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Editorial

In this issue, O. Soliman, R. Sarker and S. Zahir have contributed a techinical paper on *Fuzzy Goal Programming Model with Parametric Analysis for Regional Sustainability Development under Climate Change: A Case of Agriculture Sector*. We are delighted to be publishing this paper here for Bulletin readers. We have provided a report from the ASOR past president Associate Professor Baikunth Nath and some photographs from ASOR annual conference held in Melbourne on 3-5 December 2007.

I am pleased to inform you that the electronic version of ASOR Bulletin is available at the ASOR web site: http://www.asor.org.au/. Although the electronic version is prepared as an HTML file, for technical reasons articles posted in PDF format.

ASOR Bulletin is only national publication of ASOR. I would like to request all ASOR members, ASOR Bulletin readers and OR organizations in the country to contribute to the ASOR Bulletin. The editorial policy is available either from the Bulletin web site or from the inside back cover of the Bulletin. The detailed instructions for preparing the manuscripts is available in the URL: http://www.asor.org.au/ and http://www.itee.adfa.edu.au/~ruhul/asor.html

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FUZZY GOAL PROGRAMMING MODEL WITH PARAMETRIC ANALYSIS FOR REGIONAL SUSTAINABILITY DEVELOPMENT UNDER CLIMATE CHANGE: A CASE OF AGRICULTURE SECTOR

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Abstract

Regional sustainability development (RSD) is a development strategy for efficient use of scarce regional resources. RSD comprises multiple, conflicting and often non-measurable goals such as economic, environmental and social goals. These goals may be affected by climate change due to global warming. In this paper, we present a fuzzy goal programming (FGP) model to evaluate RSD in the agriculture sector under various potential climate change scenarios. It deals with conflicting objectives by employing fuzzy set theory for setting priorities for the objectives. A solution methodology of the FGP model is presented. The proposed FGP model is more flexible than conventional goal programming as it is capable of providing different alternative policies based on degree of uncertainty as defined by a set of parameters. These parameters correspond to the attainment problem of a stable α-optimal solution. In addition, the proposed RSD model introduces fuzzy goals (aspiration levels) for objectives in order to represent uncertainties associated with various climate change predictions.

1. INTRODUCTION

Most real life decision making (DM) problems involve multiple objectives. These objectives are generally non-commensurable and conflicting [7, 24]**.** The problems with multiple objectives are classified as multi criteria (objective, performance, measure) decision making problems (MCDM) in the operations research literature. There is no single optimum solution for these problems but a set of alternative efficient solutions which are called Pareto optimal solutions (non-inferior or non-dominated solutions). Goal programming (GP) [9, 10] plays an important role in solving real world problems with multiple conflicting goals. GP can solve a multi criteria decision making problem under different measures by transforming the decision model into a satisficing model with a given priorities structure. This special feature of GP allows the decision maker to incorporate organizational and judgmental considerations into the model through the determination of aspiration levels and their priorities. So, it is often called a promising technique. The main features of GP are the interactions with the decision makers at the initial stage of model development, and optimal solutions that satisfy real life situations.

The goals of the decision maker could be fuzzy in nature [1, 3, 8, 27, and 28]. This is due to the fact that a lot of information about the problem is either vague or not known with certainty at the time of modeling. Deterministic modeling approach would not work well for such problems. Integration of fuzzy set theory [23, 13, 15, and 18] with GP model will make it more realistic and sophisticated than the conventional (deterministic) GP approach and help the analyst to incorporate vagueness and uncertainties into the model from real life problems. So the aim of this paper is to develop a fuzzy goal programming (FGP) model for climate change impacts assessment on RSD in agriculture sector.

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The rest of this paper is organized as follows. An overview of RSD and climate change is introduced in section 2. Model formulations for RSD under climate change are introduced in section 3. The solution methodology is presented in section 4. The last section is devoted to the conclusion and future work.

2. BACKGROUND: RSD AND CLIMATE CHANGE

The issue of RSD has been considered in respect of three broad headings of economic, social and ecological concerns in a demarcated geographical area [2]. The economic aspects are related to income, production, investments, market developments, price-formation, and other. The social concerns refer to distribution and equity considerations, such as income distribution, access to markets, wealth and power positions of certain groups or regions. The environmental dimensions are concerned with quality of life, resource scarcity, pollution and related variables. Clearly, the above mentioned three classes of variables are strongly interlinked, but they, to a certain extent, are also mutually conflicting. Putting more emphasis on a higher availability of one category tends to reduce the availability or usability of either or both of the other two.

The climate system is highly complex consisting of five major components: the atmosphere, the hydrosphere, the cryosphere, the land surface and the biosphere. These components interact together and affect the climate system as a result of their interaction. The climate system evolves in time under the influence of its own internal dynamics and because of external forces such as volcanic eruptions, solar variations and human-induced forces that change the composition of the atmosphere and land-use [11]. The change in the climate system (i.e., climate change), refers to a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period of time (typically a decade longer). Climate change may be due to natural internal processes or external forces, or to persistent anthropogenic changes in the composition of the atmosphere or in land use [11].

If global warming occurs as projected, its effects will not only directly impact the land and water resources, but also how technology, economies, and societies change over time. This complexity represents a significant research challenge indeed. However, the potential impacts of global climate change are too widespread to ignore, despite many uncertainties associated with their projections. This kind of challenge needs an integrated approach [14, 16, 17, 19]**,** with stakeholders and scientists working together and sharing their knowledge and experiences. While studying climate change impact assessments for RSD, two essential questions need to be addressed [25]: what are the impacts of climate change scenarios on various RSD goals/indicators and what are the effects of various response options available to reduce the adverse consequences of climate change on RSD? A number of research works studying climate change impact assessment and regional sustainability development have been reported [5, 12, 20, 21, 22, and 26].

3. FGP MODEL FOR RSD AND CLIMATE CHANGE

In order to evaluate RSD under climate change using FGP, various goals should be specified including economic growth, resource sustainability, environmental quality, and social stability. These goals should reflect the impact of climate change on the RSD. Different indicators are used to link and assess economic, social and environmental impacts of climate change. These indicators may include economic return, energy development and transportation economics; sustainable resource production, water balance, and forest coverage enhancement for sustainability of resource use; wildlife habitat protection, soil erosion control, green-house gas (GHG) emission reduction and air quality for environmental impact; and community stability for social impact. These goals are fuzzy in nature due to missing, vague, ambiguous or uncertain nature of information.

Economic activities of land use in the agricultural sector include the production of wheat, barley, oats, canola and other crops plus livestock, poultry and fish. These crops and forage might be grown only in certain sub-regions based on the topology of the land and climatic conditions. The relationships between climate change impact assessment and regional sustainability need to be incorporated in the structure of the model by clear articulation and reconciliation of objectives/goals and decision variables.

Economic activities of land use are represented as decision variables in the FGP model; regional sustainability development indicators are represented as fuzzy goal constraints, where system constraints include area of land use, water resource, water balance, labour resource, and fertilizing resource constraints.

The notations used are as follows:

x is area of land use; x_j is area of land use for the j^{th} crop .

R_j is net production return for the j^{th} crop, and $R_j = p_j y_j - C_j$

where:

- P_j is market price of the j^{th} crop.
- y_j is yield of the j^{th} crop .
- C_j is unit cost of production of the j^{th} crop, including variable and fixed costs: labours, fertilizer, and investment cost, $C_j = Lc_j L_j + Nc_j + POc_j + Fc_j + Ic_j$

  Where: Lc_j is labor cost per man of the j^{th} crop ; Nc_j , PO_j ,Fc_j are fertilizer costs of nitrogen , potassium and phosphors for the j^{th} crop, respectively; Ic_j investment amount to the j^{th} crop.

E_j is soil erosion for the j^{th} crop.

WC is the water cost, $WC = C_{sw} Sw + C_{gw} Gw$,

Where: Sw and Gw, are surface water and groundwater volumes availability, C_{sw} and C_{gw} are the unit costs of surface water and groundwater.

NI_j is average net irrigation water required for the j^{th} crop, $NI_j = kc_j PET + PL_j - ERF$

Where: Kc_j = crop coefficient of the jth crop; PET is potential evapotranspiration; PL_j is percolation loss for the jth crop; REF is effective rainfall.

L_j is no. of man days for the j^{th} crop.

N_j is nitrogen required for j^{th} crop.

θ is Fraction of rainfall as percolation loss,

λ is irrigation efficiency of surface water

μ is field water efficiency of groundwater

ER is expected rainfall

GA is gross command area

EGw is evaporation loss of groundwater

CGw is groundwater consumption in domestic, industrial and other sectors

CGw is groundwater consumption in domestic, industrial and other sectors

LGw is Permissible mining allowance level of ground water

PO_j is potassium required for j^{th} crop.

F_j is phosphorus required for j^{th} crop.

TL is total labours availability.

TN is total nitrogen availability in the area.

TPO is total potassium availability in the area.

TF is total phosphorus availability in the area.

$\widetilde{B}_1, \widetilde{B}_2$, and $\widetilde{B}_3$ are fuzzy goals (target levels or aspiration levels); b is the total area of land use;

FGP for RSD:

Economic Goal (Net Return) $\quad G1 = \sum_{j=1}^{n} R_j x_j - WC = \widetilde{B}_1$

Environmental Goal (Soil errosion) $\quad G2 = \sum_{j=1}^{n} E_j x_j = \widetilde{B}_2$

Sustainable Resource (Production) $\quad G3 = \sum_{j=1}^{n} y_j x_j = \widetilde{B}_3$

Subject to :

Area of land use: $\quad = \sum_{j=1}^{n} x_j \le b$

Water resource use: $\quad = \sum_{j=1}^{n} NI_j x_j \le \lambda Sw + \mu Gw,$ (P1)

Water balance $\quad := \mu Gw - (1-\lambda) Sw - \theta ER\ GA + EGw + CGw, \le LGw,$

Labour resource use: $\quad = \sum_{j=1}^{n} L_j \le TL,$

Fertilizer resource use:

Nitrogen: $\quad = \sum_{j=1}^{n} N_j \le TN,$

Potassium: $\quad = \sum_{j=1}^{n} PO_j \le TPO,$

Phosphorus: $\quad = \sum_{j=1}^{n} F_j \le TF,$

$$x_j, y_j, L_j, N_j, P_j, F_j, Sw, Gw \ge 0, \quad j = 1,2,\ldots,n.$$

4. SOLUTION METHODOLOGY

4-1. Uncertainty handling:

In order to handle the uncertainty in the above model, the membership function of the fuzzy goals (aspiration levels) $\widetilde{B}_i$ should be determined by gathering the information about fuzzy goals include lower and upper bound, and tolerance of change for each fuzzy goal.

Let B_i^{min}, $B_i^{\max}$ and $\overline{B}_i$ are lower bound, upper bound and the most desirable values of the i-th fuzzy goal respectively. The degree of achievement of the i-th fuzzy goals is categorized as follows: fully achievement if ($\widetilde{B}_i = \overline{B}_i$), no achievement if ($\widetilde{B}_i \le B_i^{min}$ and $\widetilde{B}_i \ge B_i^{\max}$) and partial achievement if $\widetilde{B}_i$ within the interval ($B_i^{min}, \overline{B}_i$) or ($\overline{B}_i$, $B_i^{\max}$).

The membership function of each fuzzy goal $\widetilde{B}_i$ is defined as follow:

$$\mu_{\widetilde{B}_i}(B_i) = \begin{cases} 1 & if \quad B_i = \dfrac{B_i^{\max} + B_i^{\min}}{2} = \overline{B}_i \\ \dfrac{B_i - B_i^{\min}}{\Delta_i} & if \ \ B_i^{\min} \le B_i \le \overline{B}_i \\ \dfrac{B_i^{\max} - B_i}{\Delta_i} & if \quad \overline{B}_i \le B_i \le B_i^{\max} \\ 0 & \quad otherwise \end{cases}$$

where Δ_i is chosen by the decision maker, usually expected to be in terms of unit changes in the aspiration levels (fuzzy goals) , Δ_i can be defined as :

$$\Delta_i = B_i^{\max} - \overline{B}_i = \overline{B}_i - B_i^{\min} .$$

The fuzzy goal programming problem (FGP) is transformed to a non fuzzy α- goal programming problem (α-GP) by using the α-level set as follows :

The α-level set of the fuzzy number $\widetilde{B}_i$ is defined as the ordinary set:

$L\alpha(\overline{B}_i) = \left\{ B_i \middle| \mu_{\overline{B}_i}(B_i) \ \ge \ \alpha \quad , i = 1, 2, ...m , \right\}$ for which the degree of their membership functions exceeds the level $\alpha \in [\ 0\ ,\ 1\ ]$.

At a specified degree of $\alpha \in [0, 1]$ the problem FGP is transformed to a non-fuzzy α- goal programming model (α- GP), by adding the following constraints to the FGP model:

$$B_i \ \in L\alpha(\widetilde{B}_i), \quad i = 1, 2, \ldots, m ,$$

4-2. Goals priority setting

In order to assign goals priority based on the concept of conflict and non conflict among goals and concept of the theory of fuzzy sets as follows:

Let $(C_{i1}, C_{i2}, \ldots, C_{in})$ and $(C_{j1}, C_{j2}, \ldots, C_{jn})$ be the gradients of the goals G_i and G_j respectively. The angle θ_{ij} between G_i and G_j can be defined as follows:

$$\cos\theta_{ij} = \frac{\sum_{k=1}^{n} C_{ik} C_{jk}}{\sqrt{\sum_{k=1}^{n} C_{ik}^2 \sum_{k=1}^{n} C_{jk}^2}}$$

The function of non-conflict between G_i and G_j can be defined by using the concept of the theory of fuzzy sets as follows:

$$\eta_{G_iG_j} = \begin{cases} 1 & \theta_{ij} = 0 \\ \dfrac{\pi - \theta_{ij}}{\pi} & 0 \le \theta_{ij} \le \pi \\ 0 & \theta_{ij} = \pi \end{cases}$$

The degree of non-conflict between G_i and G_j in the above function can be categorized as, the zero degree of non-conflict (fullest conflict) if ($\theta_{ij} = \pi$), i.e the corresponding gradient vectors lie in the opposite direction of improvement and the fullest degree of non-conflict (no conflict) if (θ_{ij} =0) , i.e. their gradient vectors have the same directions of improvement .

The degree of non-conflict among the goals obtained from the above function can be arranged in the following symmetric matrix:

$$\begin{array}{c c} & \begin{array}{cccc} G_1 & G_2 & \cdots & G_K \end{array} \\ \begin{array}{c} G_1 \\ G_2 \\ \vdots \\ G_k \end{array} & \begin{bmatrix} 1 & \eta_{G1G2} & \cdots & \eta_{G1Gk} \\ \eta_{G2G1} & 1 & \cdots & \eta_{G2Gk} \\ \vdots & & \vdots & \vdots \\ \eta_{GkG1} & \cdots\cdots\cdots & & 1 \end{bmatrix} \end{array}$$

The total amount w_i can be calculated from the above matrix as follows:

$$w_i = \frac{\sum_{j=1}^{k} \eta_{G_iG_j}}{k}$$

The numerical quantities of w_i are ranked and these ranks are used as the priority level. And also, they can be interpreted as the total amount of support the goal G_i gets from all other goals.

Apply the iterative approach [4] and let P_i be the attainment programming problem corresponding to the goal i which is a single objective programming problem and we can use any suitable techniques for solving it and P_i can be defined as follows:

$$P_i: \quad \text{Minimize} \quad S_i = d_i^- + d_i^+)$$

Subject to

$$\begin{aligned} g_r(x) + d_r^- - d_r^+ &= B_r && r = 1, 2, \ldots, i \\ d_r^- + d_r^+ &= S_r^* && r = 1, 2, \ldots, i\text{-}1 && \text{(P2)} \\ h_r(x) &\le b_r && r = 1, 2, \ldots, s \\ B_j &\in L_\alpha(\widetilde{B}_j) && j = 1, 2, \ldots, i \\ d_j^-, d_j^+ &\ge 0 && j = 1, 2, \ldots, i \end{aligned}$$

Where d_j^- and d_j^+, $j = 1, 2 \ldots, i$.. are negative and positive deviational variables respectively; $h_r(x) \leq b_r$, $r = 1, 2, \ldots, s$ are the system constraints for area of land use, water resource, water balance, labour resource, and fertilizing resource constraints; and $L_\alpha(\widetilde{B}_j)$, $j= 1, 2, \ldots, i$ is the α-level set of the fuzzy goal $\widetilde{B}_j$, and S_r^* is the optimal value of the previous attainment problem P_r.

The goal at the first priority level should be satisfied first and then the goal in the second priority level and so on. Note that the solutions of the problems with higher priority levels must be considered as constraints in all the sub-problems of lower priority levels.

4.3 Parametric Analysis:

The parametric programming [29 , 30 , 33] problem corresponding to the problem α- LGP can be defined as follows :

α-LGP(ω) :

$$
\begin{aligned}
&\text{Goal } 1: \quad g_1(x) = B_1, \\
&\text{Goal } 2: \quad g_2(x) = B_2, \\
&\quad \vdots \qquad\quad \vdots \qquad \vdots \\
&\text{Goal } m: \quad g_m(x) = B_m, \\
&\text{subject to :} \\
&\quad h_r(x) \leq b_r, \quad r = 1, 2, \ldots, s, \\
&\quad \omega^0_i \leq B_i \leq \omega^1_i, \quad i=1, 2, \ldots, m \\
&\quad x_j \geq 0, \quad j = 1, 2, \ldots, n \\
&\text{where } \omega^0_i, \omega^1_i \text{ are parameters .}
\end{aligned}
\qquad \text{(P3)}
$$

Consequently, The parametric programming problem $P_i(\omega)$ corresponding to the problem P_i can be defined as follows:

$$
\begin{aligned}
&p_i(\omega): \quad \text{Minimize} \quad S_i = \sum_{j=1}^{m_i} w_{ij}(d_{ij}^- + d_{ij}^+) \\
&\textit{Subject to} \\
&\quad g_{Lj}(x) + d_{Lj}^- - d_{Lj}^+ = B_{Lj}, \quad L = 1, 2, \ldots, i, \quad j = 1, 2, \ldots, m_L, \\
&\quad \sum_{j=1}^{m_L} w_{Lj}(d_{Lj}^- + d_{Lj}^+) = S_L^*, \quad L = 1, 2, \ldots, i-1, \\
&\quad h_r(x) \leq b_r, \quad r = 1, 2, \ldots, s, \\
&\quad \omega_{Lj}^0 \leq B_{Lj} \leq \omega_{Lj}^1, \quad L = 1, 2, \ldots, i, \quad j = 1, 2, \ldots, m_L, \\
&\quad x_j \geq 0, \quad j = 1, 2, \ldots, n, \\
&\quad d_{Lj}^-, d_{Lj}^+ \geq 0, \quad L = 1, 2, \ldots, i, \quad j = 1, 2, \ldots, m_L.
\end{aligned}
\qquad \text{(P4)}
$$

where $\omega^0_{Lj}, \omega^1_{Lj}$ are parameters .

The stability set of first kind is defined as : Suppose that (X* , B*) be the α-optimal solution of the problem α-LGP , then the stability set of the first kind of the problem α-LGP(ω) corresponding to the solution (X* , B*) can be defined as follows :

$S(X^*, B^*) = \{\omega : (X^*, B^*)$ is an α-optimal solution of the problem α-LGP(ω)$\}$.

By using Kuhn-Tucker conditions we can obtain a subset W(X*, B*) of S (X* , B*) in the following manner :

First : write all constraints of the problem Pi (ω) in the form :

$\theta j(x, B, d^-, d^+, \omega) \leq 0$, $j = 1, 2, \ldots, N$.

Second : formulate the kuhn-Tucker condition :

$$\nabla Si + \sum_{j=1}^{N} \lambda j \nabla \theta j = 0 \, , \qquad (1)$$

$$\lambda j \geq 0 \, , \qquad j = 1, 2, \ldots, N \, , \qquad (2)$$

$$\lambda j \theta j(x^*, B^*, d^{-*}, d^{+*}, \omega) = 0 \, , \quad j = 1, 2, \ldots, N \, , \qquad (3)$$

$$\text{where } \nabla = \left(\frac{\partial}{\partial x}, \frac{\partial}{\partial B}, \frac{\partial}{\partial d^-}, \frac{\partial}{\partial d^+}\right) \, .$$

Condition (1) and (2) represent a polytope W(λ) , and any one of the extreme points (vertices) could be easily generated by using any algorithm based on simplex method or any suitable techniques , then W (X* , B*) = {ω : λ satisfies Kuhn-Tucker condition (3) } .

4-3. Proposed Methodology.

The solution procedure of the proposed algorithm is summarized in the following steps:

Step 1: Determine $B_i^{\min}$ and $B_i^{\max}$ for each fuzzy goal.

Step 2: Construct the membership function.

Step 3: Determine $\alpha \in [0, 1]$.

Step 4: Construct the α-level set $L_\alpha(\widetilde{B}_j)$.

Step 5: Construct the α-GP problem.

Step 6: Set goals priority level**.**

Step 7: Apply the Iterative approach; find the optimal solution of the attainment programming problem (P2) by using any suitable technique, the optimal solution is the solution of the problem α-GP.

Step 8 : Formulate the parametric programming problem (P4) and Kuhn-Tucker conditions .

Step 9 : Determine the vertices of the polytope W(λ) and the subset W (X* , B*) by solving the Kuhn-Tucker conditions at the α-optimal solution.

Step 10: Stop.

4- 4. Numerical Example.

Due to unavailability of data a simple example is used to demonstrate the use of the proposed algorithm.

Find x_j such that the following fuzzy goals are satisfied as possible:

FLGP:

$$\begin{aligned}
&\text{Goal 1:} \quad 80\,x_1 + 40\,x_2 = \tilde{B}_1\\
&\text{Goal 2:} \quad x_1 = \tilde{B}_2\\
&\text{Goal 3:} \quad x_2 = \tilde{B}_3\\
&\qquad x_1, x_2 \geq 0 \;.
\end{aligned}$$

Where the three goals $\tilde{B}_1$, $\tilde{B}_2$ and $\tilde{B}_3$ are fuzzy goals, whose membership functions can be defined as follows :

$$\mu_1\,(B1) = \begin{cases} 1 & \text{if} \quad B_1 = 630 \\ \dfrac{B_1 - 620}{10} & \text{if} \quad 620 \leq B_1 \leq 630 \\ \dfrac{640 - B_1}{10} & \text{if} \quad 630 \leq B_1 \leq 640 \\ 0 & \text{otherwise} \end{cases}$$

$$\mu_2\,(B2) = \begin{cases} 1 & \text{if} \quad B_2 = 6 \\ \dfrac{B_2 - 4}{2} & \text{if} \quad 4 \leq B_2 \leq 6 \\ \dfrac{8 - B_2}{2} & \text{if} \quad 6 \leq B_2 \leq 8 \\ 0 & \text{otherwise} \end{cases}$$

$$\mu_3\,(B3) = \begin{cases} 1 & \text{if} \quad B_3 = 4 \\ \dfrac{B_3 - 2}{2} & \text{if} \quad 2 \leq B_3 \leq 4 \\ \dfrac{6 - B_3}{2} & \text{if} \quad 4 \leq B_3 \leq 6 \\ 0 & \text{otherwise} \end{cases}$$

At a certain degree of $\alpha = 0.9$ we obtain that the α-level set as follows :

$$L_{0.9} = \{ (B_1, B_2, B_3):\; 629 \leq B_1 \leq 631,\; 5.8 \leq B_2 \leq 6.2,\; 3.8 \leq B_3 \leq 4.2 \}$$

And the α-LGP problem can be defined as follows :

0.9-GP :

$$\begin{aligned}
&\text{Goal 1:} \quad 80\,x_1 + 40\,x_2 = B_1\\
&\text{Goal 2:} \quad x_1 = B_2\\
&\text{Goal 3:} \quad x_2 = B_3\\
&\text{Subject to:}\\
&\qquad 629 \leq B_1 \leq 631\\
&\qquad 5.8 \leq B_2 \leq 6.2\\
&\qquad 3.8 \leq B_3 \leq 4.2\\
&\qquad x_1, x_2 \geq 0 \;.
\end{aligned}$$

$$\cos\theta_{ij} = \frac{\sum_{k=1}^{n} C_{ik} C_{jk}}{\sqrt{\sum_{k=1}^{n} C_{ik}^2 \sum_{k=1}^{n} C_{jk}^2}}$$

$Cos\ \theta_{12} = 80 / 30\sqrt{10} \quad \Rightarrow \quad \theta_{12} = 32^0$
$Cos\ \theta_{13} = 40 / 30\sqrt{10} \quad \Rightarrow \quad \theta_{13} = 65^0$
$Cos\ \theta_{23} = 0 / 1 \quad \Rightarrow \quad \theta_{23} = 90^0$

$$\eta_{GiGj} = \begin{cases} 1 & \theta_{ij} = 0 \\ \dfrac{\pi - \theta_{ij}}{\pi} & 0 \le \theta_{ij} \le \pi \\ 0 & \theta_{ij} = \pi \end{cases}$$

$\Rightarrow \eta_{12} = 148 / 180$, $\eta_{13} = 115 / 180$, $\eta_{23} = 90 / 180$,
The non-conflict matrix A can be constructed as follows:

$$A = \begin{array}{c} \\ G_1 \\ G_2 \\ G_3 \end{array} \begin{array}{c} \begin{array}{ccc} G_1 & G_2 & G_3 \end{array} \\ \begin{bmatrix} 1 & 148/180 & 115/180 \\ 148/180 & 1 & 90/180 \\ 115/180 & 90/180 & 1 \end{bmatrix} \end{array}$$

It implies that:
$W_1 = 0.82$, $W_2 = 0.77$, $W_3 = 0.71$.

Based on values of W_i : G_1 assigned first priority, G2 assigned second priority, G3 assigned third priority. For the goal(s) at first priority level formulate the following the single objective problem:
0.9- GP:

P_1 : Minimize $S_1 = d_1^- + d_1^+$

Subject to:

$$80 x_1 + 40 x_2 + d_1^- - d_1^+ = B_1$$
$$x_1 + d_2^- - d_2^+ = B_2$$
$$x_2 + d_3^- - d_3^+ = B_3$$
$$629 \le B_1 \le 631$$
$$5.8 \le B_2 \le 6.2$$
$$3.8 \le B_3 \le 4.2$$
$$d_1^-, d_1^+, d_2^-, d_2^+, d_3^-, d_3^+, x1, x2 \ge 0$$

The α-optimal solution corresponding to P_1 is

$S_1^* = 0$, $X^* = (x_1 , x_2) =$ (5.9 , 3.95) , $B^* = (B_1 , B_2, B_3) =$ (630 , 5.9 , 3.95)

$d^{-*} = (d_1^-, d_2^-, d_3^-)$ = (0 , 0.1 , 0.05) , $d^{+*} = (d_1^+, d_2^+, d_3^+)$ = (0, 0 , 0)

For goal(s) at second priority:

P_2 : Minimize $S_2 = d_2^- + d_2^+$

Subject to:

$$\begin{aligned}
80x_1 + 40x_2 + d_1^- - d_1^+ &= 630 \\
x_1 + d_2^- - d_2^+ &= B_2 \\
x_2 + d_3^- - d_3^+ &= B_3 \\
d_1^- - d_1^+ &= 0 \\
629 \le B_1 &\le 631 \\
5.8 \le B_2 &\le 6.2 \\
3.8 \le B_3 &\le 4.2 \\
d_1^-, d_1^+, d_2^-, d_2^+, d_3^-, d_3^+, x1, x2 &\ge 0
\end{aligned}$$

The α-optimal solution corresponding to P_2 is:

$S_2^* = 0.025$, $X^* = (x_1 , x_2) =$ (5.975 , 3.8), $B^* = (B_1 , B_2, B_3) =$ (630 , 5.975 , 3.8).

$d^{-*} = (d_1^-, d_2^-, d_3^-)$ = (0 , 0.025 , 0.2), $d^{+*} = (d_1^+, d_2^+, d_3^+)$ = (0, 0, 0).

This α-optimal solution for α-GP problem, where the first goal is fully achieve, the second and third goals are partially achieve.

Parametric Analysis :

The parametric programming problem corresponding to the problem 0.9- LGP is defined as follows :

0.9-LGP(ω) :

$$\text{minimize } S = 0.82(d_1^- + d_1^+) + 0.77(d_2^- + d_2^+) + 0.71(d_3^- + d_3^+)$$

subject to

$$\begin{aligned}
80x_1 + 40x_2 + d_1^- - d_1^+ &= B_1 , \\
x_1 + d_2^- - d_2^+ &= B_2 , \\
x_2 + d_3^- - d_3^+ &= B_3 , \\
\omega_1^0 \le B_1 &\le \omega_1^1 , \\
\omega_2^0 \le B_2 &\le \omega_2^1 , \\
\omega_3^0 \le B_3 &\le \omega_3^1 , \\
d_1^-, d_1^+, d_2^-, d_2^+, d_3^-, d_3^+, x1, x2 &\ge 0 ,
\end{aligned}$$

where ω_1^0 , ω_1^1 , ω_2^0 , ω_2^1 , ω_3^0 , ω_3^1 are parameters .

Write all constraints of the problem 0.9-LGP(ω) in the form :

$\theta_j(x , B , d^- , d^+, \omega) \le 0$, j = 1 , 2 , …, N , and assign for each constrain a multiplier λ_j as follows :

$P(\omega)$: minimize $S = 0.82(d_1^- + d_1^+) + 0.77(d_2^- + d_2^+) + 0.71(d_3^- + d_3^+)$

subject to

$$
\begin{array}{ll}
\lambda_1 & 80x_1 + 40x_2 + d_1^- - d_1^+ - B_1 \le 0 \\
\lambda_2 & -80x_1 - 40x_2 - d_1^- + d_1^+ + B_1 \le 0 \\
\lambda_3 & x_1 + d_2^- - d_2^+ - B_2 \le 0 \\
\lambda_4 & -x_1 - d_2^- + d_2^+ - B_2 \le 0 \\
\lambda_5 & x_2 + d_3^- - d_3^+ - B_3 \le 0 \\
\lambda_6 & -x_2 - d_3^- + d_3^+ + B_3 \le 0 \\
\lambda_7 & B_1 - \omega^1_1 \le 0 , \\
\lambda_8 & -B_1 + \omega^0_1 \le 0 \\
\lambda_9 & B_2 - \omega^1_2 \le 0 , \\
\lambda_{10} & -B_2 + \omega^0_2 \le 0 \\
\lambda_{11} & B_3 - \omega^1_3 \le 0 \\
\lambda_{12} & -B_3 + \omega^0_3 \le 0 \\
\lambda_{13} & -X_1 \le 0 \\
\lambda_{14} & -X_2 \le 0 \\
\lambda_{15} & -d^-_1 \le 0 \\
\lambda_{16} & -d^+_1 \le 0 \\
\lambda_{17} & -d^-_2 \le 0 \\
\lambda_{18} & -d^+_2 \le 0 \\
\lambda_{19} & -d^-_3 \le 0 \\
\lambda_{20} & -d^+_3 \le 0 \\
\lambda_{21} & -B_1 \le 0 \\
\lambda_{22} & -B_2 \le 0 \\
\lambda_{23} & -B_3 \le 0
\end{array}
$$

Apply The Kuhn-Tucker conditions we obtain the polytop $w(\lambda)$:

$$
\begin{aligned}
&80\lambda_1 - 80\lambda_2 + \lambda_3 - \lambda_4 - \lambda_{13} = 0 \\
&40\lambda_1 - 40\lambda_2 + \lambda_5 - \lambda_6 - \lambda_{14} = 0 \\
&0.82 + \lambda_1 - \lambda_2 - \lambda_{15} = 0 \\
&0.82 - \lambda_1 + \lambda_2 - \lambda_{16} = 0 \\
&0.77 + \lambda_3 - \lambda_4 - \lambda_{17} = 0 \\
&0.77 - \lambda_3 + \lambda_4 - \lambda_{18} = 0 \\
&0.71 + \lambda_5 - \lambda_6 - \lambda_{19} = 0 \\
&0.71 - \lambda_5 + \lambda_6 - \lambda_{20} = 0 \\
&-\lambda_1 + \lambda_2 + \lambda_7 - \lambda_8 - \lambda_{21} = 0 \\
&-\lambda_3 + \lambda_4 + \lambda_9 - \lambda_{10} - \lambda_{22} = 0 \\
&-\lambda_5 + \lambda_6 + \lambda_{11} - \lambda_{12} - \lambda_{23} = 0
\end{aligned}
$$

The values of the multipliers λ_1 , ... , λ_{23} , are vertices in the polytope which satisfy the condition $\lambda_j \theta_j = 0$, $j = 1, 2, \dots, 23$ are $\lambda_1 = 1.001$, $\lambda_2 = 1$, $\lambda_3 = 0.77$, $\lambda_4 = 0.154$, $\lambda_5 = 0.71$, $\lambda_6 = 0.142$, $\lambda_7 = 0.001$, $\lambda_{10} = 0.77$, $\lambda_{12} = 0.71$, $\lambda_{15} = 0.821$, $\lambda_{16} = 0.819$, $\lambda_{18} = 0.154$, $\lambda_{20} = 0.142$, and the other multiplier is zeros . Then

$$W(X^*, B^*, d^*) = \{ \omega \in R^6 : \omega^0_1 \leq 630, \omega^1_1 \geq 630, \omega^0_2 \leq 5.975, \omega^1_2 = 5.975, \omega^0_3 = 3.80, \omega^1_3 \geq 3.80 \}$$

5. CONCLUSIONS AND FUTURE WORK

In this paper, we propose a FGP model which employs the concepts of conflicting goals and fuzzy set theory for priority setting, to evaluate regional sustainability under climate change scenarios. The different membership functions of the fuzzy goals are determined based on the choice of the degree of uncertainty (α), leading to different α-optimal solutions of the problem. It makes the approach more flexible and more sophisticated compared to familiar GP approach to the problem. In addition, it is capable to analyze and evaluate different impacts on regional sustainability development under the climate change scenarios with uncertainty. It provides an assessment to climate change impacts due to the degrees of uncertainty associated with various predictions of climate change by introducing fuzzy goals in the RSD model. Also, the set of parameters for the parametric problem corresponding to the attainment problem at the α-optimal solution and the level at which the α-optimal solution is still stable could be obtained.

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Australian Society for Operations Research

National President's Report 2007

The last two years, following a successful National Conference in September 2005, in Perth, have been very busy for the National Executive. The National executive committee had three meetings, via telephone hook-up, during the period 2006-2007 (6 October 2006, 21 March 2007, and 29 October 2007). I would particularly like to thank Santosh Kumar for his excellent organisation as National Vice-President Administration, and Kaye Marion for coordinating these meetings and making the committee members feel welcome at RMIT University.

The new ASOR web site (www.asor.org.au) is up and running. Some work still needs to be done to update information on Chapters. All ASOR Chapters are therefore invited to forward an up-to-date information that may be uploaded to the web site. I am hopeful that this dedicated web site will provide a booster shot to the OR profession and the society.

Success of the Melbourne bid for IFORS 2011 was announced in March 2007 by the IFORS President, Elise del Rosario of Philippines. Today, I am delighted to reiterate our success with IFORS 2011 bid. Most of the bid preparation work is due to Kaye Marion, John Hearne and colleagues. I must acknowledge their excellent work and dedication. IFORS 2011 will be held in Australia for the first time. Preparations for this international event have begun and a professional conference organizer, ICMS Pty Ltd, has been contracted to facilitate the organization. A working group for planning IFORS 2011 is in place. Once again, we welcome any ideas and invite you to join the group. Please contact Patrick Tobin, Chair Melbourne Chapter, for further information.

It is clear that the membership in almost all Chapters is declining. I would be keen to hear any ideas that may help lift the perception of OR in the wider community. It is felt that the membership benefits offered by the society are not very attractive. We need to put in more effort into organising specialist seminars, high ranking publication medium, and enhancing networking.

The outcome of the FASTS elections held on Monday 19 November 2007 for some of the key positions may be of interest to some of you. The results are

Vice President - Amanda Lynch (Professor and Federation Fellow, Monash University)
Treasurer - Graham Taylor (industry consultant)
Ordinary member - Peter Adams (Professor, University of Queensland)
Early Career scientist - Ben McNeil (UNSW)

These elected members will join the following to comprise the FASTS Executive for 2008.

* President - Ken Baldwin
* Secretary - Charles Drew
* Policy Chair - Ruth Foxwell

Bradley Smith, CEO of FASTS, observed that there was an unusually high level of interest in the elections and acknowledged the willingness of all candidates to make a contribution to science and technology policy and representation through FASTS.

I also wish to report the decisions taken at the recent ASOR National Executive meeting held on Sunday 2nd December 2007

Incoming executive

- **President:** Erhan Kozan, Queensland University of Technology
- **Vice-President Administration:** Andrew Higgins, CSIRO, Brisbane
- **Vice President Education** Moshe Sniedovich
- **Treasurer** Kaye Marion
- **Bulleting Editor** Ruhul Sarker

ASOR Representatives

- **APORS** Erhan Kozan
- **IFORS** Baikunth Nath
- **AMSC** Lou Caccetta
- **FASTS** Lou Caccetta
- **Public Officer** Phil Kilby

I am delighted to report that Professor Jan van Vuuren, University of Stellenbosch, Matieland, South Africa - the Editor of ORiON, has invited the Australian and New Zealand OR societies to join ORiON. To this end, some discussions had taken place over a period of time, and yesterday at the Council Executive meeting it was decided not to proceed with this option at present.

Ruhul Sarker, the Editor of ASOR Bulletin, has put forward a proposal to start our own new e-Journal. This proposal was also discussed at length at the Council Executive meeting yesterday and will be put to the AGM for general consensus.

Special thanks to the conference organising committee chaired by Patrick Tobin for putting in a lot of effort into this biannual National ASOR conference. I hope you will all enjoy this conference and make it a success. Finally I extend my very warm wishes and greetings for the Festive Season to you all. May the coming year be peaceful and rewarding.

Baikunth Nath
University of Melbourne

3rd December, 2007

From ASOR Conference 2007

Michael Trick (Keynote speaker, Tepper School of Business, Carnegie Mellon University, USA, and Vice-President IFORS), Baikunth Nath (ASOR National President, Computer Science & Software Engineering, University of Melbourne), John Hearne (Head of Mathematics & Geospatial Sciences, RMIT University), Barbara Smith (Invited speaker, School of Computing, University of Leeds, UK)

Conference dinner

Conference dinner

Service to the ASOR Society Medal to Ms Kaye Marion, RMIT University

Ren Potts medal to Professor Charles Pearce, University of Adelaide

Ren Potts Medal to Professor Pra Murthy, University of Queensland (Professor Erhan Kozan receiving on Pra's behalf)

MREM to Dr Van Ha Do, University of Technology Sydney

Forthcoming Conferences

CO2008: International Symposium on Combinatorial Optimization
16-19 March, 2008 Warwick, UK
http://www2.warwick.ac.uk/fac/soc/wbs/conf/co2008/

ICOR'08: IAENG International Conference on Operations Research
Hong Kong, 19-21 March, 2008.
http://www.iaeng.org/IMECS2008/ICOR2008.html

The 2nd In. Conference on Nonlinear Programming with Applications 2008 (NPA2008)
April 7-9, 2008, Academy of Mathematics and Systems Science, Beijing, China
http://www.polyu.edu.hk/~ama/events/conference/NPA2008/an1.htm

SIAM Conference on Optimization
May 10-13, 2008 Boston, US
http://www.siam.org/meetings/op08/

International Conference Inverse Problems Modeling and Simulation,
26-30 May, 2008 Fethiye, Turkey
http://www.ipms-conference.org/

5th Int. Conference on Service Systems and Service Management (ICSSSM'08)
30 June - 2 July 2008, Melbourne
http://www.infotech.monash.edu.au/about/news/conferences/icsssm08/

IFORS2008: International Federation of Operational Research Societies Conference
13-18 July 2008, Sandown, Sandton, Zambia
http://www.acitravel.co.za/event/index.php?eventID=3

The 9th Int. Symposium on Generalized Convexity and Generalized Monotonicity
July 21-25, 2008, National Sun Yat-sen University, Kaohsiung, Taiwan
http://www.math.nsysu.edu.tw/gcm9

The 7th Int. Conference on the Practice and Theory of Automated Timetabling
19th - 22nd August 2008, Montreal, Canada
http://www.asap.cs.nott.ac.uk/patat/patat-index.shtml

15th International Symposium on Inventories
August 22-26, 2008 - Sofitel Budapest, Hungary
http://www.diamond-congress.hu/isir2008

2008 IEEE International Conference on Systems, Man, and Cybernetics
October 12-15, 2008, Suntec Singapore
http://www.smc2008.org/

9th Asia-Pacific Industrial Eng. and Management Systems (APIEMS) Conference
Bali, Indonesia, 3 - 5 December 2008
http://www.apiems2008.org

asor

BULLETIN

Editorial Policy

The ASOR Bulletin is published in March, June, September and December by the Australian Society of Operations Research Incorporated.

It aims to provide news, world-wide abstracts, Australian problem descriptions and solution approaches, and a forum on topics of interests to Operations Research practitioners, researchers, academics and students.

Contributions and suggestions are welcomed, however it should be noted that technical articles should be brief and relate to specific applications. Detailed mathematical developments should be omitted from the main body of articles but can be included as an Appendix to the article. Both refereed and non-refereed papers are published. The refereed papers are *peer reviewed* by at least two independent experts in the field and published under the section 'Refereed Paper'.

Articles must contain an abstract of not more than 100 words. The author's correct title, name, position, department, and preferred address must be supplied. References should be specified and numbered in alphabetical order as illustrated in the following examples:

[1] Higgins, J.C. and Finn, R. Managerial Attitudes Towards Computer Models for Planning and Control. Long Range Planning, Vol. 4, pp 107-112. (Dec. 1976).

[2] Simon, H.A. The New Science of Management Decision. Rev. Ed. Prentice-Hall, N.J. (1977).

Contributions should be prepared in MSWord (doc or rtf file), suitable for IBM Compatible PC, and a soft copy should be submitted either as an email attachment or on a 3.5" diskette. The detailed instructions for preparing/formatting your manuscript can be found in the web:
http://www.cs.adfa.edu.au/~ruhul/asor.html

Reviews: Books for review should be sent to the book review subeditor A/Prof. G.K.Whymark, c/- the editors. Note that the subeditor is also interested in hearing from companies wishing to arrange reviews of software.

Advertising: The current rate is $300 per page, with layout supplied. Pro-rata rates apply to half and quarter pages and discounts are available for advance bookings over four issues.

Subscriptions: For Vol. 26, bulletins will be provided to all Members of ASOR as part of the membership fee.

Deadlines: The deadline for each issue (for all items except refereed articles) is the first day of the month preceding the month of publication.

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