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Technical and water use efficiency estimation of adopters and non-adopters of pressurized irrigation systems among hazelnut farmers

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Water demand is continuously increasing worldwide parallel with the growing population. Because agriculture is considered as a significant water consumption sector, water demand in this sector may be reduced by improving water use efficiency to make farming more irrigated and sustainable. This study was planned to estimate the technical and water use efficiency of hazelnut growers in Carsamba district of Samsun, Turkey. For this purpose, a sample of 350 farmers representing this district was drawn in advance. Hazelnut growers were identified from this sample, and they were contacted in Spring 2016 season to administer a questionnaire regarding their farming practices, particularly irrigation. Results of the study showed that only 27.70% hazelnut growers were irrigating their hazelnut orchards by a specific source of water (canal, reservoir, or groundwater). Among these farmers who used irrigation for hazelnuts only 13.40% adopted the pressurized irrigation systems, namely sprinkler or drip irrigation, and the remaining farmers were using the floating irrigation method. The adopters used lower quantity of water and received higher yields as compared to non-adopters. Similarly, they were 98% technically efficient, and their water use efficiency level was 78%. The same figures for non-adopters were 94 and 54%, respectively. It was concluded that both of the two groups were technically efficient, but hazelnut growers may focus on water saving by adopting the pressurized irrigation systems which reduce water wastage and enable the growers to use water sources efficiently.

Key words: Water use efficiency, technical efficiency, pressurized irrigation, sprinkler irrigation, drip irrigation, floating irrigation, hazelnut farming, data envelopment analysis (DEA).

INTRODUCTION

Feeding world population of more than 9 billion in 2050 is a consistent and colossal challenge, which puts extra pressure on limited and scarce natural resources of the world. The increase in world population, the desire of having high living standards, more luxurious life, and increased per capita income along with climate changes has intensified the use of fresh water resources (Wallace, 2000; Zhang et al., 2017; Falkenmark, 2000). Water resources are limited and scarce on the earth. Moreover, the ability of humans to add to existing water resources is also finite (Gleick, 2003; Guvercin and Boz, 2003).

Water scarcity is not only local but also a global issue

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and its use for agriculture are divided into livestock and irrigation categories. But globally, the water use for irrigation is much higher as compared to livestock (Alcamo et al., 2000). More than 80% of total freshwater is used for agriculture irrigation in the world (Condon et al., 2004). This level of consumption by agriculture irrigation in total freshwater use is unsustainable (Hamdy et al., 2003) due to increasing competition for the use of fresh water for other purposes (industrial and domestic needs) and general thinking is that the agriculture water use is wasteful (Postel, 2000). As the returns are much lower from agriculture, the use of fresh water should be reduced, in spite of increasing demand for food all over the world (Jury and Vaux, 2005). This could be possible by developing agri-environmental programs focusing on sustainable use of agricultural resources. One of the essential objectives of these programs is to extend the use of pressurized irrigation systems which enables farmers to economic use of irrigation water (Boz, 2016; Tatlidil et al., 2009). The efficient use of water is necessary all over the world especially in developing countries mainly due to two reasons. (1) The increase in world population will mostly continue in the next 25-30 years, which is a period to prepare against huge implications. (2) Most of this population increase will be in poor (third world) countries. Thus, the focus should be on the efficient use of existing scarce water resources.

Water use efficiency is a complex concept which is mostly misinterpreted and misunderstood not only by ordinary people but sometimes also by the scientific community (Lilienfeld and Amild, 2007). Water use efficiency is a vital as well as an informative measure for the evaluation of water-saving in irrigated crops (Kang et al., 2017; Kiziloglu et al., 2009). It is an economic term rather than an engineering concept based on input specific technical efficiency (Kaneko et al., 2004; Wang and Li, 2005). Technical efficiency of water is defined as total agriculture production per unit of water used and economic efficiency as the total value of production per unit of water volume used. On the other side, water application efficiency is a property of irrigation. The efficiency of each irrigation system is different. Water use efficiency varies from 75 to 95% in the drip irrigation system and from 70 to 90% in the sprinkler irrigation system. The floating method is seen as the least efficient system having an efficiency of 50 to 70% (Rogers et al., 1997).

Water demand is increasing with the rapid economic development in Turkey, but the inefficiency of water use is a significant obstacle in the development of agriculture as irrigation plays an important and vital role both in increasing and diversifying productivity to fulfill the food demand of the large population. Water use efficiency in Turkey is low mainly due to lack of coordination among employees as well as institutions, political interventions, lack of training of both farmers and employees, excessive use of improper irrigation and agriculture practices, salinity, alkalinity problems, use of polluted groundwater, illegal use of wells for irrigation, low water prices, higher evaporation from open water transfer channels, and seepage problems (Cakmak and Kendirli, 2002; Kanber, 2006; Cakmak, 2010). The use of water in agriculture in Turkey was 22.01 km^3 in 1990, and it is expected to increase more than three times to reach 71.5 km^3 in 2030 (Cakmak et al., 2007). This means Turkey can face severe water scarcity problems in the near future.

Currently, inefficient use of water is not only a common problem in Turkey but also all over the world. Although many studies have been conducted in developing countries (Haji, 2006; Chavas et al., 2005; Abay et al., 2004; Dhungana et al., 2004; Binam et al., 2003; Wadud and White, 2000; Ul-Haq et al., 2016b), they mostly focused on crops such as maize, wheat, sugarcane, coffee, and tobacco. Similarly, most of the studies that have been conducted in Turkey (Yazar et al., 2002; Onder et al., 2009; Bozkurt et al., 2006; Istanbulluoglu et al., 2002) also focused on field crops. Moreover, these studies have not focused clearly on water use efficiency of the pressurized irrigation system, particularly on hazelnut growers in Turkey. Turkey is the largest hazelnut producer in the world. A total of 740.141 ha of agricultural land is allocated to hazelnut cultivation which makes about 77% global hazelnut cultivation area. The average annual production in Turkey was 525 thousand tons in 2009-2014 period which was approximately 68% of total global hazelnut production.

In the same period Turkey’s total export of hazelnuts was 505 thousand tons, which was 72.2% of total global exports of hazelnuts. The average production is 92 Kg/decare (Chamber of Agricultural Engineers, 2016; Tuncer and Boz, 2017). Black Sea Region of Turkey has favorable climatic conditions for hazelnut production. Hazelnut is best grown in the regions where the annual average temperature is 13-16°C. Also, the lowest temperature in these regions does not fall below -8, -10°C and the highest temperature does not exceed 36-37°C. The total annual rainfall must be over 700 mm and the distribution of rain should be balanced over the year. Besides, the relative humidity in June and July should not fall below 60%. Hazelnut is not very selective regarding soil requirements, but it shows a good improvement in nutrient-rich, temperate-humus and deep soils (Tabıder, 2018).

Although Turkey has an enormous potential for hazelnut production and exports the government has difficulties in managing this sector. Due to periodicity in hazelnut farming, the level of output exceeds the normal amount in some years, accompanied by limited exports opportunities, causes low prices for consumers whose income largely depends on hazelnut production. The government tried to respond to these inconsistencies in 2000 by implementing an alternative crop production policy but this policy produced no positive results because of the alternative crops could not compete

Figure 1. Sprinkler irrigation.

Figure 2. Drip irrigation.

with hazelnut due to climatic conditions.

Hazelnut areas are also under the pressure of urbanization, industrialization, housing, and mainly rural tourism facilities in the Eastern Black Sea Region of Turkey. Therefore, the primary policy must focus on keeping hazelnut farms environmentally, economically and socially sustainable. For these reasons besides creating alternative consumption and exports opportunities, a sustainable hazelnut farming system is also required. One of the critical elements of reaching this system is to increase the productivity of hazelnuts applying advancing cultivation technologies one of which is assumed to be pressurized irrigation methods. Although irrigation among hazelnut farmers is not common in the research area, some farmers have started to irrigate hazelnuts using three different ways which are showed in Figures 1, 2, and 3.

The present study is planned to estimate the technical and water use efficiency levels of hazelnut growers irrigating their orchards by pressurized or floating irrigation systems. The specific objectives of this study were to determine socioeconomic characteristics of hazelnut growing farmers in Carsamba district of Samsun province, to determine technical and water use efficiency scores for the farmers who used pressured or floating irrigation methods and to develop recommendations for a higher water use efficiency in the region.

MATERIALS AND METHODS

Study area and sample size

The study area was limited to Carsamba district of Samsun province. To draw an accurate sample to represent the average

Figure 3. Floating irrigation.

farmer in the district, 13 villages were selected with the help of the agricultural extension service personnel of the district directorate of the Ministry of Food Agriculture and Livestock (MFAL). Selection criteria of the villages were their proximity to city center, agricultural potential, number of farmers, and socioeconomic characteristics of the village. The lists of farmers including their names and farm sizes were obtained in advance, and these made the accessible population of the study. Considering the frequency distribution of the farm size in the entire accessible population, three strata were created as farmers owning less than 15 decares, between 15 and 30 decares, and more than 30 decares of agricultural land. For an accurate sample size determination, the proposed stratified sampling formula by Yamane (2001) was used which is described below.

$$n = \frac{N \sum N_h S_h^2}{N^2 D^2 + \sum N_h S_h^2}, \quad D^2 = \frac{e^2}{t^2}$$

n = Sample size.
N = Number of farmers in the accessible population
N_h = Number of farmers in each single stratum
S_h= Standard deviation within each stratum
D^2= Expected variance
e = Accepted error from mean
t = Value of t corresponding the accepted confidence interval

Accepting an alpha level of 0.05 and working at 95% confidence interval (t = 1.645) a sample size of 350 farmers was drawn, and this was proportionally divided into three strata. Respondents from each stratum were randomly selected (Figure 4).

Technical and water use efficiency

Rodríguez-Díaz et al. (2004) described the global relationship between output and inputs as efficiency. A farm can be evaluated based on many types of efficiency emphasizing various conceptions such as technical, allocative and economic (Speelman et al., 2008). This study is limited to technical efficiency; additionally, it emphasized the water use efficiency (WUE) of the farmer. The basic concept elaborated by Farrel (1957) has been adopted for estimation of efficiency scores of farmers. According to this concept, the efficiency refers to the "ability of a farm to produce maximum possible output from a given bundle of inputs (Output oriented) or ability to use minimum possible amounts of inputs to produce given level of output (input oriented) (Coelli et al., 2002). The input-oriented efficiency estimation model was applied because of this study aim to use the resource more efficiently rather than increasing the output level. The technical efficiency further decomposed into pure technical efficiency (PTE) and scale efficiency (SE). PTE elaborates the ability of a manager or farmer to produce the maximum output at an optimal scale while SE explains the ability of manager or farmer to choose the optimal inputs amounts that will attain the expected output level (Kumar and Gulati, 2008; Ul-Haq et al., 2016b).

Kaneko et al. (2004) elucidated that the water use efficiency is "the irrigation water use efficiency is a crop specific physical measurement in relatively small agricultural fields of given irrigation technology, presuming level of management." Though, such measurement of water use efficiency considers the water as a resource in a secluded manner which states slightly about the causes of any observed differences among the farmers regarding water use (Xue-yuan, 2010). For example, the output per cubic meter does not allow considering the difference of non-water inputs among farmers (Coelli et al., 2002). Therefore, based on the input-oriented TE concept; the water use efficiency is economic rather than engineering meaning (Kaneko et al., 2004). Thus, water use efficiency is defined as "the ratio of the minimum feasible water use to the observed water use, conditional on production technology and observed levels of output and other inputs" (Xue-yuan, 2010). So that the water use efficiency explains the radial reduction of water use may be known as a nonracial measure of input specific to

Figure 4. Map of study area, The smaller map shows Turkey while the larger map shows all districts of Samsun province including the research area of Carsamba district.
Source: Turkiye Rehberi www. turkiye rehberi net.

TE. Such that water use efficiency describes the possible quantity of water could be saved without compromising the amounts of other inputs and output quantity produced.

Theoretical model of data envelopment analysis (DEA)

Parametric and non-parametric approaches of efficiency measurement are the two most frequently used approaches globally (Omezzine and Zaibet, 1998; Karagiannis et al., 2003; Dhehibi et al., 2007; Haq et al., 2017). In this study, a non-parametric approach such as DEA was applied due to some functional and theoretical benefits over parametric approach like the stochastic frontier approach (SFA). Lansink et al. (2002) described that sub vector input efficiency measurement via stochastic frontier approaches would be highly challenging. However, the DEA has some advantages over SFA in the econometric measurement of efficiency. Firstly, it is non-parametric that's why there is no need of presumptions regarding the functional form and inefficiency terms such as required in SFA. Further DEA allows construction of the best piecewise frontier based on the real input and output observation of a farm. This construction of surface or frontier over data permits the straightforward way to measure the efficiency gap that makes comparison easy of a farmer's behavior regarding the performance index relative to the best productive practices (Wadud and White, 2000; Malano et al., 2004;).

Technical efficiency model

As DEA provides the best-practice frontier based on the concept that a farmer using fewer inputs than other farmers to produce the same level of output can be considered as a more efficient farmer. The best practice frontier is assembled piecewise by solving ordered liner programming problems for each farm relatively to each other farm to this frontier.

$$\text{Minimize}_{\theta,\lambda}\ \theta$$

$$\text{Subject to;}$$

$$-y_i + Y\lambda \geq 0$$

$$\theta x_i - X\lambda \ \geq 0$$

$$\lambda \geq 0 \qquad (1)$$

If a farm (i) using K inputs and producing M outputs, the input and output matrix for the total N sampled farm will be K × N shows input matrix (X) and M × N represents output matrix (Y) in Equation 1. For the i^{th} farmer, the input vector and output vector represented as x_i and y_i respectively. The "θ" gives the TE score, and λ presents the N × 1 vector of weights that explains the linear combination of the peers of the i^{th} farmer. N1 is the vector of ones. We followed the suggestion of Charnes et al. (1978) and Banker et al. (1984) in developing the above DEA model. Equation 1 describes the constant return to scale (CRS) condition which assumes that the farm is operating at its optimal scale (Fraser and Cordina, 1999) and an increase in input level will increase the output level in the same proportion. In agriculture, the increase in amounts of inputs used by the farm manager does not result in a linear proportional increase in the amount of output obtained. Thus, the variable return to scale (VRS) looks more suitable for this study. The VRS situation was explained by adding the convexity constraint in Equation 2.

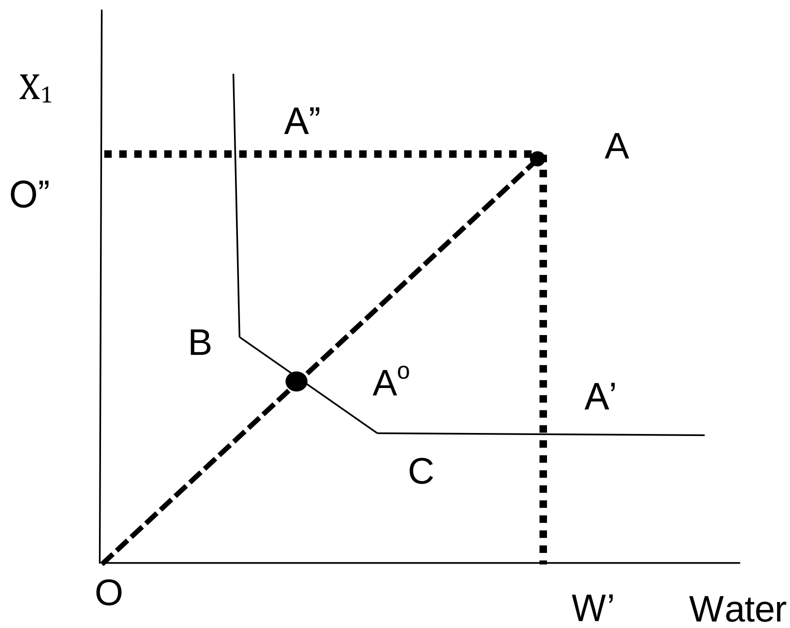

Figure 5. Technical and water use efficiency by DEA (Lansink et al., 2002; Frija et al., 2009).

Minimize $_{\theta,\lambda}$ θ

Subject to;

$$-y_i + Y\lambda \geq 0$$

$$\theta x_i - X\lambda \geq 0$$

$$N1'\lambda = 1$$

$$\lambda \geq 0 \quad (2)$$

Hence both specifications VRS and CRS will be modeled, and comparison of both situations is interesting because scale efficiency (SE) can be obtained under VRS condition. Also, a comparison of both scores is interesting because it provides information on SE. Coelli et al. (2002) present the relation between CRS and VRS conditions as follows.

$$SE = TE_{CRS}/TE_{VRS} \quad (3)$$

Equation 3 presents the SE is the ratio between the CRS TE score to VRS TE score.

Water use efficiency model

The water use efficiency (WUE) was estimated by adopting the proposed concept of sub-vector efficiency by Färe et al. (1994). Therefore, the WUE for the ith farm was measured by solving the following linear programming equation.

Minimize $_{\theta,\lambda}$ θ^k

Subject to;

$$-yi + Y\lambda \geq 0$$

$$\theta^k x_i^k - X^k\lambda$$

$$\theta^{n-k} x_i^{n-k} - X^{n-k}\lambda$$

$$N1'\lambda = 1$$

$$\lambda \geq 0 \quad (4)$$

Equation 4 explains the WUE (Sub-vector input efficiency) score as θ^k for the ith farm. In this equation, the constraint 2 and 3 is different from the earlier described TE model. Notations x_i^k and X^k includes the inputs except the kth input such as water amount. The third constraint explains that x_i^{n-k} and X^{n-k} have kth quantity used (Table 1).

Graphical explanation

Figure 5 shows the graphical presentation of technical efficiency (TE) and sub-vector input (water) efficiency using the DEA. It explains the interpretation of the model presented above. The inefficient farm named as "A" and then radially contraction performed over the input vector x_i as much as possible while remaining within the feasible input set. The inner boundary is piecewise linear frontier (isoquant) which is determined by

Table 1. Output and input variables used in the DEA analysis.

Variables	Units/Measures	Definition
Output		
Yield of Hazelnut	Kg/Decare	Hazelnut production per decare
Inputs		
Costs	Turkish Liras (TL) / Decare	Cost of producing one decare hazelnut
Water Quantity	Liter/Decare	Water quantity used to produce hazelnut per decare

combining frontier data points showing efficient farms in the sampled data. There are two inputs assumed being used by the farms named as X_1 and water. There are three farms A, B, and C. B and C lies on the best practice frontier while farm A is not on the frontier which explains that farm A is not efficiently using its inputs. The radial contraction in input vector x_i (water and X_1) projected the point A^o at the isoquant (frontier surface). This projected point explains the linear combination of observed points and constraint explained in Equation 2. It means the projected point is not outside the feasible set. The overall TE level of farm "A" can be measured by the ratio given below.

$$\theta = OA^o/OA \quad (5)$$

The θ is TE score of farm “A” which lies between 0 and 1. The value 1 means the efficient level of the farm and farm lies on the frontier while moving from 1 explains the inefficiency exists. The WUE of farm “A” could be emphasized using the scenario in which the water quantity can be reduced while the output and input X_1 remains constant. In this case, the A will be projected at A" such that the WUE is given as below.

$$\theta^k = O^{"}A^{"}/\,O^{"}A \quad (6)$$

The value of θ^k lies between 0 and 1. 1 shows the farm manager is the best performer and has no potential to reduce water use without reducing his farm output level. The value less than 1 indicates the existence of water use inefficiency and the farm manager has potential to reduce the water use while output and amount of other inputs remain unchanged. For example, the θ^k is 0.7 explains that the farm “A” could produce the same output level by using the 70% of the currently used level of water with a comparison of its benchmark which is constructed from the best practice frontier (isoquant) with similar characteristics. Such the farm “A” could save the water quantity by 30%.

RESULTS AND DISCUSSION

Use of irrigation and socioeconomic characteristics of hazelnut growers

Table 1 describes the farmers regarding their irrigation status and methods of irrigation used in their hazelnut orchards. From the table, it can be seen that the majority of farmers in the region (72%) used no irrigation for hazelnuts. The number of farmers who used irrigation with a specific source of water was 97 (27% of the sampled farmers). The reasons for farmers not using irrigation were also asked qualitatively, and most of them responded to this question focusing on the rainy climate of the region, lack of family members to deal with farming, and lack of financial support to apply irrigation.

The numbers of adopters and non-adopters of the pressurized irrigation system were also shown in Table 1. The main pressurized irrigation methods used for hazelnuts in the locality were drip and sprinkler irrigation methods, and these were adopted by only 13 (13.4%) farmers. The remaining 84 farmers (86.6%) used floating irrigation method. Considering the entire sample of 350 farmers, the adopters were only 3.7%, indicating that the adoption level of pressurized irrigation among hazelnut growers is very low. Those who applied floating irrigation were 24% of the entire sample. Farmers stressed that although the region is quite rainy, the temperature and sunny days period may extend particularly between June and August, and this makes irrigation very useful for hazelnut production.

Comparisons of socioeconomic characteristics of hazelnut farmers based on their irrigation methods are shown in Table 2. Since there were three categories of the dependent variable (pressurized irrigation, floating irrigation, and no irrigation), and all of the explanatory variables collected on a continuous basis, one-way analysis of variance was selected to achieve objective 1. The explanatory variables were the age of farmer, schooling years, farming experience, number of family labor, farm size, hazelnut area, yield per decare, and production costs per ton of yield. Results of the one-way analysis of variance showed that out of the nine selected socioeconomic characteristics two were statistically significant at 0.05 Alpha level. These were schooling years and number of parcels (Table 2). The LSD multiple comparison tests were also conducted to find out the specific differences among the three groups and the results revealed that those who adopted pressurized irrigation system had a significantly higher number of schooling years than those who used floating irrigation and no irrigation groups. On the other hand, those who adopted pressurized irrigation systems had less number of parcels in comparison with floating irrigation and no irrigation groups.

Highly educated people are more likely to observe,

Table 2. Frequency distribution of sampled farmers according to irrigation use.

Variable	Frequency	Percent
Irrigation status		
No irrigation	253.00	72.30
Irrigation	97.00	27.70
TOTAL	350.00	100.00
Adoption status of pressurized irrigation systems		
Adopters	13.00	13.40
Nonadopters	84.00	86.60
TOTAL	97.00	100.00

Table 3. Comparison of socioeconomic characteristics of hazelnut farmers on their irrigation methods.

Name of variable	Pressurized ırrigation (PI)	Floating ırrigation (FI)	No ırrigation (NI)	F	P
Age of farmer	52.92(14.81)*	51.70(10.17)	53.75(11.47)	1.034	0.357
Schooling years*	8.77(5.64)	6.33(3.12)	6.57(3.17)	3.115	0.046
Farming experience (years)	32.54(15.28)	30.65(11.18)	32.32(11.43)	0.674	0.511
Family labor (number)	3.08(1.75)	3.60(1.92)	3.60(1.65)	0.565	0.569
Farm size (decare)	28.37(26.19)	35.13(34.19)	32.94(38.53)	0.229	0.796
Hazelnut area (decare)	18.83(9.27)	24.14(15.09)	23.53(20.36)	0.442	0.643
Yield per decare (Kg/ decare)	164.6(42.12)	156.3(56.4)	148.8(66.34)	0.204	0.816
Total costs per 1 ton of yield (TL)	815.36(166.47)	822.08(179.16)	816.95(203.59)	0.674	0.978
Number of parcels*	1.77(0.59)	5.33(4.73)	5.49(5.55)	3.245	0.040

*Standard Deviations in () bracelets.
*Mean differences among schooling years: PI - FI = 2.20, PI - NI = 2.46
*Mean differences among parcel numbers: PI – FI = -3.56, PI – NI = -3.97.

interpret, and adopt new technologies and information (Abdulai and Eberlin, 2001). Concerning agricultural innovations, Rogers (2010) investigated many studies around the world and stated the generalization that early adopters of innovations have a higher level of education in comparison with late adopters. Schooling years of the adopters in the present study were significantly higher than non-adopters while the average schooling years of farmers were almost six years which describes the hazelnut growers as primary school graduates. In many earlier studies, education level was found as a significant variable affecting farmer' decision to adopt different innovations in agriculture. Among these studies are the adoption of maize cultivation among the farmers operating in Kahramanmaras province (Boz and Akbay, 2005), adoption of newly improving cotton seeds by the farmers of Eastern Mediterranean Region (Boz and Kaynak, 2015), and adoption of innovations by dairy farm operation in Eregli district of Konya province (Yener, 2013) of Turkey.

Land division and fragmentation makes it difficult to apply many technologies at a farm level. Pressurized irrigation systems are among these technologies which can be more economically applied in regularly shaped and larger land parcels. If drip or sprinkler irrigation has to be used in smaller land parcels which are not suitable to unify by land consolidation, both of the first investment costs and later on production costs will probably be higher. Thus farmers having larger and regularly shaped parcels have a higher tendency of adopting these systems. Research finding regarding this variable showed that farmers who adopted pressurized irrigation had less number of parcels in comparison with the farmers who applied floating irrigation and no irrigation. While enabling farmers to reduce first investment and production costs, these systems will also reduce water consumption and make contributions to the sustainable use of water sources.

Farm structure and efficiency scores of the sampled farmers

The TE, PTE, SC, and WUE scores of the adopters and non-adopters of pressurized irrigation system for hazelnut production in the research area were calculated and

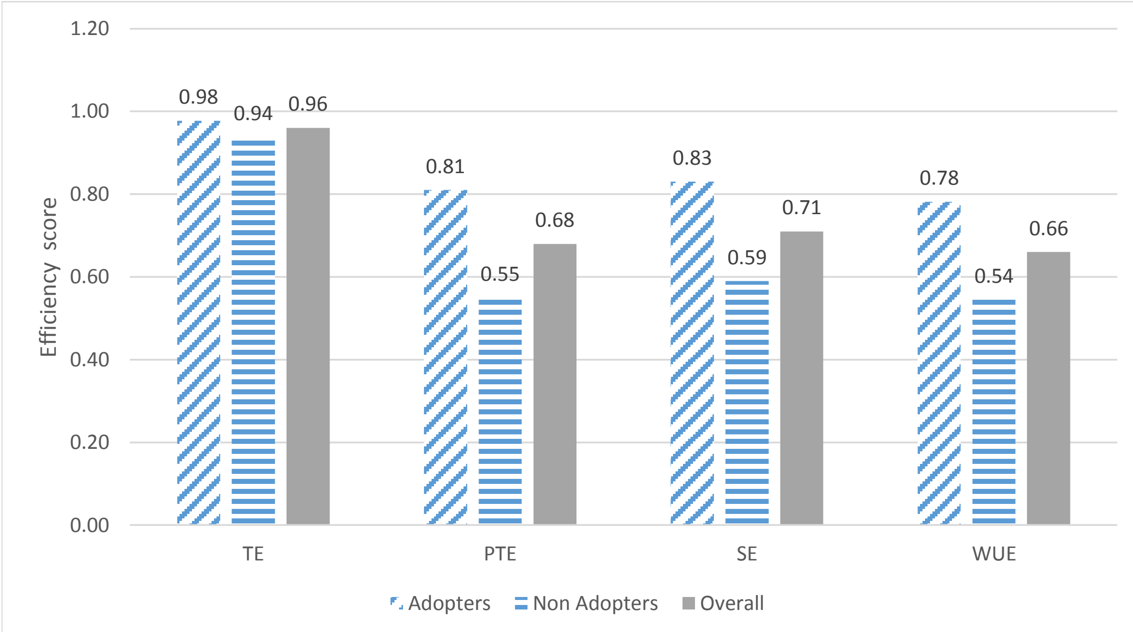

Figure 6. Efficiency scores of the adopters and non adopters.

presented in Figure 6. The overall TE score was calculated as 0.98 for the adopters, 0.94 for nonadopters, and 0.96 for both groups. These figures indicate that hazelnut farmers who used any method of irrigation in the locality are assumed to be technically efficient regardless of their adoption status of pressurized irrigation systems. To be entirely technically efficient the adopters and nonadopters still can reduce their inputs by 2 and 6%, respectively, without compromising their hazelnut yield.

The WUE of the adopters was significantly higher than the nonadopters. The average WUE score of adopters was 0.78 which is interpreted as the possibility of saving the water by 22% without compromising their crop yield. Similarly, the non-adopters' WUE score was 0.54 which implied that these farmers were wasting almost 46% water quantity by using floating irrigation. This finding indicates that pressurized irrigation system among hazelnut farmers increase the WUE. Previous work (Lamm, 2002; Yohannes and Tadesse, 1998) also reported the pressurized irrigation systems, particularly the drip irrigation as a more efficient method in comparison with floating irrigation. The average WUE score of all farmers was 0.66 which shows that hazelnut growers irrigating their orchards with a specific source of water could save water by 34% while getting the same level of hazelnut yield and with the same level of other inputs.

Conclusions

Research findings indicate that hazelnut farmers in the locality have a low tendency of adopting irrigation. Only 27.70% hazelnut farmers were irrigating their orchards with a specific source of water (groundwater, canal, and reservoir). Moreover, adoption of pressurized irrigation systems enable farmers to obtain high yield and provide economically use of water resources. Among the 27.70% of hazelnut growers who used irrigation, only 13.40% adopted pressured irrigation systems like drip or sprinkler irrigation, and the remaining were using floating irrigation. Although there was a general belief that due to profoundly rainy climate in the region no irrigation is required for hazelnuts, many farmers stressed the benefits of irrigation, particularly in July and August. However, adoption of irrigation, particularly pressurized irrigation systems requires investments which are not affordable by many farmers unless governmental subsidies or long-term low-interest loans. On the other hand, a general reluctance among farmers towards farming activities was observed during the data collection process.

Results of the study showed that the adopters of the pressurizedirrigation systems were highly efficient not only in the technical use of inputs but also in water use. Regarding TE the adopters and non-adopters were efficient by 98 and 94%, respectively. A more substantial difference between these two groups was calculated regarding their WUE which was 0.78 for adopters, and 0.54 for nonadopters. This meant the adopters used lower water quantity and obtained higher yield in comparison with non-adopters. The adopters could save their water by 22% without experiencing any change in yield of crop and other inputs level. Similarly, non-adopters could save 46% water. Farmers received water from different sources such as irrigation canals constructed by the State Hydraulic Works, underground water, and water reservoirs. Irrigation associations are functional in the region trying to deliver water to farmers and helping to solve their problems with irrigation. To increase the number of hazelnut farmers who adopt pressurized irrigation systems, these associations should be more functional and definitely should employ agricultural engineers, and irrigation experts.

The lower PTE scores mean that the managerial performance to organize inputs in the hazelnut production process is also lower. Since pure technical efficiency is closely related to the managerial performance of farm operations, training programs and extension services may increase the hazelnut growers' knowledge to manage input use properly. District Directorate of the Ministry of Food Agriculture and Livestock, irrigation associations, and farmers organizations may conduct joint work to achieve this objective.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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