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Emissions Of Greenhouse Gases From Diesel Consumption In Agricultural Production Of Turkey

Beran ADAY[1], Can ERTEKIN[1], Fatih EVRENDILEK[2]

ABSTRACT

Agricultural sector is both energy consumer in the form of human labor, fossil fuels, electricity, seeds, fertilizer, and pesticides and energy producer in the form of food, feed, and biofuels. High agricultural use of energy inputs results in adverse environmental issues such as global climate change, pollution of water, soil and air, and unsustainable agricultural production. In this study, 35 agricultural crops such as cereals, fruits, and vegetables were evaluated in terms of consumption of diesel fuel during their production process including soil preparation, fertilization, sowing, spraying, harvesting and transportation, based on minimum and maximum values reported in related literature. Greenhouse gas (GHG) emissions from diesel consumption can be expressed as total carbon dioxide equivalent (CO_{2eq}) emissions (2.76 kg per liter). a map showing total CO_{2eq} emissions from diesel consumption for agricultural production. Our estimates showed that minimum and maximum GHG emissions varied between 0.48 and 3.75 Tg CO_{2eq} for wheat, 17.15 and 65.45 Gg CO_{2eq} for chickpea, and 0.088 and 0.153 Tg CO_{2eq} for tomatoes, respectively. In order to reduce diesel-related GHG emissions, there is an urgent need for innovative agricultural practices and technologies to be put into place.

1. Introduction

Energy is vital to socio-economic development and health of all the countries. However, heavy reliance on fossil fuels has caused serious global and regional concerns such as climate change, conflicts, and refugees. Anthropogenic greenhouse gas (GHG) emissions from fossil fuel consumption are the most significant driver of climate change, with carbon dioxide (CO_2) as the primary GHG (Ozturk et al., 2016; Cabuk, 2011; Ozcan, 2016). Total GHG emissions in Turkey was estimated to increase by 125% relative to 1990 to 467.6 million tonnes CO_2 equivalent (CO_{2eq}) in 2014, with the biggest four shares belonging to energy-related sources (72.5%), industrial processes (13.4%), agriculture (10.6%), and wastes (3.5%). CO_{2eq} per capita was 3.77 tonnes in 1990 and reached 6.08 tonnes in 2014 (www.tuik.gov.tr).

Different forms of energy, in particular, considerable amounts of fossil fuels are intensively applied in in all field-to-fork stages of agricultural production directly or indirectly in order to produce food for growing population. Diesel fuel is the most commonly used energy source in different agricultural processes such as soil tillage, sowing, fertilization, spraying, harvesting, and transportation (Houshyar et al., 2015). In this study, diesel consumption for the production of 35 crops in 81 cities in Turkey was derived from related literature, converted to minimum and maximum values of total CO_{2eq} emissions and interpolated on a national scale using universal krigging.

[1] Akdeniz University, Faculty of Agriculture, Dept. of Farm Machinery and Technologies Engineering, Antalya, TURKEY.
[2] Abant Izzet Baysal University, Faculty of Engineering, Dept. of Environmental Engineering, Bolu, TURKEY.

2. Materials And Methods

Data about amount and area agricultural production were obtained from TUIK (Turkey Statistics Institution) for 81 cities across Turkey for 35 products in 2015. Site-specific minimum and maximum values of diesel fuel consumption ($L.ha^{-1}$) were derived from related literature (Table 1). These minimum and maximum values were converted to total CO_{2eq} emission using the multiplier of by 2.76 kg $CO_2.L^{-1}$ diesel fuel and were extrapolated multiplying them by agricultural production area for each city (Abdi et al., 2012; Mirasi et al., 2015). Using the interpolation method of universal kriging, total CO_{2eq} emissions were mapped at the national scale.

Table 1. Minimum and maximum values of diesel fuel consumption per hectare in production of different agricultural crops.

Product	Diesel consumption ($L.ha^{-1}$)		References
	Min	Max	
Wheat	21.99	172.50	Gozubuyuk et al., 2012; Tipi et al., 2009; Yaldiz et al., 1993; Eren et al., 2006; Canakci et al., 2005; Karaagac et al., 2012
Barley	29.53	60.50	Yaldiz et al., 1993; Baran and Gokdogan, 2014
Green bean	27.19	43.63	Yaldiz et al., 1993
Chickpea	17.29	66.00	Dellal et al., 2007; Yaldiz et al., 1993
Soybean	48.30	48.30	Yaldiz et al., 1993
Sugarbeet	41.49	105.00	Erdal et al., 2007; Yaldiz et al., 1993; Topak et al, 2010
Sunflower	39.84	96.00	Baran and Karaagac, 2014; Yaldiz et al., 1993; Uzunoz et al., 2008;
Cotton	44.82	337.20	Eren and Ozturk, 2006; Yaldiz et al., 1993; Canakci et al., 2005; Sehr, 2012; Dagistan et al., 2009; Yilmaz et al., 2005; Polat et al., 2006
Rose	26.33	113.89	Akbolat et al., 2006; Gokdogan and Demir, 2013
Potato	22.62	232.80	Dellal et al., 2007; Yaldiz et al., 1993
Tomatoes	169.80	295.70	Cetin and Vardar 2008; Canakci et al., 2005; 64
Watermelon	72.40	172.78	Baran and Gokdogan, 2014b; Canakci et al., 2005
Melon	91.70	169.27	Baran and Gokdogan, 2014b; Canakci et al., 2005
Apple	14.89	255.17	Yilmaz et al., 2010; Ekinci et al., 2005
Quince	143.62	143.62	Gundogmus, 2013a
Apricot	110.10	187.15	Gundogmus, 2006; Gezer et al., 2003
Cherry	91.00	183.80	Kizilaslan, 2009; Demircan et al., 2006
Peach	168.60	245.79	Gokdogan, 2011; Goktolga et al., 2006
Mandarin	254.70	254.70	Ozkan et al., 2004
Orange	248.40	337.50	Ozkan et al., 2004; Dellal et al., 2007

Lemon	234.40	344.40	Ozkan et al., 2004; Bilgili, 2012
Grape	70.20	134.00	Ozkan et al., 2007; Dellal et al., 2007
Pomegranate	26.92	85.60	Canakci, 2010; Akcaoz et al., 2009
Pistachio	41.78	68.80	Saglam et al., 2012; Kulekci and Aksoy, 2013
Banana	178.00	178.00	Gundogmus, 2013b
Sorgum	92.60	92.60	Eren and Ozturk, 2011
Maize (for silage)	23.09	66.77	Barut et al., 2011
Maize	46.82	134.80	Yaldiz et al., 1993; Erdogan, 2009; Canakci et al., 2005
Sesame	87.80	87.80	Canakci et al., 2005
Colza	76.61	77.97	Baran et al., 2014; Arikan, 2011
Paddy	204.00	204.00	Dellal et al., 2007
Tobacco	66.60	66.60	Dellal et al., 2007
Lentil	60.60	60.60	Dellal et al., 2007
Hazelnut	54.00	54.00	Dellal et al., 2007
Olive	57.60	57.60	Dellal et al., 2007

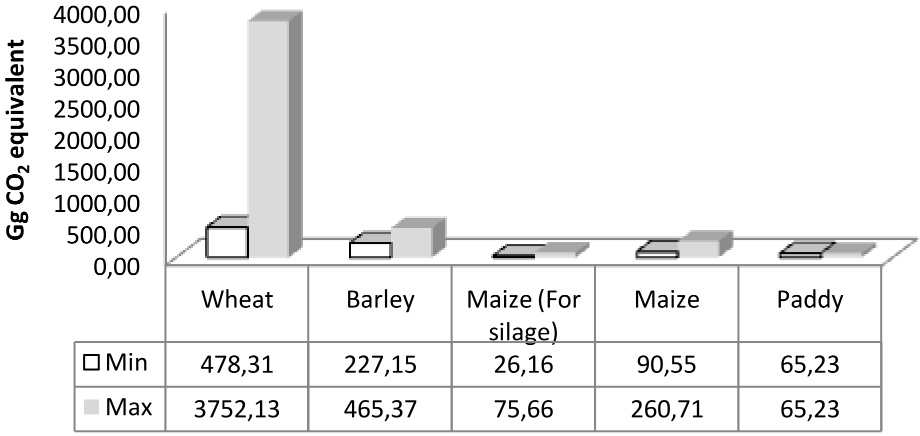
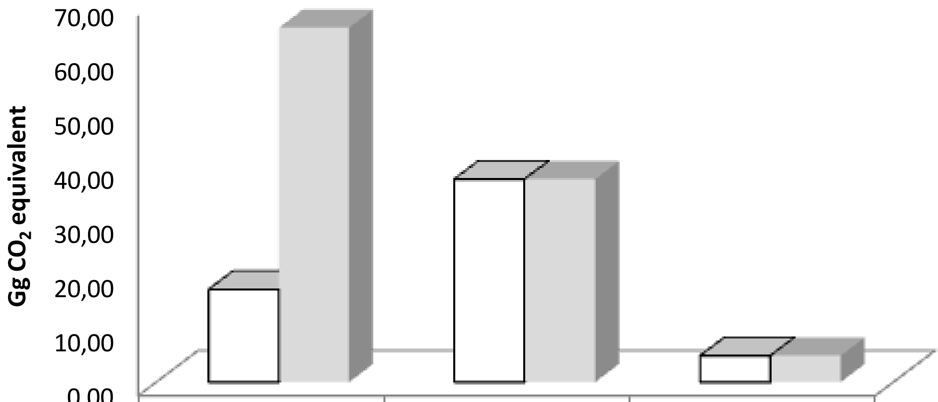


Fig. 1. CO_2-equivalent emissions from diesel consumption for growing grains in Turkey.
Maximum CO_{2eq} emission after grains belonged to industrial, tuberous and feed crops. In particular, for sugarbeet, sunflower, cotton and potato production, the differences between minimum and maximum CO_{2eq} emissions are very high because of different practices adopted during the growing season (Fig. 3).

3. Results

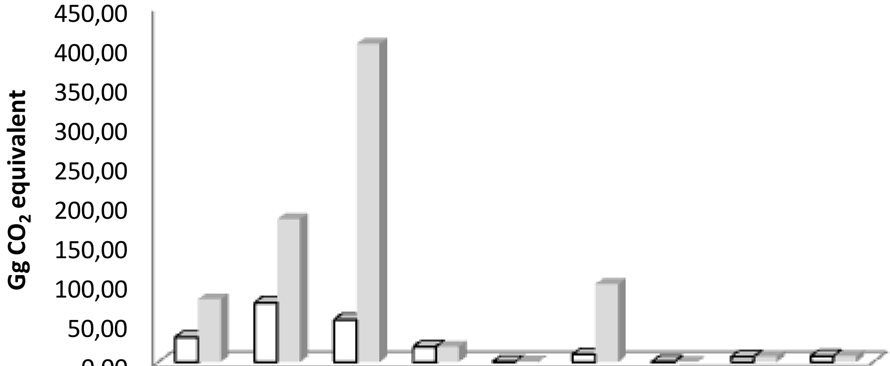
The biggest share of agricultural production in Turkey belongs to grains. Diesel consumption for wheat production ranges from 21.99 to 172.50 $L.ha^{-1}$ which correspond to 478.3 and 3752.1 Gg CO_{2eq}, respectively. These values were lower for barley, maize,

maize for silage, and paddy (Fig. 1). There exist very limited studies about leguminosae plants, and CO_{2eq} emissions varied between 17.2 and 65.5 Gg for chickpea, 37.4 Gg for lentil and 4.9 Gg for soybean (Fig. 2).



	Chickpea	Lentil	Soybean
□ Min	17,15	37,44	4,90
■ Max	65,45	37,44	4,90

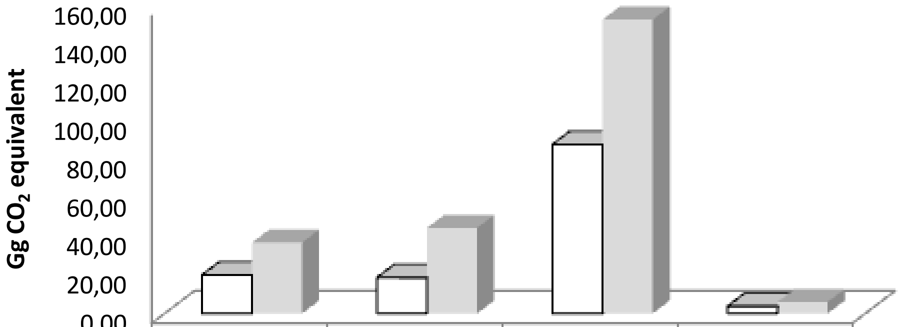
Fig. 2. CO_2-equivalent emissions from diesel consumption for growing leguminosae crops in Turkey.



	Sugar beet	Sunfl ower	Cotto n	Toba cco	Rose	Potat o	Sorg hum	Sesa me	Colza
□ Min	31,52	75,36	53,69	19,46	0,22	9,62	0,43	6,81	7,42
■ Max	79,77	181,58	403,92	19,46	0,94	99,00	0,43	6,81	7,55

Fig. 3. CO_2-equivalent emissions from diesel consumption for growing industrial, tuberous and feed crops in Turkey.

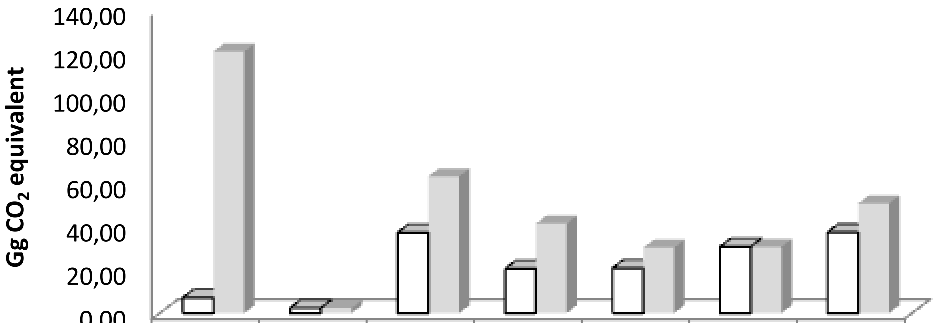
Diesel consumption was highest for tomato production among the vegetables considered. CO_{2eq} emissions from the production of vegetables varied between 3.76 and 152.75 Gg (Fig. 4).



	Melon	Watermelon	Tomato	Green Bean
Min	20,01	18,69	87,71	3,76
Max	36,93	44,61	152,75	6,04

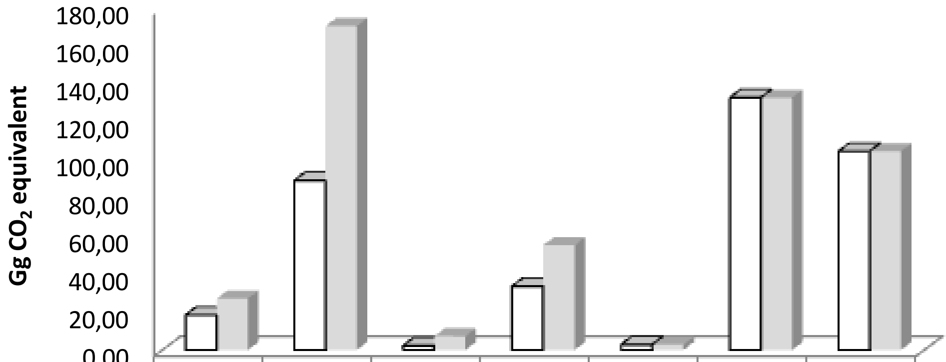
Fig. 4. CO_2-equivalent emissions from diesel consumption for growing vegetables in Turkey.

There exists many studies about fruit production in related literature, and minimum and maximum values of total CO_{2eq} emissions ranged between 2.28 and 133.05 Gg for quince and olive, respectively (Figs. 5 and 6). Minimum and maximum values of total CO_{2eq} emissions from diesel consumption for the production of these 35 crops during the growing season were interpolated based on the universal krigging method and presented in Figs. 7 and 8.



	Apple	Quince	Apricot	Cherry	Peach	Mandar in	Orange
Min	7,04	2,34	37,12	20,45	20,71	30,59	37,23
Max	120,72	2,34	63,10	41,30	30,19	30,59	50,58

Fig. 5. CO_2-equivalent emissions from diesel consumption for growing fruits in Turkey.



	Lemon	Grape	Pomegranate	Pistachio	Banana	Olive	Hazelnut
Min	18,48	89,50	2,28	33,60	2,87	133,05	104,72
Max	27,16	170,85	7,27	55,34	2,87	133,05	104,72

Fig. 6. CO2-equivalent emissions from diesel consumption for growing fruits in Turkey.

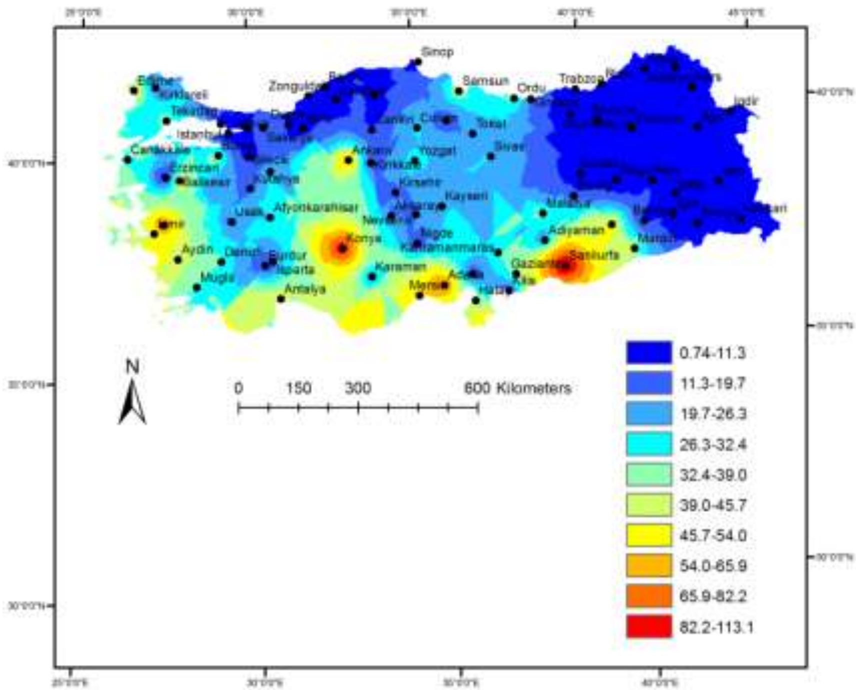


Fig. 7. National map of minimum total CO_2-equivalent emissions (Gg = 10^6 kg) from diesel consumption for agricultural production of 35 crops in 2015, based on the interpolation method of universal kriging.

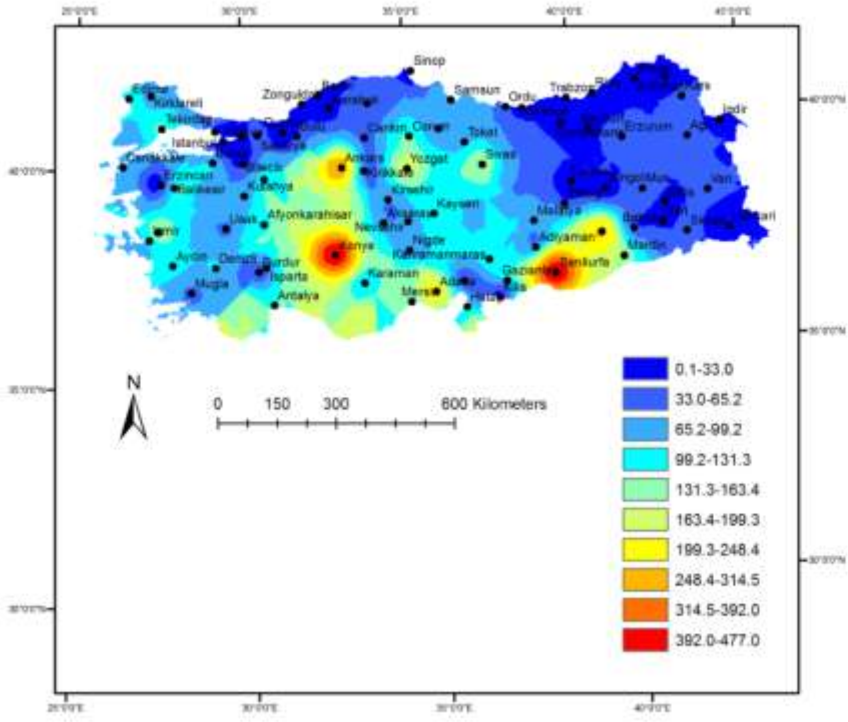


Fig. 8. National map of maximum total CO_2-equivalent emissions ($Gg = 10^6$ kg) from diesel consumption for agricultural production of 35 crops in 2015, based on the interpolation method of universal kriging.

According to the interpolation maps in Figs. 7 and 8 generated using the universal kriging method, minimum and maximum total CO_{2eq} emissions from the entire diesel consumption for the production of the 35 crops were highest near Konya in central Anatolia and Gaziantep in southeastern Anatolia.

Conclusions

In agriculture, different practices such as soil tillage, sowing, fertilizing, spraying, harvesting and transportation generally involve using tractors, and thus, diesel fuel consumption. Total CO_{2eq} emissions from total agricultural diesel consumption were estimated to vary between 1821.5 and 6606.7 thousand tonnes. The interpolation method of universal kriging led to minimum and maximum values of total CO_{2eq} emissions in 2015 that ranged from 0.7 to 113 Gg and from 0.1 to 477 Gg, respectively. In order to decrease total CO_{2eq} emissions, energy efficiency of tractors should be improved, and alternative renewable energy inputs (e.g. biofuels) should be sought to minimize reliance on fossil fuels. It is of urgent need to identify innovative practices and technologies to improve agricultural energy budget, and its spatio-temporal dynamics in accordance with social acceptance and ecological requirements not only in Turkey but also globally.

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