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Total CO_2-equivalent GHG Emissions from Agricultural Human Labour in Turkey

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Carbon dioxide (CO_2) is one of the most important greenhouse gases (GHG) whose increased emissions have significantly enhanced greenhouse effect, thus changing global climate. To keep up with the rising growth rates of human population and consumption in spite of decreasing agricultural human labour, finding ways to boost sustainable agricultural production through mechanization has gained importance instead of relying solely on human efforts. The present study aims at the quantification of total CO_2-equivalent GHG emissions (CO_{2eq}) from agricultural human labour required in tillage, cultivation, maintenance, harvesting, and transportation for 58 agricultural crops cultivated in Turkey. Our quantification was based on minimum and maximum values of human labour energy reported in related literature and the coefficient of 0.36 kg CO_{2eq} per MJ. Our results showed that GHG emissions varied between 49.41 and 1232.66 Gg CO_{2eq} for wheat, 1.44 and 72.68 Gg CO_{2eq} for chickpea, and 49.50 and 154.43 Gg CO_{2eq} for tomatoes. There is a pressing need for agricultural GHG emissions from human efforts and mechanization to be reduced and balanced.

1. Introduction

What has mattered to the socio-economic development and health of all societies has been the quantity of energy resources in particular, fossil fuels. However more recently, the importance of the type of energy resources; that is, the use of renewable energy resources and technologies instead of fossil fuels has come to the forefront due to the release to the atmosphere of the greenhouse gas (GHG) emissions associated with the burning of fossil fuels. The present atmospheric carbon dioxide (CO_2) concentration is 40% more than the levels before the industrial revolution (about 387 ppm) and is expected to rise to the range of 500 to 900 ppm by the end of the twenty first century (Karl, et al., 2009). The general circulation model results show that the doubling of the current atmospheric CO_2 level will cause an average global temperature rise of 1.5 to 4.5^o in 2050 (Ozturk, et al., 2016). Among all the GHGs, CO_2 accounts for 58.8% of all the GHG emissions. Predictions and analyzes of CO_2 emissions suggest that energy consumption and economic growth are the most important components of clean energy economics (Pao, et al., 2012).

Globally, energy-related CO_2 emissions are projected to increase from 30.2 billion metric tons (t) in 2008 to 35.2 billion t in 2020 and 43.2 billion t in 2035 by a 43% increase due to the strong dependence of economic growth on fossil fuels (Altıntaş, 2013). The top agricultural energy inputs for both establishment and postplanting harvest years are seed, human labour, machinery, diesel and oil, fertilizer, chemicals, water or seedbed preparation, seeding, fertilization hoeing, irrigation, spraying, harvesting and transportation. For example, herbicides (33%), diesel fuel (29%), and seed (23%) during the establishment year as well as nitrogen fertilizer (67%), diesel fuel (18%), and herbicides (8%) during the postplanting harvest years accounted for the majority of agricultural energy inputs in the northern Great Plains of USA (Schemer, et al., 2008). The agricultural energy input/output analyses over Turkey for different crops were also conducted (Barut, et al., 2011; Bilgili, et al., 2015; Aday, et al., 2016; Ozkan, et. al., 2004; Hatirli, et. al., 2005). In the present study, human labour energy used for the production of 58 different agricultural crops in 81 cities of Turkey was derived from related literature and converted to minimum and maximum values of total CO_{2eq} GHG emissions which in turn were interpolated on a national scale using an empirical Bayesian kriging method.

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2. Materials And Methods

Data about the amount and area of agricultural production were obtained from Turkey Statistics Institution (TUIK) for 58 different crops in 2015 from 81 cities across Turkey. Site-specific minimum and maximum values of human labour use ($h.ha^{-1}$) were derived from related literature (Table 1). These data covers the agricultural processes of tillage, maintenance, harvesting and transportation.The minimum and maximum values were converted to the human labour energy and than total CO_{2eq} emission values by multiplying with the coefficients of 1.96 $MJ.ha^{-1}$ and 0.36 kg $CO_2.MJ^{-1}$, respectively (Houshyar, et al., 2015a; Houshyar, et al., 2015b). Using the interpolation method of the empirical Bayesian kriging, total CO_{2eq} GHG emissions were mapped at the national scale. More detailed information about kriging method can be found in Evrendilek and Ertekin, 2008 and Ertekin and Evrendilek, 2007.

Table 1. Minimum and maximum values of human labour use per hectare in production of 58 agricultural crops (Koral, et al., 1998).

Crops	Tillage ($h.ha^{-1}$)		Maintenance ($h.ha^{-1}$)		Harvesting and transportation ($h.ha^{-1}$)	
	Min	**Max**	**Min**	**Max**	**Min**	**Max**
Wheat	5.7	12.6	1	43.9	2.2	165.19
Barley	5.6	13.6	0	12.7	2.8	141.4
Maize	10.9	18.5	69.6	339.1	4.2	332.3
Paddy	38.6	222.5	100.8	1164	9.6	300
Haricot bean	8.9	62.1	108.7	362.8	82.6	263.9
Chickpea	5.7	9.8	0	138.6	0	138.3
Lentil	5	8.4	0	125.5	108	167.1
Soybean	12.4	14	111.9	139.4	2.5	140.5
Sugar-beet	8.9	25.7	420.5	655.2	313	600.2
Sunflower	4.5	14.6	46.3	210.5	2.2	279.1
Cotton	10.4	21.7	277.1	676.6	411.4	721.6
Tobacco	129.9	671.9	166.3	711.5	422.1	2133.6
Poppy	13.3	16.6	387	607.9	434.5	650.7
Aniseed	24	65	159	444.4	28.3	273
Cummin	6.5	6.5	1.4	1.4	88.1	88.1
Hemp	21.5	21.5	324.5	324.5	1152.5	1152.5
Heather	13	13.2	111.8	140	242.8	299.1
Rose	0	370	219	241	0	831.6
Tea	0	2886	102.5	592.5	0	277.1
Potato	43.2	153.6	197.8	419.5	233.5	418.2
Onion	13	398.8	89.2	756.5	289.8	842.9
Garlic	198.8	528	222.7	696.5	357.9	1007.5
Alfalfa	0	186.2	29.1	216.6	0	433
Vetch	8.3	9.7	0	26.2	58.1	75.65
Sainfoin	0	10.65	39.7	41.2	80.7	95
Tomato	100.3	200.4	243.5	1112.9	390.9	978.6
Pepper	91.6	269.3	276.5	762.2	353.4	1014.5
Eggplant	92.3	255	167.8	823.2	142.7	918.8
Cucumber	93.2	255.4	303.1	505.3	416.2	2085.8
Watermelon	51.8	103.8	126.4	290	0	200.3
Melon	11.4	100.7	97.3	236.8	0	202.3
Green bean	99.8	332.8	492.3	736.1	499.4	921.1
Lettuce	13.6	13.9	5	52.7	880.5	1867.3
White-cabbage	118.3	194.97	219.1	562.91	166.3	168.37
Red-cabbage	179.2	179.2	353.4	353.4	248.2	248.2
Black-cabbage	260.2	260.2	17.4	17.4	316.1	316.1
Radish	10.1	10.1	37.4	37.4	874	874
Spinach	15.3	15.3	8	8	714.7	714.7
Leek	327.2	327.2	471.1	471.1	867.1	867.1
Carrot	14.1	72.7	410.4	668.5	870.1	1640.6
Pumpkin	8	12	122	194.8	69	101.6
Apple	0	322	84.5	366.5	0	499.5
Quince	0	0	378.9	378.9	423.6	423.6
Apricot	0	81.6	74.1	439.2	0	599.7
Cherry	0	308.8	216.9	387.9	0	2078.8

Table 1. Minimum and maximum values of human labour use per hectare in production of 58 agricultural crops (Koral, et al., 1998).

Sour cherry	0	0	261.5	261.5	1079.6	1079.6
Peach	0	290.5	166	913	0	1543.4
Mandarin	0	209.8	212.27	558.7	0	1823.7
Orange	0	0	432.8	432.8	1094.6	1094.6
Lemon	0	0	524.1	524.1	1031.7	1031.7
Grape	0	0	151.5	614.8	110.8	441.6
Fig	0	355	40	125.3	0	637.8
Hazelnut	0	1270	68	523	0	306.7
Pomegranate	0	140	433.33	646.8	0	946.8
Loqua	0	241.3	152.2	431.9	0	1604.2
Pistachio	0	138.6	0	84.1	0	163.5
Olive	0	395	11.26	206.2	0	251.5
Banana	0	0	5106.6	5106.6	441.1	441.1

3. Results

The biggest share of agricultural production in Turkey belongs to grains. Human labour use in wheat production ranged from 5.7 to 12.6 $h.ha^{-1}$ for tillage, 1.0 to 43.9 $h.ha^{-1}$for maintenance work, 2.2 to 165.19 $h.ha^{-1}$ for harvesting and transportation. CO_{2eq} GHG emissions of the total agricultural human labour varied between 49.41 and 1232.66 Gg. These values were lower for barley, maize and paddy (Figure 1). In the growing leguminosae crops, CO_{2eq} emissions ranged from 1.44 to 72.68 Gg for chickpea, 17.85 to 47.54 Gg for lentil, 3.29 to 7.62 Gg for soybean and 13.22 to 45.48 Gg for haricot bean for human labour use. (Figure 2).

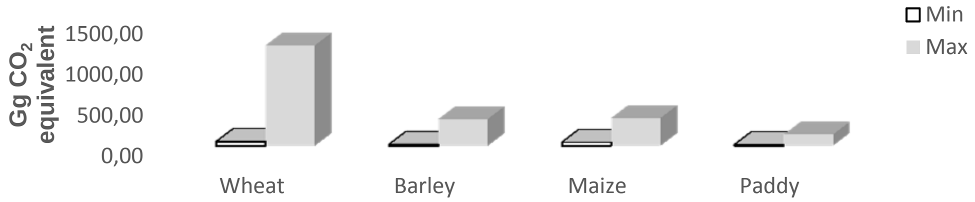

Figure. 1. CO2-equivalent GHG emissions from human labour use for growing grains in Turkey.

(kt = 10^6 kg = Gg)

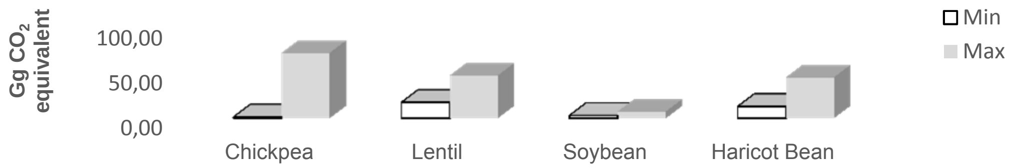

Figure. 2. CO_2-equivalent GHG emissions from human labour use for growing legumes in Turkey.

Maximum CO_{2eq} GHG emissions from grains were followed by industrial, tuberous and feed crops. In particular, for alfalfa, sunflower, tobacco, onion and tea productions, minimum and maximum CO_{2eq} GHG emissions differed significantly due to different practices adopted during the growing season (Figures 3 and 4).

Figure. 3. CO_2-equivalent GHG emissions from human labour used for growing industrial, tuberous and feed crops in Turkey

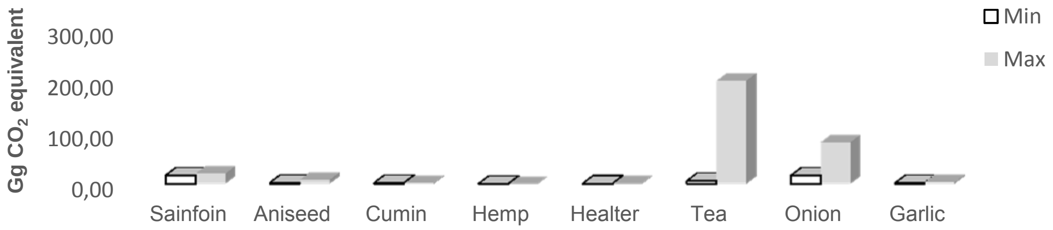

Figure. 4. CO_2-equivalent GHG emissions from human labour used for growing industrial, tuberous and feed crops in Turkey.

Human labour use was the highest for tomato production among the vegetables considered. Thus, CO_{2eq} GHG emissions from human labour for the production of vegetables varied between 2.38 and 154.43 Gg (Figures 5 and 6).

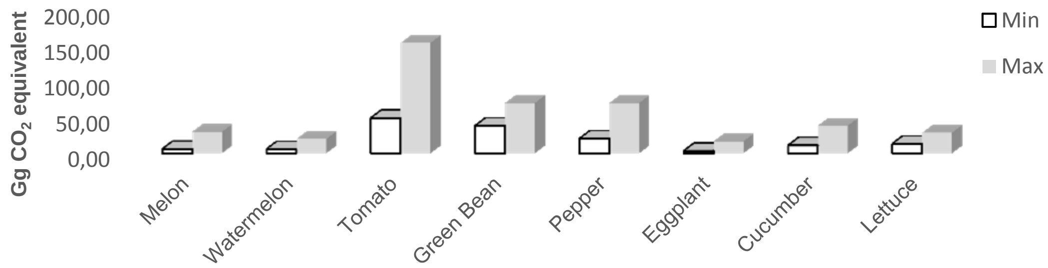

Figure. 5. CO_2-equivalent GHG emissions from human labour use for growing vegetables in Turkey.

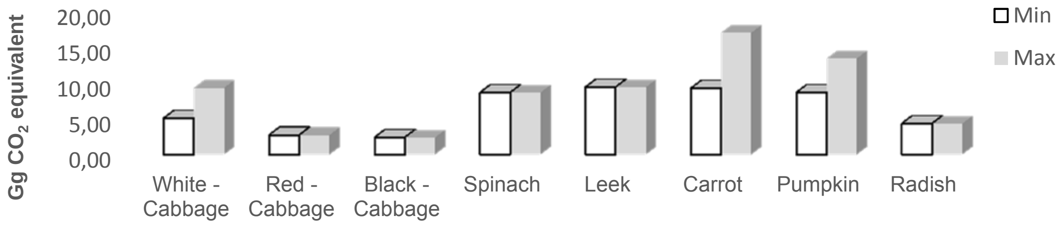

Figure. 6. CO_2-equivalent GHG emissions from human labour used for growing vegetables in Turkey.

The total CO_{2eq} GHG emissions ranged between 0.01 and 1040.96 Gg for pistachio, olive and grape (Figures 7 and 8).

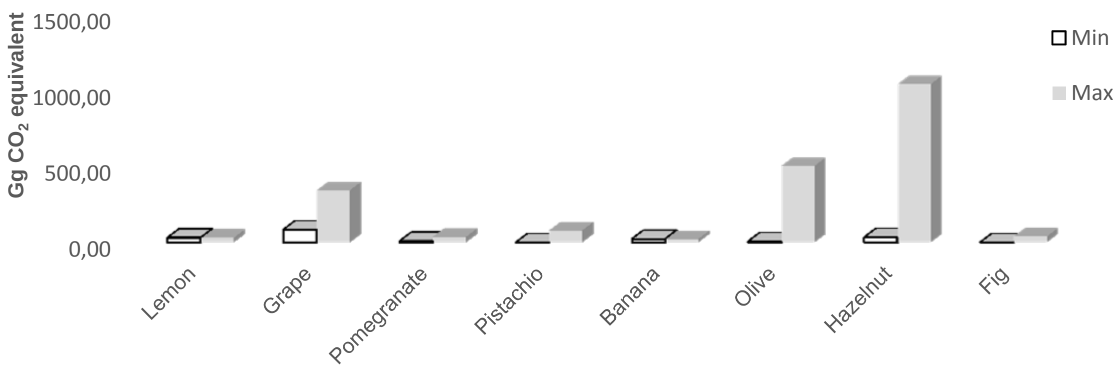

Figure. 7. CO_2-equivalent GHG emissions from human labour use for growing fruits in Turkey.

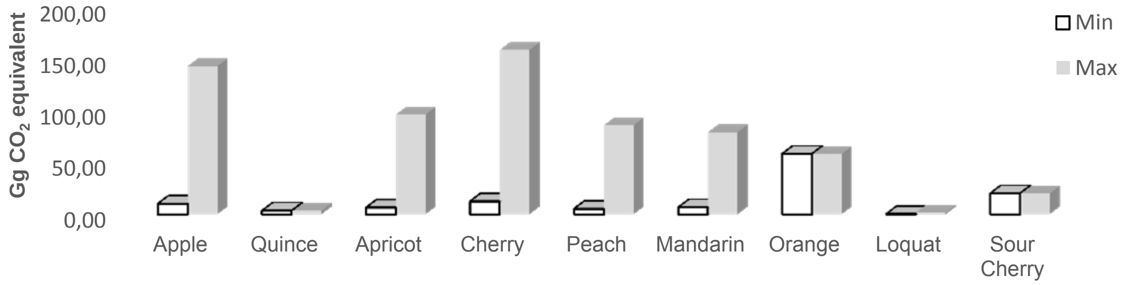

Figure. 8. CO_2-equivalent GHG emissions from human labour use for growing fruits in Turkey.

Total minimum and maximum values of CO_{2eq} GHG emissions from human labour use for the production of the 58 crops during the growing season were interpolated based on the empirical Bayesian kriging method and presented in Figures 9 and 10, respectively.

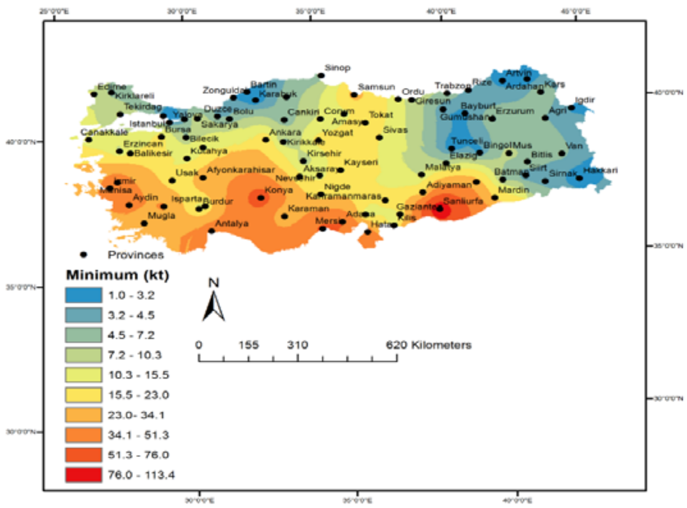

Figure. 9. National map of minimum total CO_2-equivalent GHG emissions (kt = 10^6 kg = Gg) from human labour use for agricultural production of 58 crops in 2015, based on the interpolation method of empirical Bayesian kriging.

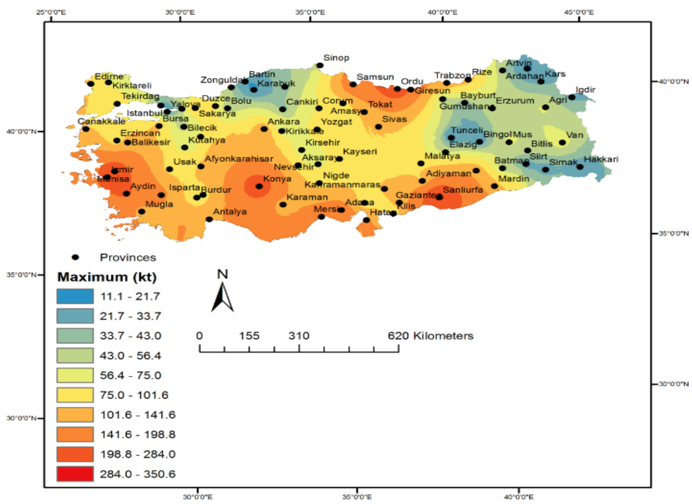

Figure. 10. National map of maximum total CO_2-equivalent GHG emissions (kt = 10^6 kg = Gg) from human labour use for agricultural production of 58 crops in 2015, based on the interpolation method of empirical Bayesian kriging.

4. Conclusion

In agriculture, human labour is applied to different activities such as tillage, maintenance, harvesting and transport. Total CO_{2eq} GHG emissions from total agricultural human labour use were estimated to vary between 1261.97 and 7553.72 thousand t. The interpolation method of empirical Bayesian kriging led to the ranges of minimum and maximum values of total CO_{2eq} emissions in 2015 of 0.32 to 125.62 Gg and 3.12 to 407.97 Gg, respectively. In order to reduce total CO_{2eq} GHG emissions, automation and robotic systems may be developed in agricultural production to reduce human labour utilization. Also, alternative renewable energy sources (e.g. biofuels) and technologies (e.g. photovoltaic systems) should be adopted to reduce the energy dependence on the fossil fuels. In addition, bigger sized machines having larger working area are needed.

References

Aday B., Ertekin C., Evrendilek, F., 2016, Emissions Of Greenhouse Gases From Diesel Consumption In Agricultural Production Of Turkey. European Journal of Sustainable Development (2016), 5, 4, 279-288.

Altıntaş H., 2013, Türkiye'de Birincil Enerji Tüketimi, Karbondioksit Emisyonu Ve Ekonomik Büyüme İlişkisi: Eşbütünleşme Ve Nedensellik Analizi. Eskişehir Osmangazi Üniversitesi İİBF Dergisi, Nisan 2013, 8(1), 263-294.

Barut Z.B., Ertekin C., Karaagac H.A. Tillage effects on energy use for corn silage in Mediterranean Coastal of Turkey. Energy, 36, 5466-5475, (2011).

Bilgili M.E., Ertekin C., Çanakcı M. Determination of Energy Usage Efficiency in Colza Production in Cukurova Region, Turkey. International Scientific XXXVI CIOSTA & CIGR Section V Conference, Environmentally Friendly Agriculture And Forestry For Future Generations, Saint Petersburg – Pushkin, 2015.

Ertekin C., Evrendilek F. Spatio-temporal modeling of global solar radiation dynamics as a function of sunshine duration for Turkey. Agricultural and Forest Meteorology, 145, 36-47 (2007).

Evrendilek F., Ertekin C. Assessing solar radiation models using multiple variables over Turkey. Climate Dynamics, 31, 131-149 (2008).

Hatirli A. H., Ozkan B., Fert C., 2005, An econometric analysis of energy input–output in Turkish agriculture. Renewable and Sustainable Energy Reviews 9 (2005) 608-623.

Houshyar E., Zareifard H., R., Grundmann P., Smith P., 2015a, Determining efficiency of energy input for silage corn production: An econometric approach. Energy 93 (2015) 2166-2174.

Houshyar E., Dalgaard T., Tarazkar M. H., Jørgensen U., 2015b, Energy input for tomato production what economy says, and what is good for the environment. Journal of Cleaner Production 89 (2015) 99-109.

Karl T.R., Melillo J.M., Peterson T.C., 2009, Global climate change impacts in the United States. Cambridge University Press.

Koral A. İ., Altun A., Ankara-1998, Türkiye'de Üretilen Tarım Ürünlerinin Üretim Girdileri Rehberi. Yayın no:104, Rehber No: 16. T.C. Başbakanlık, Köy Hizmetleri Genel Müdürlüğü, APK Dairesi Başkanlığı, Toprak ve Su Kaynakları Araştırma Müdürlüğü.

Ozkan B., Akcaoz H., Fert C., 2004, Energy input–output analysis in Turkish agriculture. Renewable energy 29 (2004) 39-51.

Ozturk K., Keles M., Evrendilek F. 2016, Quantifying rates and drivers of change in long-term sector- and country-specific trends of carbon dioxide-equivalent greenhouse gas emissions. Renewable and Sustainable Energy Reviews 65, 823-831.

Pao H.-T., Fu H.-C., Tseng C.-L., 2012, Forecasting of CO2 Emissions, Energy Consumption and Economic Growth in China Using An Improved Grey Model. Energy, 40, 400-409.

Schemer M., Vogel K. P., Mitchell R. B., Perrin R. K., 2008, Net energy of cellulosic ethanol from switchgrass. Proceedings of the National Academy of Sciences 105 (2), 464–469.

TUIK (Turkey Statistics Institution). www.tuik.gov.tr.