Tarım Makinaları Bilimi Dergisi (Journal of Agricultural Machinery Science)
2010, 6 (2), 127 - 135

Application of Precision Farming in Turkey, Comparative Analysis of Wheat, Cotton and Corn Production

Mehmet Metin ÖZGÜVEN[1], Ufuk TÜRKER[2]
[1]Gaziosmanpaşa University Agricultural Faculty Department of Agricultural Machinery, Tokat
[2]Ankara University Agricultural Faculty Department of Agricultural Machinery, Ankara
mmozguven@gop.edu.tr

Received (Geliş Tarihi): 19.07.2010 Accepted (Kabul Tarihi): 17.08.2010

Abstract: The main objective of this study is to reveal the economic potential of the possible implication of precision farming for farmer and enterprises which may invest in those areas in Turkey. With this study, it was aimed that whether the application of precision farming in different field scala and farm input level is comparatively economical or not in wheat grown in Central Anatolia, cotton in Southern Anatolia and corn in Çukurova region by using partial budgeting method with examining the variable costs in 2008. The revenue obtained from yield and the minimum saving from fertilizer, pesticide and seeds were compared with precision farming initial costs in order to cover the investment cost together with economical field sizes. Moreover, depending on the variability on field, sensitive analysis was made in + % 5, + % 10, + % 20, + % 50 variable intervals. The following conclusions can be drawn from this study; the costs of precision farming can be covered by 16,41 % yield increase in wheat production in Central Anatolia, 3,96 % yield increase in cotton in Southern Anatolia, 4,01% yield increase for corn in Çukurova in combine systems for 100 ha field size in 2008.
Key words: Precision farming, variable rate application, site specific farming

Hassas Tarım Uygulamasıyla Türkiye'de Buğday, Pamuk ve Mısır Üretiminin Karşılaştırmalı İncelenmesi

Özet: Bu çalışmanın hedefi hassas tarım teknolojileri kullanımının getirebileceği ekonomik potansiyeli ülkemizde bu alanda yatırım yapacak işletmeler ve çiftçiler için ortaya koymaktır. Bu çalışmada; hassas tarım teknolojileri uygulamasının, 2008 yılında, değişik alan büyüklüğü ve girdi miktarları için maliyetleri kısmi bütçeleme metodu yardımıyla incelenerek İç Anadolu Bölgesinde buğday, Güneydoğu Anadolu'da pamuk ve Çukurova'da mısır bitkileri için karşılaştırmalı olarak ekonomik olup olmadığının belirlenmesi amaçlanmıştır. Buna yönelik minimum gübre, ilaç ve tohum kullanımıyla elde edilecek tasarruf ile verimden elde edilen gelir hassas tarım yatırım maliyetleriyle karşılaştırılarak ekonomik alan büyüklükleri ile birlikte ortaya konmuştur. Ayrıca, tarladaki değişkenliğe bağlı olarak + % 5, + % 10, + % 20, + % 50 değişkenlik aralığı içinde duyarlık analizi yapılmıştır. Kombine sistemde, 2008 yılı için 100 ha'lık alanda, İç Anadolu Bölgesinde buğday üretiminde % 16,41 'lik denge verim artışıyla, Güneydoğu Anadolu'da pamuk üretiminde % 3,96'lik denge verim artışıyla ve Çukurova'da mısır üretiminde % 4,01'lik denge verim artışıyla hassas tarım maliyetinin karşılanabileceği sonucu elde edilmiştir.
Anahtar Kelimeler: Hassas tarım, değişken oranlı uygulama, alana özgü işletmecilik

INTRODUCTION

Precision farming (PF) technologies, combining with control, electronics, computer and data base with the account data, present an advanced system approach. Using Global Positioning System (GPS), Geographic Information System (GIS), Variable Rate Application (VRA) and Remote Sensing (RS) Technologies, PF technologies, contrary to common fixed-level application methods which are applied at all same to whole land, use the variable-level application methods (based on application of fertilizer and chemicals to each section to its own needs, tillage at different levels, planting at different norms,

irrigation and drainage at different levels) determining land and plant characteristics of small sections (soil moisture, nutrient level of soil, soil structure, product requirements, yield, etc.). As a result, PF technologies are agricultural production and management methods whose targets are more economic and more environmentally sensitive production.

It has been a great progress in PF's technological development in the last 20 years. A pretty much and comprehensive data acquisition process has started, and at the end of the process data have been analysed. Finally management decisions have been made according to the results of these analyses. The economic analysis of PF depends on many factors. (Moss and Schmitz, 1999). They can be listed as follows:

- Production functions associated with specific functional forms and land types,
- Products and product prices,
- Distribution of soil types,
- Relative differences in soil productivity,
- The degree of accuracy with classification and VRA.
- Variability of natural events.

Stafford *et al.*, (1998) They have determined that herbicide application can be reduced 40-60% by using PF technologies. To improve the efficiency of drug injection, they have used monitors measuring the efficiency of spraying by using different spray nozzles. And they have developed suitable spray nozzles.

Güçdemir *et al.*, (2004) Their first application works on project basis by taking advantage of PF technologies in our country, They stated that in two different lands in Central Anatolia region, Up to %64 crop yields productivity variances were observed. They found different level of yield in the studied fields ranged from 1 ton ha^{-1} to 8 ton ha^{-1}, and also explained the reasons. Their study showed that the uniform practice in the fields with high yield variability means a waste caused by farmers without knowing in the field of pesticides and fertilizers.

In this study with the application of PF in Turkey, wheat, cotton and corn production will be analysed comparatively. The main objective is to reveal the economic potential of the possible application of precision farming technologies for farmer and enterprises which may invest those areas in Turkey. In PF applications, some devices are needed to determine the characteristics of the soil and terrain. Because of the high acquisition costs of these equipments at present, using of them could be economical only if they are used in profitable products and in large parcels. Before the application of PF systems that can be used, their prices were determined. As a result of the literature review, wheat, cotton and corn were determined as the most important agricultural products of Turkey. It was identified that most of the production areas of these products in Turkey are based in the Central Anatolia Region for wheat, the South eastern Anatolia Region for cotton and Çukurova Region for corn. In 2008, Production center regions having different field sizes and farm input levels for wheat, cotton and corn were analysed that the revenue obtained from the yield with minimum saving from fertilizer, pesticide and seeds were compared with precision farming initial costs in order to cover the investment together with economical field sizes. Moreover, depending on the variability on field, sensitivity analysis were made in + % 5, + % 10, + % 20, + % 50 variable intervals.

MATERIALS and METHODS

Materials

Some devices are necessary in PF applications to determine the soil and terrain features. For this purpose, RDS brand Ceres 8000 model unit is chosen as yield recording and monitor system in the study. This device can perform soil mapping, yield mapping, having DGPS capability and VRA operations. Through the use with GPS, it is recorded the yield of each unit area on the surface of the land. Thus, the yield map of the field was created. And an important step was taken to determine the factors affecting the yield. In the study, NH 134 (Trimble) receiver device was selected for the purpose of GPS.

Purchase price and cost of information "CI" of the equipments necessary to make these transactions, was taken from the RDS and Micotron companies. The Prices were overseas purchase prices of selected equipments. Besides, some various expenses like customs tax, VAT and shipping were to be paid when these tools and equipments purchased. Table 1 shows Extra equipments and costs for precision farming, Table 2 indicates Euro (€) exchange rate of 2008 and Table 3 shows Cost of information

Table 1. Extra price of precision farming equipment (€)

Extra equipments	Combined systems
Yield Recording and Monitoring system	5 000.-
VRA Equipment	9 000.-
Computers and Software	1 500.-
Service, Maintenance and other	1 500.-
Total Cost	17 000.-

From the Table 1, the cost of extra equipments with service and maintenance is € 17,000.

Table 2. € Exchange Rate of 2008 (http://www.tcmb.gov.tr, 2009)

Year	2008
(TL/€)	2,1408.-

Note: € rate of that year was the last business day of the day (31 December 2008) was taken as the purchase price.

Table 3. Cost of information (€)

Features	Cost of Information (€)
Total Area (ha)	100
Sampling Area (ha)	0,40
Number of Sampling	250
Sampling Cost (€ sample^{-1})	10.-
Total Test Cost (€)	2 500.-
Per unit area cost (€ ha^{-1})	25.-

An area of 0.40 hectares sampled in an enterprise with an area of 100 hectares, and this process costs € 2,500 as it can be seen in Table 3,

In this study, Input costs of the application for spraying, fertilizing and seeding were identified as necessary process for raising the selected three products by using the charts, indicating that the variable production inputs and costs of selected agricultural products, prepared by the Ministry of Agriculture, General Directorate of Agricultural Research, GAP Research Institute Directorate, Tarsus Research Institute of Directorship. To create materials for the study, data, for 2008, of yield, sales prices and production levels for wheat in the region of Ankara, for cotton in the region GAP and for corn in the region of Çukurova as in yield per hectare and unit prices are given in Table 4.

Table 4. Wheat grown in Central Anatolia, cotton in Southern Anatolia and corn in Çukurova region yield per hectar and unit price (Altun 2008, Çıkman 2008, Bilgili 2008)

2008	Yield (kg ha^{-1})	Sale price (TL kg^{-1})	Production value (TL ha^{-1})
Wheat	1850	0,47.-	869,50.-
Cotton	4500	0,80.-	3 600.-
Corn	9000	0,40.-	3 555.-

For the year 2008 in dry conditions for wheat in Ankara region, in wet conditions for cotton in the GAP region and the main crop corn in Çukurova region were taken, the cost of production and inputs are given in Table 5.

Table 5. Wheat grown in Central Anatolia, cotton in Southern Anatolia and corn in Çukurova region production inputs and costs (Altun 2008, Çıkman 2008, Bilgili 2008)

(TL ha^{-1})	Wheat	Cotton	Corn
Pesticide	30.-	68.-	135,3.-
Seed	156.-	30.-	314,6.-
Fertilizer	171,3.-	459,5.-	567,2.-
Total	357,3.-	557,5.-	1 187,1.-

In order to determine whether the application PF is economical or not, some assumptions had to be made. These assumptions are given below;

- At the farm, except for the HT components, the equipments used are in the same size,
- The minimum conditions are considered for determining the inputs,
- Input per unit area does not change up to 500 ha.

To determine the economic size of PF applications in the area of selected products, each costs were determined separately for 11 different fields ranged from 25 hectares to 500 hectares. Also, how much reduction of fertilizer, pesticide and seeds would it cover PF costs was also examined.

Methods

According to the results of the research literature on this subject, it was decided to do some basic calculations.

Extra equipment costs were calculated by adding depreciation and interest rates to the purchase price of tools and machines required for the application of PF Technologies. The following general formula and

methods were used for the calculations. (Kıral et al., 1999):

$$D = \frac{MV}{n} \quad (1)$$

$$I = \frac{MV}{2}.ri \quad (2)$$

In equations;

D: Depreciation value (TL year^{-1}),
MV: Machine value (purchase price) (TL),
n: Economic life (year),
I: Interest expense (TL),
ri: Interest rate (real interest) (%)

If capital values are taken by the end of the production period, using of real interest rates would be appropriate (Kıral *et al.,* 1999). Real interest rates are inflation free interest rates. Real interest rates (5%) are calculated by deducting the inflation rate (9%) from current market interest rate (14%). Moreover, the economic life was determined five years for PF equipments. (Sındır and Tekin, 2002).

Costs of Extra Equipment (CEE) which is one of the components of purchase price of the tools and equipments necessary for the application PF was calculated using the following equation:

$$CEE = \frac{MV}{Area} \quad (3)$$

In equation;

CEE: Cost of extra equipment (TL ha^{-1}),
MV: Machine value (purchase price) (TL).

Total test cost (TTC) was calculated using the following equation:

$$TTC = TSC.n_{ö} \quad (4)$$

In equation;

TTC: Total test cost (TL ha^{-1}),
TSC: Total sampling cost (TL sample^{-1}),
$n_{ö}$: Number of sampling (number).

Total Return Required Cost (TRRC) which consists of per unit of extra cost of application of PF was calculated using the following equation:

$$TRRC = TTC + CEE \quad (5)$$

In equation;

TRRC: Total return required cost (TLha^{-1}),
TTC: Total test cost (TL ha^{-1}),
CEE: Cost of extra equipment (TL ha^{-1}).

Equivalent Yield Increase (EYI) which is needed to offset extra cost in application of PF was calculated using the following equation. Each point which costs are met by increasing yields or profits started to taken is called the breakeven point. Each point on the table shows the break-even point.

$$EYI_{ar} = \frac{PV + TRRC_{am}}{PV} \quad (6)$$

In equation;

EYI: Equivalent Yield Increase (%),
TRRC: Total Return Required Cost (TL ha^{-1}),
PV: Production Value (TL ha^{-1}).

Extra costs needed to cover for PF with combined systems can be compensated by reduction of total costs of fertilizer, pesticide and seeds inputs. This earnings are called Equivalent Overall Cost Decrease (EOCD). And it is calculated with the following equality:

$$EOCD = \frac{TRRC}{FC + PC + SC} \quad (7)$$

In equation;

EOCD: Equivalent Overall Cost Decrease (%),
TRRC: Total Return Required Cost (TLha^{-1}),
FC: Fertilizer Costs (TL ha^{-1}),
PC: Pesticide Costs (TL ha^{-1}),
SC: Seed Costs (TL ha^{-1}).

The analysis that in application of PF Technologies how and which degree of the variability, within the range of the lower limit of + 5%, the upper limit of +50% and intermediate values at +10% and + 20%, depending on parameters effective on land efficiency, will effect the Equivalent Yield Increase is called Sensitivity Analysis. It is calculated with the following equality:

$$EYI_{5} = \frac{TRRC + (1{,}05 * PV)}{1{,}05 * PV} \quad (8)$$

$$EYI_{10} = \frac{TRRC + (1{,}10 * PV)}{1{,}10 * PV} \quad (9)$$

$$EYI_{20} = \frac{TRRC + (1{,}20 * PV)}{1{,}20 * PV} \quad (10)$$

$$EYI_{50} = \frac{TRRC + (1{,}50 * PV)}{1{,}50 * PV} \quad (11)$$

In equations;

EYI_5 : + 5% of the variability in the sensitivity analysis EYI (%),

EYI_{10}: +%10 of the variability in the sensitivity analysis EYI (%),

EYI_{20} : +%20 of the variability in the sensitivity analysis EYI (%),

EYI_{50}: +%50 of the variability in the sensitivity analysis EYI (%),

TRRC: Total Return Required Cost (TL ha^{-1}),

PV: Production value (TL ha^{-1}).

There are different stages of PF technologies used in agricultural production. These stages are dependent upon crop yield, soil properties and plant parameters which puts projections for variable input application. A cost of an investment of PF will occur according to these stages. Investment costs of PF Technologies vary depending on the tools intended to use and its characteristics. Both investment costs and economic benefits meeting these costs were determined by Partial Budgeting "PB" method. To determine profitability in PF, PB was applied per ha. PB only takes into account varying costs. There are three types of changes in PB:

1. Product substitution,
2. Change in investment without substitution
3. Factor substitution (Barnard and Nix, 1988).

Factor substitution is used mostly in cases which production techniques change. In this study, effects on PB through factor substitution were examined. Investment costs and extra revenues obtained by the use of these costs that were examined by PB method comparatively.

RESEARCH FINDINGS

The possibilities of economic use PF Technologies in production of wheat in Central Anatolia region, cotton in Southern Anatolia region and corn in Çukurova region were revealed in this study, the results of various calculations are given below.

Cost of Extra Equipment (CEE)

Cost of extra equipment in combined system for 100 hectares and cost of extra equipment in per hectare are given in Table 6.

Total Test Cost (TTC)

Results of Total Test Cost values obtained from the calculations are given in Table 7.

Total Return Required Cost (TRRC)

Obtained from the calculation utilizing from total test cost and extra costs for equipment, the total return required cost " TRRC " are given in Table 7.

Table 6. Extra Cost of Equipment (for a 100 ha)

Extra Equipments	Combined System	
	(€ $year^{-1}$)	(€$ha^{-1}year^{-1}$)
Yield Monitor	1 225.-	12,25.-
VRA Equipment	2 205.-	22,05.-
Computers and Software	367,5.-	3,675.-
Service, Maintenance and other	367,5.-	3,675.-
Total Cost	4 165.-	41,65.-

As it can be seen from Table 6, total cost of combined system is € 4,165. To calculate Extra equipment cost for combined system, this value is multiplied by 2008 € exchange rate and then divided by the field size starting from 25 ha to 500 ha. The results of calculations are given in Table 7.

CEE and TRRC per unit area decreases, while area size increases as seen in Table 7.

Table 7. Costs For Extra Investment for Precision Farming (TL ha^{-1})

Ha / 2008	25	50	100	150	200	250	300	350	400	450	500
TTC	53,52.-	53,52.-	53,52.-	53,52.-	53,52.-	53,52.-	53,52.-	53,52.-	53,52.-	53,52.-	53,52.-
CEE	356,66.-	178,33.-	89,16.-	59,45.-	44,57.-	35,67.-	29,71.-	25,48.-	22,29.-	19,82.-	17,83.-
TRRC	410,18.-	231,85.-	142,68.-	112,97.-	98,09.-	89,19.-	83,23.-	79,00.-	75,81.-	73,34.-	71,35.-

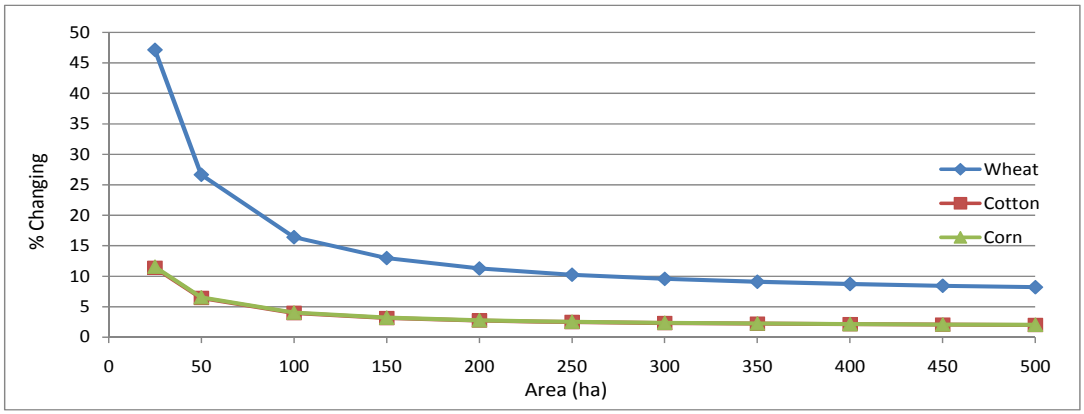

Figure 1. Equivalent Yield Increase for wheat grown, cotton and corn in combined systems

Equivalent Yield Increase (EYI)

For wheat, cotton and corn in the combined system, Equivalent Yield Increase values were obtained by adding TRRC values given in Table 7 to product values calculated by multiplication that year's yield in the region for the product by sales value which is given in Table 4, and then dividing the same yield by the product values. Changes in EYI values are shown in Figure 1.

As It is shown in Figure 1, in 2008, EYI values change between ranges for wheat 47.17% - 8.21%, for cotton 11.39% - 1,98%, for corn 11.54% - 2.01%.

Equivalent Overall Cost Decrease (EOCD)

EOCD values were obtained by dividing TRRC in combined system given in Table 7 by total costs of the related products given in Table 5 for wheat, cotton and corn. Equivalent overall cost decrease values are also given in Figure 2.

As It can be seen in Figure 2, EOCD values in 2008, changes respectively for wheat, cotton and corn between ranges of 114.80% - 19.97%, 73.57% - 12.80%, 34.55% - 6.01%.

Sensitive Analysis

This was calculated by dividing the values obtained from variability degree of +% 5, +% 10, +% 20, +% 50 in production values for wheat, cotton and corn, given in Table 4, by TRRC values as given in Table 7. Sensitivity analysis values SA (%) for wheat, cotton and corn in combined system were given in Figure 3, Figure 4 and Figure 5 respectively.

As It is shown in Figure 3, sensitivity analysis values for wheat grown in combined system in 2008, change in ranges from 31.45% to 5.47% for +% 50 variability.

In Figure 4, sensitivity analysis values for cotton grown in combined system in 2008, change in ranges from 7.60% to 1.32% for +% 50 variability.

As can be seen in Figure 5, sensitivity analysis values for corn grown in combined system in 2008, change in ranges from 7.69% to1.34% for +% 50 variability.

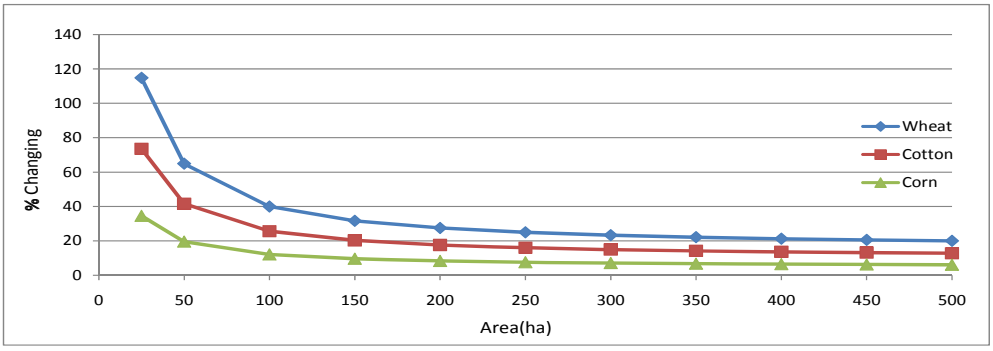

Figure 2. Equivalent Overall Cost Decrease for wheat, cotton and corn

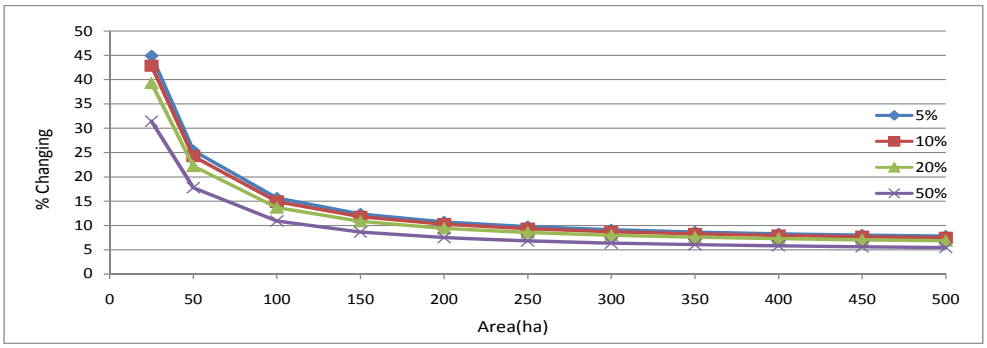

Figure 3. Sensitive Analysis (%) in 2008 for wheat grown in combined systems

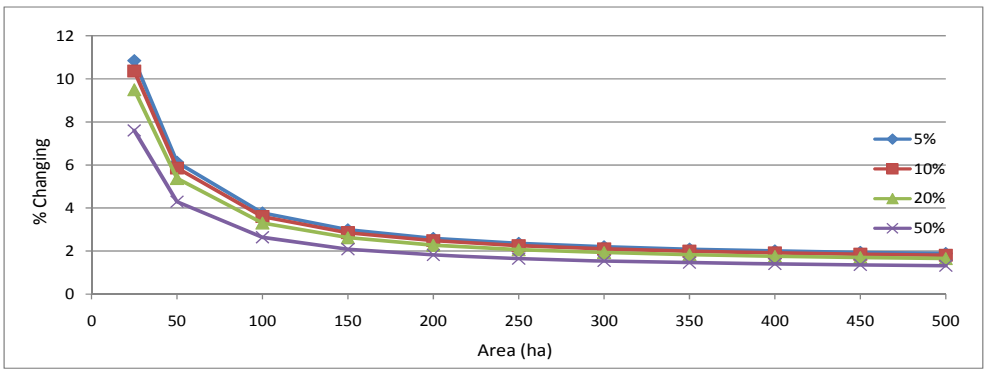

Figure 4. Sensitive Analysis (%) in 2008 for cotton grown in combined systems

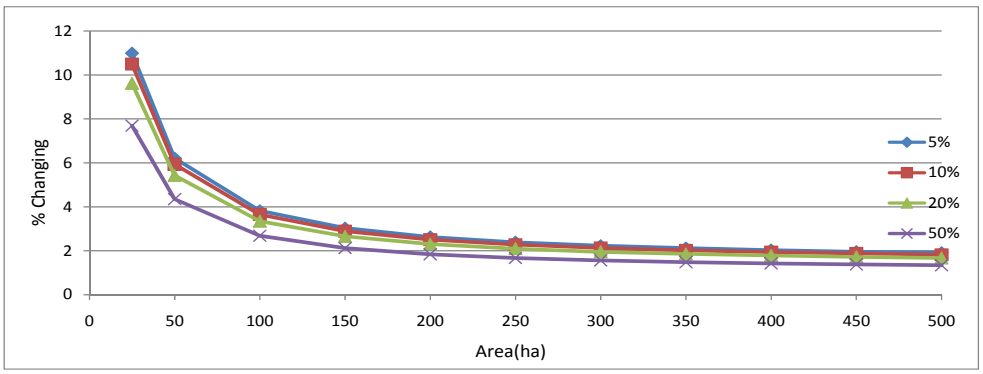

Figure 5. Sensitive Analysis (%) in 2008 for corn grown in combined systems

RESULTS and DISCUSSIONS

Arable farming areas in our country are coming to its limit. Studies to increase land productivity per unit area to meet increasing food demand are significantly needed. Renewal of production technologies in agricultural sector and especially the use of modern equipments such as PF are necessary.

It has always been a complaint about higher input costs in agricultural operations. And nothing still has changed on this debate. To bring the agricultural input applications to the more acceptable to economical level, PF Technologies should be used for profitable operations and productions especially in large parcels to have more efficiency. Therefore, farmers intend to apply the PF technologies, should select carefully both the size of land and which product to grow. It is possible that if not selected or applied correctly, profitability of production on the scale of operation may adversely be affected and unemployment rate in rural areas may increase. Besides, in order to achieve the expected benefits from PF, initially the problems irrigation, drainage, grading, etc in the field should be also solved. After these initials, variability in each land can be detected correctly and application of inputs may be done accordingly.

The necessary CEE to implement PF can be compensated with profitability provided by increased yields or reduced inputs. For example, the costs of combined systems can be covered by yield increase, in 250 ha field size, of 10.26 % wheat, 2.48 % cotton and 2.51% corn. Moreover, Equivalent Overall Cost Decrease for wheat, cotton and corn, respectively, in 25 ha field size, 114.80 %, 73.57 %, 34.55 %; in 250 ha field size 24.96 %, 16.00 %, 7.51 % and in 500 ha field size 19.97 %, 12.80 %, 6.01% respectively can cover the cost of PF. As it can be seen from these values, higher cotton prices during the transition to PF adaptation is a positive situation. High product price with increasing efficiency in production provides higher income. Looking at the cost of inputs on cotton, use of fertilizer seems to be higher than use of seeds and pesticide. The application of PF technologies in the corn production in Çukurova region would provide great benefits. Corn is a high-return product, because of its high yield. When variable inputs use was examined in the production of corn, inputs is being used unnecessarily too much in the production, and therefore seems to be costing very high. This was also verified in a study conducted by a group of researcher in Adana condition. The most important feature of PF technology is the cost decreasing effect of inputs and therefore the costs of equipments used in PF can be covered with site specific use of variable rate application. The application PF technologies in production of wheat in Central Anatolia region would be very useful especially with the presence of TİGEM connected to the enterprises. The region's conformity of PF adaptation is sufficient concerning harvesters, tractors and agricultural machinery.

There can be yield differences between the fields, even the sub-plots in the same field. Differences in yield can be arised from availability of soil fertility, pest density or inadequate grading. It can be concluded that increase in variability of the field raises the sensitivity of enterprises to Equivalent Yield Increase for the crops wheat, cotton and corn in combined system. In addition, It is observed that the most sensitive products are respectively cotton, wheat and corn against + 5%, +% 10 +% 20 and +% 50 changes. In an enterprise of 100 ha field size, in case of + 5 %, +% 10 +% 20 + 50 % variation respectively, in 2008 while Equivalent Yield Increase the value in combined system for wheat was % 16.41, the sensitivity analysis of Equivalent Yield Increase has declined respectively to % 15,63, 14.92%, 13.67 % and 10.94 % levels; While Equivalent Yield Increase value for cotton was 3.14 %, the sensitivity analysis for Equivalent Yield has declined respectively has 3.77 %, 3.60 %, 3. 30 % and 2.64 % levels; While Equivalent Yield Increase value for corn was 4.01%, the sensitivity analysis of Equivalent Yield Increase respectively has declined respectively to 3.82 %, 3.65 %, 3.34 % and 2.68 % levels. These calculations are very important for the investors who want to apply PF Technologies in their enterprises. If the investors know the variability of their farms, it would be useful to use the data obtained from calculations.

Like the "protection" concept, PF technologies that modern world takes advantage of in many fields, are very important technologies in today's world. Once trained personal problems resolved, It should be

attracted the attention of farmers of the country particularly through the demonstrative application to be held with TİGEM enterprises and leader farmers with large lands. After farmers to participate in this process and application areas should be expanded. In this wise, farmers' education, income levels and living standards will have been given the opportunity to be promoted. Especially, the most important element of implementation and application of PF by farmers would be insertion the tools, equipment and devices of PF in the scope of the incentives given by the Ministry of Agriculture. In this regard, it will encourage the entrepreneurs who will invest in this area.

REFERENCES

Altun, A., 2008. Ankara Yöresinde Kuru Koşullarda 2008 yılı Buğdayın Dekara Üretim Girdileri ve Maliyeti (Yayınlanmamış), T.C. Tarım ve Köyişleri Bakanlığı Tarımsal Araştırmalar Genel Müdürlüğü Toprak ve Su Kaynakları Ankara Araştırma Enstitüsü Müdürlüğü, Ankara.

Barnard, C.S. and Nix, J.S., 1988. Farm Planning and Control. 2nd Ed., Cambridge University Press. ISBN 0 521 29604 8, Cambridge, UK.

Bilgili, M.E., 2008. Çukurova Bölgesinde 2008 yılı Ana Ürün Mısırın Dekara Ortalama Üretim Girdi ve Maliyetleri (Yayınlanmamış). T.C. Tarım ve Köyişleri Bakanlığı Tarımsal Araştırmalar Genel Müdürlüğü Toprak ve Su Kaynakları Tarsus Araştırma Enstitüsü Müdürlüğü, Mersin.

Çıkman, A., 2008. Gap Bölgesinde 2008 yılı Pamuğun (Kanaletten) Dekara Üretim Girdi ve Maliyetleri (Yayınlanmamış), T.C. Tarım ve Köyişleri Bakanlığı Tarımsal Araştırmalar Genel Müdürlüğü Toprak ve Su Kaynakları Şanlıurfa Araştırma Enstitüsü Müdürlüğü, Şanlıurfa.

Güçdemir, İ., Türker, U., Karabulut, A. ve Arcak, Ç., 2004. Hassas Tarım Teknolojilerinin Türkiye'deki Uygulamaları. Toprak Gübre ve Su Kaynakları Araştırma Enstitüsü. Ankara.

Kıral, T., Kasnakoğlu, H., Tatlıdil, F., Fidan, H. ve Gündoğmuş, E., 1999. Tarımsal Ürünler İçin Maliyet Hesaplama Metodolojisi ve Veri Tabanı Rehberi. Tarımsal Ekonomi Araştırma Enstitüsü. Yayın No:37, Ankara.

Moss, C.B. and Schmitz, T.G., 1999. Investing in Precision Agriculture. Morrison School of Agribusiness and Resource Management Faculty Working Paper Series. Arizona State University Polytechnic Campus.

Sındır, K.O. ve Tekin, A.B., 2002. Economics of Variable Rate Fertilizer Application. International Scientific Conference, 04-06 April 2002, Rousse, Bulgaria.

Stafford, J.V., Lark, R.M. and Bolam, H.C., 1998. Using Yield Maps to Regionalize Fields into Potential Management Units. In Precision Agriculture: Proceedings of the 4th International Conference, Part A, St. Paul, MN, July 1998, pp. 225-237.

TCMB, 2009. Web sitesi. http://www.tcmb.gov.tr. Erişim: Ocak 2009.