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MODELS FOR AGRICULTURAL PRODUCTION OPTIMIZATION

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Abstract

The paper aims to present models of agricultural production optimization as tools for managers to increase yield, crop structure, crop rotation, increased efficiency and profitability. The two optimization models are: Case 1: Optimization of yield depending on wheat price and subsidy for increasing net return and profitability in wheat culture; Case 2: Optimal model for optimizing crop rotation in cereal culture with maximum income, having two solutions: (a) Basic optimal primal solution and (b) Basic optimal dual solution. The methodology included the calculations regarding the specific indicators reflecting the economic efficiency in wheat cropping for Case 1 and determination of the optimal primal and dual solutions assisted by SOLVER application from MS Excel for Case 2. The two examples come from vegetal farming but, other models of optimization could be developed in animal production for improving livestock structure by species and category and also in animal feeding setting up optimized feed ratios to sustain production.

Key words*: *optimization models, agriculture production, management

INTRODUCTION

Agriculture is a complex field of activity where farmers are focused every year on what kind of crops to cultivate on their land and what surface to allot to each plant. The decisions are always linked to economic efficiency of each cultivate hectare, more exactly on net returns level.

To make the best decision, farmers set up various alternatives taking into consideration soil type, climate conditions, crop type and its varieties, seed quality, crop rotation, fertilization, plant protection, and other factors, and all these factors quantified in costs have to be covered by the estimated delivery price at the harvest moment [40].

But price is uncertain, because it depends on market factors and offer/demand ratio, which is influenced in its turn by climate variation during the crop development with a deep impact on harvest level [36].

Therefore, the combination of crops should provide the maximum net return per surface unit, but this means to keep under control income variability which has to be minimized. From this point of view, farmers have to decide to cultivate the crops with higher expected net return in terms of risk and probability of achieving the highest level of net return.

During the last decades, climate change raised huge problems to farmers, and almost all the crops could be considered high risk crops which require that farmers to make calculations of the total expenses, total revenue and return over total expenses [40].

For modeling the farms, Hazell and Norton (1986) sustained that there are various techniques among which the most important ones are "choice of production methods, factor substitution, input/output response relations, quality differences in resources, production seasonality, buying and selling alternatives, crop rotation, joint products and intercropping, intermediate products, investment in farm activity, linear programming methods". But, in farm modeling it is compulsory to take into consideration risk factors, otherwise the farm planning decisions could be wrong, affecting the profitability and investment capacity of the farm in the long term.

Quantitative methods assisted by computing and modeling the data play a crucial role in agricultural economics. They are important tools for farmers and managers of agricultural holdings and also for policy makers and analysts in order to offer the best solutions for the large variety of problems that agriculture has [6, 12].

For predicting wheat growth and development, crop models are important tools belonging to intelligent agricultural production.

Designing a crop model is difficult task as it involves to set up equations and parameters, which require to establish the model structure and then to optimize the parameters according to the local conditions in term of climate, soil and management measures so that the simulated yield to be close to the actual local yield and the applicability of the model to be the best.

Besides maize and rice, wheat is one of the three major crops cultivated in the world. Wheat production accounted for over 781 million metric tons in 2022/2023, which is by 31.92% higher than in the year 1990-1991. The largest producers are China, the EU, India and Russia [41].

Various researchers were and are focused in wheat production optimization in order to produce more and of higher quality seeds with lower costs and high economic efficiency.

Wheat productivity is influenced by soil type and its fertility, climate conditions, seed quality, amount and type of fertilizers applied, applied agricultural system, crop maintaining from sowing to harvesting etc., aspects which have been studied by many researchers.

The importance of wheat for meeting the growth of the world population's demand, yield should be enhanced under the condition of assuring resource use efficiency by optimizing water and Nitrogen management which could contribute to a sustainable and regenerative farming as shown in China by Li et al (2022) [21].

To plan crop management in wheat farming under the climate change is a critical issue, which could affect food security. For avoiding this situation, the contribution of climate change and crop management have to be assessed and corresponding technological measures have to be taken to reach the expected wheat yield. This was proved by Liu et al. in China in 2020, who quantified the contribution of climate change and crop management on wheat yield between 1981 and 2018, using first-difference multivariate regression model [22].

In the areas where wheat is mainly cultivated, it is wise as farmers to avoid monoculture which could affect the future crops which will be cultivated in the next years and also it is compulsory to take into account climate change as mentioned by Burt and Johnson (1967) [5].

In order to avoid the negative effect of climate change, Belaqziz et al. (2021), optimized the sowing date to improve water management and wheat yield in a large irrigation scheme in the semi-arid region of Haouz (Morocco), through a Remote Sensing and an Evolution Strategy-Based Approach [1].

For the analysis and simulation of agricultural production plans, as well as for the study of impacts of the various policies in agriculture, in Greece, Manos ET AL, 2013, set up a mathematical programming model which maximized gross margin and minimized fertilizers and water used, under a set of constraints for land, labour, available capital, common agricultural policy in Thessaly region [26].

In Brazil, Osaki and Batalha (2014) established a model, based on operation research, for production planning in multiproduct farms under risk conditions in order to understand the different productive resource allocations in farms engaged in grain production. The adopted production system in Sorriso region helped the farmers to obtain good financial returns with lower risks [28].

These models usually combine the production of different products with different soil management and agricultural practices, efficiently allocating resources and minimizing costs.

In Egypt, Kheir et al. (2018) used AQUACROP and APSIM-Wheat models in North Nile Delta where succeeded to optimize wheat yield, total biomass and water productivity under irrigated conditions [19].

Also, in Egypt, a multi-model analysis was applied by Kheir et al. (2022) in order to minimize trade-offs wheat yield and resource-use efficiency in the Nile Delta [20].

Wheat is largely cultivated in Romania, a country which has good soil and climate conditions for this crop in different regions, but especially in the South, South East, South West Oltenia and West parts. Romania is among the top producing, exporting and importing countries for wheat in the EU [32, 33, 34].

Many researchers have contributed to solve problems in wheat farming to increase yield, seed quality and economic efficiency.

Varieties are of high importance in assuring wheat yield potential [27].

Monoculture is not recommended because it leads to a low yield performance and affects soil fertility and the production of the future crops. In combination with a 4 year crop rotation, monoculture could be practiced maximum 2-3 years [3, 4].

Nitrogen fertilizer is beneficial for increasing wheat yield [39].

Climate change has had a negative impact on agriculture performance and deeply affected maize, wheat, sunflower and other crops during the last decade in Romania [35, 37, 38].

Farmers have been obliged to adapt the applied technologies to diminish the impact of climate change and reach the desired yields [2, 17, 18, 24, 25].

Other researchers were focused on the effect of conservation agriculture versus conventional system, fertilization level and plant protection measures on wheat yield [9, 10, 11].

Macra and Sala (2021) studied the variation of some wheat quality indices in order to optimize the mineral fertilization with nitrogen and with the Super Fifty foliar biostimulator [23].

Economic efficiency in agricultural production in terms of gross margin was approached per ha and per animal by [30, 31].

Optimization of crop structure has been done using linear simulation model for maximizing income [13].

Farmers training level is very important for having the corresponding managerial knowledge and skills to make use of modern tools provided by artificial intelligence for developing a sustainable agriculture [14, 15, 16].

In this context, the paper aimed to sustain agricultural production by developing an optimization model in vegetal farming regarding the farmer's decision for selecting the best alternative to: (a) cultivate wheat depending of its production potential, costs, income and net return, price and subsidy; (b) to optimize crop rotation with maximum income in cereals production, with (a) Basic optimal primal solution and (b) Basic optimal dual solution, whose determination was assisted by SOLVER application from MS Excel.

MATERIALS AND METHODS

The paper is based on two case studies regarding optimization of agricultural production in different alternatives.

Case study 1, Optimization of wheat yield for increasing profitability per surface unit and per product unit, in the agricultural year 2022/2023, in a farm situated in the plain region of South Oltenia, Romania. The soil is of high quality chernozem, the agricultural system is a conventional one, with non-irrigated land. The cultivated area with wheat is 50 ha, and the variety used by the farmer is Glosa, well known for high productive potential and resistance to high temperatures and drought.

The economic indicators calculated in this case study have been:

Production value, PV, which was determined by multiplying the physical yield, Q, by the average market price at delivery, p, as follows:

PV = Q x p...(1)

Gross product, GP, is the sum between yield value, PV and subsidy per ha (S), as shown in the formula:

$GP = PV + S$..(2)

Production costs, PC, which were calculated by summing the variable costs, VC, (seeds, fertilizers, herbicide) and fixed costs, FC, according to the formula:

$PC = VC + FC$..(3)

Profit, P, per surface unit which is the difference between PV and PC, according to the formula:

$P_S = PV - PC$ ....(4)

Profit per 1 kg wheat seeds is determined by dividing profit P by wheat yield, Q, according to the formula:

$P_p = P_s / Q$...(5)

Profit rate, P_r is the percentage value resulting from dividing net profit, Pn, by Gross product, GP, as shown below:

$P_r = Pn / GP \times 100$..................................(6)

Profit rate with subsidies, P_{rs} is the percentage value resulting from dividing net profit, Pn plus subsidies, S, by production costs, PC, as shown below:

$P_{rs} = (Pn + S) / PC \times 100$ ....(7).

Case study 2, Linear model for the optimization of crop rotation in cereals production characterized by:
- The unknown x_i are the surfaces which are going to be cultivated after predecessor plants;
- The restrictions regard: bilateral restrictions for successor plants; the cultivation of the whole surface with successor crops; surfaces with predecessor crops occupied by them.
-The economic functions are: Income, Expenses, Profit, Profit rate, Marginal profit rate.

The problem data and analysis is made according to the methodology established by Ene (2011) [7] and Ene and Ionitescu (2006) [8].
Based on the primary data of the problem in cereals culture, it set up the model of cereals rotation with limited expenses and maximum income for wheat, maize and soybean as predecessors and as successors: maize and sugar beet after Wheat, wheat and sugar beet after Maize and wheat, maize and sugar beet after Soybean.
Then, there are determined the optimal solutions with maxim income for cereals: (a) Basic optimal primal solution an (b) Basic optimal dual solution.
The model was solved using **SOLVER** application from **MS Excel** as described in the paper.

RESULTS AND DISCUSSIONS

CASE STUDY 1

Economic Model for assessing crop profitability for Winter wheat, Glosa variety

the farm is situates in a plain area, in South Oltenia, Dabuleni Locality, Dolj County, Romania.
The soil type of the farm is chernozem, and the applied agricultural system is a conventional one, with non irrigated land, the data regard the agricultural year 2022/2023.
The calculations are made for 1 ha and also for the whole cultivated surface with wheat, accounting for 50 ha.

Gross Product

The farmer prefers to cultivate Glosa variety which is a winter cultivar, resistant to drought, being recommended to be used in the South Romania, where it could successfully replace Dropia and Fundulea 4 and other varieties both under an irrigated or non - irrigated land.
In the agricultural year 2022/2023, wheat yield accounted for 6,500 kg/ha, which is considered a satisfactory production by the farmer, because in the South Oltenia the weather was not favourable for agriculture, due to the lack of precipitations, high temperatures and drought. In the fall 2022, it was noticed a lack of water and the sowing

was enough difficult. Winter was a real mild season, on January 1st, 2023 the temperature reaching 20^0C, and in the first part of March decreased to 5-7^0C and then it raised to 15-17^0C. Weak rainfalls were noticed at the end of March, and then a total lack of precipitations till harvesting.

Taking into account that the farmer will get Lei 1,100 subsidy per ha and the estimated average market price at harvest is Lei 1.1/kg, the value of wheat yield is Lei 7,150/ha. Therefore, gross product accounts for Lei 8,250, subsidy being included.

Production cost

Variable costs

(a)Material costs

The most important category of costs is represented by variable costs, which include: the expenses for materials, fertilizers, pesticides and others.

Seed cost was reasonable because the farmer does not practice to buy seed from suppliers, but to retain seed from his own production for the next agricultural year. For this purpose, the farmer cultivate 4-5 ha especially for that. The amount of seed used for sowing is 250 kg per ha, and the internal cost of production is Lei 7.5 per kg seeds. Therefore, making the calculations, it resulted Lei 1,875 per ha costs with the seeds used for sowing.

Fertilization consists of the complex fertilizer (NPK) whose acquisition price in the fall 2022 was Lei 2,300 per ton. The farmer applied 300 kg complex fertilizer per ha, meaning expenses of Lei 690.

Also, the farmer bought Nitrogen (ammonium nitrate) at the market price of Lei 1,900/ton and applied a dose of 500 kg/ha, meaning expenses of Lei 960/ha.

Summing these costs, it results Lei 1,640 per ha for soil fertilization.

Plant protection required just a herbicide whose cost per ha accounted for Lei 270.

(b)Expenses with own mechanized works

The agricultural works which need the use of agricultural machinery are: plowing, disking, sowing, and also harvesting. The related costs were Lei 2,450 per ha for plowing, disking, sowing, and, respectively Lei 500/ha for harvesting. Summing the figures, it results Lei 2.950 per ha expenses with mechanical works.

(c)Irrigations are missing in the South Oltenia, because the water supply channels from the Danube river to the farms are not restored and do not work. The farmer is interested in using irrigations but as long as it is no access to water, it is not possible to sustain production level in this way.

(d)Supply expenses. The farmer has no supply expenses because the suppliers bring the ordered products directly at the farm gate.

(e)Insurance costs are zero, because the farmer decided not to conclude any contract with any insurance company, as the reimbursement system is very complicated as it happened in the previous years. For example, in case of hailestones, the insurance company send its inspectors in the field to evaluate the damaged surface and the money were given late and not enough, and only for the difference from the whole cultivated surface.

Therefore, summing the variable costs, more exactly: materials Lei 3,785 per ha and own mechanized works Lei 2,950, it results Lei 6,735 per ha.

Fixed costs are not considered in the example, because the farmer has no employees, only from time to time he used seasonal workforce for seed bagging and storing. Also, he has no general and management costs, no credits from the banks, and no depreciation costs.

In a word, there are only variable costs which have to be taken into account and considered equal to total production costs, accounting for Lei 6,735 per ha cultivated with wheat.

Gross income, in fact gross margin, results from the difference between production value plus subsidy minus total production costs, leading to Lei 1,515 per ha.

The farmer is exempted from tax payment on income according to the legislation in force.

Net income is equal to Gross income and it accounts for Lei 1,515 per ha, if the subsidy is included, and for Lei 415 per ha, if the subsidy is excluded. This shows how important is the role of subsidy of Lei 1,100 per ha to sustain positive financial results in agricultural holdings.

It worth to mention that the farmer has built a warehouse for storing the wheat seeds for a couple of months when the market price is not favourable (only Lei 0.75- 0.8 per kg), and to sell the seeds in the next spring when the price is Lei 1.1 per kg.

If the farmer will sell his production at the end of the harvest and will have no subsidy, in this case he could register a loss of Lei -1,535 per ha. If he will receive the subsidy, the loss will be smaller, accounting for only Lei -435.

Only selling at a higher price than Lei 1, wheat cropping could be profitable (Table 1).

However, this farmer has run a good business in the agricultural year 2022/2023, compared to other farmers in Romania who registered Lei 6,500 per ha cultivated with wheat.

The presented variant in Table 1 is the optimized solution chosen by the farmer taking into consideration the technological factors and also the influence of price and subsidy on the profitability of wheat crop.

Table 1. Economic efficiency in winter wheat crop, in the plain area, South Oltenia, Dolj county, Romania, Soil type chernozem, non-irrigated surface, Glosa variety, 2022/2023

		Calculation per 1 ha		Calculation for 50 ha cultivated with wheat	
		MU	Value	MU	Value
1.	**GROSS PRODUCT**				
2	Wheat yield	Kg /ha	6,500	Kg	325,000
3	Average wheat price	Lei/kg	1.1	-	-
4	Value of wheat yield , 4= 2 x 3	Lei/ha	7,150	Lei	357,500
5	Subsidy	Lei/ha	1,100	Lei	55,000
6	GROSS PRODUCT, 6 = 4 +5	Lei/ha	8,250	Lei	412, 500
7	**PRODUCTION COSTS**				
8	**Variable costs**				
9	***Materials costs***				
10	Seed cost	Lei/ha	1,875	Lei	93,750
11	Fertilization	Lei/ha	1,640	Lei	92,000
12	Plant protection	Lei/ha	270	Lei	13,500
13	Total material costs 13 = 10+11+12	Lei/ha	3,785	Lei	189,250
14	***Own Mechanized works***				
15	Plowing, disking, sowing	Lei/ha	2,450	Lei	122,500
16	Harvesting	Lei/ha	500	Lei	25,000
17	Total mechanized works	Lei/ha	2,950	Lei	147,500
18	Total variable costs 18= 13+ 17	Lei/ha	6,735	Lei	336,750
19	**Fixed costs**	-	-	-	-
20	**Total production costs 20 = 18**	Lei/ha	6,735	Lei	336,750
21	**Gross Margin** 21= 6 - 18				
22	-With subsidy	Lei/ha	1,515	Lei	75,750
23	-Without subsidy	Lei/ha	415	Lei	20,750
24	Gross Income 24 = 21				
25	Taxes	-	-	-	-
26	**Net income= Net profit**				
27	-With subsidy	Lei/ha	1,515	Lei	75,750
28	-Without subsidy	Lei/ha	415	Lei	20,750
29	**Net profit rate per ha 29= 26/20 x100**				
30	-With subsidy	%	22.49	%	22.49
31	-Without subsidy	%	5.8	%	5.8
32	**Net profit rate per kg of wheat seeds 32= 26/ 2**				
33	-With subsidy	%	23.30	%	23.30
34	-Without subsidy	%	6.38	%	6.38

Source: Own calculations based on the data provided by the farmer [29].

Below are comparatively shown the losses estimated from the wheat price volatility at harvesting and 10 months later in spring season next year.

Table 2. Losses estimated from the wheat price volatility at harvesting and 10 months later in spring season next year

	Variant 1 Average price in a favourable market Lei 1.1 / kg wheat seeds	Variant 2 Average price in at harvesting Lei 0.8 /kg wheat seeds	Estimated losses resulting from Variant 2 Lei/ha
Marketed production 6,500 kg - 250 kg retained seeds for net sowing= 6,250 kg	6,250 kg x Lei 1.1/kg = Lei 6,875/ha	6,250 kg x Lei 0.80/kg = Lei 5,000 /ha	Lei -1,875/ha

Source: Own calculations based on the data provided by the farmer [29].

CASE STUDY 2 Linear model for crop rotation in cereal production

Crop rotation is needed because monoculture could favour weeding, the appearance of diseases and pests in vegetal production.

Therefore, between the predecessor crop and the successor plant it is a direct link which differs from a crop to another according to favourability.

Table 3. Problem data for crop rotation optimization in cereals culture

Predecessor crop→ Succesor crope ↓	WHEAT	MAIZE	SOTBEAN	Threshold MIN (ha)	
WHEAT		1,200 800	1,300 700	30 ha	
MAIZE	Income 1,500 lei Expenses 1,000 lei		1,600 900	40 ha	
SUGAR BEET	1,800 1,200	1,900 1,100	2,000 1,000	4 ha	
Areas with predecessor crops	45 ha	50 ha	5 ha	Total costs(lei) ≤ 100,000	Total income (lei) ≥ 140,000

Note: The coloured cell means the fact that after a predecessor crop it is not allowed to cultivate the respective successor crop.
Source: [7, 8].

Table 4. Model of cereals rotation with limited expenses and maximum income

Predecessors→	Wheat		MAIZE		SOYBEAN				
Succesors →	Maize	Sugar beet	Wheat	Sugar beet	Wheat	Maize	Sugar beet	Sign	Thresholds
Restrictions ↓	X_1(ha)	X_2(ha)	X_3(ha)	X_4(ha)	X_5(ha)	X_6(ha)	X_7(ha)		
1.Costs (C)	1,000	1,200	800	1,100	700	900	1,000	≤	100,000 lei
2.Surface	1	1	1	1	1	1	1	=	100 ha
3.Plot with predecessor wheat	1	1	0	0	0	0	0	=	45 ha
4. Plot with maize predecessor	0	0	1	1	0	0	0	=	50 ha
5. Plot with soybean predecessor	0	0	0	0	1	1	1	=	5 ha
6.Wheat MIN	0	0	1	0	1	0	0	≥	30 ha
7.Maize MIN	1	0	0	0	0	1	0	≥	40 ha
8.Sugar beet MIN	0	1	0	1	0	0	1	≥	4 ha
Incomes (V)	1,500	1,800	1,200	1,900	1,300	1,600	2,000	**MAX**	

Source: [7, 8].

Table 5. Optimal solutions with maxim income for cereals cereals

Basic optimal primal solution	Basic optimal dual solution
1)VPP(Cultivated areas with successors after perdecessors x_1=32.5 ha maize after wheat →x_2=12.5 ha sugar beet after wheat --- x_3=25 ha wheat after maize x_4=25 ha sugar beet after maize --- x_5=0 ha wheat after soybean x_6=0 ha Maize after Soybean x_7=5 ha Sugar beet after Soybean	3)VDE(Surplus of income Lei Mil. /ha crop) ye_1=0 lei surplus of income/ha Maize after Wheat →ye_2=-166.67lei surplus of income/ha Sugar beet after wheat --- ye_3=0 lei surplus of income/ha Wheat after Maize ye_4=0 lei surplus of income /ha Sugar beet after Maize --- ye_5=0 lei surplus of income/ha Wheat after Soybean ye_6=-166.67 lei surplus of income/ha Maize after Soybean ye_7=0 lei surplus of income/ha Sugar beet after Soybean
2)VPE(Differences between the consummed Resources and their limits) **→xe_1=0 lei unspent money** xe_2=0 ha uncultivated land →xe_3=0 ha wheat predecessor uncultivated →xe_4=0 ha maize predecessor uncultivated →Xe_5=0 ha soybean predecesor uncultivated xe_6=6.67 ha wheat surplus xe_7=5 ha maize surplus xe_8=14.33 ha sugar beer surplus	4)VDP(Marginal incomes) **→y_1= 1.5 lei income gain/one more Lei spent** y_2= 0 lei income growth/the 101st ha of land →y_3= 0 lei income growth /the 46th ha Wheat predecessor →y_4= 0 lei income growth/the 51st ha Maize predecessor →y_5= -333.33 lei income growth /the 6th ha Soybean predecessor y_6=250 lei income growth/ the 31st ha Wheat y_7=500 lei income growth /the 41st ha Maize y_8= -250 lei income growth /the 5th ha Sugar beet
$f_{maxim} = g_{minim}$ = 158,750 lei	

Source: [7, 8].

Income =158,750 lei=maxim; Expenses =100,000 lei; Profit = Income – Expenses =58,750 lei.

Economic indicators:

Profit average rate RMP =0.58 lei profit /1 lei spent

Marginal profit rate RDP = y_1 – 1 =1.5 lei profit increase / 1 lei spent

Elasticity of profit rate ERP = RDP / RMP = 2.58 % profit surpplus / 1 % costs surplus .

Model solving using **SOLVER** application from **MS Excel** as follows.

Table 6. Model description in the calculation sheet (data + calculation formulas)

	A	B	C	D	E	F	G	H	I	J	K	L
1	x1	x2	x3	x4	x5	x6	x7	FO				
2	0	0	0	0	0	0	0	0				
3	c1	c2	c3	c4	c5	c6	c7	MAX				
4	1500	1800	1200	1900	1300	1600	2000					
5	**Restrictions**											
6	1000	1200	800	1100	700	900	1000	<=	100000	0		
7	1	1	1	1	1	1	1	=	100	0		
8	1	1	0	0	0	0	0	=	45	0		
9	0	0	1	1	0	0	0	=	50	0		
10	0	0	0	0	1	1	1	=	5	0		
11	0	0	1	0	1	0	0	>=	25	0		
12	1	0	0	0	0	1	0	>=	30	0		
13	0	1	0	1	0	0	1	>=	4	0		
14	Calculation method:											
15	Step 1. Starting from the initial solution x1=x2=x3=x4=x5=x6=x7=0 written in the domain A2:G2											
16	Step 2. In the field A4:G4, write the FO coefficients (Objective Function) obiectiv)											
17	Step 3. In field A6:I13, write the model data											
18	Step 4. Calculation formulas:											
19	- for the objective function FO, write in cell H2 the formula =SUMPRODUCT(A2:G2,A4:G4)											
20	- for each restriction, in the field J6:J13, write the corresponding formula =SUMPRODUCT($A$2:$G$2,A6:G6)											
21	Step 5. Position the mouse cursor in cell H2 and call SOLVER from the DATA menu (See Ribbon)											
22	Step 6. The SOLVER option will display the Solver Parameters window (table 7) in which the required information will be filled.											

Source: Own determination.

A good predecessor plant could assure for the successor crop higher yields, income and profit or with smaller expenses.

Beans, peas, soybean are good predecessor plants because they produce nitrogen which is left on the nods of the roots due to the bacteria fixing nitrogen.

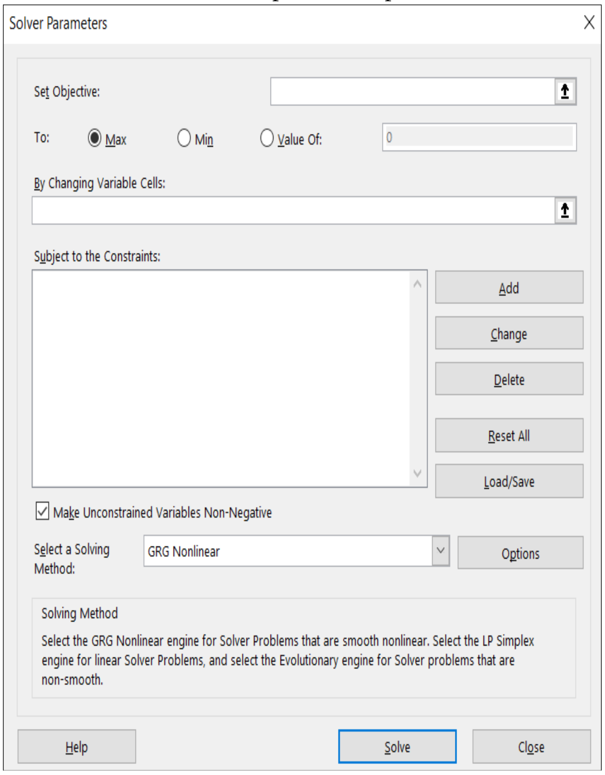
Having in mind these aspects, this case study presents an optimal linear model for crop rotation characterized by:

- The unknown x_i are the surfaces which are going to be cultivated after predecessor plants;
- The restrictions regard: bilateral restrictions for successor plants; the cultivation of the whole surface with successor crops; surfaces with predecessor crops occupied by them.

-The economic functions are: Income, Expenses, Profit, Profit rate, Marginal profit rate.

The problem data and analysis is made according to the methodology established by [7, 8].

Table 7. It should be completeed as presented below



Source: Own determination

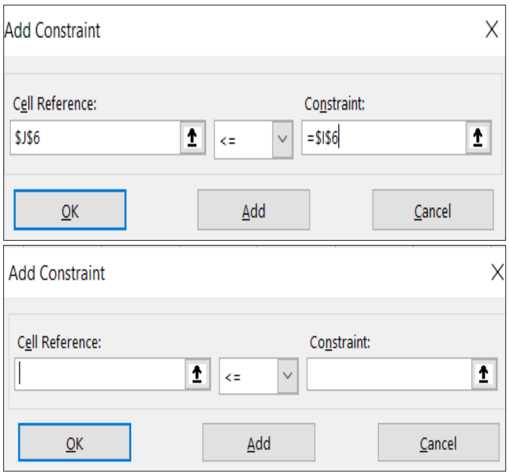
-in the zone Set objective, write the address of teh cell for FO calculus (here, it is H2)

-in the zone To, select MAX or MIN (cf. probl.)

-in the zone By Changing Variable Cells, write the field with the values of the variables (A2:G2)

-in the zone Subject to the Constraints, write each restriction, using Add (cell with the calculus formula, sign and limit).

For example:

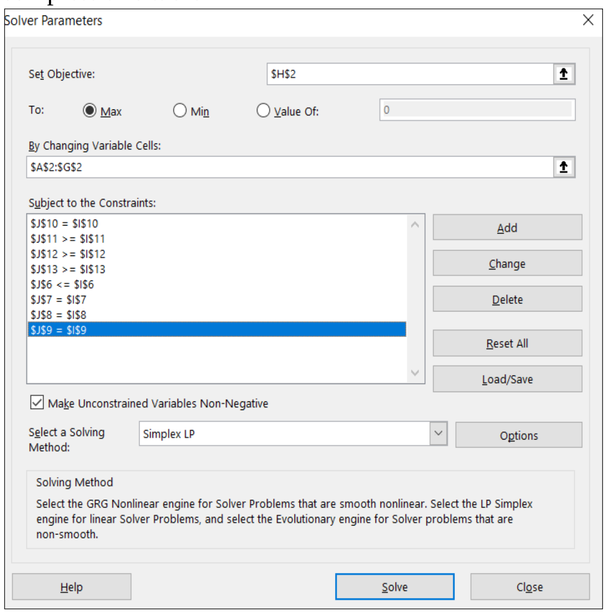


-from the zone Select a Solving, select Simplex LP

- it is launched the option SOLVE

Table completed before to launch the option SOLVE is Table 8.

Table 8. Before launching the opition Solve, complete this table



Source: Own determination.

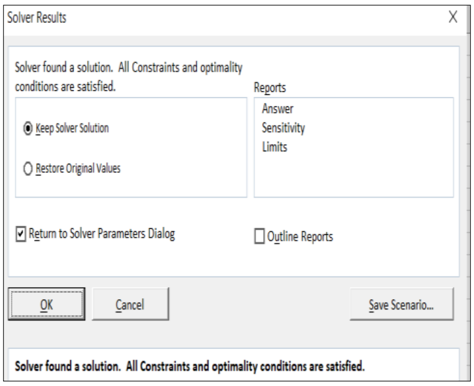
After launching the option Solve, it is obtained the next window where to tackle in case that the three types of reports: Answer, Sensitiviy and Limits will appear (Table 9).

Modification or deletion of restrictions is done with the Change and Delete options, respectively.

The **Answer**, **Sensitivity** and **Limits** options will attach to the initial spreadsheet three other reports with results, namely: *the optimal primal and dual solutions, the optimal value and the intervals for the components that do not require reoptimization.*

Note: the values of the primary variables and the value of the objective function also appear in the initial spreadsheet.

Table 9. Answer, Sesitivity and Limits which offer informations on solutions



Source: Own determination.

Table 10. Results displayed on the main data sheet after the Solver launch

	A	B	C	D	E	F	G	H	I	J	K
1	x1	x2	x3	x4	x5	x6	x7	FO			
2	32.5	12.5	25	25	0	0	5	158750			
3	c1	c2	c3	c4	c5	c6	c7	MAX			
4	1500	1800	1200	1900	1300	1600	2000				
5	Restrictions										
6	1000	1200	800	1100	700	900	1000	<=	100000	100000	
7	1	1	1	1	1	1	1	=	100	100	
8	1	1	0	0	0	0	0	=	45	45	
9	0	0	1	1	0	0	0	=	50	50	
10	0	0	0	0	1	1	1	=	5	5	
11	0	0	1	0	1	0	0	>=	25	25	
12	1	0	0	0	0	1	0	>=	30	32.5	
13	0	1	0	1	0	0	1	>=	4	42.5	

Source: Own determination

Table 11. Answer Report worksheet

Microsoft Excel 16.0 Answer Report
Worksheet: [Book1]Sheet1
Report Created: 10/3/2023 3:09:37 PM
Result: Solver found a solution. All Constraints and optimality conditions are satisfied.
Solver Engine
Engine: Simplex LP
Solution Time: 0.031 Seconds.
Iterations: 8 Subproblems: 0
Solver Options
Max Time Unlimited, Iterations Unlimited, Precision 0.000001, Use Automatic Scaling
Max Subproblems Unlimited, Max Integer Sols Unlimited, Integer Tolerance 1%, Assume NonNegative

Objective Cell (Max)

Cell	Name	Original Valu	Final Value
$H$2	FO	0	158750

Variable Cells

Cell	Name	Original Valu	Final Value	Integer
$A$2	x1	0	32.5	Contin
$B$2	x2	0	12.5	Contin
$C$2	x3	0	25	Contin
$D$2	x4	0	25	Contin
$E$2	x5	0	0	Contin
$F$2	x6	0	0	Contin
$G$2	x7	0	5	Contin

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$J$10	=	5	$J$10=$I$10	Binding	0
$J$11	>=	25	$J$11>=$I$11	Binding	0
$J$12	>=	32.5	$J$12>=$I$12	Not Binding	2.5
$J$13	>=	42.5	$J$13>=$I$13	Not Binding	39
$J$6	<=	100000	$J$6<=$I$6	Binding	0
$J$7	=	100	$J$7=$I$7	Binding	0
$J$8	=	45	$J$8=$I$8	Binding	0
$J$9	=	50	$J$9=$I$9	Binding	0

Source: Own determination.

Table 12. Sensitivity Report worksheet

Microsoft Excel 16.0 Sensitivity Report
Worksheet: [Book1]Sheet1
Report Created: 10/3/2023 3:09:37 PM

Variable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
$A$2	x1	32.5	0	1500	300	166.6666667
$B$2	x2	12.5	0	1800	166.6666667	300
$C$2	x3	25	0	1200	250	0
$D$2	x4	25	0	1900	0	250
$E$2	x5	0	0	1300	0	1E+30
$F$2	x6	0	-250	1600	250	1E+30
$G$2	x7	5	0	2000	1E+30	0

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
$J$10	=	5	500	5	0	0.5
$J$11	>=	25	-250	25	1.666666667	8.333333333
$J$12	>=	32.5	0	30	2.5	1E+30
$J$13	>=	42.5	0	4	38.5	1E+30
$J$6	<=	100000	1.5	100000	500	2500
$J$7	=	100	0	100	0	1E+30
$J$8	=	45	0	45	0	0.416666667
$J$9	=	50	250	50	0	0.454545455

Source: Own determination.

Table 13. Limits Report worksheet

Microsoft Excel 16.0 Limits Report
Worksheet: [Book1]Sheet1
Report Created: 10/3/2023 3:09:37 PM

Objective		
Cell	Name	Value
$H$2	FO	158750

Variable			Lower	Objective	Upper	Objective
Cell	Name	Value	Limit	Result	Limit	Result
$A$2	x1	32.5	32.5	158750	32.5	158750
$B$2	x2	12.5	12.5	158750	12.5	158750
$C$2	x3	25	25	158750	25	158750
$D$2	x4	25	25	158750	25	158750
$E$2	x5	0	0	158750	0	158750
$F$2	x6	0	0	158750	0	158750
$G$2	x7	5	5	158750	5	158750

Source: Own determination.

A linear model can be reoptimized by changing the values of the coefficients. The most common changes are:
- modification of the coefficients of the objective function in which it is analyzed whether the existing primal optimal solution of the model remains the optimal one (so reoptimization is not necessary);
- modification of the limits of the restrictions, in which case it is analyzed if the existing dual optimal solution of the model remains the optimal one (therefore reoptimization is not necessary).

The answer to these questions is given by the Limits Report.

CONCLUSIONS

The paper has presented two case studies of optimization in agriculture in vegetal production, emphasizing on cereals cropping which is facing with big problems related to technological aspects and climate change impact on yield mainly to wheat and maize.

Two problems were approached:

(a)optimization of profitability in relation to wheat yield, subsidy per ha and delivery price. The calculations in the agricultural year 2022/2023 proved that without irrigation it could be obtained 6,500 kg wheat per ha in South Oltenia region, but to be a profitable culture, it needs that production costs to be compensated by income whose level depends on delivery price and subsidy per surface unit. Without subsidy and a higher price than Leu 1 per kg seeds at delivery, wheat could become a non profitable crop.

(b)optimization of crop rotation using a model with maximum income which had two solutions: Basic optimal primal solution and Basic optimal dual solution, whose calculation was assisted by **SOLVER** application from **MS Excel** as described in the paper.

The both examples reflect how important is optimization in agricultural production, and that the managers need to have not only good technological knowledge and skills but also IT skills and digital infrastructure to enable them to make the right decisions.

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