Estimation of Costs at Application of Precise Fertilizers Spreading

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ABSTRACT

The study concerns determination of the required amounts of nitrogen, phosphorus and potassium at uniform and variable rate application and their comparison in terms of expenditures. The study was made for winter wheat and corn. Amounts of phosphorus and potassium for uniform rate were calculated as the weighted average content of the macro elements within the whole field, while for variable rate they were determined according to the macro element content on the specific sites. In the case of VRA, the first rate of nitrogen was diversified according to the terrain features, the second and third was based on the SPAD measurements. Claas Lexion 430 combine equipped with optical yield monitoring systems was used for crop harvest. All collected data were processed in ArcView 3.3 GIS program. Prepared maps of the required amount of fertilizers were reclassified into costs per hectare, overlapped by maps of yields and results were presented in specific cost (PLN per tone) on different sites of the field. Maps of specific costs for uniform and variable rate application were compared to find out the differences in borne expenditures. As a result of VRA on field with the wheat, gains over 30% occurred on 42.2% sites and there were no losses. Corn field was in 29% occupied by sites with gains up to 10%, nevertheless, share of negative values amounted to 56.7%.

Keywords: Fertilization, VRA, wheat, corn, costs, GIS

1. INTRODUCTION

The production efficiency is essential for being competitive and can be reached by optimization of the production process. In the area of crop production it means performing only necessary operations, in the required time and place, as well as with minimum expenditures (Rataj and Urbanovič, 2002b).

This is very current with reference to mineral fertilization. Localized fertilization is based on logical and correct idea that on a field there always occur sites with different macro elements content and different fertility and the amount of fertilizers should be adjusted to that in order to lower inputs. Mineral fertilizers not only present an environmental ballast by contributing to water sources pollution but also their manufacturing means great demand on fossil resources (Stehno, 2003).

2. MATERIALS AND METHODS

The research was carried out in 2005/06 season on fields with winter wheat (19 ha) and corn (20.6 ha). After gathering the forecrops, soil sampling for chemical analysis on phosphorus and potassium content was made. One general soil sample represented 0.25 hectares. It was prepared from 18 individual samples collected from a depth of 0.2 m, according to the one of the possible standardized patterns (PN-R-04031, 1997). A GPS receiver enabled navigation to the sampling points. The general samples were positioned in the center of 50x50 m squares of a grid overlaid on the digital map of the field (Walczykova and Zagórda, 2005a).

The fields digital maps, together with geographical co-ordinates of the general soil samples locations in number of 76 for wheat and 80 for corn, were imported into ArcView 3.3.GIS program. The results of chemical analysis presented their attributes. Based on these data the maps of macro elements spatial distribution were made using IDW interpolation method (weight=2, number of the neighboring points=12).

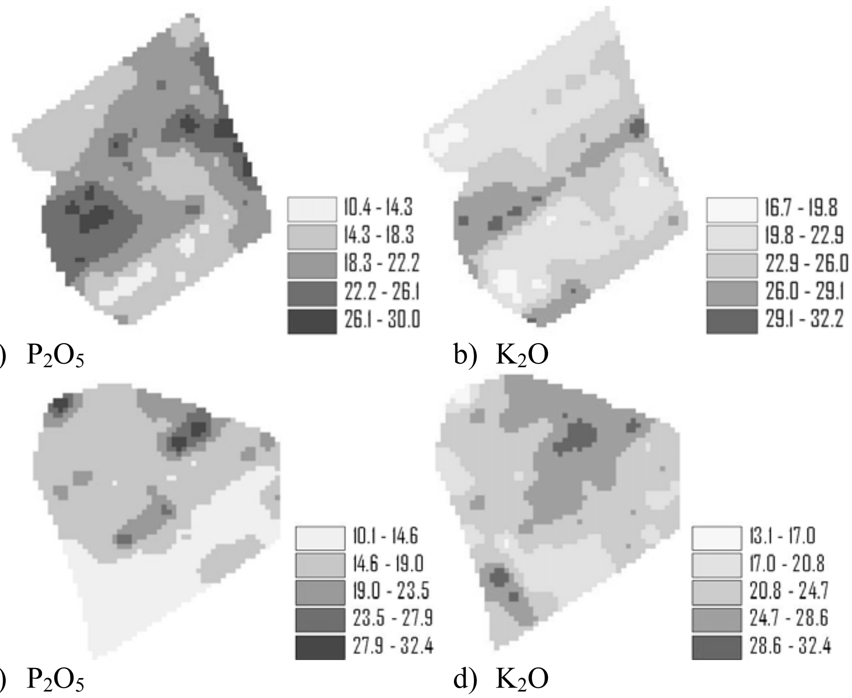


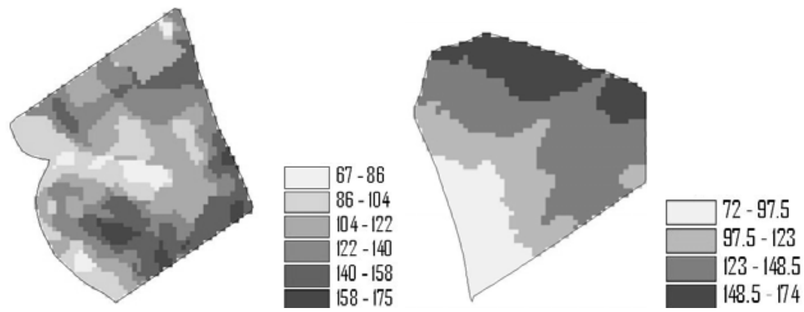
Figure 1. Maps of macro elements content spatial distribution (mg 100mg^{-1}):a) phosphorus for wheat, b) potassium for wheat, c) phosphorus for corn, d) potassium for corn.

Demand for phosphorus and potassium was calculated in computer program Agronom 2.1, designed for aiding advisory service concerning crop fertilization. The following inputs were required: macro element content on the specific sites according to the already created maps, name of the forecrop and level of its fertilization, and finally, goal average yields, which were assumed at 7.5 t ha^{-1} for wheat and 7 t ha^{-1} for corn. Having done calculations, the maps of macro elements content were converted into maps of required amounts, i.e. application maps (Figure 1).

For uniform rate fertilization practice required amounts of phosphorus and potassium were determined on the basis of weighted average content of the macro elements within the whole field.

Overall demand for nitrogen was calculated in the mentioned program automatically together with the P, K, according to formula generally accepted by agronomists. In the case of wheat the calculated amount was divided into three rates. For uniform rate application the ratio amounted to 60:20:20. For variable fertilization the first rate was diversified according to the terrain features (Jadczyszyn, 1998), whiles the second and third were based on the SPAD measurements, carried out by chlorophyll meter (Zagórda *et al.*, 2006).

On the corn field the first rate was spread as mentioned above, however the second rate of 40% was applied uniformly using liquid fertilizers.



a) b)

Figure 2. Maps of spatial distribution of overall demand for nitrogen (kg ha^{-1}): a) wheat, b) corn.

Figure 2 presents a result of overlapping all maps of nitrogen variable application. The overall demand for nitrogen includes also the amount applied during seeding.

Then, the above presented maps (Figure 1-2) were reclassified into costs of fertilizers per hectare on different sites of the fields. Calculation was made with considering prices per one kilogram of the mineral component, as given in Table 1.

Table 1. Prices of the applied fertilizers (PLN ~ 3.8 €)

Fertilizer	Price (PLN t^{-1})	Price (PLN kg^{-1})
Ammonium Nitrate (34% N)	760	2.24
Ammonium Phosphate (46% P_2O_5, 18% N)	1117	1.74 (P_2O_5 and N)
Potash Salt (60% K_2O)	751	1.25

Harvest and monitoring of yields on both fields were made by Claas Lexion 430 (Walczykova and Zagórda, 2005). Average yield ($\bar{x}$) for winter wheat (Figure 3a) amounted to 7.72 t ha^{-1}, with standard deviation σ = 0.81 t ha^{-1}. For corn (Figure 3b) the average yield and the standard deviation were 5.69 t ha^{-1} and 0.93 t ha^{-1} respectively. In the considered season differences between yields on fields with uniform and variable application were negligible.

Values intervals on the yield maps (Figure 3 a, b) are as follows:

very low $\langle 0 ; \bar{x} - 1{,}5\sigma \rangle$,

low $\langle \bar{x} - 1{,}5\sigma ; \bar{x} - 0{,}5\sigma \rangle$

medium $\langle \bar{x} - 0{,}5\sigma ; \bar{x} + 0{,}5\sigma \rangle$

high $\langle \bar{x} + 0{,}5\sigma ; \bar{x} + 1{,}5\sigma \rangle$

very high $\langle \bar{x} + 1{,}5\sigma ; \infty)$.

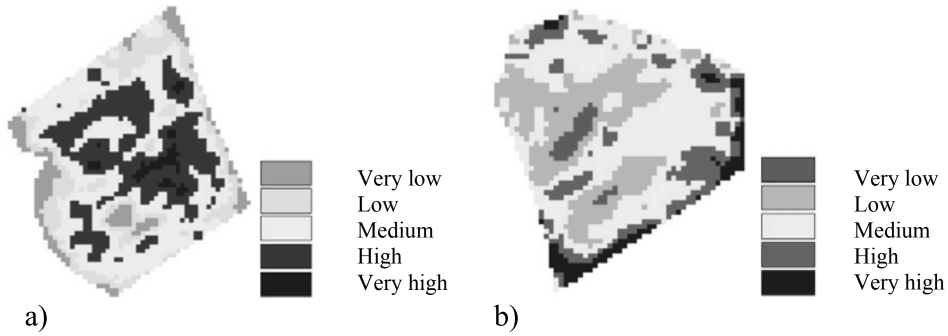


Figure 3. Maps of spatial distribution of the measured yields: a) winter wheat, b) corn.

The interval expressed in values, the area taken by them and its percentage share were included in table 2.

Table 2. Assumed yield intervals and their share in the field area

Yield	Winter Wheat			Corn		
	Yield Interval	Area		Yield Interval	Area	
	t ha^{-1}	ha	%	t ha^{-1}	ha	%
Very Low	4.42 – 6.49	1.81	8.78	3.33 – 4.30	0.58	3.03
Low	6.49 – 7.31	3.60	17.46	4.30 – 5.23	5.11	26.90
Medium	7.31 – 8.13	8.31	40.28	5.23 – 6.16	9.06	47.67
High	8.13 – 8.95	6.28	30.40	6.16 – 7.09	2.98	15.70
Very High	8.95 – 10.00	0.64	3.08	7.09 – 11.15	1.27	6.70

Maps of the required amount of fertilizers were reclassified into costs per hectare and overlapped by maps of yields and, as a result, maps presenting specific cost (PLN per tone) on different sites of the field were obtained.

Finally, maps of specific costs of uniform and variable rate application were compared to find out the differences in borne expenditures.

3. RESULTS

Calculated amounts of required fertilizers were included in tables 3 and 4. Results concerning uniform rate application are presented in Table 3. Cultivation of corn turned out to be more demanding on phosphorus and potassium in spite of lower goal yield, as the corn takes up more of these elements during its growth.

As a result of comparison of the overall demand for nitrogen, phosphorus and potassium at uniform (Table 3) and variable rate application (Table 4) on winter wheat field, it can be stated that the VRA turned out to be more beneficial. This method contributed to decrease of each mineral component demand, which for N, P, K amounted to 34.4 %, 22.3 % and 7.3 % respectively.

Table 3. Average rates and overall required amount of macro elements at uniform rate fertilization of wheat and corn

Macro Element	Winter Wheat			Corn		
	Rate	Area	Applied Amount	Rate	Area	Applied Amount

	kg ha^{-1}	ha	kg	kg ha^{-1}	ha	kg
Nitrogen	186		3839	145		2755.0
Phosphorus	36	20.64	743.0	49	19.00	931.0
Potassium	120		2476.8	157		2983.0

Table 4. Site specific minerals demands and costs at variable rate application of winter wheat

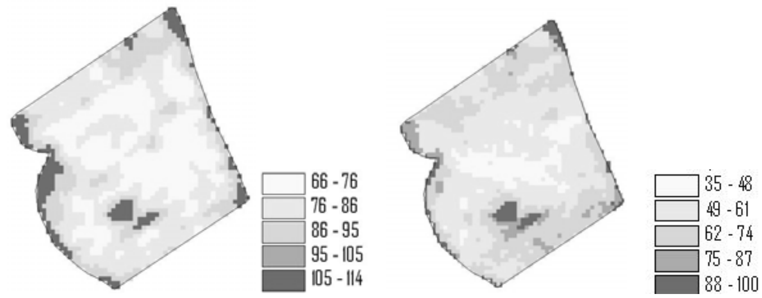
Macro Element	Rate	Costs	Area	Applied Amount
	kg ha^{-1}	PLN ha^{-1}	ha	kg
	77	172	0.94	72.4
	95	213	3.82	362.9
Nitrogen	115	258	6.21	714.1
	131	293	4.96	649.8
	150	336	3.97	595.5
	165	370	0.74	122.1
	Overall		20.64	2516.8
	56	97	1.44	80.6
Phosphorus	36	63	9.49	341.6
	16	28	9.71	155.4
	Overall		20.64	577.6
	120	150	15.72	1886.4
Potassium	84	105	4.78	401.5
	54	67	0.14	7.6
	Overall		20.64	2295.5

Table 5. Site specific demands of minerals and costs at variable rate application of corn

Macro Element	Rate	Costs	Area	Applied Amount
	kg ha^{-1}	PLN ha^{-1}	ha	kg
	72	161	3.40	244.8
	101	226	4.37	441.4
Nitrogen	145	325	7.67	1112.1
	174	390	3.56	619.4
	Overall			2417.7
	78	136	6.75	526.5
Phosphorus	49	85	10.08	493.9
	23	40	2.17	49.9
	Overall			1070.3
	276	345	0.06	16.6
	218	273	13.08	2851.4
Potassium	157	196	5.70	894.9
	100	125	0.16	16.0
	Overall			3778.9

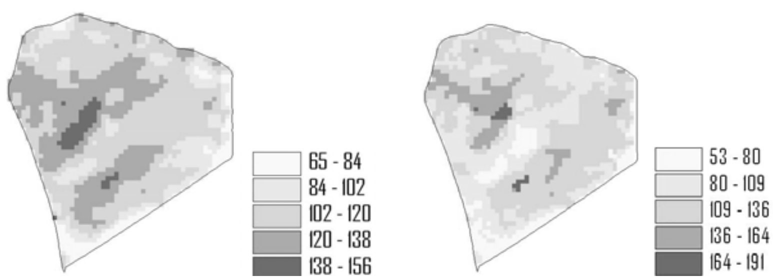
Variable application on corn field (Table 5) brought about 12.2% savings of nitrogen. As for the remaining two minerals, an increase of the required demand took place – 14.9 % for phosphorus and 26.7 % for potassium. Sites with low mineral content prevailed here and this might be the main reason for getting results opposite to the expected ones.

Spatial distribution of the expenditures borne at wheat production (Figure 4 a, b) clearly shows that regardless of the application mode, the greatest affect on costs had the yield spatial distribution. Variable rate application contributed to greater diversification of the specific costs. The last statement applies also to the Figure 5 a, b.



a) b)

Figure 4. Spatial distribution of specific costs (PLN t^{-1}) for wheat: a) uniform rate application, b) VRA.



a) b)

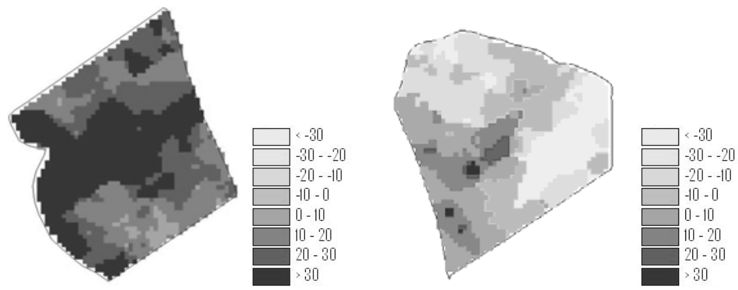
Figure 5. Spatial distribution of specific costs (PLN t^{-1}) for corn: a) uniform rate application, b) VRA.

When expressing the expenditures of uniform and variable application in terms of average values (Table 6), the lowest unit cost for VRA in wheat is clear-cut. To this contributed mainly nitrogen decrease (ca 35%), in comparison with uniform rate application, and also the fact that nitrogen fertilizers are most expensive (Table 1).

The corn cultivation gave opposite results (Table 6). Beside low mineral content on the field (Figure 1 c, d), also lack of sufficient precipitations during the considered season affected adversely the final results. The goal and final yields differed by 18.7% for worse, which further increased the expenditures.

Table 6. Average expenditures (Figure 4 a, b; Figure 5 a, b)

	Uniform Rate Application	VRA
	PLN t^{-1}	PLN t^{-1}
Wheat	82.6	59.8
Corn	105.8	110.5



a) b)

Figure 6. Maps of differences between expenditures borne at uniform and variable rate application (%): a) wheat, b) corn.

Maps in Figure 6 a, b present spatial distribution of sites with gains and losses in terms of expenditures. On the field with winter wheat, gains over 30% occurred on 42.2% of the area and there were no negative values i.e. losses (Table 7). Corn field was in 29% occupied by sites with gains up to 10%, nevertheless, share of negative values amounted to 56.7%. In the considered season introduction of VRA on the corn field was not economically beneficial.

Table 7. Percentage share of sites with gains and losses due to different mode of fertilizers application (based on Figure 6 a, b)

	< -30	-30 – -20	-20 – -10	-10 – 0	0 – 10	10 – 20	20 – 30	> 30
Wheat	0.0	0.0	0.0	0.0	2.6	17.7	37.5	42.2
Corn	0.6	17.7	19.9	18.5	29.0	11.8	2.0	0.7

4. CONCLUSIONS

Fertilizers application aims to achieving the goal yield or improving the yield quality. Both of them will affect the profit at which the farmer succeeds to sell the grain. That's why it is important to determine the expenditures he borne per mass unit of grain. Such instrument as the presented maps is good aids in proper management of the fields in the following year.

Unfavorable weather conditions can considerably affect the borne expenditures.

Introduction of variable rate application might temporarily cause increase of phosphorus and potassium required amount.

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