IMPACT OF MAIZE-GRAIN YIELD AND PRICE ON NET MARGIN AT MECHANIZED GROWING TECHNOLOGY IN ZAMBIA

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Abstract

The farm machinery is a system that is used by higher or lower efficiency and impacted by production costs, especially farm machinery prices and other technologic inputs. On the opposite side there are outputs which can generally be designed as proceeds. The proceeds especially are the yield and price of the product. Both of them can be considered as technologic outputs. However, there is still problem of proper (and sufficiently general) criterion for the assessment of the technology. Such a criterion has been chosen as the ***net margin*** *gained as a result of the difference of total costs and total incomes per unit of the production area or unit of the production. In view of the above criterion the yield and product price can also be considered as independent variables with the strongest impact on the net margin. Methodology of net margin calculation is complicated and sometimes not fully transparent. A new (proper) methodological approach has been conceived in the concept of ATMP (Agricultural Technology Management Program) that has proved its appropriateness for extension services in both developed as well as less developed countries. The Program is meant to provide not only the art of work to the extension worker in formulating sound and exact technological advice but also a modeling tool to analyze field technologic processes and find their result. The correct technological information (particularly on machinery sets and agronomic requirements) must be available so that correct and rapid economic (costs) and finally crop budget calculations could be done. The program also demonstrates an attempt to put into practice the concept of "precision technology" based on precision machinery inputs, which reduces machinery input costs. Preceding field survey carried out in Zambia (August – Sept. 2003) supplied basic data for technology design and economic calculations. Purely mechanized technology was selected for the modeling purposes. The technology was designed for Zambian conditions. In the first block, critical maize-grain yield was found, in the second the critical maize-grain price was tested while in the third one, combination of both of them was used. From more possible combinations the critical one has been found on the level of 7 ton per hectare and 115 USD per ton.*

Key words: ATMP – precision technology – crop budget - comparison table – dependent and independent variables – proceeds – net margin

INTRODUCTION

The Information Society is, in the general opinion, about to force fundamental changes in business and private life (THYSEN)[1]. How and how much will the Information Society influence agriculture? There is no reason to expect other than farmers will make use of the IT at a similar rate as other groups of the population and other business areas. However, will this produce fundamental changes in farming methods and systems and organization? So far the changes in agriculture have mainly been driven by technologic developments in farm machinery and equipment, improved crop and animal genetics, and improved feeding, fertilizing and plant protection practices. But, the experts agree that the benefits can only be achieved when all the above progressive methods are put into a balanced system. Especially mechanization inputs are very susceptible to the organization and their benefits, e.g. using new machines (necessary to application of other progressive inputs), must be their substitution benefits, their ability to reduce costs of production and, on the other hand, raise the incomes by means of growing yields or sales of the product under better conditions (HAVRLAND)[2]. Respect to the environment and rural employment are other factors that have to be considered. Thus, the process of more sophisticated farming systems introduction must be considered as changes of the whole system (HAVRLAND)[3].

This, the problem is not critical because of high inputs, but for the fact that the higher inputs are not covered by higher outputs which would compensate costs of inputs and generate the net margin. There are cases when the modern technologies are not justified in view of the set of production conditions (economic, natural and even social). Under such circumstances, the modern technologies are neither appropriate nor sustainable. The criterion of justification must be a complex one and should represent all outputs.

The proper technology is such a technologic system that is not only compatible with the whole set of production conditions but, especially, it results in a benefit expressed as net margin. There are many independent or dependent variables which impact the net margin. The most intensive are the crop yield and price of the product. It is quite interesting to know how intensive their influence is; it can be tested when considering changes of all variables as a multifactorial system or as isolated monoparametric system when changes of only one variable are arranged. The ATMP "Agro-Expert" program enables such testing to be done very quickly by modeling technologies with different input data (HAVRLAND)[4].

THEORETICAL CONSIDERATIONS ON ECONOMIC OPTIMALITY OF TECHNOLOGIES

It is desirable that the farmer or contractor reaps maximum benefit from the technologic and management innovations. Yet because of the freshness of the "precise" farm technologies, most attention has so far been paid to the technologies themselves, and little attention has been paid to the economic questions - now made practical. And while only a small amount of economic analysis has been conducted on data processing, much of what has been done has not been done well, thus limiting the practical usefulness of the studies because the economics of precision machinery use are complicated (SPUGNOLI)[5].

Monoparametric System Approach

It is a rather complex issue to define what makes user´s decisions "*economically optimal*". Underlying economic optimality must be some corresponding "*economic objective*" of the decision maker. Sometimes it is found useful to assume that a very simple model can be used to adequately frame and describe the economic objective of the user. In this model the machinery user (farmer, contractor) produces a simple output (net margin) that can be denoted by the variable "**y**", by applying a number of inputs, such as machine purchase price, period of use, annual use, fuel consumption, etc. which are described by a vector of variables $\mathbf{x} = (\mathbf{x_1, x_2, x_3 \; x_k})$. The net margin is assumed to share a fixed relationship with the application of inputs, where this relationship is described by a response function "**f**" which can be expressed as $\mathbf{y = f(x)}$.

Furthermore, it is assumed that the user observes "$\mathbf{p_u}$", the price per unit of output (*hectare or other working output*), and "**z**" a vector of prices per unit of each input $\mathbf{z = (z_1, z_2, z_3 \ldots.. z_k)}$. Then, it is assumed that the user, knowing "$\mathbf{p_u}$, **z** and **f**", wishes to choose levels of inputs $(\mathbf{x_1, x_2, x_3 \ldots.. x_k})$ so that one maximizes profits which are defined as revenues (prices times quantity of output) minus costs (the sum of the products of input prices and quantity of inputs applied) (WETZSTEIN, EDWARDS, MUSSER)[6].

In fact, it is assumed that the user´s objective is to solve the maximization task:

$$\max_{x_1 \ldots\ldots x_k} \{ \mathbf{p_u} \; \mathbf{x} \; f(\mathbf{x_1, x_2, x_3 \ldots.. x_k}) - \text{sum } \mathbf{z_k} \; \mathbf{x} \; \mathbf{x_k} \}$$

The solution of the above equation is illustrated in the following Fig. 1 for the case of there being only one input (one variable), i.e. $\mathbf{k = 1}$ and the input is than "$\mathbf{x_1}$". The result is typical for the economically optimal amount of input $\mathbf{x_1}$ (the amount that solves the equation and so maximizes revenues minus costs. Logically, the slope of "$\mathbf{f(x_1)}$" equals the cost/profit ratio "$\mathbf{z/p_r}$". This economically optimal amount is labelled as "$\mathbf{x_1}$" in Fig. 1.

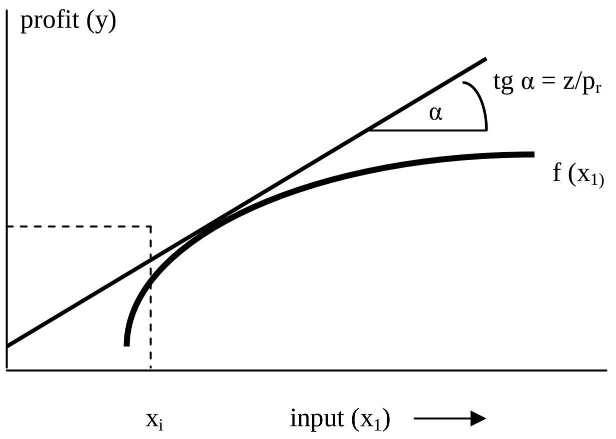


Fig. 1: Economically optimal input application in a mono-parametric (simple) model

However, the equation is multi-parametric and the solution in Fig. 1 is not sufficient. The solution is than taking a polynomial shape.

The Fig. 1 shows a function $f(\mathbf{x_1})$ as a concave one. It is intuitively appealing that the function should be concave for the case when the input-to-profit ratio rises. It can be assessed that the majority of cases the ratio will be concave and would take a logarithmic shape. It means that the response on the increase of an input value would be not proportional but it will be attenuated at higher input values. As a consequence, a logical conclusion must be that the growth of input values must have limits (CHANDRA, SINGH)[7].

The above conclusion is constrained by the fact that, in the case of profit there is little known about functions **y** = f(**x**) for most parameters.

Turning back to the **Fig. 2**, the optimal decision (with minimum risk) of the machinery user is to use less input and have less profit, that is to move to a lower level of "$\mathbf{x_1}$" value, since there the response function $f(\mathbf{x_1})$ is more steeply sloped than it is at its higher level. Similarly, when the cost/profit ratio "$\mathbf{z/p_r}$" falls, the optimal decision for the machinery user is to get more profit (move to a higher level of "x_1" input), since there the response function is less steeply sloped than at "$x_{1,i}$".

Economic Optimality with More Input Parameters

Probability Function Conception of Multi-parametric Systems

The solution when using only one factor "x_1" (input) is too simple for the analysis of profit strategy decisions. In general the final effect of many inputs on yield cannot be known with certainty until some point in time after the inputs are applied. This is because the levels of many factors of production that the manager (farmer, contractor, others) does not fully control (for instance variables depending on weather – time of machinery use, period of its use or cultural period; other set of variables can be market prices of both the inputs or outputs or so called legislative and banking parameters like depreciation and interest). The input impact cannot be assessed until after the user applies some of the inputs. This, the uncontrolled factors may be said to be stochastic and the manager is said to be making decisions under uncertainty. The graphical illustration of this case is a multidimensional as devised in Fig. 2.

It is extremely difficult or even impossible to compute such functional relationships on basis of experimental data. Other difficulties are encountered when the results should be interpreted.

The task can be well solved by the method of multi-factorial experiment at using a proper simulator that can enable modeling of the whole (very complex and dynamic) system (HAVRLAND, KAPILA, KREPL)[8]. One assumption that the economists very often make when trying to model such decision making dependent on uncontrolled factors of stochastic character (when managers operate under conditions of uncertainty). It is that the manager's objective is to maximize expected profits "*on average*".

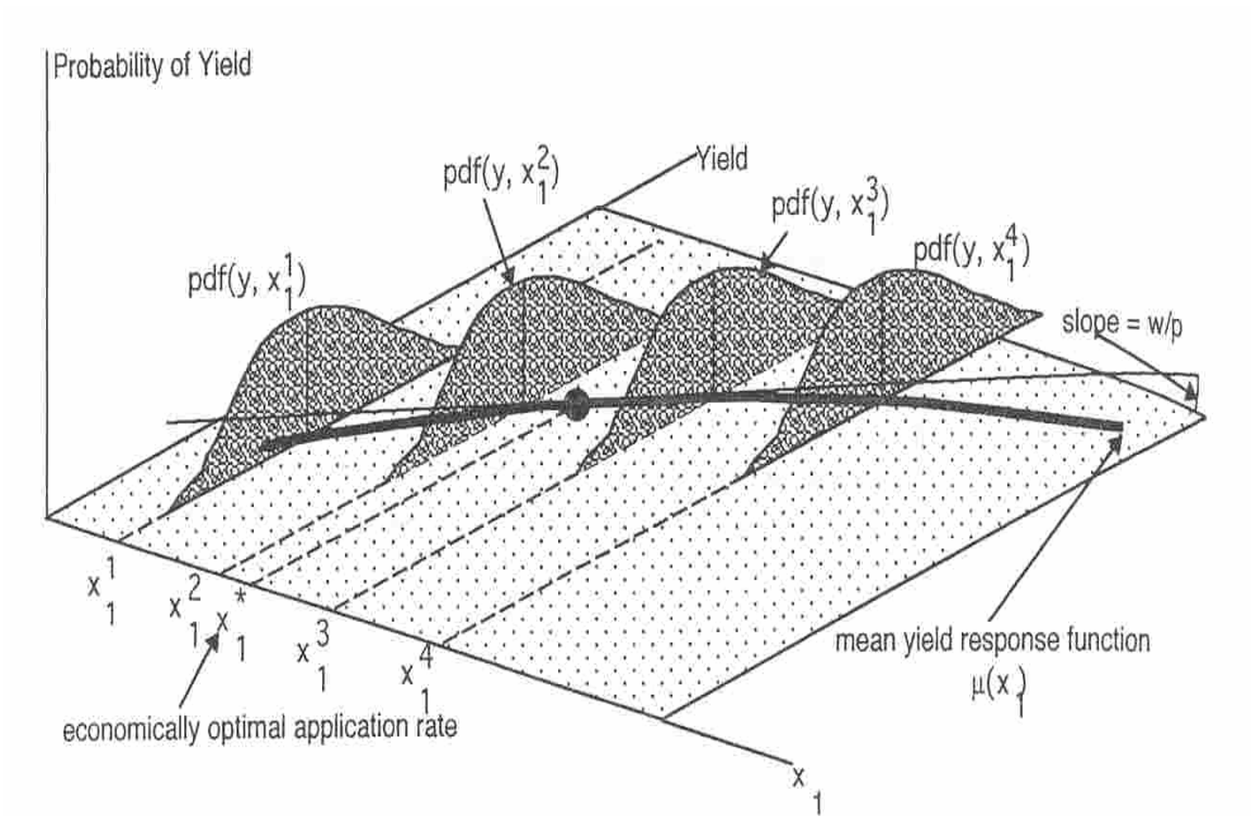


Fig. 2 Economically Optimal Input Application Rate under Uncertainty

Theoretical solution of the above assumption can be the following:

If we have in our model vector "**x**" of application values of inputs and the $\mathbf{x} = (x_1, x_2, x_3 \ldots x_k)$ has been chosen. Furthermore, it can be assumed that there are more stochastic factors impacting the technology $\mathbf{m} = (m_1, m_2, m_3 \ldots m_j)$ the values of which cannot be known with certainty at the time when the inputs "**x**" are chosen. It is obvious that the manager knows that the profit response to "**x**" and "**m**".

In the theoretical level we can write according to the function "**f**" that the profit (or any other output) is

y = f(x, m). While the manager (farmer, contractor or others) does not know the values in "**m**" with certainty the uncontrolled stochastic factors in "**m**" can be drawn from the joint probability density function p(**m**$_1$**, m**$_2$**, m**$_3$ **….. m**$_j$**)**. For example, though the contractor does not know with certainty how many days he will be able to work with his machines in March the experience (and probability) will offer him probable amount of days for March to work. Than the manager whose objective is to maximize his expected profits inclines to solve the problems according to the following formula:

$$\max_{x_1 \ldots\ldots x_j} \left\{ \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \ldots\ldots \int_{-\infty}^{\infty} \left[p_u \cdot f\left(x_1, x_2 \ldots\ldots x_k, m_1, m_2 \ldots\ldots m_j\right) - \sum_{k=1}^{k} z_k x_k \right] p\left(m_1, m_2 \ldots\ldots m_j\right) dm_1 . dm_2 \ldots\ldots dm_j \right\}$$

NOTE: *the term in curled brackets is expected profits.*

In **Fig. 2** there are four input applications (values) like, for example, annual use or purchasing price. The input has been designed as "$\mathbf{x_{1,i}}$": $\mathbf{x_{1,1}}$, $\mathbf{x_{1,2}}$, $\mathbf{x_{1,3}}$, and $\mathbf{x_{1,4}}$. Graphically pictured profit probability density functions depend on values at which the input "$\mathbf{x_1}$" is applied. If the contractor buys his machinery for a purchasing price "$\mathbf{x_{1,1}}$", than **pdf(y,**$\mathbf{x_{1,1}}$**)** shows the probabilities of various levels of profit occurring due to various levels of the uncontrolled stochastic variables (weather or economic conditions included in the vector "**z**". In order make the functional relationship simpler we consider the probability distribution as "normal" or "Gauss" distribution function. The mean profit response function "$\mu(x_1)$" runs along the plane formed by axes "input $\mathbf{x_1}$" and "profit **y**" and passes through the mean of the probability density function labelled **pdf(y,**$\mathbf{x_{1,1}}$**)**, and through the means of all the other probability density functions which are based on other levels of "$\mathbf{x_1}$". It can be shown that to solve the respective equation, the farmer must chose the level of "$\mathbf{x_1}$" at which the slope of the mean yield response function is equal to the price ration "$\mathbf{z/p_r}$". This level is labelled "$\mathbf{x_i}$".

Solution for Decisions on Optimal Input Values

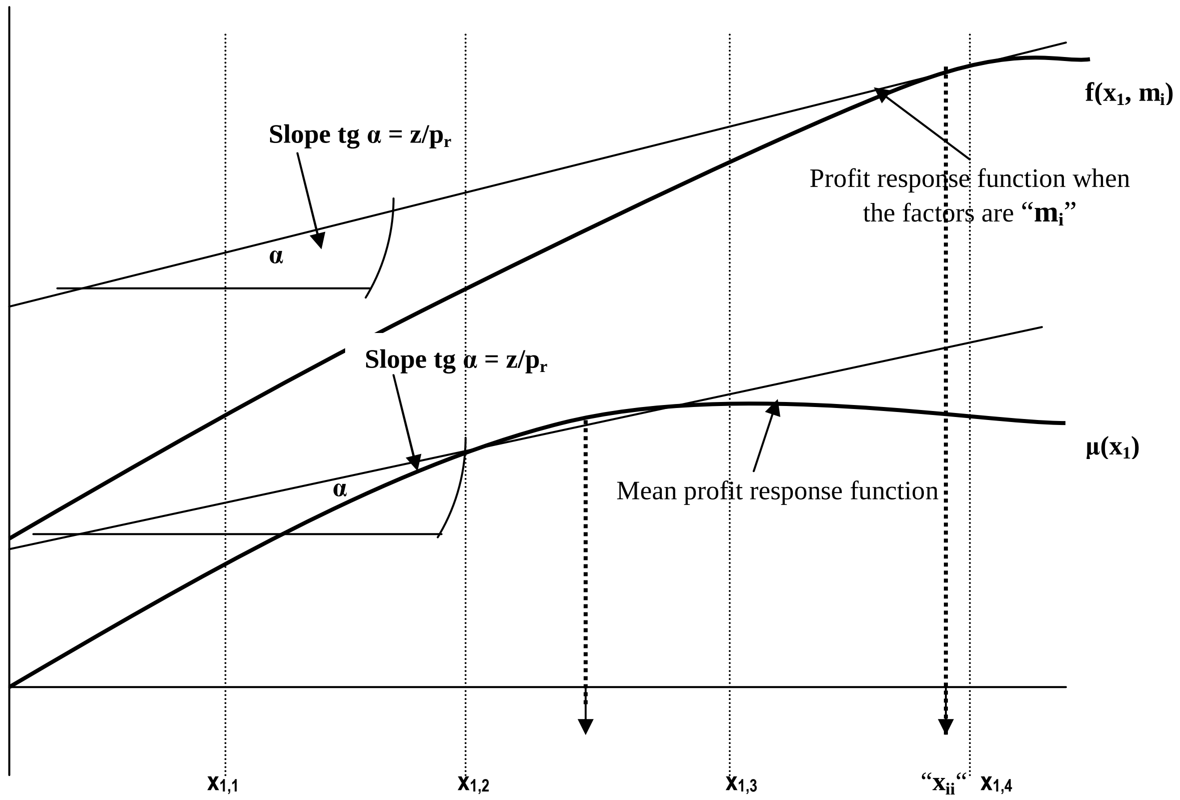
The solution is displayed in the **Fig. 4** as a profit response function and a mean profit response function to illustrate the important concept of **ex-ante** and **ex-post** economically optimal input decisions.

For the purpose of the example it is possible to focus on the **fertilizer application value** since decisions on this input value cannot be altered later. In the **Fig. 3**, "$\mathbf{x_i}$" is the ex-ante optimal value of the "$\mathbf{x_1}$" input (fertilizer application rate) because this is the value that the farmer chooses to maximize expected profits if he must make input decisions before he knows the values that the uncontrolled stochastic variables in "**m**" will take on. If, however, the farmer were able to make the input value decision after having learnt the vales of stochastic factors (in "**m**"), i.e., for example, if he knew for certain at the planning time the weather characteristics (number of rainy days) then generally quite different fertilizer application value would be more desirable (SWOBODA) [8].

The profit response function **f(x, m**$_i$**)** demonstrates how the profit responds to variations of the "$\mathbf{x_1}$" input (fertilizer application value), given that the uncontrolled stochastic variables take on the values in vector "$\mathbf{m_i}$". It is a general rule that if the "$\mathbf{m_i}$" implies quite favourable weather, the profit responds well above average for every value of "$\mathbf{x_1}$".

In fact, the probability functions of many uncontrolled stochastic variables are known at decision-making time (for example: *fertilizer application rates, number of working days, market prices*, etc.) and thus, the uncertainty is considerably reduced although not to its "*zero*".

But the "*ex-post*" profit maximizing value of "$\mathbf{x_1}$" input (fertilizer application value) at "$\mathbf{x_{ii}}$" means a hypothetic value of "$\mathbf{x_1}$" that would have maximized the profit, given that the uncontrolled stochastic variables would have taken on the value "$\mathbf{m_i}$" that would have been known for certain at time of planning. Of course, extension workers would like to be able to recommend to farmers at planning (application) time the value "$\mathbf{x_{ii}}$", which would maximize actual profits. But, since many factors of the stochastic character during the implementation of the respective technology cannot be estimated beforehand, the value of "$\mathbf{x_{ii}}$" cannot be known. Therefore the extension workers recommend more or less general application value "$\mathbf{x_i}$" of the "$\mathbf{x_1}$" input (in view of the overall production factors characteristics), which is the value that will maximize the profit "on average" if it is applied year by year.



Ex-ante economically optimal value of "$\mathbf{x_i}$"
Ex-post economically optimal value of "$\mathbf{x_{ii}}$" when uncontrolled stochastic variables are known

Fig. 3 *Ex-ante and ex-post economically optimal values of "x_1"*

METHODOLOGY

General Methodological Lay-out

The methodology based upon the ATMP Programme use was set up so that economic assessment of the conceived technology in more alternatives through the crop budget was possible. The impact assessment of influence of the grain-maize yield and price levels was done by simulating actual conditions of the mechanized maize grain growing technology in Zambian agriculture, i.e. operations and machinery and material inputs were relevant to the realistically conceived technology. For this purpose *a mechanized technology* has been worked out and further modified in three blocks:

1. block: the maize-grain yield was increasing from the lowest value (five tons per hectare) until the highest one (nine tons per hectare);

2. block: the price was growing from 90 USD per ton up to 170 USD per ton;

3. block: variations of yields and prices. Both the higher yields (above 6 tons per hectare) and prices above

110 USD per ton of maize-grain are hypothetic only for the Zambian conditions.

Technology assessment has been done through crop (technology) budgets on basis of selected parameters considered as main economic indicators. Net margins have been identified as the main criteria for the variables impact assessment. Functional liens between independent variables ($\mathbf{x_1}$, $\mathbf{x_2}$) and dependent variable (**y**) were tested and put into graphic.

Parameters of all technologies (their Crop Budgets) considered as the most important were put into the Comparison Table (see Tab. 1). The compared parameters have also been graphically illustrated in Fig. 4 - 12. Parameters of all technologies have been statistically tested and discussed.

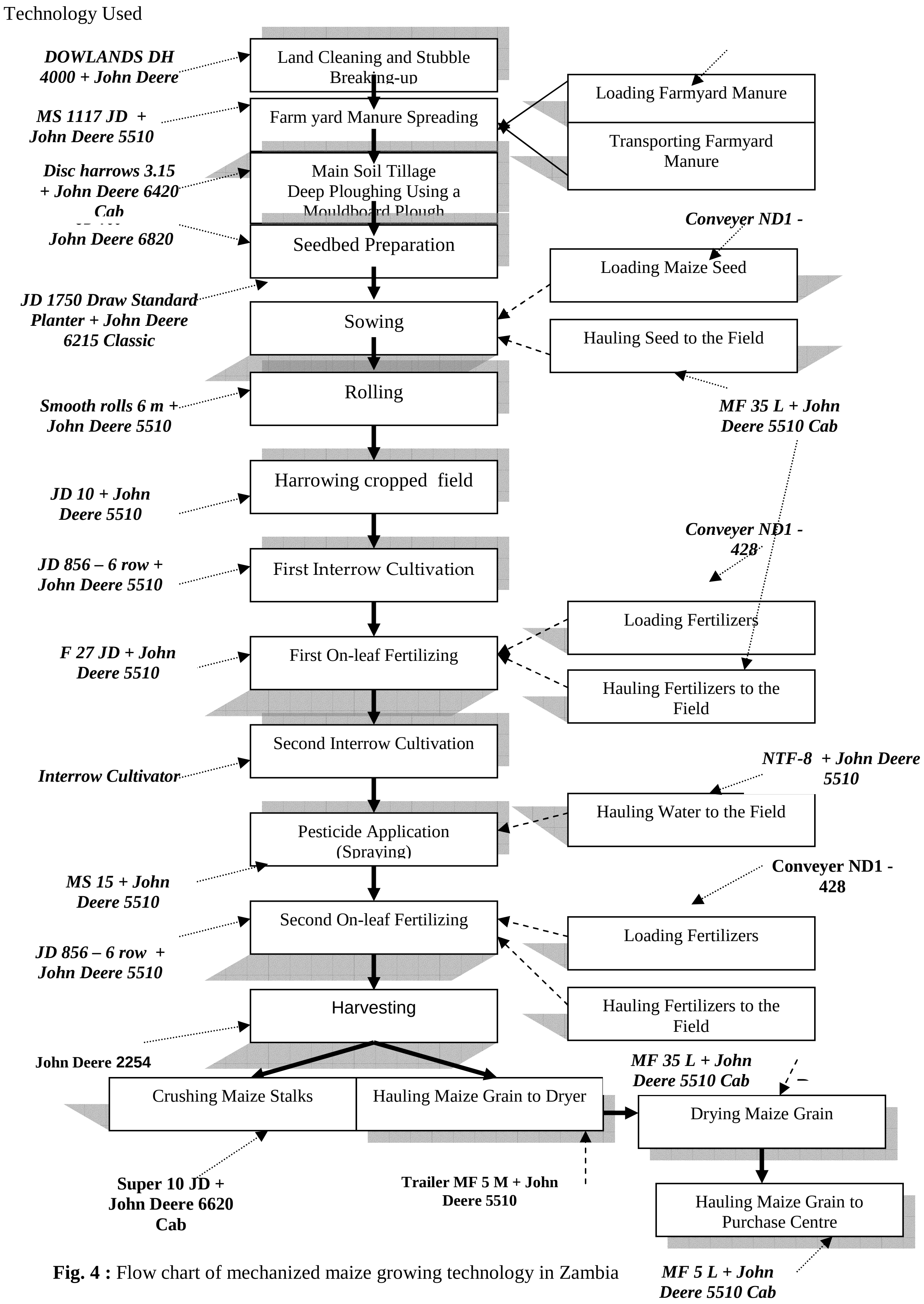


Fig. 4 : Flow chart of mechanized maize growing technology in Zambia

RESULTS AND DISCUSSION

Assessment Scheme

The assessment of all model technologies was carried out according to the crop budget parameters considered as the main economic characteristics of the relevant technology. The base technology starts with land clearing and ends with crushing maize stalks operations which represents a quite normal technologic pattern. On-farm maize-grain processing could not be included as it is not usual. However, it would make the farmer´s margin considerably grow, indeed. The technology was modified according the blocks as explained in the methodology, i.e. values of yield and prices were changed to get their response in the net margin values.

The above “manipulation” is not entirely correct because a higher yield will require higher input costs which would change the cost structure and final cost value. It is because the yield well describes the production intensity which has been neglected in the assessment scheme.

According to the Table (see Tab. 1), the most important output parameters are *total gross margin* (cur./ton), *total net margin* (cur./ton) and *percentage of total net margin* (%). However, the total net margin was taken as the most relevant parameter and its values were considered as the main criteria. No other parameters were assessed because the testing scheme did not influence them. The results are also shown in as graphics (see Fig. 5 – 7).

MODELING MATRIX	Used currency: USD				
CROP	Z.MaizeMech. I.	Z.MaizeMech. II.	Z.MaizeMech. III.	Z.MaizeMech. IV.	Z.MaizeMech, V.
VARIABLE: YIELD (Values from 5 $t.ha^{-1}$ to 9 $t.ha^{-1}$)					
Product Yield Expected (tons/ha):	5,00	6,00	7,00	8,00	9,00
Total Gross Margin (cur./ton):	-28,02	-8,35	5,70	16,24	24,43
Total Net Margin (cur./ton):	-71,37	-44,48	-25,26	-10,86	0,35
% of Total Net Margin (%):	-79%	-49%	-28%	-12%	0%
Total Net Margin = f(yield); linear regression	y = 17,70594x - 154,26514; R2 = 0,97043				
Total Net Margin = f(yield); logaritmic regression	y = 121,91656Ln(x) - 264,98303; R2 = 0,99256				
CROP	Z.MaizeMech. VI.	Z.MaizeMech. VII	Z.MaizeMech. VIII.	Z.MaizeMech. IX.	Z.MaizeMech, X.
VARIABLE: PRICE (Values from 110 $USD.t^{-1}$ to 170 $USD.\ t^{-1}$)					
IP Average Market Price (cur./ton):	110,00	130,00	150,00	160,00	170,00
Total Gross Margin (cur./ton):	-8,02	11,98	31,98	41,98	51,98
Total Net Margin (cur./ton):	-51,37	-31,37	-11,37	-1,37	8,63
% of Total Net Margin (%):	-47%	-24%	-8%	-1%	5%
Total Net Margin = f(yield); linear regression	y = x - 161,61,37060; R2 = 1				
Total Net Margin = f(yield); logaritmic regression	y = 137,30651Ln(x) - 698,12592; R2 = 0,99639				
CROP	Z.MaizeMech. XI.	Z.MaizeMech. XII	Z.MaizeMech. XIII.	Z.MaizeMech. XIV	Z.MaizeMech, XV.
VARIABLES: YIELD (Values from 6 t.ha-1 to 7 t.ha-1); PRICE (Values from 110 $USD.t^{-1}$ to 130 $USD.\ t^{-1}$)					
Product Yield Expected (tons/ha):	6,00	7,00	6,00	7,00	7,00
IP Average Market Price (cur./ton):	110,00	130,00	120,00	120,00	115,00
Total Gross Margin (cur./ton):	11,65	45,70	21,65	35,70	30,70
% of Total Net Margin (%):	-22%	11%	-12%	4%	0%
Total Net Margin (cur./ton):	-24,48	14,74	-14,48	4,74	-0,26
Total Net Margin = f(yield; price); multilinear regression	$y=-249,74+19,21x_1+x_2$; R2 = 0,93				

Tab. 1. : Crop Budget Comparison for different variables

Assessment of Variables Response

The independent variable for the first block of adapted technologies was yield in tons per hectare. With all other parameters (factors) kept constant and the price of grain on the level of 90 USD per ton, the yield was changing from 5 tons to 9 tons per hectare. The break-even point was reached around 9 tons per hectare when the net margin left red figures and started growing positive.

The independent variable for the second block of adapted technologies was price in USD per ton of grain. With all other parameters (factors) kept constant and the yield of grain on the level of 5 tons per hectare, the price was changing from 110 to 170 USD per ton of grain. The break-even point was reached at around 170 USD per ton of grain when the net margin turned positive.

The independent variables for the third block of adapted technologies were yield of grain per hectare and price in USD per ton of grain. With all other parameters (factors) kept constant, the yield was changing from 6 tons of grain per hectare and the price from 110 to 130 USD per ton of grain. The break-even point was reached at around 115 USD per ton of grain and the yield at around 7 tons of grain per hectare.

After having confronted the results obtained during modeling by the ATMP "Agro-Expert" programme with the technology potential and marketing possibilities under Zambian conditions we can conclude:

1. The yields of about 5 tons of maize-grain per hectare are realistic under Zambian conditions. However higher yields would be considered as exceptional and rarely reached. The yields of 8 – 9 tons are not realistic.
2. The prices of about 90 – 100 USD per ton of maize-grain are possible, however higher prices are not realistic even under out-season market conditions because of heavy competition of the product imported from Zimbabwe.
3. The compromise of 6 tons of maize-grain per hectare and 115 USD per ton of maize-grain is unlikely and can be considered as an exceptional under certain circumstance.

Modeling Results

In order to find functional relationships between independent and dependent variables the results as displayed in the Tab. 1 were statistically processed by linear and logarithmic regression models. The processing was done on the level of probability 95 percent (α=0.05) and relative error 0.15.

In the first block, linear and logarithmic models were used to find dependences "net margin=y=f(x_1)=f(yield)". The following empirical equations were found: linear regression y=17.706 x_1-154.27 with the correlation coefficient r_k=0.987; logarithmic regression y=121.916ln(x_1)-264.983 with the correlation coefficient r_k=0.996. Apparently, the logarithmic model is better correlated than the linear one. By the use of the above models, the break-even point was calculated (for the yield at which the net margin gets positive (y=0). **1**. For the linear model the yield (x_1) is 8.71 t.ha^{-1}; **2**. For the logarithmic one the yield (x_1) is 8.79 t.ha^{-1}. The obtained results are not too much different, however due to the better correlation, the yield resulting from the logarithmic model will be considered.

The same as the above was done for the second block to find empirical equations for "net margin=y=f(x_2)=f(price)". The results: linear regression y= x_2-161.37 with the correlation coefficient r_k=1; logarithmic regression y=137.306ln(x_2)-698.126 with the correlation coefficient r_k=1. Thus, both of two models are well correlated. The break-even point was calculated (for the price at which the net margin gets positive (y=0). **1**. For the linear model the price (x_2) is 161.37 USD.t^{-1}; **2**. For the logarithmic one the price (x_2) is 161.49 USD.t^{-1}.

The third block at which the net margin depends on two variables (yield= x_1 and price= x_2) a multiple regression model was used in the form y=a+bx_1+cx_2. The multi-linear regression was found as:

y=-249.74+19.21 x_1+ x_2. When solving the above equation searching for the break-even point (y=0) we get values of x_1 ; x_2**:** x_1(yield)=7.27 t.ha^{-1} and x_2(price) =110.07 USD.t^{-1}. If we limit the price on very realistic 100 USD.t^{-1} than we reach the break-even point at a very unrealistic yield 7.79 t.ha^{-1}. On the other hand the quite realistic yield under Zambian conditions 5 tons per hectare would require price per ton of maize-grain on the level of 153.68 USD.t^{-1}.

Conclusion

From the above said it is possible to make a conclusion that the fully mechanized technology used under the given (Zambian) conditions is too expensive, inappropriate and non-profitable. It is also not sustainable under the view of other (accompanying) effects such as increased unemployment and, by consequence, deeper rural poverty.

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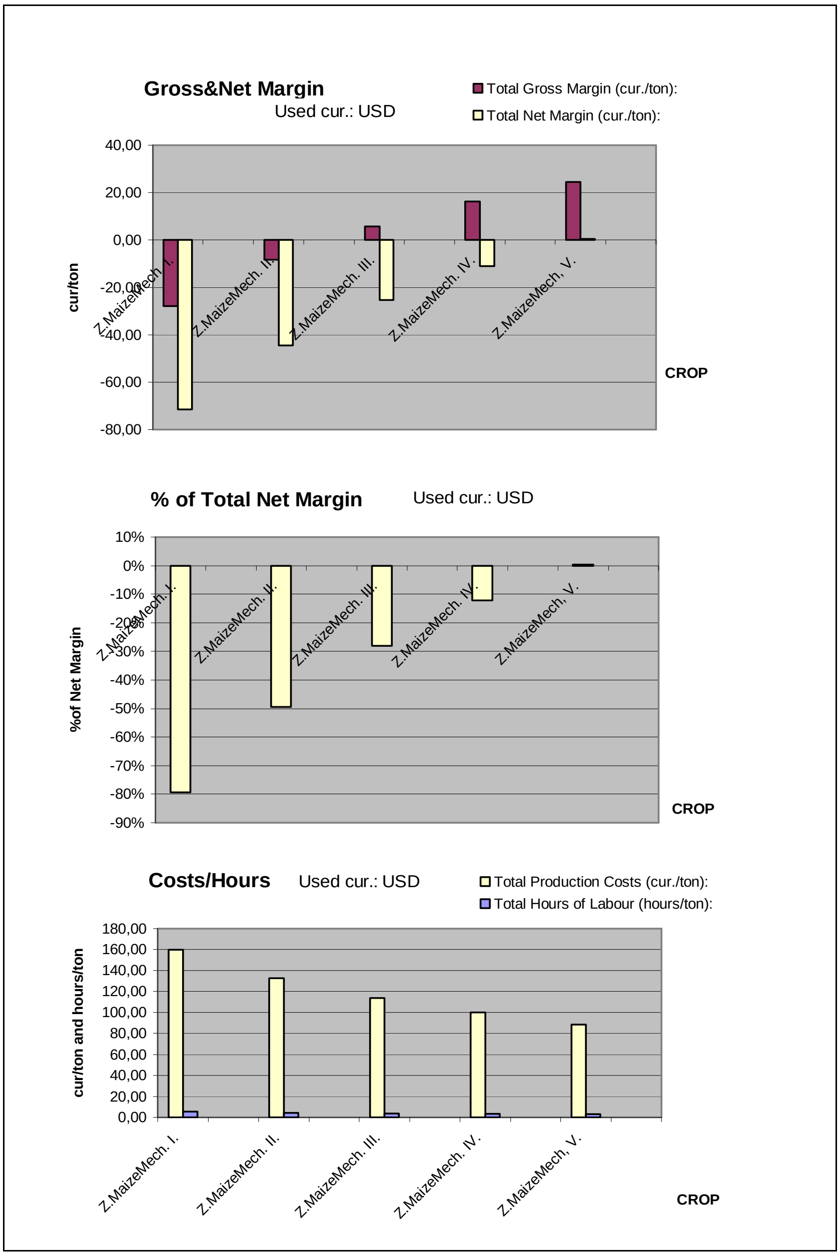

Fig. 5 : Total Gross and Net Margin as dependent on the product price

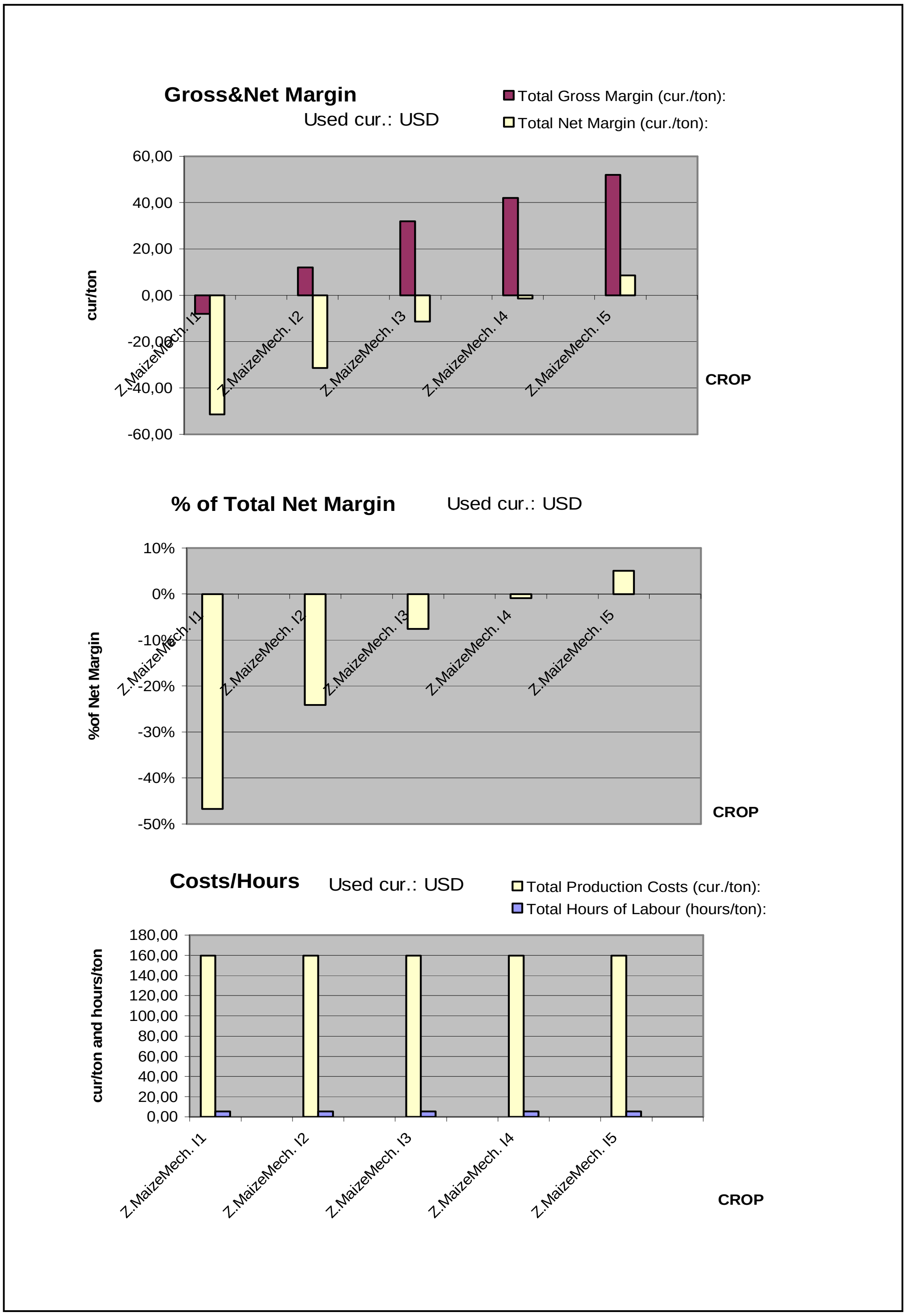

Fig. 6 : Total Gross and Net Margin as dependent on the product price

Fig. 7 : Total Gross and Net Margin as dependent on the product yield and price

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