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Original scientific paper

ASSESSING THE INFLUENCE OF SOIL PROPERTIES ON OPTIMAL PRODUCTION STRUCTURE AT VEGETABLE FARMS[#]

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The variability in soil properties influences the farm management decisions in reference to the fertilizers' optimization strategy and crop productivity. The aim of this research is to assess the influence of chemical soil properties on optimal production plan at vegetable farms in R. Macedonia, utilizing optimization potential of mathematical programming techniques. The study simulates the economic performance of a typical vegetable farm in four scenarios based on different soil contents of key nutrients; hence four fertiliser management strategies are defined. Main results point to the optimal scenario, where the solution provides highest gross margin, lowest number of enterprises, highest labour engagement, but relatively modest working capital. Vegetable crops included in the optimal production plan have more need for potassium, nevertheless the nitrogen and phosphorus are also important. The offered options for basic fertilization and additional nutrition can be considered as reasonable and realistic solution that can be applied in practice.

Key words: soil properties; optimal production structure; multi-criteria decision making; vegetable production

INTRODUCTION

Variation of soil chemical and physical properties influences both nutrition and crop management efficiencies. The variability in soil properties can cause uneven crop growth and decrease the effectiveness of the uniformly applied fertilizers on the field [1]. It can also influence the farm management decisions in reference to the fertilizers' optimization strategy and crop productivity. On the other side, the intensive agricultural practices with an excessive use of fertilizers have negative impact on the environment and due to unused nutrients, it also has negative influence on economic efficiency since they present additional unnecessary costs. Together with the sediment run-off, manure and production chemicals, soil nutrients are considered as one of the most common environmental pollutants from agriculture [2]. Consequently, these negative farm externalities are reflected on farmers' profit. As profit-maximizers on one site and risk averse behavior on the other, farmers aim to achieve stable income, through economically efficient production practices. Also, high fertilizers' prices urge to their rational application and not excessive use.

Operations research proved to be an adequate approach in assisting farmers in production planning. Such an application concerns the decision whether to use certain chemical fertilizers or to introduce alternative practices leading to more sustainable agriculture. Further, we find examples where mathematical programming techniques could be applied in preparing fertilization plan as an important task in the context of crop production [3]. Besides, such analysis based on optimization paradigm can also help policy makers to evaluate the appropriateness of agro-environmental policies [4] and is therefore common approach in estimating models for policy impact assessment.

[#]Dedicated to academician Gjorgji Filipovski on the occasion of his 100[th] birthday

The core issue in nutrition management is at what time, in which form, at what amount and what combination of manure and fertilizers to apply, in order to meet the estimated nutrition requirements considering both soil fertility and minimizing the negative consequences on the environment [3]. From methodical viewpoint, it is a common allocation problem that could be supported with mathematical programming based on constrained optimization. In that context, the linear programming (LP) approach is most commonly applied in different studies optimizing total production while minimizing the environmental impact [5].

However, classical LP technique based on single criterion optimisation (most often maximization of profit or minimizing nutrition costs) has been criticized mostly due to the emphasized rigidity of the constraints [6]. In case of developing a crop production fertilization plan, rigid constraints are impossible especially if we consider robustness of nutrition requirements estimation and what in relative terms means exceeding such a plan for one unit. On the other side farmers could be strongly motivated towards the intrinsic satisfactions of their work, rather than simply towards economic goals.

Although [7] argue that the LP optimization simplifies the agricultural production planning in practice; however it does not consider farmer's preferences in relation to efficient use of resources, minimizing the environment pollution, and stable income. In addition, a number of studies analyse the linkages between economic and environmental aspects, where beside the classical objective of profit maximisation, the most recurrent criteria are minimization of agri-chemical inputs, minimization of nutrients resulting from chemical or manure fertilizers, etc. [2].

Considering the development of agricultural technology and the diversification of farming, farmers' decisions have also increased in complexity. As a result, multi-criteria decision making (MCDM) has become an important approach in planning the agricultural production. Goal Programming (GP) is one of the most used MCDM techniques that overcome some of the listed LP drawbacks [8–10]. In the literature, we can find different examples utilising the GP paradigm in fertilisation planning and nutrition management. Such examples could be [11] who have applied GP approach supported with penalty functions (PFs). [12] applied similar approach based on Euclidean distance for the problem of sugarcane fertilizer mix. [13] have applied priority goal programming in nutrition management for rice production. For the same type of production, [14] have applied fuzzy goal programming (FGP) and genetic algorithm (GA) based on fuzzy GP approach. [15] have extended common LP with binary variables into mixed integer program (MIP) and in such a manner enables considering additional technical constraints. [3] have utilised weighted goal programming (WGP) supported with penalty functions (PF) to improve LP solution and to find compromise solution of optimal fertilisation plan.

Within the crop subsector in Macedonia, vegetable production takes place on around 60 thousand hectares (or around 10% of arable land) and is the most important in terms of contribution to the gross value added (around one-third). Characteristically in the country, the production structure includes wide range of different vegetable farm enterprises and different production technologies (open field and plastic tunnels being typical for the dominant small-scale farmers).

Taking into account the above considerations, the aim of this research is to assess the influence of chemical soil properties on the optimal production plan at vegetable farms, utilising the weighted goal programing technique. This study simulates the economic performance of vegetable farms in four scenarios based on different soil contents of the key nutritive elements; hence four different fertiliser management strategies are defined. Beside the potential applicability of the MCDM innovative tool, a significant contribution of this paper is that the results confirm the theoretical and empirical benefits of the multidisciplinary approach.

MATERIAL AND METHOD

Weighted goal programming

Instead of using the traditional linear programing approach with single criterion optimization, the multi-criteria decision making (MCDM) is better suited to situations with more than one objective (or goals), such as the typical situation in which the farmer acts as a manager facing different production, technological and economic decisions.

WGP is a MCDM technique that has become a widely used approach in management science [12] and is also often applied in nutrition management which is also the case of this study. It enables analysis of decision making considering several contradictive objectives at once and searches for the best compromise solution. Therefore, the crucial objectives that are in contradiction are converted into goals, while others are usually considered as constraints in the optimization model [16]. In its mathematical formulation (1), WGP minimizes the sum of weighted undesired deviations (*min a*) from aspired values of set goals, and does not minimize or maximize the goals themselves [17]. Contrary to the classical LP model, WGP enables determination of positive and negative deviation variables, defined for each goal. Negative deviation variables (n_q) refer to underachievement, while positive deviation variables (p_q) for overachievement of the goal value. The deviations within the WGP model are calculated as a ratio, thus any marginal change of the goal is of equal importance regardless how distant it is from the aspired value [18]. The authors also argue that in order to keep the deviations in controlled margins, the WGP model should be upgraded with the system of penalty functions (PF), which will be considered in further research.

Considering that the goals are measured in different units of measurement, the selection of preferential weights determining the relative importance of each goal is crucial. The weight itself contributes to normalization of different scales the goals are expressed in (k_q), but also to ranking the decision-makers' preferences (u_q and v_q) [9, 19, 20]; In other words, this specification allows for modelling which goal should be satisfied first (prioritised) or in larger scope.

$$\min a = \sum_{q=1}^{Q}\left(\frac{u_q n_q}{k_q} + \frac{v_q p_q}{k_q}\right)$$
$$s.t.$$
$$f_q(x) + n_q - p_q = b_q \qquad \text{for } q = 1 \text{ to } Q$$
$$x \in F$$
$$n_q \geq 0, p_q \geq 0$$

Since preferential weights are of crucial importance in applied approach, it is very important how they are defined. In the literature, different methods are applied for calculating the weights (u_q and v_q) [10, 21–23]. In this study, we will apply Analytical Hierarchy Process (AHP) to calculate consistent weights for defined goals [24].

Model

This work attempts to assess the influence of different levels of soil properties on the optimal production plan at the farm level. In order to determine the optimal production structure by satisfying the preferences of the vegetable producers in Macedonia, a two stage modular model is constructed. It is a general production model based on mathematical programming techniques. The model is developed as a spread-sheet in MS Excel, enabling integration and complementarity of its modules, and can be easily adapted on different situations at the vegetable farm. In fact, the current model specification is built upon a previous base version of such model [25], specifically adapted and for the purpose of this study. The first module is supported by normative linear programming (LP) approach and it is used for calculating the aspiration values of the specific goals. These are needed for the second module where they enter as goal values. In this context, four different objective functions are calculated, (i) maximisation of the farm gross margin, (ii) minimisation of the farm working capital, (iii) minimisation of farm labour needs and (iv) minimisation of water requirements for crop production. The aim of the second module is to determine the optimal vegetable production plan at the farm level, utilising the WGP technique, considering the above mentioned four conflicting goals (i) to (iv).

The constructed model includes 214 decision variables, divided in four aggregated group of activities: (1) crop activities including 15 vegetable crops, whereas each production activity is supported by detailed enterprise budgets; this group of activities also covers the production technology and crop rotation; (2) input related activities capturing land, labour and fertilizers; (3) infrastructure activities referring to investments in plastic tunnels or irrigation systems and (4) balanced activities ensuring integrity of the solutions. Farmers are expected to make decisions under a number of constraints. The constraints in the model are determined with the typical vegetable farm characteristics. In this context, the first group comprises the endogenous constraints dealing with the production factors scarcity, including land, labour and working capital, while another group refers to the agro-technical constraints assuring that mineral nutrient requirements are met. Nitrogen, phosphorus and potassium needs per crop are included in the model to register the nutrients flow. The irrigation systems applied per crop are also subject of the agro-technical constraints. Farm decision making is influenced by external factors affecting the production structure, as market or policy constraints. A set of balance constraints is incorporated into the model through the maximum available land per crop and minimum number of crop enterprises.

Input data

Different sources of data support the optimization model. Primary data for calculating the enterprise budgets are obtained from direct interviews with vegetable producers in 2013, using a structured questionnaire. Considering the type of production and the geographical region, 60 farms from the South-East region of R. Macedonia were included in the survey.

This region is characterized with altitude of 50 to 500 m. In this first sub-Mediterranean region is the region of Gevgelija where most of the surveyed farms are located. Based on the pedological map sized 1:50.000 [26–28], different soil types and complexes are determined in this area. Alluvial and colluvial soils are of particular importance taking into consideration the biological and production-technological specifics of most vegetable crops.

The data are supplemented with Farm Monitoring System (FMS) data for the period 2005–2011, whereas FMS as an annual survey carried out by the National Extension Agency collects production, income and costs related data per farm enterprise from 600 farms in the country. In order to obtain enterprise budgets representing the current average farming behaviour, and not that of the best and most progressive farmers, a panel of relevant experts was consulted for assessing the average current farming approach [29].

The model takes into consideration a constructed case study based on a typical vegetable farm from the South-East region of R. Macedonia [25]. The typical vegetable farm was constructed upon FMS data using the cluster analysis as a multivariate statistical technique. Four factors were used to derive the clusters (farm size in hectares, gross margin, total number of crop farm enterprises and total number of vegetable activities), utilising a hierarchical procedure and Ward's minimum variance algorithm. The similarity among the objects is measured with squared Euclidean distance as a distance measure [30]. This method optimises the minimum variance within the clusters thus creating groups of relative equal sizes and shapes [31]. The cluster analysis resulted in three clusters (very small farms, small farms and medium farms). This study's typical case farm is based on the "very small farms" cluster, which represents around 70 % of the total sample size (the constrains are set at maximum 2 hectare of utilised area under open field production plus 0.5 hectares under plastic tunnels, 2200 labour hours and 1496 euros farm working capital).

Analyzed scenarios

In order to assess the influence of different levels of soil properties over the optimal production structure and farm profitability, the model assumes four different scenarios. Each scenario represents the level of average soil contents of nitrogen, phosphorus and potassium determined as kg/ha at soil depth of 20 cm [32]. In addition to the baseline scenario, three different scenarios are included for analysing the effect of the soil enrichment with soil nutrients on the optimal production structure at vegetable farms (Table 1).

For instance, the soil is optimally secured with macro nutrients in quantities of 161 kg nitrogen, 400 kg phosphorus and 400 kg of potassium.

Table 1. Level of soil nutrients in four different scenarios

Scenarios	**Level of soil enrichments with soil nutrients**	**P_2O_5 (kg/ha)**	**K_2O (kg/ha)**	**N (kg/ha)**
Baseline scenario	Medium level	250	250	91
Scenario M_Low	Low level	150	150	50
Scenario M_Optimal	Optimal level	400	400	161
Scenario M_High	High level	650	650	310

RESULTS AND DISCUSSION

Weighted goal programming as a method based on MCDM paradigm enables obtaining more positive results, closer to the practice at farm level. The obtained results confirm that the level of soil chemical properties have strong influence on the farm optimal production plan and its economic performances.

In this section, we begin with reporting the optimized production structure under the four different scenarios, followed by nutrients and fertilizer recommendations. In the end, we present the economic effect of each scenario, with 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 vegetable crops in order to distribute the market risk and to use the labour efficiently. The production plan determined with the baseline scenario (Table 2) includes diversified structure of eleven vegetable crops, cultivated on total area of 0.38 ha. Around 58 % of land is used for open field production, while the remaining are crops produced under plastic tunnels. The production of watermelon dominates the production structure with 28 % of total land and highest gross margin per crop (279.2 EUR), followed by lettuce (15 %) and cabbage (13 %).

Table 2. Optimal production structure determined with the baseline scenario

Crops	Land per crop (ha)	Share of land (%)	Yield (kg)	GM per crop (€)
Carrot 1-1	0.02	5 %	750.0	90.5
Bean 1-1	0.02	5 %	28.1	36.6
Potatoes 1-1	0.01	3 %	349.4	26.5
Watermelon 2-1	0.10	28 %	4950.0	279.2
Onion 1-2	0.00	0 %	7.9	0.9
Beetroot 1-1	0.04	10 %	937.5	16.1
Lettuce 2-2	0.06	15 %	2812.5	204.9
Melon 1-1	0.02	5 %	581.3	351.4
Cabbage 1-1D	0.05	13 %	1874.8	79.4
Spinach 1-2D	0.04	10 %	225.0	83.8
Eggplant 1-2D	0.02	6 %	1240.7	63.3
Total	0.38	100 %	–	1232.6

Note: In the respective vegetable enterprises, the first part of the code "n-nD" refers to open field production (1) or plastic tunnel production (2); the second part refers to first crop in annual rotation (1) or second crop on same land (2); and the D refers to drip irrigation (if no D in the end, it means using standard furrow irrigation)

In the case of farms cultivating crops on soil with low level of nutrients, the optimal production plan also includes eleven crops. However, the structure itself differs from the baseline scenario. Total cultivated area under this scenario captures 0.50 ha, out of which 0.29 ha are open field production and the remaining of 0.21 ha refer to the plastic tunnel production. The production of watermelon again dominates the production plan with 27 %. In this respect, it is important to mention that the model offers a possibility for stricter market constraints; for instance, if there is a projected limitation of the possible market absorption of certain crop, than a market constraint can be activated in the model. For the moment, such constraint is set for cabbage, as in many years there are large market surpluses, so the farmer cannot rely on producing that crop only. Further in the production structure, follows onion with 19 %, lettuce (15 %) and garlic (13 %). Highest gross margin in this scenario (S_Low) is evidenced for garlic production (612.7 EUR), followed by production of melon with gross margin of 464.9 EUR.

Table 3. Optimal production structure determined with the low nutrition content scenario

Crops	Land per crop (ha)	Share of land (%)	Yield (kg)	GM per crop (€)
Pepper 1-1	0.00	0 %	0.0	0.0
Carrot 1-1	0.02	5 %	992.2	118.3
Bean 1-1	0.02	5 %	37.2	48.4
Potatoes 1-1	0.00	1 %	148.8	11.2
Watermelon 2-1	0.14	27 %	6548.8	359.0
Onion 1-2	0.09	19 %	3582.0	418.3
Garlic 1-2	0.06	13 %	620.2	612.7
Lettuce 2-1	0.07	15 %	3720.9	264.5
Melon 1-1	0.02	5 %	769.0	464.9
Cabbage 1-1D	0.00	0 %	0.0	0.0
Spinach 1-2D	0.05	10 %	297.67	110.9
Total	0.50	100 %	–	2408.2

Note: In the respective vegetable enterprises, the first part of the code "n-nD" refers to open field production (1) or plastic tunnel production (2); the second part refers to first crop in annual rotation (1) or second crop on same land (2); and the D refers to drip irrigation (if no D in the end, it means using standard furrow irrigation)

The optimal production plan determined with optimal scenario (S_Optimal) (Table 4) shows that different content of nitrogen, phosphorus and potassium result in different production structure compared to the other scenarios. This is the solution with least diversified production structure, since the optimal level of soil chemical attributes leads to production of nine vegetable crops. Although with lower number of crop enterprises, the area under these crops is higher compared to the baseline scenario. The vegetable production within this scenario is organized on in total 0.49 ha, with 57 % as open field production and the remaining of 43 % are vegetable crops under plastic tunnels. As in the other cases, four major crops in this production plan are watermelon (28 %), onion (19 %), lettuce (15 %) and garlic (13 %). The production of garlic is also the most profitable crop with a gross margin determined at 605 EUR.

Table 4. Optimal production structure determined with the optimal nutrition content scenario

Crops	**Land per crop (ha)**	**Share of land (%)**	**Yield (kg)**	**GM per crop (€)**
Carrot 1-1	0.02	5 %	978.0	118.7
Bean 1-1	0.02	5 %	36.7	47.7
Potatoes 1-1	0.00	1 %	146.7	11.3
Watermelon 2-1	0.13	28 %	6455.1	365.7
Onion 1-2	0.09	19 %	3530.7	422.7
Garlic 1-2	0.06	13 %	611.3	605.0
Lettuce 2-1	0.07	15 %	3667.7	276.5
Melon 1-1	0.02	5 %	758.0	458.2
Spinach 1-2D	0.05	10 %	293.4	109.3
Total	0.49	100 %	-	2415.2

Note: In the respective vegetable enterprises, the first part of the code "n-nD" refers to open field production (1) or plastic tunnel production (2); the second part refers to first crop in annual rotation (1) or second crop on same land (2); and the D refers to drip irrigation (if no D in the end, it means using standard furrow irrigation)

Similar production structure is determined with the fourth scenario (S_High) where a situation with richer soil properties content is assumed. Table 5 present the optimal production plan including ten crops produced on total land of 0.44 ha. Considering the given constraint related to the maximum share of land each crop can have, again most represented is the production of watermelon with 28 %, followed by onion with 19 %, lettuce (15 %) and garlic (13 %). The production of garlic is similarly as in the low and optimal scenarios, single most profitable activity, with a gross margin of 540.6 EUR.

Table 5. Optimal production structure determined with the high nutrition content scenario

Crops	**Land per crop (ha)**	**Share of land (%)**	**Yield (kg)**	**GM per crop (€)**
Tomatoes 1-1	0.00	0 %	0.0	0.0
Carrot 1-1	0.02	5 %	873.8	106.0
Bean 1-1	0.02	5 %	32.8	42.6
Potatoes 1-1	0.00	1 %	131.1	10.1
Watermelon 2-1	0.12	28 %	5767.2	326.7
Onion 1-2	0.08	19 %	3154.5	377.7
Garlic 1-2	0.05	13 %	546.1	540.6
Lettuce 2-1	0.07	15 %	3276.8	247.2
Melon 1-1	0.02	5 %	677.2	409.4
Spinach 1-2D	0.04	10 %	262.1	97.7
Total	0.44	100 %	-	2158.0

Note: In the respective vegetable enterprises, the first part of the code "n-nD" refers to open field production (1) or plastic tunnel production (2); the second part refers to first crop in annual rotation (1) or second crop on same land (2); and the D refers to drip irrigation (if no D in the end, it means using standard furrow irrigation)

In the model, we determine for each scenario and for each crop production activities the required need for additional nutrients that cannot be supplied from the soil contents [32].

In Table 6, based on the model results, different fertilization strategies are suggested for each scenario. In general, soils that have poorer content of nutrients require higher fertilization. Actually, in the case of the optimal and rich soil scenario, there is no projection for application of the basic NPK fertilizer. On the other side, the low nutrient content soils and the baseline medium content soil require significant application of NPK, as the model chose the combination 8:26:26 (1162.9 kg for total land of 0.50 ha in the low content scenario and 402.1 kg for total land of 0.38 ha in the baseline scenario). Urea is also included in the fertilization program for these two soil scenarios. In the case of optimal soil nutrient availability, there is no need for basic fertilization with NPK fertilizers, except for Urea (46 %). Additionally, potassium sulfate (K_2SO_4) is foreseen for the low and baseline scenarios, while the only type of fertilizer, given the richness of soil with the required nutrients, which is proposed for the high soil properties level is superphosphate (26 %), to compensate for the lacking of this element in the soil.

Table 6. Cost and quantities of different fertilization strategies

Scenario	S_Baseline		S_Low		S_Optimal		S_High	
Fertilizers	Total Cost (€)	Q (kg/land)	Total Cost (€)	Q (kg/land)	Total Cost (€)	Q (kg/land)	Total Cost (€)	Q (kg/land)
NPK 8:26:26	196.2	402.1	567.3	1162.9				
K_2SO_4	12.3	34.5	61.0	170.5				
UREA N 46	3.6	10.9	1.7	5.0	0.43	1.3		
Super phosphate 26 %							0.0	0.0

The economic impact of different levels of soil attributes presented in four different scenarios is reported in Table 7. Small-scale farms cultivating vegetable crops on soil with medium nitrogen, phosphorus and potassium content, as determined with the baseline scenario, reveal lowest profitability, expressed as total farm gross margin, due to the optimized crop production structure and the associated higher costs for fertilizers necessary to satisfy the selected crop nutrients needs. The economic performance improves within the other three scenarios. Farms cultivating their crops on land with low level of soil properties reveal higher gross margin for about 40% compared with the baseline, due to the larger amount of land included in the solution, as well as the derived production structure. Although the working capital requirements within this scenario is also higher, the total land under vegetable crops increases from 0.38 ha in the baseline to 0.50 hectares in S_Low scenario, leading to higher gross margin at farm level.

Highest farm gross margin is evidenced for farms with optimal level of soil properties (4929 EUR/ha) and not within the S_High scenario (4904.5 EUR/ha), which is even though more economically efficient in terms of EUR per hectare utilised than S_Low scenario (3050 EUR/ha). In that case, all production factors on the case farm are optimised to achieve the highest gross margin, which also enables highest level of labour productivity, when converted to hour of engaged workforce (4 EUR/h). The relatively low difference in the farm gross margin per hectare in the optimal and high level scenarios is due to the isolated effect of the soil nutrients requirements and the similar need for fertilizers for the obtained optimal production structure.

With regard to the physical resources, the results confirm that vegetable production is labour-intensive, whereas in the S_Low scenario there is an additional need for renting seasonal labour. Highest labour requirements are noted in the optimal scenario, which interestingly is the scenario yielding highest farm return, since more labour intensive and profitable crops are included in the solution.

The water requirements for irrigating the vegetable crops are determined for both furrow and drip irrigation systems. In all four scenarios the water requirements for drip irrigation are higher confirming that this irrigation strategy is most efficient for vegetable production and should be spread more not only in plastic tunnels, but also on the open field production.

Table 7. Multi-criteria decision making results in baseline and different soil attributes impact scenarios

Scenario	S_Baseline	S_Low	S_Optimal	S_High
Economic indicators				
Farm GM (€)	667.0	1525.0	2415.0	2158.0
Farm GM/h (€)	2.3	3.1	4.0	4.0
Farm WC (€)	1584.5	2490.4	1543.0	1378.2
Land (ha)				
Total land (ha)	0.38	0.50	0.49	0.44
Open field (ha)	0.22	0.29	0.28	0.25
Plastic Tunnel (ha)	0.16	0.21	0.21	0.19
Labour (h)				
Own labour (h)	291.0	259.0	601.3	537.2
Rented labour (h)	0.0	234.1	0.0	0.0
Water (m^3)				
Furrow irrigation (m3)	326.6	309.1	304.7	272.2
Drip irrigation(m3)	712.4	800.7	789.2	705.1
Goals achieved values (€)				
Max farm GM (€)	667.0	1525.0	2415.0	2158.0
Min farm WC (€)	1584.5	2490.4	1543.0	1378.2
Min farm LAB cost (€)	291.0	259.0	601.3	537.2
Min farm WAT cost (€)	1039.0	1109.7	1093.9	977.3
Total deviations (%)	8 %	160 %	280 %	200 %
Goals deviations (%)				
Max farm GM (%)	0 %	0 %	0 %	0 %
Min farm WC (%)	8 %	103 %	74 %	41 %
Min farm LAB cost (%)	0 %	0 %	132 %	107 %
Min farm WAT cost (%)	0 %	56 %	73 %	52 %

The second stage goal programing reported in the end of Table 7 stems from the original LP solutions. We can see that in the baseline scenario, with lowest farm gross margin, there is no or very little deviation from the set goals, whereas in the highest economic impact scenario, the goals are significantly exceeded. In this farm case exercise, stretching the goals actually leads to higher profit for the farmers – with highest deviation of the labour factor and relatively low working capital involved, this scenario yields good compensation between the set goals and hence gives the highest performance.

CONCLUSIONS

Having good basis and analysis of the soil-climatic conditions in certain areas, coupled with the knowledge of the crop biology and production technology specifics can improve the development of vegetable production strategies in Macedonia in terms of value added, quantities, assortment, technology (open field production, tunnel or glasshouses) as well as the intensity of land use. In addition to the standard economic parameters in determining and optimizing the production plan at farm level, in this study we introduce deeper assessment on some soil properties (total nitrogen, phosphorus and potassium) and in that respect nutrition balance at farm level.

The main results point to the optimal scenario as the one with most efficiently allocated and utilized production resources. In this scenario, the solution provides highest gross margin, lowest number of enterprises (9 as compared to 10 or 11 in the other scenarios), highest labour engagement (double than the baseline scenario), but relatively modest working capital. It is interesting to note that the set goals in the optimal scenario are most intensively stretched, but this compromise solution nevertheless produced the best economic output.

The content of soil with macro and micro nutrients is one of the main factors for obtaining high yields, but also product quality. Vegetable crops have more need for potassium (those that were in the solution, but also in general), but nevertheless the nitrogen and phosphorus are also important. The offered options for basic fertilization and additional nutrition can be considered as reasonable and realistic solution that can be applied in practice. This is providing evidence that the theoretical approach applied in the construction of the model, when containing up-to-date technological and economic data, gives a good platform for evaluating different management practices as a very valuable farm management tool, but can also be used on macro level for sector decisions or policy related impact assessment analysis. In this regard, having a multidisciplinary approach is very useful, so the results can be as close (positive) to the reality as possible.

The model can be further improved by enhancing the plant nutrition related aspects, such as the application time of certain fertilizers (as basic or supplementary fertilization), the potential use of manure (also seen as a circular economy practice), deeper information and selection of organic fertilizers, aspects of prices and different procurement sources of fertilizers etc… These kinds of additions would add to the sophistication of the model and contribute to make the fertilization plan more realistic; from technical point of view this would mean adding additional inequality constraints [3]. Last but not least, in order to increase the applicability of the model and its positive character and to minimize the normative assumptions, an introduction of WGP with penalty function in future efforts would add to the reflected reality of the model results.

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ОЦЕНУВАЊЕ НА ВЛИЈАНИЕТО НА ПОЧВЕНИТЕ СВОЈСТВА ВРЗ ОПТИМАЛНАТА ПРОИЗВОДНА СТРУКТУРА КАЈ ГРАДИНАРСКИ ФАРМИ

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Променливоста на почвените својства влијае на одлуките на земјоделските производители во врска со утврдување на стратегија за оптимизирање на ѓубривата, како и продуктивноста на растителното производство. Целта на ова истражување е да се оцени влијанието на хемиските почвени својства врз оптималниот план за производство кај градинарски фарми во Р. Македонија, со употреба на техники на математичко програмирање. Студијата ги симулира економските перформанси на типично земјоделско стопанство со градинарско производство во четири сценарија засновани на различна содржина на клучните нутритивни елементи во почвата; според тоа, дефинирани се четири различни стратегии за примена на ѓубрива. Главните резултати се поврзуваат со сценариото со оптимална обезбеденост на хемиски својства, каде што се добива највисока бруто маржа, најмал број на линии на производство, најголема ангажираност на работна сила, но при релативно скромен работен капитал. Градинарските култури вклучени во оптималната производна структура имаат поголема потреба од калиум, но сепак значајна е улогата и на азотот и фосфорот во почвата. Понудените опции за основно ѓубрење и дополнителна прихрана претставуваат реално решение кое може да се применува во практиката.

Клучни зборови: почвени својства; оптимана производна структура; повеќекритериумско донесување на одлуки; градинарско производство