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Uredil:
dr. Andrej Udovč

Programski odbor:
dr. Emil Erjavec (predsednik), dr. Jernej Turk, dr. Andrej Udovč, dr. Miro Rednak, dr. Martin Pavlovič, dr. Stane Kavčič

Izdajatelj:
Društvo agrarnih ekonomistov Slovenije – DAES; zanj dr. Jernej Turk

Prelom in priprava za tisk:
dr. Andrej Udovč, Maja Mihičinac

Oblikovanje naslovnice:
Grega Kropivnik

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SPREADSHEET TOOL FOR ECONOMIC EFFICIENT PRODUCTION PLANNING; CASE OF MACEDONIAN VEGETABLE FARMS

Ivana JANESKA STAMENKOVSKA[a], Dragi DIMITRIEVSKI[a], Emil ERJAVEC[b], Jaka ŽGAJNAR[b], Aleksandra MARTINOVSKA STOJCHESKA[a]

ABSTRACT

Macedonian vegetable farms face big challenge in decision making to improve their production plans. To increase economic efficiency, different tools could be applied that beside natural conditions, resource allocation, technical and technological conditions, consider also economic viewpoint. In this paper we present an example of a spreadsheet tool based on mathematical programming paradigm. It enables one to utilise optimization potential of linear programming, with an objective function of maximising the expected gross margin, subject to set of different constraints. To have a representative tool, special focus has been put on data that are obtained with direct interviews with relevant experts and stakeholders: researchers, crop technology specialists, extension agents, input suppliers and vegetable farmers and supplemented with Farm Monitoring System data for 2010. The tool was tested on hypothetical vegetable farm. It proved to be an efficient tool that could support operative, tactical and strategic planning at the farm level, since it facilitates the selection of adequate production activities of vegetable crops, while taking into consideration the limitations of the available production factors. Due to its flexibility it is also an appropriate tool for analysing decision making in different production conditions that may occur.

Key words: linear programming, optimization, spreadsheet tool, Macedonian vegetable farms

ORODJE ZA EKONOMSKO UČINKOVITO NAČRTOVANJE PROIZVODNJE; PRIMER MAKEDONSKIH ZELENJADARSKIH KMETIJ

IZVLEČEK

Makedonski kmetje se soočajo z velikimi izzivi pri izboljšanju proizvodnih načrtov. Za izboljšanje ekonomske učinkovitosti so na voljo različna orodja, ki poleg naravnih

[a] Institute of Agricultural Economics, Faculty of Agricultural Sciences and Food in Skopje, Aleksandar Makedonski bb, 1000, Skopje, R. Macedonia; ivanajaneska@yahoo.com, dragi_dimitrievski@yahoo.com, sanims@gmail.com

[b] Faculty, University in Ljubljana, Groblje 3, SI 1230-Domžale, Slovenia; emil.erjavec@bf.uni-lj.si, jaka.zgajnar@bf.uni-lj.si

pogojev, alokacije proizvodnih enot, tehničnih in tehnoloških pogojev upoštevajo tudi ekonomski vidik. V prispevku predstavljamo primer orodja zasnovanega v obliki elektronske preglednice, ki temelji na konceptu matematičnega programiranja. Orodje omogoča uporabo optimizacijskega potenciala linearnega programiranja, s ciljno funkcijo maksimiranja pričakovanega pokritja ob nizu različnih omejitev. Da bi bilo predstavljeno orodje, kar se da reprezentativno, smo posebno pozornost namenili podatkom, ki smo jih pridobili preko neposrednih intervjujev s ključnimi strokovnjaki in deležniki: raziskovalci, specialisti na področju rastlinskih tehnologij, svetovalci, dobavitelji proizvodih enot, zelenjadarji in jih dopolnili s podatki iz sistema za spremljanje kmetij za leto 2010. Orodje smo testirali na hipotetičnem kmetijskem gospodarstvu. Orodje se je izkazalo je za učinkovito in je lahko v pomoč pri operativnem, taktičnem in strateškem načrtovanju na ravni kmetijskega gospodarstva, saj omogoča izbiro ustreznih zelenjadarskih aktivnosti ob upoštevanju danih omejitev proizvodnih faktorjev. Glede na prilagodljivost orodja, ga lahko uporabimo tudi za analizo odločanja v različnih proizvodnih pogojih, ki lahko nastopijo.

Ključne besede: linearno programiranje, optimizacija, orodje v obliki elektronske preglednice, makedonski zelenjadarji

1 Introduction

The changing environment in which the farmers operate represents a big challenge in the decision making processes about what to produce, which technology to choose, as well as what quantities to produce (Hazell and Norton, 1986). How to achieve better results and economic efficient production, are continuous issues the farmer is faced with. In order to increase economic efficiency and to support decision making, different tools can be applied, that beside the natural, technical and technological conditions, consider also the economic viewpoint.

Macedonia is a country where crop production dominates, contributing with around three-fourths to the total value of agricultural production (SSO, 2011). Vegetables take the most significant share in the value of agricultural production with up to 40% in 2010 (MAFWE, 2011). The climate in Macedonia enables successful production of different types of vegetables. The most common type of vegetable farm is mixed family farm; the Macedonian family farm has an average size of 1.37 hectares, while the average size of a vegetable farm is 0.2 hectares (SSO, Ag Census, 2007).

Most of the Macedonian farmers make their decisions intuitively, based on their experience and without the use of analytical tools recommended and developed by researchers. Additionally, the policy decision-makers in Macedonia also need empirical tools for monitoring the agriculture and for agri-policy impact analyses at the micro-level (at the level of farms).

In this context, the aim of the paper is to present an optimization tool for economically efficient production planning, utilizing deterministic mathematical programming approach-linear programming (LP). LP has been proven as a useful method in farm production planning (Scarpari and Beauclair, 2010; Alabdulkader *et al.*, 2012; Kebede and Gan, 1999; Majewski and Was, 2005), which can be applied to almost any resource allocation problems (Žgajnar *et al.,* 2007).

The tool is tested and presented on hypothetical vegetable farm, providing an optimal production plan.

2 Material and methods

Optimisation is commonly used approach for solving problems of farm production planning in the sense of optimal resource allocation. LP is the most often used mathematical programming method that chooses between farms - activities on the basis of determined objective function considering a set of fixed farm constraints, thus representing the preferences of the farm (Žgajnar *et al.*, 2007). Even due to its simplified linear and normative nature, it proved to be more applicable for solving complex problems than other more simple methods as budgeting and marginal analysis (Žgajnar *et al.*, 2007). As a mathematical procedure, LP utilizes the simplex algorithm with an aim to find the optimal combination of farm enterprises under maximisation or minimisation of the objective function (Kay *et al.,* 2008). Therefore, it requires clear definition of farm activities, resource requirements and specific constraints such as market and policy constraints (Hazell and Norton, 1986).

Standard LP model can be mathematically presented as

$max\ Z = c_1x_1+c_2x_2+...+c_nx_n,$, subject to
(1)

$$a_{11}x_1+a_{12}x_2+...+a_{1n}x_n \leq b_1 \quad (2)$$
$$a_{21}x_1+a_{22}x_2+...+a_{2n}x_n \leq b_2$$
$$.$$
$$.$$
$$.$$
$$a_{m1}x_1+a_{m2}x_2+...+a_{mn}x_n \leq b_m$$

$$x_1...x_n \geq 0 \quad (3)$$

where, equation (1) determines the objective function of the model of maximizing the total gross margin (Z) per farm annually. Its value is calculated as sum products of the total gross margin ($c_1,...,c_n$) per activity and the level of the farm activity, i.e. hectares per each crop ($x_1,...,x_n$). LP models are subject to fixed resource constraints (2), imposing restrictions on the activities in optimizing the objective function.

Here, a_{ij} represents the quantity of the resources necessary for production of one unit of the activity, while b_i refers to the extent of the available resources. The common requirement for linear programming models in respect to the nonnegative values of the decision variables is expressed in equation (3).

2.1 Tool for optimization of vegetable production

For the purpose of this research, a spread sheet tool utilizing the linear programming paradigm was constructed in MS Excel and Visual Basic (Version 14.0.6129.5000, 2010). It enables an analysis of the changing optimal vegetable production structure at the farm level in different production conditions. Optimal solution is found under assumption of maximising total gross margin, subject to different equality and inequality constraints that define production margins of the analysed farm.

The tool is initially fed with production activity levels, supported by detailed enterprise budgets developed on one hectare basis arable land. An important aspect in this part is the definition of the technical coefficients (matrix A, equation (2)) which resume the key features of the applied technology for a specific vegetable crop. Considering that the complexity of the tool increases with the increasing number of the activities, at this stage the research captures only the vegetable sub-sector of the Macedonian agriculture. There are 162 decision variables included in this tool and they are divided into four groups: i) activities referring to the most representative vegetable crops, ii) input related activities, iii) infrastructure capacity, and iv) balance activities for assuring integrity of the solutions. Different production technologies and possibility to include second crops are applied as specific activities into the tool.

Additionally, there are number of constraints that influence farmer's decisions. One set of constraints considers the production factors insufficiency. In this context, constraints for available land, labour and working capital are introduced. The land use is incorporated according the current farming practice, while the labour availability according the seasonal character of the vegetable production with possibility for hiring extra non-family labour in the peak seasons. In this type of model, the labour resources are most fitting to be determined on a monthly basis (Kay *et al.*, 2008). This is especially important in vegetable production, since in addition to being very labour intensive, there is an uneven distribution of the labour requirement throughout the year, with labour peaks in the seedling phase and in the harvest phase.

Other sets of constraints refer to the agronomic constraints, external factors that affect farmer's decision, as well as the balance constraints. The tool offers possibility to choose whether certain constraints to be considered and certain activities to be included in the given optimisation or not.

Different sources of data were used for supporting the tool. Basic data for calculating the enterprise budgets were obtained consulting a panel of relevant experts: researchers, crop technology specialists, extension agents, input suppliers and vegetable farmers (Monke *et al.*, 1989), and calculated using the average current farming practice approach (*ibid*). Furthermore, they were supplemented with the Farm Monitoring System (FMS) data for 2010 (NEA, 2011). FMS is an annual survey on production, income and cost related data per farm activities of 300-400 farms in Macedonia.

The tool is applied on hypothetical farm, reflecting the typical situation on vegetable family farms in Macedonia. The hypothetical farm owns four hectares of open field area and has infrastructure for production under plastic tunnels that could be utilised at maximum on one hectare of arable land. Labour availability is taken in consideration with a threshold of 4,400 hours per annum and equally distributed per seasons. The capital constraint is included, as the minimum amount the farmer should have in order to cover the variable costs of the farm.

2.2 Scenario description

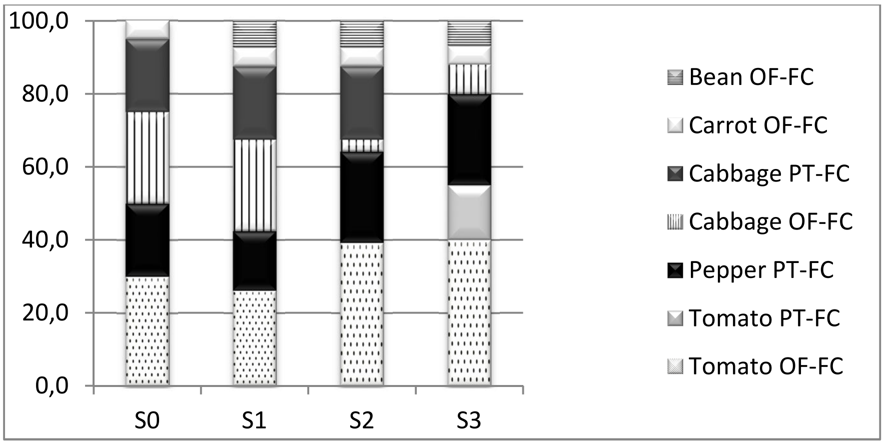
In addition to the baseline scenario (S0) where the area under vegetable crops is limited on five hectares and the labour restricted on two workers annually, three different scenarios were introduced for analysing the effect of the most binding constraints on the optimal production plan. The scenarios differ in the market and the capital constraints. S1 considers a restriction in the working capital to 13,000 Euros, while in addition to S1, S2 scenario introduces a market constraint of 20 tones for cabbage. This market constraint is introduced considering the high yield received in the baseline solution vs. the demand for cabbage in practice. The capital constraint is relaxed in S3 where only the demand for cabbage is fixed on 20 tones.

3 Results and discussion

The production structure obtained with all scenarios corresponds to the most often cultivated vegetable crops in Macedonia, thus confirming that the Macedonian farmers avoid monoculture and produce different vegetables in order to distribute the market risk and to use the labour efficiently. The optimal production plan captures tomato, pepper, cabbage, carrot and beans. The main results are presented in Table 1 and Table 2.

Considering that there are no restrictions in the available capital and the market demand, the gross margin of 17,924 Euros is highest in the base case scenario (S0). The land resource is fully exhausted and the shadow price for investing in one additional hectare of production under plastic tunnel is 3,000 Euros. Regardless the production of cabbage dominates in terms of share of land (Picture 1), the production of pepper under plastic tunnel reveals to be most profitable crop contributing 60% of the total farm gross margin. The labour availability is sufficient however there is a need of hiring extra non-family labour in the peak seasons. A drop of 50% and 43% in the gross margin has been received in case of implementing the scenarios S1 and S2 respectively; corresponding to the average gross margin of a vegetable farm in Macedonia (8,000 euros), and thus confirms the situation at a vegetable farm in practice (Martinovska Stojcevska *et al.*, 2011). The working capital reveals to be the most binding constraint in these two scenarios. On the other side, the optimal solutions in case of implementing the S1 and S2 scenarios do not exhaust the land and labour. The optimal solutions in S1 and S2 indicate 1 ha of open field production and 0.7 ha of production under plastic tunnels, which corresponds to the average size of a Macedonian vegetable farm (SSO, 2011). Considering the market demand as a most binding constraint in S2, the production plan was taken by production of tomatoes with around 40% of the total arable land of the farm.

The production of tomatoes also dominates in S3, where the land resource is fully exhausted. The production of tomatoes requires an additional investment in 1 ha under plastic tunnel, which will increase the gross margin by 960 euros/ha.



*OF-Open Field, PT-Plastic Tunnel, FC-First Crop, SC-Second Crop

Picture 1: Optimal production plan in case of implementing different scenarios (share of land in ha)

Additionally, three types of fertilizers are used in the production, and getting the nutrients from manure seems to be expensive. The seasonal character of the vegetable production was also reflected in the crop rotation analysis, whereas it is more intensive during the first half of the year when the land is mostly utilized.

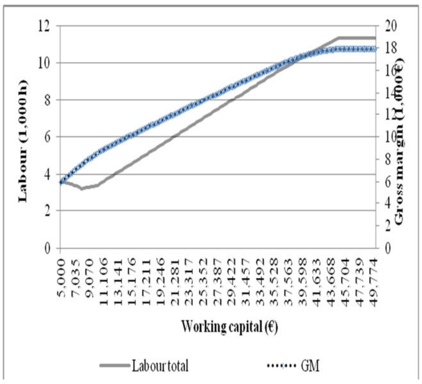
Table 1: Optimal vegetable production in case of implementing of different scenarios

	S0		**S1**		**S2**		**S3**	
Crop	**ha (%)**	**GM (€)**	**ha (%)**	**GM (€)**	**ha (%)**	**GM (€)**	**ha (%)**	**GM (€)**
Tomato OF-FC	30.0	7,092	26.1	2,428	39.2	2,932	40.0	9,456
Tomato PT-FC	0.0	0	0.0	0	0.0	0	15.0	7,615
Pepper PT-FC	20.0	11,219	16.4	3,610	25.0	4,436	25.0	14,024
Cabbage OF-FC	25.0	6,446	25.0	2,534	3.3	268	8.0	2,063
Cabbage PT-FC	20.0	6,363	20.0	2,501	20.0	2,013	0.0	0
Carrot OF-FC	5.0	716	5.0	281	5.0	226	5.0	716
Bean OF-FC	0.0	0	7.5	58	7.5	46	7.0	137
GM Per farm		17,924		9,479		7,871		11,720

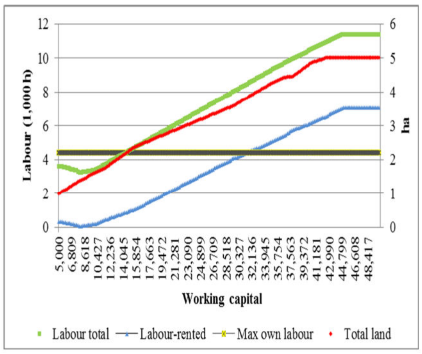
Table 2: Resource requirements and yields in different scenarios

Scenario	S0	S1	S2	S3
Working capital (€)	44,881	13,008	13,008	65,247
Land (ha)				
Open field	3.00	1.25	0.87	3.00
Plastic tunnel	2.00	0.71	0.71	2.00
Labour (h)				
Own	4,331	3,424	3,188	3,651
Rented	7,023	637	846	2,382
Production (kg)				
Tomato	75,000	25,673	31,005	160,000
Pepper	55,000	17,698	21,746	68,750
Cabbage	117,500	46,183	20,000	20,000
Carrot	8,750	3,439	2,768	8,750
Beans	0	221	178	525

A working capital parametrisation was done for sensitivity analysis of the farm gross margin of 17,924 euros determined with the baseline scenario. The parametrisation captures 200 runs of the solver within the given range of working capital. The results reveal that the working capital influences the optimal farm size, i.e. investing more working capital increases the land use. However, the restriction of 5 hectares hinders the increase in the farms size and therefore the profit also stagnates at this point (Picture 3). Investing more than 10,000 euros of working capital imposes a need of hiring extra labour (Picture 2).



Picture 2: Working capital parameterization



Picture 3: Relation between working capital and land/labour

4 Conclusions

Linear programming proved to be a useful approach for analysing farm management problems on vegetable farms in Macedonia. Such tool can be also applied in other countries in the region with similar production structure. Having an appropriate decision making tool is important for farmers in order to determine their production structure and make a combination that will bring the highest profit, given the resources available. Additionally, such a tool could be used by policy makers for impact assessment of different agricultural policy measures. Considering the benefits of such tool an analysis of typical/hypothetical farms is also enabled.

Additionally, the developed tool for optimisation of vegetable production is functional and gives plausible results regarding the available working capital, farm size, production structure as well as the technological, market and policy constraints.

Results show that the labour is not a binding constraint. However, in the peak season, the farm cannot fulfill the requirements, hence seasonal labour must be hired. The most binding constraint is the available working capital on the farm. As the working capital increases, the farm size stops at the maximal land constraint, and the farm gross margin also stagnates from this point.

The tool is also quite flexible as it enables different crop activities to be added.

5 References

Alabdulkader A.M., Al-Amoud A.I., Awad F.S. 2012. Optimization of the Cropping Pattern in Saudi Arabia Using a Mathematical Programming Sector Model. Agric. Econ.-Czech, 58, 56-60

Boehlje M.D., Eidman V.R. 1984. Farm Management. John Wiley and Sons, 806p

Calker K.J, Berntsen P.M.B., Giesen G.W.J., Huirne R.B.M. 2008. Maximising sustainability of Duch dairy farming systems for different stakeholders: A modelling approach. Ecological Economics, 65, 407-419

Hardaker J.B., Huirne R.B.M., Anderson J.R., Lien G. 2007. Coping with Risk in Agriculture. 2nd edition. Oxfordshire, CABI Publishing, 332 p.

Hazell, P.B.R, Norton, R.D. 1986. Mathematical Programming for Economic Analysis in Agriculture. New York, Macmillon, 400

Howitt R.E. 2005. Agricultural and Environmental Policy Models: Calibration, Estimation and Optimisation.

Kay D. R., Edwards M. W., Duffy A. P. 2008. Farm management. McGraw-Hill Companies, New York.

Kebede E., Gan J. 1999. The Economic Potential of Vegetable Production for Limited Resource Farmers in South Central Alabama. Journal of Agribusiness 17, 1, 63-75

Lee S.M., Olson D.L. 2006. Introduction to Management Science. Cengage Learning Custom Publishing

Majewski E., Was A. 2005. Optimal Structure of Farm in a Region – A Modelling Approach. 99th EAAE Seminar, Copenhagen

Martinovska-Stojceska A., Dimitrievski D., Surry Y., Sergo L, Andersson H. 2011. Economic and technical analysis of Macedonian farms based on farm accountancy data. UniCoop, Skopje, 51

Monke E.A., Pearson S.R. 1989. The Policy Analysis Matrix for Agricultural Development. http://www.stanford.edu/group/FRI/indonesia/documents/pambook/pambook.pdf

Ministry of Agriculture, Forestry and Water Economy 2011. Annual Agricultural Report for 2010. MAFWE, Skopje

National Extension Agency 2011. Farm Monitoring System. NEA, Bitola

Scarpari Maximiliano Salles, Beauclair Edgar Gomes Ferreira 2010. Optimized Agricultural Planning of Sugarcane using Linear Programming. Revista Investigacion Operacional, Vol. 31, no. 2, 126-132

State Statistical Office of the Republic of Macedonia 2007. Agricultural Census. SSO, Skopje

State Statistical Office of the Republic of Macedonia(2011. Economic Accounts in Agriculture in 2010. SSO, Skopje

State Statistical Office of the Republic of Macedonia 2011. Typology of Agricultural Households. SSO, Skopje

Strauss PG, Meyer FH, Kirsten JF. 2008. Facilitating Decision Making in Agriculture by Using a System of Models. Agrekon, Vol. 47, no. 3, 346-364

Turner J., Taylor M. 2003. Applied Farm Management. Blackwell Publishing, BSP Professional Books.

Žgajnar J., Erjavec E., Kavcic S. 2007. Optimisation of Production Activities on Individual Agricultural Holdings in the Frame of Different Direct Payments Options. Acta agriculturae Slovenica, 90, 45-56

Žgajnar J. (2011) Weighted Goal Programming and Penalty Functions: Whole-farm Planning Approach Under Risk. XIII EAAE Congress 2011, Zurich.

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