Analysis of the Key Factors Affecting the Productivity of Cereal Crops in Georgia

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Abstract

The paper describes the analysis of key factors affecting corn and wheat yields in Georgia by quantifying the role of factors based on statistical analysis. In order to characterize the situation in Georgia and to identify the main trends, the statistical indicators published by GEOSTAT were analyzed. The results of the GEOSTAT 2014 agricultural census and agricultural survey have been analyzed, based on the conducted studies or developed expert assessments, the factors affecting the average yield of grain crops were analyzed and problems identified. A statistical analysis of the GEOSTAT agricultural survey database was carried out, which included the construction of regression models and factor analysis. The project carried out a small survey of wheat and corn farms in two stages. The above steps revealed the following: Grain farmers have a problem with access to agricultural machinery, which in turn leads to disruption of agro-terms and consequently reduced yields. Also, the problem for the farmers is the malfunction of the irrigation system, the lack of access to quality seeds and the lack of knowledge and information about modern technologies. Regression analysis and database review showed that the existence of irrigation infrastructure and the use of machinery significantly affect the grain yield. The analysis also showed that crop yields are higher in those farms that produce mainly for sale. Based on the analysis and the existing problems, recommendations were issued to the Ministry of Environment Protection and Agriculture of Georgia, the National Statistics Office of Georgia and the private sector.

Keywords: Corn, Wheat, Yield, Regression.

I. Introduction

Maximum utilization and targeted use of Georgia's agricultural potential is vital for the country's economy in general, as well as for the country's food security. Increasing the production of cereal crops is one of the most important guarantees of food security. The cereals self-sufficiency ratio is low in Georgia; according to the available statistics, the self-sufficiency ratio for the last 5 years in the case of wheat is on average 15% and 74% in the case of Corn. Also, the further development and perfection of the cattle feed base depends on the development of cereals production. Based on the resources available in the country, achieving full self-sufficiency in this direction is unrealistic, but it is possible to raise the level of self-sufficiency. Georgia is not distinguished by high productivity of cereal crops, although the natural conditions of the country are very favorable for better development of cereal crops. For example, the average yield of wheat per hectare in 2016-2019 was 2.4 tons, while the same figure averages 5.7 tons in EU countries, although the development of production technologies and the use of additional land resources can improve the level of self-sufficiency.

In the context of the 2020 pandemic, the need to develop the agro-food sector to ensure the country's food security has become particularly important. The world has also clearly seen the strong impact of the agricultural sector on the socio-economic situation of the population. During this period, the existence of such important cultural stocks as wheat became especially important, because bread is an essential daily consumption product of the world's food ration. According to world statistics[1], the demand for wheat grains is growing every year; that is why, for others as well as for Georgia wheat production and reducing dependence on imports is a vital task. In the context of the pandemic, the countries of the world have also applied certain protective measures and introduced export restrictions, which did not last long, but this lesson should still be taken into account. Georgia depends on wheat imports and it is necessary to make the most of local opportunities, especially when such a challenge is faced by the world and delivery to the world market can be delayed at any time.

Increasing the productivity of cereal crops is a stimulus factor for local production, which will contribute to the availability of food, reduce imports, as well as increase the competitiveness of local farmers, which will have a positive impact on both farmers' incomes and consumers.

The economic problems in the value chain of cereal crops production in the field of agriculture are of vital importance and practical. It is advisable to analyze the main factors affecting the productivity of cereal crops in Georgia, to establish correlation relationships, to identify existing problems and to find ways to solve them. Accordingly, the following questions are examined in this study: Which factors affect the yield of cereals in Georgia? What problems and challenges do grain farmers face? How should the state promote the proper management of farmers' activities?

The purpose of this paper is to analyze the main factors affecting the productivity of cereal crops in Georgia, to identify correlation relationships, which will allow policy makers to get more information in this area and assist them in pursuing a targeted policy.

[1] https://www.fao.org/faostat/en/#data/QCL

The objectives of this paper are to identify the main factors affecting the productivity of cereal crops in Georgia and to quantify the role of factors based on the analysis of statistical indicators; Analysis of the implemented policy and legal framework; Analysis of the policy implemented for the improvement of cereal varieties/seeds.

Data Sources

For the general analysis of the factors affecting the yield, the results of the agricultural survey as well as the results of the 2014 agricultural census of GEOSTAT have been used. In addition, FAOSTAT statistics have been used to analyze the productivity of other countries and to ensure comparability with the productivity of Georgia. For the regression analysis, the GEOSTAT agricultural survey database have been used, which provides detailed records of the farmers participating in the survey, allowing us to obtain detailed information about the variables involved in the regression (information on variables and models can be found in the Data and Methods section).

For the analysis, the results of the survey conducted within the project was also used. (relevant links are presented in "References").

Methods

In order to characterize the situation in Georgia and to identify the main trends, the statistical indicators published by GEOSTAT was analyzed. The results of the 2014 census and agricultural holdings survey were analyzed in relation to cereal crops, in particular wheat and Corn sown areas, production, average yields, balances, prices, etc.

In addition, a small survey of wheat and Corn farms was conducted in two stages within the project. In the first stage, a focus group survey was conducted through in-depth interviews, which allowed to clarify the main factors affecting the average yield per hectare of cereals, the problems in this area and possible ways to solve them. As a result of the focus group survey, a questionnaire was developed (see Annex 1), based on which the second phase of the wheat and corn producers (small, medium and large producers) survey was conducted.

Statistical analysis of GEOSTAT agricultural holdings survey database was carried out to identify the main factors affecting the average yield per hectare of cereals, to determine correlation and to quantify the impact of the key factors affecting the yield, which includes the construction of regression models and factor analysis. Regression analysis is used to determine the correlation relationship between variables. It is a reliable method of determining which variables influence the subject under study, in our case the yield of cereals. Regression analysis determines the necessity of introducing this or that factor in the regression equation and evaluates the suitability of the obtained regression equations at each step or verifies how "good" the agreement of the data with the existing model is.

Results

Based on the data of the Agricultural Survey of the National Statistics Office of Georgia, we can say that the production of wheat and corn and, consequently, the yield and self-sufficiency coefficient are low in Georgia. Georgia is mainly dependent on imported products (mostly wheat), the market is not diversified and more than 90% of imported grain comes from Russia. According

to FAO data, the average yield per hectare of corn and wheat is low in Georgia compared to neighboring countries. A survey of corn and wheat growers additionally conducted to further scrutinize the factors affecting crop yields showed that the main problem for farmers is the lack of irrigation system, access to quality seeds, shortage of agricultural machinery.

Regression analysis and database review showed that the existence of irrigation infrastructure and the use of machinery significantly affect the grain yield. The analysis also showed that crop yields are higher in those farms that produce mainly for sale.

II. Conceptual Framework/Theoretical Background

The study deals with the analysis of factors affecting the yield of grain crops. For that end the various papers, such as the results of research conducted by state laboratories, as well as articles published in scientific journals were reviewed and analyzed.

In the next step, variables were identified for regression analysis based on the existing GEOSTAT agricultural research database. These variables are region, area harvested, number of plots, irrigation, equipment, consumption of cereals, consumption of fertilizers / pesticides, costs, etc.

Based on the GEOSTAT agricultural survey database and taking into consideration existing reality and various researches, the main variables that determine yields were identified: the existence of irrigation infrastructure, agricultural machinery and sales revenue have a significant impact on yields (See Figure 1).

Based on the theoretical assumptions and the list of variables that affect yields, we assumed that climatic conditions, seed supply, fertilizer use, pests and diseases, traction and machinery, GDP, and population should have been considered; however it should be noted that problems clearly appeared during the database analysis:

- The time series published by the National Statistics Office of Georgia are small because the data for 2006-2013 are not comparable to the data for 2014-2020. Therefore, economic variables, such as population and GDP could not be used. It was decided to use spatial data (cross-section data) - the 2017 database based on individual observations.
- Some variables in the database need to be additionally calculated or do not exist. The total amount of fertilizers / pesticides used is given and is not identified in the case of individual crops. Same applies to pests and diseases. Therefore, additional variables had to be added, such as region, costs, revenues, etc., which may not directly but indirectly affect yields.

Significance of grain production

According to the available historical sources, Georgia is one of the oldest wheat growing countries. this is confirmed by the fact that out of 27 world-famous wheat species, 14 species have been discovered and described in Georgia, including 5 endemics. Although Georgian endemic varieties

are mostly characterized by low yields, which is one of the reasons for their gradual extinction and disappearance due to their unique varietal and qualitative characteristics, they are rich genetic material and important for scientific research. However, there are some cases of high average yields.

The popularization of corn in Georgia is partly due to its high productivity and special geofigureical adaptation. In addition, the popularity of Corn is due to the fact that it is an important product for food and animal feed.

According to the data of the National Statistics Office of Georgia 2020, Corn occupies an area of about 82 thousand hectares in Georgia. Most of its crops are located in western Georgia, where corn is the main cereal crop used for both food and fodder in cattle. The average yield of corn in Georgia is low compared to the leading countries in the world[2]. An increase in this figure is one of the opportunities for increasing the level of self-sufficiency. In the modern world, corn selection is focused on the production of hybrid corn, thus significantly increasing yields and sown area.

In terms of food security, it is important to note that according to the data of 2014-2020, Georgia consumes up to 400 thousand tons of wheat and 300 thousand tons of corn per year (Figure 2 and Figure 3).In the case of wheat, almost 95% of the wheat consumed comes from food consumption, while in the case of corn, the share of food consumption and livestock consumption is evenly split.

In 2014-2020 the self-sufficiency ratios of wheat averaged 15%, and in the case of corn averaged 74% (Figure 4).

In 2020, after the spread of the pandemic, major exporters of cereal crops imposed various restrictions on exports. This on the one hand increased the risk of cereal crops shortages in Georgia, and on the other hand led to higher prices for imported products. This is especially true of wheat flour and wheat bread, which have a high share in food consumption and have a significant impact on inflation. Figure 5 shows the percentage change in wheat bread prices compared to the corresponding period of the previous year. This demonstrates the importance of increasing the wheat self-sufficiency ratio.

In 2014-2020, 92.5% of the total wheat imported to Georgia was imported from Russia, while in 2010-2012, only 40-45% of the wheat imported into the country came from Russia and the active market players were Kazakhstan and Ukraine. Since 2013, the share of wheat imported from Russia in total imports has increased, the data are presented in Figure 6, which shows the rates of wheat imports in Georgia by years and countries. Today, the market is no longer diversified and 99% of the wheat imported into the country is Russian.

In 2014-2020, 93.2% of the total corn imported to Georgia was imported from Russia, while in 2009-2011, Ukraine was the largest importer in Georgia. The share of corn imported from Russia in total imports has started to increase since 2012. This information is given in Figure 7, which provides information on the quantity of imported corn by years. Today the market is no longer diversified and 96% of imported corn is Russian.

[2] https://www.fao.org/faostat/en/#data/QCL

As for the dynamics of the import price of cereal crops from Russia, it is not characterized by large variability from month to month.

Analysis of major cereal crops indicators and assessment of existing problems

According to GEOSTAT, in 2014-2020, despite the reduction of sown areas of cereals, its share in the sown areas of annual crops averaged more than 70% (Figure8.). While in 2014-2020, the production of grain crops (corn, wheat) in Georgia amounted to 350-400 thousand tons, which is only 42% of the total annual crop production. This is confirmed by the data of grain crops and annual crops presented in Figure9.

In Georgia, corn has the largest share in the sown areas of cereals (Figure 10). According to the data of 2014-2020, corn crops decreased by 47 thousand ha (36%) during this period. This led to a decrease in the share of corn by 11 percentage points in the sown areas of cereals and an increase in the share of wheat by 7 percentage points, respectively. As for the total sown areas of cereals, it decreased by 47 thousand hectares (23%) during the same period.

From 2014 to 2020, the reduction of Corn sown areas was mainly due to the reduction of 19 thousand (47%), 11 thousand (31%) and 10 thousand (42%) hectares in Imereti, Samegrelo-Zemo Svaneti and Kakheti regions, respectively. As for the sown areas of wheat, it changed slightly during the same period, in particular, wheat decreased by 2%.

Kakheti region is also an important region in terms of the sown areas of cereal accounting for 42-43% of sown areas (Figure 11). In Kakheti region, wheat occupies almost 60% of the sown areas of grain crops, while the sown areas of corn in 2014, respectively, accounted for 33%.

Apart from Kakheti, Samegrelo-Zemo Zvaneti Region is another area with quite significant amount of corn sown areas (Figure12).

Analysis of grain crops production

From 2014 to 2020, the total production of cereals increased by 37 thousand tons (10%) and amounted to 403 thousand tons. During this period, the increase in cereal crops production was due to the increase in wheat production by 55 thousand (116%). During the same period, Corn production decreased by 37 thousand tons (13%) (Figure 13).

The following facts should be noted when considering the dynamics of cereal crops production:

- From 2014 to 2020, despite the fact that the sown areas of wheat decreased by 2%, the production of this crop increased by 116%, which is due to a significant increase in the average yield per hectare during this period.
- From 2014 to 2020, although the sown areas of Corn decreased by 36%, the decrease in Corn production was only 13%, which was also due to the increase in average yield per hectare during this period.

- From 2018 to 2020, wheat production decreased by 4%, while during the same period, wheat sown areas increased by 9%. The reason for this is the decrease in the average yield per hectare of wheat during the same period.
- Corn production was characterized by declining dynamics from 2014 to 2017, and since 2017 this figure has been growing steadily.

Kakheti region holds leading positions in wheat production and the dynamics of the production of the mentioned crop is due to the changes observed in Kakheti region. According to recent years, the share of Kakheti in the total wheat production exceeds 80% on average.

Unlike wheat, corn production is highly developed in the Samegrelo-Zemo Svaneti region, and as well as in the Imereti region, which is clearly shown in Figure14, which presents information on corn production by regions and years.

Yield data by country

The average wheat yield per hectare in Georgia in 2015-2019 ranged from 2.2 to 2.6 tons, which is significantly lower than similar figures not only in EU countries but also in neighboring countries (Figure 15).

The average yield per hectare of corn by country is presented in Figure16. The chart shows that Turkey is the leader among Georgia's neighboring countries, where the average yield of corn in 2015-2019 is 9.4 t/ha, which is four times higher than the same figure in Georgia.

III. Data

Regression analysis

Regression analysis was used to quantify the impact of factors affecting corn and wheat yields and to build a regression model. It is a reliable method of determining which variables influence the subject under study, in our case the yield of cereals.

Regression analysis determines the necessity of introducing this or that factor in the regression equation and evaluates the suitability of the obtained regression equations at each step or verifies how "good" the agreement of the data with the existing model is.

The Geostat 2017 Selective Agricultural Survey Database was used to quantify the impact of factors affecting Corn and wheat yields and to build a regression model.

Based on the possible factors affecting corn yield (independent variables), the research questionnaire and the database structure, the following indicators were pre-selected for further analysis:

- Region - A dummy variable is used. The use of this variable was considered reasonable because according to the data published by Geostat, it was observed that the largest share of corn production falls in two regions - Samegrelo and Imereti.
- Area harvested - It is presented in the form of hectares, from which the yield is calculated.
- Number of land plots - Shows the number of plots of land used by the farmer, which is important in a way because it may be one of the ways to increase yields using other additional plots for corn production.
- Existence of irrigation infrastructure - In the regression, a dummy variable is used. If the land area is irrigated, then the variable takes a value equal to one, if not irrigated it is equal to zero.
- Distribution of the volume of corn consumed during the year by categories (sales, food consumption, fodder consumption, etc.) - The share of sales in the total amount of corn consumed is presented in quantitative form.
- Use of agricultural machinery (corn harvester).

It was important to consider the fact that due to the design of the survey of the agricultural holdings questionnaire, most of these factors are reflected in the database at the level of farms, therefore calculation of corn yield is carried out only from net sown areas. In addition, the Geostat Agricultural Survey Database listed farms that had sown corn in a very small area. Due to the high risk of fluctuations in Corn yields such farms (less than 0.5 ha) were not included in the model to avoid misinterpretation.

Based on the mentioned circumstances, the farms that met the following conditions were selected for further analysis:

- Owned/leased the net sown areas of corn.
- Did not own areas of perennial crops.
- Did not produced products in greenhouses.
- The share of net sown areas of corn was 90% or more of the total sown areas of annual crops.
- The net sown area of corn was 0.5 ha and more.

162 farms were selected according to these criteria.

The following variables are used in the case of wheat yield analysis: A dummy variable is used in the irrigation variable, if the land area is irrigated, then the variable takes a value equal to one, if not irrigated it is equal to zero. It should be noted that irrigation is one of the essential factors for increasing yields, so in the case of a dummy variable, cases are taken in which if the plot did not require irrigation and therefore was not irrigated, the variable takes on a value equal to one.

- Revenue from products sold is presented in GEL and is one of the motivating factors for producers.
- Costs - Costs are depicted in GEL, which determines the costs incurred by the producers and whether it will be able to increase yields and whether it is worthwhile to incur costs.

- The use of machinery is also a dummy variable, if the farmer uses the technique, the variable takes a value equal to one, and if farmer does not use it, it is equal to zero.

Focus group interview and survey of grain farms

A survey of grain farms was conducted to better identify the factors affecting crop yields and to better identify the problems facing producers. The survey was conducted in two stages.

In the first stage of the survey of grain producers, six producers from different regions (Kakheti, Samegrelo-Zemo Svaneti, Imereti, Shida Kartli, Kvemo Kartli) were selected, representing individual entrepreneurs and enterprises and smallholder farms. The meetings were held through the online platform "Zoom" and each lasted for two hours.

The purpose of the meetings was to hold discussions with cereal producers of all categories and to identify problems and challenges related to cereal yields. Additionally, to refine the design and structure of the pilot questionnaire. The discussion focused on the following issues:

- What preparatory work is going on before sowing and in what period?
- Which months are best for sowing?
- How are plants protected before harvest?
- Which months are best for harvesting?
- What problems do grain farmers face?
- Ways to solve problems and recommendations.

In-depth interviewing revealed an additional questions and topics of discussion, such as seed rotation, irrigation infrastructure. All important issues were addressed in the final questionnaire (see Annex 1).

In the second phase of the survey, given the pandemic situation, a telephone interview was conducted. A total of 30 farmers were interviewed, of whom the required information was obtained from only 20 farmers. In other cases the farmers did not remember or did not have information on various important aspects for the survey (amount of yields taken, frequency and cost of work performed, etc.). Farmers were interviewed from major producer regions, namely wheat producers in Kakheti and Kvemo Kartli, and corn producers in Samegrelo, Imereti and Kakheti regions.

IV. Methods

Corn

As mentioned above, data on the availability of irrigation infrastructure and the quality of irrigation are reflected in the database at the plot level. At the plot level, information is also given about the area and volume of corn harvested. Based on the above, two econometric models were developed.

Impact of the existence of irrigation infrastructure on the average of corn per hectare, where, in addition to the corresponding dummy variable, two additional variables were included - the number of plots and the area of corn harvested (see Annex 2). The estimated model is represented by Equation (1). Information on the description of the coefficients of the equation is given in the Data section, while the t statistics and p values are presented in detail in Annex 2.

$$Yiled = 1.05 + 0.01AreaHarvested + 0.32Numberofplots + 0.73Existenceofirrigationinfrasructue \quad (1)$$

Influence of other factors on average corn yield per hectare, where the number of plots was selected as independent variables, use of corn harvester (dummy variable), share of sales in total amount of corn consumed, area of harvested corn and region, in particular, Imereti and Samegrelo regions (dummy variable) See Annex 3). The estimated model is represented by Equation (2). Information on the coefficients of the equation is given in the Data section, while the t statistics and p values are given in detail in Annex 3.

$$Yiled = 0{,}77 + 0{,}31numberofplots + 2{,}05cornharvester + 0{,}01sumofsale - 0{,}04cornharvestedarea - 0{,}58imeretiandsamegreloregion \quad (2)$$

Statistical tests of the linear regression model showed that the significance of the regression equations was relatively low, due to the fact that other important factors were not included in both models, and such an important factor as climatic conditions was not considered in either model. Also, the tests have shown that in both equations, the variables used independently are significant, the model is not characterized by heteroscedasticity and multicollinearity (see Annex 2 and Annex 3).

Wheat

The data for the year 2017 was analyzed according to the existing database for the analysis of wheat yield.

Productivity (tons/ha) was used as the outcome variable to construct the regression model and the factors acting on it were determined according to the existing database. The factors are: irrigation, the amount received from the products sold, the use of machinery and costs. In the first stage we discuss the effect of the irrigation, the amount received from the products sold and the use of machinery on the yield. The estimated model is represented by Equation (4) and Equation (5). Information on the coefficients of the equation is given in the Data section, while the t statistics and p values are given in detail in Annex 4 and Annex 5.

$$Yiled = 1592.3 + 0.01salevalue + 330.44irigation + 323.01machuse \ (4) Yiled = 2139.9 + 0.52moneyamtha \ (5)$$

It should be noted that it was important to include other variables in the model, such as the use of fertilizers and pesticides, climatic conditions, rainfall, etc. However, the Geostat database does not allow the analysis of fertilizer consumption for a particular crop, as they have a total value for all

the crops produced by the household. Also, there is no way to determine the climatic conditions or the amount of precipitation.

Since we are using a 2017 database in which the data presented is not a time series data, we can use the usual linear regression model and see the relationship between the dependent and independent variables.

V. Results

Key results of Regression analysis

Corn

As for the results of the regression equation, after estimating the existing coefficients, the modeling showed the following - under other equal conditions:

- Existence of irrigation infrastructure in corn crops increases the average yield per hectare of corn by 0.73 tons.
- The use of a corn harvester and, consequently, the reduction of losses in the field, increases the average yield per hectare of corn by 2.0 tons.
- An important trend was observed in the fact that in Samegrelo and Imereti regions, the average yield per hectare of corn decreased by 0.58 tons, which is in line with the figures published by Geostat - the average yield per hectare of corn by region. According to Geostat, in 2017, compared to the national average, the average yield per hectare of corn was 39% lower in Imereti and 33% lower in Samegrelo, and in general, in recent years, despite the fact that the biggest share of total corn production in the country comes on these two regions, the yield per hectare is low compared to other regions.
- There is also a positive impact on the share of quantities of sold corn, which indicates the fact that sales-oriented farms are investing more in increasing corn yields. According to the coefficient of the econometric equation, the increase of the share of sales in the volume of consumed corn by 1 percentage point increases the average yield by 0.01 tons.
- In both equations, the high value of the independent variable indicates that the corn yield is affected by other important variables that were not reflected in the models because of the structure of the existing data base.

In the case of some variables, we are only dealing with a high correlation and not a causal relationship, because such variables in turn act on other factors and therefore indirectly affect the yield. In this regard, we can distinguish the use of the corn harvester and the dummy variables of the region and the share of sold corn in the total amount of corn consumed.

The use of a corn harvester, in addition to reducing losses in the field, also indicates that the relevant farm has large areas of corn. Additionally, the high share of sales indicates that agriculture is more focused on the sale of products and not on consumption. Consequently, such farms invest more resources in increasing profits and, consequently, productivity.

As for the dummy variable of the region, it should be taken into account that in Samegrelo and Imereti regions, corn production is often more of a tradition than profit/business orientation, and therefore, small agricultural farms produce corn mainly for consumption. Therefore, in the Samegrelo and Imereti regions, farmers spend relatively few resources to increase yields.

Wheat

Based on the results obtained through t statistics and p value (see Annex 4.- Table for coefficients), we can say that irrigation and sales revenue are statistically significant in terms of yield factors. According to the above, the yield of the irrigated area is 330.4 kg higher than the yield obtained from the area that is not irrigated. At the same time, sales revenue has a positive effect on productivity. In addition, according to the existing reality, the productivity is also affected by the machinery used. However, according to the above data, it is statistically insignificant, but its presence in the model is important, since the model as a whole is statistically significant.

In the second stage, costs were included in the model as a factor affecting productivity. Because inclusion with other variables caused the problem of multicollinearity, it was therefore discussed and evaluated independently (see Annex 5- Table for coefficients). By including it, we get that under other equal conditions, an additional 100 GEL increase in costs leads to an average yield increase of 52.1 kg per hectare.

In addition, it is important to highlight that although both coefficients and the model as a whole were statistically significant, it is still not possible to well explain the result variable – productivity. One of the possible reasons for this is the fact that the model failed to take into account such important demofigureic and social variables (based on the existing database) that have the greatest impact on productivity. For example, weather influence, farmers' expectations, their preferences, etc.

The results of the survey of grain farms

According to the surveyed farmers, the average yield per hectare is 3.7 tons in the case of wheat and 7.2 tons in the case of corn. The weighted data are calculated according to 123 ha of wheat and 69 ha of corn field.

The vast majority of surveyed farmers carry out almost all activities using machinery, although in some cases there is a problem with access to agricultural machinery (both physical and financial), as well as frequent delayed works due to shortages in machinery and consequent violations of agro-terms, especially in Kvemo Kartli.

The survey clearly reveals the impact of a number of factors on productivity. Significant impacts are observed both in the use of fertilizers and pesticides, as well as in the cultivation of the soil and the quality of seed material.

In the case of corn, the yield per hectare ranges from 3.5 tons to 9.5 tons, which is obviously a large range, although there is also a large range in costs, ranging from GEL 654 to GEL 2,500. The survey confirms that farmers who spend less than 1000 GEL per hectare, their yield does not

exceed 4 tons / ha, in case of spending 1000-2000 GEL the yield is 5-7 tons / ha, and in case of spending 2000-2500 GEL the yield reaches 8-9.5 tons / ha. It should also be noted that farmers who have a small amount of corn sown area (less than 1 ha) avoid spending and their yields are correspondingly low, the cost of less than 1000 GEL is mainly observed in the case of such farmers.

According to information provided by wheat farmers, the impact of costs on yields is certainly evident, though not as pronounced as in case of corn. Costs range from 630 GEL to 1990 GEL, and the yield is in the range of 1.3-6.0 tons / ha. In case of expenditures up to 1000 GEL, the yield varies in the range of 1.3-3.8 tons per hectare, and in case of expenditures above 1000 GEL in the range of 3.1-6.0 tons. In the case of wheat, along with costs, there was a significant correlation between plot area and yield, the survey shows that relatively high yields are observed in large plots, namely, in plots larger than 5 ha wheat yield always exceeds 3 tons / ha.

According to the survey, the cost of fertilizers and pesticides is in the first place in terms of costs for both crops. This figure reaches 48% of the total costs for wheat, and 42% for corn. As for soil cultivation costs, they are sharply different for corn and wheat (21% of total expenditure wheat producers and 36% of total expenditure for corn producers) (Figure 17). This can be explained by the fact that most of the selected corn producers were from Samegrelo and Imereti regions, where the cost of renting soil cultivation equipment is relatively expensive.

As for the problems mentioned by the farmers, the main problem is the lack of irrigation system in the mentioned plots. An important problem is also the availability of quality seeds. The survey shows that the purchase of quality seeds is associated with significant costs, which in many cases farmers cannot afford.

Lack of agricultural machinery is another problem, especially for the farmers interviewed in Kvemo Kartli region. Violation of agro-terms caused by delayed services from agricultural machinery owners is also observed, which has a significant impact on yields. Farmers often mention the problem of access to the laboratory as well, as there are no laboratories in different municipalities to conduct soil and seed analysis, which is why interested farmers have to travel to other municipalities for this purpose, hence additional costs.

Additional evidence

Based on the regression analysis and farmers survey, it was found that the productivity of cereals is affected by many factors, of which at this stage we can additionally distinguish the following:

Neglecting crop rotation: The effectiveness of the use of crop rotation practices in agriculture is of great importance. Many years of experience show that the correct rotation of crops helps to increase soil fertility and increase yields. This was confirmed by the survey conducted within the project. Farms that alternately sowed grain crops were characterized by relatively high yields. However, it should be noted that this practice was rarely used among respondents. According to the survey, the main alternate crop of wheat was barley and sunflower. And in the case of corn alfalfa, or the method of resting the soil was used.

According to the grain farm survey the interviewed farmers who do not apply the practice of crop rotation named two main reasons: 1) Part of the farmers do not expect that the rotation will actually increase the yield and 2) Lack of coordination - Part of the farmers who are ready to change the culture depends on the decision of the neighboring farmers.

High share of small land farmers in agriculture:

Most of the agricultural farms in Georgia are characterized by small land area, which is a hindering factor in the production of grain crops (Table 1). According to presented data, 87% of the population owns arable land up to 1 ha, which makes it difficult to introduce modern technologies and use of machinery in the production of grain crops without significantly increasing the cost of production. For example, 69% of the sown area of wheat and 93% of corn are cultivated on land areas less than one hectare (Table 2).

Figure18 shows the percentage distribution of farms using more than 1 ha of arable land. In this regard, Kakheti, Samtskhe-Javakheti and Shida Kartli regions are distinguished, where 28%, 27% and 22% have more than 1 ha of arable land, respectively. Kakheti is also distinguished in that respect, as the share of farms that use wheat crops with an area of more than 1 ha is high.

Disorganized windbreaks: Protects the soil from erosion. Windbreaks are built to increase soil fertility, ensure abundant and solid yields of agricultural crops, and protect them from natural disasters. By reducing the wind speed during the vegetation period, the windbreaks help to retain moisture in the adjacent fields, and in winter - to retain the snow cover and thus increase the soil moisture.

Strong winds often cause the cultivated soils to dry out and the humus layer to overflow, causing the crops to die. Annual crops are destroyed by scattering and drying of the soil. Under the influence of windbreaks, the yield of agricultural crops increases.[3]

In 2018, the Agricultural Scientific Research Center developed a windbreak program for farmers, although the problem remains unresolved. According to the grain farm survey conducted within the project, the problem of windbreaks affects all regions, mainly the plants are cut down, do not have the desired length and width, and in most cases there are bushes left, which does not hold the wind well enough.

Lack of access to irrigation: A major problem in Georgia is the lack of an irrigation system in the regions, which is also an obstacle to achieving high yields of cereals (especially wheat). Although significant funds have been spent from the budget for the rehabilitation of infrastructure since 2012 and as a result, 134 thousand hectares are provided with water, but the problem of irrigation still remains. It is also noteworthy that farmers in irrigated areas prefer to sow crops with

[3] https://srca.gov.ge/files/qarsafar_16_gv.pdf

higher profit margins, because as mentioned above, in most regions, small farms make up a large share of agriculture and, consequently, the production of high-yield crops is more profitable. Therefore, increasing the area of irrigated land has less than desirable effect on increasing the average yield per hectare of cereals, as crops are replaced and sown areas of cereal crops are reduced.

Although the process of irrigation has started, there are still regions where even drinking water is a big problem, such region is Kakheti for example. According to the grain farm survey results, most areas of wheat are still not irrigated. In the case of corn, irrigation is not a problem in some regions, although in some cases, delays in water supply due to the transition to new re-metering have reduced farmers' corn yields from 15 tonnes to 8-9 tonnes per hectar, which once again underlines the importance of irrigation in increasing yields.

Low prices on local products (price at the farm gate) and competitiveness: The average yield per hectare of cereals is indirectly affected by prices at the farm gate; in particular, in 2014-2020, the prices at the farm gate in the case of wheat were 0.41-0.67 GEL (see Figure19), and in the case of corn were 0.51-0.69 GEL (see Figure 20). Low price and, consequently, low income (profit) from the sale of cereal crops per hectare is an obstacle for the producer to introduce modern technologies, use high quality mechanization, etc., which will increase the cost of production and make it competitive with imported products.

In the case of corn, prices at the farm gate vary by region (prices for corn by regions are given in Figure 21). In contrast to wheat, in the largest producer regions, Samegrelo-Zemo Svaneti and Imereti, farm gate prices are high compared to other regions. This may be due to high quality products (including appropriate conditions for the crop) or at the expense of the feed needed for cattle breeding, as these regions are the leaders in the number of cattle.

One of the reasons for the low price of local wheat in the market can be considered the production of low-quality grain, which may also be due to the use of low-quality seeds. According to the survey conducted under the project, most farms use foreign varieties for sowing, which are pre-treated with pesticides. Farmers also noted that such seeds are often unreliable, but there are no laboratories where the seeds will be tested and certified. Despite the unreliability, farmers still prefer to use foreign seeds. Farmers have also studied the fact that sowing primary seeds increases the yield per hectare, while in the second year using their own grain production as seeds reduces the yield.

Wheat sowing and cultivation costs: Maintaining the agro-technology required for growing wheat with high productivity is associated with high costs. Figure 22 shows the percentage distribution of costs necessary for wheat production, according to the Agricultural Scientific Research Center. According to them, about 1800 GEL is needed for an average of 1 hectare. The largest share of costs (42%) comes from the amount needed for fertilizers and preparations, followed by soil preparation costs which account for 30%. Under these costs and proper agronomic

measures, the average yield should reach 5 tons per hectare. Considering the price at the farm gate in 2020 and the above mentioned yield (5 tons / ha), the income from 1 ha of wheat field is 3,350 GEL, and the net profit is 1550 GEL.

Corn sowing and cultivation costs
According to the Georgian Farmers' Association, in the case of corn, the costs per hectare are even higher and reach 2500 GEL. The percentage distribution of corn growing costs is presented in Figure 23, which shows that 38% of the costs come from fertilizers and preparations, followed by labor and drying costs at 24%. According to the above mentioned information, the estimated harvest is 6 tons per hectare, which in terms of price in 2020 at the farm gate is 4140 GEL, while the net profit is 1640 GEL.

It is noteworthy that the cost of stubble and straw, which is not included in the above calculations, their cost is about 400-500 GEL.

Consumption / Use of Fertilizers and Pesticides - General - The law in Georgia regulates the effective use of pesticides and agrochemicals and the legal basis for safe use for humans and the environment. In addition, the circulation of banned and severely restricted pesticides is noteworthy, as registration tests have shown a high potential for negative impact on human health and the environment.

As mentioned above, Georgia is a small country and therefore in order to get the harvest, attention should be paid to the abundant harvest of cereal crops with intensive technologies. One of its most important conditions is the effective protection of crops from pests and diseases. This requires knowledge of the symptoms of diseases, the characteristics of pests, modern, safe methods of control.

The grain farm survey conducted as part of the project found that farms that were used fertilizers twice and more often had higher yields per hectare than those who used them once or did not use soil fertility and plant protection products at all.
Farmers explained the low frequency of fertilizer and pesticide use by the increase in prices during the sowing period.

It is also noteworthy that several farmers, who were characterized by high yields of corn, mentioned the state program on pesticides, according to which they used it for free.

Agricultural machinery and agricultural equipment - According to the data of the Ministry of Environment Protection and Agriculture of Georgia "Agricultural Logistics and Services Company" Ltd is equipped with 508 tractors, 117 combines and up to 5000 implements; however, it should be noted that the equipment used to cultivate and harvest the land is outdated and often needs to be repaired. According to the results of the 2014 agricultural census, there is quite a big difference between farms with land cultivation equipment and farms that used agricultural machinery (Table 3), roughly speaking, only 2% of households can afford to cultivate their own land, while the rest depend on daily hired labor, which will greatly complicate working conditions during the harvest period, as the process of placing the crop must be carried out in a short period

of time. However, if we take into account the fact that the vehicle fleet needs to be renewed and equipped with outdated equipment, the problem becomes more acute.

As we have already mentioned, the Ministry of Environment Protection and Agriculture of Georgia launched a co-financing program for harvesting agricultural machinery in 2020, which aims to increase access to harvesting agricultural machinery and according to their forecast, as a result of this project farmers save GEL 4.1 million annually on hiring agricultural machinery.

Nevertheless, according to the survey conducted within the project, grain producers named the challenges related to mechanization as a problem. During the wheat harvest, the main harvesting machinery is usually mobilized in the Kakheti region, because due to the climatic conditions, wheat harvest starts first in Kakheti. At the same time, there is a greater concentration of large producers in Kakheti. When due to the weather conditions the harvest dates coincide in Kakheti and Kvemo Kartli regions then there is a shortage of machinery. As a result, the harvest is delayed, the fields dry up and the grains fall into the field before harvesting. As a result, most of the harvest remains in the field, added to the problem of seed drying, the grains break during harvesting and, consequently, the harvest is very low quality.

Climatic conditions - Cereal crops are sensitive to climate change. It is affected by the long-term average rainfall, temperature, and annual climate variability. Some cultures are more resilient to certain types of stress than others, however, different types of climate change affect each culture in different ways. For example, wheat areas are almost not irrigated in Georgia, which is why its yield is falling significantly in drought years. The negative impact of drought reaches a maximum after sowing, in the spring and during the grain filling period. Sowing in Kakheti is often carried out in drought conditions. Not so rare when wheat sown in October cannot emerge until winter, and it emerges only after winter (February-March) when sufficient moisture has accumulated in the soil. As a result, sparse crop is formed, which in turn reduces the yield. During the wheat spearing period, drought stops stem growth which causes undersizing. Low altitude is almost always associated with high dryness during the spearing phase. Under conditions of reduced humidity, the plant cannot grow normally, as for the Corn, in Kolkheti there is enough moisture and there is no need to irrigate the Corn. Consequently, the dependence of Corn yield on rainfall is small and is manifested only in particularly dry or hot years.[4]

Existence of pests and plant diseases - Cereal crops are significantly damaged by pests, diseases, and weeds, which massively multiply when creating favorable climatic conditions. Pests, due to their developmental characteristics, damage the sown seeds and sprouts, their roots, and some feed on vegetative organs (roots, stems, leaves), thus directly reducing the crop, often completely destroying. It is also very important that grain pests have already formed natural enemies that do a great deal of useful work under certain supporting conditions, knowing and keeping them in

[4] National Plan for Adaptation to Climate Change for the Agricultural Sector 2017

crops also significantly contributes to crop protection and ecologically clean production. Knowledge of the use of modern technologies and preparations is necessary to solve these problems.

The survey of grain producers conducted as part of the project showed that birds also have a large impact on yields, for example, in the Kakheti region, in 2020, in corn fields, during the seed germination phase, more than half of the grains were eaten by birds which then negatively reflects in the final yield.

This paper will, on the one hand, enable the policymakers to see the problems identified in the corn and wheat production process, and on the other hand, provide important information for farmers and the private sector engaged in grain production on the importance of fertilizer and pesticide use, irrigation, land consolidation etc.

VI. Conclusion

As mentioned above, Georgian endemic varieties are mostly characterized by low yields, which is one of the reasons for their gradual disappearance and extinction from their commercial point of view, which was confirmed by studies survey of grain farms, according to which producers mainly consume foreign varieties.

On the one hand, the low self-sufficiency rate of wheat (15%), and on the other hand, the non-diversified market increases the risks to the availability of grain and grain products in a critical situation (92.5% of wheat is imported from Russia).

Grain farmers have a problem with access to machinery, which in turn leads to disruption of agro-terms and consequently reduced yields.

The survey conducted within the project showed that the high price of pesticides reduces the availability of them, and which in turn reduces the yield. Also, the problem for the farmers is the malfunction of the irrigation system, the lack of access to quality seeds, the disorder of the windbreaks, the neglect of the seed rotation, the lack of knowledge and information about modern technologies.

- Most of the farms in Georgia are small, which has a negative impact on the yield of grain crops.

- Regression analysis and review of the database showed that the existence of irrigation infrastructure and the use of machinery significantly affect the grain yield. The analysis also showed that crop yields are higher in those farms that produce mainly for sale.

Recommendations

For the Ministry of Environmental Protection and Agriculture of Georgia

- It is advisable on the one hand to effectively inform farmers about the advantages of alternate sowing and on the other hand to facilitate the coordination process on crop rotation between farmers.
- It is advisable for the Ministry to facilitate coordination between potential investors and small landowners to make it possible for an investor to lease fragmented land. At the same time, the focus should be shifted to high-tech investors. This will enable more efficient use of existing lands on the one hand, and popularization of the use of modern technologies in villages on the other hand.
- Disorganized windbreaks are again primarily due to lack of coordination, smallholder farmers do not take the initiative and avoid excessive costs in this regard. Cooperating farmers and uniting for a common goal will solve this problem, of course, for this, each farmer must get the right information about the importance of windbreaks. Farmers have the opportunity to plant windbreaks on the recommendation of the Scientific Research Center.
- The Ministry of Environment Protection and Agriculture of Georgia, with the assistance of the Rural Development Agency, should provide small crop farmers in the unirrigated regions with technical knowledge on how to obtain irrigation water at a specific location (wells, irrigation canals, etc.), and on the other hand to help coordinate and find the necessary credit resources.
- It is necessary to find, select, restore, improve and create a genetic bank of local varieties in the country. Laboratories should also be set up where the farmer will be able to adapt the seed varieties, fertilizers and pesticides to the climatic conditions and soil characteristics of his/her region.
- It is desirable to offer financial support for elevator owners in the form of a cheap loan/credit. This will allow the owners to fully equip the elevators with modern technologies, including dryers.
- The state should ensure increased access to financial resources to purchase fertilizers and pesticides.

For GEOSTAT:

- The quality of the GEOSTAT database needs to be improved, which implies the following: Important indicators such as equipment consumption, use of fertilizers, pesticides, etc. cannot be determined in relation to concrete crops. It would also be interesting to have a list of reasons for crop destruction (losses) which would allow users and decision makers to better analyze the problems in the sector for data analysis.
- The statistics for 2006-2013 published on Geostat in the framework of the "Agricultural Survey" are not comparable to the data after 2014, which complicates the analytical work. It is desirable to recalculate previous years to ensure comparability.

VII. Acknowledgment

This research was financially supported by the 50x2030 Initiative through the International Fund for Agricultural Development (IFAD). We gratefully acknowledge Dr. Heath Henderson for his constructive review and comments.

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IX. Figures and Tables

Figure 1.

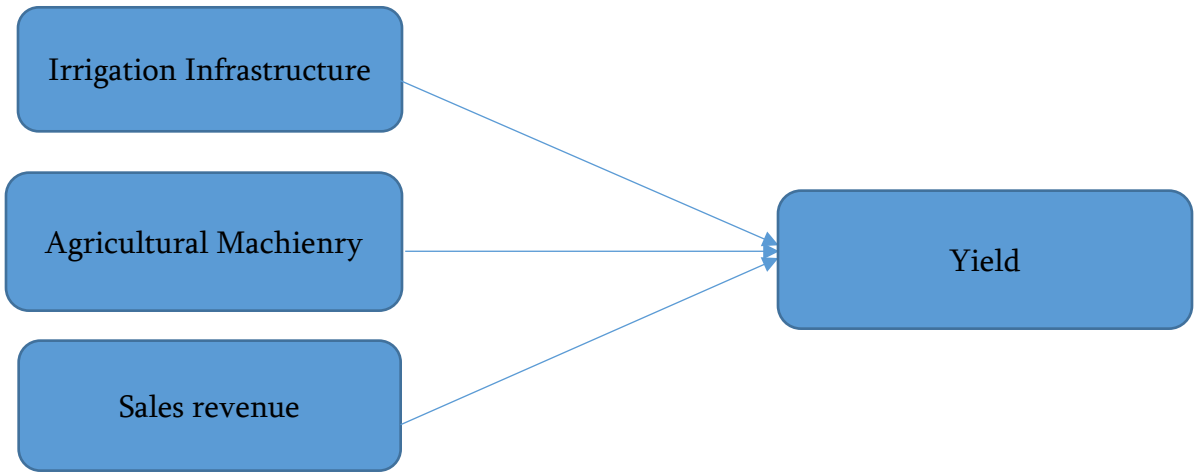
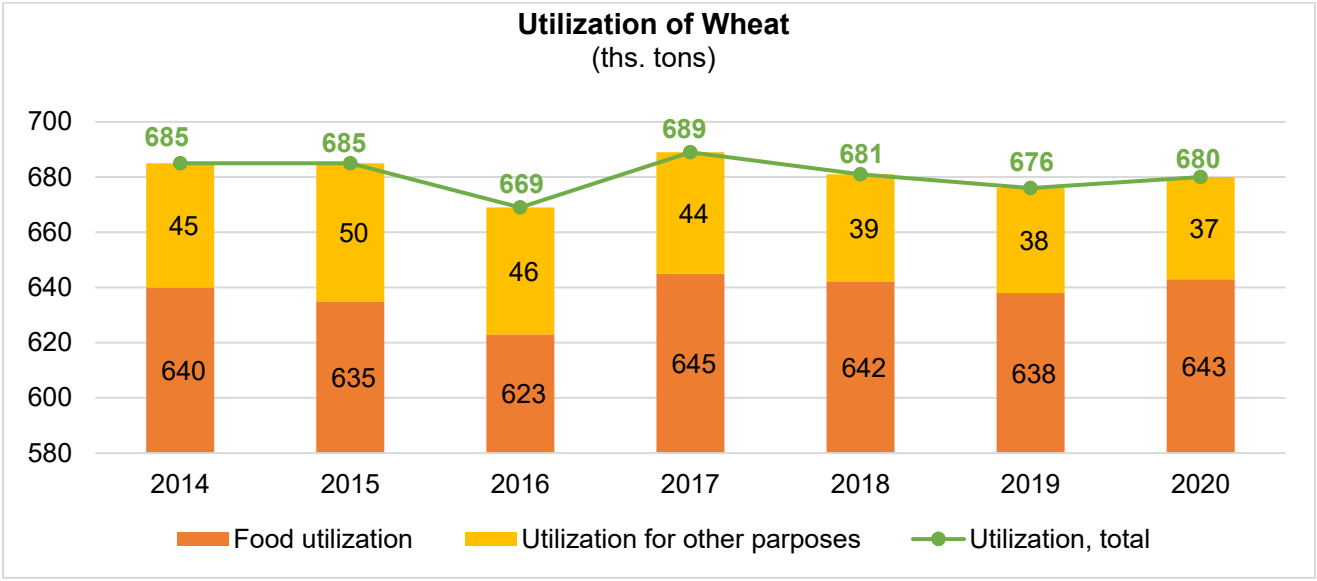


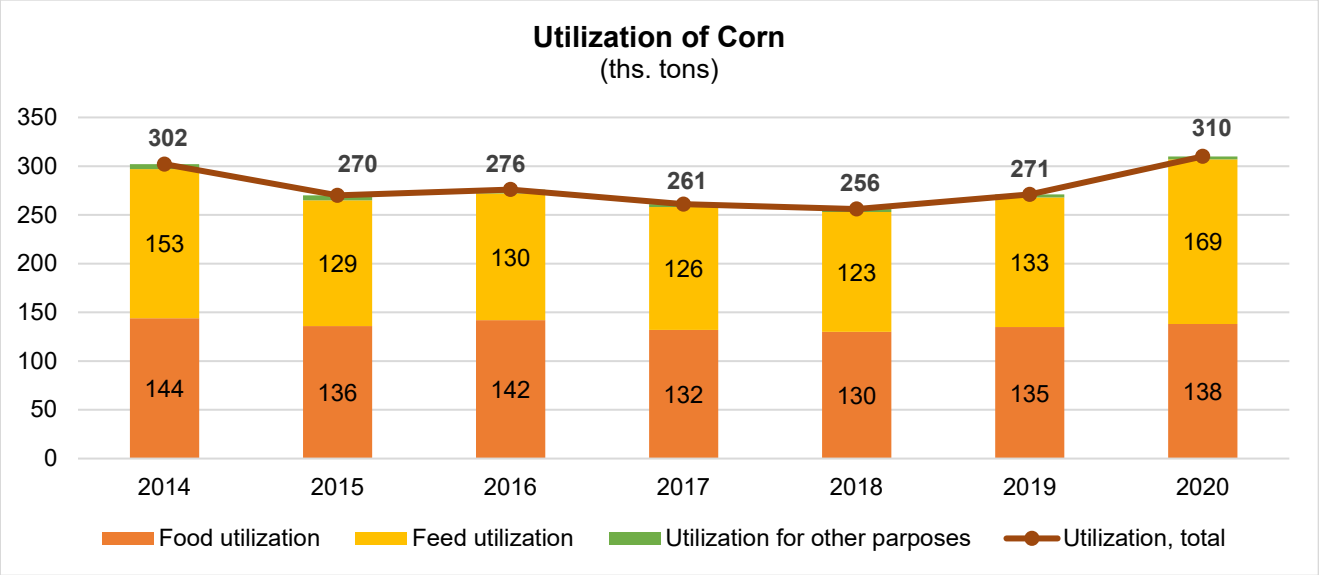
Figure2.



Source: Geostat

The X axis represents the years, while the Y axis represents the amount of wheat consumed in thousand tons.

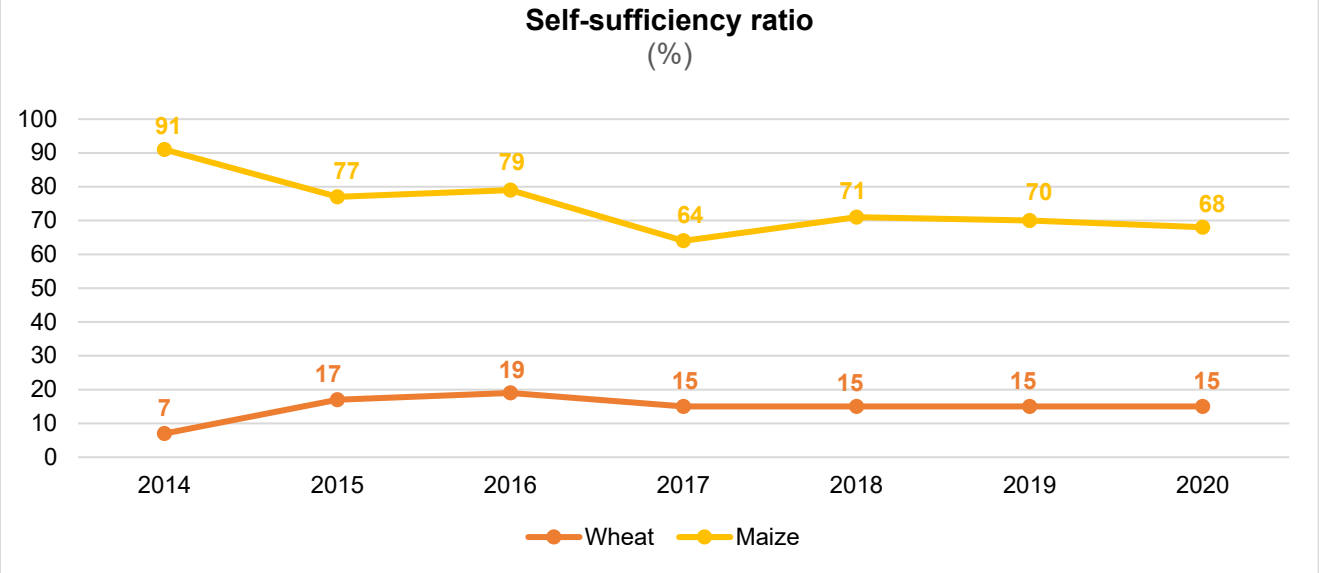
Figure3.



Source: Geostat

The X axis represents years, and the Y axis the amount of corn consumed in thousands of tons.

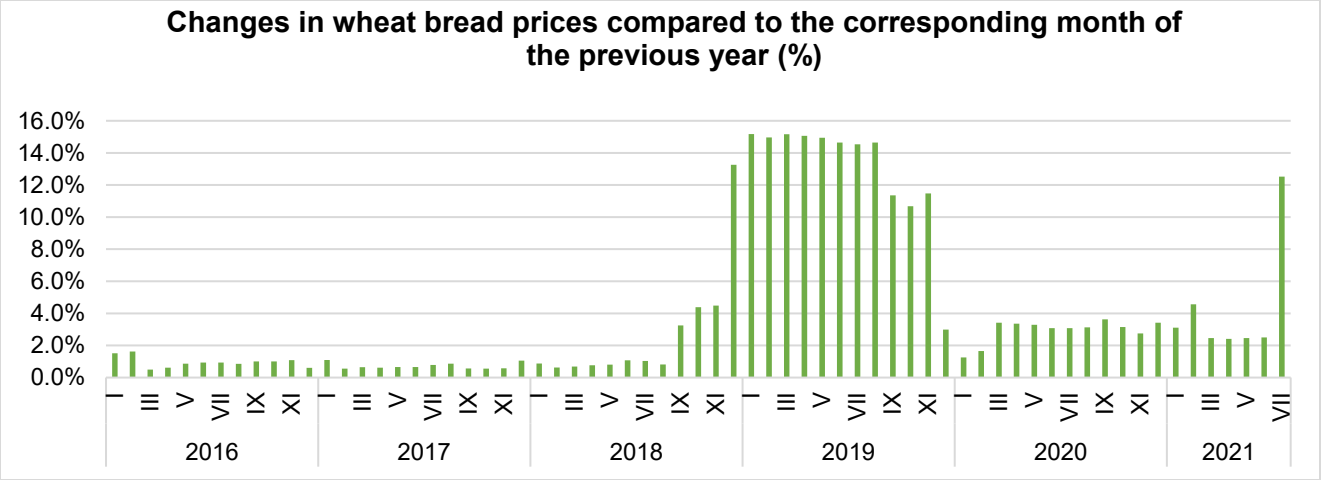
Figure4.



Source: Geostat

The X axis represents years, and the Y axis is the percentage Self-sufficiency ratio.

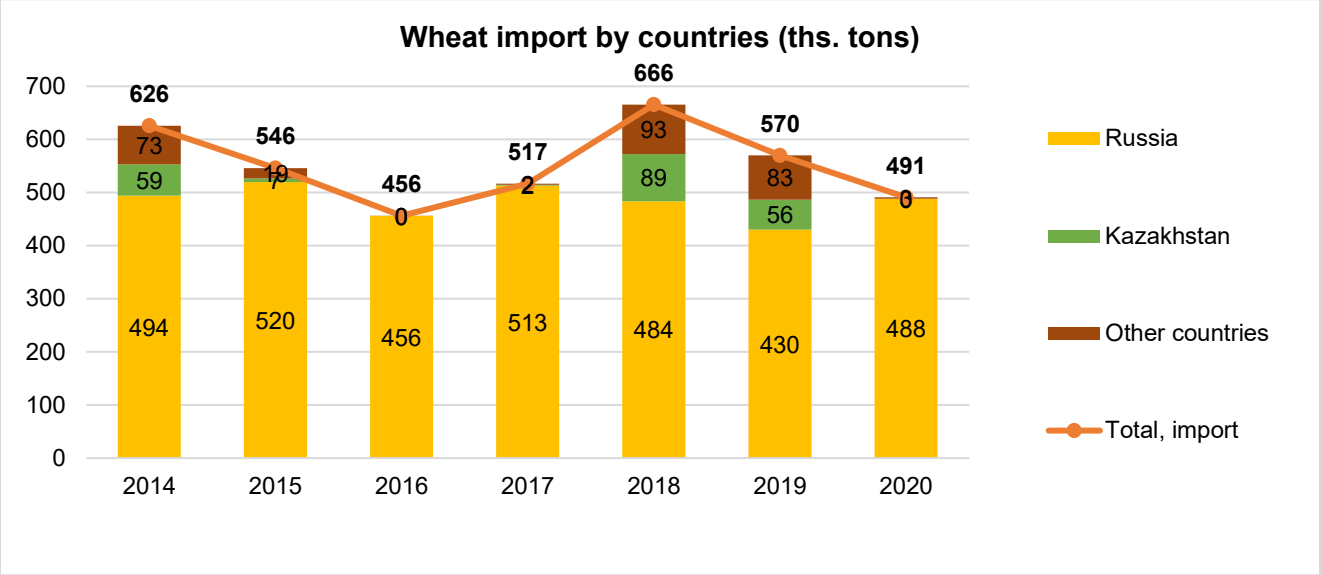
Figure5.



Source: Geostat

X axis represents the time period by years and months, and the Y axis shows the percentage of changes in wheat bread prices compared to the corresponding month of the previous year.

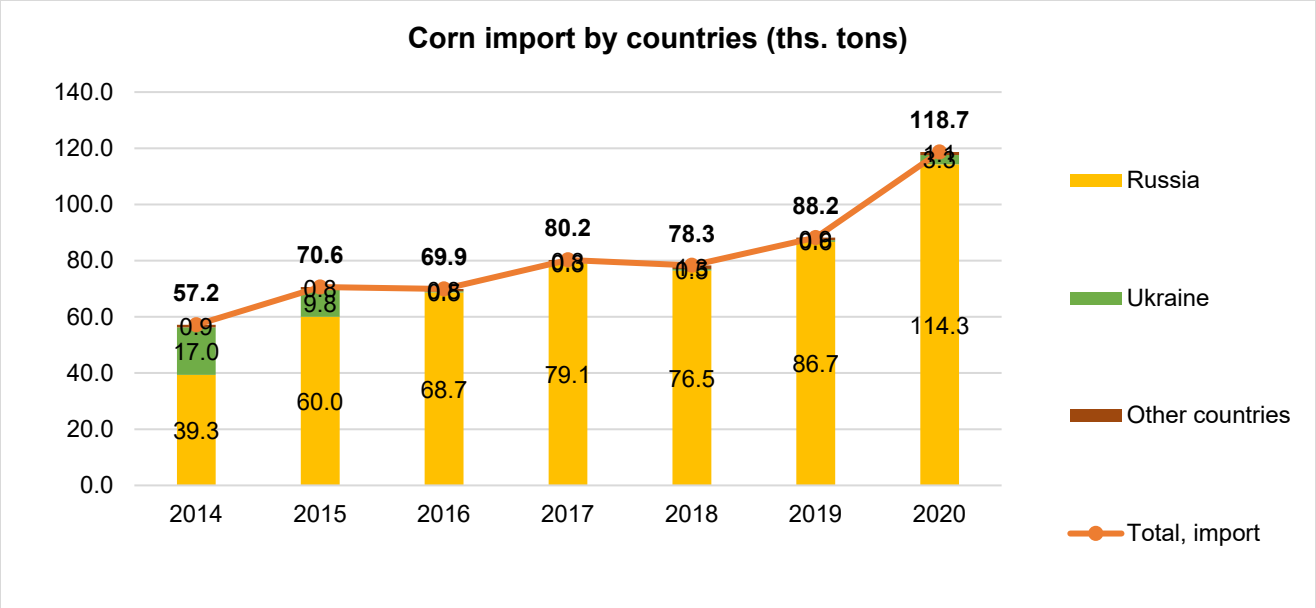
Figure6.



Source: Geostat

The X axis of the given Figure shows the years, while the number of wheat imports in the Y axis is represented in thousand tons.

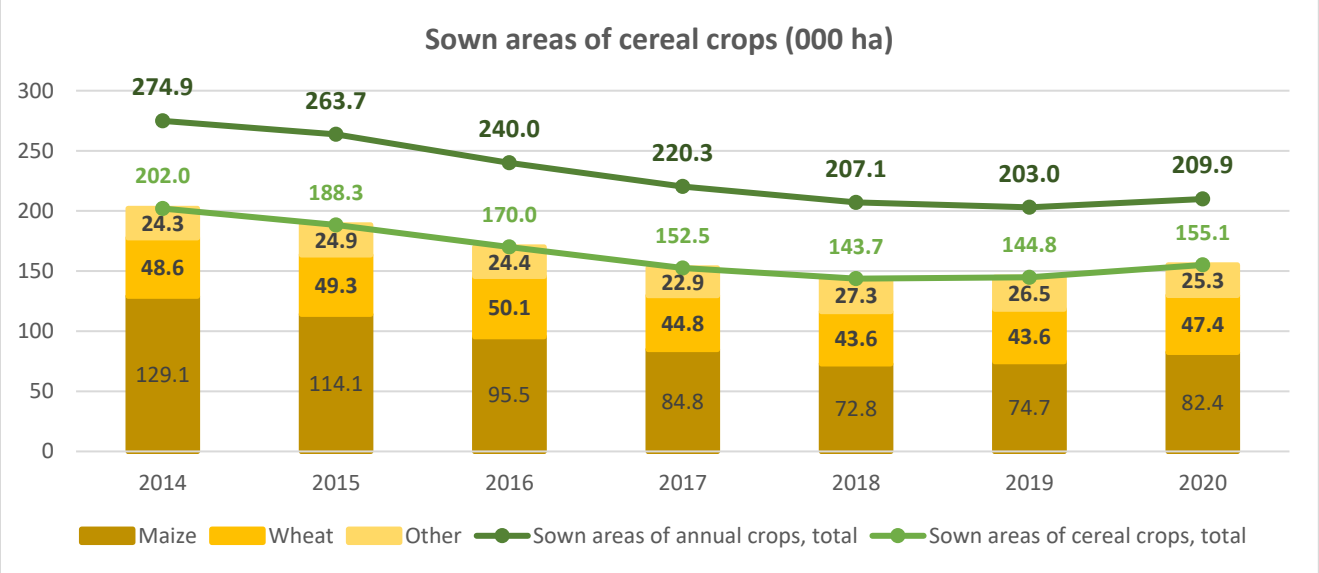
Figure7.



Source: Geostat

The X axis represents years, and the Y axis the amount imported corn in thousand tons.

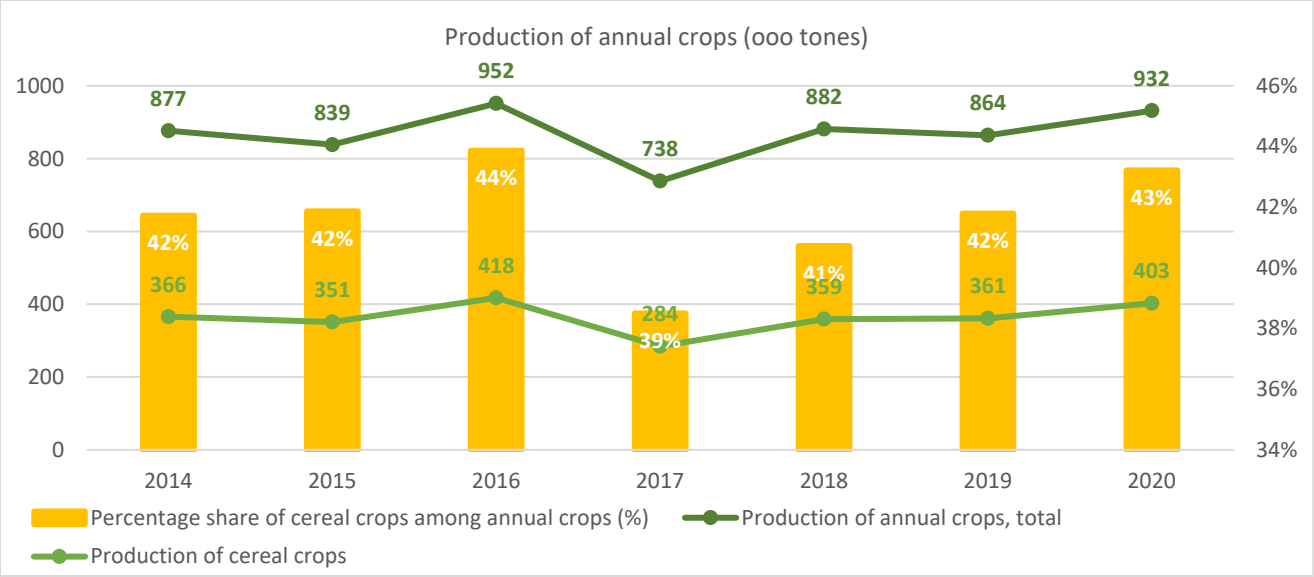
Figure8.



Source: Geostat

The X axis represents years, and the Y axis is the Sown areas of cereal crops in thousand hectares.

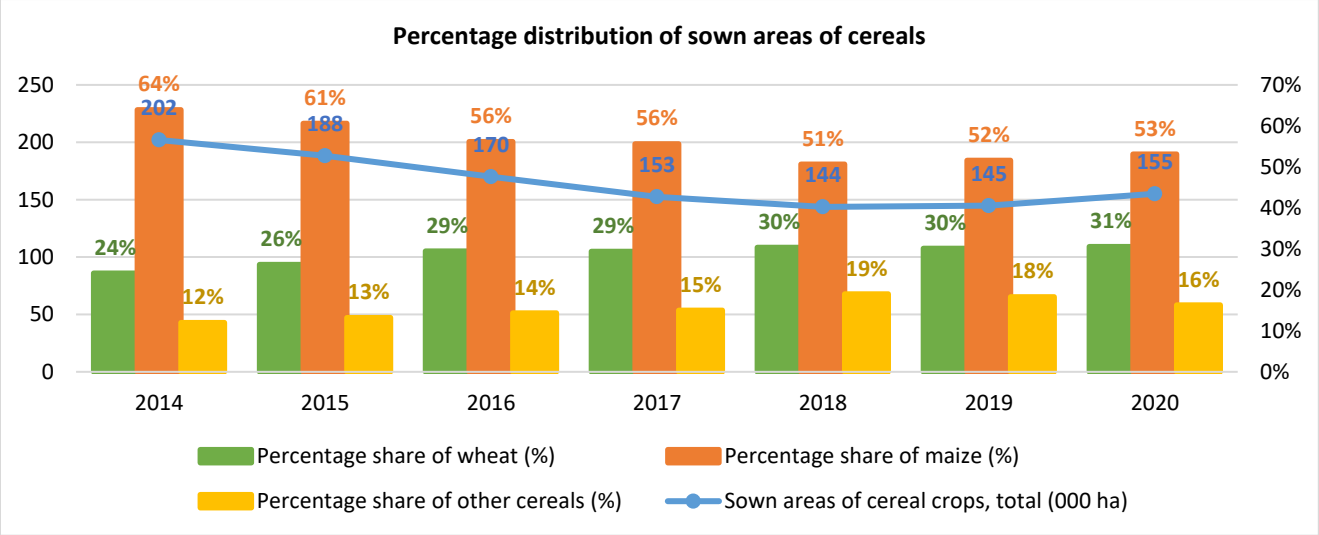
Figure9.



Source: Geostat

The X axis represents years, and the Y axis is the production of annual crops in thousand tones and secondary Y axis is percentage share of cereal crops among annual crops.

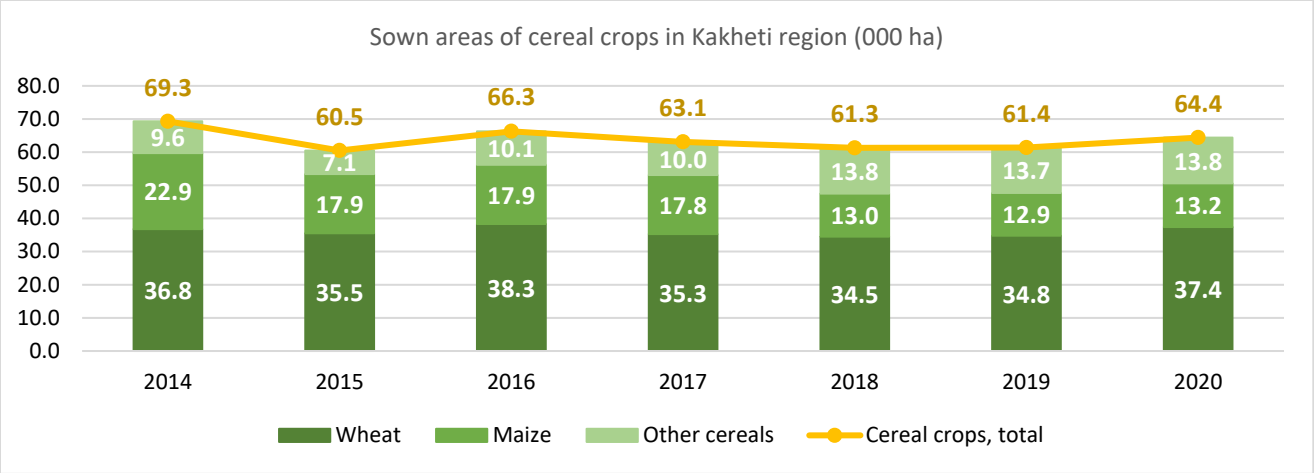
Figure10.



Source: Geostat

The X axis represents years, and the Y axis is the sown areas of cereal crops in thousand hectares and secondary Y axis is percentage share of wheat, maize and other cereals of total cereals.

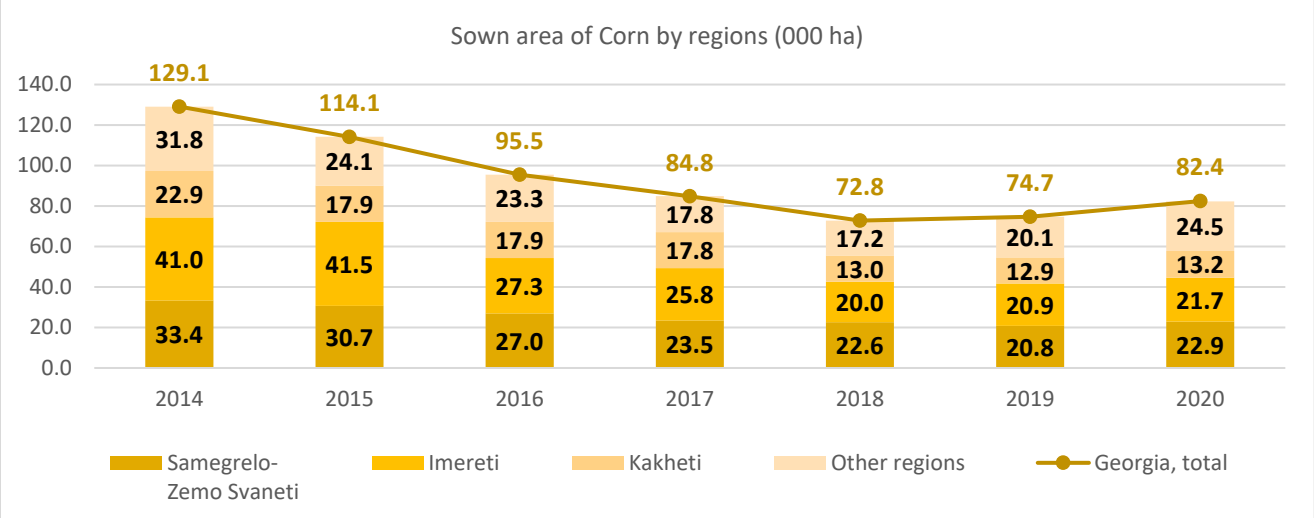
Figure11.



Source: Geostat

The X axis represents years, and the Y axis is the sown areas of cereal crops in thousand hectares.

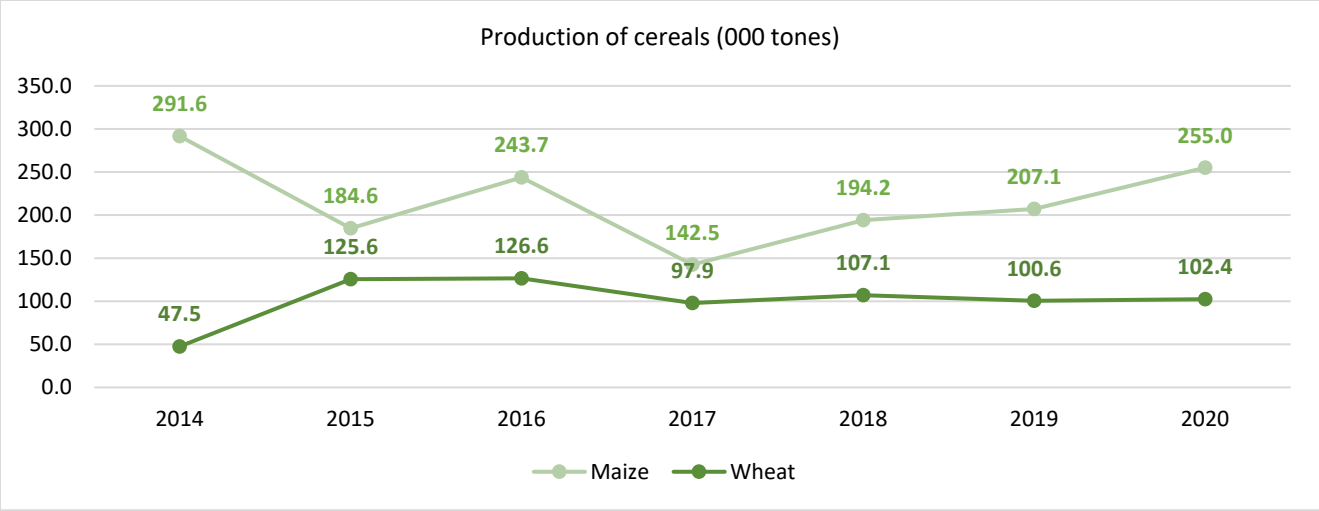
Figure12.



Source: Geostat

The X axis represents years, and the Y axis is the sown areas of cereal crops in thousand hectares.

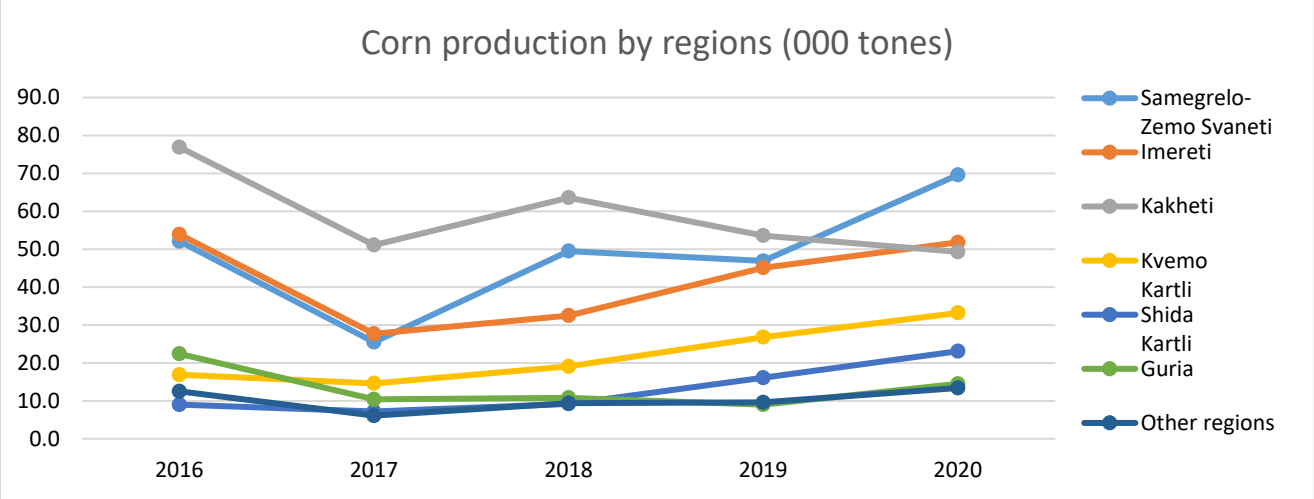
Figure13.



Source: Geostat

The X represents years, and the amount of grains produced in Y axis is expressed in thousand tons.

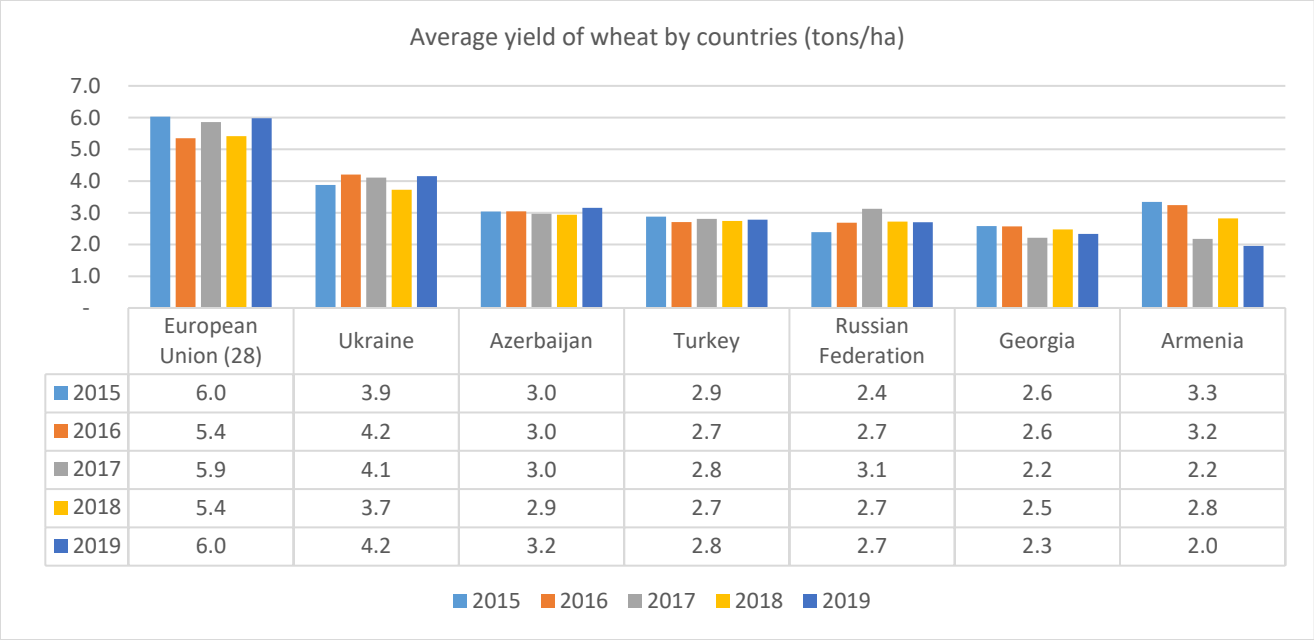
Figure14.



Source: Geostat

The X axis represents years, and the Y axis the production of corn in thousand tons.

Figure15.

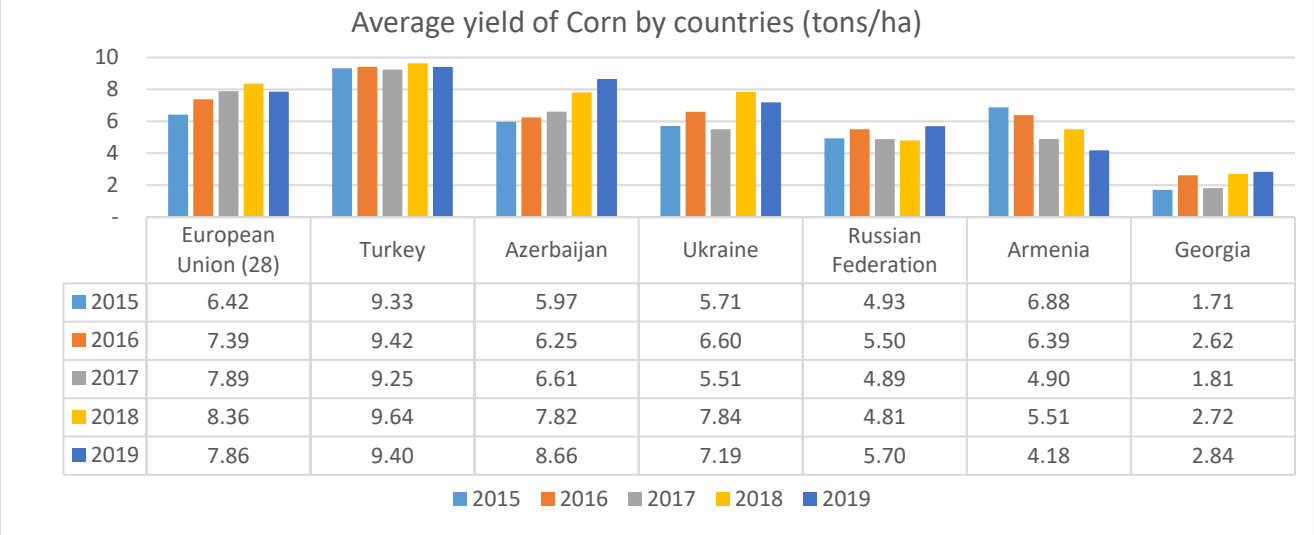


	European Union (28)	Ukraine	Azerbaijan	Turkey	Russian Federation	Georgia	Armenia
2015	6.0	3.9	3.0	2.9	2.4	2.6	3.3
2016	5.4	4.2	3.0	2.7	2.7	2.6	3.2
2017	5.9	4.1	3.0	2.8	3.1	2.2	2.2
2018	5.4	3.7	2.9	2.7	2.7	2.5	2.8
2019	6.0	4.2	3.2	2.8	2.7	2.3	2.0

Source: FAOSTAT

The X axis represents country (country group), and the Y axis the average yield of wheat in tons/ha.

Figure16.

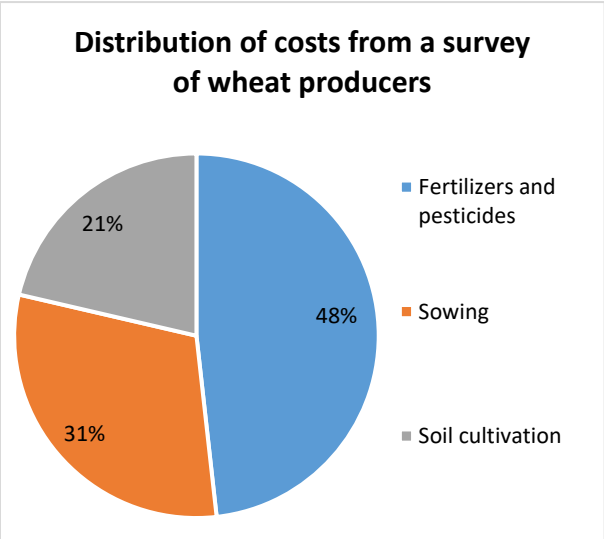


	European Union (28)	Turkey	Azerbaijan	Ukraine	Russian Federation	Armenia	Georgia
2015	6.42	9.33	5.97	5.71	4.93	6.88	1.71
2016	7.39	9.42	6.25	6.60	5.50	6.39	2.62
2017	7.89	9.25	6.61	5.51	4.89	4.90	1.81
2018	8.36	9.64	7.82	7.84	4.81	5.51	2.72
2019	7.86	9.40	8.66	7.19	5.70	4.18	2.84

Source: FAOSTAT

The X axis represents country (countries union), and the Y axis the average yield of corn in tons/ha.

Figure17.



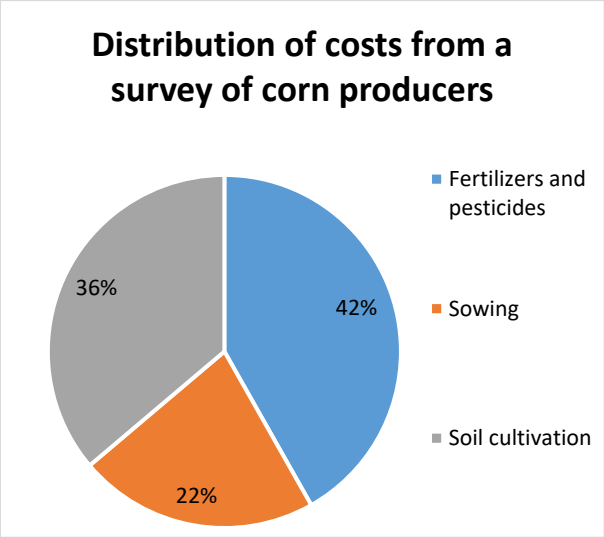
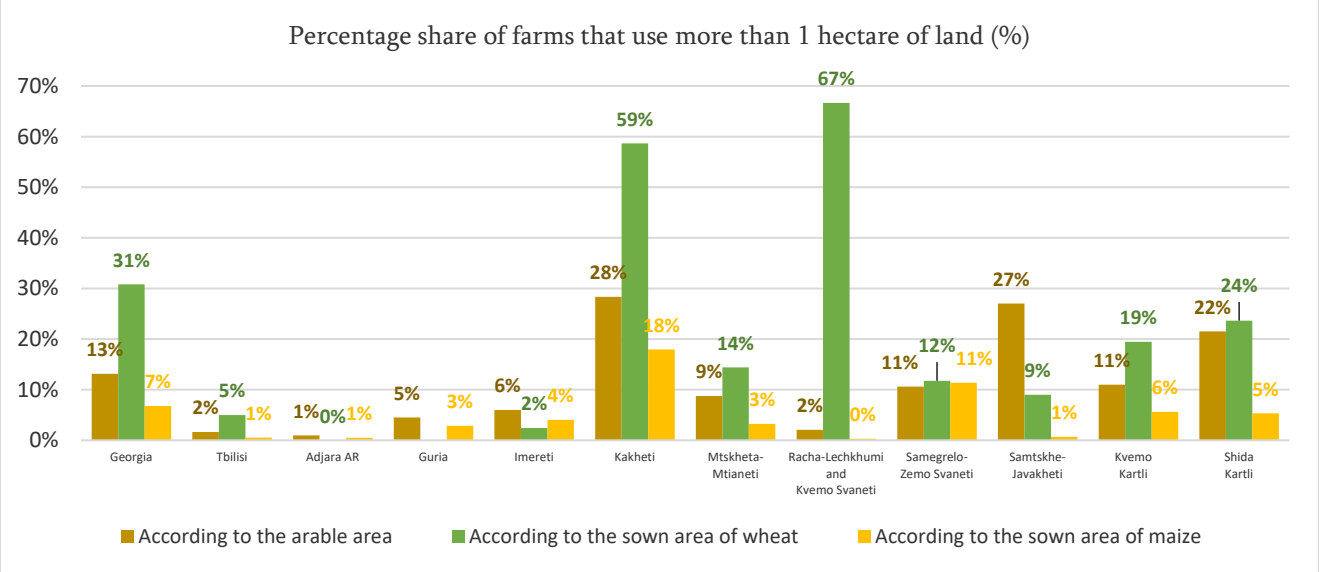


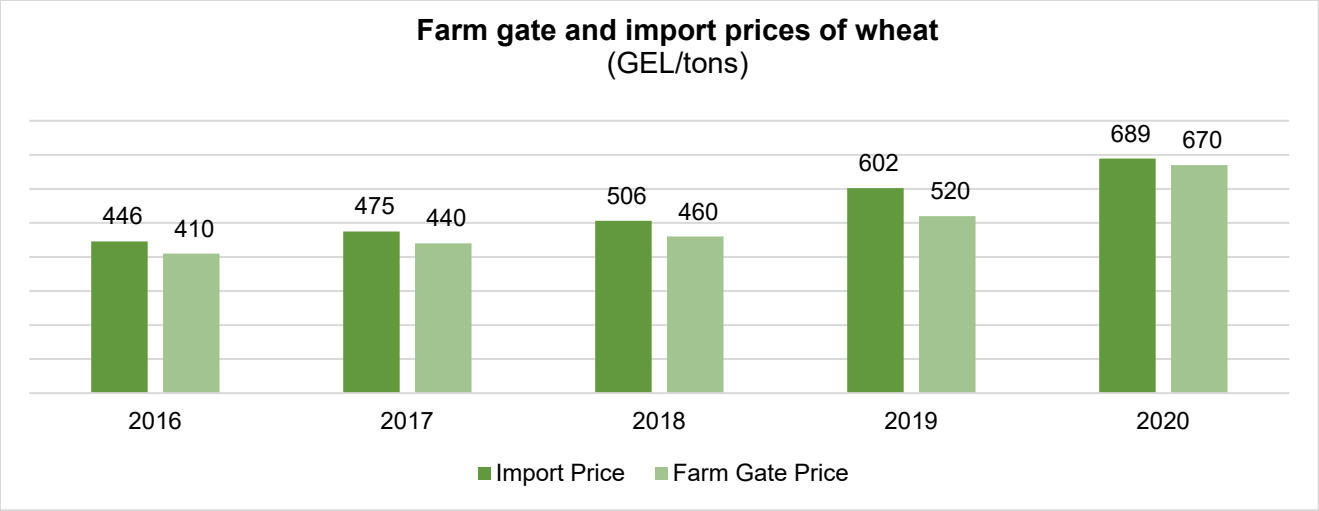
Figure18.



Note: According to the 2014 census data

The X axis represents regions, while farms that use more than 1 hectare of land are represented in the Y axis in percentage.

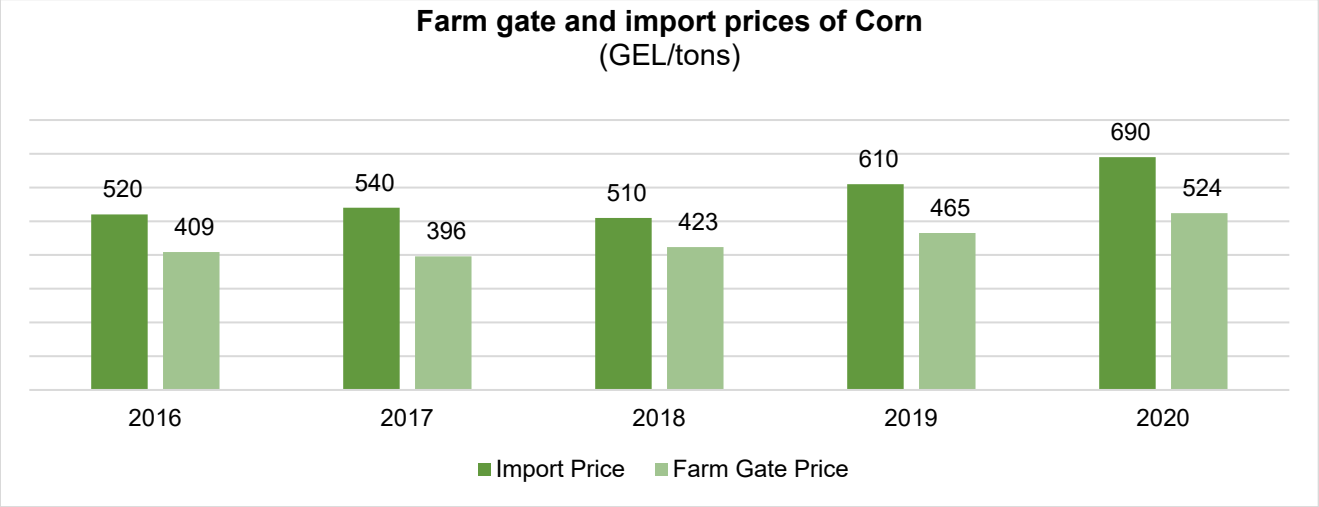
Figure19.



Source: Geostat

The X axis represents years, and the Y axis is wheat import price and farm gate price in GEL.

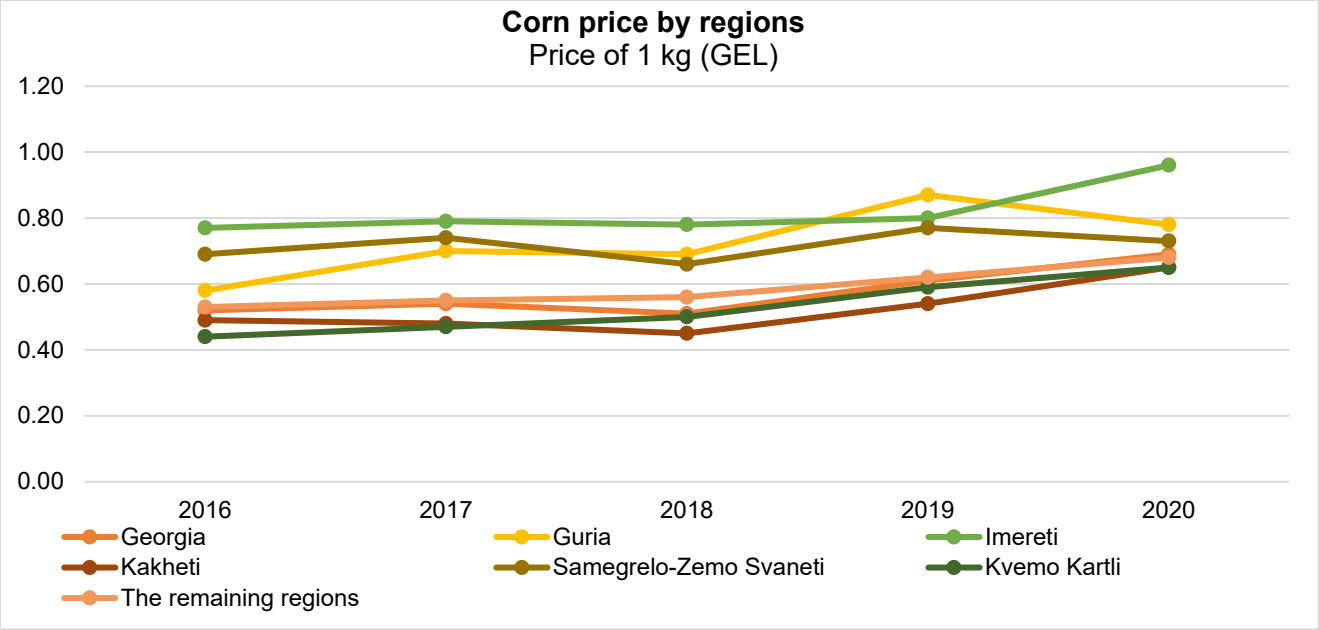
Figure20.



Source: Geostat

The X axis represents years, and the Y axis is the one tons corn price of import and farm gate price in GEL.

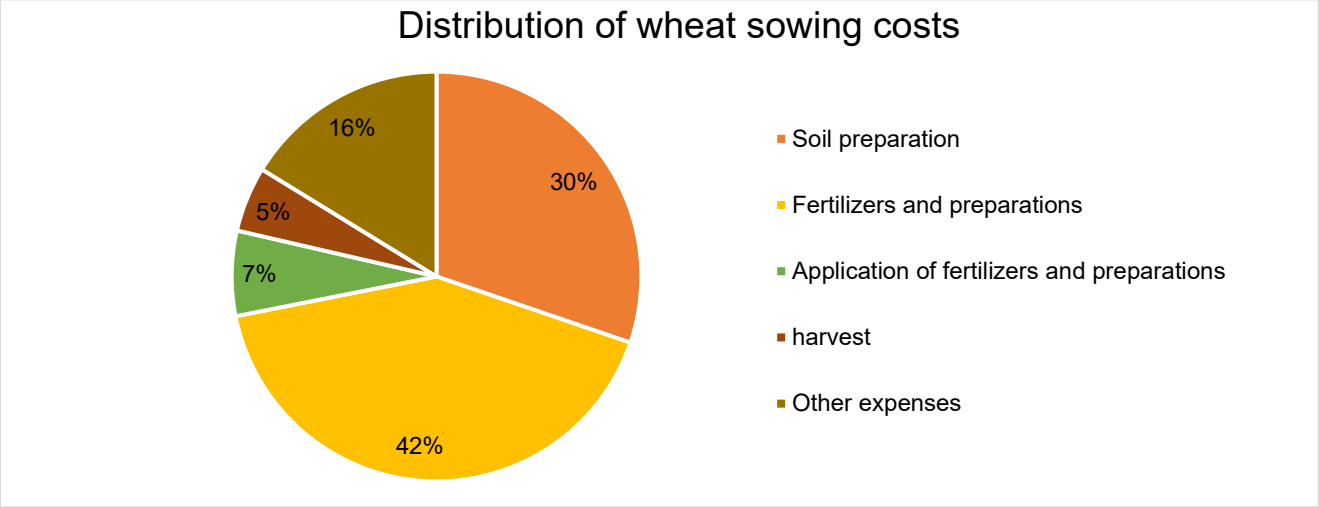
Figure21.



Source: Geostat

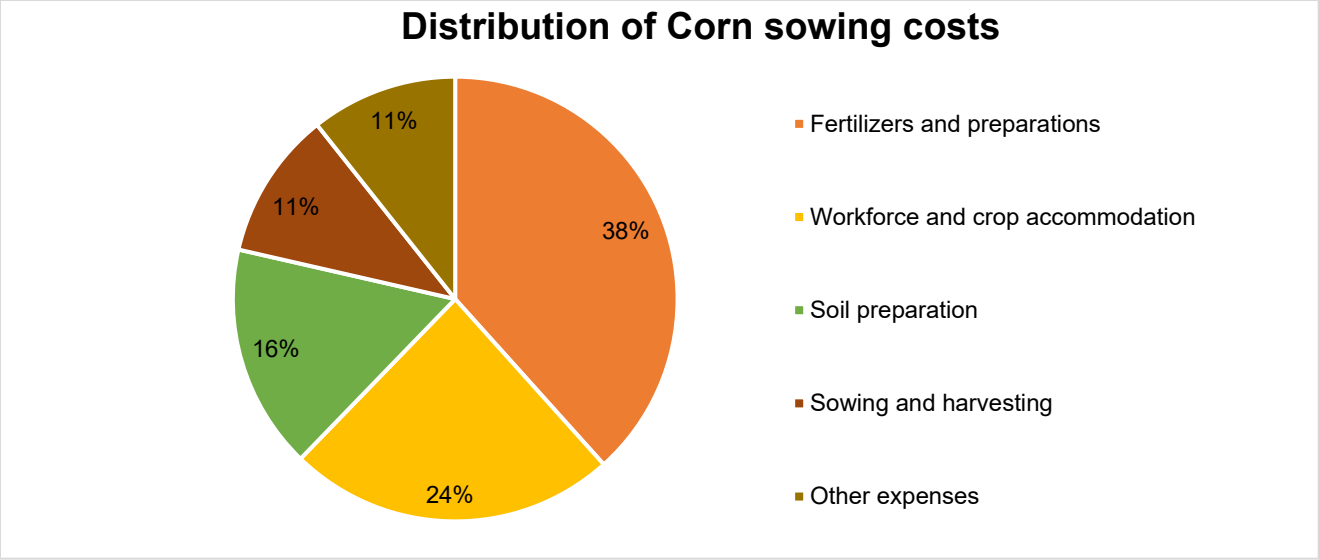
The X axis represents years, and the Y axis the price of one kg of corn in GEL.

Figure22.



Source: scientific-research center of agriculture

Figure23.



Source: Georgian Farmers' Association

Table 1.

Holdings with arable land and Distribution of farms by sown area (ths. ha)

	total	<0.1	0.1-0.49	0.5-0.99	1-2.99	3-4.99	5-9.99	10-49.99	50-99.99	≥100
Holdings with arable land	535 194	120 253	226 016	118 627	60 414	4 899	2 597	1 907	284	197
Holdings with wheat sown area	25 964	1 143	10 629	6 190	6 081	738	462	583	90	48
Holdings with Corn for grain sown area	284 085	47 368	155 508	61 898	17 866	701	413	288	29	14

Table 2.

Holdings with arable land and Distribution of farms by sown area (%)

	Total (ha)	<0.1	0.1-0.49	0.5-0.99	1-2.99	3-4.99	5-9.99	10-49.99	50-99.99	≥100
Holdings with arable land	100%	22%	42%	22%	11%	1%	0%	0%	0%	0%
Holdings with wheat sown area	100%	4%	41%	24%	23%	3%	2%	2%	0%	0%
Holdings with Corn for grain sown area	100%	17%	55%	22%	6%	0%	0%	0%	0%	0%

Table 3.

	Holdings with land cultivation equipment	Holdings with working land cultivation equipment	Holdings with trucks	Holdings with working trucks

Number of agricultural holdings with land cultivation equipment and trucks in property (units)	5 921	5 202	13 765	12 159
	Tractors	**Hand tractors**	**Land cultivation equipment**	**Trucks**
Number of agricultural holdings which utilized agricultural machinery and equipment in their holdings during the reference year (units)	268 788	73 853	218 593	144 758

Source: 2014 Agriculture Census of Georgia

X. Annexes

Annex 1: Questionnaire

Personal Information
Name:
last name:
Tel:
Region:
Municipality:

Information about the farm

Cereal crop: _____

Arable land area, total _____ (ha):
Hence, sown grain area _____ (ha):
Number of sown fields (plots): _____ (units)

Information about the land Plot

(In the case of several plots, data is filled in for the largest plot)
Plot area _____ (ha):
Distance between rows of sowing unit (in case of corn) _____ (cm):
When did the sowing of the field end (date): day / month / year ____ / _____ / _____
When harvesting ended (date): day / month / year ____ / _____ / _____
Yield obtained, total _____ (tons):

Soil cultivation

List of land cultivation works	**Multiplicity of work performed**	**Periods of works performed**		**by hand / technique** (Hand - 1, equipment - 2)	**Cost of equipment service Per 1 hectare (GEL)**
		Start	finish		
Plowing		__/__/__	__/__/__		
Cultivation					
Soil Compaction					
Other 1					

Other 2					
Other 3					
Other 4					

Sowing

Sowing period	Seed material used				Quantity of seed material used Per 1 hectare (kg)	Cost of seed material (GEL)	Wheat irrigation periods	Cost of sowing equipment service Per 1 hectare (GEL)
	Local variety	*Foreign variety*	*Own production*	*Bought or gifted*				

Soil fertilization

Name of fertilizers used	Frequency of work performed	Fertilizer application periods	Number of fertilizers applied per 1 ha (kg / liter) Indicate the unit	By hand/ machinery	Cost of applying fertilizer by machinery Per 1 hectare (GEL)	The cost of fertilizer per 1 hectare (GEL)

Plant Protection

General name of the plant protection means (herbicide, fungicide or insecticide)	Purpose (Name of disease and pest, weed, etc.)	Frequency of application	by hand / machinery	The cost of applying plant protection means per 1 ha (GEL)	Cost of plant protection means per 1 ha (GEL)

6. Do you do seed rotation? 0 Yes (go to question 7) 0 No

7. What crops do you use for seed rotation?

Annex 2

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.48
R Square	0.23
Adjusted R Square	0.23
Standard Error	2.14
Observations	316

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	439.0	146.3	31.83337	5.59E-18
Residual	312	1434.3	4.6		
Total	315	1873.3			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.05	0.20	5.20	0.00	0.65	1.45	0.65	1.45
Area harvested	0.01	0.02	0.52	0.60	-0.02	0.04	-0.02	0.04
Number of plots	0.32	0.04	8.04	0.00	0.24	0.40	0.24	0.40
Existence of irrigation infrastructure	0.73	0.29	2.52	0.01	0.16	1.31	0.16	1.31

Annex 3

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.57
R Square	0.32
Adjusted R Square	0.30
Standard Error	1.25
Observations	162

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	5	116.18	23.24	14.82	0.00
Residual	156	244.61	1.57		

Total	161	360.79						

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.77	0.32	2.38	0.02	0.13	1.41	0.13	1.41
Number of Plots	0.31	0.10	2.93	0.00	0.10	0.51	0.10	0.51
Corn harvester	2.05	0.52	3.92	0.00	1.02	3.08	1.02	3.08
SumOfSale	0.01	0.00	3.64	0.00	0.01	0.02	0.01	0.02
Corn harvested area	-0.04	0.02	-2.72	0.01	-0.07	-0.01	-0.07	-0.01
Imereti and Samegrelo regions	-0.58	0.22	-2.69	0.01	-1.00	-0.15	-1.00	-0.15

Annex 4

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.2688
R Square	0.0722
Adjusted R Squ	0.068
Standard Error	1096.6
Observations	663

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	61700697	20566899	17.102	0.000
Residual	659	792494343	1202571		
Total	662	854195040			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1592.30	203.19	7.84	0.000	1193.32	1991.29	1193.32	1991.29
SaleValue	0.00	0.00	5.53	0.000	0.00	0.01	0.00	0.01
MachUse	323.01	198.48	1.63	0.104	-66.71	712.73	-66.71	712.73
Irrigation	330.44	92.82	3.56	0.000	148.18	512.71	148.18	512.71

Annex 5

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.11298
R Square	0.01277
Adjusted R Square	0.01127
Standard Error	1129.5
Observations	663

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	10904190	10904190	8.54707	0.003579149
Residual	661	843290850	1275780		
Total	662	854195040			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	2139.91	50.51	42.37	0.0000	2040.74	2239.08	2040.74	2239.08
MoneyAmtha	0.52	0.18	2.92	0.0036	0.17	0.87	0.17	0.87