Multiobjective planning for farms, using the Dominance-based Rough Set Approach

Luisa Paolotti
PhD in Agri-food Economics and Politics
Faculty of Agriculture, University of Perugia - Italy

2010 COST IC0602 International Doctoral School
Algorithmic Decision Theory: Computational Social Choice
April 9-15, 2010 - Estoril

Research Project: OBJECTIVES

1. To present the new decision support method which combines the Dominance-based Rough Sets Approach with Interactive Multiobjective Optimization (IMO-DRSA – Greco et al., 2008).

2. To underline the applicability of the method to the agricultural sector, in order to determine optimal planning strategies for farms.

Research Project: OBJECTIVES

CASE STUDY:

to determine an optimal planning strategy for a farm

(area: Alta Valle del Tevere Umbra)

conciliating

ECONOMIC objectives with ENVIRONMENTAL ones

MAX revenue of the farmer
MIN costs of the farm

MIN nitrates, phosphorus pollution
MIN water consumption

Research Project: CONTEXT

Field of research: *farm management* and farm planning.

FIRST PHASE:

- ✓ Analysis of the existing tools supporting farm management, and of their temporal evolution.

- ✓ Analysis of the scientific applications of these tools in the sector of farm planning

Research Project: METHOD

New decision support method, applicable also to farm planning

↓

Multiobjective Optimization method

+

Dominance-based Rough Set Approach

Multiobjective Programming*

- Optimization of ONE objective (objective function)
- Other objectives put as constraints
- Set of efficient solutions obtained through parametrization of the right part of the constraints

Maximise Z_k (x)
subject to
$x \in F$ (technical constraints of the problem)
$Z_j (x) >= L_j$ $\quad$ j= 1, 2, …, k-1, k+1, … q

* Romero C., Rehman T. (1989), *Multiple Criteria Analysis for agricultural decisions*, Elsevier, Netherlands.
MOP problem formulated by Kuhn and Tucker in 1951, university of California

ROUGH SETS APPROACH

Dominance-based Rough Set Approach (DRSA):

(GRECO et al., 2001)

It is a method, within multicriteria decision analysis, which permits to represent the preferences of the Decision Maker (DM) in terms of easily understandable "if… then…" decision rules, induced by some "exemplary decisions", obtained from past or simulated choices of the DM.

EXEMPLARY DECISIONS: often inconsistent or incomplete

ROUGH SETS approach: deals with inconsistency in information

ROUGH SETS APPROACH

Assignment of *objects* (solutions, alternatives) to decision classes, by means of the EVALUATION of these objects with respect to a set of ATTRIBUTES (criteria or objectives).

Link through decision rules: *if*… *then*…"

- **CLASSIC approach** (Pawlak, 1982): only sorting
- **DOMINANCE-based* approach**: also ranking and choice (takes into account prefered ordered attributes)

*Greco S., Matarazzo B., Słowiński R. (2001), *Rough sets theory for multicriteria decision analysis*, European Journal of Operational Research, 129 no.1, 1- 47.

ROUGH SETS APPROACH

EXEMPLARY DECISIONS

The DM makes its choices

(solutions, or sorting examples)

↓

"GRANULES"

(sets of indiscernible objects)

obtained from conditional attributes

$D^{+}_{P}(x) = \{y \in U: y\, D_P\, x\}$

$D^{-}_{P}(x) = \{y \in U: x\, D_P\, y\}$

↓

DECISION CLASSES:

inferior approximation

superior approximation

$\mathbf{P}_{inf}(\mathbf{Cl}_t^{\geq}) = \{x \in U: D_p^{+}(x) \subseteq Cl_t^{\geq}\}$

$\mathbf{P}_{sup}(\mathbf{Cl}_t^{\geq}) = \{x \in U: D_p^{-}(x) \cap Cl_t^{\geq} \neq \emptyset\}$

↓

DECISION RULES

If Literature=good, then the student is good

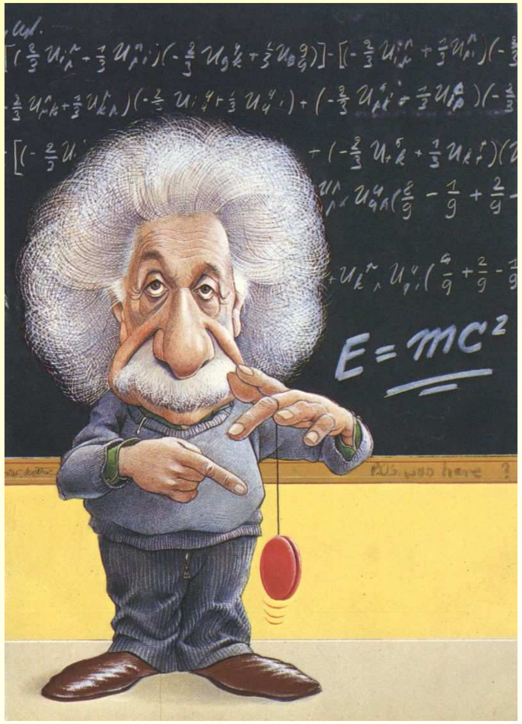
If Mathematics=bad, then the student is bad

DSRA and multiobjective optimization

PROCEDURE:

1) Present to the DM a set of representative efficient solutions;
2) If the DM finds a satisfactory solution, then process ends, otherwise go to the next step;
3) The DM marks efficient solutions considered as good (ex. decisions);
4) DRSA “if...,then...” decision rules are induced (preference model);
5) The most interesting decision rules are presented to the DM;
6) The DM selects one decision rule;
7) Constraints relative to the decision rule are adjoined;
8) Go back to step 1.

CASE STUDY



THE AREA

ALTA VALLE DEL TEVERE UMBRA: area with industrial crops (tobacco) and cereals, and with good avalaibility of water:

- Avoid too much intensive cultivation (nitrates lisciviation, erosion)
- Avoid excessive water consumption
- Attention to multiple use of water

THE DATA

Database of National Institute of Agricultural Economics

Data about productivity and costs (aggregated data – year 2006)

Data of Alto Tevere mountain community

Data about water consumption and relative costs, for each crop

Environmental data (previous study in the area)

- Annual nitrate lisciviation (kg N/ha)
- Annual soil loss (T/ha)

THE FARM

Municipality: Città di Castello (PG – Italy)

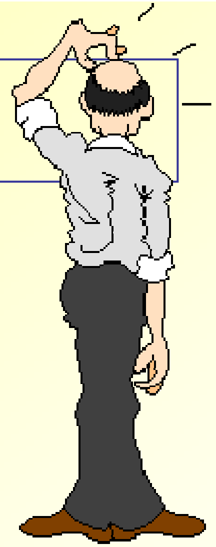
Total surface: 61.79 ha   Agricultural surface: 58.96 ha

CROPS

- Durum wheat: 13.6 ha
- Common wheat: 10.84 ha
- Maize: 2.7
- Tobacco: 27.8
- Forest: 0.95 ha
- Set-aside: 4.02 ha
- Other surface: 1.88 ha

Irrigable surface: 31.00 ha   Irrigated surface: 30.50 ha

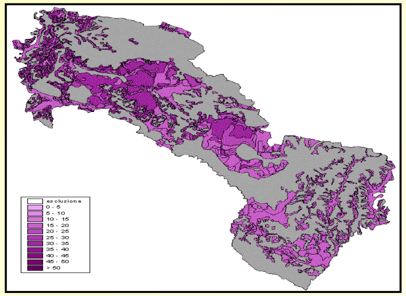
THE MULTIOBJECTIVE MODEL



OBJECTIVES TO OPTIMIZE

1. Max Gross Revenue

2. Min lisciviation



3. Min erosion

4. Min water consumption

THE MULTIOBJECTIVE MODEL

A) SIMULATED CROPS **(X_1, X_2 , ... , X_8)**

Durum w., Common w., Maize, Tobacco, Barley, Sunflower, Melon, Alphalpha

B) THE OBJECTIVE FUNCTIONS

Max Gross Revenue MAX= RL; dove RL= PLV – CV;

Min Lisciviation MIN= $17.56*X_1 + 17.56*X_2 + 62.40*X_3 + ... + 10.53*X_8$;

Exc.

C) THE CONSTRAINTS

Land availability $X_1 + X_2 + X_3 + ... + X_8 = 58.96$;

November: sowing wheat, barley $2*X_1 + 2*X_2 + 2*X_5 <= 700$;

March: sowing sunflower, alphalpha $3*X_6 + 2*X_8 <= 700$;

Exc.

THE MULTIOBJECTIVE MODEL

D) PARAMETRIZATION (software LINGO)

1) **Max Gross Revenue and parametrization lisciviation**
   - begin parametrization: common wheat and alphalpha (< Qlisc)
   - then introduced durum wheat, melon and tobacco

2) **Max Gross Revenue and parametrization erosion**
3) **Max Gross Revenue and parametrization water**
4) **Parametrization Gross Revenue**

→ Selected a first subset of solutions from the whole set of the efficient solutions

First set of efficient solutions

Solution	Revenue	Lisciviation	Erosion	Water	Evaluation	Durum	Common	Maize	Tobacco	Barley	Sunflower	Melon	Alphalpha
1	156682.9	3392.74	3.14	147822.8		0	0	22	30	0	0	6.96	0
2	41727.26	1000	1.3	70324.08		0	24.25	0	0	0	0	4.71	30
3	77108.25	1400	2.19	16402.74		19.16	30	0	2.84	0	0	6.96	0
4	107055.8	1800	2.72	49278.43	**GOOD**	8.36	30	0	13.64	0	0	6.96	0
5	136813.2	2200	3.25	82154.11	**GOOD**	0	27.57	0	24.44	0	0	6.96	0
6	151365.2	2400	3.51	98591.95	**GOOD**	0	22.17	0	29.84	0	0	6.96	0
7	24740.84	2264.83	0.6	127168.1		0	0	30	0	0	0	1.98	26.98
8	57515.52	2435.76	1	124047.2		0	0	30	0.5	0	0	5.35	23.12
9	86984.3	2814.15	1.6	130408		0	0	30	8.48	0	0	5.95	14.53
10	106630.2	3066.4	2	134648.5	**GOOD**	0	0	30	13.8	0	0	6.34	8.81
11	126276	3318.66	2.4	138889	**GOOD**	0	0	30	19.13	0	0	6.74	3.09
12	143785.7	3433.35	2.8	143493.8		0	0	27.22	24.79	0	0	6.96	0
13	46860.6	1202.81	1.82	5000		24.47	30	0	0	0	0	4.49	0
14	71275.78	1322.1	2.08	10000		21.26	30	0	0.74	0	0	6.96	0
15	98603.76	1687.11	2.57	40000		11.41	30	0	10.59	0	0	6.96	0
16	134906.2	2173.79	3.21	80000	**GOOD**	0	28.27	0	23.73	0	0	6.96	0
17	151900.2	2424.45	3.51	100000	**GOOD**	0	21.59	0.41	30	0	0	6.96	0
18	50000	1077.88	1.5	54858.31		1.05	30	0	0	0	0	5.39	22.52
19	140000	3445.27	2.7	142223.1		0	0	28.75	23.26	0	0	6.96	0
20	120000	1972.89	2.95	63488.28	**GOOD**	3.7	30	0	18.31	0	0	6.96	0

First set of decision rules

1) If GR ≥ 106630.15 euro and Qlisc ≤ 3066.40 kgN, then the solution is good (supported by solutions 4, 5, 6, 10, 16, 17, 20)

2) If GR ≥ 126276 and Qlisc ≤ 3318.66, then the solution is good (supported by solutions 5, 6, 11, 16, 17)

3) If GR ≥ 106630.15 and Qeros ≤ 2, then the solution is good (supported by solution 10)

4) If GR ≥ 126276 and Qeros ≤ 2.40, then the solution is good (supported by solution 11)

5) If GR ≥ 106630.15 and Qwater≤ 134648.50, then the solution is good (supported by solutions 4, 5, 6, 10, 16, 17, 20)

6) If GR ≥ 126276 and Qwater ≤ 138889, then the solution is good (supported by solutions 5, 6, 11, 16, 17)

Second set of efficient solutions

Solution	Revenue	Lisciviation	Erosion	Water	Evaluation	Durum	Common	Maize	Tobacco	Barley	Sunflower	Melon	Alphalpha
1	152900.25	2626.93	3.43	110000.00		0.00	17.08	4.92	30.00	0.00	0.00	6.96	0.00
2	143758.95	2295.46	3.37	90000.00	**GOOD**	0.00	24.99	0.00	27.01	0.00	0.00	6.96	0.00
3	134906.20	2173.79	3.21	80000.00	**GOOD**	0.00	28.27	0.00	23.73	0.00	0.00	6.96	0.00
4	125931.74	2052.12	3.05	70000.00	**GOOD**	1.56	30.00	0.00	20.45	0.00	0.00	6.96	0.00
5	116822.41	1930.45	2.89	60000.00	**GOOD**	4.84	30.00	0.00	17.16	0.00	0.00	6.96	0.00
6	107713.08	1808.78	2.73	50000.00		8.13	30.00	0.00	13.88	0.00	0.00	6.96	0.00
7	122358.92	3066.40	2.40	139556.90		0.00	0.00	24.89	19.75	0.00	0.00	6.41	7.91
8	114494.54	3066.40	2.20	137102.70	**GOOD**	0.00	0.00	27.45	16.78	0.00	0.00	6.37	8.36
9	106630.20	2559.95	2.20	138443.58		0.00	0.00	17.20	18.02	0.00	0.00	5.70	18.04
10	106630.20	1839.34	2.80	49527.23	**GOOD**	4.49	30.00	0.00	13.72	3.79	0.00	6.96	0.00
11	106630.20	1993.93	2.60	58028.57		4.16	30.00	4.89	12.96	0.00	0.00	6.96	0.00
12	106630.20	2375.31	2.40	75796.16		0.00	25.80	14.12	12.08	0.00	0.00	6.96	0.00
13	106630.20	2772.88	2.20	94481.97		0.00	17.07	23.63	11.30	0.00	0.00	6.96	0.00

Second set of decision rules

1) If GR ≥ 143759 and Qlisc ≤ 2295.461 then the solution is good.
(supported by solution 2)

2) If GR ≥ 134906.2 and Qlisc ≤ 2173.791 then the solution is good.
(supported by solution 3)

3) If GR ≥ 125931.7 and Qlisc ≤ 2052.12 then the solution is good.
(supported by solution 4)

4) If GR ≥ 116822.4 and Qlisc ≤ 1930.45 then the solution is good.
(supported by solution 5)

5) If GR ≥ 143759 and Qeros ≤ 3.372 then the solution is good.
(supported by solution 2)

6) If GR ≥ 134906.2 and Qeros ≤ 3.211 then the solution is good.
(supported by solution 3)

7) If GR ≥ 125931.7 e Qeros ≤ 3.05 then the solution is good.
(supported by solution 4)

8) If GR ≥ 114494.5 and Qeros ≤ 2.2 then the solution is good.
(supported by solution 8)

9) If Qwater ≤ 49527.2 then the solution is good.
(supported by solution 10)

10) If GR ≥ 143759 and Qwater ≤ 90000 then the solution is good.
(supported by solution 2)

11) If GR ≥ 134906.2 and Qwater ≤ 80000 then the solution is good.
(supported by solution 3)

12) If GR ≥ 125931.7 and Qwater ≤ 70000 then the solution is good.
(supported by solution 4)

13) If GR ≥ 116822.4 and Qwater ≤ 60000 then the solution is good.
(supported by solution 5)

13) IF GR ≥ 116822.4 euro and Qwater ≤ 60000 m^3 THEN the solution is GOOD (supported by solution 5)

Solution	Revenue	Lisciviation	Erosion	Water	Evaluation	Durum	Common	Maize	Tobacco	Barley	Sunflower	Melon	Alphalpha
1	152900.25	2626.93	3.43	110000.00		0.00	17.08	4.92	30.00	0.00	0.00	6.96	0.00
2	143758.95	2295.46	3.37	90000.00	**GOOD**	0.00	24.99	0.00	27.01	0.00	0.00	6.96	0.00
3	134906.20	2173.79	3.21	80000.00	**GOOD**	0.00	28.27	0.00	23.73	0.00	0.00	6.96	0.00
4	125931.74	2052.12	3.05	70000.00	**GOOD**	1.56	30.00	0.00	20.45	0.00	0.00	6.96	0.00
5	116822.41	1930.45	2.89	60000.00	**GOOD**	4.84	30.00	0.00	17.16	0.00	0.00	6.96	0.00
6	107713.08	1808.78	2.73	50000.00		8.13	30.00	0.00	13.88	0.00	0.00	6.96	0.00
7	122358.92	3066.40	2.40	139556.90		0.00	0.00	24.89	19.75	0.00	0.00	6.41	7.91
8	114494.54	3066.40	2.20	137102.70	**GOOD**	0.00	0.00	27.45	16.78	0.00	0.00	6.37	8.36
9	106630.20	2559.95	2.20	138443.58		0.00	0.00	17.20	18.02	0.00	0.00	5.70	18.04
10	106630.20	1839.34	2.80	49527.23	**GOOD**	4.49	30.00	0.00	13.72	3.79	0.00	6.96	0.00
11	106630.20	1993.93	2.60	58028.57		4.16	30.00	4.89	12.96	0.00	0.00	6.96	0.00
12	106630.20	2375.31	2.40	75796.16		0.00	25.80	14.12	12.08	0.00	0.00	6.96	0.00
13	106630.20	2772.88	2.20	94481.97		0.00	17.07	23.63	11.30	0.00	0.00	6.96	0.00

Optimal Solution

OBJECTIVES	Unit	MIN	MAX	Optimal solut.
REVENUE	Euro	0	156.683	**116.822**
LISCIVIATION	kg N	827	3.393	**1930**
EROSION	T soil	0,38	3,14	**2,89**
WATER	m^3	0	147.823	**60.000**

CROPS

Durum wheat: 4.84 ha

Common wheat: 30 ha

Maize: 0 ha

Tobacco: 17.16 ha

Barley: 0 ha

Sunflower: 0 ha

Melon: 6.96 ha

Alphalpha: 0 ha

- < tobacco surface of 10 ha
- > wheat surface of 19 ha
- elimination of maize
- introduction of melon

CONCLUSIONS

STRENGHTS OF DSRA

INPUT:

- It doesn't require specific parameters (es. weights, substitution rates) while uses "exemplary decisions"

OUTPUT:

- "GLASS BOX"
  - rules easily understandable: they reflect DM choices
  - determination of solutions supporting each rule

CONCLUSIONS

WEAKNESSES OF DSRA

CRITICAL POINT: DISCRETION

- High dependance of results on subjective choices
- Key role of the Decision Maker (interest only for GR?)

Reccomendable the use of the method within
CONSULTING SERVICE

CONCLUSIONS

STRENGHTS OF APPLICATION

- The method fits well with the application in the farms.
- Optimal strategy: conciliated the 4 objectives and hypothesized changes of farm situation which are auspicable in the Italian reality (decreasing of tobacco)

CONCLUSIONS

WEAKNESSES OF APPLICATION

DIFFICULTIES IN THE AVALAIBILITY OF DATA

- Data about farm management for non standard crops
- Environmental data

DIFFICULT PREDICTION OF PRICES AND COSTS

CONCLUSIONS

FUTURE RESEARCH

- This is the first application of IMO-DRSA in this sector: prosecution with other applications
- Introduction of other crops in the model
  Ex. orchards, wood
- Interesting the application at TERRITORIAL LEVEL
  (DM: public authority)

Thank You!