# CONDITIONING FACTORS FOR DECISION-MAKING REGARDING PRECISION AGRICULTURE TECHNIQUES USAGE

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## ABSTRACT

The present study sought to list and analyze the main responsible factors for defining whether an area will succeed or not in the use of precision agriculture. The method used for this analysis was to estimate revenue and cost of production by the use of an agricultural production function and consider the different conditions we find in the field if inputs are applied to fixed and varied rates. The results showed that the factor to influence most the gain in producer profitability, considering the use of precision agriculture tools in relation to uniform input application, was the sampling method performed for uniform application. Corroborating other studies, the results also indicated that the use of precision agriculture for varied application of fertilizers is economically more advantageous if applied over large areas. However, unlike it is described in other studies, we cannot affirm that precision agriculture reduces input or increases crop productivity. One or both cases would occur depending on the area's condition and the sampling that is taken for uniform application of inputs. Therefore, it is concluded that there is no sense in scientific papers that analyze the economic impact of applying techniques of precision agriculture, since this impact must be analyzed individually for each area.

**Index terms**: wide application; inputs; productivity.

## INTRODUCTION

The main goal of substituting conventional techniques (uniform input application) for those of precision agriculture (diverse application of inputs) consists in obtaining one of the following results: (A) cost reduction by reducing use of inputs; (b) increase in agricultural productivity by more efficient application of inputs and; (c) reduction in water and environmental pollution.

However, according to Costa and Guilhoto (2012), studies that measured reductions of input applied and productivity increase are divergent and do not present similar tendencies. This result can be expected, since the effectiveness of these techniques depends on the environment in which they are employed. Thus, the present work sought to elaborate some of the main conditioning factors for success in the use of precision agriculture. The conditions to reduce input use and to increase productivity were analyzed. These two factors were analyzed for they are the ones that spawn profit growth for the crop producer and, hence, they ultimately define its implementation. Environmental benefits of differentiated input applications were not a target for this study for two reasons: they don't represent immediate financial gains for the producer; and they are always present when compared to uniform application.

Precision agriculture techniques are also called differentiated applications, opposed to uniform input applications usually carried out by producers. Differentiated application may be used for several inputs within the agriculture and cattle industries. Furthermore, new instruments to enable more accurate applications and for different inputs are constantly improving. However, in order to fulfill the main goal proposed in this study, differences in producer income derived from adopting uniform or differentiated applications of chemical fertilizing input were analyzed. The choice for this input is justified since research carried out (Whipker and Akridge, 2009) indicates that differentiated application of fertilizers is the most common technique among users of precision agriculture. Also, according to data from the Input-Ouput Matrix regarding the Brazilian economy for the year 2005 (latest document released by the Brazilian Institute of Geography and Statistics - IBGE), 31% of the cost with inputs for production within sectors "Agriculture, forestry and vegetal exploitation" in the Brazilian economy occurs with inorganic chemical products, whose main feature are chemical fertilizers. Besides, considering all production value (costs and value added), the participation of inorganic chemical products amounts to 13%.

Another factor that justifies the precision agriculture analysis with the varied fertilizer application is that, among agricultural inputs, fertilizers are those which present the most obvious relation with the crops' productivity. According to Alcarde et al. (1998), fertilizers alone are responsible for around 30-50% of the crops' productivity increase.

In order to accomplish the proposed objective, the next section describes a theoretical and microeconomic reference regarding the role of agricultural production and how it sets profit maximization for agro producers. This segment describes the relation between fertilizer use and crops' agricultural productivity. This is the defining relation upon producers' revenues and, consequently, their decision to adopt or not the varied fertilizer application. Methods and data applied for the simulations are following presented. And subsequently, the results and conclusion are described.

## THEORETICAL REFERENCES

As any other product of the economy, agricultural production works as function of production where growth in input quantity generates increased production, up to a certain technical limit. The analysis performed in this study is based on this production function and on the scenarios used to simulate agricultural crops. This section considered the operation of an production function with a single input product, in this case, fertilizer, aiming to show the relation between these two factors: fertilizer and productivity.

Fig. 1 shows a typical production function for an agricultural product (X) in function of the fertilizer quantity applied (I). There is hence a region of intensified growth, where marginal productivity ($MP_I$), as well as average productivity ($AP_I$) regarding the increase in the use of fertilizer are both growing. There is then an increase in fertilizer use that reduces $MP_I$, but the average product ($AP_I$) is still growing. This region is considered the first stage of the production function. In the following phase (stage two of the production function), $MP_I$ remains on the downslope, $AP_I$ as well. Finally, when production begins to decline with the additional fertilizer, we reach the third stage of the production function, where $MP_I$ is negative.

In equilibrium, production only occurs in the second phase of the production function. This occurs because, in stage 1, since the $PMe_I$ is growing, the producer is encouraged to apply more input, up to the point which he identifies $PMe_I$ has stopped growing (standing, in this point, in phase 2). As per phase 3, it is not used by the producer, for in this case raising input use reduces productivity. Therefore, phase 1 and 3 both are economically inefficient for further output and equilibrium is set in phase 2.

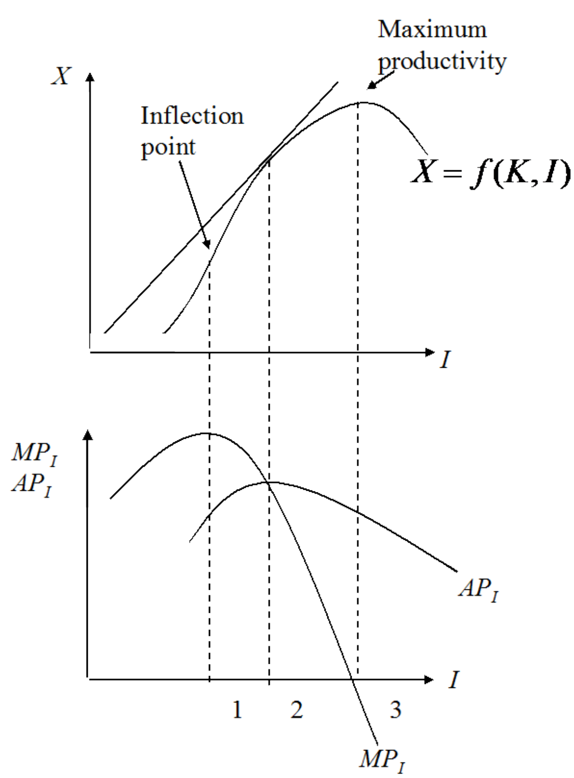


**Fig. 1. Representation of the agriculture production function**
**Source**: Perloff (2008).

Productivity growth is beneficial for the producer because, in this manner he can increase his revenues per area through more product sales. The increase in input use so this higher productivity is achieved, however, also draws additional costs. The producer's challenge is, therefore, to establish the input quantity which would spawn his maximum economic return. In order to do so, using only the area of the representative function from the second production phase and multiplying it by the product price (*Px*), we have, in Fig. 2, a representative function of the producer's revenue. Multiplying the quantity of fertilizing input (*I*) by its price (*Pi*) we have a representation, also in Fig. 2, of the cost curve. In this figure it is observed that maximum production ($X_{MAX}$) occurs with $I_2$ input quantity. At this point, revenue is also maximum ($VX_{MAX}$). Nonetheless, this point does not correspond to the production level that generates maximum economic return for the producer, which is his profit ($\pi$). The producer's maximum profit, described as $\pi_A$ in this figure, corresponds to the quantity of input $I_1$, which originates an output level of $X_A$ and revenue $VX_A$, lower than the one described for the point of maximum production ($VX_{MAX}$).

Thus, we are able to evaluate two distinct terms: one of maximum productivity (*MP*) and one of maximum economic productivity (*MEP*). In the case described in Fig. 2, maximum productivity (*MP*) occurs for the input $I_2$ level, originating maximum productivity level ($X_{MAX}$), and *MEP* occurs for the input level $I_1$, generating productivity $X_A$, at which the producer has the greatest profit level.

Assuming variability in the chemical properties of the crop, it is expected that, by using precision agriculture techniques for varied fertilizer application, the cost function described in Fig. 3 is not unique for the entire crop. Thus, considering two sub-areas with different chemical characteristics, Fig. 3 describes the prescription and cost functions, as well as the resultant maximum profit in each one of these sub-areas. The crop's total area is indicated by letter *A*, according to the description in Fig. 2. This area, on the other hand, is subdivided into sub-areas *B* and *C*, which are represented, respectively, by the graphics to the left and to the right in Fig. 3.

The fertilizing demand is defined by a delta ($\Delta$), indicating variation, because the input quantity that defines the *MEP* is the one provided for the plant and not for the fertilizing demand. The latter is calculated by subtracting from $I_1$ the fertilizer quantity already available in the soil. Sub-area *B* is poorer in fertility and, hence, in order to reach the point of *MEP*, that is, to have fertility in the volume represented by $I_1$, it needs a fertilizer quantity of as much as the volume represented by $\Delta I_B$. As for the second sub-area (*C*), represented by the graph to the right, it is more fertile, having all nutrient quantity ($I_1$) needed to reach the *MEP*. Therefore, in this second area, the fertilizer demand is void, that is, $\Delta I_C = 0$. Respecting the soil fertility limit that offers the maximum economic return for the producer ($I_1$) in each sub-area, the productivity in both sub-areas (*B* and *C*) is the same ($X_B = X_C$) and equal to the *MEP*. The revenues are, thus, also equivalent: $VX_B = VX_C$. However, if uniform fertilizer application was to be carried out, the fertilizing need for the total area (*A*) would be in the volume $\Delta I_A$, which is the weighted average between the fertilizing demand for these two sub-areas (for a perfect soil sampling for all of the area). In that case, the productivity and, consequently, the revenue, is different from the one obtained with the varied application described previously. In sub-area *B* the revenue would be of $VX'_{AB}$, smaller than revenue $VX_B$, since the quantity of input available in this area is less than $I_1$. As per sub-area *C*, the revenue would be $VX'_{AC}$, more than $VX_C$ obtained for *MEP*. This occurs because the input quantity in this second sub-area is $I_1+\Delta I_A$.

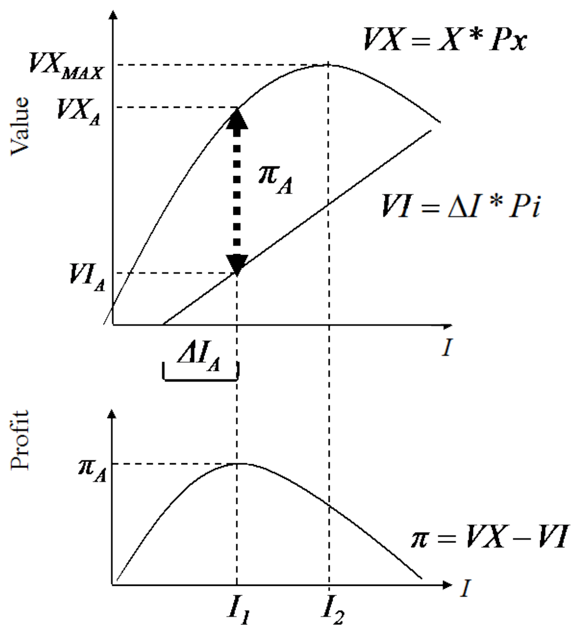


**Fig. 2. Representation of revenue, cost and producer profit elaborated from the function of agricultural production**

**Source**: Perloff (2008). Elaborated by authors.

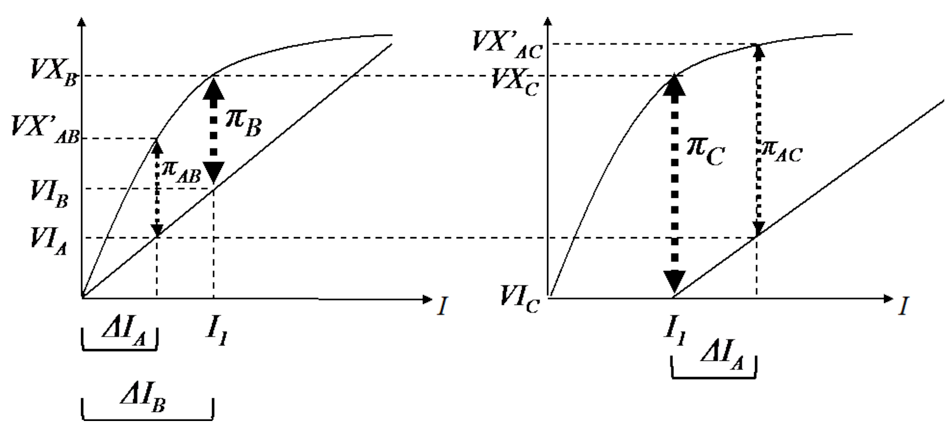


**Fig. 3. Representation of revenue and cost elaborated with uniform and varied fertilizer application in two sub-areas with different chemical properties**

**Note**: $I_1$ it indicates the input quantity to obtain maximum profit in each one of the two sub-areas; $\Delta \boldsymbol{I_A}$ is the uniformly applied input quantity in the two sub-areas; $\Delta \boldsymbol{I_B}$ and $\Delta \boldsymbol{I_C}$ are the variable input quantities applied.

**Source**: Perloff (2008). Elaborated by authors.

In this manner, the varied input application is better financially for the agro producer regarding the uniform application if, for the crop with sub-areas whose chemical characteristics are the same as those previously described, the condition described in equation (1) is true:

$$\pi_A < \%AreaB * \pi_B + \%AreaC * \pi_C + CAAV \quad (1)$$

where $\pi_A = \%AreaB * \pi_{AB} + \%AreaC * \pi_{AC}$ and the coefficients *% AreaB* and *% AreaC* which are multiplied by the profit of sub-areas *B* and *C*, respectively, indicate the share percentage of each one of these sub-areas in the crop's total area (*A*). Hence, if the areas have the same size these two coefficients are equal to 0.5. *CAAV* represents the additional costs of varied application in relation to uniform application. Such costs are generally considered as fixed costs, since they are used for several harvests in that crop and involve: productivity map constructions and use of appropriate implements for varied application. Because they are fixed costs, the *CAAV* represents the cost of opportunity for value on them expended. Nonetheless, these costs also depend on the crop's total area, for they are divided by it.

As shown on Fig. 2, the profit function can be described in the following manner:

$$\pi = VX - VI = X * P_x - \Delta I * P_i \quad (2)$$

Because product and input prices do not change depending on how the input is applied to the crop, (whether uniform or varied application), the inequality described in equation (1) occurs as a result of at least one of these two factors: (i) varied application reduced the input quantity applied to the crop; (ii) varied application increased the crop's total average productivity. Therefore, to satisfy equation (1), at least one of the conditions described in the following equations (3) and (4) should be satisfied:

$$\Delta I_A > \%AreaB * \Delta I_B + \%AreaC * \Delta I_C \quad (3)$$

$$(X_A = \%AreaB * X'_{AB} + \%AreaC * X'_{AC}) < (X_B = X_C) \quad (4)$$

Since the producer's decision between adopting a technology is based on economic return, this work sought to identify if: this always occurs and, if not, in which situations this is expected. Also analyzed was if the variation in profit occurred due to variation in input quantity, or in agricultural productivity, or in both. For this, next are described the method and the data used in this work.

## METHODS AND DATA USED IN THE ANALYSIS

The approach utilized in this study was estimating the variations in profit, in productivity of the agricultural culture and in the quantity of chemical fertilizers applied when the producer switches from uniform fertilizer application to varied application. That is, it consists in simulating, for different conditions that define the effectiveness of this technological change, the results of variables $\Delta\pi$, $\Delta I$ and $\Delta X$ described in equations (5) to (7) as follows:

$$\Delta\pi = \pi_A - \sum_{J=B}^{n} \%AreaJ * \pi_J \quad (5)$$

$$\Delta I = \Delta I_A - \sum_{J=B}^{n} \Delta I_J \quad (6)$$

$$\Delta X = X_A - \sum_{J=B}^{n} \%AreaJ * X_J \quad (7)$$

Where "$n$" is the number of the crop's sub-areas. Therefore, the results obtained from equations (5) to (7) are analyzed, respectively, in the following manner: what is the producer's profit gain in case varied fertilizer application is carried out, and not uniform application?; what is the saved fertilizer quantity in varied application compared to uniform application?; and what is the average increase in the crop's productivity in case varied fertilizer application is used, instead of uniform application?

In order to estimate the described equations and answer these questions, initially we described a function of typical agricultural output is described and the product and input prices used in this analysis are defined. Based on this information we calculated the input quantities that originate the points of maximum productivity (*MP*) and maximum profit (*MEP*). Following we described the factors that can determine the efficiency of this technological change on the crop, then the scenarios for each one of these factors are elaborated. For each combination of the elaborated scenarios the results of profit variation were generated, as well as those of productivity and input use. The generated results indicated which factors, as well as scenarios, that can contribute most to achieve a positive economic impact for the agro product according to the analyzed modification. They also indicated the conditions where this gain is determined by input reduction and/or, by the productivity increase.

## Production Function

As described in Fig. 2, the typical function of agricultural production (phase 2 of the production function described on Fig. 1) is concave. Thus, a random function has been adopted that can be used to describe any agricultural production function. The function adopted in this study is described in equation (8).

$$X = 1 + 0{,}35 * I - 0{,}003 * I^2 \quad (8)$$

where $X$ is productivity, in tons per hectare (ha), and $I$ is the quantity of fertilizer, in sacks of 60 kg, per ha. Hence, with 1 sack*ha$^{-1}$ of fertilizer the crop's productivity under this production function is 1.3 ton*ha$^{-1}$. With 119.5 sacks*ha$^{-1}$ of fertilizer the crop's productivity would be null. This shows that this function has a point of maximum, as illustrated in Fig. 2.

To discover the input volume that corresponds to the point of maximum physical production of this product (*MP*), the first derivative in the production function should be equalized to zero, as described in equation (9).

$$\frac{dX}{dI} = 0{,}35 - (2 * 0{,}003) * I = 0 \quad (9)$$

Proceeding in this way, the point of maximum corresponds to the input volume of 58.3 sacks*ha$^{-1}$.

However, the point of maximum production is not the interesting one for the agro producer, but the point of *MEP* is. Thus, to find this point, the first derivative of the profit function must be equalized to zero, as described by equation (2). Replacing equation (8) into equation (2) we have the profit function represented by equation (10).

$$\pi = (100 + 0{,}35 * I - 0{,}003 * I^2) * P_x - \Delta I * P_i \quad (10)$$

And the first derivative equals zero represented in equation (11):

$$\frac{d\pi}{dI} = 0{,}35 * I * P_x - (2 * 0{,}003) * I * P_x - P_i = 0 \tag{11}$$

However, we note in equation (11) that, to find the maximum point of this function, that is, to find the value of $I$ that equalizes the first derivative to zero, we need to define other two variables that appear in this function. They are: the product price ($P_x$) and the input price ($P_i$).

Adopting the product price ($P_x$) of 600 Brazilian Reals (R$600) per ton, and the input price ($P_i$) of R$90 per 60 kg sack, the input quantity that generates the *MEP* is 33.3 sacks*ha$^{-1}$.

In varied fertilizer application, it was considered that, for each of the crop's sub-areas, the input quantity applied is the one that spawns the point of maximum economic productivity (*MEP*). Thus corresponding to the points of *MEP* the variables $\pi_J$, $\Delta I_J$ and $X_J$, described in equations (5), (6) and (7), respectively. The values of these variables depend, however, on some of the crop's conditions, which are considered next (4.2). As for the profit, the input quantity and productivity obtained from uniform application, that is, the variables $\pi_A$, $\Delta I_A$ and $X_A$, in spite of having been estimated in order to also obtain the *MEP* point for the average of sampled sub-areas, they generate different values for these variables depending on both the environment variability and the soil sample on which this technology depends for an estimate of the input quantity applied in the crop. All these variations and scenarios used for the simulations carried out in this work are described in the next section.

## Environment Variabilities: scenarios

Agricultural production can be modeled, as any another manufactured product, as a function of production (described in the previous section). However, in this kind of production there are specificities that can alter the profits obtained by the producers. The main factors that define the crop's specificities are related to the climate and to the soil type. Regarding climate, variations occur according to temperature and rainfall. As for the soil type, there are variations in its physical, chemical, and biological characteristics.

These are the variations that define, for example, coffee producing regions, which need milder temperature; or manioc producing regions, which need sandier soils. These are variations that occur between different crops. However, some of these variations may also occur within a same crop, justifying the use of precision agriculture techniques to develop, in a specific manner, different edaphoclimatic conditions. Since the most common variations within a same area are those related to the soil type, the precision agriculture techniques used to handle these specificities are also the most usual ones.

Since in this work the objective was to identify the conditioning factors for economic efficiency in the use of precision agriculture in fertilizer applications, next are described the factors that, within a same crop, may contribute so that varied input application is more or less lucrative than uniform application. These factors may be related: to the environment, or to the variability that can exist in the soil sampling to identify the fertilizer need for uniform application in the crop.

## Soil variabilities

Initially, when we consider an area (or crop) that can be worked with the use of precision agriculture for fertilizer application, we need to define the number of sub-areas with distinct fertility that exists. Thus, the first variable to be considered is the number of these sub-areas (factor FA). Logics lead us to conclude that, the larger the number of these sub-areas, larger is the efficiency of the precision agriculture technique, since this larger number of sub-areas indicates a higher heterogeneity of the crop.

To analyze the efficiency of the varied fertilizer application, in this work were analyzed the following scenarios regarding the number of sub-areas with different needs of this input's application: (FA.1) two sub-areas; (FA.2) four sub-areas; (FA.3) eight sub-areas; (FA.4) sixteen sub-areas; (FA.5) twenty-four sub-areas; (FA.6) thirty-two sub-areas; (FA.7) forty sub-areas. Considering that a larger number of sub-areas is related to a higher heterogeneity, it is expected that the higher the number of sub-areas with fertility differences in a larger crop, the higher will be the efficiency in the use of the varied fertilizer application compared to the uniform application.

This it is not, however, the only important variable. This work shows the importance of the interaction of this factor with others and the degree to which such interactions can contribute for the use of precision agriculture to contribute with the reduction in the use of inputs, with productivity and, consequently, with the agro producer's profit.

Other factors related to the variability of the soils that may contribute to the efficiency of this technique are: variation level that this area's fertility presents (factor FB) and the size of each one of these sub-areas (factor FC).

Regarding the level of fertility variation in the crop (factor FB), we have that, the more fertile the sub-area, less is the need of complementary fertilizing. Fig. 4 illustrates the variation range in the fertility level of the soil exemplified in this simulation. In this case, the soil fertility varied from the equivalent to 33.3 sacks*ha$^{-1}$, represented by the letter "a" in Fig. 4, indicating fertile soils and with no need of fertilizing, to a soil with a low fertility level, represented by the letter "e" in this same figure. It is verified that the maximum soil fertility was equal to the input level that originated maximum economic productivity (*MEP*) of the production function used in this work, which was estimated in section 4.1. In the "e" point was considered a fertility of barely 20% of the maximum fertility observed, that is, equivalent to 7 sacks*ha$^{-1}$. The points "b", "c" and "d" indicate points whose soil fertility is medium between the points "a" and "e" and correspond to an equivalent fertility of 26 sacks*ha$^{-1}$, 20 sacks*ha$^{-1}$ and 13 sacks*ha$^{-1}$, respectively, of fertilizer.

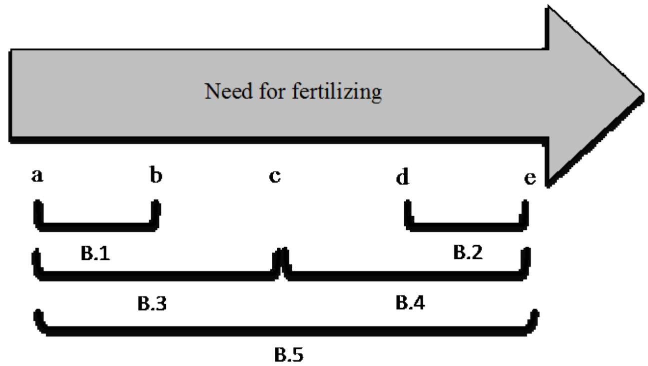


**Fig. 4. Representation of the variation possibilities in the soil fertility level of a crop and the scenarios analyzed regarding this factor**

Thus, five scenarios that can occur within a same crop were analyzed. They are: (FB.1) crop with sub-areas from situation "a" to situation "b"; (FB.2) crops with sub-areas from the condition presented in "d" to situation "e"; (FB.3) crops with sub-areas whose fertilizing needs are situated from "a" to "c"; (FB.4) crops with sub-areas with fertilizing needs that vary from "c" to "e"; (FB.5) crops with sub-areas that comprise all the variation schemed in Fig. 5, that is, from "a" to "e". It is expected that, the larger is the variation in the fertility level existing among the sub-areas for a same crop, larger will be the efficiency in the use of varied fertilizer application regarding uniform application.

Finally, it is assumed that the effectiveness may be defined by the size of each one of the sub-areas existing in the crop (factor FC). Three scenarios were considered for this factor. In scenario FC.1, all sub-areas have the same size. Thus, considering its interaction with scenario FA.1, where there are two different sub-areas, each one of them has 50% (1/2) of the total crop area. As per the scenario FA.7, where there are forty different sub-areas, each one has 2.5% (1/40) of the crop's total area. Factor FC.2 considered that 95% of the total crop area is concentrated in ¼ of the sub-areas with less fertility and factor FC.3 weighted the 95% of the crop area farming in ¼ of the sub-areas with higher fertility. It is expected that, the smaller the concentration of the sub-areas, that is, the better they are distributed, smaller is the efficiency in the use of varied fertilizer application compared to uniform application.

## Variability in sampling for uniform fertilizer application

Knowledge of uniform fertilizer application is another important factor in this analysis since input quantity and agricultural productivity produced based on the use of analyzed precision agriculture technique (varied fertilizer application) should be compared exactly to the uniform application of this input. Therefore, if within the varied application there is reduction in the total input use for the crop and/or productivity increase, compared to uniform application, we may have profit gain as result of precision agriculture use. In this sense, if we have the locations where the soil samples are made for uniform fertilizer application (factor FD), carried out only on the more fertile sub-areas, or on the less fertile, or on all sub-areas, the impacts on the difference of input quantity and productivity between the varied and uniform applications will be different. Consequently, the producer's profit will also be affected.

In order to evaluate this characteristic were considered seven scenarios: (FD.1) all sub-areas were sampled; (FD.2) around 80% of the more productive sub-areas sampled; (FD.3) around 80% of the less productive sub-areas sampled; (FD.4) around 40% of the more productive sub-areas and 40% of the less productive sub-areas sampled; (FD.5) around 10% of the more productive sub-areas and 10% of the less productive sub-areas sampled; (FD.6) only around 10% of the less productive sub-areas sampled; (FD.7) only around 10% of the more productive sub-areas sampled. It is expected that, the more homogeneous are the sampled sub-areas in uniform application, better will be the efficiency in the use of the varied fertilizer application compared to uniform application. In this sampling situation (few sub-areas and more uniform), we have a smaller representativeness of the analyzed crop's total fertility, which reduces the efficiency of uniform application.

In spite of the great range of scenarios analyzed for this factor, the scenarios described where the sampled sub-areas are more homogeneous are the characteristic scenarios of poorly conducted samples. Thus, if adequate agricultural practices are applied, such scenarios do not occur. For the case of sub-areas with the same size (scenario FC.1), the poorly conducted samples are those described in scenarios FD.6 and FD.7. For scenarios FC.2 and FC.3, where 95% of the crop area is concentrated, respectively, in the less and more fertile sub-areas, the inadequate samplings occur within the interaction of these with the scenarios: FD.2 and FD.7 for the scenario FC.2 and, FD.3 and FD.6 for the scenario FC.3. These specific cases were discussed in this study's results.

From the interaction of all of the scenarios previously described were simulated and calculated the magnitude of variations in input use and agricultural productivity. From the results regarding these two variables, it was described and applied the financial method to determine the economic efficiency in the use of varied input application in comparison to uniform application. The simulations were carried out in calculation spreadsheets and the results obtained were summarized in the next section.

## RESULTS AND DISCUTION

From the interaction of the seven scenarios of factor FA, the five factor FB scenarios, the three factor FC scenarios, and the seven factor FD scenarios, a total of 735 scenarios were originated, where the results using techniques of varied and uniform input application were simulated. Then we calculated the variations in producer profit, in agricultural productivity and in input quantity, by the two alternative technologies.

Initially the results regarding variation in the rural producer's profitability were presented, that is the most important result for producer decision-making regarding usage or not of the precision agriculture technique. Next are described in which situations the input reduction objectives and productivity increase through the use of precision agriculture can be achieved. As described in this work's introduction, the span of these objectives is something still controversial in fieldworks related to the use of this technique.

## Financial impact for the adopting producer

In order to analyze the variation in direct financial profit obtained by the producer the calculation described in equation (5) was applied for each one of the interactions between the scenarios presented in the previous section. An important limitation in this analysis is that the additional costs of the varied application regarding the uniform application were not considered. That is, the variable *CAAV* described in equation (1) was equal to zero. Thus, if the cost increase upon adopting the new application technology (*CAAV*) is superior to the producer's profit gain, the change is not economically beneficial for the adopter.

In Table 1 (on Annex) are described the values of profit gain, in Brazilian Reals (R$) by hectare per year, that the producer would have upon migrating from uniform to variable fertilizer application. It is verified in this table that the results of the producer's profit gain upon migrating from uniform to varied fertilizer application present resemblances in some scenarios:

i. in all scenarios of factors FA, FC and FD, the results in scenarios FB.1 to FB.4 were similar and there was significant increase of gain to the producer's profit by changing the fertilizer application technology when the scenario indicates that the crop analyzed presents the maximum variation in its fertility (FB.5);
ii. A big difference is also verified in the results presented when scenarios of uniform application sampling carried out in uniform manner in the simulated crops are considered. In the FC.1 scenarios, this occurred where the sample performed for the uniform application was carried out on only 10% of the sub-areas with the lowest (FD.6) or highest (FD.7) fertility levels. That is, the scenarios FD.1 to FD.5 presented similar results. Similar results were also observed between scenarios FD.2 and FD.7 and between FD.3 and FD.6 for the case of the FC.2 and FC.3 scenarios. In these cases, scenarios FD.1, FD.4 and FD.5 also presented similar results;
iii. Finally, it also is observed that, for crops with up to 4 sub-areas (scenarios FA.1 and FA.2), that is, for crops with few sub-areas with difference in fertility, the profit gain was also larger than in crops with a larger number of sub-areas. For more than 8 sub-areas (scenarios FA.3, FA.4, FA.5, FA.6 and FA.7) it is verified that the gain in profit by changing fertilizer application technology was more stable than in scenarios FA.1 and FA.2.

The scenarios for factor FC, despite not presenting results as divergent as those of the three previously described factors, were analyzed individually. For scenario FC.1, considering the similarities and differences accentuated between the scenarios of factors FA, FB and FD, Fig. 8 shows the average values of profit increase for the producer upon changing the fertilizer application technology. In this figure, the graphic to the left presents the result in Real by hectare per year and in the graph to the right the profit increase in a percentage of the revenue obtained from production using uniform application, which is the fertilizer application basic technology on which this study seeks to compare with varied application. Grouped in Fig. 5, the differences described in articles (i), (ii) and (iii) may quickly be visualized. Thus, while the producer's average profit gain was R$20,00 by ha per year (0.4% of the basic revenue) in crops with many sub-areas (FA.3 to FA.7), whose soil samples are more uniform (FD.1 to FD.5) and in soils whose fertility variation was not maximum (that is, FB.1 to FB.4), only changing for the scenario for which the soil fertility variation was maximum (FB.5), the average value of the increase in the producer's profit gain rose to R$126,00 by ha per year (or 2.3% of his revenue). However, this profit increase may still be higher, especially in scenario FB.5. In this case, for the situation where the sample performed for uniform application occurred only in 10% of the sub-areas with the lower (FD.6) or higher (FD.7) levels of fertility, the producer's profit gain upon migrating from uniform application to varied fertilizer application was R$409,00 by ha per year in average of scenarios FA.3 to FA.7, which is worth 8.3% of his revenue in uniform application. But scenarios FD.6 and FD.7 correspond to very specific conditions where, as described in section 4.2.2, the soil samples are inadequate in the uniform application system. Therefore, just a correction in the soil sample would generate around half of this profit gain for the producer, without need to change fertilizer application technology.

Since the sub-area sizes are the same for this set of results, the most probable of occurring in uniform application are samples carried out between scenarios FD.1 to FD.5. Another important observation regards the interaction of factors FA (number of sub-areas), FB (level of soil fertility variation) and FD (sample performed in uniform application). It is expected that the more diversified is the crop (factor FB), higher is the number of sub-areas (factor AF). Thus, more rare would be the situations presented in the results, for example, of interactions between FA.2 and FA.1 with FB.5. Furthermore, even in the case of these interactions occurring, as the fertility difference in the sub-areas is very expressive, they can be more easily identified by the producer and, more hardly, different areas would not be sampled for soil analysis in the situation of uniform fertilizer application. And this differential treatment returns a considerable increase in profitability for the producer, as shown by the results in Table 1, where it is observed, for these cases, the biggest profit gains in the differentiated treatment for such sub-areas. Thus, the situations of scenarios FA.2 and FA.1 with scenario FB.5 and scenarios FD.6 and FD.7, which were those with higher profit gains for the producer, are very specific cases and with low probability of occurrence.

Comparing the scenarios of factor FC, we observe in Fig. 5-7 that, while for the condition of higher profitability gain, in the average of scenarios FA.3 to FA.7, in FC.1 the producer's profit gain was R$409,00 by ha per year, for these same conditions in scenarios FC.2 and FC.3, the producer's profit gain was around R$630.00. However, in percentage of the producer's revenue using the technology base (uniform application), scenario FC.3 presented results similar to or lower than scenario FC.1. This indicates that the producer's revenue with the technology base in scenario FC.3 was superior to the one obtained in scenario FC.1.

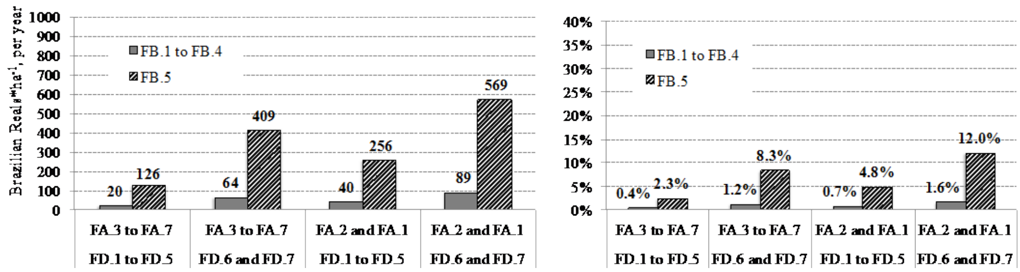


**Fig. 5. Average values (in Brazilian Real by ha per year and in percentage of the producer's revenue with the technology base) of the producer's profit gains upon migrating from uniform to varied fertilizer application considering different scenarios and whose crop sub-areas have the same size (FC.1)**

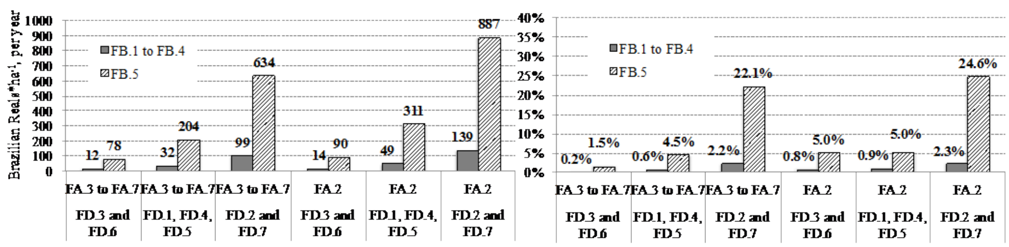


**Fig. 6. Average values (in Brazilian Real by ha per year and in percentage of the producer's revenue with the technology base) of the producer's profit increase upon migrating from uniform to varied fertilizer application considering different scenarios and where 95% of the crop's area is found in less fertile sub-areas (FC.2)**

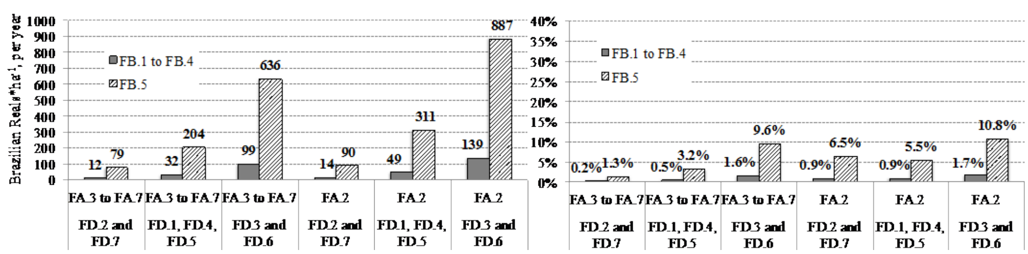


**Fig. 7. Average values (in Brazilian Real by ha per year and in percentage of the producer's revenue with the technology base) of the producer's profit increase upon migrating from uniform to varied fertilizer application considering different scenarios and where 95% of the crop's area is found in more fertile sub-areas (FC.3)**

For the situation presented in scenario FC.2, where 95% of the crop area is located in the smaller fertility level sub-areas, it is very unlikely that the sample carried out in the uniform application occurs only in the more fertile sub-areas (which corresponds to 5% of the crop). Hence, the results presented in the Table 1 related to FD.7 scenarios are extreme and less representative cases. Likewise, the FD.2 scenario, where 80% of the sampling occurs in more fertile sub-areas is not very realistic. This results in a small probability that the results presented in Table 1 that present the highest profit gains in varied application in detriment to the uniform fertilizer application. On average, these values were R$634,00 for the FA.3 to FA.7 scenarios and R$887,00 in FA.2.

On the other hand, the sampling of the most probable uniform application for scenario FC.2 corresponds to those described in scenarios FD.3 and FD.6, since this sample occurs in a predominant manner (in FD.3) or only (in FD. 6) in the sub-areas that are in 95% of the crop. In that case, it is verified that the highest profit gains for the producer due to varied fertilizer application instead of uniform application reached R$78,00 by ha per year (average of scenarios FA.3 to FA.7) and R$90,00 (FA.2 scenarios), for the most favorable condition of varied application, that is, when soil presents the maximum fertility variation (FB.5). This value represents less than 2% of the producer's revenue in the fixed input application, a similar condition to the one observed as more probable in scenario FC.1.

Considering still that the crop sampling is one of those described in scenarios FD.1, FD.4 and FD.5, that are intermediate cases between the worst (FD.2 and FD.7) and best (FD.3 and FD.6) samples carried out in crops of scenario FC.2, Fig. 6 shows that, on average, at best the producer's profit gains would be R$204.00 by ha per year. This corresponds to 4.5% of the producer's revenue in uniform application (Fig. 6).

In the extreme opposite case to the one described in scenario FC.2, there is, for scenario FC.3, that 95% of the crop's area is located in sub-areas of higher fertility levels. In that case, a similar analysis to the one described for Fig. 6 results may be applied to Fig. 7 results. That is, the results that presented the higher levels of return for the producer are those unique cases that have low occurrence probability. They are: FD.6 scenarios, where only the less fertile sub-areas (5% of the crop) are sampled in uniform application and FD.3, where 80% of these same sub-areas are sampled. And the most probable of occurring correspond to the scenarios described in FD.2, where 80% of the sampled sub-areas are the most fertile, and FD.7, where only the more fertile sub-areas are sampled. The producer profit gain values for these more and less probable cases, as well as for the intermediate scenarios (FD.1, FD.4 and FD.5) in FC.3 were practically equal to those obtained in FC.2. Only when we observe the values relative to the producer's revenue (graphs to the right in Fig. 6 and Fig. 7), is that the results in FC.2 become more expressive. This occurs since, as FC.2 assumes that 95% of the crop's area is located in sub-areas of lower fertility levels, its productivity and, consequently, the producer's revenue using uniform application, is lower to the one obtained when the crop's larger part is located in the sub-areas with higher fertility levels of (FC.3). Thus, having conditions closer to the one described in FC.2, the producer's profit gain regarding his base revenue is superior to the one obtained in crops closer to the one described in FC.3.

Both for the conditions presented in FC.3 and the ones described in FC.2, that is, having differences in sub-area crop sizes, regardless of being the more or less fertile that occupy most of the crop, it is interesting to observe the producer's possible profit gains upon correction of soil sampling for uniform fertilizer application. This can be observed by the difference in profit gain for the scenarios of worse (FD.2 and FD.7 for FC.2 and FD.3 and FD.6 for FC.3) and best (FD.3 and FD.6 for FC.2 and FD.2 and FD.7 for FC.3) samples. By the average values described in Fig. 6 and 7, this profit gain, in soils with maximum fertility difference analyzed, reached more than R$500.00 by ha per year when the crop presented more than 8 sub-areas. Considering the previous example of a crop of 100 ha, this correction in sampling could mean a gain of more than R$50,000.00.

That, it was verified for the results described in scenarios FC.2 and FC.3 that the profit gain expected by the producer upon altering the fertilizer application technology is, for the most probable conditions, similar to those observed for scenario FC.1. As per the profit gains spawning from the soil sample correction in uniform application, without need to change fertilizer application technology, it was more superior in conditions of heterogeneous sizes of sub-areas (FC.2 and FC.3) than in conditions of higher homogeneity (FC.1).

As described in section that describes environmental variability, it is expected that a higher efficiency, expressed in higher profitability, in the use of varied fertilizer application in relation to uniform application, occurs in situations where the sub-areas of a crop have: a higher fertility difference (factor FB), higher difference in area size (factor FC) and where the sample carried out in uniform application occurs in less fertile sub-areas that do not express the fertility diversity of the considered crop (factor FD). However, unlike as described in that section as expected for factor A, a higher profit gain was observed in crops with less sub-areas.

The justification, specifically for this result, is because it is less probable that the scenarios described in factors FB, FC and FD occur in crops with a smaller number of sub-areas. That is, the more diversified in terms of fertility is a crop's soil and consequently with a higher number of sub-areas, higher should also be the difference between the areas of higher and lower fertility (factor FB) and higher the probability of having a sample in the uniform application less representative of that crop (factor FD). As it can be observed in Fig. 8, a great importance in terms of variation in the profitability increase in function of the number of sub-areas (factor FA) was not observed. But, the higher the number of sub-areas, higher is the probability of observing scenarios closer to those described in scenarios FB.5, FD.6 and FD.7, that presented higher profit gains in the change of fertilizer application technology. Additionally, the costs by hectare for the technological change (*CAAV*) described in equation (1) are reduced with area increase and the larger is the crop area, higher also are the possibilities of having a larger number of sub-areas.

This section's results described the producer's profit increase due to precision agriculture techniques adoption for varied fertilizer application. Such profitability gain was present in all the scenarios analyzed, although costs for this technological change were not considered. Such profit increase had two sources: reduction in input use (fertilizer) and/or, increase in the crop's productivity. Next are analyzed if and which of these factors occurred to influence the results observed in this section. Such verification is important for, as previously described, they are the ones that define the profit gain for different conditions of input prices or the agricultural product. Furthermore, the quantification of input use reduction and the increase in productivity are two of the main goals to be achieved in academic works that evaluate precision agriculture techniques.

**Productivity increase and input use reduction**

The Tables 2 and 3 (on Annex) describe the changes, respectively, in the agriculture productivity values, in tons per hectare, and in the variation in the use of fertilizers, in sacks (60 kg) by hectare, caused in each one of the analyzed scenarios of technology change in fertilizer application. Productivity was determined by the production function described in equation (8), using uniform and varied fertilizer application. The input quantity was calculated considering the fertility levels of each soil (scenarios FB) and the type of sampling used (scenarios FD). As opposed to the results presented for the profit, which were positive in all scenarios where there had been changes from uniform application to varied fertilizer application, both results of productivity gain and loss were observed for the fertilizer quantity in the analyzed scenarios. However, the similarities described in articles (i) and (iii) in the scenarios analyzed for the impact on producer profit (section 4.1) remain when we analyze the impact on productivity and on the input use in this section. That is, the impacts are larger when the crop soil presents a higher fertility variation (FB.5) and simulations with less sub-area in the crop present larger results than in the crop with the larger quantity of sub-areas. As per the similarities observed regarding factor FD, described in item (ii) of the previous section, they present some differences.

It was verified that the impact in productivity due to the change in fertilizer application technology will always be positive, that is, the increased productivity when we compare the varied fertilizer application with uniform application in scenarios FD.7. This occurs because, in this scenario, it is assumed that the soil sample for uniform application occurs predominantly in the more fertile sub-areas, generating a low content of fertilizer applied and, consequently, low response in the crop's productivity. For this same reason, in this scenario there always is input increase in the varied application compared to uniform. As for where the sample is performed mainly in the less fertile areas (FD.6) the opposite occurs, that is, reduction in productivity and inputs. Thus, while in the case of FD.7 scenarios the profit gain occurs by the increase in the productivity and consequent increase in the producer's revenue, in the scenario FD.6 this is explained just by the cost reduction due to the reduction in the fertilizer applied.

For the FD.1 to FD.5 scenarios, the results regarding productivity and fertilizer quantity applied comparing both application technologies (uniform and varied) depend on the FC factor, that is, on the size of the crop's sub-areas. With all the same size sub-areas (scenario FC.1), FD.2 reacts as FD.7 and FD.3 presents a similar reaction to FD.6. Therefore, considering scenarios FA.7 and FB.5, while in FD.7 the productivity increased in 2.49 tons*ha$^{-1}$ and the volume of applied fertilizer increased in 12.3 sacks*ha$^{-1}$ per year, in FD.2 these raises in productivity and in fertilizers were, respectively, of 0.56 and 2.4. And while in FD.6 a decrease in 1.20 ton*ha$^{-1}$ in productivity and in 12.3 sacks*ha$^{-1}$, per year, was observed, in FD.3 these reductions were 0.2 and 2.7, respectively, for those productivity and fertilizer volumes. As for scenarios FD.1, FD.4 and FD.5, since the soil sampling was well performed for uniform input application, there were no modifications in fertilizer quantities between one or other application technology. However, since in varied application the input is better distributed in the crops, it spawns, as a result, an increase in the level of agricultural productivity in 0.19 tons*ha$^{-1}$ per year (Tables 2 and 3 on Annex).

For the conditions described in scenario FC.2, where 95% of the crop area is concentrated in the less fertile sub-areas, except for scenario FD.6, the producer's profit increase upon using varied input application occurred through productivity increase, even while also occurring an increase in fertilizer use. Thus, for the FA.7 and FB.5 scenarios, while in FD.6 it was observed a reduction of 0.34 tons*ha$^{-1}$ in productivity and 2,7 sacks*ha$^{-1}$ in fertilizers, per year, in the remaining scenarios was verified an increase between 1.21 (in FD.3) and 4.76 (in FD.7) tons*ha$^{-1}$ in productivity and between 9.6 (in FD.1, FD.4 and FD.5) and 21.9 (in FD.7) sacks*ha$^{-1}$ in fertilizers, per year (Tables 2 and 3 on Annex).

On the other hand, for the crop conditions described in scenario FC.3, since the crop area is concentrated in the more fertile sub-areas, the soil sampling is predominantly performed in these sub-areas. This generates a fertilizer sub-application when it is done uniformly. For this reason, all scenarios described from FD.1 to FD.6 resulted in profits for the producer due to reduction in fertilizer application and costs. Considering scenarios FA.7 and FB.5, only in the case of scenario FD.7, it was observed an increase of 0.48 tons*ha$^{-1}$ in productivity and 2.7 sacks*ha$^{-1}$ in fertilizers, per year. In the remaining scenarios the reduction in both variables was between 0.88 and 1.8 tons*ha$^{-1}$ in the productivity sacks*ha$^{-1}$ and between 7.2 and 21.9 sacks in fertilizers*ha$^{-1}$, per year (Tables 2 and 3 on Annex).

Therefore, it was verified that gains in varied application, when compared to the uniform fertilizer application whose soil samples are technically well performed, occur:

- exclusively through the raise in productivity in crops whose sub-areas are equally distributed;
- through the increase of productivity, followed by fertilizer increase in crops where the main portion has the more fertile sub-areas;
- through fertilizer reduction, followed by productivity reduction, in crops where the main portion has less fertile sub-areas.

## Sensibility analysis

In spite of the multidimensional analysis carried out in this study, some considerations that depend mainly on the market conditions and of the agricultural crop were given as fixed. The main ones, and which most affect the results, are: the response of agricultural productivity to the fertilizer, the input price and product price. In this section alterations in these budgets were simulated in a way to know the sensibility of the results obtained in the sections previous to them.

The response of the agricultural product to the fertilizer is given mainly by the coefficient 0.35 described in equation (8). This coefficient is multiplied directly by the fertilizer quantity applied to determine the crop's productivity. Thus, to analyze the sensibility of the results in relation to this variable, the same results described previously were simulated, modifying the value of this coefficient to (a) 0.23 and (b) 0.43. These new values indicate, respectively, a weaker and a stronger response of agricultural productivity to the fertilizer applied. The prices of input and product were altered from R$90.00 by fertilizer sacks and R$600,00 per ton of the product for: (C) R$45,00 per fertilizer sacks; (d) R$135,00 per fertilizer sacks; (and) R$1.200,00 per ton of the product and (f)

R$400,00 per ton of the product. The sensibility of the results presented in the sections previous to such changes is presented in Table 4. Each line in these tables shows the sensibility of the previous results for each of the alterations described in items from (a) to (f).

In Table 4 are presented the percentage modifications for the results described in Table 1, 2 and 3, in regard to those results. Such modifications refer to the average of all results obtained in those tables. As in Tables 2 and 3 there are results of both increase and reduction, respectively, for the variables productivity and fertilizer quantity applied. Such percentage alterations in these results were presented separately for the cases of increase and reduction in those variables. This table also shows the standard deviation of the percentage modifications (which are presented in parentheses) since these percentages are their average value.

**Table 4. Analysis of sensibility (medium and standard deviation for all scenarios) of the producer profit gain, and in the increases and reductions of productivity and in fertilizer quantity applied in the crop caused by the change in fertilizer application technology**

| | Producer profit gain variation | Productivity behavior change variation | | Fertilizer quantity used behavior change variation | |
|---|---|---|---|---|---|
| | | scenarios with productivity increase | scenarios with productivity reduction | scenarios that increased input quantity | scenarios that reduced input quantity |
| (a) from 0.35 to 0.23 | -84% (0%) | -68% (9%) | 55% (5%) | -60% (0%) | 60% (0%) |
| (b) from 0.35 to 0.43 | 96% (0%) | 59% (22%) | -29% (11%) | 40% (0%) | -40% (0%) |
| (c) from R$90.00 to R$45.00 | 89% (0%) | 10% (46%) | 54% (23%) | 37% (0%) | -38% (0%) |
| (d) from R$90.00 to 135.00 | -61% (0%) | -25% (21%) | -4% (11%) | -38% (0%) | 37% (0%) |
| (e) from R$600.00 to R$1,200.00 | 278% (0%) | 10% (46%) | 54% (23%) | 37% (0%) | -38% (0%) |
| (f) from R$600.00 to R$400.00 | -74% (0%) | -25% (21%) | -4% (11%) | -38% (0%) | 37% (0%) |

The values of 0% for the standard deviation of the variations observed indicate that the behavior of the change in the producer's profit and in the input quantity upon changing from uniform to varied fertilizer application was the same described previously, only altering those variations' magnitude. However, for the productivity it is observed that the variations described in articles (a) to (f) to measure the sensibility of the obtained results has a very large variation. Thus, we conclude that the behavior of the productivity variable depends on other conditions besides those described in the previously analyzed scenarios.

Given this consideration, we verify in Table 4 that, on one side, the profit gain results for the producer described in each one of the Table 1 scenarios are limited by: reducing the agricultural productivity response to the fertilizer application (a); increasing the input price (d) or; upon reducing the agricultural product price (f). For these same cases, in those scenarios where the fertilizer quantity increased with varied application, this increase was reduced and; in the scenarios where the fertilizer quantity was reduced, this reduction became smaller. In agricultural productivity, as described previously, the results presented great variation. However, on average, a reduction in those cases of productivity gain was observed.

On the other hand, in this same table was observed that the magnitude of the producer's profit gain results upon changing fertilizer application technology was maximized by: raising the agricultural productivity response to the fertilizer application (b); reducing the input price (c) or; raising agricultural product price (e). In the conditions of variation of the productivity response to fertilizers and of prices analyzed in those scenarios, the profit gain increases were 96%, 89% and 278% (Table 4), respectively, for items (b), (c) and (e). As per the variations in the magnitude of behavior change in the fertilizer quantity used, it was opposite to what was verified previously. That is, for the scenarios where the fertilizer quantity was elevated by the varied application, this gain was even higher (between 37% and 40%) and; for the scenarios where the fertilizer quantity was reduced in the technological change, this reduction was even higher (between -38% and -40%). The average variation in productivity magnitude also presented a negative sign, that is, it increased in those scenarios of productivity increase caused by technological change.

## CONCLUSION

- There is no sense in scientific works, designed to generalize results, for P.A. technology economic impacts. This is so because each crop is unique for the producer and should be analyzed one by one.
- It cannot be affirmed that P.A. reduces input and/or, increases productivity. Generally one of these cases will occur depending on conditions of crop and sampling for uniform application. The productivity answer caused by technological change also depends on agriculture and market parameters.
- Productivity increased followed by input reduction in varied application compared to difficult uniform application occurs. In this study unique situations were only observed in sensibility analysis, by raising product price or reducing input price.
- The factor that most influenced producer profit gain using precision agriculture tools in fertilizer application (compared to uniform application) was the sampling performed for uniform application. Therefore, only the correction of the soil sampling system, without fertilizer application technology change, can generate considerable profit gain for the agro producer.

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## ACKNOWLEDGMENT

The authors thank the National Center of Scientific and Technological Development (CNPq).

## ANNEX

**Table 1. Variation of the producer's profit by the change of uniform application for the varied fertilizer application in Brazilian Reals (R$) per ha/year**

| | FC.1 | | | | | FC.2 | | | | | FC.3 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **FB.1** | **FB.2** | **FB.3** | **FB.4** | **FB.5** | **FB.1** | **FB.2** | **FB.3** | **FB.4** | **FB.5** | **FB.1** | **FB.2** | **FB.3** | **FB.4** | **FB.5** |
| **FA.7** | | | | | | | | | | | | | | | |
| **FD.1** | 7 | 7 | 28 | 28 | 112 | 12 | 12 | 48 | 48 | 191 | 12 | 12 | 48 | 48 | 191 |
| **FD.2** | 8 | 8 | 31 | 31 | 122 | 18 | 18 | 71 | 71 | 283 | 7 | 7 | 30 | 30 | 119 |
| **FD.3** | 8 | 8 | 31 | 31 | 126 | 7 | 7 | 27 | 27 | 110 | 19 | 19 | 75 | 75 | 298 |
| **FD.4** | 7 | 7 | 28 | 28 | 112 | 12 | 12 | 48 | 48 | 191 | 12 | 12 | 48 | 48 | 191 |
| **FD.5** | 7 | 7 | 28 | 28 | 112 | 12 | 12 | 48 | 48 | 191 | 12 | 12 | 48 | 48 | 191 |
| **FD.6** | 24 | 24 | 96 | 96 | 385 | 2 | 2 | 10 | 10 | 39 | 55 | 55 | 222 | 222 | 887 |
| **FD.7** | 24 | 24 | 96 | 96 | 385 | 55 | 55 | 222 | 222 | 887 | 2 | 2 | 10 | 10 | 39 |
| **FA.6** | | | | | | | | | | | | | | | |
| **FD.1** | 7 | 7 | 28 | 28 | 114 | 12 | 12 | 48 | 48 | 193 | 12 | 12 | 48 | 48 | 193 |
| **FD.2** | 8 | 8 | 31 | 31 | 126 | 18 | 18 | 74 | 74 | 295 | 7 | 7 | 29 | 29 | 116 |
| **FD.3** | 8 | 8 | 31 | 31 | 126 | 7 | 7 | 29 | 29 | 116 | 18 | 18 | 74 | 74 | 295 |
| **FD.4** | 7 | 7 | 28 | 28 | 114 | 12 | 12 | 48 | 48 | 193 | 12 | 12 | 48 | 48 | 193 |
| **FD.5** | 7 | 7 | 28 | 28 | 114 | 12 | 12 | 48 | 48 | 193 | 12 | 12 | 48 | 48 | 193 |
| **FD.6** | 25 | 25 | 98 | 98 | 394 | 3 | 3 | 10 | 10 | 41 | 57 | 57 | 226 | 226 | 906 |
| **FD.7** | 25 | 25 | 98 | 98 | 394 | 57 | 57 | 226 | 226 | 906 | 3 | 3 | 10 | 10 | 41 |
| **FA.5** | | | | | | | | | | | | | | | |
| **FD.1** | 7 | 7 | 29 | 29 | 116 | 12 | 12 | 49 | 49 | 197 | 12 | 12 | 49 | 49 | 197 |
| **FD.2** | 8 | 8 | 33 | 33 | 131 | 20 | 20 | 78 | 78 | 314 | 7 | 7 | 28 | 28 | 111 |
| **FD.3** | 8 | 8 | 33 | 33 | 131 | 7 | 7 | 28 | 28 | 111 | 20 | 20 | 78 | 78 | 314 |
| **FD.4** | 7 | 7 | 29 | 29 | 116 | 12 | 12 | 49 | 49 | 197 | 12 | 12 | 49 | 49 | 197 |
| **FD.5** | 7 | 7 | 29 | 29 | 116 | 12 | 12 | 49 | 49 | 197 | 12 | 12 | 49 | 49 | 197 |
| **FD.6** | 26 | 26 | 102 | 102 | 409 | 3 | 3 | 11 | 11 | 43 | 59 | 59 | 234 | 234 | 937 |
| **FD.7** | 26 | 26 | 102 | 102 | 409 | 59 | 59 | 234 | 234 | 937 | 3 | 3 | 11 | 11 | 43 |
| **FA.4** | | | | | | | | | | | | | | | |
| **FD.1** | 8 | 8 | 30 | 30 | 121 | 13 | 13 | 51 | 51 | 206 | 13 | 13 | 51 | 51 | 206 |
| **FD.2** | 8 | 8 | 33 | 33 | 134 | 20 | 20 | 79 | 79 | 314 | 8 | 8 | 31 | 31 | 123 |
| **FD.3** | 8 | 8 | 33 | 33 | 134 | 8 | 8 | 31 | 31 | 123 | 20 | 20 | 79 | 79 | 314 |
| **FD.4** | 8 | 8 | 30 | 30 | 121 | 13 | 13 | 51 | 51 | 206 | 13 | 13 | 51 | 51 | 206 |
| **FD.5** | 8 | 8 | 30 | 30 | 121 | 13 | 13 | 51 | 51 | 206 | 13 | 13 | 51 | 51 | 206 |
| **FD.6** | 25 | 25 | 100 | 100 | 400 | 2 | 2 | 10 | 10 | 39 | 58 | 58 | 233 | 233 | 931 |
| **FD.7** | 25 | 25 | 100 | 100 | 400 | 58 | 58 | 233 | 233 | 931 | 2 | 2 | 10 | 10 | 39 |
| **FA.3** | | | | | | | | | | | | | | | |
| **FD.1** | 9 | 9 | 34 | 34 | 137 | 15 | 15 | 59 | 59 | 235 | 15 | 15 | 59 | 59 | 235 |
| **FD.2** | 10 | 10 | 41 | 41 | 163 | 25 | 25 | 102 | 102 | 407 | 7 | 7 | 29 | 29 | 115 |
| **FD.3** | 10 | 10 | 41 | 41 | 163 | 7 | 7 | 29 | 29 | 115 | 25 | 25 | 102 | 102 | 407 |
| **FD.4** | 9 | 9 | 34 | 34 | 137 | 15 | 15 | 59 | 59 | 235 | 15 | 15 | 59 | 59 | 235 |
| **FD.5** | 9 | 9 | 34 | 34 | 137 | 15 | 15 | 59 | 59 | 235 | 15 | 15 | 59 | 59 | 235 |
| **FD.6** | 29 | 29 | 114 | 114 | 457 | 3 | 3 | 11 | 11 | 43 | 67 | 67 | 267 | 267 | 1.067 |
| **FD.7** | 29 | 29 | 114 | 114 | 457 | 67 | 67 | 267 | 267 | 1.067 | 3 | 3 | 11 | 11 | 43 |
| **FA.2** | | | | | | | | | | | | | | | |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **FD.1** | 11 | 11 | 44 | 44 | 178 | 19 | 19 | 78 | 78 | 311 | 19 | 19 | 78 | 78 | 311 |
| **FD.2** | 13 | 13 | 53 | 53 | 213 | 34 | 34 | 136 | 136 | 545 | 9 | 9 | 37 | 37 | 147 |
| **FD.3** | 13 | 13 | 53 | 53 | 213 | 9 | 9 | 37 | 37 | 147 | 34 | 34 | 136 | 136 | 545 |
| **FD.4** | 11 | 11 | 44 | 44 | 178 | 19 | 19 | 78 | 78 | 311 | 19 | 19 | 78 | 78 | 311 |
| **FD.5** | 11 | 11 | 44 | 44 | 178 | 19 | 19 | 78 | 78 | 311 | 19 | 19 | 78 | 78 | 311 |
| **FD.6** | 31 | 31 | 124 | 124 | 498 | 2 | 2 | 8 | 8 | 33 | 77 | 77 | 307 | 307 | 1.228 |
| **FD.7** | 31 | 31 | 124 | 124 | 498 | 77 | 77 | 307 | 307 | 1.228 | 2 | 2 | 8 | 8 | 33 |
| **FA.1** | | | | | | | | | | | | | | | |
| **FD.1** | 20 | 20 | 80 | 80 | 320 | 20 | 20 | 80 | 80 | 320 | 20 | 20 | 80 | 80 | 320 |
| **FD.2** | 20 | 20 | 80 | 80 | 320 | 20 | 20 | 80 | 80 | 320 | 20 | 20 | 80 | 80 | 320 |
| **FD.3** | 20 | 20 | 80 | 80 | 320 | 20 | 20 | 80 | 80 | 320 | 20 | 20 | 80 | 80 | 320 |
| **FD.4** | 20 | 20 | 80 | 80 | 320 | 20 | 20 | 80 | 80 | 320 | 20 | 20 | 80 | 80 | 320 |
| **FD.5** | 20 | 20 | 80 | 80 | 320 | 20 | 20 | 80 | 80 | 320 | 20 | 20 | 80 | 80 | 320 |
| **FD.6** | 40 | 40 | 160 | 160 | 640 | 40 | 40 | 160 | 160 | 640 | 40 | 40 | 160 | 160 | 640 |
| **FD.7** | 40 | 40 | 160 | 160 | 640 | 40 | 40 | 160 | 160 | 640 | 40 | 40 | 160 | 160 | 640 |

**Table 2. Agricultural productivity variation by the change of uniform fertilizer application for the varied application, in ton by hectare per year**

| | FC.1 | | | | | FC.2 | | | | | FC.3 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **FB.1** | **FB.2** | **FB.3** | **FB.4** | **FB.5** | **FB.1** | **FB.2** | **FB.3** | **FB.4** | **FB.5** | **FB.1** | **FB.2** | **FB.3** | **FB.4** | **FB.5** |
| **FA.7** | | | | | | | | | | | | | | | |
| **FD.1** | 0.01 | 0.01 | 0.05 | 0.05 | 0.18 | 0.38 | 0.38 | 0.80 | 0.80 | 1.75 | -0.34 | -0.34 | -0.64 | -0.64 | -1.13 |
| **FD.2** | 0.10 | 0.10 | 0.23 | 0.23 | 0.56 | 0.48 | 0.48 | 1.02 | 1.02 | 2.26 | -0.26 | -0.26 | -0.49 | -0.49 | -0.89 |
| **FD.3** | -0.09 | -0.09 | -0.15 | -0.15 | -0.21 | 0.27 | 0.27 | 0.56 | 0.56 | 1.21 | -0.43 | -0.43 | -0.80 | -0.80 | -1.36 |
| **FD.4** | 0.01 | 0.01 | 0.05 | 0.05 | 0.18 | 0.38 | 0.38 | 0.80 | 0.80 | 1.75 | -0.34 | -0.34 | -0.64 | -0.64 | -1.13 |
| **FD.5** | 0.01 | 0.01 | 0.05 | 0.05 | 0.18 | 0.38 | 0.38 | 0.80 | 0.80 | 1.75 | -0.34 | -0.34 | -0.64 | -0.64 | -1.13 |
| **FD.6** | -0.42 | -0.42 | -0.77 | -0.77 | -1.22 | -0.10 | -0.10 | -0.19 | -0.19 | -0.35 | -0.73 | -0.73 | -1.28 | -1.28 | -1.84 |
| **FD.7** | 0.50 | 0.50 | 1.08 | 1.08 | 2.48 | 0.91 | 0.91 | 2.01 | 2.01 | 4.74 | 0.11 | 0.11 | 0.22 | 0.22 | 0.48 |
| **FA.6** | | | | | | | | | | | | | | | |
| **FD.1** | 0.01 | 0.01 | 0.05 | 0.05 | 0.19 | 0.38 | 0.38 | 0.80 | 0.80 | 1.77 | -0.34 | -0.34 | -0.65 | -0.65 | -1.13 |
| **FD.2** | 0.11 | 0.11 | 0.25 | 0.25 | 0.59 | 0.49 | 0.49 | 1.04 | 1.04 | 2.32 | -0.25 | -0.25 | -0.48 | -0.48 | -0.87 |
| **FD.3** | -0.08 | -0.08 | -0.14 | -0.14 | -0.18 | 0.28 | 0.28 | 0.58 | 0.58 | 1.25 | -0.43 | -0.43 | -0.80 | -0.80 | -1.36 |
| **FD.4** | 0.01 | 0.01 | 0.05 | 0.05 | 0.19 | 0.38 | 0.38 | 0.80 | 0.80 | 1.77 | -0.34 | -0.34 | -0.65 | -0.65 | -1.13 |
| **FD.5** | 0.01 | 0.01 | 0.05 | 0.05 | 0.19 | 0.38 | 0.38 | 0.80 | 0.80 | 1.77 | -0.34 | -0.34 | -0.65 | -0.65 | -1.13 |
| **FD.6** | -0.43 | -0.43 | -0.78 | -0.78 | -1.23 | -0.10 | -0.10 | -0.20 | -0.20 | -0.36 | -0.74 | -0.74 | -1.29 | -1.29 | -1.85 |
| **FD.7** | 0.51 | 0.51 | 1.10 | 1.10 | 2.52 | 0.92 | 0.92 | 2.03 | 2.03 | 4.81 | 0.11 | 0.11 | 0.23 | 0.23 | 0.49 |
| **FA.5** | | | | | | | | | | | | | | | |
| **FD.1** | 0.01 | 0.01 | 0.05 | 0.05 | 0.19 | 0.39 | 0.39 | 0.81 | 0.81 | 1.79 | -0.35 | -0.35 | -0.65 | -0.65 | -1.14 |
| **FD.2** | 0.12 | 0.12 | 0.27 | 0.27 | 0.65 | 0.51 | 0.51 | 1.08 | 1.08 | 2.41 | -0.25 | -0.25 | -0.47 | -0.47 | -0.85 |
| **FD.3** | -0.10 | -0.10 | -0.16 | -0.16 | -0.22 | 0.27 | 0.27 | 0.56 | 0.56 | 1.21 | -0.44 | -0.44 | -0.82 | -0.82 | -1.39 |
| **FD.4** | 0.01 | 0.01 | 0.05 | 0.05 | 0.19 | 0.39 | 0.39 | 0.81 | 0.81 | 1.79 | -0.35 | -0.35 | -0.65 | -0.65 | -1.14 |
| **FD.5** | 0.01 | 0.01 | 0.05 | 0.05 | 0.19 | 0.39 | 0.39 | 0.81 | 0.81 | 1.79 | -0.35 | -0.35 | -0.65 | -0.65 | -1.14 |
| **FD.6** | -0.44 | -0.44 | -0.79 | -0.79 | -1.25 | -0.11 | -0.11 | -0.21 | -0.21 | -0.38 | -0.75 | -0.75 | -1.31 | -1.31 | -1.85 |
| **FD.7** | 0.52 | 0.52 | 1.13 | 1.13 | 2.59 | 0.94 | 0.94 | 2.08 | 2.08 | 4.92 | 0.12 | 0.12 | 0.24 | 0.24 | 0.52 |
| **FA.4** | | | | | | | | | | | | | | | |
| **FD.1** | 0.01 | 0.01 | 0.05 | 0.05 | 0.20 | 0.40 | 0.40 | 0.83 | 0.83 | 1.83 | -0.35 | -0.35 | -0.66 | -0.66 | -1.16 |
| **FD.2** | 0.11 | 0.11 | 0.26 | 0.26 | 0.62 | 0.51 | 0.51 | 1.08 | 1.08 | 2.41 | -0.26 | -0.26 | -0.50 | -0.50 | -0.90 |
| **FD.3** | -0.09 | -0.09 | -0.15 | -0.15 | -0.18 | 0.29 | 0.29 | 0.60 | 0.60 | 1.30 | -0.44 | -0.44 | -0.82 | -0.82 | -1.39 |
| **FD.4** | 0.01 | 0.01 | 0.05 | 0.05 | 0.20 | 0.40 | 0.40 | 0.83 | 0.83 | 1.83 | -0.35 | -0.35 | -0.66 | -0.66 | -1.16 |
| **FD.5** | 0.01 | 0.01 | 0.05 | 0.05 | 0.20 | 0.40 | 0.40 | 0.83 | 0.83 | 1.83 | -0.35 | -0.35 | -0.66 | -0.66 | -1.16 |
| **FD.6** | -0.43 | -0.43 | -0.77 | -0.77 | -1.22 | -0.09 | -0.09 | -0.17 | -0.17 | -0.31 | -0.75 | -0.75 | -1.31 | -1.31 | -1.85 |
| **FD.7** | 0.51 | 0.51 | 1.10 | 1.10 | 2.53 | 0.94 | 0.94 | 2.07 | 2.07 | 4.89 | 0.10 | 0.10 | 0.20 | 0.20 | 0.44 |
| **FA.3** | | | | | | | | | | | | | | | |
| **FD.1** | 0.01 | 0.01 | 0.06 | 0.06 | 0.22 | 0.43 | 0.43 | 0.90 | 0.90 | 1.99 | -0.38 | -0.38 | -0.71 | -0.71 | -1.22 |
| **FD.2** | 0.16 | 0.16 | 0.35 | 0.35 | 0.84 | 0.59 | 0.59 | 1.26 | 1.26 | 2.84 | -0.25 | -0.25 | -0.47 | -0.47 | -0.84 |
| **FD.3** | -0.13 | -0.13 | -0.22 | -0.22 | -0.31 | 0.27 | 0.27 | 0.56 | 0.56 | 1.22 | -0.50 | -0.50 | -0.92 | -0.92 | -1.51 |
| **FD.4** | 0.01 | 0.01 | 0.06 | 0.06 | 0.22 | 0.43 | 0.43 | 0.90 | 0.90 | 1.99 | -0.38 | -0.38 | -0.71 | -0.71 | -1.22 |
| **FD.5** | 0.01 | 0.01 | 0.06 | 0.06 | 0.22 | 0.43 | 0.43 | 0.90 | 0.90 | 1.99 | -0.38 | -0.38 | -0.71 | -0.71 | -1.22 |
| **FD.6** | -0.45 | -0.45 | -0.82 | -0.82 | -1.26 | -0.10 | -0.10 | -0.18 | -0.18 | -0.33 | -0.79 | -0.79 | -1.37 | -1.37 | -1.87 |
| **FD.7** | 0.55 | 0.55 | 1.19 | 1.19 | 2.75 | 1.01 | 1.01 | 2.24 | 2.24 | 5.35 | 0.10 | 0.10 | 0.22 | 0.22 | 0.47 |
| **FA.2** | | | | | | | | | | | | | | | |
| **FD.1** | 0.02 | 0.02 | 0.07 | 0.07 | 0.29 | 0.50 | 0.50 | 1.06 | 1.06 | 2.38 | -0.44 | -0.44 | -0.81 | -0.81 | -1.37 |
| **FD.2** | 0.19 | 0.19 | 0.42 | 0.42 | 1.02 | 0.69 | 0.69 | 1.49 | 1.49 | 3.43 | -0.29 | -0.29 | -0.54 | -0.54 | -0.96 |
| **FD.3** | -0.15 | -0.15 | -0.25 | -0.25 | -0.32 | 0.32 | 0.32 | 0.66 | 0.66 | 1.44 | -0.58 | -0.58 | -1.05 | -1.05 | -1.65 |
| **FD.4** | 0.02 | 0.02 | 0.07 | 0.07 | 0.29 | 0.50 | 0.50 | 1.06 | 1.06 | 2.38 | -0.44 | -0.44 | -0.81 | -0.81 | -1.37 |
| **FD.5** | 0.02 | 0.02 | 0.07 | 0.07 | 0.29 | 0.50 | 0.50 | 1.06 | 1.06 | 2.38 | -0.44 | -0.44 | -0.81 | -0.81 | -1.37 |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **FD.6** | -0.45 | -0.45 | -0.80 | -0.80 | -1.19 | -0.03 | -0.03 | -0.05 | -0.05 | -0.08 | -0.84 | -0.84 | -1.44 | -1.44 | -1.87 |
| **FD.7** | 0.55 | 0.55 | 1.21 | 1.21 | 2.82 | 1.10 | 1.10 | 2.44 | 2.44 | 5.88 | 0.04 | 0.04 | 0.08 | 0.08 | 0.19 |
| | | | | | | | | **FA.1** | | | | | | | |
| **FD.1** | 0.03 | 0.03 | 0.13 | 0.13 | 0.53 | 0.03 | 0.03 | 0.13 | 0.13 | 0.53 | 0.03 | 0.03 | 0.13 | 0.13 | 0.53 |
| **FD.2** | 0.03 | 0.03 | 0.13 | 0.13 | 0.53 | 0.03 | 0.03 | 0.13 | 0.13 | 0.53 | 0.03 | 0.03 | 0.13 | 0.13 | 0.53 |
| **FD.3** | 0.03 | 0.03 | 0.13 | 0.13 | 0.53 | 0.03 | 0.03 | 0.13 | 0.13 | 0.53 | 0.03 | 0.03 | 0.13 | 0.13 | 0.53 |
| **FD.4** | 0.03 | 0.03 | 0.13 | 0.13 | 0.53 | 0.03 | 0.03 | 0.13 | 0.13 | 0.53 | 0.03 | 0.03 | 0.13 | 0.13 | 0.53 |
| **FD.5** | 0.03 | 0.03 | 0.13 | 0.13 | 0.53 | 0.03 | 0.03 | 0.13 | 0.13 | 0.53 | 0.03 | 0.03 | 0.13 | 0.13 | 0.53 |
| **FD.6** | -0.43 | -0.43 | -0.73 | -0.73 | -0.93 | -0.43 | -0.43 | -0.73 | -0.73 | -0.93 | -0.43 | -0.43 | -0.73 | -0.73 | -0.93 |
| **FD.7** | 0.57 | 0.57 | 1.27 | 1.27 | 3.07 | 0.57 | 0.57 | 1.27 | 1.27 | 3.07 | 0.57 | 0.57 | 1.27 | 1.27 | 3.07 |

## Table 3. Variation of the fertilizer quantity utilized by changing the uniform application for the varied fertilizer application, in fertilizer sacks by hectare per year

| | | | **FC.1** | | | | | **FC.2** | | | | | **FC.3** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **FB.1** | **FB.2** | **FB.3** | **FB.4** | **FB.5** | **FB.1** | **FB.2** | **FB.3** | **FB.4** | **FB.5** | **FB.1** | **FB.2** | **FB.3** | **FB.4** | **FB.5** |
| | | | | | | | | **FA.7** | | | | | | | |
| **FD.1** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.4 | 2.4 | 4.8 | 4.8 | 9.6 | -2.4 | -2.4 | -4.8 | -4.8 | -9.6 |
| **FD.2** | 0.6 | 0.6 | 1.2 | 1.2 | 2.4 | 3.0 | 3.0 | 6.0 | 6.0 | 12.0 | -1.8 | -1.8 | -3.6 | -3.6 | -7.2 |
| **FD.3** | -0.7 | -0.7 | -1.4 | -1.4 | -2.7 | 1.7 | 1.7 | 3.4 | 3.4 | 6.8 | -3.1 | -3.1 | -6.2 | -6.2 | -12.3 |
| **FD.4** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.4 | 2.4 | 4.8 | 4.8 | 9.6 | -2.4 | -2.4 | -4.8 | -4.8 | -9.6 |
| **FD.5** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.4 | 2.4 | 4.8 | 4.8 | 9.6 | -2.4 | -2.4 | -4.8 | -4.8 | -9.6 |
| **FD.6** | -3.1 | -3.1 | -6.2 | -6.2 | -12.3 | -0.7 | -0.7 | -1.4 | -1.4 | -2.7 | -5.5 | -5.5 | -10.9 | -10.9 | -21.9 |
| **FD.7** | 3.1 | 3.1 | 6.2 | 6.2 | 12.3 | 5.5 | 5.5 | 10.9 | 10.9 | 21.9 | 0.7 | 0.7 | 1.4 | 1.4 | 2.7 |
| | | | | | | | | **FA.6** | | | | | | | |
| **FD.1** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.4 | 2.4 | 4.8 | 4.8 | 9.6 | -2.4 | -2.4 | -4.8 | -4.8 | -9.6 |
| **FD.2** | 0.6 | 0.6 | 1.3 | 1.3 | 2.6 | 3.1 | 3.1 | 6.1 | 6.1 | 12.2 | -1.8 | -1.8 | -3.5 | -3.5 | -7.1 |
| **FD.3** | -0.6 | -0.6 | -1.3 | -1.3 | -2.6 | 1.8 | 1.8 | 3.5 | 3.5 | 7.1 | -3.1 | -3.1 | -6.1 | -6.1 | -12.2 |
| **FD.4** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.4 | 2.4 | 4.8 | 4.8 | 9.6 | -2.4 | -2.4 | -4.8 | -4.8 | -9.6 |
| **FD.5** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.4 | 2.4 | 4.8 | 4.8 | 9.6 | -2.4 | -2.4 | -4.8 | -4.8 | -9.6 |
| **FD.6** | -3.1 | -3.1 | -6.2 | -6.2 | -12.5 | -0.7 | -0.7 | -1.4 | -1.4 | -2.8 | -5.5 | -5.5 | -11.1 | -11.1 | -22.1 |
| **FD.7** | 3.1 | 3.1 | 6.2 | 6.2 | 12.5 | 5.5 | 5.5 | 11.1 | 11.1 | 22.1 | 0.7 | 0.7 | 1.4 | 1.4 | 2.8 |
| | | | | | | | | **FA.5** | | | | | | | |
| **FD.1** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.4 | 2.4 | 4.9 | 4.9 | 9.7 | -2.4 | -2.4 | -4.9 | -4.9 | -9.7 |
| **FD.2** | 0.7 | 0.7 | 1.4 | 1.4 | 2.9 | 3.2 | 3.2 | 6.3 | 6.3 | 12.6 | -1.7 | -1.7 | -3.4 | -3.4 | -6.8 |
| **FD.3** | -0.7 | -0.7 | -1.4 | -1.4 | -2.9 | 1.7 | 1.7 | 3.4 | 3.4 | 6.8 | -3.2 | -3.2 | -6.3 | -6.3 | -12.6 |
| **FD.4** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.4 | 2.4 | 4.9 | 4.9 | 9.7 | -2.4 | -2.4 | -4.9 | -4.9 | -9.7 |
| **FD.5** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.4 | 2.4 | 4.9 | 4.9 | 9.7 | -2.4 | -2.4 | -4.9 | -4.9 | -9.7 |
| **FD.6** | -3.2 | -3.2 | -6.4 | -6.4 | -12.8 | -0.8 | -0.8 | -1.5 | -1.5 | -3.0 | -5.6 | -5.6 | -11.2 | -11.2 | -22.5 |
| **FD.7** | 3.2 | 3.2 | 6.4 | 6.4 | 12.8 | 5.6 | 5.6 | 11.2 | 11.2 | 22.5 | 0.8 | 0.8 | 1.5 | 1.5 | 3.0 |
| | | | | | | | | **FA.4** | | | | | | | |
| **FD.1** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.5 | 2.5 | 5.0 | 5.0 | 10.0 | -2.5 | -2.5 | -5.0 | -5.0 | -10.0 |
| **FD.2** | 0.7 | 0.7 | 1.3 | 1.3 | 2.7 | 3.2 | 3.2 | 6.3 | 6.3 | 12.6 | -1.8 | -1.8 | -3.6 | -3.6 | -7.3 |
| **FD.3** | -0.7 | -0.7 | -1.3 | -1.3 | -2.7 | 1.8 | 1.8 | 3.6 | 3.6 | 7.3 | -3.2 | -3.2 | -6.3 | -6.3 | -12.6 |
| **FD.4** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.5 | 2.5 | 5.0 | 5.0 | 10.0 | -2.5 | -2.5 | -5.0 | -5.0 | -10.0 |
| **FD.5** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.5 | 2.5 | 5.0 | 5.0 | 10.0 | -2.5 | -2.5 | -5.0 | -5.0 | -10.0 |
| **FD.6** | -3.1 | -3.1 | -6.2 | -6.2 | -12.4 | -0.6 | -0.6 | -1.2 | -1.2 | -2.5 | -5.6 | -5.6 | -11.2 | -11.2 | -22.4 |
| **FD.7** | 3.1 | 3.1 | 6.2 | 6.2 | 12.4 | 5.6 | 5.6 | 11.2 | 11.2 | 22.4 | 0.6 | 0.6 | 1.2 | 1.2 | 2.5 |
| | | | | | | | | **FA.3** | | | | | | | |
| **FD.1** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.7 | 2.7 | 5.3 | 5.3 | 10.7 | -2.7 | -2.7 | -5.3 | -5.3 | -10.7 |
| **FD.2** | 1.0 | 1.0 | 1.9 | 1.9 | 3.8 | 3.6 | 3.6 | 7.2 | 7.2 | 14.5 | -1.7 | -1.7 | -3.4 | -3.4 | -6.9 |
| **FD.3** | -1.0 | -1.0 | -1.9 | -1.9 | -3.8 | 1.7 | 1.7 | 3.4 | 3.4 | 6.9 | -3.6 | -3.6 | -7.2 | -7.2 | -14.5 |
| **FD.4** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.7 | 2.7 | 5.3 | 5.3 | 10.7 | -2.7 | -2.7 | -5.3 | -5.3 | -10.7 |
| **FD.5** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.7 | 2.7 | 5.3 | 5.3 | 10.7 | -2.7 | -2.7 | -5.3 | -5.3 | -10.7 |
| **FD.6** | -3.3 | -3.3 | -6.7 | -6.7 | -13.3 | -0.7 | -0.7 | -1.3 | -1.3 | -2.7 | -6.0 | -6.0 | -12.0 | -12.0 | -24.0 |
| **FD.7** | 3.3 | 3.3 | 6.7 | 6.7 | 13.3 | 6.0 | 6.0 | 12.0 | 12.0 | 24.0 | 0.7 | 0.7 | 1.3 | 1.3 | 2.7 |
| | | | | | | | | **FA.2** | | | | | | | |
| **FD.1** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.1 | 3.1 | 6.2 | 6.2 | 12.4 | -3.1 | -3.1 | -6.2 | -6.2 | -12.4 |
| **FD.2** | 1.1 | 1.1 | 2.2 | 2.2 | 4.4 | 4.2 | 4.2 | 8.4 | 8.4 | 16.9 | -2.0 | -2.0 | -4.0 | -4.0 | -8.0 |
| **FD.3** | -1.1 | -1.1 | -2.2 | -2.2 | -4.4 | 2.0 | 2.0 | 4.0 | 4.0 | 8.0 | -4.2 | -4.2 | -8.4 | -8.4 | -16.9 |
| **FD.4** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.1 | 3.1 | 6.2 | 6.2 | 12.4 | -3.1 | -3.1 | -6.2 | -6.2 | -12.4 |
| **FD.5** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.1 | 3.1 | 6.2 | 6.2 | 12.4 | -3.1 | -3.1 | -6.2 | -6.2 | -12.4 |
| **FD.6** | -3.3 | -3.3 | -6.7 | -6.7 | -13.3 | -0.2 | -0.2 | -0.4 | -0.4 | -0.9 | -6.4 | -6.4 | -12.9 | -12.9 | -25.8 |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **FD.7** | 3.3 | 3.3 | 6.7 | 6.7 | 13.3 | 6.4 | 6.4 | 12.9 | 12.9 | 25.8 | 0.2 | 0.2 | 0.4 | 0.4 | 0.9 |
| | | | | | | | | **FA.1** | | | | | | | |
| **FD.1** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **FD.2** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **FD.3** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **FD.4** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **FD.5** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **FD.6** | -3.3 | -3.3 | -6.7 | -6.7 | -13.3 | -3.3 | -3.3 | -6.7 | -6.7 | -13.3 | -3.3 | -3.3 | -6.7 | -6.7 | -13.3 |
| **FD.7** | 3.3 | 3.3 | 6.7 | 6.7 | 13.3 | 3.3 | 3.3 | 6.7 | 6.7 | 13.3 | 3.3 | 3.3 | 6.7 | 6.7 | 13.3 |