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# CHEMICAL USE IN CROP PRODUCTION – CAN IT BE REDUCED BY NEW TECHNOLOGIES?[1]

## *OCHRONA CHEMICZNA W PRODUKCJI ROLNICZEJ – CZY MOŻNA JĄ OGRANICZYĆ PRZEZ NOWE TECHNOLGIE?*

**Key words: pesticide savings, new technologies, indirect subsidy**
*Słowa kluczowe: oszczędność pestycydów, nowe technologie, dopłaty pośrednie*

**Abstract.** The necessity of chemical use reduction in agriculture is frequently mentioned. Due to the technical development of chemical and machine industries, we have solutions to spread fewer ingredients per hectare than we did 30 years ago. One of these techniques is site-specific crop production. Depending on the number of farms and land used by turning to site-specific pesticide use, the savings vary between 5341 to 10 682 tons of ingredient in Hungary, and 5110 to 10 221 tons in Poland. Although site-specific crop production is compatible with ecological, economic and social sustainability, its real diffusion is not as fast as it could be. In both countries it is suggested to strengthen medium sized farms and encourage shifting them to site-specific farming, supporting machine sharing forms and services offered by other companies.

## Introduction

Site-specific farming is a holistic system, a technology that allows target oriented treatments, thus managing the spatial and temporal variability within an ecosystem, by applying spot treatment applications. The technique of site-specific crop production means that we consider the environment (soil parameters, fall and precipitation, numbers of sunny hours, biodiversity, etc.), economic background (farm size, capacity and level of equipment, capital sources, other facilities, etc.), management skills and need of seeds, chemicals and other elements to optimize resource use. Site-specific crop production is compatible with sustainability from ecological, economic and social aspects. Social sustainability means the sustainability of food, energy and industrial production, and compliance with economic criteria in terms of the producer, as well as sustainability of the environment. "Feeding the World" is one aim of sustainable agriculture. But at the same time there is huge pressure from society to reduce the use of pesticides, both in terms of applied quantities and frequency of use.

Site-specific technology has a history of about 25 years. Swinton [1997] stated that applying precision technology itself would not result in the unambiguous reduction of fertilizer usage. In those cases where the aim of production is not homogeneous yield but potential yield, a surplus amount of nutrient ingredients could be the aim. The so called redundant amount in those parcels could be reduced, where the potential yield is lower, due to heterogeneous soil parameters. Competitiveness would occur by the higher than average yield with rational nutrient supply, not by polluting the environment but at the same time giving a higher income for farms. Twenty years later, relevant studies also highlighted that the main economic advantage, besides the reduction of yield risk, is the stabilization of farmers' income. [Griffin at al. 2004, Larkin et al. 2005, Watson et al. 2003, Takács-György 2009]

One of the less examined areas of economic relationships of precision crop production is site-specific crop protection. Savings in ingredients depend on the number of harmful organizations, the dynamics of their growth, the potential damage and other environmental deliberations. Real substance saving amount to 60% [Hall, Faechner 2005], However, other authors stress that actual chemical savings do not necessarily mean similar levels of cost savings. They claim real substance

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savings of between 20-25 % [Gutjahr et al. 2008], [Toews 2005]. Unfortunately, regardless of the fact that the technical-technological conditions for producers are accessible, crop protection is the least used among the existing precision crop production components. Due to the result of a survey carried out among Hungarian farmers, only 8% of farmers apply more than one precision component, 75% of them use site-specific fertilizer technology and 62.5% use site-specific plant protection. [Lencsés 2013, Lencsés et al. 2014] In Denmark, 14% of the farmers use at least one component of precision technology, 29.6% of them use site-specific fertilizer technology and 20.9% use site-specific plant protection. [Lawson et al. 2010, Pedersen et al. 2010] However, the design of additional equipment does not mean a disproportionate investment burden. Despite the approaching 25th anniversary of precision farming technology, it is still in its early adoption stage. For smaller farms the technology is not so easy to get. [Gallido 2012] The question is: what has caused this? Precision crop production is an agricultural innovation. During its introduction it had a relative advantage compared with precision nutrition in animal husbandry, but was relatively slow is its dispersion. The technology is less compatible, requires specialized knowledge and skills from farmers and their management, more attention, precise work and a wide range of information. Some of the available benefits are directly observable, such as material savings, improvements in cost-effectiveness and an increase in yield, together with additional costs and expenses. The indirect effects, such as the reduction of environmental load and improvements in food safety, are less obvious. Here, what must be mentioned is the role – or potential role – of site-specific crop production in meeting the green component of new CAP. While the measurable positive returns remain unclear to the farmer, and the risks remain high, even in the presence of a good financial background, the spread of the technology is slow. Hungary and Poland joined the EU in 2004 with a different – but characteristic – farm structure.

The aim of this paper is to estimate the potential participants implementing site-specific technology, to examine what can be the role of site-specific farming in the reduction of chemical use and environmental load in Hungary and in Poland.

## Material and methods

Based on the Farm Structure Survey (FSS), EUROSTAT and OECD database, the savings in chemical ingredients are modeled with scenario analyses for arable land in the year of 2004 and 2012. The first model was built up in 2008 for EU-25. [Takács-György 2009, Takács-György 2009] Arable and mixed farms can switch to precision farming only if they are above a certain size, owing to the additional equipment required for the technology adoption. The estimations are made for crop production and mixed farms on total utilized agricultural land cereals, other field crops and forage crops, based on the different levels of chemical use [OECD 2013]. The following assumptions are taken into consideration:

- the savings of site-specific fertilize use is lower, due to the fact that here the so-called optimizing aim is more frequently used. This means higher yield – depending on soil heterogeneity – is the aim of production,
- farms above 500 000 EUR are able to switch to precision crop production by making their own investments based on their farm size and production level, while farms within the 50-100 000 and 100-500 000 EUR size classes can convert by using shared machinery and services,
- farms applying site-specific fertilizer use in the scenarios: 15-25-40%,
- fertilizer savings in the scenarios: 5-10-20% of ingredients,
- farms applying site-specific plant protection in the scenarios: 15-25-40%,
- pesticide savings in the scenarios: 25-30-50% of ingredients.

It must be mentioned that due to the rapid development of the chemical industry the average ingredient content/need of new-coming out pesticides is lower than was ten years before. Other reasons include the increasing ecological area – more typical for Poland in this period – and the regulations for environmental purposes. Also, what must be mentioned as a reason for chemical reduction are the limited resources, and the unfavorable financial conditions of farms.

Table 1. Pesticide use in Hungary and in Poland (2010)
*Tabela 1. Pestycydy używane na Węgrzech i w Polsce w 2010 roku*

| Pesticide/ *Pestycydy* | Hungary/*Węgry* | | Poland/*Polska* | |
|---|---|---|---|---|
| | t | kg/ha (ingredient/ *składnika*) | t | kg/ha (ingredient/ *składnika*) |
| Insecticide | 4 717.00 | 0.88 | 972.73 | 0.07 |
| Herbicide | 4 832.00 | 0.91 | 12 408.49 | 0.86 |
| Fungicide | 9 115.00 | 1.71 | 5 766.03 | 0.40 |
| Other (regulators)/ *Inne (regulatory)* | 4 782.00 | 0.90 | 2 384.96 | 0.17 |
| Total/*Razem* | 23 392.00 | 4.38 | 21 532.21 | 1.49 |

Source: own calculation based on the dataset [2013 Edition of the OECD Environmental] Database
*Źródło: opracowanie własne na podstawie [2013 Edition of the OECD Environmental Database]*

Comparing fertilizer (NPK) usage in Hungary in the years of 1980, there was a huge decrease from 264.2 kg/ha till 2001 to 67.3 kg/ha. During the last 15 years, the average was between 60-70 kg/ha. In Poland, the average fertilizer use was 231.3 kg/ha in 1980 and the decrease was not so high till the year 2001 - (107.8 kg/ha) based on the OECD data (2005). In the year 2014, fertilizer usage was 91.2 kg/ha (61.2 kg nitrogen, 15.4 kg phosphorus and 14.6 kg potassium per hectare) in Hungary. To make the comparison, average fertilizer data were considered from 2002-2010, in Hungary 60.67 kg/ha and in Poland 81.12 kg/ha.

Pesticide use was three times higher in Hungary than in Poland (Tab. 1). In both countries a declining tendency could be observed based on the OECD Environmental Database (2005, 2013). Data from the year of 2010 were used in model calculations. At the same time it was 3.39 kg/ha in Germany, 8.75 kg/ha in the Netherlands, 6.44 kg/ha in Portugal, 1.6 kg/ha in Denmark and 2.79 kg/ha in the United Kingdom.

The potential savings in fertilizer and pesticide ingredients and cost savings were calculated for field crops and mixed types of farms and for country groups differentiated by the level of chemical use. Both Hungary and Poland belong to the lower level use group in EU, Hungary is closer to the medium group from the point of view of pesticide usage.

## Results

### Changes in farm number and land use

In 2004, the represented farms in the FSS meant 107.7 thousand farms and 5.25 million hectares of agricultural land in Hungary, and 733.8 thousand farms and 11.54 million hectares of agricultural land in Poland. In 2012, the represented farms in the FSS meant 105.3 thousand farms and 4.88 million hectares of agricultural land in Hungary, and 728.2 thousand farms, 13.72 million hectares of agricultural land in Poland. There was a slow decrease both in the number

Table 2. Represented farms and agricultural land in Hungary and in Poland (2004 and 2012)
*Tabela 2. Reprezentowane gospodarstwa i grunty rolnych na Węgrzech i w Polsce w latach 2004 i 2012*

| Economic size categories [thous.EUR]/ *Kategorie wielkości ekonomicznej [tys. euro]* | Represented farms [thous. pcs]/ *Liczba gospodarstw [tys. szt.]* | | | | Total represented agricultural area [thous. ha]/ *Powierzchnia ogółem gruntów rolnych [tys. ha]* | | | |
|---|---|---|---|---|---|---|---|---|
| | Hungary/*Węgry* | | Poland/*Polska* | | Hungary/*Węgry* | | Poland/*Polska* | |
| | 2004 | 2012 | 2004 | 2012 | 2004 | 2012 | 2004 | 2012 |
| (1) 2 - < 8 | 43.3 | 43.3 | 300.0 | 271.6 | 431.5 | 322.7 | 2139.1 | 2251.5 |
| (2) 8 - < 25 | 45.8 | 39.4 | 318.0 | 307.9 | 1074.5 | 850.7 | 4359.6 | 4221.4 |
| (3) 25 - < 50 | 7.4 | 8.0 | 80.5 | 94.6 | 415.9 | 397.5 | 2221.0 | 2560.1 |
| (4) 50 - < 100 | 6.7 | 8.5 | 23.7 | 35.7 | 756.0 | 798.6 | 1117.2 | 1681.9 |
| (5) 100 - < 500 | 3.2 | 4.8 | 10.3 | 16.3 | 825.8 | 1054.4 | 1054.3 | 1710.6 |
| (6) ≥ 500 | 1.3 | 1.4 | 1.3 | 2.1 | 1744.7 | 1453.7 | 653.1 | 1293.4 |

Source: own calculation
*Źródło: obliczenia własne*

of represented farms (2.8%) and in agricultural land (7.9%) they use in Hungary, the number of farms decreased by 0.8%, but the utilized agricultural land increased by 19.8% in Poland from 2004 to 2012. Farms operating over an economic size of 50 000 EUR increased by 30.5% and the land they were operating remained at nearly the same level in Hungary. Farms operating over economic sizes of 50 000 EUR grew by 52.9% and the land they are operated amounted to 65.8% in Poland. A concentration process can be observed in both countries, but in Poland, recruitment and concentration in agricultural land use was higher after EU accession (Tab. 2).

## Changes in chemical use

It can be observed that if the 40% of the farms over a size of 50 000 EUR shift to precision fertilize use and can reduce their fertilizer by 5% per hectare the estimated saving is 14 796 tons and in the case when they reduce the usage by 20% the total amount is 59 186 tons in Hungary for the year of 2012. In Poland, taking into consideration that agriculture is 2.8 times greater, the savings are 55 645 tons in the first case and 222 579 tons in the second case (Tab. 3).

The estimated amount of pesticide savings – if 40% of farmers apply site-specific component of the technology – the optimistic scenario is 10 682 tons (equal to 10 682 000 kg) pesticides in Hungary. Due to the lower level of average pesticide usage in Poland the savings in the optimistic scenario are slightly lower, amounting to 10 221 tons for the year of 2012 (Tab. 4). In EU-27 in the optimistic scenario, the estimated savings amount to around 30.4 thousand tons.

Table 3. Estimated savings in fertilizer in Hungary and in Poland (2012)
*Table 3. Szacowane oszczędności zużycia nawozów na Węgrzech i w Polsce (2012 rok)*

| Country/*Kraj* | Agricultural area [thous. ha/ *Powierzchnia rolna [tys. ha]* | Used average ingredient/ *Średnie zużycie skladnika [kg/ha]* | Spared ingredient at/*Oszczędność składnika w:* | | |
|---|---|---|---|---|---|
| | | | 5% | 10% | 20% |
| | | | decreased use/*zmniejszenie zużycia [t]* | | |
| Hungary/*Węgry* | 4,877.8 | 60.67 | 14,796 | 29,593 | 59,186 |
| Poland/*Polska* | 13,719.1 | 81.12 | 55,645 | 111,289 | 222,5 79 |

Source: own calculation
*Źródło: obliczenia własne*

Table 4. Estimated savings in pesticides in Hungary and in Poland (2012)
*Tabela 4. Szacowane oszczędności zużycia pestycydów na Węgrzech i w Polsce (2012 rok)*

| Country/*Kraj* | Agricultural area [thous. ha]/ *Powierzchnia rolna [tys. ha]* | Used average ingredient/*Średnie zużycie skladnika [kg/ha]/* | Spared ingredient at/*Oszczędność składnika w:* | | |
|---|---|---|---|---|---|
| | | | 25% | 35% | 50% |
| | | | decreased use/*zmniejszenie zużycia [t]* | | |
| Hungary/*Węgry* | 4,877.8 | 4.38 | 5,341 | 7,477 | 10,682 |
| Poland/*Polska* | 13,719.1 | 1.49 | 5,110 | 7,155 | 10,221 |

Source: own calculation
*Źródło: obliczenia własne*

## Cost changes due to site-specific crop production

The estimated cost savings in fertilize use in the year 2006, was 9.52 Million EUR from which 4.48 Million EUR (47.1%) came from 4-5 economic size farms in Hungary in the worst case scenario and is 38.05 Million EUR in the best case scenario. In 2012, the same values amounted to 20.60 million EUR and 82.40 Million EUR. In Poland, the potential cost savings due to site-specific fertilizer usage was 23.48 Million EUR that means that 69.3% of the savings came from 4-5 economic size farms in the pessimistic scenario in the year 2006. Regarding the optimistic scenario the total savings increased to 190.17 Million EUR. These data show that in the case of Poland, due to the lower level of the estimated fertilizer usage, the farms belonging to size 4 and 5, can gain higher cost savings, increasing their income (Tab. 5). As it was mentioned earlier, higher savings can be expected if a farm uses a site-specific plant protection component of the technology.

The estimated cost savings in pesticide use was 43.85 Million EUR in the pessimistic scenario and 87.71 Million EUR in the optimistic scenario in Hungary, in the year 2006. Based on the estimation for the year 2012, the savings grew to 66.81 Million EUR in the case of the pessimistic scenario and 133.62 Million EUR in the optimistic scenario (by 52.3%).This is connected to the fact that the pesticide cost among the total cost is relatively high. In Poland, the potential cost savings due to site-specific crop protection was 64.04 Million EUR (nearly three times higher the amount than in fertilizer cost savings) in the pessimistic scenario in 2006, while in the optimistic scenario the total saving were 128.06 Million EUR. In 2012, the pessimistic scenario amounted to 102.95 Million EUR and the optimistic 205.88 Million EUR (Tab. 6).

Table 5. Cost savings in fertilizer use due to site-specific crop production
*Tabela 5. Oszczędności zużycia nawozów ze względu na specifikę produkcji rolnej*

| Country/ *Kraj* | Year/ *Rok* | Group of economic size/ *Kategoria wielkości ekonomicznej* | | | | | |
|---|---|---|---|---|---|---|---|
| | | 4 and 5 | | | 6 | | |
| | | 5% | 15% | 20% | 5% | 15% | 20% |
| | | savings [mln EUR]/*oszczędności [mln euro]* | | | | | |
| Hungary/ *Węgry* | 2006 | 4.48 | 8.95 | 17.90 | 5.04 | 10.08 | 20.15 |
| | 2012 | 10.42 | 20.84 | 41.68 | 10.18 | 20.36 | 40.72 |
| Poland/ *Polska* | 2006 | 16.26 | 32.51 | 65.02 | 7.22 | 14.44 | 28.88 |
| | 2012 | 32.85 | 65.69 | 131.38 | 14.70 | 29.39 | 58.79 |

Source: own calculation
*Źródło: obliczenia własne*

Table 6. Cost savings in pesticide use due to site-specific crop production
*Tabela 6. Oszczędności zużycia pestycydów ze względu na specifikę produkcji rolnej*

| Country/ *Kraj* | Year/ *Rok* | Group of economic size/*Kategoria wielkości ekonomicznej* | | | | | |
|---|---|---|---|---|---|---|---|
| | | 4 and 5 | | | 6 | | |
| | | 5% | 15% | 20% | 5% | 15% | 20% |
| | | savings [mln EUR]/*oszczędności [mln euro]* | | | | | |
| Hungary/ *Węgry* | 2006 | 19.07 | 26.70 | 38.14 | 24.78 | 34.70 | 49.57 |
| | 2012 | 32.58 | 45.61 | 65.16 | 34.23 | 47.92 | 68.46 |
| Poland/ *Polska* | 2006 | 39.12 | 54.76 | 78.23 | 24.92 | 34.88 | 49.83 |
| | 2012 | 65.56 | 91.78 | 131.11 | 37.39 | 52.34 | 74.77 |

Source: own calculation
*Źródło: obliczenia własne*

## Conclusions

The model calculations showed that precision crop production can result in significant savings in chemical use, especially in site-specific crop protection at the macroeconomic level. The amount of savings depends on the share of converting farms and the size of agricultural land they cover. In Hungary, as farms belonging to the largest size category 14.7 thousand farms (13.94%) of the represented farms, using 61.9% of agricultural land – can be reach a higher amount of chemical savings if the same ratio of the farms are using the technology. In Poland 54.1 thousand farms (6.84% of total represented farms) belong to these size categories, using 34.16% of agricultural land.

Although site-specific crop production is compatible with ecological, economic and social sustainability its real diffusion is not as fast as it can be. Both in Hungary and Poland medium sized farms should be encouraged to shift to site-specific farming, supporting machine sharing forms - services offered by other companies.

Site-specific crop production is not included into the greening component of CAP (2014-2020). However, it is the author's belief that it should have been included, because it has a real "greening" impact on chemical reduction, without leading to yield and income loss. At the same time unnecessary fertilizer and pesticide use can be avoided and the environmental burden can be reduced. This technology is intended to encourage environmentally friendly farming practices. Site-specific farming is an abiotic factor, which is/should be the ultimate tool for the reform of agricultural production.

## Bibliography

Gallido P.A., Granell C., Molin P.G., Guijarro J.H. 2012: *Participative sit.Specific agriculture analysis for smallholders,* Precision Agric., 13, 594-610.

Griffin T.W., Lowenberg-DeBoer J., Lambert D.M., Peone J., Payne T., Daberkow S.G. 2004: *Adoption, profitability, and making better use of precision farming data*, Department of Agricultural Economics, Purdue University, Staff Paper, 20 p.

Gutjahr C., Weiss M., Sökfeld M., Ritter C., Möhring J., Büsche A., Piepho H.P., Gerhards R. 2008: *Erarbeitung von Entscheidungsalgoorithmen* für die teilflächenspezifische Unkrautbekämpfung, Journal of Plant Diseases and Protection, XXI, 143-148.

Hall L., Faechner T. 2005: *Weed management with precision farming*, Working paper, Saskatchewan Soil Conservation Association, Alberta Agriculture, Food and Rural Development, 5.

Larkin S.L., Perruso L., Marra M.C., Roberts R.K., English B.C., Larson J A., Cochran R.L., Martin S.W. 2005: *Factors affecting perceived improvements in environmental quality from precision farming*, Journal of Agricultural and Applied Economics, 37(3), 577-588.

Lencsés E. 2013: *Precision farming technology and motivation factors of adaptation,* Annals SERiA, vol. XV, no. 5, 185-189.

Lencsés E., Takács I., Takács-György K. 2014: *Farmers' Perception of Precision Farming Technology among Hungarian Farmers,* Sustainability, 4(6), 8452-8465.

Pedersen S.M, Fountas S., Blackmore B.S., Gylling M., Pedersen J.L. 2010: *Adoption and perspectives of precision farming in Denmark,* Acta Agriculturae Scandinavica, section B, Plant Soil Science, 54(1), 2-8.

Swinton S.M. 1997: *Precision farming as green and comptetive*, Michigan State University, Working paper, [online], http://www.aec.msu.edu/agecon/ Smith_Endowment/documents/swinton.htm, download 5. 12.2007.

Takács-György K. 2009: *Economic aspects of chemical reduction in farming – future role of precision farming*, *Food Economics,* Acta Agriculturae Scandinavica, section C, Economy, 5(2), 114-122.

Toews T. 2005: Ökonomik teilflächenorientierter Unkrautbekämpfung, Dissertation zur Erlangung des Doktorgrades der Justus, Liebig, Universität Giessen, 198 p.

Watson S., Segarra E., Machado S., Bynum E., Archer T., Bronson K. 2003: *Precision farming in irrigated corn production: an economic perspective*, Southern Agricultural Economics Association. Annual Meeting, [onlnie], http://ageconsearch.umn.edu/bitstream/35053/1/sp02wa01.pdf, download 11.15.2008.

*2013 Edition of the OECD Environmental Database*, [online], http://ec.europa.eu/eurostat/help/new-eurostat-website.

## *Streszczenie*

*Coraz częściej poruszany jest temat potrzeby ograniczenia zastosowania ochrony chemicznej w rolnictwie. Dzięki rozwojowi przemysłu technicznego i chemicznego, a także maszynowego, dysponuje się rozwiązaniami umożliwiającymi aplikację mniejszej ilości substancji na 1 ha niż miało to miejsce 30 lat temu. Jedną z tych technik jest rolnictwo precyzyjne. W zależności od liczby gospodarstw rolnych i pól stosujących oraz zwracających się ku precyzyjnemu zastosowaniu środków ochrony, oszczędności wynoszą od 5341 do 1682 ton produktu na Węgrzech i od 5110 do 1221 ton w Polsce. Mimo że rolnictwo precyzyjne współgra ze zrównoważoną ochroną środowiska, rozwojem gospodarczym i społecznym, jego rozpowszechnienie nie zachodzi tak szybko jakby mogło. W obu krajach sugeruje się umocnienie średnich gospodarstw rolnych oraz zachęcanie ich do przestawienia się na rolnictwo precyzyjne przez wspieranie inicjatyw dzielenia się maszynami i usługami oferowanymi przez inne firmy.*

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