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Application of Linear and Non-linear Programming Model to Assess the Sustainability of Water Resources in Agricultural Patterns

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Abstract

Water resources sustainability is one of the major issues in the agricultural sustainability. In this study sustainability of water resources has been investigated by use of linear and non-linear models in six models based on optimal utilization of water resources in the north parts farms of Iran because of incorrect use of agricultural water resources, from 2011 to 2012. Also "gross margin per a unit of water consumption" and "employment per a unit of water consumption" are used as indicators for assessing the sustainability of cropping patterns. The results show that cropping pattern of fractional goal programming (FGP) model has been near to current situation and has shown realistic conditions according to expertise and advantage of this area in cultivation of certain crops. So the FGP model has desirability in each of indicators than other five models.

Keywords:
Consumers, Hedonic Pricing, Cowpeas, Nigeriawater resources sustainability, Fractional goal programming, Cropping pattern, The north parts farms of Iran

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INTRODUCTION

Sustainability of natural resources, especially water and soil that are considered as the main sources of production are one of the most fundamental challenges that all countries are faced them (Amini Faskhodi and Nori, 2010). Water is a basic need for the sustainability of life on earth (Amini Faskhodi and Nori, 2010). Sustainability is not a new concept and human always has tended to maintain its vitality resources (Oron and Gillerman 2008). In recent decades, attention to sustainability and management of water resources as vital sources of life have become the main and significant issue (Borimnejad and Sharifat, 2012). Low productivity leads to loss of water resources. Productivity of water use in the agricultural sector of Iran is very low (Bakhshi *et al.*, 2011). In the north parts farms of Iran, water transfer efficiency from the source to field is low that leading reduces of crop production. 33% of the water extracted from various sources of this area is wasted (Faskhodi and Nori, 2010). Actual efficiency in the north parts farms of Iran is 32 percent and 80 billion m3 of agricultural water has been wasted. This has led to that agriculture is not profitable in this area (Faskhodi and Nori, 2010). Based on, farmers' attention to the correct exploitation of these resources is essential. Ratios are considered a natural way to deal with related issues to the sustainability of agricultural systems. In this framework, the purpose is not just to maximize or minimize the objective function, rather optimization the inputs to the outputs is proposed. So in order to explain the stability, should be paid to the comparison of input and output. Accordingly, sustainable use of agricultural water resources is one of the most important issues in the sustainability issues that in this study are considered as input. On the other, appropriate levels of income are considered as an economic factor and creation of employment opportunities as needed social factors for sustainability of agricultural systems. To this aim, in this study sustainability of water resources has been investigated by use of linear and non-linear models in six models based on optimal utilization of water resources in the north parts farms of Iran because of incorrect use of agricultural water resources, from 2011 to 2012. Also "gross margin per a unit of water consumption" and "employment per a unit of water consumption" are used as indicators for assessing the sustainability of cropping patterns.

Studies that have been done in this case, Lara and Minasiam (1999) are presented Fractional Programming as a tool for studying the sustainability of agricultural systems. This study, the essentials of the technique in both the single and the multi-objective cases are outlined. Their results show, fractionalizing can also be a useful way of getting a reduced set of efficient solutions. So, FP has a theoretical as well as a practical usefulness. Borimnejad and Sharifat (2012) present a multi-objective model for efficient allocation of water resources from the perspective of sustainable development. The results gained from this study indicate that with the increase for water demand, the efficient allocation can be carried out in a way that different users of water resources will suffer the least and thus move towards sustainability. Amini Faskhodi *et al.*, (2010) in their paper introduces two ratio objective functions in order to assess the sustainability of a rural farming system by simultaneously optimizing these ratio indicators and subsequently determining the optimal cropping pattern. Aimed to this, the Fractional Programming (FP) procedure has been used. Results of this study show, the associated environmental impacts of farming activities can be reduced by more efficient use.

MATERIALS AND METHODS

Usually in agricultural economics studies for calculating water sustainability indicators, fractional and goal programming models are used that we will try to choose the best model to calculate the indicators by creation a relationship among the models. In this study, to determine the pattern and assessment of agricultural sustainability indicators in north parts farms of Iran, Linear Programming, Goal Programming, Fractional Programming and Fractional Goal Programming model are used with multiple objectives that are connected as rings. Accordingly, the considered model can be used the terms of three objectives of maximizing gross revenue, employment and minimizing of water consumption. In order to linearize multi-objective programming models, three methods of restricted, weighted and non-inferior set estimation methods are used (Sabouhi, 2012). We use weighted method for this study. In fact, the weight of each objective enters in the objective function due to their weight.

According to the proposed model, Simple linear programming model is minimized or maximized the objective function given the restrictions. But, in this case, the inputs used in production are assumed to be homogeneous. In other words, restrictions of related to sustainable agriculture are not in the model. However, Fractional programming model can enter restrictions of sustainable agriculture in the objective function (Zamani *et al.*, 2010). Also this model makes easy manage of answers (Borimnejad and Yazdani, 2006). The next model is Goal programming that is a branch of multi-objective optimization, which in turn is a branch of multi-criteria decision analysis (MCDA), also known as multiple-criteria decision making (MCDM). This is an optimization programmer. It can be thought of as an extension or generalization of linear programming to handle multiple, normally conflicting objective measures (Pati *et al.*, 2006). Also, in Fractional Goal Programming model, objectives are linear fractional functions (Caballero and Hernandez, 2010). Thus if these ratios had it verify certain target values, we would have a set of fractional goals (Gomez *et al.*, 2006).

Models of this study

The linear and goal programming model are defined as follows:

$$\begin{aligned}
&Max\left\{\sum g_i \times x_i, \sum L_i \times x_i\right\}\\
&st:\\
&1)\sum_i a_{ij} \times x_i \le b_j \qquad \forall j\\
&2)\sum_i t_j \times x_i \le 0 \qquad \forall_i\\
&3)\sum_i w_i \times x_i \le \lambda tw \qquad \forall_i\\
&4) x_i \ge f_i \qquad \forall_i\\
&x_i \ge 0
\end{aligned} \tag{1}$$

$$\begin{aligned}
&Minz = w_m \times n_m\\
&st:\\
&1)\sum g_i \times x_i, \sum_i L_i \times x_i + n_m - p_m = u_m \qquad \forall_i\\
&2)\sum a_{ij} \times x_i \le b_j \qquad \forall_j\\
&3)\sum_i t_i \times x_i \le 0 \qquad \forall_i\\
&4)\sum_i w_i \times x_i \le \lambda_{Tw} \qquad \forall_i\\
&x_i \ge 0
\end{aligned} \tag{2}$$

The Fractional and Fractional Goal Programming model are defined as follows:

$$\begin{aligned}
&Max\left\{\frac{\sum g_i \times x_i}{\sum w_i \times x_i}, \frac{\sum L_i \times x_i}{\sum w_i \times x_i}\right\}\\
&st:\\
&1)\sum_i a_{ij} \times x_i \le b_j \qquad \forall_j\\
&2)\sum_i t_i \times x_i \le 0 \qquad \forall_i\\
&3) x_i \ge f_i \qquad \forall_i\\
&x_i \ge 0
\end{aligned} \tag{3}$$

$$\begin{aligned}
&Minz = w_m \times n_m\\
&st:\\
&1)\frac{\sum g_i \times x_i}{\sum w_i \times x_i}, \frac{\sum L_i \times x_i}{\sum w_i \times x_i} + n_m - p_m = u_m \forall_m\\
&2)\sum_i a_{ij} \times x_i \le b_j \qquad \forall_j\\
&3)\sum_i t_i \times x_i \le 0 \qquad \forall_i\\
&4) x_i \ge f_i \qquad \forall_i\\
&x_i \ge 0
\end{aligned} \tag{4}$$

In these models:

i is products of cropping pattern in the north parts farms of Iran (rice, wheat, barley, cucumber, tomato and watermelon); **j** is production inputs (land, fertilizer, pesticides, labor, machinery, nitrogen and potassium fertilizer); **n** is negative deviations; **p** is positive deviations; $\mathbf{g_i}$ is gross revenue of each **i** product; $\mathbf{L_i}$ is the amount of used labor in each **i** product; $\mathbf{w_i}$ is the amount of required water to produce an hectare of **i** product; $\mathbf{a_{ij}}$ is technical coefficients of **i** product of **j** input; $\mathbf{b_j}$ is available amount of input **j**; $\mathbf{t_j}$ is coefficients of the **i** product in period; **λ** is irrigation efficiency (this factor represents the amount of irrigation efficiency that use to calculate the total plant available water); $\mathbf{t_w}$ is the total available water resources; $\mathbf{f_i}$ is at least of **i** product cultivation levels; $\mathbf{w_m}$ is each of goals weight (typically two ways are used to calculate the objective weights, AHP method and relative weighting method, which in this study relative weighting method is used and due to unification of deviation variable units, this variables are divided on the right values into their equations and are multiplied at 100); nm is negative deviations of m goal and pm is positive deviations of m goal (as mentioned, for goal programming model, levels of objectives are obtained by solving two linear programming model with the goal of maximizing profits and minimizing employment).

Objective function is maximizing of employment and gross profit in equation (1). In this equation, restriction (1) is availability of production inputs, restriction (2) is crop rotation (in order to not culture of fall and spring crops, this limitation is used as a limitation rotation), restriction (3) is available water in the region and restriction (4) is the minimum strategic crops of this area (rice, wheat, tomatoes). Since these crops are the only strategic crops and farmers of this area have expertise in cultivation of these crops, to prevent of products removal, in proposed cropping pattern minimum cropping is considered for these products. After solving the model and obtaining the objective function values, these values are considered as a goal in the equation (2). Objective function is minimum achievement of goals level given the importance of each of these in equation (2). In this equation, restriction (1) is goal restriction (goal amount of solving the model (1) for each of the objectives). Other restrictions of this equation are such as the previous equation. Objective function is maximizing level of gross revenue and employment than water used in equation (3). Equation (4) is calculated after solving the model (3) and clarification each of goals. Objective function and restrictions of this model is such as equation (2).

Required data set is collected through random sampling and completing the questionnaires of 115 farmers at 2011-2012 crop years in the north parts farms of Iran that are statistical population of this study. Major activities of farmers production are includes of: x_1: rice (ha), x_2: irrigated wheat (ha), x_3: irrigated barley (ha), x_4: watermelon (ha), x_5: cucumber (ha), x_6: tomatoes (ha). In this study **TL** is total of workforce (person/day), **TGP** is total gross profit (million rials), **TW** is total water used (100 m^3), **LPGM** is linear programming model with the objective of maximize the gross margin, **LPL** is linear programming model with the objective of maximize the employment, **LPG** is linear goal programming model, **FGPM/TW** is fractional programming model with the objective of maximizing the gross margin to water used, **FPL/TW** is fractional programming model with the objective of maximizing the employment to water used and **FGP** is fractional goal programming model.

RESULTS AND DISCUSSION

In this study, two linear programming models were calculated with the objectives of maximizing employment (LPL) and gross margin (LPGM). As these results show, barley cultivation due to the low gross revenue and also cucumber cultivation due to the high cost of cultivation and having roughly equal income to other products have not included in the cropping pattern. So that it also happened in the LPL model. Rice cultivation because of having potential employment in this area and making income in both linear model patterns has contributed high cropping pattern. The results of solving linear and nonlinear models show in table (1).

The next step, results of LGM (2,346,894.399 million Rials) and LPL (2,702,174.435 person/day) model as goal for LPG models have used. By using results of the cropping pattern from each of the models have calculated amounts of TL, TGM and TW. Then, due to objectives of this study, division between the gross profit and employment on the function of water used, two fraction objective functions have been created that shown in model (5). Two models of

Table 1: Results of activity patterns in linear and nonlinear programming models

Models	Patterns					
	X1	X2	X3	X4	X5	X6
LPGM	23147	49.9697	0	13908	0	50.458
LPL	70.29383	1408	31.3464	40.25231	0	420
LPG	30.24906	1408	56.3210	20.37435	0	420
FGPM/TW	19800	1408	41.8559	10.13638	0	3805
FPL/TW	19800	1408	60.1624	40.17187	0	420
FGP	19800	1408	1624	111817	17.1845	420

Source: Research findings

Table 2: Results of water sustainability indicators in linear and nonlinear programming models

Models	Indicators				
	TL	TGM	TW	TL/TW	TGM/TW
LPGM	689.1995059	399.2346894	016.2258876	883.0	038.1
LPL	425.2702174	796.3090520	2826853	955.0	093.1
LPG	2352785	4.3193235	3.2367696	993.0	348.1
FGPM/TW	287.1908357	245.2379749	513.2046247	932.0	162.1
FPL/TW	453.2106586	453.2106586	9.1920405	953.0	096.1
FGP	4435297	6420362	5.4545515	975.0	412.1

Source: Research findings

FGPM/TW and FPL/TW with amount of 1.162 and 0.932 as goal for model (6) have determined for simultaneously maximizing of this two fraction function. As show in table (1), cropping of cucumbers and tomatoes due to the high water requirement compared with employment have small contribution in the FPL/TW model that this issue is true for cropping of cucumbers in FGPM/TW and cropping tomatoes in FGP model.

In the following, to compare the results of this activity patterns in relation to two indicators of TL/TW and TGM/TW have been explained as instrument for assessing sustainability of agricultural systems in the different models. As the table (2) shows, the amount of each indicator compared to other linear model has been developed in LPG model. Indeed, TGM/TW indicator in LPG model has grown 29% than LPGM model and 18% than LPL model. Also TL/TW indicator in LPG model has grown 12% than LPGM model, but this indicator has decreased 3% than LPG model.

On the other hand given the results of Table (2), results of LPG model have considerable growth in all indicators comparison with other nonlinear models. So that two indicators of TGM/TW and TL/TW in this model than FGPM/TM and FPL/TW models have increased respectively 21%, 28% and 4%, 2%. Indeed, as can be seen linear and nonlinear of goal programming model than single-objective fractional and linear models is created more favorable conditions in both indicators. The fractional programming models than linear programming models are created more favorable conditions in TGM/TW indicator than TL/TW indicator. So that FGP model than other models has shown favorable condition. Cropping pattern by FGP model will be created more favorable conditions in each of both indicators.

The shape (1) shows suitable condition in order to compare each of the indicators in different models than current condition. TGM/TW and TL/TW indicators in fractional goal programming model have been developed respectively 25% and 2% than current condition. This topic show high capacity of this region to develop sustainability indicators, specifically, the TGM/TW indicator.

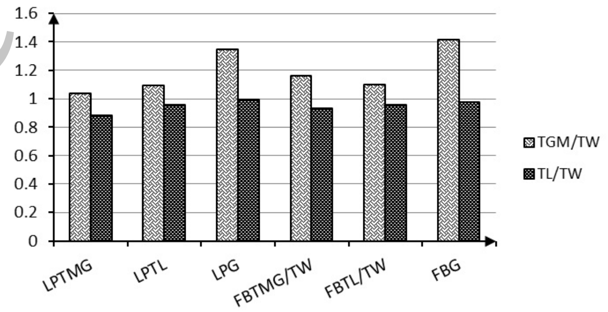

Figure 1: Condition of water sustainable indicators in linear and non-linear models and current condition.
Source: Research findings

CONCLUSION AND RECOMMENDATION

In this study in order to assess the sustainability of cropping patterns in the north parts farms of Iran, six models have been investigated. The results show that FGP model has desirability in each of indicators than other five models. On the other, cropping pattern of this model has been near to current situation and has shown realistic conditions according to expertise and advantage of this area in cultivation of certain crops. Results show that changes in cropping patterns according to the proposed goal programming models could be improved a significant portion of farmers lost profits that lead to decrease of the TGM/TW indicator in current situation.

According to the results of this study, the fractional goal programming model is appropriate tool for analysis on water resources suitability and policy makers could benefit of this instrument to achieve more accurate planning.

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