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Determination of Optimal Pattern of Conventional Agrarian Activities of Forest Fringe Villagers in Hezarjarib Area, Iran

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ABSTRACT

For the rural population, an improvement in the income of the agriculture and allied sectors is essential for improving the welfare, rural economic prosperity, and the overall economic development. The objective of this study was to determine the optimal pattern in various activities of forest fringe villagers of Hezarjarib area in 2013 for management of resources and rural development planning. For this purpose, the sample size was estimated to be 160 households out of a total of 472, by the use of proportional random sampling method. To collect data, we used a questionnaire whose reliability coefficient was determined as 0.81, by using the split-half method. The results of linear and goal programming model showed that, among the conventional activities of villagers, animal husbandry activity with the highest proportion played the key role in households' welfare, representing 51.42% of the total income of household. Moreover, Goal Programing (GP) model was determined as a useful model to increase households' welfare (10.42%) and reduce deforestation (74.6%). Accordingly, it is indicated that there is a potential to improve existing conditions and access to greater welfare in the study area. Thus, the production planning and guidance according to the above results can play an important role in villagers' activity development.

Keywords: Multi objective planning, Rural economy, Welfare.

INTRODUCTION

A glance at rural development history shows that agriculture development in developing countries has been considered as the most important factor in rural development during the 1950s and 1960s. (Dias and Vikramanayak, 1998). According to many researchers and policy makers in the past (before 1980s), rural economy of developing countries has long been regarded as synonymous with agriculture development, but in recent years, this view has changed. Such diverse activities as government, commerce, and services are seen as providing most income in rural households (Richard and Adams, 2001).

The crop planning issue of agricultural system is usually formulated as a single objective Linear Programming (LP) model, that is an optimal decision making tool. But, many real world problems in the agricultural sector are Multi-Objective (MO) in nature. However, at a regional level and in terms of agricultural development, MO being in conflict with each other need to be addressed further (Xevi and Khan, 2005). For the MO functions, the Decision Maker (DM) could set goals for each objective that he/she wishes to attain. Multi-Objective Linear Programming (MOLP) techniques such as Goal Programming (GP) and Compromise Programming (CP) can be used to solve all these problems. The GP is the most widely used Operations Research/Management Science (OR/MS) technique which has been used for many years in agricultural management decision-making. GP was originally proposed by Charnes and Cooper (1961) and further developed by Ignizio

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(1976), Charnes and Cooper (1977). The GP and its variants have been successfully introduced in agricultural planning (Rehman and Romero, 1984). There are three major models in GP which are most widely used as Lexicographic GP (LGP), Weighted GP (WGP) and MINMAX (Chebyshev) GP (MGP) (Yaghoobi and Tamiz, 2007; Tamiz *et al.*, 1998).

Many studies have been conducted in Iran and other countries. For example, Sarker and Quaddus (2002) combined goals of maximization of return from cultivated land and the minimization of cost of cultivation. They argued that the GP model provides better insights to the problem and thus allows better decision support. Sharma *et al.* (2006), by using LGP and fuzzy GP techniques, considered goals of minimizing operating costs and increase economic activity and employment opportunities for rural development planning.

Amini Faskhodi *et al.* (2008) with the help of multi-criteria approach showed that GP model had substantial potential to increase the area under cultivation, reduce water consumption, and increase income with respect to farmers' current pattern. Sabouhi and Khosravi (2009), by using GP model, stated that farmer decision making in unfavorable environmental conditions is easy. Also, according to the environmental objectives, there are increasing amount of profit and agricultural resources productivity with respect to the current situation. In another study, Ballarin *et al.* (2011) applied a WGP model to identify the optimal land use combinations that simultaneously maximize farmers' income and biomass energy production under three constraints: labor, land, and water availability. They showed that trade-off exists between the two considered targets. Keramatzadeh *et al.* (2011), by using LP and Multi-goal Linear Programming (MGLP) models, indicated that optimizing the cropping patterns along with proper allocation of irrigation water has yet substantial potential to increase the net return from agriculture. Fooks and Messer (2012) evaluated the potential gains in benefits from using GP model to preserve forestland. They outlined models that use GP to consider the trade-offs between environmental benefits and in-kind cost sharing in conservation programs. Results showed that program managers can achieve substantially better results by considering such trade-offs. In another study, Aldea *et al.* (2014), by using the GP approach, applied real forest management case where five criteria were selected: wood production, mushroom harvest, carbon sequestration, profitability, and normal structure of the forest. In the results of LGP solutions, an important variation in the mushroom harvest and profitability criterion (58 and 16%, respectively) was noted.

However, the mentioned studies suggest the types of GP models that are flexible and more capable in the estimation of the goals and ideals. This study was based on LP model to determine a pattern of agrarian activities with optimum economic value and improve the sustainability of forest resources of forest fringe villagers of Hezarjarib area through GP model.

MATERIALS AND METHODS

Study Area

The study area is located in the northern part of the Hezarjarib zone, located in the Alborz Mountains, 50 km south of Behshahr City, east of Mazandaran Province. Elevation varies from 1,000 to1,500 meters above sea level, with a total area of more than 10,000 ha, of which forest covers an area of 3,200 ha, where a variety of villages exist. The villages are small, scattered, and very diverse in terms of their population. The most important activities in this region are crop cultivation, animal husbandry, forest-related activities, and non-farm activities (Yakhkeshi, 2006).

The main tool for quantitative data collection was household questionnaires. In order to modify questionnaires and fix sample size, pilot questionnaires were conducted among 40 households before the main household survey. Split-half method was used

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to measure reliability coefficient of the questionnaire (Seif, 2008), which was determined as 0.81 and showed the survey instrument reliability. After administering the pre-test, the sample size was estimated to be 160 households, according to Cochran's formula for sampling (Cochran, 1977). In the household survey, proportional random sampling was applied. Sample size was based on the number of households per village.

The survey collected information on key socio-economic elements, including household demographic properties, sources of income from various activities, costs of production, sales and consumption of crop, livestock and forest, miscellaneous and garden non-farm sector products. Production activities and sources of income were based on the questionnaires surveys of the households. The method of calculating the total income was based on the Cavendish (2002), which is equal to the cash income plus the value of those goods and services that are used by the household for free. In this study, the considered index of the households' welfare is household net income (or net profit). Calculating net income involves summing up the cost of all the inputs used in an income-generating activity and deducting these from the value of income gained in that activity. For example, forest foliage is an important input for animal husbandry, and the value of foliage should be deducted in the livestock income calculation and reclassified as forest income (for more detail see Cavendish, 2002). Therefore, we took into account the net income of household in agriculture, livestock, forest, garden, miscellaneous, and non-farm sectors.

Linear Programming (LP) Model

Linear Programming (LP) is an optimal decision making tool: A problem of optimizing (maximizing or minimizing) a linear function subject to linear constraints (Kulej, 2011)

Objective Function of LP Model

The objective function of LP model is maximizing households' welfare. The welfare was computed by Total Net Income (TNI) of production from conventional activities of household, in the same way as other authors such as Soltani *et al.* (2010). Thus, the objective function was defined as follows:

$$Max\ wel_1 = TNI = \sum_{i=1}^{n} \mathrm{G_i} \times \mathrm{X_i} + \sum_{nf=1}^{G} \mathrm{W_{nf}} \times X_{nf} \qquad (1)$$

Where, G_i is the net income (difference between gross income and total costs) per one unit of *i*th product, X_i is the amount of *i*th product in each activity in which *i* represent the different productions of each activity. X_{nf} is the amount of non-farm activities (man-day) and W_{nf} is the labor wage in non-farm activities. Cropping products include wheat, barley, provender, millet, vegetables, beans, garlic, potatoes and onion. Garden products include walnut, apple, quince, peach, hazelnut and poplar. Livestock products include domestic cattle, hybrids cattle, sheep, and goat. Forest products include wood, forest herb, plum, apple, hawthorn, wild medlar, persimmon, mushroom, vegetable, medicine plants, raspberry, pear, oak and grazing. Miscellaneous products include borage and honey production. Non-farm activities include working in town as builders, drivers, and working as farm laborer.

Linear Programming Constraints

The objective function of LP model in this study was to be solved, subject to the following essential constraints. Constraints in the model included the current major constraints to the various activities in the area:

Land Resource Constraint

Land area constraints were divided into two groups. The first group contained annual

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crops while the second included the orchard crops. These constraints were introduced into the models as follows:

$$\sum_{f=1}^{F} X_f \leq fl \quad (2)$$

$$\sum_{g=1}^{G} X_g \leq gl \quad (3)$$

Land area (ha) of annual farming crops of *f*th crop (X_f) should not be higher than the total cultivable lands in region (f_l) [Equation (2)]. Also, land area (ha) of orchard crops of *g*th crop (X_g) should not be higher than the total orchard area in region (g_l) [(Equation (3)]

Livestock Constraint in Terms of Livestock Grazing Capacity

Livestock Constraints is defined based on the minimum number of livestock (head) that can be kept according to the area ecological capacity. The coefficients of 0.75, 5, and 1 are for the conversion of animals head (goat, native cattle, and sheep) to animal units. For example, one goat is equivalent to 0.75 animal unit. (Animal Husbandry Research Institute, 1971) [Equation (4)].

$$\sum_{l=1}^{L} b_j \times X_l \leq V \quad (4)$$

Where, $b_j$is coefficient for conversion of *lth* animals head to livestock units, X_l is the amount of *l*th animal head product, and *V* is the number of animal unit based on grazing capacity of the area (1.5 animal units per ha).

Environmental Constraint

The amount of forest products used by households for various consumptions should be less than the annual growth rate of those products in the forest. This constraint is as follows:

Biomass Consumption

The amount of woody biomass consumed by households for various consumptions should be less than the annual growth rate of biomass in the forest [Equation (5)].

$$\sum_{w=1}^{W} X_w \leq BT \quad (5)$$

Where, X_W is the amount of wood biomass (m^3) utilized by households for various purposes (heating, cooking, and making dairy products), BT is the annual growth rate of biomass that is expressed as 2.5 m^3 ha^{-1} (Forest, Rangeland and Watershed Organization, 2009). Constraint of non-wood products in forest is as Equation (6):

$$\sum_{s=1}^{S} X_s \leq sp_s \quad (6)$$

Where, X_S is the amount of *sth* non-wood products (kg) utilized by households for various purposes and $sp_S$is the annual product rate of *sth* non-wood products in the forest. For example, annual product rate of oak in the forests of the study area is reported as 500 kg/ha (Forest, Rangeland, and Watershed Organization, 2009).

Household Self-consumption

The household consumptions must not be greater than their products, which can be expressed as the constraint. This constraint is due to the personal consumption of households (people and animals' consumption) in each of the activities. For example, they included the minimum barley and wheat requirement of animals, the number of animals that provide meat for households' self-consumption, minimum forage production for livestock, minimum manure that is used in agriculture, which can be expressed as follows:

$$X_i \geq selfc \quad (7)$$

Where, $selfc$ is the minimum production per each activity.

Cash Capital

The aim of minimum required money is the amount of cash needed for cropping, horticulture, livestock and miscellaneous production, and living expenditures. This amount of money should not be more than the total cash that the household could get

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over the years. This constraint is shown in the relationship 8.

$\sum_{i=1}^{n} C_i \times X_i \leq Tcash$ (8)

Where, C_i is the liquidity needed to produce one unit of *ith* product, *Tcash* is the total cash (net receiving from subsidies, relatives, aid committee, gifts, savings, cash income from the sale of different goods, receivable loans, and non-farm income) minus annual cost of household life.

Production Inputs

The production inputs include chemical fertilizer (kg ha^{-1}), organic fertilizer (kg ha^{-1}), pesticide (kg ha^{-1}), seed (kg ha^{-1}), and machinery application times for production (hour ha^{-1}). Inputs in the production of livestock are animal feed (bran, barley, wheat, beet, farm and forest forage and oak). This constraint is shown in the relationship (9).

$\sum_{i=1}^{n} u_{ij} \times X_i \leq Tinput_j$ (9)

Where, u_{ij} is the amount of *jth* inputs required to produce one unit of *ith* product, and $Tinput_j$ is the total current *jth* inputs in the region.

Labor Constraint

Labor constraint is considered during year as defined in notation (10).

$\sum_{nf=1}^{G} X_{nf} + \sum_{i=1}^{n} L_i \times X_i \leq Inputl$ (10)

Where, X_{nf} is the non-farm labor (man-day), and $L_i$is the amount of labor required to produce one unit of *ith* product, and $Inputl$is the total current labor in the region.

Goals Programming Model

In the conventional GP problems, the aspiration (target) levels are determined precisely. GP models attempt to minimize the deviations from precise aspiration levels to find an optimal solution for GP problems (Tamiz *et al.*, 1998). Among the major models in GP, we applied MGP model introduced by Flavell (1976), where the maximum deviation from any single goal is minimized. It provides an optimal solution that represents the most balanced solution among the achievements of different goals (Romero, 2004). The purpose of utilization of MGP model is reducing timber harvesting of forest and increase households' welfare. In this study, according to the opinion of forest experts, zero harvesting of timber is desired (Forest and Pastures and Watershed Organization of Iran, 2012, personal communication). A general MGP is stated as follows:

Objective Function of Goal Programming

Since the principle of GP can be traced to LP, a starting point for the GP model can be found by restating the LP model, its assumptions and modeling notation. The objective function in MGP model is the minimization of the deviation from the optimal level of wood harvest.

Min D (11)

Where, *D* is an extra continuous variable that measures the maximum deviation. Variable *D* represents the maximum weighted deviation, with respect to the attached target.

Goal Programming Constraints

In addition to the constraints defined in LP model, other constraints were introduced into the MGP model as follows:

$\alpha n + \beta p \leq D$ (12)

$\sum_{w=1}^{W} x_w + n - p = b$ (13)

$\sum_{i=1}^{n} G_i \times X_i + \sum_{nf=1}^{G} W_{nf} \times X_{nf} \geq wel_1$ (14)

Where, *n* and *p* (deviation variables) are negative and positive deviations from aspiration (target) value of the goal, $\alpha(\beta) = w_1/k_1$ (w_2/k_2) if $n(p)$ is unwanted, otherwise $\alpha(\beta) = 0$ (i.e. here $\alpha = 0$, $\beta = 1$ were considered). The parameters *w* and *k* are the weights reflecting preferential and normalizing purposes attached to the achievement of the goal, *b* is the achievable goal level of the wood harvest (zero harvesting), *D* is maximum deviation, x_w is the amount of wood harvest ($m3$). In the relationship 14, achievement to greater

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welfare was mentioned, which should be more than the welfare from LP model (wel_1).

RESULTS AND DISCUSSION

In this study, we have introduced LP and GP techniques to determine the optimal pattern in agronomic activities of forest fringe villagers of Hezarjarib area. First, the results of the LP model for maximizing welfare are shown. Next, the MGP model employed has been justified on the basis of the main result of the LP model and its solution was compared with LP model. In this study, the models are solved through Gams Software. The solution for the LP and MGP models is given in Table 1, where net mean income of household in agriculture, livestock, forest, garden, non-farm, and miscellaneous sectors are mentioned in current and optimal pattern.

Based on the current pattern, forest income makes up 29.3% of the household income and has the largest share of revenue after livestock income (38.4%). Comparison of forest and livestock income with 9% difference showed the importance of forest income in household livelihood. Therefore, forest products and resources have contributed significantly in the economic welfare of the households. Hence, ignoring it among the income sources will create incorrect estimation in definition of household income and, consequently, will cause significant gap in our understanding of the real contribution of environmental resources (forest) in the rural economy of study area. The labor most widely used in forest activities in the area. But, decreasing the forest income from LP and GP models showed that the opportunity cost of labor in the harvest of forest product was not cost-effective, therefore, villagers' use of resources to secure their self-consumption needs in the household is justified. Based on the optimal pattern of the LP and MGP models, the highest level of the net income belonged to livestock activity with 42.31% in LP model and 51.42% according to MGP model; while the least was in non-farm activity with 3.16% in LP model and 3.26% according to GP model. Even though the livestock activity has the largest share of revenue in the current situation, the existing activity in the region was not optimal and reapplication of the present resources in LP and GP models leads to more return in this sector. Also, because of the high opportunity cost of labor and its lower return in non-farm activities, the employment of labor between non-farm activities in the LP and GP model is less than the current situation. Notable point in the current and LP pattern

Table 1. Distribution of the net income of rural household's income sources in different condition (MIRR= Million Iranian Rials and M^3= Cubic Meter).[a]

	Net mean income					
Income resources	Current pattern	Percent	Linear programming	Percent	Goal programming	Percent
Garden	35.18	14.05	49.3	17.85	59.708	21.6
Livestock	96.28	38.4	116.884	42.31	142.091	51.42
Farm	29.850	11.94	33.845	12.25	30.682	11.11
Forest	73.4	29.3	56.347	20.4	21.491	7.77
[wood harvest (m^3)]	(1839)	-	(1657)	-	(467)	-
Non-farm	12.59	5.03	8.748	3.16	9.011	3.26
Miscellaneous	2.96	1.18	11.124	4.03	13.370	4.84
Total	250.26	100	276.243	100	276.354	100

[a] Reference: research results.

is the same important rank of revenue sources. But, according to the LP model aimed at the maximum household welfare, there was a gap of 25.983 Million Rials (10.38%) between the total income of current and optimal LP model. Also, the GP model showed that household welfare was significantly more than the current model [26.094 Million Rials (10.42%)] compared to the LP model (0.111 Million Rials (0.04%)). Income sources important to the GP model include livestock, horticulture, farm, forest, miscellaneous, and non-farm activity.

According to Table 1, the minimum level of firewood harvest was estimated as 467 m^3 in GP model, whereas it was determined as 1,190 (71.8%) and 1,372 m^3 (74.6 %) lower as compared to the LP and current state, respectively. The GP solution offers a reduction of 74.6 and 71.8% with respect to current and LP wood harvest, respectively. Therefore, the GP model has been able to reduce the use of wood biomass in addition to increasing the household welfare to the amount of 276.35 Million Rials. Furthermore, this model allows the farmers to obtain maximum income in line with the environmental considerations to prevent the environmental degradation.

A significant reduction in the firewood harvest was shown as one of the major goals of the GP model. So, supplying fuel for the villagers through a rural services company can be an effective step to reduce dependence on forest resources. Moreover, household employment in animal husbandry in line with the other activities can guarantee the increase in income. The central point of this activity is replacement of traditional cattle breeds with hybrids cattle. This approach increases the yields per animal unit and, in addition, there is no need to move large animals to pasturage.

CONCLUSIONS

This study resolved the goal programming (an MOLP tool) with real-world data set from questionnaire of rural households, and compared its solution with linear programing. However, the solutions obtained from the GP model shows an increase in households' welfare through suitable activities development such as animal husbandry and horticulture rather than other activities, thereafter reducing the pressure on forest ecosystems (reducing the rural dependence on forest wood resources). The principle and sustainable exploitation of resources based on area potential (spatial planning), and rural tourism can be important parts of economic activity which may be effective in improving rural livelihoods. Thus, identifying the tourism attractions (ecotourism) within the region, such as natural landscapes, tourists' accommodation in rural houses, and supplying rural products to them help rural economy and development. Also, according to the available resources and climatic conditions, suitable mixed activities development such as agroforestry -that is cultivating trees and agricultural crops in intimate combination with one another- can be introduced as an agronomic system to support the agricultural activities.

The GP model used in this study is general enough for economic and environmental goals and considered for rural activities development and improves the sustainability of forest resources. In essence, the model is useful in helping to capture varying economic activities that are essential for rural development planning. Although the models have been applied to regional rural development, the approach described in this paper can be extended to planning problems with different sizes. It may be useful for agricultural policy maker and planners who can guide the farmers for spatial planning and rural development planning. Generally GP extended itself by reengineering many of the prior single objective LP models with multiple objectives and so it can do much more and in different ways. Unlike LP, the GP model can permit a variety of alternative solutions that may allow at least one of the model's goals to be improved without worsening or degrading the others. It is quite logical to start with a problem formulation as an LP model, recognize LP's limitations to deal with multiple objectives in the decision environment, and then revise the model in terms of GP. Therefore, it is only logical for researchers to use this connection to structure virtually all of the models related to LP, as GP models.

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تعیین الگوی بهینه فعالیت‌های کشاورزی متعارف روستاییان حاشیه جنگل در منطقه هزارجریب، ایران

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چکیده

بهبود درآمد کشاورزی و سایر بخش‌های وابسته به آن برای ساکنان روستایی، در جهت بهبود رفاه و توسعه اقتصادی کلی ضروری است. هدف از پژوهش حاضر تعیین الگوی بهینه‌ی فعالیت‌های متنوع روستاییان حاشیه جنگل منطقه هزارجریب در سال ۲۰۱۳ در راستای مدیریت منابع و برنامه‌ریزی توسعه روستایی است. بدین منظور، حجم نمونه ۱۶۰ خانوار از مجموع ۴۷۲ خانوار با استفاده از روش نمونه گیری تصادفی متناسب تعیین شد. برای جمع آوری داده ها، از پرسشنامه استفاده شد که ضریب پایایی آن با استفاده از روش دونیم‌کردن ۰/۸۱ برآورد شد که قابلیت اطمینان ابزار سنجش را نشان می‌دهد. نتایج حاصل از برنامه ریزی خطی و هدف نشان می‌دهد که در میان فعالیت‌های متعارف روستاییان، فعالیت دامپروری با بالاترین نسبت، نقش کلیدی در رفاه خانوارها دارد، به طوری که ۵۱/۴۲ درصد از درآمد کل خانوار را نشان می‌دهد. همچنین، مدل برنامه ریزی آرمانی به عنوان یک مدل مفید برای

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افزایش رفاه خانوارها (۱۰/۴۲٪) و کاهش تخریب جنگل (۷۴/۶٪) تعیین شده است. بنابراین آن نشان می‌دهد که پتانسیلی برای بهبود شرایط موجود و دسترسی به رفاه بیشتر در منطقه مورد مطالعه وجود دارد. بنابراین برنامه‌ریزی تولید و هدایت در راستای نتایج یاد شده، می‌تواند نقش مؤثری در توسعه‌ی فعالیت‌های روستاییان ایفا نماید.