Ecological Indicators 45 (2014) 350–354

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

The evaluation of the air pollution index in Turkey

Aylin Çiğdem Köne [a], Tayfun Büke [b,*]

[a] Muğla Sıtkı Koçman University, Faculty of Economics and Administrative Sciences, Department of Economics, 48000 Muğla, Turkey
[b] Muğla Sıtkı Koçman University, Faculty of Technology, Department of Energy Systems Engineering, 48000 Muğla, Turkey

ARTICLE INFO

Article history:
Received 29 November 2013
Received in revised form 15 April 2014
Accepted 21 April 2014

Keywords:
Air pollution
Environmental pressures
Index
AHP

ABSTRACT

This paper evaluates the air pollution index in Turkey for the period 1990–2011 by using the four different environmental pressure categories, namely global warming potential, acidification potential, tropospheric ozone forming potential and particulate formation potential. These categories have weighted on a comparison basis, applying the Analytic Hierarchy Process methodology. Twenty-five academicians with environmental engineering backgrounds were asked to fill in the comparison matrices in order to reduce bias in the evaluation.

According to the results obtained for the air pollution index in Turkey are better for the time period 2001–2011 than the time period 1990–2000. The study provides deeper insights into the causes of air pollution, and gives further implications on air pollution protection strategies in Turkey.

1. Introduction

Environmental pollution is a major problem facing all nations of the world. The pollutants such as carbon monoxide (CO), ammonia (NH_3), nonmethane volatile organic compounds (NMVOC), nitrogen oxides (NO_x), particulate matter (PM_{coarse}), sulphur dioxide (SO_2), carbon dioxide (CO_2) and (CH_4) emitted into the atmosphere do not remain confined to the area near the source of emission or to the local environment, and can be transported over long distances, and create several regional and global environmental problems. The air pollutants are categorized according to their environmental effects. The different pollutants and corresponding environmental pressure categories are presented in Table 1 (Houghton et al., 1996; De Leeuw, 2002; Kortelainen, 2008). The individual pollutants are aggregated into the environmental pressure indicators by using scientifically valid conversion factors from environmental impact assessment studies. Some individual emissions such as CH_4 and NH_3 cause different types of pressures, they are accounted for in several pressure indicators. The conversion factors for each pressure category are presented in Table 2 (EEA, 2011).

This paper evaluates the air pollution index in Turkey for the period 1990–2011 by using the four different environmental pressure categories, namely global warming potential (GWP), acidification potential (AP), tropospheric ozone forming potential (TOFP) and particulate formation potential (PFP).

2. Method

There are several studies to find out the environmental policy performance of the countries (Ellis et al., 2010; Juwana et al., 2012; Singh et al., 2012). In this study, GWP, AP, TOFP and PFP categories have been considered as indicators to develop an air pollution index for Turkey. It is important to note that air pollutant emissions strongly depend on the primary energy supply. On the other hand the pollutant emission intensities (pollutant emission/energy consumption) are useful indicators that can be used to establish baselines for the emission of certified of a country (Mielnik and Goldemberg, 1999; Sun, 2006). Therefore we have used individual air pollutant intensities of the Turkey representing 4 different environmental pressure categories namely GWP, AP, TOFP and PFP (Table 1) by using the conversion factors given in Table 2. The conversion factors given in Table 2 are taken from the references EEA (2011), Houghton et al. (1996) and De Leeuw (2002).

National data for CO, NH_3, NMVOC, NO_x, PM_{coarse} SO_2 emissions and the CO_2, CH_4 emissions for the time period 1990–2011 are obtained from the Centre on Emission Inventories and Projections-European Monitoring and Evaluation Programme (CEIP-EMEP, in press) and Turkish Statistical Institute (TurkStat) respectively. Total primary energy supply is taken Republic of Turkey Ministry of Energy and Natural Resources (RTMENR). The calculated air pollutant emission intensities of Turkey according to the environmental pressure categories are presented in Table 3.

* Corresponding author. Tel.: +90 252 2111593.
E-mail addresses: cigdem.kone@gmail.com (A.Ç. Köne), tayfun.buke@gmail.com (T. Büke).

http://dx.doi.org/10.1016/j.ecolind.2014.04.032
1470-160X/

Table 1
Individual pollutants and environmental pressure categories.

Pollutants	Environmental pressure	Units
CO_2	GWP	(Gg CO_2 equivalent)
SO_2, NO_x, NH_3	AP	(Gg AP equivalent)
CO, NO_x, NMVOC, CH_4	TOFP	(Gg TOFP equivalent)
NO_x, SO_2, NH_3, (PM_{coarse})[a]	PFP	(Gg PFP equivalent)

[a] PMcoarse means particulate matter between 2.5 and 10 μm in diameter.

Table 2
Conversion factors for air pollutants.

Pollutant	Environmental pressure	Conversion factors	Units
SO_2	AP	0.03125	Tons of AP eq.
NO_x		0.02174	
NH_3		0.05882	
CO	TOFP	0.11000	Tons of TOFP eq.
NO_x		1.22000	
NMVOC		1.00000	
CH_4		0.01400	
NO_x	PFP	0.88000	Tons of PFP eq.
SO_2		0.54000	
NH_3		0.64000	
PM10		1.00000	

Table 3
Turkey air pollutant emission intensities according to the environmental pressure categories (tonnes of PC[a]/toe).

Year	GWP	AP	TOFP	PFP
1990	3.55616	0.00183	0.02875	0.04661
1991	3.69671	0.00182	0.02828	0.04592
1992	3.73527	0.00179	0.02814	0.04523
1993	3.70165	0.00166	0.02804	0.04265
1994	3.69594	0.00168	0.02803	0.04264
1995	3.75037	0.00160	0.02765	0.04118
1996	3.72076	0.00155	0.02665	0.03956
1997	3.70340	0.00147	0.02526	0.03747
1998	3.68510	0.00157	0.02533	0.03987
1999	3.71619	0.00155	0.02526	0.03893
2000	3.70447	0.00149	0.02461	0.03723
2001	3.70343	0.00145	0.02452	0.03581
2002	3.66675	0.00134	0.02377	0.03479
2003	3.62382	0.00124	0.02290	0.03224
2004	3.56726	0.00120	0.02208	0.03065
2005	3.62273	0.00125	0.02171	0.03141
2006	3.52057	0.00122	0.02039	0.03024
2007	3.53954	0.00124	0.02040	0.03073
2008	3.45327	0.00121	0.02051	0.03070
2009	3.48606	0.00124	0.02085	0.03088
2010	3.68004	0.00118	0.02010	0.03024
2011	3.68990	0.00120	0.02147	0.03027

[a] PC: pressure category.

Normalization is required prior to any data aggregation as the indicators in a data set often have different measurement units. In this study minimum–maximum normalization method (OECD, 2008) is applied to raw value of individual indicator. This method is used to produce an identical range for the values of indicators, e.g., 0–1. The general equation to calculate the normalized value of individual indicator i (S_i) is given as follows:

$$S_i = \frac{(X_i - X_{\min})}{(X_{\max} - X_{\min})} \quad (1)$$

where X_i is the raw value of individual indicator i, and $X_{\min}$ and $X_{\max}$ are the minimum and maximum raw values of individual indicator i.

Table 4
Normalized values of the air pollutant intensities of Turkey.

Year	GWP	AP	TOFP	PFP
1990	0.65370	0.00000	0.00000	0.00000
1991	0.18062	0.01084	0.05455	0.04245
1992	0.05084	0.06037	0.07062	0.08452
1993	0.16399	0.26316	0.08137	0.24179
1994	0.18320	0.23529	0.08333	0.24240
1995	0.00000	0.34830	0.12691	0.33181
1996	0.09966	0.43189	0.24214	0.43062
1997	0.15811	0.55882	0.40372	0.55839
1998	0.21970	0.39938	0.39482	0.41187
1999	0.11505	0.42879	0.40268	0.46898
2000	0.15449	0.52941	0.47839	0.57280
2001	0.15799	0.58978	0.48821	0.65995
2002	0.28147	0.75232	0.57582	0.72182
2003	0.42597	0.90403	0.67603	0.87804
2004	0.61631	0.97833	0.77127	0.97502
2005	0.42961	0.89474	0.81392	0.92873
2006	0.77348	0.94582	0.96648	0.99988
2007	0.70963	0.90248	0.96475	0.97008
2008	1.00000	0.95820	0.95169	0.97191
2009	0.88964	0.90712	0.91297	0.96067
2010	0.23671	1.00000	1.00000	1.00000
2011	0.20353	0.97523	0.84085	0.99817

Eq. (1) is used when the $X_{\min}$ is the least preferred value and the $X_{\max}$ is the most preferred value. If $X_{\min}$ and $X_{\max}$ are the most and least preferred values, respectively, Eq. (1) is modified to:

$$S_i = 1 - \frac{(X_i - X_{\min})}{(X_{\max} - X_{\min})} \quad (2)$$

In this study, Eq. (2) has been used for the normalization since we have preferred to use the minimum values rather than the maximum values for normalizing of the air pollutant emission intensities. The calculated normalized values of the air pollutant intensities of Turkey according to the four environmental pressure categories by using the raw values of each individual indicator given in Table 3 are presented in Table 4.

In this study, the Analytic Hierarchy Process (AHP) has been employed to calculate the weight of each environmental pressure category in order to build a single index while taking into account that environmental problems have different importance.

AHP is a well-known technique based on the fact that the inherent complexity of multicriteria decision-making problem can be modelled breaking down it into several levels in such a way that they form a hierarchy with unidirectional hierarchical relationships between levels. The top level of the hierarchy is the main goal of the decision problem. The lower levels are the tangible and/or intangible criteria and sub-criteria that contribute to the goal. The bottom level is formed by the alternatives to evaluate in terms of the criteria. In each hierarchical level paired comparisons are made with judgments using numerical values taken from the AHP absolute fundamental scale of 1–9. These comparisons lead to dominance matrices from which ratio scales are derived in the form of principal eigenvectors. These matrices are positive and reciprocal ($a_{ij} = 1/a_{ji}$). The synthesis of AHP combines multidimensional scales of measurement into a single one-dimensional scale of priorities. The method also calculates a consistency ratio to verify the coherence of the judgments, which must be about 0.10 or less to be acceptable (Saaty, 1980; Saaty and Peniwati, 2007; García Melón et al., 2008; Aragonés Beltran et al., 2010).

There are many papers dealing with the application of AHP to pollution and environmental indicators. Some of the applications of AHP to pollution and environmental indicators are found in environmental quality indexing of large industrial development alternatives Solnes (2003); composite sustainability performance index (Singh et al., 2007); construct an environmental pressure index proposal for urban development planning Gómez-Navarro