GROUP DECISION MAKING IN AGRICULTURE

Mathematical programming model + Group Decision Support System Approach

WP8: Agri-food supply chain decision-making under uncertainty

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How to support group decision making in horticulture: An approach based on the combination of a centralized mathematical model and a Group Decision Support System

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Introduction

• Planning of crops planting and harvest:
  • Balance between supply and demand
  • Objective \(\rightarrow\) maximize profits
  • Volatility of prices \(\rightarrow\) depend on supply-demand balance

• How can farmers decide which crops to cultivate each season to maximize their profits?
  • One solution:
    • Centrally plan the planting and harvest for all farmers
    • Maximize the profits of the region.
    • Problem: inequalities in profits obtained by farmers \(\rightarrow\) unwillingness to cooperate
Introduction

• Multi-objective mathematical programming model (MPM):
  • $\varepsilon$-constraint method $\rightarrow$ several Pareto optimal solutions
  • Need to choose one solution to be implemented

• Group Decision Support System:
  • MPM solutions as input data
  • Farmers of the region decide collaboratively between options
  • One selected solution to be implemented.

• Combination of two approaches to generate a satisfactory solution for a group
2. Related work

• Group Decision Support Systems for agriculture or horticulture
  • Existing DSS for agriculture (Perini and Susi, 2004):
    • Single user (one decision maker)
    • No possibility to make group decisions
    • Focused on pest management

• More than one decision-maker is involved in Agriculture decisions:
  • Farmers
  • Producers
  • Transporters
  • Sellers
  • ...
2. Related work

• Collaborative planning for agriculture or horticulture
  • Research on coordination issues in agricultural supply chains is in its early development.
  • Research addressing coordination among actors in the same stage is even more scarce.
  • Collaboration mechanisms among the members of vegetable supply chains for:
    • Achieving sustainability
    • Increase revenues and customer satisfaction
    • Reduce the negative impact of uncertainty.
3. MPM for the tomato planning problem

• Centralized MPM

• Coordination among farmers.
  • **Planting** decisions: How many tomato plants of each type to plant per period and farmer?
  • **Harvesting** decisions: How many tomato of each type to harvest per period and farmer?
  • **Transport** decisions: How many tomato of each type to transport from each farmer to each market per period?
3. MPM for the tomato planning problem

• Three objectives ➔ three dimensions of sustainability:
  • **Economic:** maximize profits of the supply chain
    • Profits = sales incomes – production costs – distribution costs
  • **Environmental:** minimize the tomato wastes
    • Wastes before harvest = matured – harvested tomatoes
    • Wastes after harvest = harvested – transported tomatoes
    • Wastes at market = transported – sales tomatoes
  • **Social:** minimize the unfulfilled demand
    • Unfulfilled demand = demand – sales
3. MPM for the tomato planning problem

• The model is subject to the following constraints:
  • **Planting constraints:**
    • The acreage for each type of tomato should not exceed the available planting area in each farm.
    • To ensure the flow of products:
      • All tomato types are planted in all planting periods.
      • All farmers plant tomatoes at all planting periods.
  • **Harvest constraints:**
    • The maximum quantity to be harvested at each period is fixed by the yield per unit area harvested.
  • **Transport constraints:**
    • The quantity of tomatoes to be transported can not exceed the quantity of harvested tomatoes at the same period.
  • **Market constraints:**
    • The quantity of tomatoes to be sold can not exceed the supply nor the demand.
4. GRoUp Support (GRUS) Decision

• GRUS system ➔ web application
  • Developed on the GRAILS framework (open source planform)
  • Can be used by users:
    • At the same or different location
    • At the same or different time
    • One or several meeting simultaneously

• Requirements:
  • Internet connection
  • Invitation to the meeting
4. GRoUp Support (GRUS) Decision

- Two steps:
  - Meeting creation $\rightarrow$ definition of the process used to jointly make decisions
  - Meeting achievement $\rightarrow$ decision-makers follow the process to make decisions.
5. Experiment: Case study

• Tomato planting and harvest in La Plata (Argentina):
  • One year horizon with monthly periods.
  • Five farmers with areas between 15 and 20 ha.
  • Three type of tomatoes to be planted: round, pear and cherry tomato.
  • Three planting seasons: July, October and January
  • Harvest dependent on planting:

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• Yield per plant depends on planting, harvest and type of tomato
• Limited workforce → planting and harvest activities
5. Experiment: Case study

- Tomato planting and harvest in La Plata (Argentina):
  - Two types of customers: Central market and Restaurants
  - Transport costs depend on origin and destination
  - Known demand
  - Variation of price in function of the balance between supply and demand.
    - Price ↑ when supply is lower than demand
    - Price ↓ when supply is higher than demand
- Penalizations for:
  - Wastes
  - Unmet demand
5. Experiment: Results of MPM

- The \(\varepsilon\)-constraint method is used to solve the multi-objective model
  - One objective is fixed as the single objective of the model.
  - The rest of objectives are transformed into constraints.

- Several non-dominated solutions are obtained
  - Decision-makers are provided with the following information per solution:
    - Profits per farmer and for the entire SC.
    - Wastes
    - Unmet demand
    - Acreage per tomato type
5. Experiment: GRUS for solution selection

• Context:
  • Ten alternatives (non-dominated solutions)
  • Five decision-makers with same importance (represent five farmers)
  • Three step process:
    • Alternative generation → made by facilitator
    • Vote → made by decision-makers
    • Final ranking → made by GRUS system
5. Experiment: GRUS for solution selection

• Results:
  • Solution 4: 24 points
  • Solution 3: 23 points
  • Solution 2: 20 points
  • Solutions 1 and 5: 17 points
  • Solutions 6 and 8: 16 points
  • Solution 9: 15 points
  • Solution 7: 10 points
  • Solution 10: 8 points
5. Experiment: GRUS for solution selection

• Best solution for the group: Solution 4
  • Five farmers have benefits
  • The three types of tomatoes are planted.
  • It is not the solution that generates the best profits for the entire SC.

• Best solution in terms of SC profits: Solution 1
  • The solution with higher profits is not necessarily the best one for the group of decision makers.
6. Conclusions

• Combination of two approaches (MPM and GDSS) for agriculture
  • MPM to generate ten optimal solutions
  • GDSS to select the solution in a group of five farmers

• The use of GDSS reduces conflicts between farmers → consensus

• Limitations
  • Group of researches have acted like the real farmers
7. Future work

• GRUS + Multi-objective centralized model (weighted sum method)
  • Use GRUS for the objectives definition and weights assigned to objectives.
  • Use MO model to obtain an optimal solution for the objectives and weights defined.

• Multi-objective centralized model ($\varepsilon$-constraint method) + GRUS
  • Use MO model to obtain several optimal solutions.
  • Use GRUS with real farmers to decide which solution to implement.

• Comparison of both approaches
References