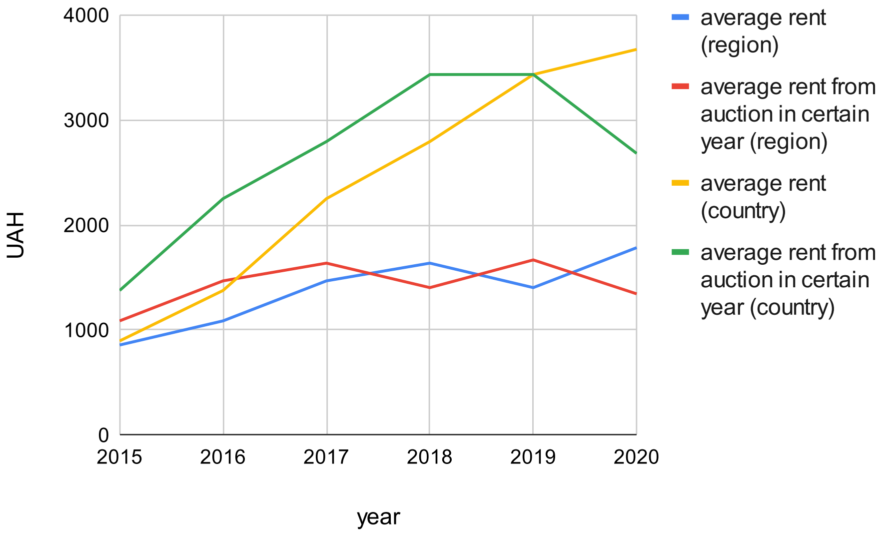


FIGURE 3.5: Country and regional average rent price for 1 ha
Source: Author

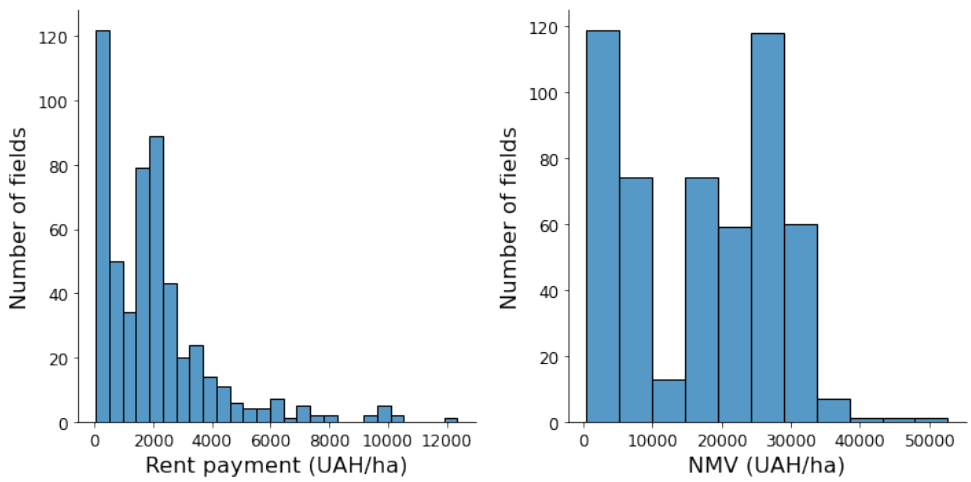


FIGURE 3.6: NMV and rent price of the fields from auctions
Source: Author

[11]http://torgy.land.gov.ua/auction

3.4 Expenses

The last part for land valuation is expenses. Since there is no open data for expenses for required crops, we studied online agriculture magazines, like kurkul.com[12] or agro-business.com.ua[13] and interviewed the experts in the field to set the expenses. Finally, we set expenses for the year 2021, as shown in table 3.5.

crop	mean	std
Wheat	14000	1400
Maize	16000	1600
Soybeans	25000	2500
Sunflower	15000	1500

TABLE 3.5: Mean and standard deviation of expenses for each crop

[12] https://kurkul.com
[13] http://agro-business.com.ua/

Chapter 4

Proposed approach

4.1 Modeling of the future price, yield and expenses

4.1.1 Price forecasting

To predict the revenue of the farmer, we need to estimate the future crop price. We consider the following methods for price forecasting: AR(1) (Eq. 4.1), linear trend (Eq. 4.2), exponential trend (Eq. 4.3) and average growth rate (Eq. 4.4).

$$p_t = \lambda p_{t-1} + \beta \tag{4.1}$$

$$p_t = \lambda t + \beta \tag{4.2}$$

$$p_t = \lambda e^{\beta t} \tag{4.3}$$

$$p_t = \lambda p_{t-1} \tag{4.4}$$

where:
p_t – price at the time t
t – moment of the time (year)
λ, β – model parameters

We fit the data from 2000 till 2015 and tested it on 2015-2021. Table 4.1 shows the parameters of the fitted models.

crop	param	exponential trend	linear trend	average growth rate	AR(1)
Wheat	λ	0.134721	20.7749	0.154048	1.1068
	β	-265.664399	-41554.7181	-	6.9590
Maize	λ	0.142560	18.1232	0.162980	1.1145
	β	-281.639382	-36258.7770	-	6.2105
Soybeans	λ	0.145006	43.4524	0.166058	1.2605
	β	-285.722204	-86945.9658	-	-18.1273
Sunflower	λ	0.141528	47.7606	0.193962	1.1067
	β	-278.594727	-95554.6499	-	22.8801

TABLE 4.1: The parameters of fitted models

We evaluate the models on the test years using MSE (Table 4.2). We can see that the exponential trend has the lowest MSE among mentioned four models. It showed promising results, but if we plot the predictions (see Fig. 4.1), the exponential trend slope is high and will produce high estimates after 2021. It means that exponential trend overestimates the predictions, which will cause overestimated land valuation.

	exponential trend	linear trend	average growth rate	AR(1)
Wheat	4723.63	21352.70	19095.01	5752.41
Maize	8335.52	16495.67	27876.66	12813.32
Soybeans	50746.28	92273.74	277978.11	924683.63
Sunflower	28665.91	109474.75	360471.38	69007.52

TABLE 4.2: MSE on test set for each model and crop

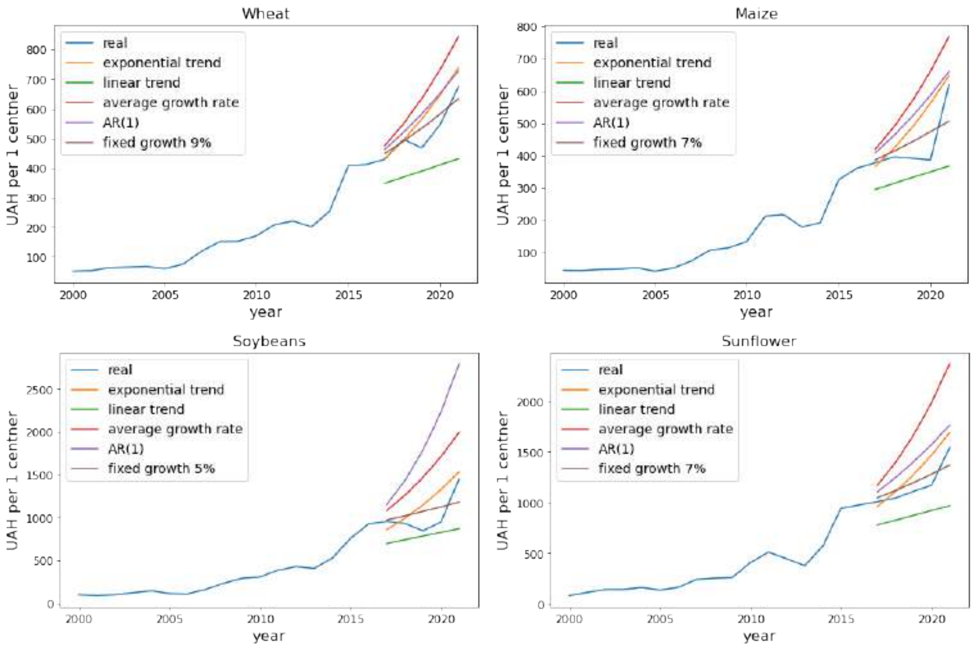


FIGURE 4.1: Crop price prediction
Source: Author

None of the models describes the future price in a way as experts expect it. Exponential trend, AR(1), and average growth rate give too optimistic results, while linear trend - too pessimistic. Therefore, we decided to fit the data on the test set (last five years) because the train set does not represent the present market situation. Also, we decided to choose not the average growth rate but the fixed growth rate that will have the smallest MSE on the last five-year data (Table 4.3). We tried all discrete values between $4 - 10\%$ and chose the growth rates for each crop with the lowest MSE. The growth rate equals 9% for wheat, 7% for maize and sunflower, and 5% for soybean.

Compared to the linear and exponential trend that we fitted on the last five years, the fixed growth rate has a bigger MSE (Table 4.4). Figure 4.2 shows the fitted and predicted values by three models. Though the growth rate had the biggest MSE, it shows the most realistic forecast. Also, the growth rate has more economic meaning than linear or exponential trends. What is more, we can apply it to the last known year - 2021 and start forecasting from it. Therefore, we decided to use this model as a forecast for crop prices.

	4%	5%	6%	7%	8%	9%	10%
Wheat	7321.0	5186.9	3494.6	2290.2	1622.9	**1545.2**	2113.2
Maize	6884.6	5803.9	5073.7	**4729.5**	4809.3	5353.4	6405.2
Soybeans	33683.8	**32940.0**	34677.4	39133.3	46560.6	57229.1	71426.3
Sunflower	25299.0	17923.2	13152.6	**11248.5**	12489.8	17174.3	25619.2

TABLE 4.3: MSE on test set for different growth rates

	exponential trend	linear trend	fixed growth rate
Wheat	1167.38	1380.67	1545.26
Maize	3934.84	4183.76	4729.53
Soybeans	25277.39	26535.22	32940.05
Sunflower	6987.56	8272.36	11248.51

TABLE 4.4: MSE for trend models and fixed growth rate fitted on last five years

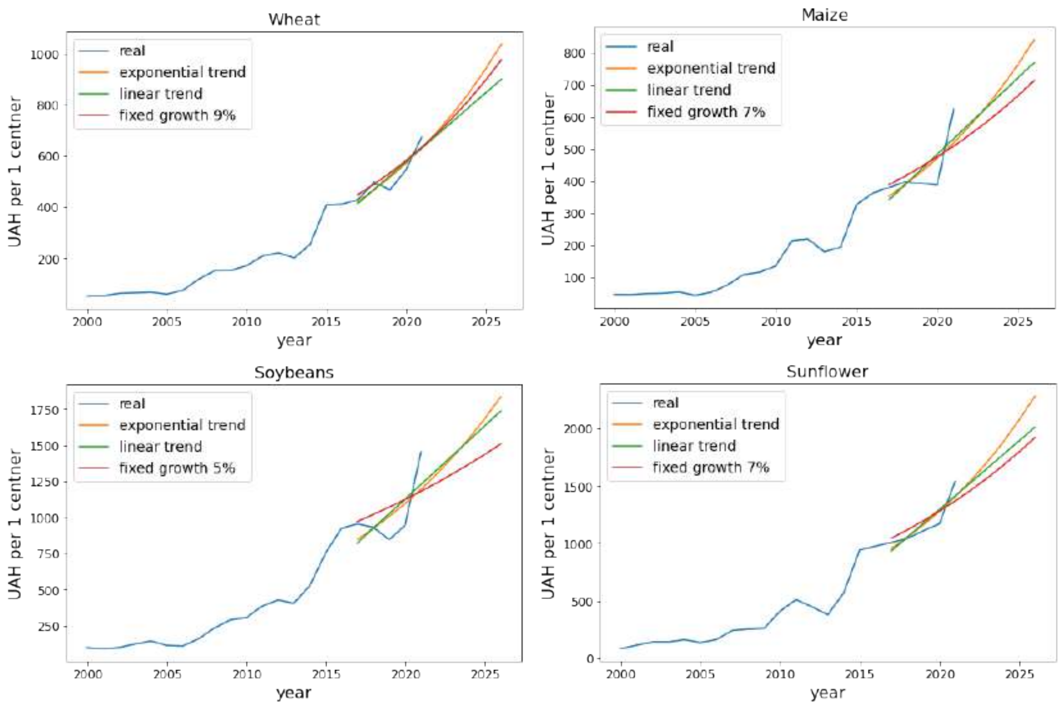
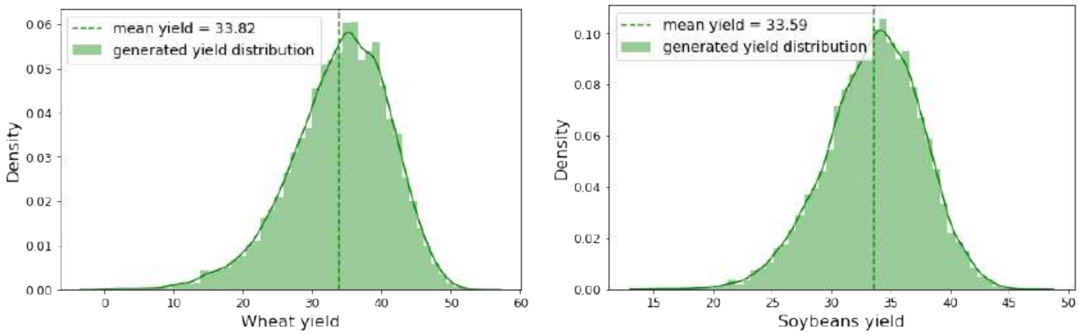


FIGURE 4.2: Crop price prediction (fitted on last 5 years)
Source: Author

For price simulation, we will sample from a normal distribution with forecasted price with growth rate as a mean and historical standard deviation as in Table 3.2.

4.1.2 Yield modeling

For modeling yield in each KOATUU, we decided to use left-skewed lognormal distribution. The choice of left-skewed distribution is justified by modeling the harvest failure. We set the mean and standard deviation and then found the lognormal distribution parameters for each crop and KOATUU separately. For each KOATUU, the mean crop yield is set as an average of KOATUU mean yield and Kherson regional mean yield. The standard deviation is mutual to all the KOATUU and is equal to the standard deviation of region yield (Table 3.3). Since we had too little data about regional soybean yield, we took the standard deviation of country yield for soybean. Moreover, to avoid negative yield, we set zero as the lower limit for the distribution. Figure 4.3 shows the example of generated yield distribution for one KOATUU for wheat and soybean yield.



(A) Wheat yield distribution with mean = 33.82 and std = 7.28

(B) Soybean yield distribution with mean = 33.59 and std = 4.01

FIGURE 4.3: Modeling of crop yield distribution for KOATUU 6525455100
Source: Author

4.1.3 Expenses modeling

Since we know the general expenses, they are mutual for each KOATUU. Therefore, we assume that the expenses are distributed normally with mean and standard deviation according to Table 3.5. Also, we consider that each year the expenses rise by 10%.

4.2 Land valuation based on rent price

The perpetuity in finance is a situation when the cash flow payments are obtained indefinitely and are constant. This method is a type of income method since it considers future income. The formula contains just two components - the CF payment and interest rate (Eq. 4.5).

$$V = I/r \tag{4.5}$$

where

V – monetary valuation of the asset (PV)
I – CF payment (rent payment)
r – interest rate

In the context of the land valuation, the indefinite payments are the rent payments. According to the National Bank of Ukraine, at the end of April 2021, the discount rate is equal to 7.5%[1] and the discount rate for a 3-year Ukrainian government bond is 12.3%[2]. Therefore, we consider reasonable to set the interest rate as 12%.

[1] https://bank.gov.ua/ua/monetary/stages/archive-rish
[2] https://bank.gov.ua/ua/markets/primary-ovdp-chart?date=27.04.2021&valcode=UAH

4.3 Modeling of monocroping farming

Monocroping farming is a practice to grow a single crop year by year on the same land. It is the most straightforward practice for farmers because they follow the same strategy over and over again. Also, it is simple to find the monocropping farming land value since most variables are constant.

We will use DCF analysis to find the land valuation. For this method, we need to estimate the future CF for a long enough period. In this research, we forecast the income 20 years ahead from 2022. The valuation of 1 ha of the land is found with the DCF formula (Eq. 4.6).

$$\begin{aligned} V &= \sum_{i=1}^{20} I_i/(1+r)^i \\ I_i &= (p_i y_i - c_i)(1 - tax) \end{aligned} \tag{4.6}$$

where

V – monetary valuation of the asset (PV)
I_i – income on i year
r – interest rate
p_i – crop price on i year (UAH per 1 centner)
y_i – crop yield on i year (centners per 1 ha)
c_i – expenses on i year (UAH per 1 ha)
tax – tax rate

It is important to emphasize that $(p_i y_i - c_i)$ is the EBITDA, but we need to discount net income in DCF analysis. Since we do not have data on investment in equipment, we assume that depreciation, amortization, and interest are equal to zero. Therefore, EBITDA equals EBT.

The farming is much riskier than leasing and includes industry risk, liquidity risk, and others. Therefore, we set 20% as the discount rate for DCF valuation. According to State Tax Service of Ukraine[3], the tax for agriculture is 14%. Using models of the price, yields, and expenses that were described in section 4.1, we simulated 10000 DCF valuations using Monte-Carlo sampling. As an output, we obtain the distribution of the land value. The results of the simulation are described in chapter 5.

In fact, monocropping farming has two main disadvantages: soil depletion and absence of risk diversification. Since monocropping farming ignores crop rotation, it decreases soil fertility. Moreover, when the economic, weather, or any other circumstances cause crop failure or additional expenses, the farmer loses money because he has grown only one crop that suffered under mentioned circumstances. In our monocropping model, we assume that soil fertility is constant during the years.

4.4 Modeling of monoculture farming

Contrary to monocropping farming, monoculture farming takes into account crop rotation, but it still means that farmers grow one crop on the whole field. To model this type of farming, we need to simulate the crop rotation process. It is possible with a crop-predecessor matrix. We used the Methodology by The Ministry of Agrarian

[3]https://cv.tax.gov.ua/media-ark/publichni-zahodi/print-457967.html (in Ukrainian)

Policy and Food of Ukraine[4] to create the matrix which shows how one crop is recommended to proceed after another (Table 4.5a). For simulation we normalized this matrix to get transition matrix (Table 4.5b). We start the simulation from a random crop and then sample the next crop from the transition matrix.

prev. crop / next crop	wheat	corn	soy	sun
wheat	0	0	1	0
corn	1	0.5	1	0.5
soy	1	1	1	1
sun	1	0.5	0.5	0

(A) Crop rotation recommendation: 1 - recommended, 0.5 - allowable, 0 - inadmissible

prev. crop / next crop	wheat	corn	soy	sun
wheat	0.00	0.00	0.28	0.00
corn	0.33	0.25	0.28	0.33
soy	0.33	0.50	0.28	0.67
sun	0.33	0.25	0.14	0.00

(B) Transition matrix from predecessor to the next crop

TABLE 4.5: Crop-predecessor matrix: the columns are predecessors and the rows - next crop

This approach is closer to reality since it includes crop rotation, but still, it does not cover the risk diversification problem.

4.5 Modeling of polyculture farming based on crop portfolio

In this approach, we assume that the field is big enough to split it for different crops (usually more than 2000 ha). We consider crop as an asset that will bring some profit and form a portfolio of those assets with w_j weights. Formula 4.7 describes the profit of the portfolio.

$$P = \sum_{j=1}^{4} w_j (p_j y_j - c_j) \tag{4.7}$$

where

P – portfolio profit
w_j – weight of j crop in portfolio
p_j – price of j crop (UAH per 1 centner)
y_j – yield of j crop (centners per 1 ha)
c_j – expenses on j crop (UAH per 1 ha)

The weights w_j mean the field fractions that will be planted by j crop. The idea is to find such weights that maximize the profit and minimize the uncertainty. Therefore, we will maximize the information ratio that is the rate between the expected value of profit and standard deviation of the profit (Eq. 4.8). There is one condition for the optimization: the sum of weights equal to 1.

$$\begin{gathered} IR = \mathbb{E}(P)/\hat{\sigma}(P) \rightarrow max \\ \sum_{j=1}^{4} w_j = 1 \end{gathered} \tag{4.8}$$

where

[4] Methodical recommendations on the optimal ratio of crops in crop rotations (in Ukrainian)

IR – information ratio
$\mathbb{E}(P)$ – expected value of profit
$\hat{\sigma}(P)$ – standard deviation of the profit
w_j – weight of j crop in portfolio

The modeling of polyculture farming consists of two steps. Firstly, we find the optimal weights based on simulated historical data and discard any forecasting strategy. In the second step, we model the land valuation using found weights and simulate future profit.

In this method, we conduct the Monte Carlo sampling of profit differently than it was for monocropping because the profit of each crop is correlated. That is why we need to sample price, expenses, and yields from multivariate distributions. We sample price and expenses from normal distribution, therefore we need Pearson correlation matrices (Tables 4.6, 4.7). We calculated the Pearson correlation matrix for prices from historical data, and experts helped form the Pearson correlation matrix for expenses. We expected that crop prices are positively correlated because the same economic factors impact them. For example, during crises (the Great Recession in 2008 and the Covid-19 pandemic in 2021), the demand for all the crops rises, and the prices rise as well. Also, we calculated the correlation on the year average prices, which could raise the correlation. Since the yields are sampled from the dependent lognormal distributions, we use copulas[5] and Kendall correlation (Table 4.8). Kendall's correlation of the yields is calculated on averaged regional yields. The Kendall's correlation is commonly less than the Pearson correlation. Moreover, crops require different weather conditions. Therefore, we observe a positive but not very big correlation.

	wheat	corn	soybeans	sunflower
wheat	1.00	0.98	0.98	0.99
corn	0.98	1.00	0.99	0.98
soybeans	0.98	0.99	1.00	0.98
sunflower	0.99	0.98	0.98	1.00

TABLE 4.6: Pearson correlation of crop prices

	wheat	maize	soybeans	sunflower
wheat	1.0	0.8	0.8	0.8
maize	0.8	1.0	0.8	0.8
soybeans	0.8	0.8	1.0	0.8
sunflower	0.8	0.8	0.8	1.0

TABLE 4.7: Pearson correlation of crop expenses

4.6 Modeling with expand option

Installing the irrigation system on the land proved to be good practice to increase the yield 1.5-3 times. In Ukraine, two types of irrigation systems are used: lateral move irrigation and drip irrigation. It is important to emphasize that the type of irrigation system depends on the shape, size, and plot landscape. Therefore, if there

[5] https://en.wikipedia.org/wiki/Copula_(probability_theory)

	wheat	maize	soybeans	sunflower
wheat	1.00	0.35	0.33	0.57
maize	0.35	1.00	0.14	0.67
soybeans	0.33	0.14	1.00	0.48
sunflower	0.57	0.67	0.48	1.00

TABLE 4.8: Kendall correlation of crop yields

is an opportunity to install the irrigation system, the land will be more attractive for the investors and have a bigger value.

We communicated with the expert in the agricultural field about the expenses on the irrigation system. The drip irrigation costs 27000 UAH/ha and is valid for 7.5 years. The maintenance costs 8000 UAH/ha each year. The lateral move irrigation is bought for 40000 UAH/ha for 30 years. The costs of maintenance equal 2000 UAH/ha each year. Additionally, the costs for the water reach 7000 UAH/ha each year for both systems.

In this method, we assume that water absorption efficiency is equal for both systems. Also, the yield will increase twice after installing. The amount of water depends on the soil moisture, the weather, type of crop, and the duration of the growing season. We consider the average water use.

Chapter 5

Results

In this section, we outline the results of the proposed approaches. Since the market farmland price is unknown due to the moratorium, we had to find another way to assess the results. The first valuation to compare with is the NMV, but as was mention in chapter 2, NMV is inaccurate. The second way is to use a rent price. However, the rent price is known only for state-owned agricultural land. The third option is to use the expert valuation and research from agriculture magazines. Online magazine Agropolit[1] surveyed different experts from economics, politics, and agriculture. They expect the average land price to be 1500-2000 USD per ha. We considered the exchange rate as 28UAH/USD. This sum is equal to 42000-56000 UAH per ha. This price is the average expectation and can change due to different factors, but the experts claimed that the price would not exceed 3000 USD (84000 UAH) per ha.

It is appropriate to mention that the NMV in the Kherson region is equal to 24450.00 UAH/ha. We computed the land value with infinite rent payments in the Kherson region using region average rent price in 2020 equal to 1783 UAH (Fig. 3.6) as a regular payment and got the valuation of 14858.83 UAH/ha. We see that the obtained value is twice smaller than the NMV. It means that, on average, the rent price on government lands is underestimated compared to NMV and should be at least doubled to have the same value as NMV.

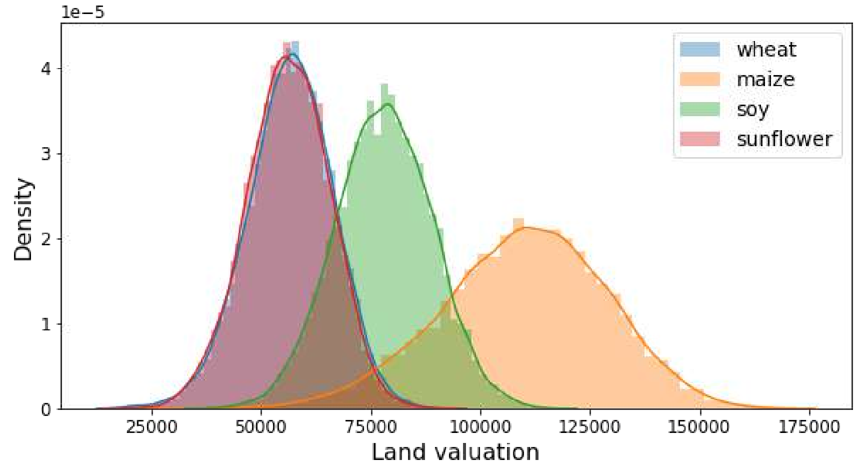
5.1 Results on one KOATUU

To start from, we decided to choose one village council and run all experiments to find the value of 1 ha in KOATUU 6525455100 (Chaplynka village council). The 3-year average yield for this territory is the following: wheat - 39.84 centners/ha, maize - 67.71 centners/ha, soybeans - 34.65 centners/ha, sunflower - 22.27 centners/ha. The yields of chosen KOATUU are higher than the regional and country yields (Table 3.3); therefore, we expect the land valuation of this sector will be higher than average.

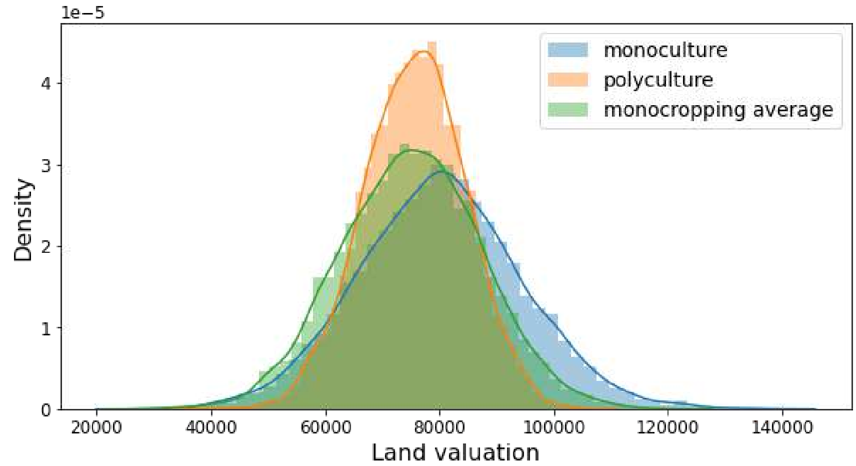
5.1.1 Land value estimates

Firstly, we simulated the value distribution for monocropping, monoculture, and polyculture farming. This experiment required six simulations (monocropping farming requires valuations for each crop separately). Figure 5.1 shows the distributions, and table 5.1 shows the mean and standard deviation of the land valuation.

[1]https://agropolit.com/spetsproekty/867-vartist-1-ga-silskogospodarskoyi-zemli-pislya-vidkrittya-rinku–prognozi



(A) Distribution from monocropping farming modeling



(B) Distribution from average monocropping, monoculture and polyculture modeling

FIGURE 5.1: Modeling of land valuation distribution
for KOATUU 6525455100
Source: Author

We can conclude the following considerations:

1. The valuation using rent payments (22929.26 UAH) showed close value to the NMV (24534.78 UAH), although the regional rent payment valuation (14858.83 UAH) was twice lower than NMV. This observation show how inaccurate the average estimates are and why it is important to use the data on the lowest level.

2. The distribution of land valuation using wheat and sunflower monocropping farming are almost the same. It means that the income from growing wheat and sunflower in this region is equal.

3. The most profitable crop is maize since it generated the biggest land value. The least profitable crops are sunflower and wheat. This can be explained by the fact that regional maize yields are bigger than the average in Ukraine, and the sunflower yield is less (Table 3.3). Obtained results contradict the reality because the regional harvest area of sunflower in the 2020 year was 331.2 ha and

method	mean	standard deviation
NMV	24534.78	-
Rent payments	22929.26	-
Monocroping farming		
Wheat	56682.71	9738.57
Maize	109962.10	18834.02
Soybeans	78025.79	10953.24
Sunflower	56204.24	9468.79
Average	75218.71	12248.65
Monoculture farming	80084.30	14408.68
Polyculture farming	75644.30	8871.83

TABLE 5.1: Land valuation of land in KOATUU 6525455100 (UAH/ha)

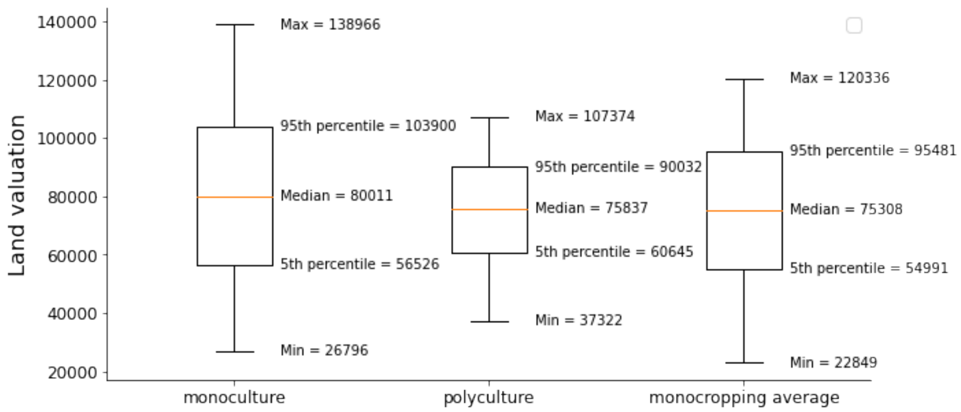


FIGURE 5.2: Statistics of average monocropping, monoculture and polyculture modeling

45.2 ha for maize. Therefore, the farmers grow the sunflower more than maize even though the expected profit from maize is bigger than from the sunflower. The possible reason for this is that the land somehow not prepared for maize or sunflower take place in rotation cycle. According to the standard deviation of the valuation, the maize is much riskier, making it less preferable.

4. The land valuation of monoculture farming is bigger than the average of monocropping farming by 5000 UAH. It shows that the recommended crop rotation positively impacts the income and land value.

5. All the valuations are roughly more than three times larger than the NMV. As a conclusion, the NMV underestimates market price and underlying formula (Eq. 2.1) should be revised.

6. We can see that the standard deviation of land value rises with the mean value. It is expected because the greater the reward, the greater the risks. Nevertheless, polyculture farming valuation showed the least deviation with a high enough mean value. This proves that crop portfolio optimization decreases the risks.

7. The 5% and 95% quantiles of the distribution show the interval where 90% of the data is located (Fig. 5.2). Therefore, we can be confident with 90% that the land valuation in selected KOATUU is between 60645 and 90032 UAH per ha according to the polyculture model. The interval is higher than the experts expect on average. It is because the historical crop yields in this particular KOATUU are higher than average in the region.

5.1.2 Crop weights for polyculture farming

The weights from polyculture farming modeling (portfolio optimization method) is shown in Table 5.2. The weights show what fraction of land has to be planted by some crop. We can see that the soybean has 45% weight. Theoretically, it is expected because soybean monocropping farming gives a good income with a moderate standard deviation. However, in reality, soybeans cover less than 5% of agricultural land in the Kherson region. Therefore, additional research and data are required to assess the specifics of this KOATUU and explain the low fraction of soybean in polyculture farming.

	weight
crop_name	
Wheat	0.1555
Maize	0.1658
Soybeans	0.4537
Sunflower	0.2248

TABLE 5.2: Weights of portfolio

5.1.3 Sensitivity analysis

To understand how sensitive the land valuation is to the change of the discount rate (Fig 5.3) and price growth rate (Fig. 5.4), we can analyze the direction and the slope of the line.

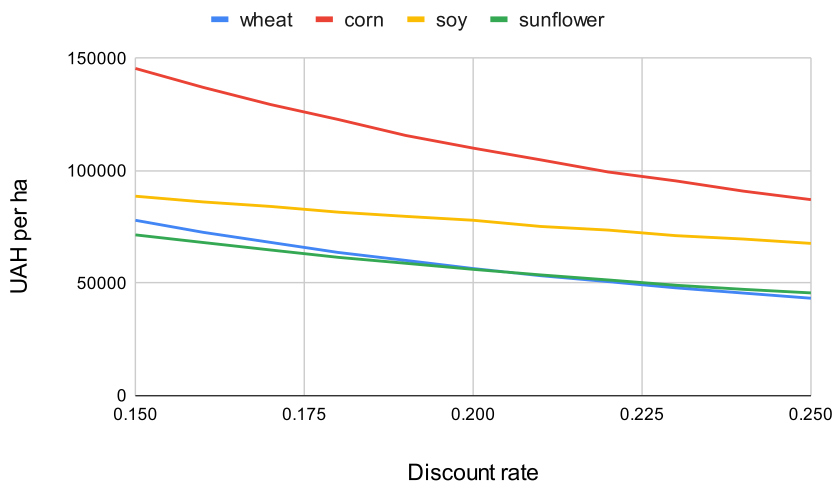


FIGURE 5.3: Sensitivity analysis of land valuation on discount rate (Monocropping farming)

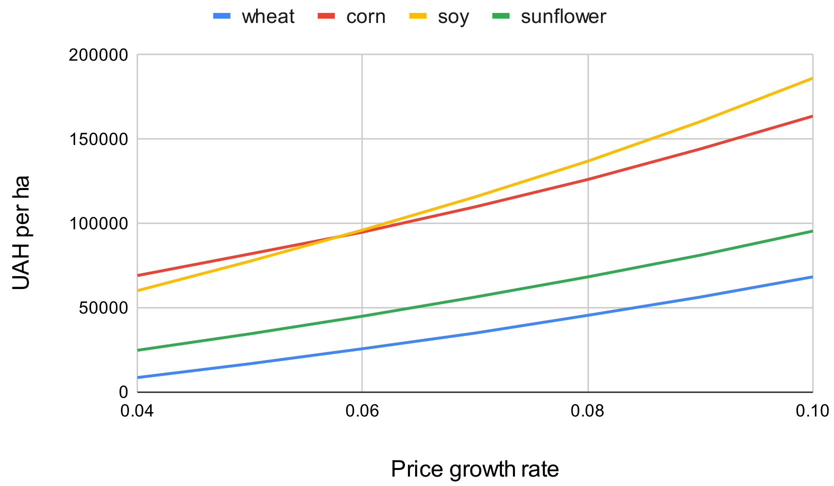


FIGURE 5.4: Sensitivity analysis of land valuation on price growth rate (Monocropping farming)

The maize is the most sensitive to the discount rate that makes it the riskiest crop. The most stable crop to the discount rate is soybeans. Moreover, if the price growth rate of soybean will be bigger than we assumed, the profit (and therefore the land value) will exceed the maize profit. The sensitivity of land value based on sunflower and wheat to the price growth rate is almost the same, but the sunflower is more stable to the discount rate.

5.1.4 Land value estimates with irrigation system option

Finally, table 5.3 represents the results of the expand option valuation.

	drip irrigation		**lateral move irrigation**		**no irrigation**	
	mean	std	mean	std	mean	std
method						
Monocroping						
Wheat	78399	10398	122311	10497	56682	9738
Maize	202232	19639	246406	19827	109962	18834
Soybeans	209138	14121	253716	14234	78025	10953
Sunflower	86310	10742	130363	10853	56204	9468
Average	144020	13725	188199	13853	75218	12248
Polyculture	166596	9973	204630	9950	75644	8871

TABLE 5.3: Land valuation of land in KOATUU 6525455100 (UAH/ha) with the expand option

We want to highlight the following considerations:

1. Including the new opportunity in the model (such as development of irrigation system), we can double land valuation. Of course, this model can be applicable only to the land, where realization of this opportunity is possible.

2. Also, the standard deviations increased. With the new options, the new risks come.
3. Portfolio optimization of polyculture farming combined with the option to install the irrigation system gives the highest valuation with the smallest standard deviation.
4. Even though lateral move irrigation requires more investments (40000 UAH/ha) in the first period than drip irrigation (27000 UAH/ha), it will generate bigger cash flow in the future.

5.2 Results on multiple KOATUU

To make general conclusions about land valuation, analysis of one field is not enough. Therefore, we extended the monocropping farming approach and rent payment method to the set of KOATUU. The set of fields for this experiment were taken from the auctions (described in section 3.3). We chose only those KOATUU that has at least three fields in the data. Finally, we got 69 KOATUU records with average NMV and rent price per ha (see distribution on Fig. 5.5).

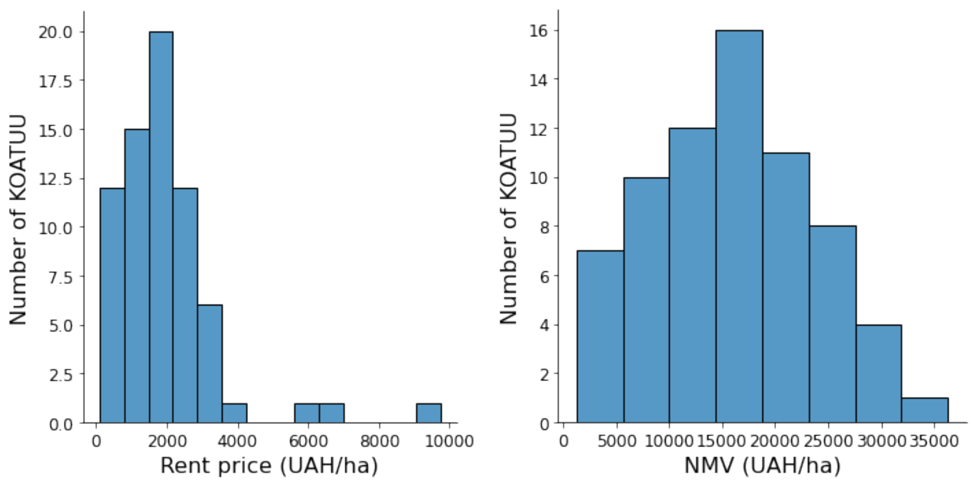


FIGURE 5.5: Distribution of average NMV and rent price of KOATUU
Source: Author

Some KOATUU does not have the data about crop yields. The data can be missed for two reasons: the data is absent in the State Statistics Service of Ukraine database or that the crop was not planted during the observed period. In these cases, we make the data imputation with the Kherson region yield.

5.2.1 Sensitivity analysis of the land value from the crop yields

From the modeling point of view, each KOATUU differs only by the crop yield. Also, the monocropping farming method considers each crop separately. Taking into account these two facts, we can build the dependency of land valuation from the crop yields. Therefore, it looks like the sensitivity analysis of land valuation on the crop yields (Fig. 5.6). From the figure, we can see that the land valuation (and therefore the income) is very sensitive to the crop yield in the case of sunflower and soybeans. The main factor that impacts crop yields is the weather, especially drought. Therefore, the farmers that grow sunflower and soybeans have to take steps to ensure a good yield. In contrast, the valuation based on wheat and corn is more stable but still depends on yields. Also, it is appropriate to highlight that if the yield is too low, the land valuation can be negative.

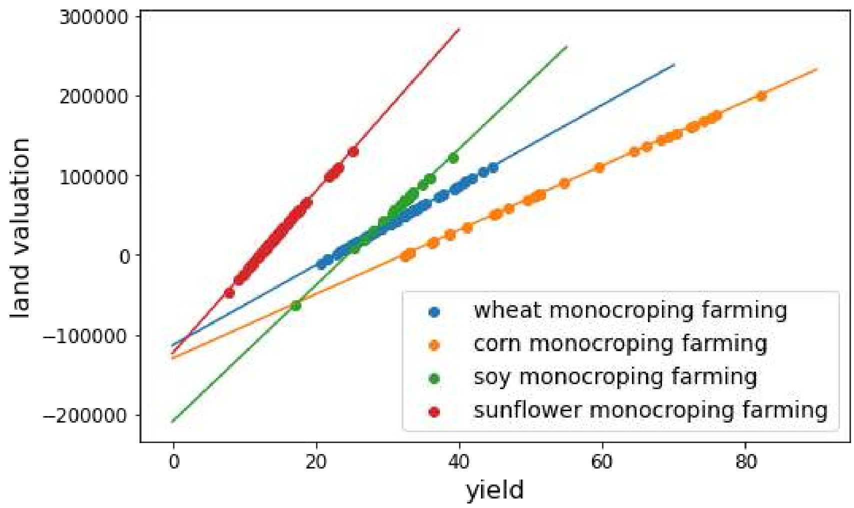


FIGURE 5.6: Sensitivity of land valuation on the crop yields
Source: Author

5.2.2 Land value estimates for Kherson region

We took four monocropping farming valuations, their average, and rent payment valuation for the land valuation by KOATUU. Figure 5.7 shows the distribution of land valuations using monocropping farming. The first consideration is that the land value can be negative. It means that crop yield was so low that it causes dramatic losses. Secondly, we can see the picks for maize and soybean monocropping farming. The reason for this is data imputation. Lots of KOATUU did not have the data about yields of maize and soybean, and we had to impute the data with the regional average.

Next, we took the average of four monocropping farming valuations. The distribution of land valuations is right-skewed (Fig. 5.8) that shows the existence of developed and profitable sectors. We can assume that the fields are equipped with an irrigation system, making the yields in these sectors higher than in others.

method	mean
NMV	15840.07
Rent payments	16179.91
Monocroping farming	
Wheat	39997.58
Maize	87733.75
Soybeans	60005.33
Sunflower	24527.88
Average	53015.55

TABLE 5.4: Results of the land valuation on multiple KOATUU

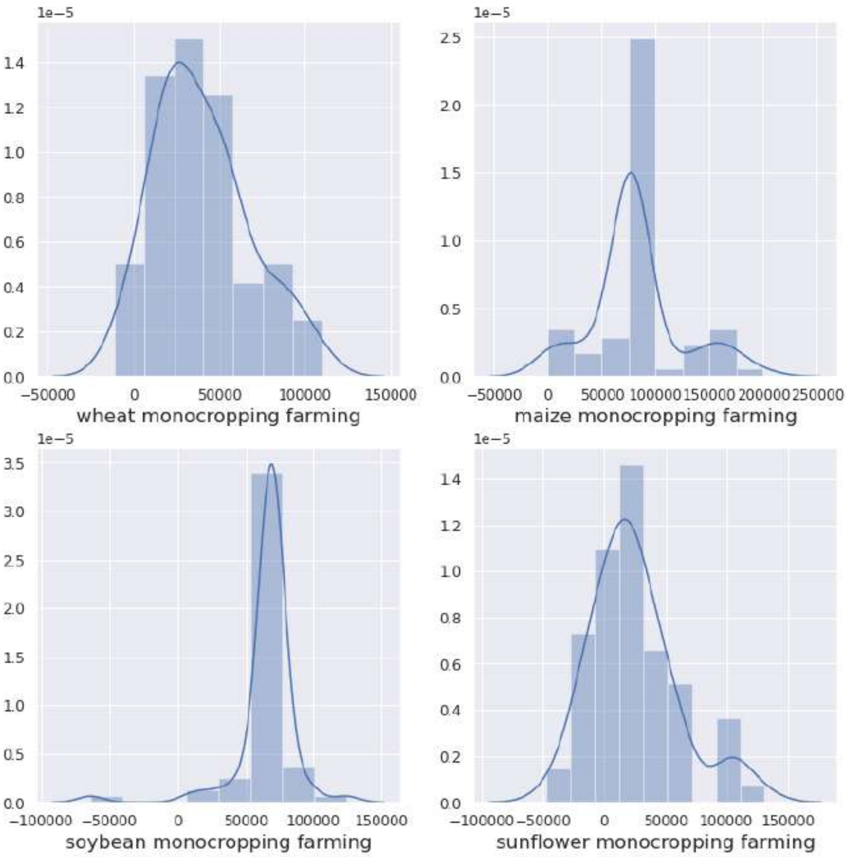


FIGURE 5.7: Distribution of monocropping farming land valuations across different KOATUU
Source: Author

Finally, table 5.4 summarizes the estimated valuations taking the mean of all the KOATUU. The average land valuation (53015 UAH) corresponds to the expert expectations. Again we observe that the fair land valuation is three times bigger than the NMV (15840 UAH).

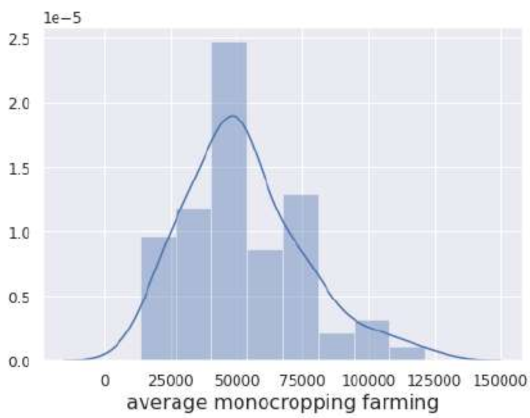


FIGURE 5.8: Distribution of averaged monocropping farming land valuations across different KOATUU
Source: Author

Chapter 6

Conclusions

6.1 Future work

To continue further with research in this area we need to consider new options or use more data. Future work includes the following directions:

1. Investigation why the preferable crops from the modeling (maize and soybeans) are less usable in the reality.
2. Land valuation considering the insurance option. The insurance mitigates the risk of harvest failure, which is the biggest risk in farming. Using the option of insurance, the farmer protects himself from big losses.
3. The commonly used tool in agriculture is futures contracts. The producer and the buyer fix the crop price to fulfill the agreement in the future. In such a way, the farmers mitigate the risk of a price drop. Usage of the futures is one more real option that can increase valuation.
4. We can use the experience of other countries to model the situation in Ukraine. The experiment is to build the regression analysis of economic factors into the growth rate of the land price in different countries during some period after the free market launch.
5. In this research, we cover only some KOATUU in the Kherson region. Although we can scale the land valuation to the whole of Ukraine if we collect appropriate data.
6. The prediction of crop yield and crop price are challenging tasks. The correct prediction and simulation of crop yield and price will make the land valuation more accurate. Moreover, the crop yield prediction on the land characteristics (not on the previous yields) will estimate the yields on the fields where the particular crop was never grown.

6.2 Conclusions

This paper estimated the fair land valuation with the income method and showed that it is three times bigger than the NMV. Therefore, we expect the rise of the farmland price after the opening of the free land market. Our estimation confirmed the expert's expectations.

Secondly, we introduced a few methods that approximate reality in some way and compared them. The experiments showed that crop rotation increases the land valuation and the portfolio optimization method showed how to mitigate the risks.

Moreover, if the land allows developing the irrigation system, the land value is doubled.

Thirdly, we analyzed crop attractiveness by the income. Since the soybeans are the most stable to the discount rate change, produce the least standard deviation in the land valuation and give the highest income with irrigation system, it should be the preferable crop in the Kherson region.

We used the data in terms of KOATUU. It gave more accurate results than the averaged regional data. Nevertheless, it would be better to analyze the data on the lower level - the level of specific fields. Unfortunately, such data is not available in Ukraine. Therefore, for more accurate results, we need to collect the required data.

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