XXII EUROPEAN CONFERENCE ON OPERATIONAL RESEARCH

TRADE-OFFS BETWEEN ECONOMIC AND ENVIRONMENTAL CRITERIA IN THE IRRIGATED AGRICULTURE: THE CASE OF THE MONEGROS COUNTY IN SPAIN

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PRAGUE, JULY, 2007

MOTIVATION

a) **SUSTAINABILITY IS A NORMATIVE CONCEPT**

IT IMPLIES THE CURRENT GENERATION´S CONCERN WITH THE RIGHTS OF FUTURE GENERATIONS

b) **SUSTAINABILITY IS A MULTI-CRITERIA CONCEPT**

IT IMPLIES NOT ONLY THE PERSISTENCE OF ECONOMIC RETURNS BUT ALSO THE FUTURE CONSERVATION OF ENVIRONMNETLA CONDITIONS

SUSTAINABLE AGRICULTURE ENTAILS AN AMALGAMATION OF ECONOMIC AS WELL AS ENVIRONMENTAL CRITERIA MEASURED IN DIFFERENT UNITS, WITHIN A NORMATIVE PERSPECTIVE

THE INTRODUCTION OF THE "SUSTAINABILITY PARADIGM" BRINGS WITH IT NEW CONCEPTS, BUT ALSO REQUIRES THE USE OF DIFFERENT ANALYTICAL TOOLS.

THIS PAPER AIMS TO EXPLORE HOW THE SIMONIAN BOUNDED RATIONALITY THEORY MERGED WITH GOAL PROGRAMMING, CAN BE A FRUITFUL AND OPERATIONAL FRAMEWORK FOR DEALING WITH THE SUSTAINABLE MANAGEMENT OF FARM SYSTEMS.

OUTLINE OF THE PRESENTATION

1. INTRODUCTION
2. BRIEF DESCRPTION OF THE CASE STUDY
3. CHARACTERISATION OF THE CONSTRAINTS AND CRITERIA
4. THE PAY-OFF MATRIX
5. THE EXTENDED GOAL PROGRAMMING FORMULATION
6. RESULTS
7. CONCLUDING REMARKS

BRIEF DESCRIPTION OF THE CASE STUDY

THE MONEGROS DISTRICT LOCATED IN NORTHERN SPAIN, IS A SEMI-ARID REGION, WHERE IRRIGATED AGRICULTURE IS THE PRIMARY LAND USE, REPRESENTING 86% OF ARABLE LAND. FIELD CROPS REPRESENT 98% OF THE TOTAL CROPPING AREA. THE MAIN IRRIGATED AGRICULTURE ENTERPRISES IN DECREASING ORDER OF IMPORTANCE ARE: MAIZE, ALFALFA, RICE, BARLEY, WHEAT, SET-ASIDE AND SUNFLOWER, COVERING 38,472 HECTARES.

THE MASSIVE USE OF WATER AND FERTILIZERS (MAINLY NITROGEN) HAVE CAUSED SERIOUS ENVIRONMENTAL PROBLEMS LIKE: GROUND WATER CONTAMINATION BY NITRATES, SALT LOAD IN RIVER BASIN, ETC

CHARACTERISATION OF THE CONSTRAINTS AND CRITERIA

CONSTRAINTS

ACCOUNTING AREA

$$\sum_{i=1}^{n} X_i = A$$

WATER BALANCE

$$\sum_{i=1}^{n} W_i X_i \le W_k \quad k \in \{1,2\}$$

LABOUR BALANCE

$$\sum_{i=1}^{n} L_i X_i \le L_l \quad l \in \{1,...,5\}$$

SEQUENCE OF CROPS

$$X_i \le \sum_{\forall A} X_A$$

FREQUENCY OF CROPS

$$X_i \le \frac{\alpha}{\alpha+\beta} B$$

SET-ASIDE CONDITIONS, ACCORDING TO THE CURRENT CAP

$$X_h^* I_c \le X_S \le X_h^* (I_c + I_v)$$

CRITERIA

1. MAXIMISATION OF THE GROSS MARGIN EXPECTATION.

$$MAX \sum_{i=1}^{n} E_i X_i$$

2. MAXIMISATION OF THE GROSS MARGIN UNDER THE WORST STATE OF NATURE ("WALD MAXIMIN").

MAX R

s.t.

$$\sum_{i=1}^{n} R_{ij} X_i \geq R \quad j \in \{1, \ldots, m\}$$

3. MINIMISATION OF WATER CONSUMPTION.

$$MIN \sum_{i=1}^{n} W_i X_i$$

4. MINIMISATION OF NITROGEN CONSUMPTION.

$$MIN \sum_{i=1}^{n} N_i X_i$$

THE PAY-OFF MATRIX

TABLE 2. PAY-OFF MATRIX FOR THE FOUR CRITERIA CONSIDERED. BOLD CHARACTERS DENOTE IDEAL VALUES AND UNDERLINED FIGURES ANTI-IDEALS.

	Gross Margin (1)	Water Consumption (2)	Nitrogen Consumption (3)	"Wald Maximin" (4)
Gross Margin(€)	**35,297,876**	14,473,166	18,329,564	33,938,524
Water Consumption(m^3)	274,968,992	**91,563,360**	181,772,960	260,518,128
Nitrogen Consumption(Kg)	8,086,172	3,924,144	**2,652,397**	7,564,090
"Wald Maximin" (€)	28,714,312	9,225,586	15,365,626	**29,921,370**

1. THERE IS A STRONG CONFLICT BETWEEN THE ECONOMIC AND THE ENVIRONMENTAL CRITERIA. THE MAXIMUM GROSS MARGIN IS ONLY COMPATIBLE WITH WATER CONSUMPTION AROUND THREE TIMES OVER ITS IDEAL VALUE.

2. THERE IS A RELATIVELY WEAK CONFLICT BETWEEN THE ECONOMIC CRITERIA. THUS, THE MAXIMUM GROSS MARGIN IMPLIES A "WALD MAXIMIN" AROUND THE 90% OF ITS IDEAL VALUE.

3. THERE IS A MODERATE LEVEL OF CONFLICT BETWEEN THE TWO ENVIRONMENTAL CRITERIA. THE MINIMUM WATER CONSUMPTION IS COMPATIBLE WITH A LEVEL OF NITROGEN CONSUMPTION AROUND 50% HIGHER THAN ITS MINIMUM LEVEL.

4. NO SOLUTION GENERATED BY THE SINGLE OPTIMISATION OF ANY CRITERION AND REPRESENTED BY EACH OF THE FOUR COLUMNS OF THE PAY-OFF MATRIX SEEMS ACCEPTABLE FROM THE POINT OF VIEW OF SUSTAINABILITY.

THE EXTENDED GOAL PROGRAMMING FORMULATION

Achievement function:

Lex min $=[\ [\ (1-\lambda)D+\lambda[\ 5W_1\frac{n_1}{t_1}+5W_2\frac{p_2}{t_2}+5W_3\frac{p_3}{t_3}+W_4(\sum_{j=1}^{5}\frac{u_j}{t_4})\ ]\ ,\ -(\ p_1+n_2\ +n_3+$

$v_1+v_2+v_3+v_4+v_5)\ ]$

Subject to:

CONSTRAINTS PREVIOUSLY DEFINED

Goals

$\sum_{i=1}^{7}E_iX_i+\mathbf{n_1}-p_1=t_1$ (Gross margin expectation)

$\sum_{i=1}^{7}W_iX_i+n_2-\mathbf{p_2}=t_2$ (Water consumption)

$\sum_{i=1}^{7}N_iX_i+n_3-\mathbf{p_3}=t_3$ (Nitrogen consumption)

$\sum_{i=1}^{7}R_{ij}X_i+\mathbf{u_j}-v_j=t_j \quad j\in\{1,\ldots,5\}$ ("Wald Maximin")

$5W_1\frac{n_1}{t_1}-D\le 0$

$5W_2\frac{p_2}{t_2}-D\le 0$ (MINMAX conditions)

$5W_3\frac{p_3}{t_3}-D\le 0$

$W_4(\sum_{j=1}^{5}\frac{u_j}{t_4})-D\le 0$

SET OF SATISFICING TARGETS

t_1 (GROSS MARGIN EXPECTATION) = 34,000,000 Euros

t_2 (WATER CONSUMPTION) N= 150,000,000 m^3

t_3 (NITROGEN CONSUMPTION) = 4,000,000 kg

t_4 ("WALD MAXIMIN") = 22,000,000 EUROS

IF THESE FIGURES ARE ACHIEVED THE CORRESPONDING CROPPING PATTERNS IMPLY SUSTAINABLE STRATEGIES

	[0,0.3)	[0.3,0.4)	[0.4,0.5)	[0.5,0.6)	[0.6,0.7)	[0.7,0.9)	[0.9,1]
EGM	-25	-28	-29	-35	-37	-40	-41
WATER	25	28	27	14	8	3	0
NITROGEN	25	3	0	0	0	0	0
MAXMIN	-8	-17	-19	-27	-30	-33	-35

PERCENTAGE DEVIATIONS WITH RESPECT TO THE TARGET VALUES

RESULTS

a) ASSIGNING THE SAME PREFERENTIAL WEIGHTS TO ALL CRITERIA, THE ENVIRONMENTAL CRITERIA FULLY ACHIEVED THEIR TARGETS FOR λ=1, WHEREAS THE ECONOMIC CRITERIA ARE FAR AWAY FROM THEIR RESPECTIVE TARGETS.

b) WE DECREASED THE VALUE OF CONTROL PARAMETER Λ WITHIN THE CLOSED INTERVAL [0,1] TO GET A MORE BALANCED ACHIEVEMENT OF ALL CRITERIA. IN THIS WAY, THE MODEL PROVIDES MORE BALANCED SOLUTIONS, BUT WITHOUT SIGNIFICANT IMPROVEMENTS IN THE ECONOMIC CRITERIA, WHICH ARE STILL FAR AWAY FROM THEIR TARGETS.

c) TO IMPROVE THE PERFORMANCE OF THE ECONOMIC CRITERIA, WE INCREASED THE VALUES OF THE PREFERENTIAL WEIGHTS ATTACHED TO THESE CRITERIA. NOTE THAT A WEIGHT EQUAL TO 7 HAS TO BE ATTACHED TO THE GROSS MARGIN CRITERION TO ACHIEVE THE TARGET, AND THE VALUE OF THE PREFERENTIAL WEIGHT MUST BE AT LEAST 9 TO ACHIEVE THE "MAXIMIN" TARGET.

d) THESE RESULTS REVEAL, ON THE ONE HAND, THE VULNERABILITY OF THE ENVIRONMENTAL CRITERIA IN THE DECISION MAKING PROCESS AND, ON THE OTHER HAND, THE IMPORTANCE OF THE ECONOMIC CRITERIA IN THIS PROCESS.

e) THIS KIND OF NORMATIVE ANALYSIS CAN BE USED US A GUIDE TO PUBLIC AUTHORITIES, BY INDICATING THE MANOEUVRABILITY MARGIN WITHIN WHICH A SET OF ENVIRONMENTAL IMPROVEMENTS CAN BE MADE WITHOUT AN EXCESSIVE DETERIORATION OF THE ECONOMIC BENEFITS.

f) IN THIS STUDY, THIS MANOEUVRABILITY MARGIN CORRESPONDS TO SITUATIONS WHERE POTENTIAL ECONOMIC IMPROVEMENT REQUIRES AN IMPORTANT INCREASE IN WATER AND NITROGEN CONSUMPTION, AND VICE VERSA.

CONCLUDING REMARKS

BASIC STATEMENT

THE NORMATIVE "WHAT SHOULD BE" WITHIN AGRICULTURAL MANAGEMENT MEANS ECONOMIC DEVELOPMENT WITHOUT JEOPARDIZING THE WELFARE OF FUTURE GENERATIONS. THEREFORE, THE CONSIDERATION OF ENVIRONMENTAL CRITERIA, SUCH AS WATER AND NITROGEN CONSUMPTION, IS VITAL FOR THE WELFARE OF FUTURE GENERATIONS.

EMPIRICAL FINDINGS

a) SOLUTIONS ACCEPTABLE FOR ENVIRONMENTAL REASONS DO NOT APPEAR TO BE SUSTAINABLE FROM THE POINT OF VIEW OF FINANCIAL PROFITABILITY, AND VICE VERSA. HENCE, IT IS NECESSARY TO LOOK FOR "SATISFICING" OR BEST-COMPROMISE SOLUTIONS AMONG THE FOUR SINGLE OPTIMUM SOLUTIONS IN ORDER TO DESIGN SUSTAINABLE CROPPING PATTERNS.

b) THE COMPROMISE SOLUTIONS PROVIDED BY DIFFERENT SIMULATIONS OF THE EXTENDED GP MODEL DEMONSTRATE THAT IT IS POSSIBLE TO ACHIEVE SATISFACTORY SOLUTIONS FROM BOTH POINTS OF VIEW; i.e., THE ECONOMIC AND THE ENVIRONMENTAL PERSPECTIVES.

c) CONSIDERING THIS CONCLUSION AND BASED ON THIS KIND OF NORMATIVE STUDIES, PUBLIC AUTHORITIES CAN ADOPT MEASURES THAT ARE MORE RESPECTFUL OF THE ENVIRONMENT BUT DO NOT HAVE DRASTIC ECONOMIC CONSEQUENCES.

POSSIBLE FURTHER RESEARCH

ONE POSSIBLE EXTENSION OF THE ACTUAL STUDY WOULD INVOLVE A SIMILAR ANALYTICAL APPROACH WITHIN A POSITIVE DECISION-MAKING CONTEXT, i.e.,. A CONTEXT DEFINED BY CRITERIA AND PREFERENTIAL WEIGHTS ABLE TO REPRODUCE THE OBSERVED FARMERS' BEHAVIOUR. A COMPARISON OF THE "NORMATIVE" AND THE "POSITIVE" RESULTS COULD THROW UP INTERESTING CONCLUSIONS ABOUT "WHAT SHOULD BE" AND "WHAT IS". SUCH INFORMATION COULD HELP IN THE DESIGN OF SENSIBLE AGRICULTURAL POLICIES.

THANK YOU VERY MUCH FOR YOUR ATTENTION

COMMENTS, QUESTIONS, SUGGESTIONS…ARE VERY WELCOME