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Full Length Research Paper

Inconsistent rate of fertilizer application in Turkish wheat agriculture: Economic evaluation

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Fertilizer application is one of the most important operations in agricultural production. Traditionally, fertilizer is applied onto the whole farmland regardless of the variations across the land. Soil cores are taken randomly through the field and mixed into a single sample, which is then analyzed, and consequently a unique fertility recommendation is made in accordance with the results. However, with this new technology of precision farming, grid or zone sampling is employed to determine the variability of the farmland soil fertility and fertilizers at variable-rates are applied onto each of these grids or zones. In this study, economics of variable-rate fertilizer application in Turkish wheat production is examined, an investment appraisal and partial budgeting analysis is made to determine the applicable conditions for farmers. Applying fertilizer considering the variations in soil nutrients could be economically justified. The key factor for the implementation of precision agriculture is the degree of variability; highest variability easiest the implementation. The annual cost per hectare of the above equipment over a 5 year depreciation period, at an interest rate of 21% together with maintenance vary between \$13 and \$131 ha^{-1} for an area managed by the precision farming system of 500 - 50 ha. The benefits is of greater importance the additional costs of the investment in precision farming systems for only considering the yield varies between 10 to 1% due to the farmed area. Whereas, percentage was 37 to 4% for fertilizer saving. The costs of detailed soil sampling and analyzing is a barrier for collection from a dense grid of data points.

Key words: Precision agriculture, economic assessment, wheat production, variable rate fertilizer application.

INTRODUCTION

Besides the existing risk of environmental and economical conditions, generally speaking, gross margins in agricultural crop production is very low and steadily diminishing due to economical measures of countries to approach the world market prices. Farmers should take utmost care of their expenditures and input usage in order to make money or at least to avoid deficits while trying to yield as much as possible by applying the nutriation requirements of plants to the soil and to avoid hazardous effects of weather conditions and natural enemies of the crops, e.g. pests. Fertilizers, sprays, seeds, labour, machinery and mechanical power in terms of tractors and other engines are the major sources of production costs. On the other hand there has been an increasing concern on the environmental impact of agricultural production in terms of its risk on air, soil and water pollution. This concern had lead scientists to deal with the problem of pollution and study the environment friendly practices and inputs rather than traditional farming and usage of pollutant chemicals in the form of fertilizers, sprays, growth regulators, etc. Sustainability in agricultural production, which is meant to produce crops and animals while keeping an eye on the balance of nature, has become widely accepted approach of farming in the western world.

In many of the member states of the European Union, incomes from agriculture are diminishing at a rate between 1 - 12%. The developments in agricultural policy, such as in Agenda 2000, the WTO negotiations, and the forthcoming eastward extension of the EU exert a significant influence on agriculture. Those measures planned as part of the Agenda 2000 may lead to a notice-able income reduction for the affected farms (Matthias and Meier, 2001). The EU's Agenda 2000 has lead the integration of environmental goals into the Common

Abbreviations: PF, Precision farming.

Agricultural Policy (CAP) and managing natural resources and contributing to landscape conservation have become increasingly important objectives for the CAP. The so-called “agri-environmental measures” will support the sustainable development of rural areas and will respond to society’s increasing demand for environmental services by encouraging farmers to use farming practices compatible with environmental protection and natural resources conservation.

Precision Farming (PF), in this respect, is a promising technology through which:

1. Crop yields, field performance and operating productivity in agricultural operations could be maximized.
2. Performance of various seed types, hybrids, chemicals and soils could be measured.
3. Fertilizer, chemical application costs could be reduced.
4. Pollution through poor use of chemicals could be reduced,
5. Field performance to the square meter could be tracked, mapped and analyzed so that to allow farmer to be able to know how well or poorly each part of a field is producing,
6. Decision-making process in farm-management could be improved,
7. Better farm records essential for sale and successions could be provided.

Numerous researchers have studied the economic impact of PA. Swinton and De-Boer (1998), and Lowenberg-De-Boer (2000) demonstrated basic budgeting methods to measure average profitability of variable rate technology. Pedersen and Have (1998) also presented an estimate of what is to be obtained from precision farming by linking an economic model with data from field experiments of 3 successive years. Tekin (2005) economically analyzed variable rate fertilizer applicator in cotton and maize production by using basic budgeting method.

They also concluded that development of cheaper methods for measurement of soil and crop variables, cheaper precision equipment, improved decision support systems and/or taxes on fertilizer and pesticides would all increase the economic profitability. Production system has been changed for several years in different part of Turkey. The driving force for the changing is closely related to world climatic changing and facing with fresh water supply shortage to farmlands. Several years there have not been enough rain to feed soil water reservoir and damps. Beside this factor, economic pres-sure caused from oil and fertilizer price increase is also other important factor.

In this study, investment analysis by partial budgeting method is demonstrated and minimum savings of fertilizers as well as minimum increase in yield that corresponds to investment costs of precision farming are calculated in order to project the potential of PF application in wheat farming in Turkey considering the field size and input-output prices.

MATERIALS AND METHODS

Materials

In this study, three set of data were used for economic analysis:

- The price of variable rate fertilizer system components
- Fertilizer price
- Sale price of crop

The price of the system components are obtained from market. The price of fertilizers is received from The Association of Turkish Agricultural Cooperatives. Sale price of crop, in this case wheat, for basic budgeting the input are obtained by the compilation of the data which were collected in 2008 by the Turk Stat. Agricultural prices have been compiled monthly via internet. The prices are compiled with the output questionnaire forms and, for field products, commercial buyer (merchants) and factory prices of the producers are compiled as wholesale prices.

Methods

Economic analysis of precision farming technology is not different than that applied to any other new technologies. Partial budgeting on a per hectare basis has been the most common tool to estimate the profitability of precision farming. Partial budgeting is used when only a partial change in the existing plan is being considered, so that some – possibly most – of the cost and receipt items on the farm will not alter. Thus only the changes in costs and receipts are calculated (Barnard and Nix, 1988). There are three main types of change that can be calculated by partial budgeting method. These are; (i) product substitution, (ii) change of enterprises without substitution and (iii) factor substitution.

The factor substitution is often a change in production techniques and adoption of precision farming can be considered in this category. It subtracts losses (increased costs plus reduced revenues) from gains (reduced costs plus increased revenues) to estimate the change in net revenue that results from adopting a new practice such as variable rate input control.

Precision Farming as an application of Information Technology in agriculture concerns with the software and hardware required to collect process and store the information in order to control the farm equipment. Within this definition there are mainly two areas of investment; information and the equipment. The economic analysis of both is presented below.

Information cost

Information must be valued in accordance with the easiness and the technology employed to reach it and also the possibilities it provides. There are various ways of estimating, for example the nutrient requirement of the soil for a particular plant. However, although it is the most expensive method, the nutrient analysis is gives the most precise information. Yield maps, soil maps, air photographs are the information that should be considered within the PF cost calculations. Yield mapping is a way of local yield information gathering. The map is generated by using a combination of yield monitor, GPS and field computer that were attached to harvesters such as combine. For site specific soil mapping the field is divided into grids. At each grid point, the soil is examined by taking soil sample which is then analyzed in laboratory. Soil samples are collected on a homogenous grid size such as 20 m by 20 m. Each measured parameter can be incorporated into GIS so that each soil attributes can be used to identify different management zones.

Table 1. Wheat yield and price.

Yield (kg/ha)	6.500
Price ($/kg)	0.32
Price ($/ha)	20801.99

Table 2. Extra price of precision farming equipment (US$).

PF Costs	Price (US$)
Boundry mapping and surveys	2.000
Yield Monitor	4.000
DGPS	4.000
VRT equipment	7.000
Microcomputer and printer	1.750

Table 3. Miscellaneous financial data.

Financial data	Value
Inflation rate (%)	15
Interest rate (%)	21
Real interest rate (%)	5.22
Real interest rate (decimal)	0.05
Life of equipment (years)	5
Exchange rate (TL/**$**)	1.5

Aerial photography is the basic tools to be used in several soil mapping mission. While stereoscopic air photos are used to map the soil boundaries, multispectral remote sensing are used for identification and categorization of soil conditions over a large area (Zhu et al., 2001). Using multi-band sensors from satellite, experts are able to obtain additional views that the traditional air photography cannot provide, based on the extra spectral (color) information they carry. Spectral information indeed advances one's ability to discriminate soil properties. It has been revealed that soil spectra across the Visible-Near InfraRed-Short Wave InfraRed (VIS–NIR–SWIR; 400-2500 nm) spectral region are characterized by significant spectral signals that enable quantitative analysis of several soil properties including soil degradation (salinity, erosion, and deposition), soil mapping and classification, soil genesis and formation, soil contamination, soil water content, and soil swelling (Ben-Dor et al., 2009). Soil properties such as NO_3N, P, K, Ca are the example of the data that can be interpreted by this method (Viscarra-Rossel et al., 2006).

According to information gathered in methods mentioned above, application map is created and uploaded to the control unit of variable rate fertilizer applicator which applies chemicals to the field.

Although different methods mentioned above would be used in nutrient requirements, in this study grid soil sampling is employed in information cost due to the fact of Turkey.

Costs of equipment

It is well known that the cost of equipment is a function of purchase price of the equipment, its economical life, repair and maintenance frequencies and the market conditions such as interest rate and inflation rate.

The cost of a whole or an additional component of an equipment can be calculated by the following equation which provides the annual fixed costs, that is, depreciation and interest charges, as equal annual mortgage payments, considering that the equipment is bought by borrowing the money and paying a series of equal annual mortgage payments;

$$R = (C_0 - C_N)\frac{I_R.(1+I_R)^N}{(1+I_R)^N - 1} + C_N.I_R$$

Where;

R : Annual mortgage payment ($/year)
C_0 : Purchase price of the equipment
($) C_N : Resale value of the equipment
($) i_r : Real interest rate (decimal)

The real interest rate under inflation can be calculated by the following equation:

$$I_R = \frac{I_N - I_G}{1 + I_G}$$

Where;

i_r : real interest rate (decimal)
i_n : interest rate on loan capital
(decimal) i_g : inflation rate (decimal)

The calculation assumptions

Assumptions made in this study in order to simplify the problem are as follows;

1. The farm will be using the same size of equipment only with a difference of PF components.
2. The input usage is considered for the worst conditions, e.g. the highest possible amount of fertilizer application.
3. There is no change in unit input application, farm tractor size and number as the farm size increases up to 500 ha. (Please note that in reality this is not possible because of soil workability due to weather conditions.)

The input data

Table 1 gives the yield and unit price ($/kg, $/ha) of wheat production in Turkey. Extra equipment required to be purchased for PF application is listed in Table 2. As technology for precision farming is improving very fast and therefore may be out of date long before it is technical obsolete, the expected service life of equipment in calculations are estimated to be 5 years (Table 3). Real interest interest rate is calculated according to the equation given below and presented in Table 3. The average fertilizer and spray applications and their costs are presented in Table 4.

RESULTS AND DISCUSSION

Table 5 gives the cost calculations of information in terms of soil sample analyses taken from grid cells of 0.4 ha. Costs per years and per hectares of that extra equipment required to be purchased for PF applications are calculated in accordance with the method described

Table 4. Wheat production inputs and costs.

Input	Amount (kg/ha)	Unit price ($/kg)	Total ($/ha)	Description
Fertilizer (1)	250	1,26	316.66	Ammonium phosphate
Fertilizer (2)	350	0.93	326.66	Urea
Total	550		643.33	

Table 5. Cost of information (for a 100 ha farm).

Cost items	Quantity
Total area (ha)	100
Grid cell area (ha)	0,40
No of grid cells	250
Grid sampling cost ($/sample)	16.66
Total soil test cost ($)	4166.6
Soil test cost $/ ha	41.66

Table 6. Extra investment cost of equipment (for a 100 ha farm).

Equipments	(US$/year)	(US$/ha)
Boundary mapping and surveys	490	4,90
Yield monitor	979	9,79
DGPS	979	9,79
VRT equipment	1.714	17,14
Microcomputer and printer	428	4,28

before and presented in Table 6. Cost calculations were made for various farm scales; 50, 100, 150, 200, 250, 300, 350, 400, 450, 500 and the results provided at Table 7.

1. The percentage increase in yield,
2. The percentage decrease in fertilizer application rate, required to cover these extra costs of Precision Farming investment are also calculated and given in Table 7 and Figures 1 and 2.

Figure 1 reveals that depend on the size of cultivated area, the change in yield is decreasing; the extra cost can be covered with 10% yield increase at 50 ha wheat farming. But the rate of yield change is decreasing sharply while the size is closing to 100 ha and then becoming steadily. The rate is reached to 1% at 500 ha.

In Figure 2, the rate change of fertilizer decrease is seen. The trend line of fertilizer decrease follows the same trend line with the line of yield. Hovewer, the rate is 37% for 50 ha wheat agriculture, is dropping sharply to 17% while the size is reaching 100 ha and steadily decline to 4% at 500 ha. In practice, the percentage of yield change which coincides 650 kg per ha (10%) is achievable considering 50 ha. This change is 65 kg per ha at 500 ha. The fertilizer saving also would be achievable for N application. The change is 200 kg/ha in 50 ha but reduce to 22 kg/ha at 500 ha.

Beside these, in farming process it is assumed that increase in yield and the decrease in fertilizer consumption would occur together depend on variable rate fertilizer application. So the combination of fertilizer consumption and yield change will determine the area size. The operated land size will be smaller than the area used in calculation.

Conclusions

These conclusions are based on the fertilizer price, wheat price and for equipment prices in 2008 in Turkey. The results of the research indicate:

1.The degree of variability is a key for the implementation of precision agriculture. Highest variability promote the implementation.

2. Applying nitrogen fertiliser considering the variations in soil nutrients could be economically justified.

3. The annual cost per hectare of the above equipment over a 5 year depreciation period, at an interest rate of 21% together with maintenance vary between $13 and $131 ha^{-1} for an area managed by the precision farming system of 500 - 50 ha. These costs will change in inversely with area managed per unit.

4. The benefits outweigh the additional costs of the investment in precision farming systems for only considering the yield varies between 10 to 1% due to the farmed area. Whereas, percentage was 37 to 4% for fertilizer saving.

5. Depend on the yearly price variation of input-outputs will affect these cost covering values.

6. Increase in yield and the decrease in fertilizer consumption would occur together, hence it is expected that in a smaller area than the area used in calculation will be covered extra cost of the system.

7. The costs of detailed soil sampling and analyzing is a barrier for collection from a dense grid of data points.

New techniques, for soil mapping in order to reduce the cost, must be developed and used. Remote sensing and multispectral photography is promising in this context. In Turkey many institutions have GIS laboratories. Recently, in these laboratories, soil is characterized in national level by the experts. These data and maps which will help the transition to PF will be available for the PF exercises.

Table 7. Costs for extra investment for precision farming.

	Farm scale									
	50	**100**	**150**	**200**	**250**	**300**	**350**	**400**	**450**	**500**
Total cost of information ($/ha)	113	113	113	113	113	113	113	113	113	113
Total cost of extra equipment ($/ha)	131	65	44	33	26	22	19	16	15	13
Total return required ($/ha)	236	118	79	59	47	39	34	29	26	24
Equivalent yield increase (%)	9.96	4.98	3.32	2.49	1.99	1.66	1.42	1.25	1.11	1.00
Equivalent fertilizer decrease (%)	36.86	18.43	12.29	9.22	7.37	6.14	5.27	4.61	4.10	3.69

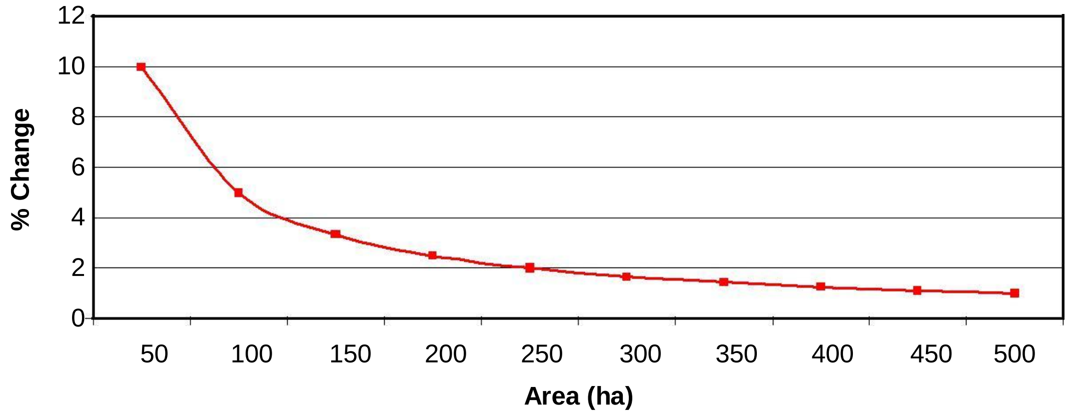

Figure 1. Increase (%) in yield required to cover the extra costs of PF.

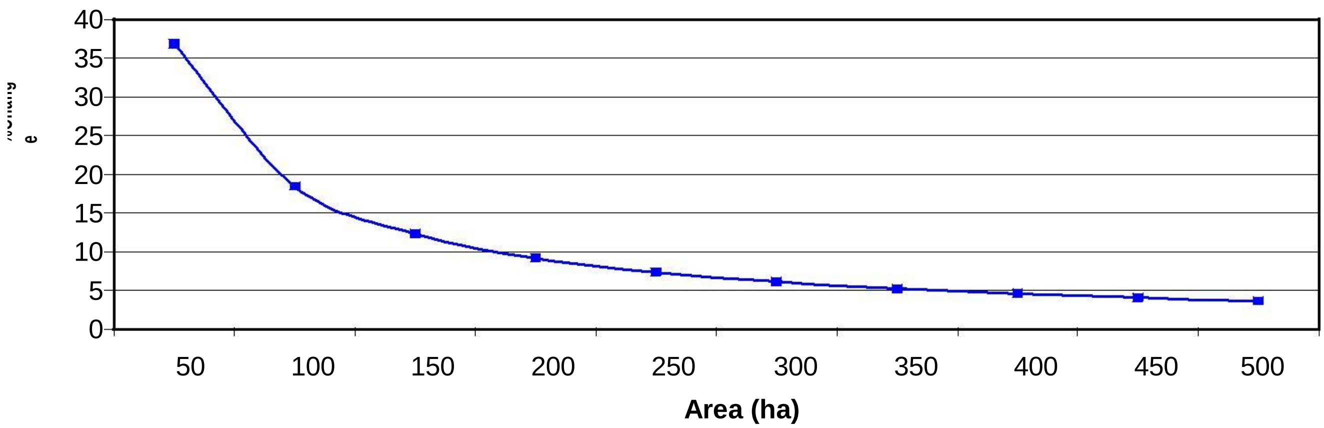

Figure 2. Decrease (%) in fertilizer application to cover the extra costs of PF.

Wheat yield is varying greatly between agricultural regions due to soil characteristics and micro climatic deviation. Therefore it will not be possible to apply PF in all relatively big farms in Turkey; possibly some part of the central Anatolia and East Anatolia will not have the potential.

The combined information related to wheat farming such as agricultural structure, must be used for the evaluation process of agricultural regions so that the map of PF potential in wheat farming will be demonstrated.

Statistical information about holding size according to agricultural regions and input-output prices will be used to draw a picture of PF application in wheat cultivation for Turkey. The study also should be applied to different industrial crop production such as corn, cotton.

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