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Analysis of changes in grain production on fruit and vegetable cultivation areas in Turkey through geographically weighted regression

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The main purpose of this paper is to address the question of whether and how farmers have tried to increase agricultural productivity after the regulatory role of governments on the agricultural industry has been reduced due to financial crises. The relationship between agricultural sowing area shifts (grain to fruit, grain to vegetables, vegetables to fruit) were explored by using geographically weighted regression model. This model showed how the decrease of grain sowing areas led to an increase of fruit and vegetable sowing area in Turkey. It was demonstrated that farmers tended to choose more productive agricultural crops in order to address agricultural sustainability problems. Geographical information system data sets regarding the years between 2000 and 2010 were obtained from 923 districts. The results of the analysis showed a strong relationship between changes in grain, vegetable and fruit areas. According to geographically weighted regression, the variation of local coefficients ranged from - 0.62 to 0.34. Because of the productivity factors, grain and vegetable areas have been replaced by fruit production. However, Turkey will be faced with food security problems in the future due to the decrease of grain cultivation. The increasing opportunity for irrigation has had a profoundly important role in shifting from grain to vegetable and fruit production.

Key words: Geographically weighted regression, geographical information system, sustainable agriculture, farm policy, food security.

INTRODUCTION

Statist policies have been replaced by liberal agricultural and trade policies in Turkey after 1980 (Ediger and Huvaz, 2006; Özmucur, 2007; Hasanov et al., 2010; Türkekul and Unakıtan, 2011). The agricultural support policy, which underpinned agricultural policies in Turkey during the planned period between 1960 and 1980, consisted of three main headings: The government's purchase of farmers' products for a base price above the market price; the availability of state subsidies for agricultural inputs such as fertilizer, pesticide and seed; and privileged loan interest rates for farmers (Önal, 2007). After the introduction of liberal policies, the

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Abbreviations: GWR; Geographically weighted regression, **GIS;** geographical information system, **OLS;** ordinary least squares.

Table 1. Agricultural planted areas and changes between 2000 and 2010.

Agricultural planted area (decare)	2000	2010	Percent of change
Total Agricultural	263.790.670	243.942.052	-7.52
Grain planted	180.377.820	163.303.020	-9.47
Vegetables planted	9.043.770	8.015.980	-11.36
Fruit planted	26.109.420	30.105.797	1531

regulatory role of the state on prices was left to the market's own operation (Kepenek and Yentürk, 2000).

In the post-1980 period, Turkey frequently experienced economic crises followed by decreases in agricultural supports. Within six years following the financial crisis in 1994, institutions operating in main areas that contributed to the regulation of products such as milk, forage, meat, fish, forest products, tractors and fertilizer were privatized (Önal, 2007). Significant structural transformations were also experienced following the financial crisis in 2001. The most important agricultural change experienced in this period was the initiation of membership negotiations with the European Union (EU). Thus, in Turkish agriculture, a process of comprehensive transformation that included legislative activities aimed at adjusting with the EU Common Agricultural Policies began. After the agricultural reform in 2001, employment in agriculture declined, the share of agriculture in Gross Domestic Product became smaller, internal migration increased as small farmers withdrew from agriculture, and employment opportunities could not be offered to these newcomers with low educational levels in cities (BSB, 2008).

Agricultural production has decreased because of the radical transformations in agriculture in the post-1980 period. The state regulations in favor of farmers in important areas such as meat, fish, forage, seed, fertilizer and tractors has diminished rapidly (Önal, 2007). Important changes have also been observed in the structure of agricultural ownership after the 2001 crisis. While the share of those with an enterprise size of more than 10 ha was 34% in 2001, it rose to 65.7% in 2006 (TUIK, 2008). This increase shows that traditional family enterprises have been increasingly vanishing, leaving mainly large enterprises. Further, agricultural crop type has been influenced by this transformation in order to increase productivity. Table 1 demonstrates that in agrıcultural sowing areas there have been some notable changes; while total fruit areas rose, grain and vegetables areas decreased (TUIK, 2011).

Agricultural production is unevenly distributed in Turkey. Farmers living in the coast of Aegean and Mediterranean who have higher income levels concentrated on fruit production. Farmers living in the Southeastern Anatolia who have irrigation opportunities concentrated grain, vegetable and fruit production, since these regions have lower income levels compared to rest of the regions. Large scale irrigation projects change not only agriculture production, but also income structure (Eraydın, 1992). With regard to agricultural production, any location is linked to the rest of the world through three broad channels; production, trade and climate. That is why agricultural production should be handled in a multifaceted manner. Many studies have tried to answer the question of which factors affect agricultural production and productivity. For example, fertilizer usage (Marinoa et al., 2011; Shengli et al., 2012) efficient irrigation area, (Yujian et al., 2013; Guang-Cheng et al., 2014) drought (Keating and Meinke, 1988; Venuprasad et al., 2008; Chris and Budde, 2009; Ananda et al., 2011; Jana et al., 2013) affects grain production. The main purpose of this paper is to address the question of whether and how productivity plays role in the agricultural production of grains, vegetables and fruits.

METHODOLOGY

The data between the years 2000 and 2010 was obtained from the Turkish Statistical Institute; 923 districts were used for geographically weighted regression analyses. Districts were taken as the units of analysis. Regions are shown in Figure 1. The year 2000 was selected as the starting point in this research due to the financial crisis, after which striking differences have been observed in spatial organization. ArcGIS was employed as the geographical information system (GIS) program in the analyses. Grain, fruit and vegetables crop variables consist of the total sowing areas (decare) in districts. It was investigated in this study if decreasing of grain crop has a spatial distribution effect or if it contributes to fruit crop and vegetables crop because of the productivity. In this study, in order to explain spatial variability in agricultural production across Turkey, GWR was used instead of OLS.

GWR extends the global regression ordinary least squares (OLS). For each location, regression coefficient can be estimated by using a GWR model (Fotheringham et al., 1996, 2002). GWR method allows for analyzing the spatial variability of the local coefficients of independent variable or variables. Geographically weighted regression is a powerful tool to explain the spatial heterogeneity. OLS creates a regression coefficient which assumes that the relationship between the variables are constant across regions. The OLS can be written as:

$$y = \beta_0 + \sum_{i=1}^{k} \beta_i x_i + \varepsilon \tag{1}$$

Where y is a dependent variable, xi are exploratory variables; k is the number of independent variables; β_1 and β_0 represent and coefficient and intercept respectively; and ε is the error term.

As a local regression technique, GWR is an extension of global regression technique (Fotheringham et al., 2002). GWR assumes that relationships between the change in grain, vegetable and fruit area may vary over space. It can be formulated as:

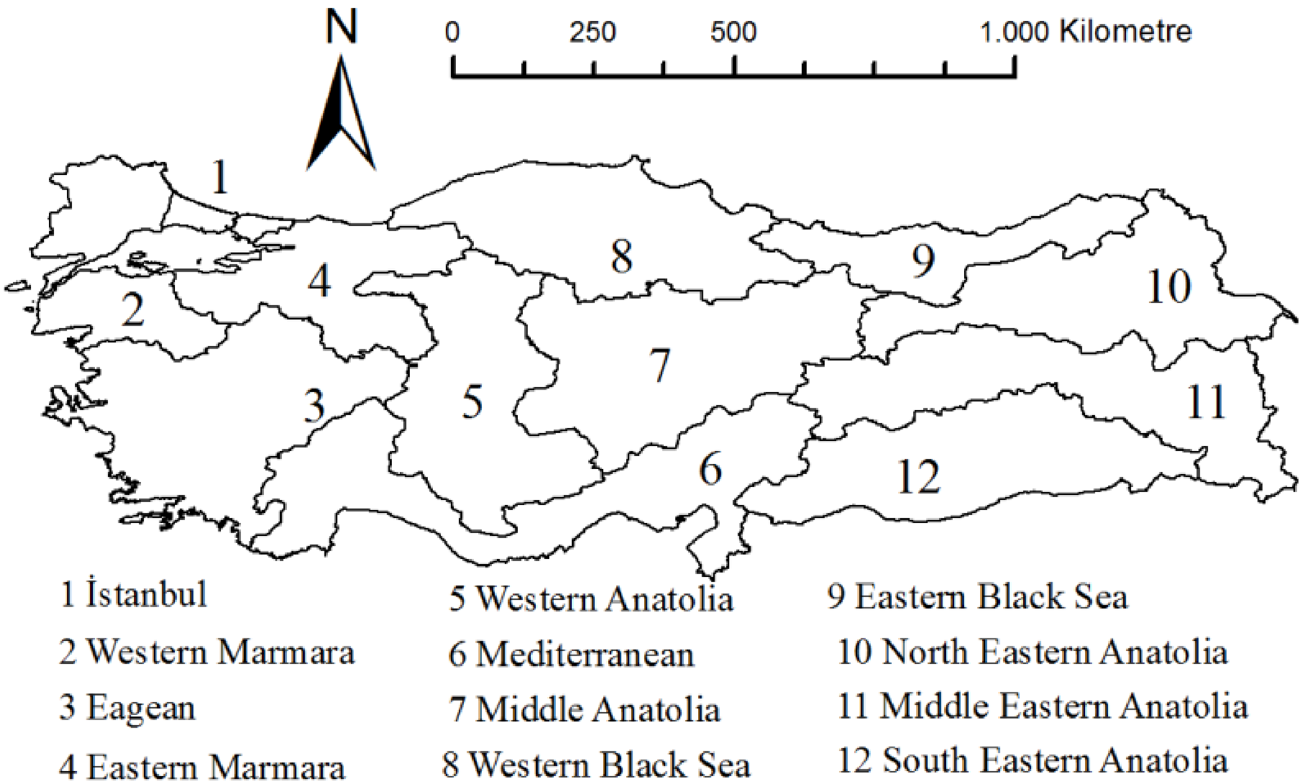

Figure 1. Map of Turkey's regions.

$$y_i = \beta_0\left(u_j, \mathrm{v}_i\right) + \sum_{i=1}^{k} \beta_i\left(u_j, \mathrm{v}_i\right) x_{ij} + \varepsilon_j \quad (2)$$

where u_j and v_j denote the spatial positions of location j; β_0 (u_j,v_j) is the intercept for location j; $\beta_{ik}(u_j,v_j)$ is the local estimated coefficient for the exploratory variable; x_k at point i, and $\varepsilon_j$is the random error term at location i.

In case of spatial heterogeneity, local model performance is better than that of the global model. Even if there is a significant relationship between the dependent and independent variable, the result of the global model would be insignificant since there is a positive or negative relation in different regions. In other words, spatially heterogeneous structure can be represented by just one coefficient by a global model, whereas a local model estimates a set of parameters containing independent variable or variables for each spatial unit. During the past five years a considerable amount of literature has been published on GWR in a variety of fields: the regional spillover effect (Rasekhi et al., 2013), land use and water quality (Tu, 2011), agriculture (Su et al., 2012), cancer risks (Gilbert and Chakraborty, 2011), traffic levels (Selby and Kockelman, 2013), migration (Lehtonen and Tykkyläinen, 2010) and grain production (Yang et al., 2013).

RESULTS

This study is based on the assumption that as long as total agricultural sowing area remains almost constant, when either grain or vegetable sowing areas decrease and fruit area increases in the same district, it can be said that grain or vegetable area are replaced by fruit area.

The maps in Figure 2 were created so that the remarkable difference between 2000 and 2010 in terms of change of grain, fruit and vegetable sowing areas can be seen. Figure 2 also demonstrates the wide range of agricultural sowing areas between districts. Figure 2a shows that grain areas were concentrated in the Middle Anatolia (Figure 1 no: 7) and South Eastern Anatoliain 2000 in Turkey. It can be seen that grain production in Middle Anatolia is dramatically losing its importance. The other important change is that grain area rose in Southeastern Anatolia and Eastern Anatolia (Figure 1 no: 10-11), while it was declining sharply in Middle Anatolia. The grain area decrease in Middle Anatolia will have dramatically effects on Turkey’s agricultural production.

The distribution of fruit areas at the coast is more dense than at the center of the Turkey (Figure 2c and f). Fruit areas were concentrated in the Aegean (Figure 1 no:3), western part of Southeastern Anatolia, Eastern part of the Mediterranean (Figure 1 no: 6), the Black Sea (Figure 1 no: 8-9) coast and the Eastern part of Marmara (4). Vegetable area is widespread in the Aegean, Mediterranean, western part of Southeastern Anatolia and Western Anatolia (Figure 2b and e). The increase in fruit area from 2000 to 2010 across Turkey in contrast to grain area is profoundly important for Turkey’s agricultural production process because in fruit is more productive than grain. On the other hand, grain plays a crucial role in food security.

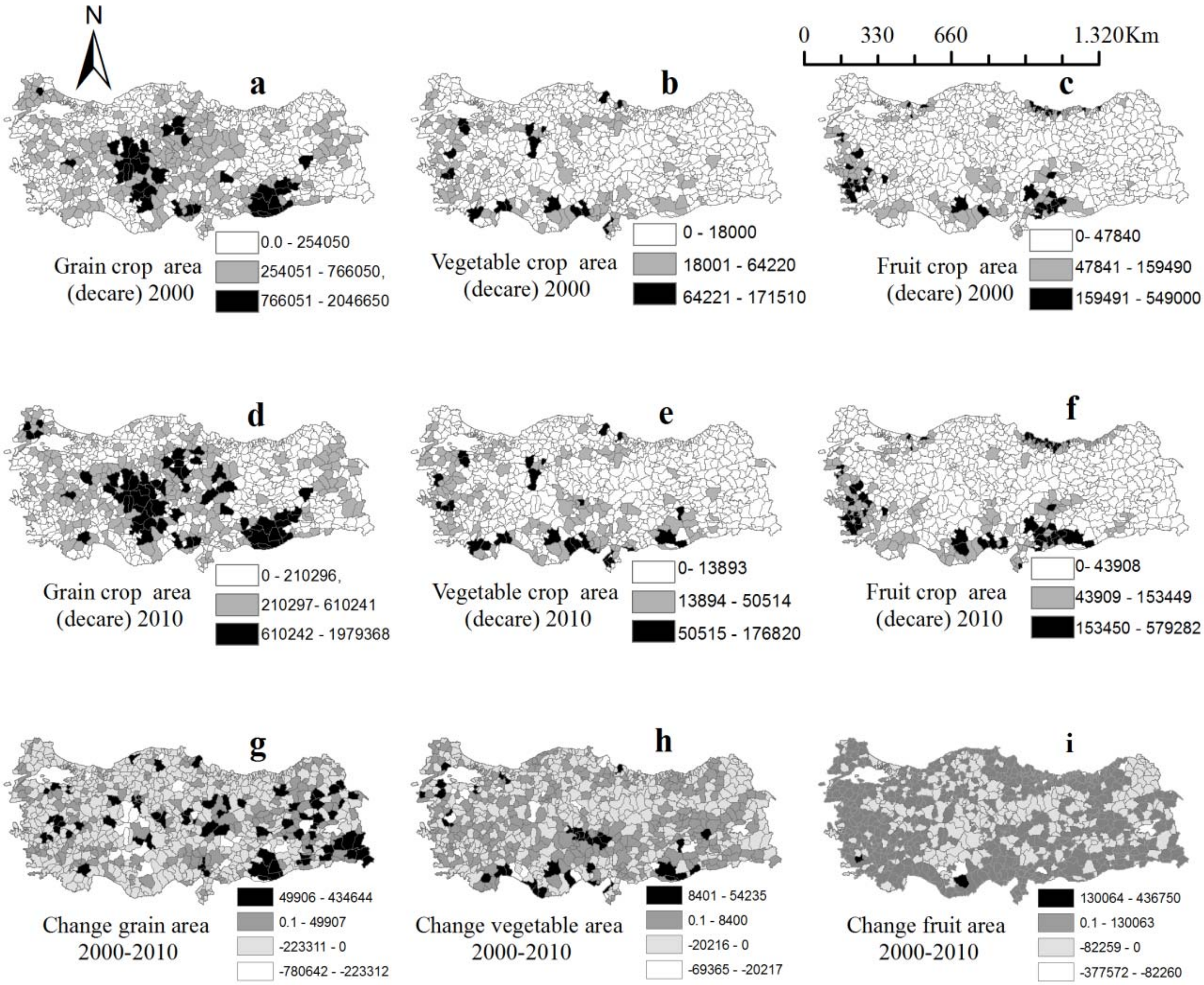

Figure 2. Spatial mapping of grain, fruit and vegetable areas between 2000 and 2010 in Turkey.

Figure 2 can be briefly summarized such that after 2000 among the Turkish agricultural crop types, many transitions such as from grain to fruit production have occurred. In this study, how grain areas are replaced by fruit and vegetable areas is explained by using spatial econometric model. As seen in Figure 2, there are so many spatial transitions from one crop type to another that it can be very difficult to see without using spatial econometric model.

GWR model, which estimates a set of parameters of independent variable for each districts was used to characterize transitions from either grain or vegetable to fruit sowing areas. Local model GWR was performed to determine whether there was a significant spatial non-stationary relationship between the change in grain and fruit area variables over the period. GWR presented better solutions than OLS (Table 2). The AIC results from the GWR model were lower than those from the OLS model, which suggests that the GWR model was a better fit than OLS (Fotheringham et al., 2002; Tuand and Xia, 2008).

The considerable spatial variability in grain, vegetable and fruit sowing area indicates that there is a significant spatial non-stationary relationship between dependent and independent variables. Spatial non-stationery means that the relationship between independent and dependent variables are not constant over space (Fotheringham et al., 2002). The fact that the variation of local coefficients ranges from negative to positive indicates that the relationship between independent and dependent variables is non-stationary. At the same time, the variation of local R-squared, which explains different

Table 2. Model performance as judged by AIC_{GWR} and AIC_{OLS}.

Dependent variable	Independent variable	AIC_{GWR}		AIC_{GWR}	
Fruit	Grain	AIC_{GWR}	21543,9	AIC_{OLS}	21554
Vegetable	Grain	AIC_{GWR}	18824,1	AIC_{OLS}	19036
Vegetable	Fruit	AIC_{GWR}	18898,4	AIC_{OLS}	19045

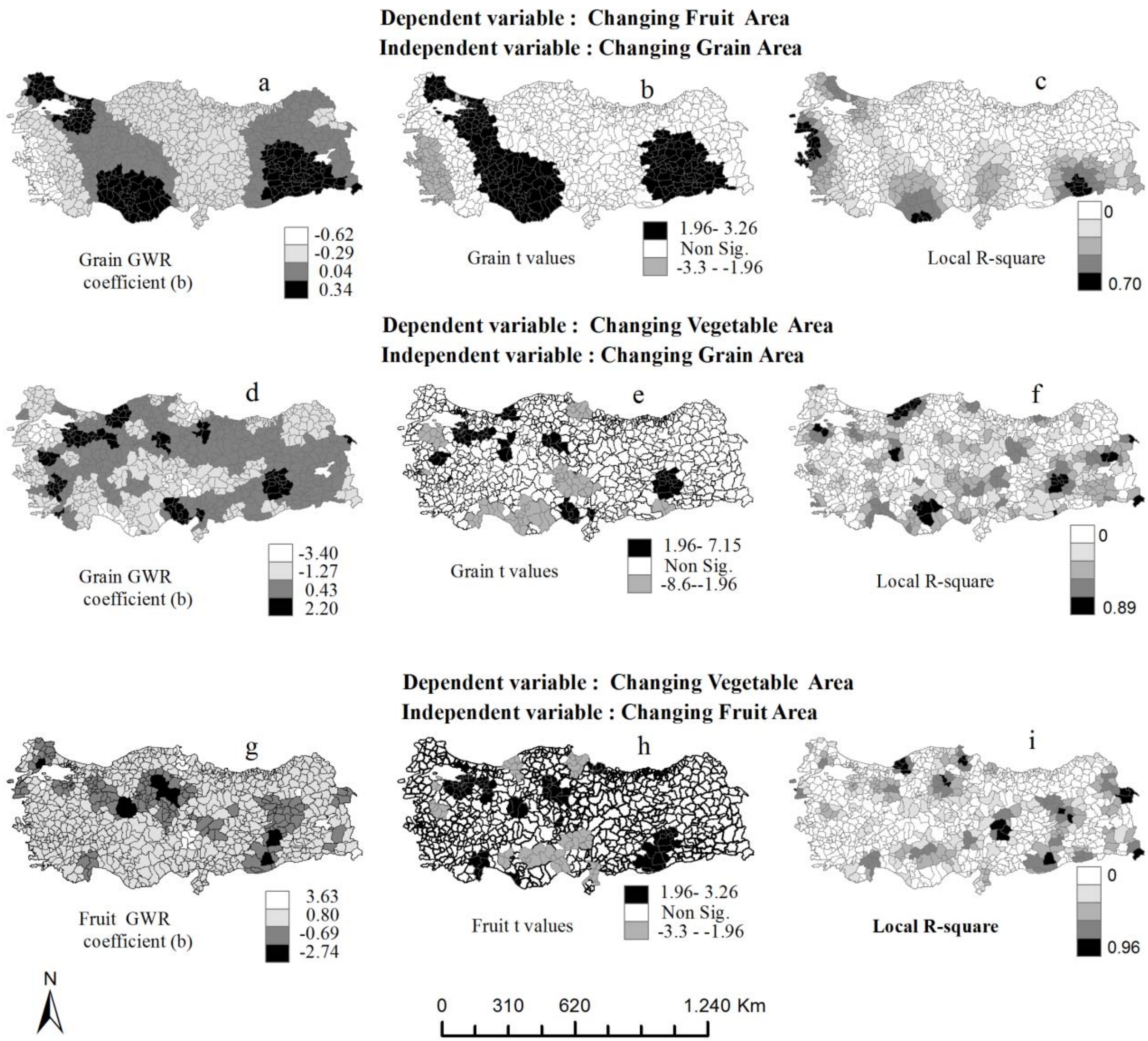

Figure 3. Spatial distribution of local coefficients, R-squared and t-statistics from the GWR. T-values are significant in some districts at a 0.05 level (t-values above 1.96 and lower than -1.96).

localization, shows the relationship between grain, vegetable and fruit variables (Table 3). Figure 3 shows the results of the GWR analysis that was performed to determine the relationship of spatial variability between changing grain, vegetable and fruit sowing areas.

Here, we show how there is a relationship between the agricultural sowing types shift by taking into account GWR results. The share of fruit among arable areas

Table 3. Variation of local R-squared.

Dependent variable	Independent variable	Coefficient			
Fruit	Grain	Grain coefficient	-0.64-0.34	Local R-squared	0.0-0.70
Vegetable	Grain	Grain coefficient	0.06-2.67	Local R-squared	0.0-0.89
Vegetable	Fruit	Fruit coefficient	-2.74-3.63	Local R-squared	0.0-0.96

increased in all regions. Figure 3a, d and g show the spatially varying coefficients. In those maps, white and light-gray district clusters indicate a negative relation between independent and dependent variables and dark-gray and black colors represent that both independent and dependent variables increased. Some of the t-values that are represented by white color in the Figure 3b, e and h were insignificant at a 0.05 level (t-values above -1.96 or lower than 1.96). Figure 3c, f and i show R-squared variables for each district. There are of course black and dark gray clusters, indicating a strong relationship between the variables.

Grain coeffients range from -0.62 to 0.34 (Figure 3a). The fact that the variation of local coefficients range from negative to positive account for relationships between changing grain and fruit sowing area spatial heterogeneity distributions. Positive coefficient values are found in Mediterranean, Southeastern Anatolia (SEA) and western Marmara. Considering fruit productivity, those regions have advantages of sustainable development of agricultural areas. In addition, they have a relative advantage in terms of irrigation systems. In particular, the SEA region is the site of the important Southeastern Anatolia irrigation project that is likely to be a contributing factor in increasing both grain and fruit area (Akpınar and Kaygusuz, 2012; Çelik and Gülersoy, 2013).

Black color clusters in Figure 3a reflect how farmers meet sustainability conditions after government regulations in the agricultural industry have been reduced. The negative coefficients are highly concentrated in the coast of Aegean. This negative spatial relationship is evidence of how the grain area was replaced by fruit area. The reason why the agricultural area shifted from grain to fruit is likely due to irrigation opportunities. Another reason in SEA is that farmers have large arable areas which have both sunshine duration and irrigation advantages. The reason that fruit area is increasing while grain area is decreasing is based on the fact that fruit is definitely more productive than grain.

Unlike fruit, vegetable and grain planting and production cycle is less than 1 year. Since it takes about 3 to 10 years to reach the first fruit harvest, it is very difficult for poor farmers to shift from grain to fruit. Even if poor farmers have enough arable land to produce fruit, they have to continue to crop grain. Apart from the Black Sea region, regions in the coast of Turkey have relatively higher income levels. Therefore, in those regions, agricultural sowing areas have shifted from grain to fruit smoothly.

Figures 3d, e and f show the results of the GWR analysis that was performed to show the relationship of spatial variability between changing grain and vegetable areas. Grain coefficients variable ranged from -3.40 to 2.20 (Figure 3d). Therefore we can say that relationship between changing grain and vegetable area spatially heterogeneously distributed. Negative coefficients, concentrated on the coast of Aegean, Eastern Black Sea, Mediterranean, Southwest Marmara. Middle Anatolia and Southeastern Anatolia are a very clear demonstration of how the grain area was replaced by vegetable. Shift from grain to vegetable is easier than shift from grain to fruit because of the long amount of time to first harvest for fruit cultivation. In this reason negative coefficients between the grain to vegetable are more widespread than grain to fruit. The reason that grain production is being replaced by vegetables in the coastal regions of Turkey is that those regions have irrigation advantages compared to the rest of the Turkey.

Figure 3g shows that grain coefficients variable ranged from -2.74 to 3.63. Coefficients ranging from negative to positive indicate how well the local regression model is obtained. Negative coefficients represent shifts from vegetable to fruit and positive coefficients represent that both vegetable and fruit increased. The negative relationship between vegetable and fruit area is concentrated in the SEA, north of Mediterranean, north of Aegean and west Black Sea. Because both vegetable and fruit need irrigate systems, the shift from vegetable to fruit is relatively easily. Significant positive relationships suggest that changing vegetable sowing area from 2000 to 2010 is associated with higher changing fruit sowing area.

DISCUSSION

Many farmers are beginning to recognize the need to increase agricultural productivity. In order to cope with and adapt to agricultural productivity challenges, farmers prefer fruit production instead of grain. Farmers attempted to overcome and adapt after new economic crisis conditions by raising sustainability limits through new spatial organizations. In the coastal regions of Turkey, it is obvious that agriculture has shifted from grain area to fruit area. The reason why there is a spatial transition from grain and vegetable area to fruit area is based on the fact that fruit productivity is much higher than vegetable and grain. There is a controversial situation here in that this process may lead to new food security problem. The shift from grain to fruit may solve the farmers' sustainable agriculture problem but cause a food security problem for the nation because grain is such an essential food.

Fruit agriculture crop requires high amount of water compared to grain areas. Middle Anatolia has disadvantages in irrigated agriculture compared to the coast of Turkey. SEA is one of the poorest regions in Turkey. Accordingly, there are many districts in which per capita income is far below the average in the east of Turkey. In 2010, the richest province (Istanbul) had a per capita income more than 3 times than that of the poorest provinces (Mardim, Batman, Siirt, Sırnak). The probability that in the SEA region, positive agricultural changes will contribute towards catching up to wealthier provinces is very high.

Conclusions

The purpose of this study was to determine how farmers have tried to increase agricultural productivity. This paper shows that agricultural productivity can play an important role in grain production. One of the more significant findings to emerge from this study is that Turkey's types of agricultural production have changed drastically. Striking evidence shows that grain production is moving from the center of Turkey to the east and southeast. The second major finding was that agricultural productivity can play important role in the shift from grain and vegetable to fruit production. There is a spillover effect between agricultural production types, because grain is crucial for human life. The decline of government support for farmers and economic crises make sustainable agriculture extremely difficult. It can be said that sustainable agricultural production is at risk in Turkey since droughts have increased in central Anatolia, which is an important region for grain production. It is understood that farmers prefer fruit, but we do not know what kinds of fruit have replaced grains and vegetables. Further research needs to be done to establish how climate conditions influence types of agricultural production and to analyze which kind of fruit has been preferred in order to more comprehensively characterize the current situation and trends.

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