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Scientific paper
ISSN 0351-9465, E-ISSN 2466-2585
UDC:502.171:531.62 -048.34+633.11
doi: 10.5937/zasmat1904321S

Zastita Materijala 60 (4)
321 - 330 (2019)

Application of evolutionary algorithm in estimation of environmental performance in farm systems

ABSTRACT

The vast application of energy from different resources in agricultural production has resulted in negative environmental consequences. The importance of food security and sustainable production is undeniable therefore finding appropriate solutions to meet world's food requirements from one hand and environmental requirements from the other hand has become an interesting topic in the recent decades. Evolutionary algorithm (EA) can be employed in these problems because they can simultaneously focus on two or more objective functions. Multi-objective genetic algorithm (MOGA) as one of the EAs was selected and wheat as one of the most important strategic crops was chosen in order to test the application of these algorithms in farm systems. MOGA was employed to find the best mix of agricultural inputs which can be able to minimize greenhouse gas emissions and maximize output energy and benefit cost ratio simultaneously. The results revealed that on average 41% of the total energy input can be reduced and simultaneously, 68% of the total greenhouse gas emissions (GHG) emissions can be decreased. The outcomes demonstrated that on average a total amount of 28024 MJ energy from different sources is needed for wheat cultivation in the region while in the present condition on average an amount of 47225 MJ per ha is consumed. This amount of energy is responsible for 4217 kg CO_2 while it can be reduced to the value of 1502 kg CO_2 per ha wheat cultivation. The outcomes of the present study showed the valuable application of multi-objective genetic algorithm for optimization of energy consumption in wheat cultivation.

***Keywords**: Optimization; Energy management; Wheat; Greenhouse gas emissions.*

1. INTRODUCTION

The importance of food security from one hand and the sustainable food production from the other hand have caused a great deal of attention to be paid in food and agricultural sectors. Agricultural decision makers are taking advantage of all potential methods to increase the total level of production to meet world's requirements and consequently ensure food security through the world. To enhance the total level of production different approaches can be taken into consideration including increasing in the area under cultivation, the use of highly yielding varieties and intensive farming systems as well as the utilization of modern technologies [1].

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Paper received: 02. 04. 2019.
Paper accepted: 25. 08. 2019.
Paper is available on the website:
www.idk.org.rs/journal

These changes and modifications necessitate employing a large amount of inputs and energy from distinctive resources; meaning that in all modern farming and cropping systems, energy plays a key role [2-4]. Agriculture, which is both energy user and supplier in the form of bio-energy, uses large quantities of locally available non-commercial energies, such as seeds, manure and animate energy, and commercial energies directly and indirectly in the forms of diesel, electricity, fertilizers, plant protection, chemicals, irrigation water, machinery, etc. [5,6].

Though the high consumption of energy inputs in agriculture has resulted in the partial increase in production, its devastating effects on the environment should not be overlooked. A literature review clearly shows that how much concern the researchers are about the environmental impacts caused by excessive consumption of energy resources, especially non-renewable and fossil sources of energies in the agricultural sector [7,8]. Accordingly, many studies aimed at evaluating the energy consumption in agricultural sector have been conducted using different approaches. In some of these studies only input-output energies were studied [9,10] while in some of them sensitivity analysis and linear regression were exercised to find a mathematical relation between inputs and outputs [11,12]. Also, some researchers employed artificial intelligence to find a non-linear relation between inputs and outputs in crop production [13,14].

Due to the fact that energy consumption in cropping systems are not efficient, especially those farming systems located in the third world and developing countries, a lot of interests have been attracted to the field of energy optimization in crop production in these countries. Consequently, some non-parametric approaches such as data envelopment analysis (DEA) have been applied to find the optimal energy inputs which should be used in crop production [15]. The considerable disadvantage of these methods used in the conducted studies was that these models were not able to calculate global optimum values [16]. For example, in DEA approach the optimum values are calculated based on units under consideration while they may not be global optimum (based on the results reported by researchers). On the other hand, in these methods the only objective of the study was to assess the decision making units (DMU) which consumed energy efficiently in comparison with all DMUs under study. In other words, only one objective is selected to differentiate efficient DMUs from inefficient ones.

It is well documented that energy analysis, along with economic and environmental analyses, is an important tool to define the behavior of agricultural systems. Economics, Energy, and Environment are the three E's that necessarily have to be considered in all agricultural projects [17]. Therefore, a multi-objective optimization algorithm MOGA (multi-objective genetic algorithm) is needed to consider simultaneously economics, energy and environment when it is optimizing the input application rate of agricultural inputs. With regard to the descriptions above, the main goal of this study is to optimize the use of agricultural inputs using MOGA in order to maximize total output energy and benefit cast ratio and minimize the total greenhouse gas emissions (GHG) simultaneously.

2. MATERIALS AND METHODS

2.1. Data collection and processing

The Figure 1 shows distinctive steps and procedures followed to complete this research. The first step includes obtaining information about farm operations and practices to estimate how much agricultural inputs are consumed through this province during the cultivation season. A face to face questionnaire which is the prevalent method to obtain adequate information was used to gather initial information [18,19]. The agricultural inputs used in wheat farms through the region, comprising farmyard manure, N, P and K-based fertilizers, diesel fuel, seeds, pesticides and human labor, can be observed in Fig 1 and Table 3. In order to estimate how much energy from different sources is consumed to cultivate one hectare of wheat, energy coefficients which is used widely in similar studies were employed and energy equilibrium was investigated. The employed energy coefficients are presented in Table 1.

Because it was aimed to develop an optimization model to introduce the optimal amount of agricultural inputs and simultaneously evaluate its effects on environmental performance of wheat cultivation in the surveyed region, GHG emission coefficients of agricultural inputs were exercised and the total GHG emission was estimated. The three greenhouse gases considered in this study are carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4). This step includes estimation of GHGs emitted off farms and on farms.

The emissions from background system which are caused during the production of agricultural inputs are typically regarded as off farm emissions meaning that farmers do not have any control over them. The second part includes foreground information or emissions from actual crop production. These emissions are called on farm emissions and any better management can affect their amounts. The emissions included in this study comprise of emissions of N_2O as an intermediate product in the denitrification process or as a by-product in nitrification process, CH_4 and CO_2. Direct N_2O emissions resulting from the application to soils of nitrogen contained in both chemical fertilizers and manure were calculated considering that 1% of the total nitrogen applied is released as N_2O [20,21]. Indirect N_2O emissions was estimated as 0.01 kg N_2O-N emitted per kg N volatilized and 0.0075 kg N_2O-N per kg N leaching/runoff [20]. NH_3 emission was calculated as 10% and 20% of the amount of nitrogen contained in chemical fertilizers and manure respectively [21,22]. Combustion of diesel fuel during farm operations is also responsible for N_2O, CO_2 and CH_4 emissions.

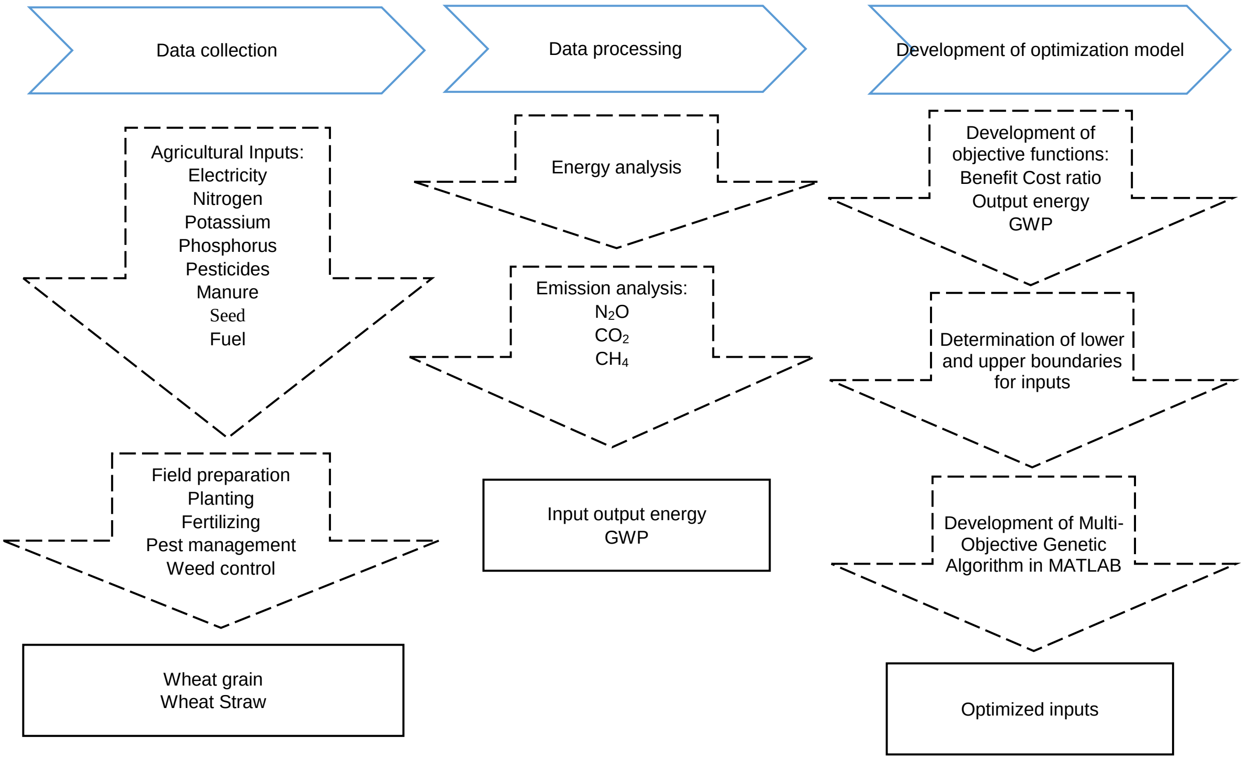

Figure 1. Research methodology of the present study

Slika 1. Metodologija istraživanja

To convert three GHGs under consideration to $CO_{2,eq}$ the following relation was used:

$$1\ kg\ CO_2 = 1\ kg\ CO_{2,eq} \quad (1)$$

$$1\ kg\ CH_4 = 23\ kg\ CO_{2,eq} \quad (2)$$

$$1\ kg\ N_2O = 296\ kg\ CO_{2,eq} \quad (3)$$

The amount of produced CO_2 equivalent was calculated by multiplying the input application rate by its corresponding emission coefficient that is shown in Table 1.

Table 1. Greenhouse gas (GHG) emission coefficients of agricultural inputs

Tabela 1. Koeficijenti emisije gasova staklene bašte od ulaza

Inputs	Unit	kg CO_2 / Unit	kg $CH_{4,eq}$ / Unit	kg $N_2O_{,eq}$ / Unit	kg $CO_{2,eq}$ / Unit
Diesel	MJ	87.64E-3	-	-	87.64E-3
Nitrogen (N)	kg	2827E-3	8.68E-3	9.64E-3	5880.6E-3
Phosphate (P_2O_5)	kg	964.9E-3	1.33E-3	0.051E-3	1010.7E-3
Potassium (K_2O)	kg	536.3E-3	1.57E-3	0.012E-3	576.1E-3
Seed	kg	151.1E-3	0.28E-3	0.4E-3	275.9E-3
Pesticide	kg	9886.5E-3	25.53E-3	1.68E-3	10971.3E-3
Electricity	MJ	114.48E-3	0.367E-3	0.005E-3	124.42E-3
Farmyard manure	kg	5E-3	-	-	5E-3

2.2. Multi-objective genetic algorithm

Genetic algorithm (GA) inspired from the natural process that drives biological evolution is widely employed to solve both constrained and unconstrained optimization problems. The genetic algorithm repeatedly modifies a population of individual solutions. At each step, the genetic algorithm selects individuals at random from the current population to be parents and uses them to produce the children for the next generation. Over successive generations, the population "evolves" toward an optimal solution. The genetic algorithm uses three main types of rules at each step to create the next generation from the current population:

- Selection rules select the individuals, called parents, which contribute to the population at the next generation.
- Crossover rules combine two parents to form children for the next generation.
- Mutation rules apply random changes to individual parents to form children.

Matlab software was used to develop MOGA. The first step was to define the objective functions. Three objective functions were considered in this study. As above-discussed, it was aimed at including economics, environment and output energy in optimization. The objective functions can be generally defined as follows:

$$F_{\max/\min} = \sum_{i=1}^{j} C_i X_i + \alpha \qquad (4)$$

where, $F_{max/min}$ = Maximizing or Minimizing objective function, Xi = Input variables, C_i = Confidents of model. SPSS software was employed to develop linear functions between input variables and output. In order to form the objective functions correctly, some important points should be taken into consideration. First of all, if linear regression is used to form objective function the variance inflation factor (VIF) should be noticed. VIF quantifies the severity of multicollinearity in an ordinary least squares regression analysis. It provides an index that measures how much the variance (the square of the estimated standard deviation) of an estimated regression coefficient is increased because of collinearity. If VIF for one of the variables is around or greater than 5, there is collinearity associated with that variable [23]. Therefore, some of the variables were excluded from the model.

The second important issue is that MATLAB software typically finds minimum of function while solving a problem. Two objective functions (benefit cost ratio (F1) and output energy (F3) should be maximized while the third objective function (greenhouse gas emission (F2) needs to be minimized. Accordingly, in order to introduce objective functions one and three appropriately, they should be multiplied by (-1) as follows:

$$F_1 = (-1) \times (\beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8) \qquad (5)$$

$$F_2 = \lambda_1 X_1 + \lambda_2 X_2 + \lambda_3 X_3 + \lambda_4 X_4 + \lambda_5 X_5 + \lambda_6 X_6 + \lambda_7 X_7 + \lambda_8 X_8 + \lambda_9 X_9 + \alpha \qquad (6)$$

$$F_3 = (-1) \times (\gamma_1 X_1 + \gamma_2 X_2 + \gamma_3 X_3 + \gamma_6 X_6 + \gamma_7 X_7 + \gamma_8 X_8) \qquad (7)$$

The constraints of the problems need to be defined so precisely. There are three forms of constraints which can be employed in an MOGA optimization.

- Linear equality: i.e. A*X=B
- Linear inequality: i.e. A*X <= b
- A set of upper and lower bounds: i.e. lb <= X <= ub

There were only upper and lower bounds which were considered to run the model. Table 2 summarizes the selected upper and lower bounds.

Table 2. Lower and Upper bounds in optimization problem

Tabela 2. Donje i gornje granice u optimizacionom problemu

Variables	Lower bounds	Upper bounds
Manure	1.5	4
P_2O_5	65	110
K_2O	50	90
Seed	160	350
N	100	160
Pesticide	4	-
Labor	250	450
Diesel	80	150
Electricity	450	800

The following pseudo code was used to develop GA optimization model:

```
Begin
    Input npo, pc, pm Max iteration;
    Generate initial population;
    Evaluate fitness value of initial population;
    Assign rank base on pareto dominance sort;
For i=1 to Max iteration do
        For j=1 to 2*round ((pc*npop)/2);
        Select parent by binary tournament selection;
        Select one of the crossover;
        Apply Crossover;
End for
    Combine offspring and population p=Intersection (P,Q);
    For j=1 to round (pm*npop);
        Select Chromosome by random selection;
        Apply mutation;
End for
    Combine mutation members and population p=Intersection (P,Q);
    Assign rank based on pareto dominance sorting algorithm;
    Calculate the crowding distance of individuals in each front;
    Select the best npop individual based on rank and crowded distance;
    Assign rank based on pareto dominance sorting algorithm;
    Calculate the crowding distance of individuals in each front;
End for
    Output: Extract the best pareto front;
End
```

3. RESULTS AND DISCUSSIONS

3.1. Energy flow in wheat cultivation

The analysis of input-output energy flow in wheat cultivation in the selected area clearly shows that a high amount of energy from different sources is used while the most part of the consumed energies belongs to the non-renewable sources. The outcomes of the energy analysis of wheat cultivation are summarized in Table 3. The average of total energy input was calculated as 21609 MJ per ha. This manifestly reveals that the consumption of energy in wheat cultivation in this region is not efficient and under different farm managements different amount of energy is consumed. As can be inferred from the results depicted in the Table 3, the consumption of energy from different sources varies from farm to farm. The results of the present study are compatible with those studies conducted in different parts of Iran in which the authors unanimously declared that most of the farmers in Iran are not aware of accurate farm managements especially about management of agricultural inputs and a high degree of deficiency can be seen in Iranian cropping systems [24, 25].

Table 3. Energy equivalents of agricultural inputs and outputs
Tabela 3. Ekvivalenti energije od ulaza i izlaza

Item	Unit	Energy equivalent (MJ unit^{-1})	Quantity (Unit ha^{-1})	Average (MJ ha^{-1})
A. inputs				
Labor	hr	1.96	380	744.8
Diesel fuel	L	47.8	98	4684.4
Chemical fertilizers				
Nitrogen(N)	kg		110	8591
Phosphate(P2O5)	kg	17.4	70	1218
Potassium(K2O)	kg	13.7	50	685
Farmyard manure	tonne	0.3	2000	600
Pesticides	kg	120	4	480
Electricity	kWh	12	541	3033
Seed	kg		121	1573
Total energy input	MJ			21609.5
B. output				
Wheat	kg	13	2900	37700
Wheat Straw	kg	17.25	3500	60375

Taking a look on the specific results of the input-output energy analysis (Fig 2) provides us with more details about wheat cultivation in the surveyed region. N-based fertilizers and diesel fuel are the most important energy inputs in wheat cultivation. Electricity is the third important energy input and this energy is a direct form of energy which is consumed to extract water from wells. The water, which is itself a sensitive issue in recent decades, is generally extracted from local wells using electrical pumps. It means that a high amount of electricity is used in irrigation systems. Electricity is accounted for 14% of the total energy input followed by Seed (7%) and phosphate (6%).

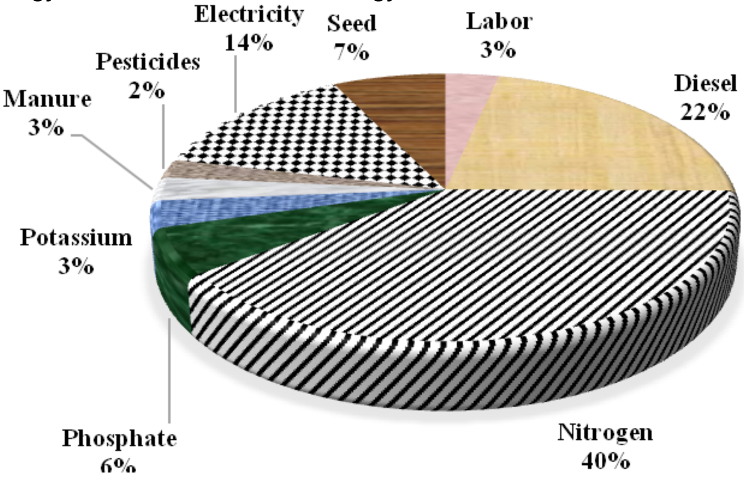

Figure 2. The share of energy inputs in wheat cultivation in Esfahan Province

Slika 2. Ulazi energije u proizvodnji pšenice

These results are compatible with the findings of [26] where similar observations have been achieved. They reported that N based fertilizers dominated total input energy in wheat cultivation and followed by diesel fuel which was used for farm operations (11% of the total energy input) and water extraction (9% of the total energy input).

3.2. Evaluation of GHG emissions

To evaluate the GHG emissions in wheat cultivation, a land based functional unit was chosen meaning that all emissions were calculated per ha. The brief results of GHG emissions are depicted in Table 4 and Fig 3. On average, 2503 kg $CO_{2,eq}$ per ha is emitted during wheat cultivation season. N-based fertilizers accounts for 62% of the total GHG emissions (1542 kg $CO_{2,eq}$) followed by electricity and diesel fuel with a share of 15% and 12% respectively. In another study entitled conducted in [27], it was concluded that on average, 1171 kg $CO_{2,eq}$ was emitted in wheat cultivation

Table 4. Greenhouse gas emissions of inputs in wheat production

Tabela 4. Emisija gasova staklene bašte od ulaza u proizvodnji pšenice

Item		Land Based FU (kg emission per ha)			
		CO_2	CH_4	N_2O	$CO_{2,eq}$
N		311.0	1.0	4.1	1542.3
P_2O_5		67.5	0.1	0.0	70.7
K_2O		26.8	0.1	0.0	28.8
Pesticides		39.5	0.1	0.0	43.9
Seed		18.3	0.0	0.0	33.4
Diesel		693.1	0.01	0.0	294.6
Electricity		347.3	1.1	0.0	377.4
Manure		10.0	1.6	0.2	111.9
Total		1513.5	4	4.4	2503

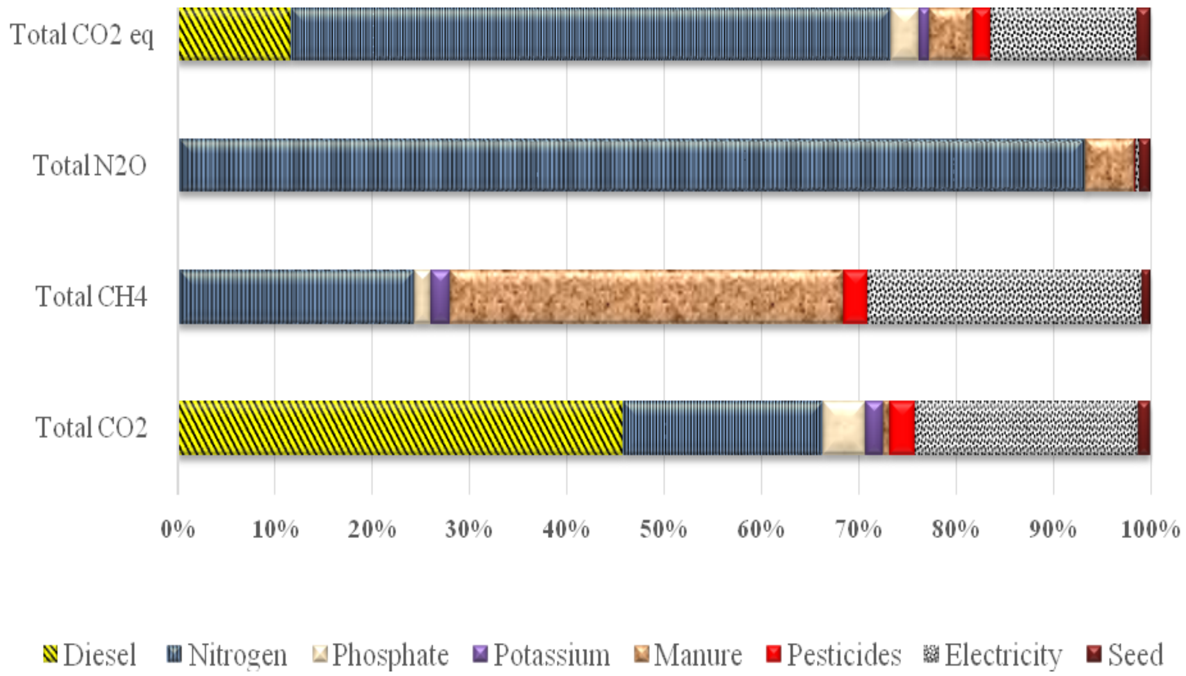

Figure 3. The contribution of agricultural inputs in the GHG emissions

Slika 3. Uticaj ulaza na emisiju gasova staklene bašte

On farm emissions account for more than 55% of the total emissions where direct and indirect N_2O emissions from application of N-based fertilizers to the soil is responsible for 69% of the total on farm emissions followed by Diesel fuel (22%) and manure (9%). N-based fertilizers, diesel fuels and electricity are the most important contributors to the GHG emissions in crop production. Many researchers who appraised environmental consequences of cropping systems have asserted that these input energies are inefficiently applied in crop cultivation and are responsible for the high amount of GHG emissions [16]. Therefore, the optimization of agricultural inputs, especially N-based fertilizers, diesel fuel and electricity should be seriously considered.

3.3. The results of MOGA

GA is capable of searching different regions of a solution space simultaneously, therefore, it can find a diverse set of solutions for difficult problems with non-convex, discontinuous, and multi-modal solutions spaces [28]. The process of finding optimum solutions by MOGA is repeated until a termination condition has been reached. Common terminating conditions are as follows:

- A solution is found that satisfies minimum criteria.
- Reaching a fixed number of generations
- Getting an allocated budget (computation time)
- The highest ranking solutions fitness is reaching or has reached a plateau such that successive iterations no longer produce better results
- Combinations of the above

MOGA computed 99 optimal solutions by which the total output energy and benefit cost ratio were maximized while total GHG emission was minimized. To find the best solutions some criteria were defined as follows:

1. The total GHG emissions should be less than that of in the current condition.
2. The total input energy calculated from optimum solutions should be less than the average of the region.
3. The total output energy cannot exceed the maximum output energy observed in the region.

Accordingly, the best optimum solutions out of 99 which were generated by genetic algorithm were selected. The optimum solutions can be seen in Table 5.

Table 5. Total energy input and total GHG emission under optimum condition

Tabela 5. Ulaz ukupne energije i emisija ukupnih gasova staklene bašte pod optimalnim uslovima

Item	Unit	Quantity (Unit ha^{-1})
A. inputs		
Labor	hr	380.9
Diesel fuel	L	80.4
Chemical fertilizers		
Nitrogen(N)	kg	100
Phosphate(P2O5)	kg	65.3
Potassium(K2O)	kg	50.2
Farmyard manure	tonne	1.6
Pesticides	kg	4.1
Electricity	kWh	452.8
Seed	kg	160.4
Total energy input	**MJ**	**18911.3**
Total GHG emission	**kg CO_{2eq}**	**2112.2**

The results signifies that there is a high potential for reduction of negative environmental impacts of GHG emissions in the region while the output energy and benefit cost ratio are kept in an acceptable level. These results demonstrates that the total GHG emissions can be reduced to the value of 2112 kg $CO_{2,eq}$ per ha which is significantly fewer than the average of the region. Under this condition, the total input energy was calculated as 18911 MJ per ha while the average of the region was 21609 MJ per ha.

It should be highlighted that the values presented in Table 5 are the most optimum amount of agricultural inputs which can be employed in a cultivation season, meaning that all agricultural inputs are used completely efficiently while in reality it is not possible that a system behaves completely efficiently. But it can be a good help for farm managers to find practical ways for reduction of agricultural inputs. i.e. the results revealed that the irrigation system in wheat cultivation needs to be changed and the traditional irrigation systems should be replaced with modern ones. Base on the outcomes on average 3033 MJ energy is used for extraction and farm irrigation while it can be reduced to the value of 1630 MJ per ha.

Fig 4 displays the difference between current and optimum conditions of wheat farms from energy input and total GHG emissions point of views. The results shows that for wheat cultivation in this region on average 100 kg N-based fertilizers should be used while in the current condition an average of 110 kg is applied and it ranges between 90 to 150 kg. For this purpose, applying soil analysis to specify the soil fertilizer requirements (to decrease high chemical fertilizer energy consumption and GHG emissions) is a practical way which helps farmers decrease application of fertilizers. It should be mentioned that such a deep transition from an inefficient cropping system to an efficient one necessitates special support from agricultural policy makers and the government to farmers.

In this study, wheat production was selected as a case study to evaluate the pros and cons of suggested approaches. This approach is so practical and can be used in other production systems where there are concerns about efficient use of resources. Application of MOGA necessitates developing production functions. To reach trustable and valuable results, it is highly recommended considering several objectives, simultaneously. Economic issues (benefit cost ratio), environmental impacts, input/output energy, etc. are some of the most important factors which can be considered in this approach.

In a production system which comprises of several stages (a cradle to grave approach), MOGA can be applied in each step separately. It means that a supply chain can be divided into subsections, then suggested approach is used in each subsection. For example, imagine we face a production chain in which the final product is bread. In this example we should deal with production of agricultural inputs, farm practices, a factory in which the wheat produced is converted to flour and the bakeries which can be considered separately. MOGA in a factory stage is similar to that in a farm stage. Determination of objective functions is one of the most important part of this approach. These objective functions need to be defined clearly for each subsection. Constraints, which play a key role in optimization problems, should be assessed and instructions suggested above should be followed. This causes that the results of each subsection is not affected by previous step(s). i.e. while the farm stage is or is not optimized, the factory stage can be optimized separately. It helps us to use this approach either in whole life cycle of a product or in hot spots only.

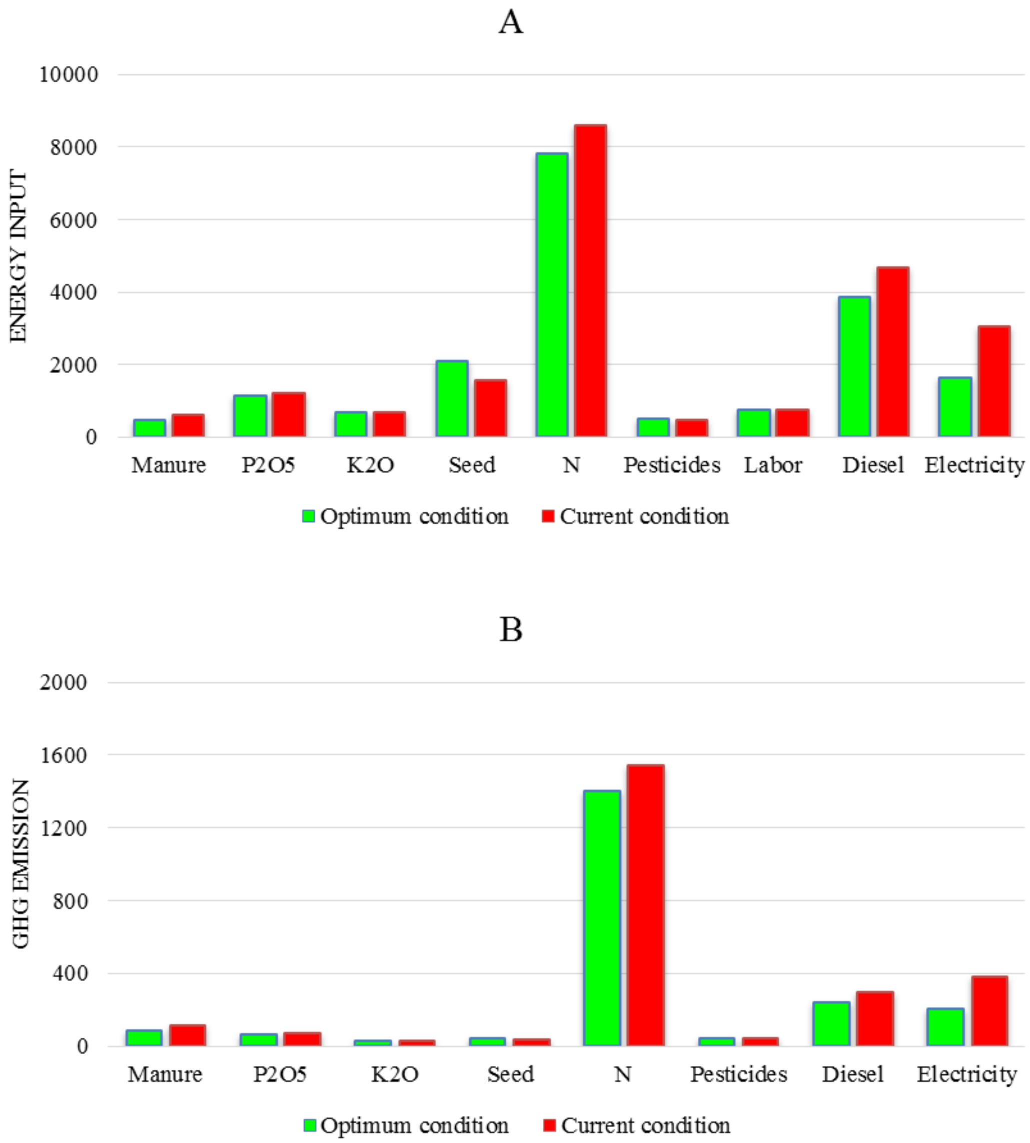

Figure 4. Comparison of energy input (A) and GHG emission (B) under current and optimum conditions

Slika 4. Upoređenje ulaza energije A i emisije gasova straklene bašte B pod trenutnim i optimalnim uslovima

4. CONCLUSIONS

In this study the potential of multi-objective genetic algorithm as one of the evolutionary algorithms for optimizing agricultural inputs in wheat cultivation was evaluated using data gathered from wheat farms. The importance of economics, energy and environmental issues have caused three objective functions were developed in order to find the best optimal agricultural inputs which are necessary in wheat cultivation. The best solutions were chosen from last generation produced by developed algorithm based on genetic programing. The optimal solutions demonstrated that the consumption of energy in the current condition is 12% more than that of optimum conditions and it causes 16% extra GHG emissions. Of all energy inputs, electricity held the first rank with a reduction of 46%. It shows that current irrigation system in wheat cultivation is not efficient at all. The flood irrigation can be replaced with sprinkler irrigation or drip irrigation systems. Apart from deep changes in irrigation systems, it is highly recommended that renewable sources of energy should be utilized to generate electricity. Also, chemical fertilizers especially the N-based fertilizer should be utilized based on plants' requirements which can be determined based on soil analyses. Fertilization management, integrating a legume into the crop rotation, application of composts, chopped residues and other soil managements were proposed to reduce the chemical fertilizer energy requirements. Diesel fuel is another input which is applied during farm operations. The results of this study showed that the current application of this input is not efficient and there is a high potential for its reduction. Better farm managements like application of new agricultural machineries which can carry out some farm operations simultaneously is highly recommended.

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IZVOD

APLIKACIJA EVOLUCIONOG ALGORITMA ZA ESTIMACIJU UTICAJA SISTEMA FARME NA PRIRODU

Široka primena energije od različitih izvora u poljoprivrednoj proizvodnji je rezultovalo u negativnom uticaju na prirodu. Važnost sigurnosti hrane i održiva proizvodnja je neizbežna i prema tome pronalazak pogodnih solucija za zadovoljavanje svetskih zahteva za hranu kao i zahteva spoljašne prirodne okoline je interesantan zadatak u skorijim dekadama. Evolucioni algoritmi se mogu koristiti za ove probleme zato što oni mogu simultano da se fokusiraju na više ciljnih funkcija. Višekriterijumski genetski algoritam je jedan od tih evolucionih algoritama koji je korišćen u ovom radu, a pšenica je korišćena kao jedan od najbitnijih izvora hrane. Cilj je bio pronaći optimalne ulazne parametre koji će minimizovati emisiju gasova staklene bašte i maksimizovati izlaznu energiju istovremeno. Rezultati prikazuju da u proseku 41% ukupne ulazne energije se može smanjiti i simultano, 68% od ukupne emisije staklene bašte se može smanjiti. Retultati prikazuju da je ukulno 28024 MJ ukupne energije potrebno od različitih izvora za obrađivanje pšenice u datom regionu dok je u datim uslovima ukupno 47225 MJ potrešene energije u proseku. Ta količina energije je odgovorna za 4217 kg CO_2 dok se to može smanjiti na vrednosti od 1502 kg CO_2 po hektaru za proizvodnju pšenice. Dobijeni rezultati u ovom istraživanju prikazuju korisnu aplikaciju više kriterijumskih genetskih algoritama za optimizaciju potrošnje energije u proizvodnji pšenice.

***Ključne reči**: Optimizacija; Menadžment energije; Pšenica; Emisija staklene bašte.*

Naučni rad
Rad primljen: 02. 04. 2019.
Rad korigovan 26.05.2019.
Rad prihvaćen: 25. 08. 2019.
Rad je dostupan na sajtu: www.idk.org.rs/casopis