

# WEATHER INDICES IN THE PROFITABILITY CALCULATIONS OF SELECTED CROPS AT THE SECTORAL LEVEL ON THE EXAMPLE OF FODDER MAIZE

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## Abstract

*The objective of this paper is to use weather indices to estimate the cost of production risk in the profitability calculations of selected crops on the example of fodder maize. The source of data are GUS secondary data (concerning, among others, yields) and System of Collection of Data on Agricultural Products - Agrocots (Agrokoszty) in the Agricultural Accountancy Department of IAFE-NRI. The indicator analysis method was used, taking into account measures and indicators used in the economics of agriculture. The methodical approach to estimating the cost of production risk that is proposed by authors is based on the use of so-called weather indexes (WI). Methodology for estimating the cost of production risk for fodder crops is based on the category of yield lost due to unfavourable weather conditions, as the difference between yields potentially achievable in optimal weather conditions and real yield. The cost of production risk corresponds to the monetary effects of the materialization of unfavourable weather phenomena. The weather index as a synthetic measure can take positive values. Green maize is the alternative (competitive feed) for clover and alfalfa forage. Taking into account the cost of risk in total production costs reduced the profitability index (including the cost of risk) of fodder maize only in 2014-2015. The production of fodder maize was profitable in 2009-2013, which resulted from the favourable price of fodder barley on the market. In the calculation of costs, the cost of risk cannot be omitted because its omission leads to underestimation of*

*economic and financial results, which in turn may lead to incorrect decisions at the micro level regarding, for example, agricultural crop portfolio, investment activities, and macro level too high support in the form of payments area (mainly, decoupled payment as remuneration for lost income.*

**Keywords:** *production risk, , profitability calculations, risk management, subsidies, weather index.*

**JEL classification:** *Q18, Q14.*

## 1 Introduction

Agriculture is treated as a specific branch of the national economy, which results from its strong dependence on factors beyond farmers's control. In particular, crop production is exposed to difficult to predict changes in natural factors affecting agricultural output (Lidsky et al., 2017, Majewski et al., 2008). In addition, Harwood et al. (1999) indicate that for the majority of field crops, price volatility is the main risk factor, followed by yield variability, while other risk categories that are associated with total yield loss are of marginal importance. This means that the production risk seems to be one of the main problems in crop production.

The above situation is conducive to the emergence of difficulties in predicting production volume, income, costs and losses (Jerzak, 2008). Sokołowska (2008) stated that about 80% of the variability of agricultural production is conditioned by weather factors, which significantly affects the financial results of agricultural holdings. It is also noticed by El Benni and Finger (2012), who prove that costs play a small role in determining income volatility, but the risk of prices and profits is of great importance and is specific to particular crops. Hence, profitability calculations are important for making the right economic decisions that result in minimizing the negative financial consequences for farm households. The group of risks with a particular intensity in agriculture include production risk, which is closely related to climatic and weather changes. The biggest threats to crop production are caused by strong changes in temperatures and rainfall. It is therefore important to take over the risk costs in the profitability calculations for individual crops. This also allows to assess the need for subsidizing a given crop.

The objective of this paper study is to use weather indices to estimate the cost of production risk in the profitability calculations of selected crops on the example of fodder maize (*Zea mays L.*).

The remainder of this article is following. After a brief justification for tackling of the research problem, we provide a literature review that focuses on a plethora of implications of weather risk from the perspective of crop production and

agricultural policies. Then, we present data and methodology, depicting our approach to implementing of weather indices. Our results, including calculations for green fodder maize, are discussed. We conclude with some research and political recommendations.

## Literature review

In the existing literature, weather risk is usually divided into two types and several categories. As for the types, these are: extreme events (varying from short-lived, violent phenomena of limited extent to the effects of large systems; the most common examples being tornadoes, thunderstorms, cyclones or floods) and regional climate anomalies (mesoscale storms, severe local storms, hail, etc.). The commonly used categories of weather risk, on the other hand, are as follows: (i) droughts, (ii) heavy rainfall and floods, (iii) strong winds (tornadoes, storms and tropical cyclones), (iv) temperature (frost and heatwaves), and (v) others (duststorms and sandstorms, hailstones, fog, smoke, haze and pollution, locust) (WMO, 2010). It is worth noting that in recent decades the scale of the occurrence of both types and most of the above categories has steadily progressed due to climate change and that it is likely to increase even further in the future. For instance, a report by Global Food Security ([GFS], 2015) suggests that the risk of a 1-in-100 year production shock in agriculture is likely to increase by 2040 to 1-in-30 or more. The existence of numerous and diverse weather risks implies appropriate strategies to both prevent their occurrence and, once they occur, to reduce and eliminate their effects. According to World Development Report 2000/2001 (World Bank, 2001, p. 140), risk management strategies in agriculture can be divided, in general, into two basic categories: informal strategies (identified as “arrangements that involve individuals or households or such groups as communities or villages”) and formal strategies (“market-based activities and publicly provided mechanisms”). In the case of the former, as indicated by the authors of *Managing Risk in Agriculture: a Holistic Approach* (Organisation for Economic Co-operation and Development [OECD], 2009), farmers have essentially three options for dealing with weather risks: „prevention strategies to reduce the probability of an adverse event occurring, mitigation strategies to reduce the potential impact of an adverse event, and coping strategies to relieve the impact of the risky event once it has occurred” (p. 21). In the case of formal strategies, on the other hand, the policymakers either put emphasis on training farmers, compensate them for catastrophes, or rely on (subsidized) insurance mechanisms (Lorant & Farkas, 2015).

In addition to intrinsic sources of uncertainties in agricultural production (market price volatility, animal and plant health-related risks, etc.), the impact

of weather-related risks<sup>1</sup> on this sector, especially in the context of the advancing climate change, has become more and more important concern for both farmers and policymakers worldwide. Addressing the problem of weather risk we should, however, begin with the discussion of the term itself. The essential—from the point of view of agriculture—distinction between weather and climate requires clarification in the first place. World Meteorological Organization in its Guide to Agricultural Meteorological Practices (World Meteorological Organization [WMO], 2010) explains that “The term weather is used to describe day-to-day variations in our atmosphere.... Weather is therefore an instantaneous concept. The climate of a region is described by collating the weather statistics to obtain estimates of the daily, monthly and annual means, medians and variability of the weather data. Climate is therefore a long-term average of weather” (p. 7-1). Weather risk, as we understand it in the context of agricultural production, applies to both weather and climate.

Among numerous weather risk insurance solutions, a weather index-based insurance (WII) is of particular importance<sup>2</sup>. This product was created in response to numerous problems with traditional weather risk insurance (and with traditional insurance in general), primarily related to asymmetric information and high transaction costs (Conradt et al., 2015). Index-based insurance product offers some potential in this regard by conditioning the payout not on actual losses experienced by policyholders, but on the realization of an independent index, making use of variables exogenous to the insured individual but with a strong correlation to farm-level losses (BuChun et al., 2010; Hess, 2007). The fact that weather index-based insurance product does not—as it is the case with conventional insurance—require loss assessment therefore reduces transaction costs, while the use of an objective indicator (unlike conventional insurance which is

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<sup>1</sup> The use of the term ‘risk’ in the context of weather hazards—the distinction between risk, hazard and anomaly in particular—also requires some explanation. By hazard we understand a potentially destructive event or process, risk corresponds to the magnitude of a potential loss within the area subject to hazard for a particular location and a reference period, while anomaly is the deviation of a meteorological quantity value from the normal (mean) value for a given period (WMO, 2010).

<sup>2</sup> As Spicka and Hnilica (2013) explain, “a weather index that is the collection of weather variables measured at a stated location during an explicit period” (p. 1). Hess (2007) points out that the measurement risk for the index must be low which means that the indicator is required to be believable, reliable, and void of human manipulation (the conditions that are usually met by publicly available measures of weather). He also emphasizes the role of new technology innovations (e.g. automated instrument calibration) in the increase of index credibility. Moreover, he draws attention to the special requirements for indices that are to serve as the basis for weather insurance: they must be, above all, strongly correlated with yield or revenue outcomes for farms across a large geographic area.

based on yield loss, where the insurer is often unable to determine to what extent the loss is due to a weather- or climate-related event and to what—due to farmer's lack of work) prevents information asymmetries (Ricome et al., 2017).

The main problem with the use of the index, however, is the so-called basis risk: the difference between farmer's loss and the payout it triggers. This can manifest itself in a situation where a policyholder experiences yield loss, but does not receive a payout, or—alternatively—in a payout without any actual loss. Weather index-based insurance therefore works best where losses are homogeneous (both time- and area-wise) and highly correlated with the indexed risk (International Fund for Agricultural Development, 2011; Fuchs & Wolff, 2011). A key challenge to achieve the potential benefits from WII is thus to improve the design of both insurance and the index itself (Conradt et al., 2015).

In recent decades the use of weather index-based insurance in agriculture has been the subject of numerous studies, empirical ones in particular. In their analyses, most of the authors deal with a simple index based either on rainfall or temperature (e.g. Turvey, 2001; Martin et al., 2001; Barnett & Mahul, 2007; Berg & Schmitz, 2008; Kellner & Musshoff, 2011; Daron & Stainforth, 2014). An alternative approach, trying to address the problem of indices' oversimplification can be found, for example, in Conradt et al. (2015).

Sivakumar and Motha (2007) point out that risk management strategies in agriculture can involve such basic categories of activities as: (i) avoiding the dangers, (ii) preventing/reducing the frequency impacts, (iii) controlling/reducing the consequences, (iv) transferring the risk, (v) responding appropriately to incidents/accidents, and (vi) recovering or rehabilitating as soon as possible. The same authors draw attention to a specific aspect of weather risk management in agriculture, related to its time perspective: "The climate-based decisions that farmers make are mainly strategic in nature, e.g. choice of a crop/cropping system, allocation of acreage, purchase of inputs such as seed and fertilizer ahead of the cropping season, etc. In contrast, the weather-based decisions are tactical in nature and affect the operational activities such as sowing, fertilizer application, irrigation, weeding, harvesting, etc. Farm-level risk management strategies have to deal with both the changing and variable climatic conditions as well as the weather conditions" (p. 477). Since some of the management strategies in the case of weather risk in agriculture are not available at all (e.g. avoiding the dangers, preventing the frequency impacts, etc.), while others can be applied only to a limited extent and under certain conditions, the most popular strategies include transferring the risk, in particular through weather risk insurance. This, moreover, remains in line with the global trend—an increasing reliance on insurance in agricultural risk management in general. For instance, Lorant and Farkas (2015)

notice that, according to estimates, agricultural insurance premiums worldwide amounted to as much as USD 23.5 billion in 2011, while other studies (e.g. Wang et al., 2011) show that this trend applies not only to developed countries (and state organizations, such as the EU with its Common Agricultural Policy) but to developing ones as well.

Finally, the possible impact of government policies on the weather risk insurance sector cannot be left unnoticed. This applies in particular to insurance subsidies. Governments frequently subsidize agricultural insurance in order to increase the demand for it by lowering the premiums charged to farmers. The subsidies may take different forms, e.g. direct premium subsidies, administrative or product development costs reimbursements, or below-market premium rates reinsurances (Hess, 2007). It is noteworthy, however, that not only farmers but also private insurance companies may be beneficiaries of government subsidies, since the latter often provide coverage for farmers against different weather- and climate-related risks with public support. Lorant and Farkas (2015) observe that farm insurance (including weather risk-related) is particularly intensively subsidized in numerous developed countries, the two most notable examples being the United States and the EU.

Strategic risk management starts with decisions made at the farm-level, where various types of risk management strategies and instruments are selected and implemented. Nevertheless, Wolf et al. (2009), however, note that the impact of risk management instruments on risk mitigation depends, inter alia, on from the scope of risk resulting from yields and prices, hence production costs may vary and affect farmers' income. This is confirmed by the studies of El Beni and Finger (2012), who indicate that both prices and yields contribute on average from 88% (barley) to 98% (sugar beet) to the volatility of net income. It seems reasonable, therefore, to take into account the costs of production risk reflecting the variability of yields and prices in profitability calculations.

To conclude, the approach based on weather indices can be applied for assessment of profitability of selected crops. This is of great importance for decisions on to construct criteria of eligibility for I Pillar payments (within Common Agricultural Policy, CAP).

## **2 Data and Methods**

The sources of secondary data (concerning, among others, yields) included GUS (Główny Urząd Statystyczny, Central Statistic Office) and System of Collection of Data on Agricultural Products - AgrocOSTS (Agrokoszty) in the Agricultural Accountancy Department of IAFE-NRI. The indicator analysis method was used,

taking into account measures and indicators used in agricultural economics. The algorithm of calculation for margin categories can be described as follow (Skarzyńska, Jabłoński 2016, p. 167):

Total output

- *Direct costs*

= Gross margin without subsidies

- *Actual indirect costs (excl. the cost of external factors)*

= Gross value added from an agricultural activity

- *Indirect estimated costs minus depreciation*

= Net value added from an agricultural activity

- *The cost of external factors*

= Income from activity without subsidies

+ *Additional payments*

= Income from an agricultural output

When calculating the production risk for fodder plants, including alfalfa, clover and maize, the problem is the lack of so-called active market, hence the most-favoured variable for the production of non-commodities. The methodical approach to estimating the cost of production risk is based on the use of so-called weather indexes, IP. These indexes are designated only for selected crops, and in the absence of an indexed index, plants with the most similar physiological traits are usually taken over (Kopiński et al., 2013).

A methodological approach for estimating the cost of production risk for fodder is based on use the category of yield lost due to outstanding (unfavourable) weather conditions, as the difference between yields potentially achievable in optimal weather conditions and real yield (Kopiński et al., 2013, pp. 53-63). The cost of production risk corresponds to the monetary effects of the materialization of unfavourable weather phenomena.

It should be underlined that the weather index (WI) as a synthetic measure based on a set of agro-meteorological parameters - can take only positive and total values:

$WI = 100$  - average weather conditions determined in the area,

$WI < 100$  - unfavorable conditions (materialization of weather risk),

$WI > 100$  - above-average conditions.

The amount of yields potentially achievable is determined in accordance with equation (1):

$$y_i = (x/WI) \cdot 100 \tag{1}$$

$y_1$  – potential yield that is achievable in optimal weather conditions [dt/ha];

$x$  – real index [dt/ha];

$WI$  – weather index (derived from the Institute of Soil Science and Plant Cultivation - State Research Institute, ISSPC-SRI, IUNG-PIB).

Yield that was potentially lost due to extraordinary weather conditions ( $v$ ) was determined as the difference between the potential yield ( $y_p$ ) and real yield ( $x$ ), as below (2):

Due to the use of averaged values (at the country level), there were no grounds to increase the yield for above-average benefits.

The cost of production risk ( $c_{pr}$ ) - as a monetary value - is the product of the equivalent of fodder barley (constant - 0.144), its market price and lost yield (if exist), according to equation (3).

$$c_{pr} = 0,144 \cdot p \cdot v \quad (3)$$

where: 0,144 - fodder barley equivalent (1dt of green equals to the content of nutrients 0.14 dt of feed barley);

$p$  - price of feed barley [PLN/dt].

### 3 Results and Discussion

Table 1 presents calculations of profitability for green fodder maize (timespan: 2009-2015), whereas table 2 contains calculations costs of production risk. Yields of fodder maize were relatively stable (excluding the last year of timespan). Only in 2014 and 2015 potential maize yield was lower than real yields. Consequently, lost yields and cost of production risk were calculated. Taking into account the cost of risk in total production costs reduced the profitability index (including the cost of risk) of fodder maize only in 2014-2015. The production of fodder maize was profitable in 2009-2013, which resulted from the favourable price of fodder barley on the market.

Table 1 Calculations of profitability for green fodder maize

Description	2009	2010	2011	2012	2013	2014	2015
Yield of fodder maize [dt/ha]	449	437	496	499	486	478	357
Yield as an equivalent of fodder barley [dt/ha]	64,7	62,9	71,4	71,9	70	68,8	51,4
Purchase price of fodder barley (GUS) [dt/ha]	38,4	46	71,5	78,6	72,7	60	57
Total output (TO) [PLN/ha]	2484	2892	5106	5647	5090	4131	2930
Total direct costs [PLN/ha]	1262	1061	1419	1528	1543	1497	1492

Description	2009	2010	2011	2012	2013	2014	2015
<b>Gross margin without subsidies [PLN/ha]</b>	1222	1831	3687	4119	3547	2633	1438
<b>Total indirect costs [PLN/ha]</b>	1032	868	1161	1251	1263	1225	1221
<b>Income from activity without subsidies [PLN/ha]</b>	190	963	2526	2868	2284	1408	218
<b>Total costs [PLN/ha]</b>	2294	1929	2580	2779	2806	2722	2713
<b>Costs of production risk, CPR [PLN/ha]</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>128</b>	<b>643</b>
<b>Total costs + CPR [PLN/ha]</b>	2294	1929	2580	2779	2806	2850	3356
<b>Income from activity without subsidies excl. CRP [PLN/ha]</b>	<b>190</b>	<b>963</b>	<b>2526</b>	<b>2868</b>	<b>2284</b>	<b>1280</b>	<b>-425</b>
<b>Profitability indicator (Total Output/Total Costs) [%]</b>	108,3	149,9	197,9	203,2	181,4	151,8	108,0
<b>Profitability indicator incl. CPR (Total Output/Total Costs) [%]</b>	108,3	149,9	197,9	203,2	181,4	144,9	87,3

Source: Own computation based on GUS, Agrokoszty (team of A. Skarżyńska) and IUNG-PIB data.

Table 2 Calculation of costs of production risk

	2009	2010	2011	2012	2013	2014	2015
Yield of maize for green fodder (GUS) [dt/ha]	449,0	437,0	496,0	499,0	486,0	478,0	357,0
Yield in feed barley equivalent [dt/ha]	64,7	62,9	71,4	71,9	70,0	68,8	51,4
Purchase price for barley yield (GUS)	38,4	46,0	71,5	78,6	72,7	60,0	57,0
Weather index for grain corn (IUNG-PIB) [-]	104,0	101,0	113,0	106,0	100,0	97,0	82,0
Total output (TO) [dt/ha]	2484	2892	5106	5647	5090	4131	2930
Real crop yield [dt/ha]	449,00	437,00	496,00	499,00	486,00	478,00	357,00
Potential crop yield [dt/ha]	431,73	432,67	438,94	470,75	486,00	492,78	435,37
Lost yield [dt/ha]	0,00	0,00	0,00	0,00	0,00	14,78	78,37
Total output for lost crop [dt/ha]	0,00	0,00	0,00	0,00	0,00	127,75	643,23

	2009	2010	2011	2012	2013	2014	2015
Cost of production risk [dt/ha]	0,00	0,00	0,00	0,00	0,00	127,75	643,23

*Source:* Own computation based on GUS, Agrokoszty (team of A. Skarżyńska) and IUNG-PIB data.

Green fodder maize is the alternative (competitive feed) for clover and alfalfa forage. In terms of soil and fertilizers, fodder maize belongs to fastidious crops, strongly exposed to high production risk, especially high sensitivity to changing weather conditions (e.g. the so-called drought stress and low tolerance to spring chill, hail or rainfall) and high susceptibility to diseases. Including production risk in the profitability calculations for fodder maize seems to be strongly justified. This is indicated by Zaliwski and Hołaj (2005), who emphasized that a correct economic calculation must take into account production capabilities (e.g. environmental conditions, prices) and production restrictions (cost of technologies used, risk, required quality level, etc.). Cost-effectiveness calculations that take into account the production risk can be used to seek better solutions to the decision-making situation. This allows a more accurate assessment of the economic effects of fodder maize.

Research including the cost of risk minimization in profitability calculations was carried out, among others, by General Manitoba Agriculture, Food and Rural Development ([MAFRD], 2016) and Skarżyńska et al. (2017). They point out that the inclusion of the cost of risk in the profitability calculations of fodder crops can significantly affect the production decisions of economic entities. This is especially important in the case of maize for green fodder because of its growing economic importance, both in Poland and in the world. Research conducted by Lipski (2004) indicates that the area of maize cultivation in Poland—as well as the yield of grain and green fodder—has been growing constantly since 1996. This is undoubtedly the reaction of producers to the increasing market demand caused by the concentration of animal production. These results are confirmed by Skarżyńska et al. (2017), who indicate that in 2003-2015 the area of maize for green fodder cultivation in Poland increased significantly from around 240,000 ha to over 555,000 ha and it was several times larger than the acreage of clover and alfalfa. This is the effect of, among others, high nutrient content in maize. Calculations by Skarżyńska et al. (2017) indicate that the content of nutrients in silage produced from the harvested crop of 1 ha of green fodder from is higher than in the case of alfalfa silage. In 2009-2015, the protein content in the former was on average 25.5% higher and fat content—238.6% higher than corresponding values in the latter. At the same time, the cost of producing 1 kg of protein and fat

contained in fermented was 18.3% lower comparing to alfalfa silage. These results indicate a significant advantage of maize silage in terms of economic value.

## 4 Conclusion

The weather risk that is strongly linked to climate changes is one of significant risk factors in crop production. Calculation of crop production profitability cannot omit cost of materialisation of risk. This is a difficult methodological challenge so calculations are presented at the sectoral level (mainly, *ex-post*).

The analysis of production costs calculation for selected arable crops, followed by the analysis of profitability is an important element of the managerial calculations that are important from the point of view of the selection of production branches on the farm, taking into account the preference of the farmer. The evaluation of the profitability of maize, in comparison to other alternative fodder plants (e.g. alfalfa or clover), is of great importance from the point of view of profitability of livestock production (for example, ruminants, including dairy cows).

Taking into account the cost of risk in total production costs reduced the profitability index (including the cost of risk) of fodder maize only in 2014-2015. The production of fodder maize was profitable in 2009-2013, which resulted from the favourable price of fodder barley on the market.

In the calculation of costs, the cost of risk cannot be omitted because its omission leads to underestimation of economic and financial results, which in turn may lead to incorrect decisions at the micro level regarding, for example, agricultural crop portfolio, investment activities, and macro level too high support in the form of payments area (mainly, decoupled payment as remuneration for lost income).

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