

## **Creation of carbon footprint originating from road transportation in Turkey and digital mapping of it**

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**Abstract:** In this study, the carbon footprint created by the greenhouse gases originating from road transportation in Turkey was calculated. In emission calculations, the methodology recommended by the Intergovernmental Panel on Climate Change and determined by the tier-1 and tier-2 approaches was used. As a result of the study, it was observed that the CO<sub>2</sub> emission, which was 95,689 GgCO<sub>2</sub> in 2018 according to the tier 1 method, decreased to 92,424 GgCO<sub>2</sub> in 2020, and the CO<sub>2</sub> emission, which was 417,359 GgCO<sub>2</sub> in 2018 in the tier-2 method, decreased to 404,631 GgCO<sub>2</sub> in 2020. Among the fuels used, it was determined that the diesel fuel type had the highest CO<sub>2</sub> emission in both methods. Among the provinces, it was determined that Istanbul, Ankara and Izmir have the highest CO<sub>2</sub> emissions, respectively. CO<sub>2</sub> emissions were calculated for each province and presented visually on maps prepared using the ARCGIS method.

**Keywords:** carbon footprint; greenhouse gases; road transportation; carbon dioxide; global warming.

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## **1 Introduction**

Human activities such as energy production, industrialisation, transportation and agricultural activities cause greenhouse gas emissions such as carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>) and dinitrogen monoxide (N<sub>2</sub>O) to be released into the atmosphere. Due to the increase in global greenhouse gas emissions, a significant increase in the average temperature of the earth's surface has been observed (Güzel and Alp, 2020). Greenhouse gas emission producers in Turkey are energy industries, transportation, manufacturing industry, construction, waste and forestry applications. The most significant increase in the amount of carbon dioxide in Turkey was observed in the energy sector in 2012 with 250%. While it was 136% in the transportation sector, 123% in the public and agricultural sector and 49% in the manufacturing sector. When greenhouse gas emission statistics are examined in the 2016 results, 72.8% of total emissions are caused by energy emissions, 12.6% by industrial processes and product use, 11% by agricultural activities and 3.3% by waste. Compared to 1990, it is known that the total share of the energy sector increased from 64% to 73% (Baycan and Zengin, 2021).

The transportation sector emits significant amounts of carbon through direct fuel combustion and is a significant contributor to overall CO<sub>2</sub> emissions (Li et al., 2021). Three-quarters of these emissions are from road transport due to the high dependence on traditional fossil fuels such as gasoline and diesel (Navas-Anguita et al., 2020). Road vehicles are a major contributor to greenhouse gas emissions in the transport sector. Therefore, reducing emissions from transportation is an important element in any comprehensive strategy to reduce global greenhouse gas emissions (La Notte et al., 2018). Greenhouse gas emissions from transportation are the result of dynamic interactions between human behaviour, vehicle technology and fuel technology (Kay et al., 2014). Transport is Europe's largest source of carbon emissions, contributing 27% to total CO<sub>2</sub> emissions, with cars and vans accounting for more than two-thirds of these, according to the European environment agency. Similar to the European Union, a significant portion of greenhouse gas emissions in Turkey originate from the transportation sector due to the use of fossil fuels (Coşkun and Oktay, 2020). The increasing number of vehicles, traffic congestion, high emission amount of existing vehicles, lack of regular vehicle maintenance and polluted gas control, low fuel quality and population growth along the highways are considered the causes of the continuous increase in greenhouse gas emissions originating from road transportation (Dündar, 2021).

Wiedmann and Minx (2008) have defined carbon footprint as "a measure of the total amount of carbon dioxide emissions caused directly or indirectly by an activity or accumulated during the life stages of a product" (Zhao et al., 2022; Pandey et al., 2011). The carbon footprint, which is a quantitative expression of greenhouse gas emissions from an activity, helps in emission management and evaluation of mitigation measures (Pandey et al., 2011). The carbon footprint (CF) is used as an indicator to measure greenhouse gas emissions in CO<sub>2</sub> equivalents (CO<sub>2</sub>-eq) (Zhao et al., 2022).

In this study, Turkey's carbon footprint calculations originating from road transportation were made separately for each province and visually presented with maps using the ARCGIS method and comparisons were made. The study was conducted for 2018 and 2020. In the study, tier-1 and tier-2 methods developed by the IPCC were used to calculate greenhouse gas emissions. The data on the amount of fuel used in the study were obtained from the Energy Market Regulatory Authority (EMRA) reports.

## 2 Materials and method

### 2.1 Study area

Turkey (Figure 1) is located in the middle belt of the Northern Hemisphere, where land masses occupy a large area, between 36–42 degrees north parallels and 26–45 degrees east meridians (Balci, 2012; Çelik, 2020a; Kaya, 2017). Turkey's surface area is 779,452 km<sup>2</sup>. Turkey, whose population exceeded 83 million at the last census, is among the most populous countries in the world. Turkey, which has land in both Asia and Europe, is considered as a land bridge connecting the two continents. The fact that Turkey is located in the central climate zone of the northern hemisphere has brought the chance to have the effect of the subtropical middle zone climate, which is most suitable for people's life. Towards the north of this area, the harsh continental climate and lush vegetation limit human activities in places, while towards the south, the extremely hot tropical climate and large deserts on large land masses limit their habitats (Çelik, 2020a).

**Figure 1** Maps of Turkey (see online version for colours)



Source: Muratoğlu (2020)

### 2.2 IPCC methodology

In this study, tier-1 and tier-2 approaches, which are from the tier approaches recommended by the Intergovernmental Panel on Climate Change (IPCC), were used. The tier-1 approach is a simpler method that requires less data. Tier-2 and tier-3 approaches are more complex and require more data (IPCC, 2006). Tier-3 approach was not used because data belonging to tier-3 approach could not be reached.

2.2.1 Tier-1 approach

The tier-1 method is a fuel-based approach, as emissions from all fuel sources are estimated based on the amounts of fuel burned and average emission factors, usually derived from national energy statistics. In the tier-1 calculation method, emissions resulting from combustion are calculated using the amount of fuel consumed and the emission factor depending on the fuel type (IPCC, 2006). Tier-1 equations are given below (Dündar, 2021):

$$\text{Energy consumption (TJ)} = \text{Fuel consumption (t)} \times \text{Conversion factor (TJ/kt)} \times 10^{-3} \tag{1}$$

$$\text{Carbon content (Gg C)} = \text{Carbon emission factor (tC/TJ)} \times \text{Energy consumption} \times 10^{-3} \tag{2}$$

$$\text{Carbon emission (Gg C)} = \text{Carbon content (GgC)} \times \text{Carbon oxidation rate} \tag{3}$$

$$\text{CO}_2 \text{ emission (Gg C)} = \text{Carbon emission (GgC)} \times \text{Molecular weight ratio (44/12)} \tag{4}$$

Conversion factors in equation (1), carbon emission factors in equation (2) and carbon oxidation rates in equation (3) were obtained from the IPCC guideline and are presented in Table 1. Fuel consumptions are obtained from EMRA reports for each province and presented in Table 2.

**Table 1** Fuel data used in tier-1 approach

Fuel	Conversion factor (TJ/kt)	C emission factor (tC/TJ)	C oxidation rate (%)
Gasoline	44,3	18,90	0,99
Diesel	43,0	20,20	0,99
LPG	47,3	17,20	0,99

Source: IPCC (2006)

**Table 2** Annual fuel consumptions

Provinces	2018			2020		
	Gasoline	Diesel	LPG	Gasoline	Diesel	LPG
Adana	51,536	544,922	133,739	52,914	563,120	129,955
Adıyaman	7,295	125,442	36,386	7,836	99,000	33,362
Afyonkarahisar	18,779	236,793	57,331	20,449	292,981	54,245
Ağrı	4,005	74,782	11,738	4,239	74,893	11,085
Aksaray	8,972	137,404	29,514	10,406	146,798	28,342
Amasya	7,408	97,285	27,896	7,950	95,592	28,342
Ankara	205,827	2,065,451	401,524	196,172	2,029,160	354,879
Antalya	98,040	722,051	156,810	96,156	653,274	150,731
Ardahan	1,795	22,867	2,855	1,882	110,324	3,298

Source: EMRA (2018a, 2018b, 2020a, 2020b)

**Table 2** Annual fuel consumptions (continued)

<i>Provinces</i>	<i>2018</i>			<i>2020</i>		
	<i>Gasoline</i>	<i>Diesel</i>	<i>LPG</i>	<i>Gasoline</i>	<i>Diesel</i>	<i>LPG</i>
Artvin	4,436	55,142	6,619	4,645	59,220	6,682
Aydın	41,231	301,557	76,666	41,993	546,217	70,529
Balıkesir	50,131	414,970	78,549	53,559	420,410	75,351
Bartın	5,116	39,303	13,478	5,367	34,724	12,733
Batman	5,893	102,587	12,479	5,564	166,801	11,216
Bayburt	1,380	17,795	3,138	1,462	16,725	3,057
Bilecik	6,522	80,824	12,021	6,889	76,417	11,700
Bingöl	2,674	34,955	7,763	2,995	33,513	6,581
Bitlis	2,954	52,506	9,385	3,076	59,595	8,825
Bolu	14,986	151,512	27,857	16,936	135,658	25,588
Burdur	8,176	154,978	24,860	8,277	126,356	22,179
Bursa	108,096	856,326	118,491	110,566	828,134	111,296
Çanakkale	25,620	185,699	30,722	27,132	204,104	27,509
Çankırı	4,321	71,955	13,910	5,090	134,314	12,732
Çorum	10,947	149,894	42,504	12,398	177,288	39,551
Denizli	30,641	439,462	76,801	30,230	583,449	71,129
Diyarbakır	18,132	197,822	46,612	18,746	191,793	46,303
Düzce	12,646	118,694	29,312	13,161	110,200	27,991
Edirne	21,472	355,743	20,852	20,455	535,045	19,311
Elazığ	10,702	136,176	26,372	12,069	123,758	27,320
Erzincan	5,855	69,139	12,656	6,450	66,779	11,811
Erzurum	14,086	143,879	27,471	14,342	137,936	25,568
Eskişehir	28,761	345,633	45,097	27,708	309,024	40,201
Gaziantep	42,055	545,352	95,851	41,593	590,711	89,342
Giresun	8,805	103,887	24,569	10,218	116,086	24,337
Gümüşhane	2,025	37,504	5,649	2,395	29,880	5,095
Hakkari	1,611	24,836	3,790	1,833	26,612	4,143
Hatay	37,680	444,739	84,985	38,866	438,939	83,378
Iğdır	2,423	23,990	4,050	2,725	28,125	3,858
Isparta	13,344	114,669	30,565	13,166	98,975	28,080
İstanbul	542,808	3,971,717	335,153	510,329	3,439,428	299,546
İzmir	148,903	1,349,316	251,584	147,928	1,136,952	214,551
Kahramanmaraş	18,738	208,765	81,428	20,595	197,061	79,239
Karabük	6,275	89,036	16,594	6,235	128,119	14,887
Karaman	4,602	58,017	15,660	4,965	60,484	15,266
Kars	4,463	52,816	6,837	4,501	49,589	6,603

*Source:* EMRA (2018a, 2018b, 2020a, 2020b)

**Table 2** Annual fuel consumptions (continued)

Provinces	2018			2020		
	Gasoline	Diesel	LPG	Gasoline	Diesel	LPG
Kastamonu	9,953	100,783	29,424	10,593	107,935	27,284
Kayseri	34,398	385,445	96,381	35,742	329,535	88,703
Kırıkkale	6,963	206,419	33,338	7,441	160,332	29,920
Kırklareli	16,481	141,670	16,156	16,898	153,197	16,385
Kırşehir	4,992	49,406	17,606	5,373	51,152	17,283
Kilis	3,835	20,177	6,803	3,910	23,250	6,868
Kocaeli	65,429	840,748	97,175	65,557	728,916	90,415
Konya	49,384	869,020	159,677	49,398	711,522	144,954
Kütahya	14,302	210,075	43,604	14,443	237,825	39,645
Malatya	14,900	146,073	38,184	16,478	134,461	38,422
Manisa	40,671	469,730	106,223	46,048	487,544	100,053
Mardin	7,361	130,743	19,280	7,583	172,104	17,920
Mersin	51,226	1,251,630	116,447	52,025	898,628	115,601
Muğla	63,375	382,852	80,014	66,430	344,561	76,805
Muş	2,578	44,055	9,772	2,879	43,375	9,471
Nevşehir	7,571	207,058	24,858	7,923	105,253	20,824
Niğde	6,846	123,403	21,983	7,600	124,933	22,086
Ordu	14,649	142,125	38,621	17,235	146,865	37,932
Osmaniye	9,653	116,639	38,964	10,408	89,627	40,170
Rize	7,672	87,677	14,263	8,290	87,760	13,561
Sakarya	30,768	315,678	83,064	31,844	296,209	76,145
Samsun	28,860	453,726	72,558	30,912	424,539	68,394
Siirt	2,183	50,881	5,575	2,230	57,712	6,536
Sinop	5,246	45,927	15,243	5,696	41,824	13,354
Sivas	12,956	181,313	34,738	13,299	146,481	33,812
Şanlıurfa	21,459	249,662	89,057	21,869	273,713	92,952
Şırnak	2,146	94,855	6,065	2,697	118,172	6,798
Tekirdağ	40,102	495,744	52,541	40,576	566,661	51,446
Tokat	11,126	148,669	33,335	12,582	153,688	33,005
Trabzon	18,003	240,716	34,125	19,146	205,413	31,883
Tunceli	1,167	15,092	2,782	1,350	13,345	2,696
Uşak	9,962	87,027	26,450	9,824	104,742	25,185
Van	10,329	95,443	25,053	10,162	84,716	23,565
Yalova	9,514	74,423	10,819	10,835	76,469	10,082
Yozgat	6,622	115,653	32,443	7,273	127,640	31,165
Zonguldak	14,207	99,890	35,699	14,536	117,602	32,626

Source: EMRA (2018a, 2018b, 2020a, 2020b)

**Table 3** Average amount of fuel consumed per 100 km by motor vehicle type

<i>Car</i>			<i>Minibus</i>	<i>Bus</i>	<i>Small truck</i>	<i>Truck</i>	<i>Motorcycle</i>
<i>Gasoline</i>	<i>Diesel</i>	<i>LPG</i>	<i>Diesel</i>	<i>Diesel</i>	<i>Diesel</i>	<i>Diesel</i>	<i>Gasoline</i>
8.5	7.3	11.2	10.9	29.9	10.9	29.9	4

Source: IPCC (1996)

### 2.2.2 Tier-2 approach

In the tier-2 calculation method, the amount of distance travelled by the vehicle is taken into account instead of fuel consumption. In the tier-2 method, emissions from combustion are estimated from similar fuel statistics as used in the tier-1 method, but using country-specific emission factors instead of tier 1 defaults. The tier-2 approach is the same as tier 1, except that the country-specific carbon content of the fuel sold in road transport is used. In tier 2, CO<sub>2</sub> emission factors can be adjusted to account for either unoxidised carbon or carbon emitted from a gas other than CO<sub>2</sub> (IPCC, 2006). Tier-2 calculations are made using equations (5)–(9) (Çelik, 2020b).

$$\begin{aligned} \text{Fuel consumption (kt)} &= \text{Number of vehicles} \times \text{Range (km)} \\ &\times \text{Fuel consumption (L/km)} \times \text{Density (kg/L)} \times 10^{-6} \end{aligned} \quad (5)$$

$$\begin{aligned} \text{Energy consumption (TJ)} &= \text{Fuel consumption (kt)} \\ &\times \text{Conversion factor (TJ/kt)} \end{aligned} \quad (6)$$

$$\text{Content of fuel (tC)} = \text{Energy consumption (TJ)} \times \text{C emission factor (tC/TJ)} \quad (7)$$

$$\text{Carbon emission (tC)} = \text{C content of fuel (tC)} \times \text{C oxidation rate} \quad (8)$$

$$\begin{aligned} \text{CO}_2 \text{ emission (Gg CO}_2\text{)} &= \text{C emission (t)} \\ &\times \text{Molecular weight ratio (44/12)} \times 10^{-3} \end{aligned} \quad (9)$$

The annual range data of the vehicles in equation (5) were found on average with the help of the fuel consumption values at 100 km and the number of vehicles given in Table 3 as reported by Bıyık and Civelekoğlu (2020) and presented in Table 4. The number of vehicles and the distribution of registered automobiles by fuel type were obtained from the Turkish Statistical Institute (TSI) for 2018 and 2020 (TSI, 2018, 2020, 2022), and they were proportioned to the provinces. The densities of fuels are shown in Table 5. The following steps were followed while calculating the annual range of the vehicles (Bıyık, 2018).

- the total volume of fuels was calculated with the help of the amount of fuel consumed by the vehicles and the densities of the fuels
- the fuel volume consumed by 1 vehicle was found by dividing the total fuel volume by the total number of vehicles
- the average annual range of the vehicles in km was found by dividing the fuel volume consumed by 1 vehicle by the fuel consumption of the vehicle at 100 km.

**Table 4** Average annual range of vehicles (km)

Provinces	2018													
	Car		LPG		Minibus		Bus		Small truck		Truck		Motorcycle	
	Gasoline	Diesel	LPG	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Gasoline	Gasoline
Adana	9,714	74,095	17,368	542,243	459,557	59,902	110,395	12,989						
Adiyaman	9,339	115,850	32,093	296,781	1,302,752	89,995	146,131	17,470						
Afyonkarahisar	13,215	120,212	27,797	539,330	565,930	75,833	98,887	15,743						
Ağrı	25,550	344,130	51,590	334,248	886,277	110,389	139,895	106,255						
Aksaray	8,679	95,880	19,669	1,087,950	391,009	87,166	88,403	22,465						
Amasya	7,912	74,964	20,529	354,895	539,959	63,247	111,557	19,840						
Ankara	8,875	64,248	11,928	904,920	466,599	76,988	103,322	138,167						
Antalya	12,214	64,893	13,460	544,748	268,280	43,632	124,295	11,573						
Ardahan	28,592	262,697	31,319	320,762	1,842,868	87,129	190,379	127,015						
Artvin	17,454	156,512	17,944	275,793	694,355	45,390	65,738	91,891						
Aydın	14,133	74,569	18,106	319,826	400,633	48,716	136,102	10,657						
Balıkesir	15,010	89,631	16,204	724,160	464,607	67,310	135,077	14,380						
Bartın	10,868	60,238	19,729	283,568	262,636	56,309	99,729	34,525						
Batman	24,280	304,917	35,423	409,214	1,440,324	95,958	154,186	30,475						
Bayburt	12,946	120,392	20,275	339,126	640,216	69,136	106,228	38,384						
Bilecik	12,134	108,470	15,407	856,548	384,510	76,423	102,868	29,057						
Bingöl	21,847	206,034	43,700	289,855	582,037	80,128	122,481	141,643						
Bitlis	23,326	299,101	51,061	367,088	1,330,639	93,487	118,860	183,001						
Bolu	16,565	120,818	21,215	1,083,962	609,299	101,369	102,025	43,795						
Burdur	9,278	126,875	19,438	1,264,228	690,799	109,592	108,511	8,012						
Bursa	13,535	77,352	10,222	642,368	406,810	56,392	122,235	36,214						
Çanakkale	17,967	90,760	14,340	788,554	391,562	61,788	125,718	14,798						
Çankırı	12,231	146,927	27,126	1,067,579	569,631	96,406	151,882	31,406						
Çorum	8,313	82,110	22,236	606,456	525,216	74,865	104,915	20,685						
Denizli	9,748	100,861	16,834	689,796	437,561	76,356	145,806	14,315						
Diyarbakır	21,954	172,790	38,884	363,344	573,883	94,794	116,556	61,117						
Düzce	13,901	94,128	22,201	508,516	293,422	76,549	103,033	26,120						



**Table 4** Average annual range of vehicles (km) (continued)

Provinces	2018											
	Car		Minibus		Bus		Small truck		Truck		Motorcycle	
	Gasoline	Diesel	LPG	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Gasoline
Edirne	19,402	231,893	12,982	2,078,312	763,700	183,267	326,902	24,795				
Elazığ	9,452	86,765	16,048	375,456	699,897	60,848	103,026	49,654				
Erzurum	14,838	109,335	19,937	553,744	495,522	59,125	99,240	165,723				
Erzincan	12,903	109,930	19,218	463,161	575,607	67,714	143,309	23,844				
Eskişehir	10,724	92,970	11,585	1,026,993	519,868	84,232	133,339	30,969				
Gaziantep	11,397	106,622	17,898	460,926	515,481	68,031	118,457	11,829				
Giresun	13,079	111,332	25,146	147,616	1,095,847	40,207	89,908	80,610				
Gümüşhane	11,925	159,295	22,917	374,811	723,064	69,882	101,765	47,019				
Hakkari	46,444	516,627	75,305	191,970	1,471,690	112,369	71,026	169,275				
Hatay	11,165	95,069	17,350	408,872	464,147	77,564	88,787	8,110				
Iğdır	23,357	166,838	26,896	193,276	321,160	48,021	30,476	12,775				
Isparta	10,195	63,200	16,089	515,025	310,731	50,576	100,798	11,582				
İstanbul	11,686	61,687	4,972	462,734	375,558	65,524	117,605	57,600				
İzmir	12,090	79,037	14,074	954,712	346,310	64,618	130,526	19,111				
Kahramanmaraş	8,922	71,708	26,712	317,671	406,190	54,858	111,346	30,168				
Karabük	9,413	96,357	17,152	565,925	561,453	101,208	118,484	51,153				
Karaman	7,819	71,110	18,332	345,707	366,426	53,245	93,400	5,952				
Kars	23,203	198,088	24,490	334,171	552,785	72,893	112,012	94,533				
Kastamonu	9,849	71,942	20,060	390,738	359,067	62,838	76,206	31,850				
Kayseri	9,092	73,500	17,553	676,050	318,007	66,845	92,964	64,876				
Kırıkkale	10,153	217,143	33,494	1,365,430	1,248,898	268,586	320,774	59,430				
Kırklareli	16,965	105,203	11,458	779,073	378,805	94,095	133,628	20,428				
Kırşehir	8,048	57,459	19,555	491,543	341,477	63,258	85,663	36,713				
Kilis	22,007	83,533	26,897	217,796	508,141	58,064	75,630	5,566				
Kocaeli	17,514	162,351	17,921	1,088,059	476,348	124,926	146,626	75,718				
Konya	8,690	110,315	19,359	867,324	598,891	78,691	96,439	15,538				
Kütahya	8,331	88,279	17,500	585,340	437,692	85,479	118,574	15,762				

**Table 4** Average annual range of vehicles (km) (continued)

Provinces	2018													
	Car		LPG		Minitibus		Bus		Small truck		Truck		Motorcycle	
	Gasoline	Diesel	LPG		Diesel		Diesel		Diesel		Diesel		Gasoline	
Malatya	10,063	71,173	17,769		347,750		349,318		47,462		113,193		49,738	
Manisa	11,685	97,362	21,028		717,142		259,462		73,178		121,386		7,496	
Mardin	19,672	252,082	35,502		323,012		737,856		75,304		51,468		34,644	
Mersin	11,614	204,724	18,191		1,568,922		918,325		131,672		157,978		11,483	
Mugla	19,100	83,240	16,615		430,412		346,052		58,798		164,345		13,233	
Muş	17,752	218,832	46,360		311,755		929,431		62,818		99,174		96,050	
Neşehir	9,009	177,728	20,378		680,349		1,060,152		120,648		122,661		16,695	
Niğde	9,216	119,843	20,389		692,746		536,408		76,317		86,403		15,296	
Ordu	12,548	87,822	22,793		143,716		562,565		44,394		97,529		80,407	
Osmaniye	7,589	66,156	21,106		326,311		447,616		56,349		129,726		9,475	
Rize	14,074	116,036	18,028		281,478		541,032		29,984		60,330		92,099	
Sakarya	13,031	96,447	24,238		605,993		358,014		73,177		117,021		32,704	
Samsun	10,526	119,385	18,233		369,581		1,194,960		74,182		180,287		25,846	
Siirt	19,142	321,807	33,677		332,193		1,627,168		102,797		180,956		40,280	
Sinop	10,396	65,661	20,813		250,322		552,431		56,231		89,750		31,142	
Sivas	9,652	97,447	17,831		595,580		533,286		77,341		118,297		59,505	
Şanlıurfa	13,961	117,183	39,922		288,300		698,134		89,117		69,688		10,604	
Şimşak	30,263	964,874	58,920		627,825		1,950,087		173,645		33,210		28,005	
Tekirdağ	17,389	155,078	15,697		1,038,994		378,333		122,681		189,220		45,553	
Tokat	8,624	83,138	17,803		385,751		465,472		63,396		130,800		19,820	
Trabzon	10,623	102,472	13,874		266,072		580,469		46,503		83,387		90,633	
Tunceli	21,056	196,358	34,572		254,679		683,282		92,675		132,488		70,338	
Uşak	9,219	58,102	16,865		427,150		231,469		50,642		85,364		13,836	
Van	23,138	154,241	38,667		138,157		600,916		44,513		60,852		115,098	
Yalova	16,384	92,457	12,837		399,917		299,589		61,950		143,625		41,740	
Yozgat	8,355	105,269	28,203		491,488		787,203		99,981		88,615		64,259	
Zonguldak	9,281	47,074	16,067		245,143		211,957		42,019		64,701		43,073	

**Table 4** Average annual range of vehicles (km) (continued)

Provinces	2020											
	Car		Minibus		Bus		Small truck		Truck		Motorcycle	
	Gasoline	Diesel	LPG	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Gasoline
Adana	9,628	69,598	16,487	549,955	489,239	59,064	113,534	12,547				
Adıyaman	9,626	82,607	28,575	243,012	1,017,653	69,492	115,328	16,600				
Afyonkarahisar	14,313	139,287	26,472	651,335	767,100	89,098	120,050	16,078				
Ağrı	30,640	367,659	55,861	360,548	1,055,175	119,454	149,618	95,976				
Aksaray	9,727	93,211	18,473	1,102,320	429,573	87,543	90,766	24,525				
Amasya	8,192	66,904	20,361	358,174	582,733	59,337	107,145	19,145				
Ankara	7,850	55,151	9,901	852,688	443,339	70,219	98,059	111,956				
Antalya	11,040	50,944	12,066	443,135	237,171	36,669	105,934	10,467				
Ardahan	31,454	1,252,403	38,427	1,688,995	8,232,410	431,971	909,101	118,826				
Artvin	17,539	151,873	17,590	312,002	734,235	45,701	64,756	85,176				
Aydın	14,076	124,364	16,483	570,226	760,269	83,149	241,972	9,835				
Balıkesir	15,568	83,002	15,271	717,676	539,675	65,891	132,585	14,138				
Bartın	11,406	50,128	18,868	250,368	267,020	49,062	85,892	32,721				
Batman	23,020	468,721	32,353	684,124	2,358,326	161,559	262,138	25,853				
Bayburt	13,696	106,427	19,970	321,510	607,149	63,030	99,400	38,108				
Bilecik	12,769	96,207	15,120	767,877	353,526	69,161	97,075	28,430				
Bingöl	23,724	180,317	36,349	306,397	555,725	80,722	116,515	138,367				
Bitlis	24,977	328,734	49,967	426,357	1,510,289	110,896	137,299	162,388				
Bolu	18,607	101,239	19,602	984,558	585,261	87,576	90,592	46,072				
Burdur	9,438	97,875	17,635	1,009,877	616,405	86,406	88,456	7,760				
Bursa	13,085	66,567	9,183	586,361	411,412	51,623	115,004	32,348				
Çanakkale	18,116	92,568	12,806	844,341	462,570	65,169	136,393	13,930				
Çankırı	14,589	261,506	25,446	2,022,651	1,050,909	176,720	282,031	30,032				
Çorum	9,431	91,597	20,975	729,030	673,944	86,077	124,327	22,169				
Denizli	9,300	121,911	15,256	884,527	597,611	95,491	193,307	13,317				
Diyarbakır	22,799	158,442	39,264	353,562	544,245	96,529	117,433	56,928				
Düzce	14,335	81,532	21,258	453,831	287,225	68,228	94,479	24,150				

**Table 4** Average annual range of vehicles (km) (continued)

Provinces	2020											
	Car		Minitibus		Bus		Small truck		Truck		Motorcycle	
	Gasoline	Diesel	LPG	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Gasoline	Gasoline
Edirne	18,238	324,034	12,005	2,977,874	1,191,138	262,824	477,194	22,182				
Elazığ	10,041	69,936	15,847	356,422	628,064	51,595	88,592	51,272				
Erzurum	15,092	98,587	18,758	571,676	463,563	56,498	95,813	150,588				
Erzincan	13,945	98,069	17,805	460,181	554,813	63,490	135,696	24,320				
Eskişehir	10,093	76,459	10,210	864,968	476,180	72,073	115,533	27,016				
Gaziantep	10,885	105,005	16,302	481,658	525,214	68,451	120,040	10,926				
Giresun	14,693	113,387	24,401	169,840	1,196,338	41,844	100,423	77,767				
Gümüşhane	13,849	116,570	20,542	311,262	580,569	53,650	80,159	51,062				
Hakkari	53,930	531,900	84,996	237,029	1,489,350	136,498	80,264	142,861				
Hatay	11,023	84,557	16,487	448,697	455,147	74,423	86,548	7,945				
Iğdır	27,212	190,768	26,860	229,595	419,732	56,553	34,636	13,394				
Isparta	9,892	50,513	14,710	442,741	279,874	42,400	86,287	10,339				
İstanbul	10,757	49,245	4,402	391,423	350,483	54,135	103,165	45,341				
İzmir	11,415	59,591	11,543	736,516	303,300	51,127	106,288	17,466				
Kahramanmaraş	9,366	60,874	25,126	309,535	395,447	48,967	103,366	31,423				
Karabük	9,588	133,825	15,962	840,943	888,562	145,544	169,097	44,248				
Karaman	8,431	69,759	18,073	382,249	421,662	53,220	94,796	6,285				
Kars	23,818	178,254	24,366	336,687	541,514	71,213	110,275	84,070				
Kastamonu	10,634	73,600	19,098	445,666	439,762	63,902	80,781	30,663				
Kayseri	9,231	57,809	15,973	554,496	255,260	54,346	77,567	60,811				
Kırıkkale	11,362	166,284	31,853	1,041,253	1,131,449	209,605	246,775	57,353				
Kırklareli	17,192	105,867	11,623	726,760	368,542	99,691	142,041	19,437				
Kırşehir	8,627	55,783	19,347	503,923	409,774	63,110	85,419	35,779				
Kilis	22,129	89,369	27,099	273,691	650,607	65,610	88,887	5,291				
Kocaeli	16,609	125,438	15,972	860,606	417,270	103,776	124,996	65,324				
Konya	8,663	84,757	17,724	675,839	502,731	61,787	75,315	15,106				
Kütahya	8,514	95,227	16,295	687,801	529,164	95,370	132,657	14,668				

**Table 4** Average annual range of vehicles (km) (continued)

Provinces	2020											
	Car		Minibus		Bus		Small truck		Truck		Motorcycle	
	Gasoline	Diesel	LPG	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Gasoline
Malatya	10,473	58,046	17,026	323,942	301,005	40,933	98,708	48,776				
Manisa	13,119	94,347	19,875	722,969	277,558	72,411	125,187	8,021				
Mardin	20,784	320,403	34,246	450,256	1,009,449	104,621	69,176	30,637				
Mersin	2,738	131,662	17,386	6,479,378	6,910,342	1,269,703	2,222,848	317,208				
Muğla	19,358	68,200	15,605	395,778	317,786	49,269	139,412	12,639				
Muş	20,556	210,391	47,157	330,645	856,752	64,885	101,971	97,415				
Neveşehir	9,061	81,767	16,606	314,433	545,839	56,887	61,200	16,395				
Niğde	9,846	109,940	19,950	675,932	538,989	72,440	85,863	16,269				
Ordu	13,947	80,724	21,402	148,605	526,507	43,582	97,769	77,031				
Osmaniye	7,732	45,227	20,808	252,983	338,791	40,665	94,990	9,589				
Rize	14,637	105,249	16,695	284,471	605,530	28,501	60,151	84,556				
Sakarya	13,199	83,391	22,005	559,295	372,642	66,314	109,282	30,311				
Samsun	10,496	97,910	16,191	348,373	1,128,415	65,056	163,654	25,476				
Siirt	20,917	367,726	42,749	412,085	1,845,623	123,506	239,741	35,884				
Sinop	11,275	56,230	18,430	240,778	540,156	50,010	81,062	28,633				
Sivas	9,749	72,936	17,282	509,316	469,568	60,675	95,509	55,403				
Şanlıurfa	15,077	128,172	44,680	338,721	731,868	105,663	77,502	10,239				
Şırnak	35,775	1,064,667	62,865	896,499	2,493,052	250,038	44,627	32,227				
Tekirdağ	17,470	165,714	15,443	1,169,440	423,000	136,836	209,041	42,165				
Tokat	9,266	76,876	16,947	408,358	525,262	62,096	133,466	20,784				
Trabzon	10,514	76,617	12,207	225,764	548,516	37,002	71,189	81,287				
Tunceli	22,979	154,341	32,001	256,985	537,744	79,778	120,570	74,862				
Uşak	9,130	66,124	16,321	491,408	309,427	58,686	101,603	12,694				
Van	23,820	134,883	38,514	129,893	492,588	42,302	57,401	97,971				
Yalova	18,504	88,700	12,004	381,596	307,822	62,643	148,783	38,991				
Yozgat	9,383	111,850	28,033	596,304	908,702	107,322	97,818	62,761				
Zonguldak	9,470	52,044	14,821	297,325	264,884	49,887	75,398	37,103				

**Table 5** Fuel densities

<i>Fuel</i>	<i>Density at 15°C, kg/L</i>	<i>Density accepted in the study, kg/L</i>
Gasoline	0.730–0.780	0.760
Diesel	0.810–0.850	0.830
LPG	0.508–0.584	0.550

*Source:* Bayrakçeken and Kuş (2004)

### 2.2.3 Tier-3 approach

For energy, the tier-3 method uses either detailed emission models or individual plant-level measurements and data where appropriate. When properly applied, these models and measurements provide better estimates primarily of non-CO<sub>2</sub> greenhouse gases, although at the expense of more detailed information and effort (IPCC, 2006). Since the necessary data for the tier-3 method could not be obtained, calculations could not be made according to the tier-3 method in this study.

## 3 Results

Within the scope of this study, carbon footprint calculations originating from road transportation in Turkey for 2018 and 2020 were calculated using Tier 1 and Tier 2 methods for each province and presented with maps prepared using the ARCGIS method.

### 3.1 Carbon footprint by tier-1 method

CO<sub>2</sub> emissions calculated according to the tier-1 method for all provinces are presented in Table 6. Looking at Table 6, it is seen that diesel fuels have the highest CO<sub>2</sub> emissions and gasoline has the lowest CO<sub>2</sub> emissions among the fuels consumed in Turkey. As can be seen in Table 2, this is the result of the fact that diesel fuel is preferred the most throughout the country. In Figure 2, the CO<sub>2</sub> emissions generated by the fuel consumed for 2018 and 2020, respectively, are presented. In the calculations made according to the Tier 1 method, it is seen in Figure 2 that the CO<sub>2</sub> emissions from gasoline are 7.4% and 7.7%, the CO<sub>2</sub> emissions from diesel fuel are 79.8% and 79.9%, and the CO<sub>2</sub> emissions from LPG are 12.8% and 12.4%, for 2018 and 2020 respectively. Figure 2 shows that there is no significant difference between 2018 and 2020 in the CO<sub>2</sub> emission values. According to the tier-1 method, it is seen in Figures 3 and 4 and Table 6 that Istanbul, Ankara and Izmir have the highest CO<sub>2</sub> emissions in Turkey respectively for 2018 and 2020, followed by the big cities. Again, when Figures 3 and 4 are examined, it is seen that western provinces have higher CO<sub>2</sub> emissions than eastern provinces. It is thought that CO<sub>2</sub> emissions are high as a result of the higher population density of the western provinces.

**Table 6** CO<sub>2</sub> emissions of provinces according to tier-1 method

<i>Provinces</i>	<i>2018</i>			<i>2020</i>		
	<i>Gasoline</i>	<i>Diesel</i>	<i>LPG</i>	<i>Gasoline</i>	<i>Diesel</i>	<i>LPG</i>
Adana	157	1,718	395	161	1,776	384
Adıyaman	22	396	107	24	312	99
Afyonkarahisar	57	747	169	62	924	160
Ağrı	12	236	35	13	236	33
Aksaray	27	433	87	32	463	84
Amasya	23	307	82	24	301	84
Ankara	626	6,512	1,186	596	6,398	1,048
Antalya	298	2,277	463	292	2,060	445
Ardahan	5	72	8	6	348	10
Artvin	13	174	20	14	187	20
Aydın	125	951	226	128	1,722	208
Balıkesir	152	1,308	232	163	1,326	223
Bartın	16	124	40	16	109	38
Batman	18	323	37	17	526	33
Bayburt	4	56	9	4	53	9
Bilecik	20	255	35	21	241	35
Bingöl	8	110	23	9	106	19
Bitlis	9	166	28	9	188	26
Bolu	46	478	82	51	428	76
Burdur	25	489	73	25	398	66
Bursa	329	2,700	350	336	2,611	329
Çanakkale	81	586	91	82	644	81
Çankırı	13	227	41	15	423	38
Çorum	33	473	126	38	559	117
Denizli	93	1,386	227	92	1,840	210
Diyarbakır	55	624	138	57	605	137
Düzce	38	374	87	40	347	83
Edirne	65	1,122	62	62	1,687	57
Elazığ	33	429	78	37	390	81
Erzincan	18	218	37	20	211	35
Erzurum	43	454	81	44	435	76
Eskişehir	87	1,090	133	84	947	119
Gaziantep	128	1,720	283	126	1,863	264
Giresun	27	328	73	31	366	72
Gümüşhane	6	118	17	7	94	15
Hakkari	5	78	11	6	84	12
Hatay	115	1,402	251	118	1,384	246

**Table 6** CO<sub>2</sub> emissions of provinces according to tier-1 method (continued)

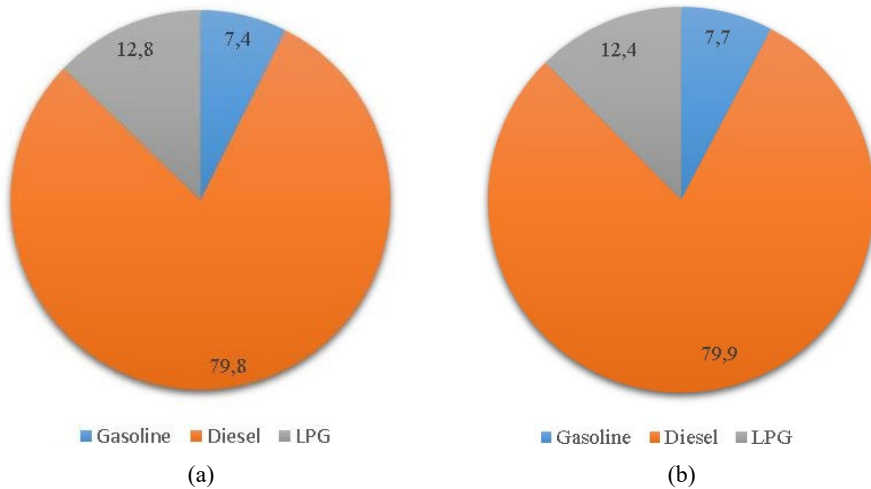
Provinces	2018			2020		
	Gasoline	Diesel	LPG	Gasoline	Diesel	LPG
İğdir	7	76	12	8	89	11
Isparta	41	362	90	40	312	83
İstanbul	1,650	12,523	990	1,551	10,845	885
İzmir	453	4,254	743	450	3,585	634
Kahramanmaraş	57	658	240	63	621	234
Karabük	19	281	49	19	404	44
Karaman	14	183	46	15	191	45
Kars	14	167	20	14	156	20
Kastamonu	30	318	87	32	340	81
Kayseri	105	1,215	285	109	1,039	262
Kırıkkale	21	651	98	23	506	88
Kırklareli	50	447	48	51	483	48
Kırşehir	15	156	52	16	161	51
Kilis	12	64	20	12	73	20
Kocaeli	199	2,651	287	199	2,298	267
Konya	150	2,740	472	150	2,243	428
Kütahya	43	662	129	44	750	117
Malatya	45	461	113	50	424	113
Manisa	124	1,481	314	140	1,537	295
Mardin	22	412	57	23	543	53
Mersin	156	3,946	344	158	2,833	341
Muğla	193	1,207	236	202	1,086	227
Muş	8	139	29	9	137	28
Nevşehir	23	653	73	24	332	62
Niğde	21	389	65	23	394	65
Ordu	45	448	114	52	463	112
Osmaniye	29	368	115	32	283	119
Rize	23	276	42	25	277	40
Sakarya	94	995	245	97	934	225
Samsun	88	1,431	214	94	1,339	202
Siirt	7	160	15	7	182	19
Sinop	16	145	45	17	132	39
Sivas	39	572	103	40	462	100
Şanlıurfa	65	787	263	66	863	275
Şırnak	7	299	18	8	373	20
Tekirdağ	122	1,563	155	123	1,787	152
Tokat	34	469	98	38	485	97



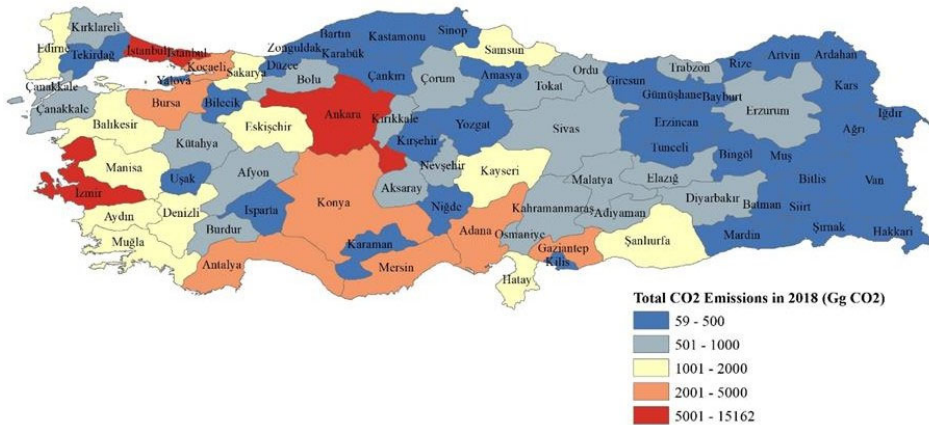
**Table 6** CO<sub>2</sub> emissions of provinces according to tier-1 method (continued)

Provinces	2018			2020		
	Gasoline	Diesel	LPG	Gasoline	Diesel	LPG
Trabzon	55	459	101	58	648	94
Tunceli	4	48	8	4	42	8
Uşak	30	274	78	30	330	74
Van	31	301	74	31	267	70
Yalova	29	235	32	33	241	30
Yozgat	20	365	96	22	402	92
Zonguldak	43	315	105	44	371	96

**Figure 2** CO<sub>2</sub> emissions of fuels used in road transportation according to the tier-1 method, (a) for 2018 (b) for 2020 (see online version for colours)



**Figure 3** CO<sub>2</sub> emissions in 2018 according to the tier-1 method (see online version for colours)









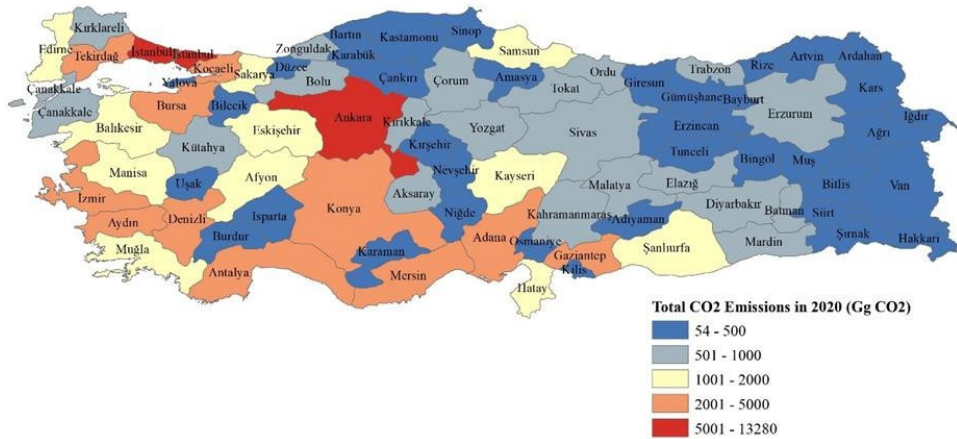


**Table 7** CO<sub>2</sub> emissions of provinces according to tier-2 method (continued)

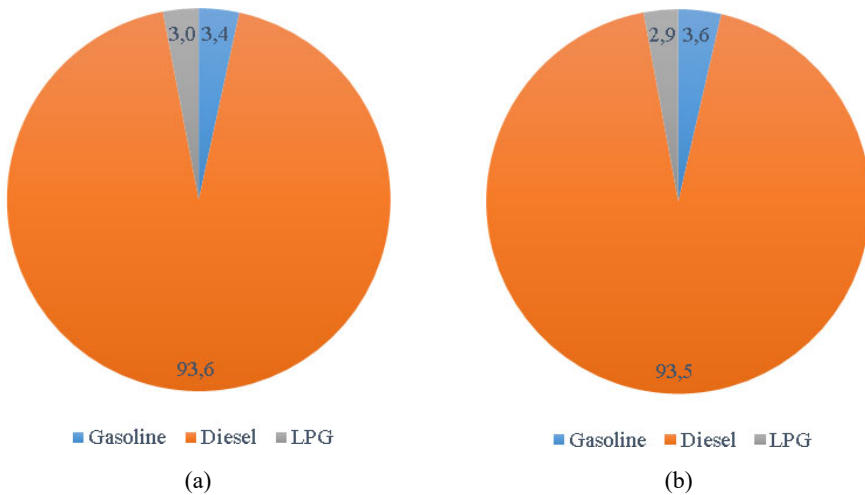
Provinces	2020													
	Car		LPG		Minibus		Bus		Small truck		Truck		Motorcycle	
	Gasoline	Diesel	LPG		Diesel		Diesel		Diesel		Diesel		Gasoline	Gasoline
Edirne	62	1,687	57		1,687		1,687		1,687		1,687		1,687	62
Elazığ	37	390	81		390		390		390		390		390	37
Erzurum	20	211	35		211		211		211		211		211	20
Erzincan	44	435	76		435		435		435		435		435	44
Eskişehir	84	974	119		974		974		974		974		974	84
Gaziantep	126	1,863	264		1,863		1,863		1,863		1,863		1,863	126
Giresun	31	366	72		366		366		366		366		366	31
Gümüşhane	7	94	15		94		94		94		94		94	7
Hakkari	6	84	12		84		84		84		84		84	6
Hatay	118	1,384	246		1,384		1,384		1,384		1,384		1,384	118
Iğdır	8	89	11		89		89		89		89		89	8
Isparta	40	312	83		312		312		312		312		312	40
İstanbul	1,551	10,845	885		10,845		10,845		10,845		10,845		10,845	1,551
İzmir	450	3,585	634		3,585		3,585		3,585		3,585		3,585	450
Kahramanmaraş	63	621	234		621		621		621		621		621	63
Karabük	19	404	44		404		404		404		404		404	19
Karaman	15	191	45		191		191		191		191		191	15
Kars	14	156	20		156		156		156		156		156	14
Kastamonu	32	340	81		340		340		340		340		340	32
Kayseri	109	1,039	262		1,039		1,039		1,039		1,039		1,039	109
Kırıkkale	23	506	88		506		506		506		506		506	23
Kırklareli	51	483	48		483		483		483		483		483	51
Kırşehir	16	161	51		161		161		161		161		161	16
Kilis	12	73	20		73		73		73		73		73	12
Kocaeli	199	2,298	267		2,298		2,298		2,298		2,298		2,298	199
Konya	150	2,243	428		2,243		2,243		2,243		2,243		2,243	150
Kütahya	44	750	117		750		750		750		750		750	44



**Figure 4** CO<sub>2</sub> emissions in 2020 according to the tier-1 method (see online version for colours)



**Figure 5** CO<sub>2</sub> emissions of fuels used in road transportation according to the tier-2 method, (a) for 2018 (b) for 2020 (see online version for colours)



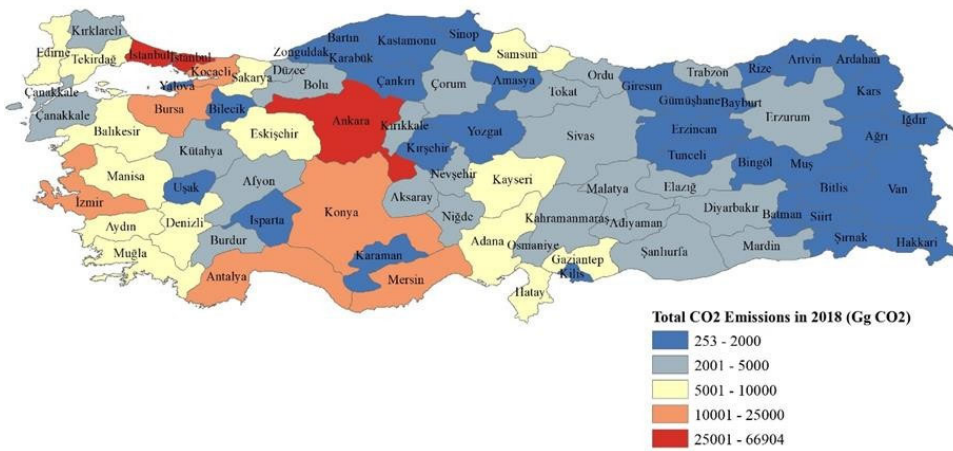
### 3.2 Carbon footprint by tier-2 method

According to the Tier 2 method, CO<sub>2</sub> emissions for all provinces were calculated and presented in Table 7. Looking at Table 7, it is seen that diesel fuels have the highest CO<sub>2</sub> emissions and LPG has the lowest CO<sub>2</sub> emissions among the fuels consumed in Turkey. When Table 7 is analysed on a provincial basis: Although CO<sub>2</sub> emissions from gasoline are lower than those from LPG in most of the provinces, in some densely populated provinces, especially Ankara, Istanbul and Izmir, LPG-originated CO<sub>2</sub> emissions are lower than gasoline-originated CO<sub>2</sub> emissions, resulting in a lower total LPG-originated CO<sub>2</sub> emission than gasoline-originated CO<sub>2</sub> emissions. In Figure 5, the CO<sub>2</sub> emissions generated by the fuel consumed for 2018 and 2020, respectively, are presented. In the calculations made according to the tier-1 method, it is seen in Figure 5 that the CO<sub>2</sub>

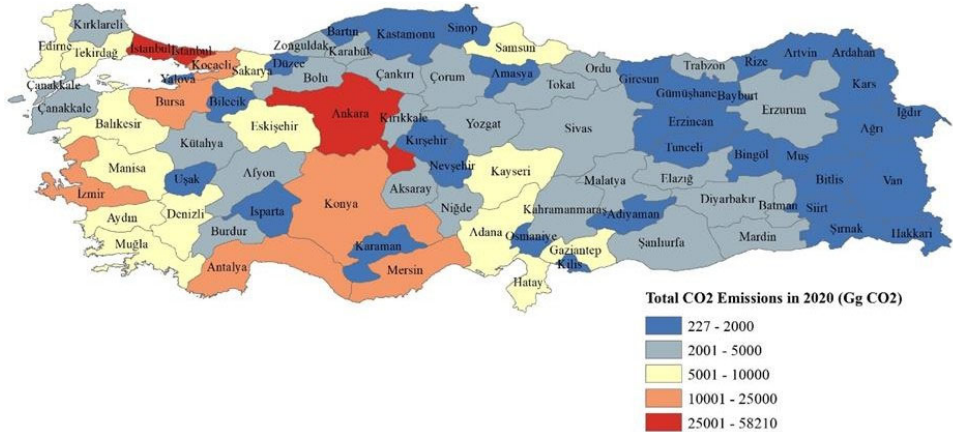


emissions from gasoline are 3.4% and 3.6%, the CO<sub>2</sub> emissions from diesel fuel are 93.6% and 93.5%, and the CO<sub>2</sub> emissions from LPG are 3.0% and 2.9%, for 2018 and 2020 respectively. Figure 5 shows that there is no significant difference between 2018 and 2020 in the CO<sub>2</sub> emission values. According to the tier-1 method, it is seen in Figure 6, Figure 7 and Table 7 that Istanbul, Ankara and Izmir have the highest CO<sub>2</sub> emissions in Turkey respectively for 2018 and 2020, followed by the big cities. Again, when Figures 6 and 7 are examined, it is seen that western provinces have higher CO<sub>2</sub> emissions than eastern provinces. It is thought that CO<sub>2</sub> emissions are high as a result of the higher population density of the western provinces, similar to Figure 3 and Figure 4. Dündar (2021), similarly, used the Tier 1 method in his study investigating the greenhouse gas emissions of big cities and stated that the highest greenhouse gas emissions belonged to the provinces of Istanbul, Ankara and Izmir, while the greenhouse gas emissions were lower in the provinces further east.

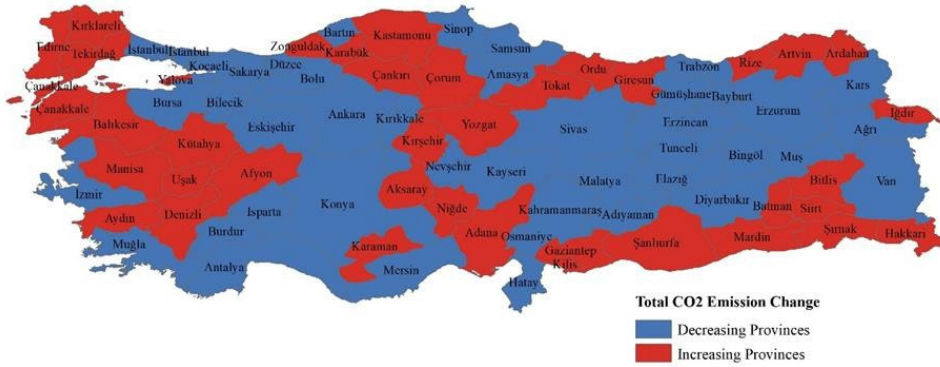
**Figure 6** CO<sub>2</sub> emissions in 2018 according to the tier-2 method (see online version for colours)



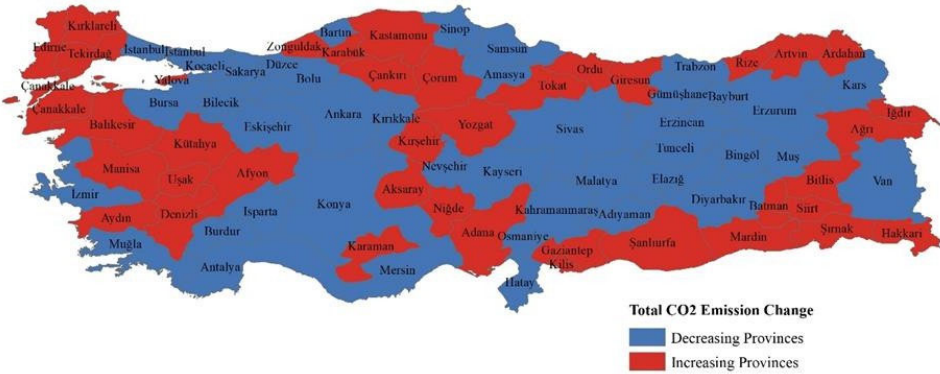
**Figure 7** CO<sub>2</sub> emissions in 2020 according to the tier-2 method (see online version for colours)



**Figure 8** Change in CO<sub>2</sub> emissions between 2018 and 2020 according to the tier-1 method (see online version for colours)



**Figure 9** Change in CO<sub>2</sub> emissions between 2018 and 2020 according to the tier-2 method (see online version for colours)



As a result of the study, provinces with increasing and decreasing CO<sub>2</sub> emissions between 2018 and 2020 according to tier-1 and tier-2 methods were determined and presented in Figures 8 and 9. The only difference between the two methods is seen in Ağrı province. While CO<sub>2</sub> emission decreased according to tier-1 method for Ağrı province, it increased according to tier-2 method. However, it is only about 1 Gg CO<sub>2</sub> in increase and decrease, and it is at a negligible level. In 2020, CO<sub>2</sub> emissions increased in about half of the provinces compared to 2018, while a decrease was observed in about half of them. Istanbul, Ankara and Izmir came first among the provinces that saw reductions in CO<sub>2</sub> emissions. Since these provinces have the highest CO<sub>2</sub> emissions, CO<sub>2</sub> emissions have decreased all over Turkey. This decrease was 3.4% according to the tier-1 method and 3.0% according to the tier-2 method. Looking at Turkey's total CO<sub>2</sub> emissions, it was 95,689 Gg CO<sub>2</sub> for 2018 and 92,424 Gg CO<sub>2</sub> for 2020, according to the tier-1 method, while it was 417,359 Gg CO<sub>2</sub> for 2018 and 404,631 Gg CO<sub>2</sub> for 2020 according to tier-2 calculations. Since more specific data are used in the tier-2 method, it is thought that the tier-2 method gives more accurate results. The results of the calculations made according to the tier-2 method were found to be approximately 4–5 times higher than the results of the studies carried out according to the tier-1 method. In the study conducted by Bıyık

and Civelekoğlu (2021) for the province of Isparta, it was stated that the results of the tier-2 method were higher than the tier-1 method at similar rates. Dündar (2021) calculated CO<sub>2</sub> emissions in 30 big cities in Turkey in 2010 and 2019 according to the tier-1 method and stated that they were 40,403 Gg CO<sub>2</sub> and 70,271 Gg CO<sub>2</sub>, respectively. Soylu (2007), on the other hand, stated that the CO<sub>2</sub> emission originating from road transportation in Turkey for 2004 was 36,858 kt according to the COPERT III method.

#### 4 Discussion

The transportation sector is among the main sectors that generate CO<sub>2</sub> emissions. It is known that road transportation has the highest CO<sub>2</sub> emission among the transportation sector. As a result of the study, Turkey's carbon footprint from road transportation in 2018 and 2020 was calculated. IPCC tier-1 and tier-2 approaches were used in the study. While there was a 3.4% reduction in CO<sub>2</sub> emissions according to the tier-1 method in 2020, there was a 3% reduction according to the tier-2 method. In 2020, it was observed that CO<sub>2</sub> emissions decreased from 95,689 Gg CO<sub>2</sub> to 92,424 Gg CO<sub>2</sub> according to the tier-1 method, and from 417,359 Gg CO<sub>2</sub> to 404,631 Gg CO<sub>2</sub> according to the tier-2 method. In fuels used in vehicles, it was determined that diesel fuels cause the highest CO<sub>2</sub> emissions in both tier-1 and tier-2 methods. In the study, it was seen that Istanbul, Ankara and Izmir have the highest CO<sub>2</sub> emissions among the provinces in Turkey, respectively. As a result of the study, it was observed that CO<sub>2</sub> emissions increased in parallel with the population, but the small decrease in CO<sub>2</sub> emissions in 2020 is a promising situation for Turkey.

As a result of the study, it is possible to suggest some solutions for reducing CO<sub>2</sub> emissions and carbon footprints caused by road transportation in Turkey. Based on the knowledge that a tree absorbs 12 kg of CO<sub>2</sub> per year during photosynthesis, afforestation efforts in cities should be accelerated without delay. Instead of using private vehicles, people should be encouraged to use public transportation and, where possible, pedestrian transportation. Alternative modes of transportation such as railway and seaway should be expanded. Non-motorised transportation should be encouraged by providing adequate bicycle lanes. The use of vehicles with hybrid technology should be expanded. Vehicles should be maintained regularly.

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