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# Fuzzy Environmental-Economic Model for Land Use Planning

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**Abstract:** Sustainable development has been accepted in modern economic life to balance the economic growth and environment. This requires resources and environment that are be utilized today can be sustained and transferred in good condition to future generations. Land use is the most important issue in sustains management of resources. Because economic benefits obtained from the land should take into account environmental aspects such as flood, erosion etc. The Fuzzy theory was introduced by Zadeh as a means to model the uncertainty of natural language and is described by membership function. Fuzzy logic is a superset of conventional (Boolean) logic that has been extended to handle the concept of partial truth-truth values between “completely true” and “completely false”. This paper proposes a mathematical programming of fuzzy model for land use optimization with economic, social and environmental objectives and implications in regions. In short, the model is a fuzzy multi-objective linear programming that determines the optimal land use of region.

**Key words:** Fuzzy multi-objectives % Land use % Environmental-Economic model

## INTRODUCTION

Ecologically sustainable management of natural resources, also known as ecosystem management (EM), requires a complete and accurate accounting of the social, economic and ecological impacts of human. Many ecological services, such as air and water purification, mitigation of floods and drought, detoxification and decomposition of wastes, generation and renewal of soil, maintenance of biodiversity and partial stabilization of climate are not valued in the marketplace [1]. There are multiple conflicting objectives in land use planning such as profit, flood, erosion, employment and so on. To achieve the sustainable management of land use planning it is important to explore an integrated optimal planning between the conservation of environmental quality and the economic development of different uses of lands. Therefore multiple objective decisions-making (MADM) is framework for evaluating and selecting land use planning. Land use planning is also dependent on many factors that are not fully known quantitative and, are not fully controllable (e.g. weather, marketing and resources availability).These factor lead to uncertainty. For example uncertainty plays an important role in most land use programs due to essential levels of water quality to be maintained and possible economic rewards to be pursued in variations land use programs [2]. Therefore in land planning model with multi objectives and uncertainties needs to be considered. This can be carried with fuzzy multi objective model. The fuzzy mathematical programming approach should results in more realistic and flexible optimal solutions for water resources systems planning, especially for sustainable development and management of land use [2]. This paper introduces a fuzzy multi objective linear programming for land use.

## FRAMEWORK THEORY

Multi-objective programming is concerned with decision-making problems in which there are several conflicting objectives. Multi-objective problems arise in the design, modeling and planning of many complex resource allocation systems in the areas of industrial production, urban transportation, land use planning, agricultural and livestock production and water resources management [3]. The multi objective usually formulated to maximize and /or minimize several objectives subject to a constraint set.

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The term fuzzy was proposed by Zadeh in 1965, when he published the famous paper on Fuzzy Sets. The fuzzy set theory is developed to improve the oversimplified model, thereby developing a more robust and flexible model in order to solve real-world complex systems involving human aspects. In this approach, an element can belong to a set to a degree k ($0 < k < 1$), in contrast to classical set theory, where an element must definitely belong or not belong to a set. E.g., in classical set theory one can be definitely ill or healthy, whereas in fuzzy set theory we can say that someone is ill (or healthy) in 60 percent (i.e. in the degree 0.6) [4]. In other words, in classical set theory, membership in a set or a class is crisp and defined only as either non-complete (=0) or complete (=1). In fuzzy set theory, membership in a set or a class can range from non-complete (=0) until complete (=1) [5]. For fuzzy set, the characteristic function allows various degrees of membership for elements of given set.

The fuzzy is identified as an alternative approach to supplement the vagueness description of the planning goals and uncertainties involved in the parameter values. In the last two decades, fuzzy sets theory has received wide attention in the field of environmental planning and management [6-14].

**Fuzzy Multi Objective Linear Programming (FMOLP):** Bellman and Zadeh [15] and Zimmermann [16] introduced fuzzy programming and Young and Ching [17] and Chang et al. [12,13] provide detailed explanation for it. Consider Equations as:

Find x (1)

Such that $f_K(x)$ $Z i

Ax <b

X>0

Where $Z_i$ is corresponding goals.

Here objective functions of the equations are considered fuzzy constraints. If the tolerances of fuzzy constraints are given; we could establish their membership function $\mu_k(x)$.

Under the concept of min-operator, the feasible solution set is defined by the interaction of the fuzzy objective set. This feasible solution set is then characterized by its membership $\mu_D(x)$, which is:

$$\mu_D(x)=\min(\mu_1(x),\ldots\ldots, \mu_k(x)).$$

Table 1: The pay off table of positive ideal solution

| | f1 | f2 | f3 | ……… | fk | X |
|---|---|---|---|---|---|---|
| Max f1 | f1* | f2(x') | f3(x') | ………. | fk(x') | X' |
| Max f2 | f1*(x²) | f2* | f3(x²) | ……. | fk(x²) | X2 |
| Max f3 | f3(x³) | f2(x³) | f2* | ..... | fk(x³) | X3 |
| . | .. | | | | | . |
| . | ........ | | | | | . |
| Max fk | f1 (x^k) | f2 (x^k) | f3 (x^k) | | fk* | xk |
| | f1' | f2' | f3' | fk' | | |

Note: fk' is the minimum value in each column

Furthermore, a decision maker makes a decision with a maximum $\mu_D$ (x) value in the feasible decision set. The chosen solution can then be obtained by solving the problem of maximize $\mu_D$ (x), subjective to X>0, that is

$$\text{Max } [\min_k(x)] \quad \text{S.t. } X>0 \qquad (2)$$

Now, let " = $\min_k \mu_k(x)$ be the overall satisfactory level of compromise, then the following equivalent model follows:

Max "

s.t. "# (x), œ5 (3)

X>0

To establish the membership functions of objective functions, we must first obtain the payoff table of Positive Ideal Solution (PIS) as shown in Table 1. Assuming that membership functions are linear and non-decreasing between $f^*_k$ and $f_k$, then,

$$\mu_k(x) = \begin{cases} 1 & \text{if } f_K(x) > f_k^* \\ [f_K(x) - f_k^*][f_k^* - f_k^{'}] & \text{if } f_k^{'} \le f_K(x) \le f_k^* \\ 0 & \text{if } f_K(x) > f_k^{'} \end{cases}$$

These membership functions are essentially based on the concept of preference or satisfaction. It is worth noting that the only feasible solution region of practical relevance includes those elements in the critical area, {x |$f_k$#$f_K$(x)#$f^*_k$,œ5and xOX }. Finally, we obtain the following problem (Young and, Ching, (1994):

Max "

Subject toµ (x)= [$f_k$(x)- $f_k$]/[$f^*_k$-$f_k$] > " (4)

X>0

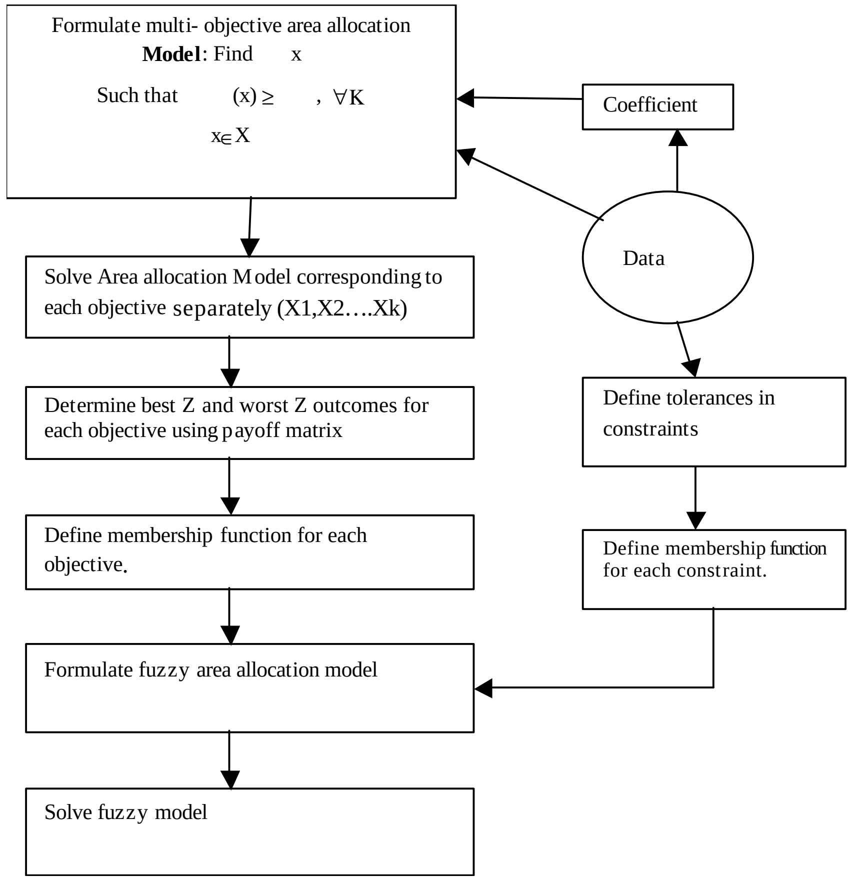


Fig. 1: Flowchart of Fuzzy Approach Methodology

## NUMERICAL EXAMPLE

For example, a decision-maker is going to land use planning for agricultural sector in a watershed. There are four land uses: orchard ($X_1$), Irrigated land ($X_2$), dry land ($X_3$) and rangeland ($X_4$). The decision- maker would like to plan with max profit and min erosion for this watershed. Table 2 shows summary of data.

The data formulated as:
Objectives:

$$\text{Max } 300X_1+250X_2+100X_3+50X_4 \quad (5)$$
$$\text{Min} 1.5X_1+2.5X_2+6X_3+5X_4$$

The objectives are subject to:

$$X_1<600$$

The first constraint indicates that area under orchard could be increases up to 600ha.

$$X_2<1700$$

The second constraint is that area under irrigated lands, should not more 1700ha because some land is not suitable for irrigated farming.

$$X_3< 1800$$

Some area has sloped more than 20% are not suitable for dry land farming. Therefore area under dry farming should not be more than 1800ha.

$$X_1+ X_2< 2000$$

On the limitation of water, this constraint implies that are under orchard and irrigated farming could not more than 2000ha

$$X_1>100$$

Based on the current land use area under orchard should be not less than 100ha.

$$X_4>6000$$

Based the rule of government the rangeland should be at least 6000ha in this watershed.

$$X_1+X_2+X_3+X_4<11100$$

This constrain is the area limitation in this watershed.

$$X_1, X2, X3, X4>0$$

The variable must be positive.

To solve this multi objective, the first is obtaining the pay of table as follow:

| | F1 | F2 | $X_1$ | $X_2$ | $X_3$ | $X_4$ |
|---|---|---|---|---|---|---|
| Max F1 | 1075000 | 51700 | 600 | 1400 | 1800 | 7300 |
| Min F2 | 330000 | 30150 | 100 | 0 | 0 | 6000 |
| ) | 745000 | 21550 | | | | |

Membership functions for these two objectives can then be obtained as follows:

$$U1(x)=\begin{cases} 1 & \text{if } 1075000<F(profit) \\ F(profit)-330000/745000 & \text{if } 330000<F(profit)<107500 \\ 0 & \text{if } F(profit)<33000 \end{cases}$$

$$U2(x)=\begin{cases} 1 & \text{if } F\ (erosion)<30150 \\ F(erosion)-\ 51700/-21550 & \text{if } 30150<\ F(erosion)<51700 \\ 0 & \text{if } F\ (erosion)>51700 \end{cases}$$

Finally we can compute the following linear programming.

Max "
Subject to (6)
"<= F(profit)-330000/745000
"<= F(erosion)- 51700/-21550
X1<600
X2<1700
X3< 1800
X1+ X2< 2000
X1>100
X4>6000
X1+X2+X3+X4<11100
" O[0,1]

After solves the problem, the optimal solution X1 =600, X2=1400, X3=319, X4=6000 with optimal effect of the balance of trade profit equal $1,010,000 and sediment 45200 t/ha/y where the overall satisfactory level "=0.71

## CONCLUSION

This paper emphasis that the objectives of land use planning is multi-objectives and uncertainty. The fuzzy approach allows the selection of the most profitable land use while considering environmental consideration. This model can achieve an integrated agricultural production planning with considerations for economic, social and environmental targets.

This study has confirmed that the present fuzzy multi objective model is more appropriate than non-fuzzy problem formulation in terms of reflecting a realistic situation. It is also an effective tool for generating a set of more realistic and flexible optimal solution in solving real world complex land development in sustainable agricultural development issues.

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