Investigating supply planning of agricultural renewable resources to be refined for industrial production processes under consideration of varying qualities and quantities

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Agenda

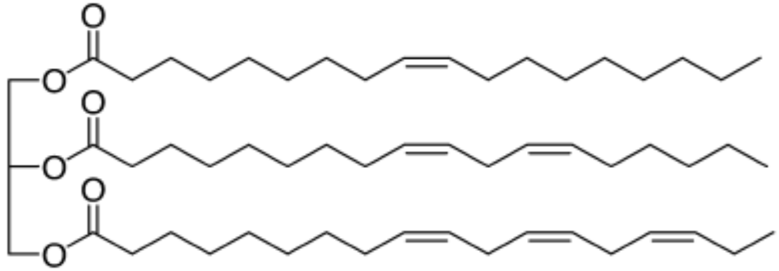
- Need of uncertainty handling for material use of renewable resources
- Industrial use of linseed oil
- Why investigate the problem of the refiner?
- Bicriterial decision problem of supply planning under uncertain quantity
- Problem formulation as stochastic nonlinear mixed integer program
- Possible directions for further research

Need of uncertainty handling for material use of renewable resources

- Aspiration of independence from crude oil in the long run. Need to investigate alternative raw materials
- Raw materials: Thin margins, need for efficient planning[3]
- Variations in qualities and quantities
- Origin of variations: e.g. quality of land, weather influences, application of fertilizers and pesticides, harvesting technology[3]
- High complexity! Difficult to incorporate quantitative correlations between influencing factors and resulting productivity of the land in a supply planning model.

Industrial use of linseed oil

- Cultivation in very different climatic regions[7]
- Existence of 100 to 300 cultivars mentioned in literature[7]
- Possible products e. g. binders for coating, softening agents, PVC-stabilizers, linoleum, bioplastics[6,7]
- Chemical processing allows the use of plant oils for the production of plastics by **polymerization** processes. The key property of plant oils facilitating this reaction is the presence of fatty acids with **double bonds**. Linseed oil has an exceptional high concentration of linolenic acid, a fatty acid molecule with 18 carbon atoms and three double bonds (C18:3).[6]
- A measure for the content of double bonds is the iodine value, defined as the mass of iodine in grams that is consumed by 100 grams of a chemical substance.[7]
- Example of a triglyceride with C18:1, C18:2 and C18:3 fatty acid



Biermann et al.(2000)

Why investigating the problem of the refiner?

- **Uncertainty** can arise on the supply side in **quality**, **quantity** and **price**
- Oil crops and oils are often traded as **commodities** with **standardized quality**[7]
- Till 2005: Commodity future on linseed was traded at the Winnipeg Commodity Exchange in Canada, three quality standards[7]
- Now: Commodity trading on **Over-the-counter markets**, three quality standards[7]
- Alternative: Use different quality specifications and buy from **known supplier**.
- Both parties can have incentives to establish **long term contracts**. Farmers need to consider **crop rotation.** Very strict **quality requirements** maybe require the planting of specific cultivars. Genetic engineers are working on improving the properties of plants. [6,7]
- Besides the important quality restrictions given through the required iodine value there are other **quality parameters** that need to be specified, e.g. moisture, admixture and free fatty acids.[4]

Why investigating the problem of the refiner?

- Given the knowledge which factors influence the quality and quantity of the harvest we can assume in the first place that a known supplier of linseed can provide the oil mill with more **information** about these random variables then any source of supply that is not known to the oil mill.
- In long term relationships with the supplier there is a need to mitigate uncertainty. One option is **contract farming**[7], where the buyer of the good agrees to take a certain quantity for a fixed price. Quality is uncertain. Essentially this type of contract is a **future**.
- Another option is to agree on a **contingency supply** that can be utilized in case the harvest quantity is not enough to satisfy the demand or doesn‘t comply with quality specifications. Price and quantity are fixed, but at the time of ordering it is not shure wheter it will be required or not. Essentially this type of contract is an **option**.
- The linseed oil is extracted at the oil mill. Some of the refiner offer to **process the goods further**, if the customer whishes so. The demand for these differently modified oils is obviously smaller then the demand of the natural linseed oil itself. The production processes ad huge **complexity** to the problem. Being aware of that problem, for simplities sake we begin the investigation with the assumption that the demanded product is a natural oil.

Bicriterial decision problem of supply planning under uncertain quantity

- The goals of the optimization problem for the oil mill are the maximization of the profit and the ability to deliver during the month t_{12} to t_{24}. Penalty costs have to be paid if demand cannot be satisfied.

The decision process has two stages:

- At the **first stage** (at $t_{0,}$ time of order placing) the decision maker decides how many m^2 land x he wants to contract for the farming of the oil crop. The productivity of the land α is uncertain. He agrees to take the uncertain quantity for contract farming Q_{cf} at the time of harvesting. As well at the first stage he has to decide how many m^3 contigency supply Q_{cs} he wants to order. The price P_{cs} inludes a risk charge P_r that adds to the price P_{cf}.
- At the **second stage** (at $t_{12,}$ time of harvest) the productivity α of the soil is revealed and the decision maker decides whether to take the whole contingency supply or not.

Problem formulation as stochastic nonlinear mixed integer program

max $\min\{Qp, Qos\} * Pp$ (revenue for the demanded product)

$-sgn * \max\{Qp - Qos, 0\} * Cp$ (penalty cost)

$- Qcf * Pcf$ (cost for contract farming)

$- y * Pr$ (risk charge contingency supply)

$- yz * Pcf$ (price contingency supply)

s.t. $x \leq A_{cf}/f$ (bound due to crop rotation)

$Qcf = x * \alpha$ (quantity contrated)

$Qos = \beta * (Qcf + y)$ (overall oil production)

$x, y \geq 0$

$z \in \{0,1\}$

Q_p – demand quantity of product for month t_{12} to t_{24}
P_p – price of demanded product
P_{cf} – price of linseed from contract farming per m^3
P_r – risk charge for contingency supply per m^3
C_p – penalty cost
A_{cf} – available farmland for contract farming
f – crop rotation
α – productivity of the land (m^3 linseed / m^2 land)
β – productivity of the mill (m^3 oil / m^3 linseed)
x – number of m^2 of the farmland to be contracted
y – quantity of contingency supply to be ordered
z – decision if contingency supply is used

Problem reformulation[5]

max $Qd * Pp$ (revenue for the demanded product)

$- xs * Cp$ (penalty cost)

$- Qcf * Pcf$ (cost for contract farming)

$- y * Pr$ (risk charge contingency supply)

$- Ccs$ (price contingency supply)

s.t. $Q_p \leq Qd$

$Q_p \leq Qos$

$Q_p - Qos \leq Mxs$

$(1 - z)M + Ccf \geq y * Pcs$

$x \leq A_{cf}/f$ (bound due to crop rotation)

$Qcf = x * \alpha$ (quantity contrated)

$Qos = \beta * (Qcf + y)$ (overall oil production)

$x, y \geq 0$

$z \in \{0,1\}$

Possible directions for further research

- Consider **uncertain quality** of supply. The acceptable levels of these parameters are given in specifications.
- Investigate the **effect** of available **information** structure on different modelling options. Is the distribution function of the **random variables** known or only sample information?
- **Generalize** the **model** for a wider range of renewable resources.
- Investigate the consideration of extreme events.
- Uncertainty can be further mitigated by **keeping inventory,** but for some renewable resources **restrictions on** the **shelf life** have to be considered.
- Another option is **purchasing from unknown commodity dealers** with very rough quality classification and prices according to the commodity market.
- Possibly **add further decision criteria** e.g. the aim of a strategic partnership with the contracted supplier.

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