



**AgEcon** SEARCH  
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

*The World's Largest Open Access Agricultural & Applied Economics Digital Library*

**This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.**

**Help ensure our sustainability.**

Give to AgEcon Search

AgEcon Search

<http://ageconsearch.umn.edu>

[aesearch@umn.edu](mailto:aesearch@umn.edu)

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

# Managing weather and price risk on a farm level

*A case study of linear programming in optimization of farm production structure*

Andrzej Mazurkiewicz, PhD

Wyższa Szkoła Ekonomiczna “Almamer”, Warsaw, Poland



**Paper prepared for presentation at the 108<sup>th</sup> EAAE Seminar ‘Income stabilisation in a changing agricultural world: policy and tools’, Warsaw, February 8-9, 2008**

*Copyright 2008 by Andrzej Mazurkiewicz. All rights reserved. Readers may make verbatim copies of this document for non-commercial purposes by any means, provided that this copyright notice appears on all such copies*

# Managing weather and price risk on a farm level

## *A case study of linear programming in optimization of farm production structure*

Andrzej Mazurkiewicz, PhD

Wyższa Szkoła Ekonomiczna “Almamer”, Warsaw, Poland

### **Abstract**

Weather and price risks have always been a significant factor in agriculture. Although, on academic level, a number of advanced methods of reducing the above risks is known, polish farmers definitely do not use them. During long history of agriculture, however, heuristic methods regarding the weather risk have been developed by them. Those methods can be embedded while constructing linear models of farms.

This paper presents results obtained from a practical application of a newly developed linear farm model generator. It has been used to analyze profitability of the “Plant Breeding and Acclimatization Experimental Station” in Radzików in Poland, while taking the weather and price risks in consideration.

### **Introduction**

Weather and price risk have always been a significant factor when planning every farm activity. On the academic level, a number of methods of taking weather and price risk into consideration have been developed. One group of them exists within stochastic programming, the ones most known in the academic society are Markowitz, Madansky, Dantzig-Madansky [Dantzig1961], Charnes-Cooper[Borkowski1993]. In 2002 [Dominguez2002] at least 8 different systems for modeling and solving problems under uncertainty were known to be developed. However, none of those methods are used in practice in polish agriculture. It should be stressed here that polish farmers are very traditional. They approach new management methods with suspicion. One reason for that is a relatively low level of their education.

During the history of agriculture, certain heuristic methods have been developed by farmers to decrease the influence of the weather risk. Those methods can be embedded into linear models of farms. Although less sophisticated than the academic ones, they should be accepted easier by the farmers as planning aid.

Another factor to be taken into account, is the complexity of linear models of farms. This technique, even without advanced methods of decreasing the influence of the above-mentioned risks, is too difficult for the average farmer. In the opinion of the author, hiding the linear model behind objects and terms understandable for the average farmer gives a chance to promote among farmers the linear programming applications and methods to decrease the influence of the weather and price risks.

The purpose of this article is a demonstration of feasibility of linear programming together with a newly developed generator of farm models as a tool to help farmers decrease the influence of the risks and to make more rational decisions.

It is the author's first step in introducing new tools in practical weather and price risk analysis.

## **Methods of decreasing the influence of the weather risk, traditionally applied on the farm level**

The weather has always influenced agriculture. Now, in the 21<sup>st</sup> century, even though mankind has tremendous potential for using advanced technology, weather is a factor that cannot be overlooked. During the long history of agriculture, certain heuristic methods of decreasing the influence of the weather risk have been developed. They can be split among: having necessary resources to survive (as a farm as well as the farmers) and keeping a production structure that is relatively weather-resistant. Methods used in practice of Polish agriculture are presented below.

Generally, the animal production is less directly influenced by the weather than the plant production. In most animal husbandry technologies, animals are somehow insulated from the weather. Usually, they occupy stands in buildings. During cold weather it is warmer inside than outside. During hot weather – a bit colder. Maintaining a reasonable share of the animal husbandry, while preserving extra feed reserve, inhibits fluctuations of the farm income, providing a predictable input of money to the farm in certain periods. In Polish conditions, this particularly applies to the milk production and the pig production, as both stabilize farm income.

Different plants have different sensitivity to variations of the weather. From the economics point of view, some of them are relatively resistant to those changes. Sugar beet is such a crop. It gives the surplus, constant to a certain extent, at a relatively wide range of the weather conditions. Sugar beet has a long vegetation period. It means that if it survives harsh weather period, it has time to grow. It also has a relatively deep root system that gives it an opportunity to survive drought weather well. There is an economical factor too. Price system of sugar beet is constructed in such

a way that it depends on beet's sugar content. When it is colder and wetter, there is a relatively big crop with lower concentration of sugar. When it is hot and dry, not to a level of a disaster however, the crop volume is lower, but the concentration of sugar is higher. The overall result is that the sugar beet stabilizes the farm's income.

A summary of a common-sense strategy for farmers is:

- to keep animal production that gives stable income,
- to keep necessary feed reserve for the animals,
- to have substantial amount of plant production with relatively weather resistant crops.

In the case of the analyzed farm, an additional factor exists. The farm has been producing certified seed lots. Consequently, as a stabilizing tool, an area reserve for the seed production crops has always been maintained. It means that a reserve of the seed material has always existed, to be sold in case of increased demand. Such situation occurred in 2006. Because of a drought in that year, the demand increased and all seed material produced in 2006 was sold within two months after the harvest.

After considering the above factors, farm managers select the rest of plants planned for cultivation. Crop rotation needs and a surplus that the plants provide are main selection factors. This, with a calculation of the surplus from branches of the animal husbandry, completes the list of the tools practically used by polish farmers to protect them against weather risk. Of course it does not mean that farmers estimate them with a calculator or a spreadsheet program. Generally, farmers are “a traditional species of the mankind”. A lot of their behavior is strictly customary. The choice of the production structure is customary as well. What has been interesting, in Poland, many farmers do not even calculate precise surplus of the cultivated plants or plants planned for cultivation. However, relatively precise total income and total cost is known for every farm.

## **Price risk in the practice of polish farms**

As precise calculation of the surplus of the plant activities is uncommon, the author has not encountered any estimation of the price risk outside of the academic society. However, crop rotation requirements force farmers to maintain certain plant portfolio. Also, maintaining the animal husbandry widens the activities portfolio and subsequently reduces not only the weather risk but makes the farm resistant to price variations. Of course, the above reasoning does not apply to monoculture production. Apart from the above, a contract for delivery of farm products is the only remaining method used by polish farmers to protect against the price risk.

## Taking the risks into consideration while entering the farm data

Decreasing the influence of the weather and price risk can be faster and easier with a novel tool. Such a tool, is a developed by the author generator of linear models of farms. It consists of: a specialized database, an entire generator, optimizer and a set of reports. It hides the linear model layer under a model of farm resources and production relationships that are common to every farmer. Like every generator, it significantly decreases work necessary to construct the farm model. The generator has been used by the author to generate a model of the “Plant Breeding and Acclimatization Experimental Station” in Radzików in Poland (PBAES) and to analyze how rational the production is.

The computations have been carried out for: average weather conditions; drought (conditions of the year 2006 in Poland); intermediate conditions. The wet weather conditions were not analyzed, as such did not happen during last 10 years.

All earlier considered ways of decreasing the influence of the weather risk have been applied.

- The animal production data has been input into the database.
- The feed reserve has been defined as selling conditions with a very low price, since the tool forces every sold product to have a non-zero price.
- The sugar beet has always been planted in the PBAES. An amount produced is a contract value. A selling condition for the sugar beet was entered with negotiated price, taking a planting reserve into consideration.
- For the additional certified seed material reserve, two types of selling conditions have been defined. First one, for true certified seed material, in predicted selling volume, at the price of seed material. Second one, for the seed material reserve, without additional seed processing, at the price of standard grain, with limits set on the minimal volume.

A number of price risk scenarios has been calculated for the average polish weather conditions.

- A price of sugar beet has decreased from 41 Euro to 20.5 Euro.
- A price of milk has decreased from 27 to 8 cents.
- Area subsidies have decreased from 130 Euro to 0 Euro.
- Prices of consumed materials have increased. An index of consumed materials has been

defined. The index value was equal 1 for prices in 2005. An assumption has been made, that for every 20% increase of diesel oil price, prices of other consumed materials have increased by 10%. The index reflects the prices of diesel oil, i. e. every 10% increase of the price index means a 10% increase of the diesel oil price and a 5% increase of the price of other consumed materials.

## Results

The generated linear models have been sized from about 10000 rows and 8000 variables to about 19000 rows and 10000 variables.

### ***A comparison of an actual production structure and the computed optimal one***

Interestingly, except for the winter wheat, the actual plant structure has been evolving to the computed optimal one for the weather conditions in between the average ones and a drought of the year 2006 (ref. to tab. 1). In the opinion of the author, it means that competent management staff of the farm maintains the farm in a suboptimal area, taking weather risk into consideration. Except for the mentioned winter wheat, the biggest change from the structure of the year 2005 to the structure of the year 2006 was in an area of winter raps. The author had asked the manager of plant production for the reason of such a significant change. The answer was: “We had wanted to produce more raps, however, in autumn 2004, we did not have enough good forecrops for it”.

*Table 1: Optimal production structure in different weather conditions – comparison with actual values.*

Farm activities	Actual values		Computed optimal values		
	2005	2006	Average weather conditions	Intermediate weather conditions	Actual weather conditions of the year 2006 (drought)
Cereals (ha), among them:	477.5	452.8	453.1	429.1	438.8
winter wheat (ha)	142.4	171.0	146.9	129.8	137.7
spring wheat (ha)	64.0	55.0	61.4	20.9	24.9
rye (ha)	47.0	34.0	41.3	31.5	38.2
triticale (ha)	64.0	38.0	20.0	23.5	28.6
spring barley (ha)	47.1	34.8	61.0	100.9	86.8
grain maize (ha)	113.0	120.0	122.6	122.6	122.6
winter raps (ha)	142.6	172.0	219.7	229.3	210.7
sugar beet (ha)	142.6	134.7	129.3	129.9	128.8

forage plants (ha)	110.5	99.7	107.1	121.0	130.9
green maize (ha)	70.8	61.0	60.5	68.5	78.4
other green forage plants (ha)	34.0	33	46.6	52.5	52.5
milk cows	207 - 211	180 - 210	209 - 210	204 - 218	197 - 213
sold cows	62	68	69.6	69.5	67
sold heifers - total (24 months)	20	14	39.5	17	17
sold pregnant heifers		0	17.7	0	0
sold young bulls (14 month)	0	0	0	22	0
sold calves (2.5 months)	115	109	110.4	129	128
milk production (k l)	1 452	1 495	1 467	1 467	1 467
objective function (k Euro)	x	x	875	826	731
fixed cost (k Euro)	x	x	686	686	686
profit (k Euro)	120	62	172	123	35

The differences in forage crops area have been due to comparison of dynamical actual values with optimal multi-year values. Actual values of forage crops area have depended on feed reserve from previous year, something that has changed from one year to another.

### **Price change scenarios**

The following results have been obtained from the price scenarios analysis.

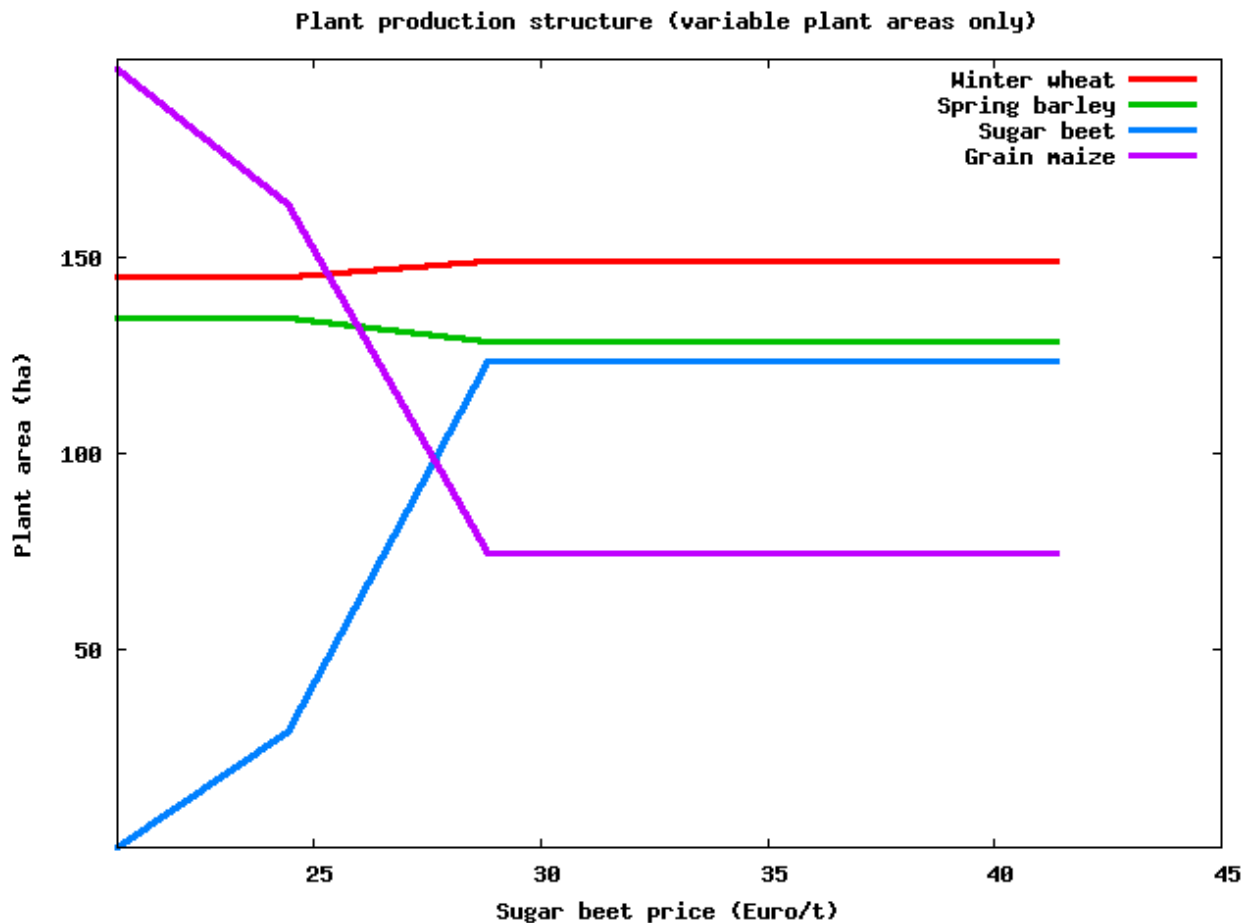
- Influence on the profit.
  - The only scenario when the farm has lost its profitability has been the decrease of the milk price from 27 cents below 13 cents. In all other scenarios, the farm has been profitable.
- Sensitivity of the optimal solution.
  - Except for the changes of the sugar beet prices, the optimal production structure has not changed within the analyzed variation of prices.
  - The changes of the plant production structure, caused by the decreasing of the sugar beet prices from initial 41 Euro, are presented on fig. 1. The production structure has not changed till the price has dropped below 29 Euro. However, while making the decision, the stabilizing influence of the sugar beet on income within the wide range of weather



conditions should be taken into consideration.

## Summary

The weather and price risk have always been a significant factor when maintaining farm production. On the academic level, a number of methods of taking weather and price risk into consideration have been developed. Polish farmers definitely do not use them. During long history of agriculture, however, heuristic methods of reducing the influence of the weather risk have been developed. These methods can be summarized as: keeping a balanced portfolio of animal and plant activities, maintaining the feed reserve for animals, growing plants that are relatively resistant to weather variations.



*Figure 1: Optimal plant production structure depending on sugar beet price*

All those methods can be used while applying linear programming methods. Manual construction of linear models is a labor consuming and an error prone process. In this article, results of the application of a new tool, generator of linear models of farms has been presented. The tool presented here hides the linear programming model behind user-friendly interface, with names and objects commonly used by the farmers. At the same time, all above-mentioned heuristic methods of

decreasing the influence of the weather risk can be applied. Analysis of price change scenarios is made easier as well.

The generator has been used for an analysis of the “Plant Breeding and Acclimatization Experimental Station” in Radzików in Poland (PBAES). The linear model variants of the PBAES for average weather conditions, drought of year 2006 and intermediate conditions have been generated and the computation results compared with real values. A number of simulations of price changes have been computed as well. Following results have been obtained:

- Competent farm management maintain their farm in the suboptimal area, taking weather risk into consideration (ref. to tab. 1).
- In average weather conditions, the PBAES farm would lose profitability if milk price decreased from 27 cent/l to below 13 cent/l. In all other scenarios it has remained profitable.
- Except for the changes of the sugar beet prices (ref. to fig. 1), the optimal production structure has not changed within the analyzed variation of prices. As for the sugar beet, the optimal plant structure has changed when the sugar beet price has decreased from 41 Euro/t to below 29 Euro/t.
- Additionally, this research has shown that hiding the linear model structure from the end user is possible and it does not affect interpretation of results by the end user.

## References

Dantzig G. B., Madansky A. (1961): *On the Solution of Two-stage Linear Programs under Uncertainty*. Proceedings of The Fourth Berkeley Symposium on Mathematical Statistics and Probability, 165-176.

Dominguez-Ballesteros B.; Mitra G.; Lucas C.; Koutsoukis N-S. (2002): *Modelling and solving environments for mathematical programming (MP): a status review and new direction*, Journal of the Operational Research Society, Volume 53, Number 10, 1 October 2002, pp. 1072-1092(21).

Borkowski B. (1993): *Modyfikacja i zastosowanie metody Charnesa-Coopera do planowania struktury produkcji gospodarstw rolniczych*. Roczniki Nauk Rolniczych 1993, seria G, T. 86, Z. 2.

Mazurkiewicz A.: *Application of graph theory to automatic construction of linear models of farms (in Polish)*. PhD thesis, Szkoła Główna Gospodarstwa Wiejskiego, Warsaw 2007.

