Environmental Science and Pollution Research (2019) 26:12894–12906
https://doi.org/10.1007/s11356-019-04779-x

RESEARCH ARTICLE

The impact of carbon emission and forest activities on health outcomes: empirical evidence from China

Muhammad Umar Farooq[1,2] · Umer Shahzad[3] · Suleman Sarwar[4,3] · Li ZaiJun[5]

Received: 4 August 2018 / Accepted: 4 March 2019 / Published online: 19 March 2019

Abstract
The higher economic growth of China intensifies the consumption of fossil fuel, such as coal and oil, for electricity generation, transportation etc., which is responsible for environmental degradation through the emissions of carbon, sulfur, and nitrogen etc. The objectives of this study are to investigate the impact of greenhouse gas emission on health issues and provide the effective solution to overcome health-related issues, caused by carbon, sulfur, and nitrogen emission. For this purpose, we propose that higher afforestation activities can help to mitigate the carbon emission and can help to reduce the health diseases. The findings of quantile regressions reported that an increase in carbon emission causes significantly higher health issues. On the contrary, afforestation activities reported a negative coefficient, suggesting that growth of forests can be useful measure in control of health issues. The findings of the current study can be utilized in policy making and to explore the nexus between greenhouse gas emission, afforestation, and health issues.

Keywords Carbon emission; afforestation · Health issues · China

Introduction

Carbon emission (CO_2) is the major culprit for environmental degradation which adversely affects human health in various ways such as inhalation, skin contact, and eye contact ingestion, resulting to even carcinogenic effects through long-term exposure (Tox Town 2017; CCOHS 2017; Fernandoa and Lin Hor 2017; Dong et al. 2018a). In global CO_2 emission, China

Highlights
1. Carbon emission induces increase in health issues in China.
2. Greenhouse gases such as nitrogen, sulfur, and carbon are the major contributor of air pollution and harmful diseases.
3. Afforestation activities and stop deforestation can help to minimize health issues and to save health-related expenditures.
4. By increasing investments on forests can help to reduce greenhouse gases and carbon emission, which further lowers health issues.
5. The government should provide better living conditions to the urban and rural population, through planting green belts, parks, and better sewerage systems.

Responsible editor: Muhammad Shahbaz

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s11356-019-04779-x) contains supplementary material, which is available to authorized users.

✉ Umer Shahzad
Shehzad-umer@hotmail.com

Muhammad Umar Farooq
umarfarooqgcuf@yahoo.com

Suleman Sarwar
ch.sulemansarwar@gmail.com

Li ZaiJun
junzailiny@gmail.com

Extended author information available on the last page of the article

stands at the first position with 28% total emissions. In fact, the country submitted its Intended National Determined Contribution (INDC) in Paris climate conference stating that the country has to reduce its CO_2 emission by 2030 from its level in the year 2005 (Shao et al. 2018). Besides, the country has also witnessed a tremendous increase in health issues which have consequently increased the health expenditures. Figure 1a demonstrates the CO_2 emission, Fig. 1b total population, and Fig. 1c health expenditures patterns of China from 2000 to 2015, showing that CO_2 emission, population, and health expenditures have increased over the last few years. The health expenditure in China to be precise has to be expanded to cater for the health issues related to environmental degradation, population growth, and lack of facilities. To successfully manage the issue, China needs massive environmental reforms (e.g., China's new environmental protection law 2016) to mitigate carbon level to protect human development and to minimize the funds spent on health treatment plans. In the study, we consider CO_2, NO_2, and SO_2 gases on the investigation of the impact of human health in China as a whole and as regional analysis (Zhang, 2017).

More healthcare problems add to the health care financing both in developing and developed countries with a goal of improving the population's health outcomes (Sirag et al. 2016). The high healthcare-related issues place a lot of pressure on the government which has to squeeze the budget to cater for them and provide better treatment facilities (Yazdi and Khanalizadeh 2017). The increase in healthcare spending suggests that environmental conditions affect human health. The primary source of environmental degradation is air pollution sourcing mainly from greenhouse gas emission including carbon dioxide, nitrogen dioxide, and sulfur dioxide emissions (Gerdtham and Jonsson 1992; Jerrett et al. 2003; Yazdi and Khanalizadeh 2017). There is clear evidence that these greenhouse gas emissions threaten human health both directly and indirectly, and it is bound to cause adverse effects to human development in future (Field et al. 2014; Ebi et al. 2017; Gao et al. 2018). Climate change also affects human health through various ways such as extreme weather events, air pollution, ultraviolet radiation, and increased temperatures rising above sea level (Stanley and Farrant 2015; Field, 2009; Field et al. 2014; Gao et al. 2018). The present study only discusses the adverse effects on human health from air pollution and greenhouse emissions. The Kyoto protocol divides greenhouse emissions into carbon dioxide (CO_2), methane (CH_4), nitrous oxide (NO_2), sulfur oxide (SO_2), and halocarbons. In order to control global warming to 2 °C and to protect human health, it has become an urgent need to reduce greenhouse emissions. Among all greenhouse emissions, the carbon emission share in the atmosphere is 76%, methane accounts for 16%, while nitrous oxide accounts for 6% and F-gases (such as hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride, and sulfur oxide, etc.) 2% (IPCC 2014).

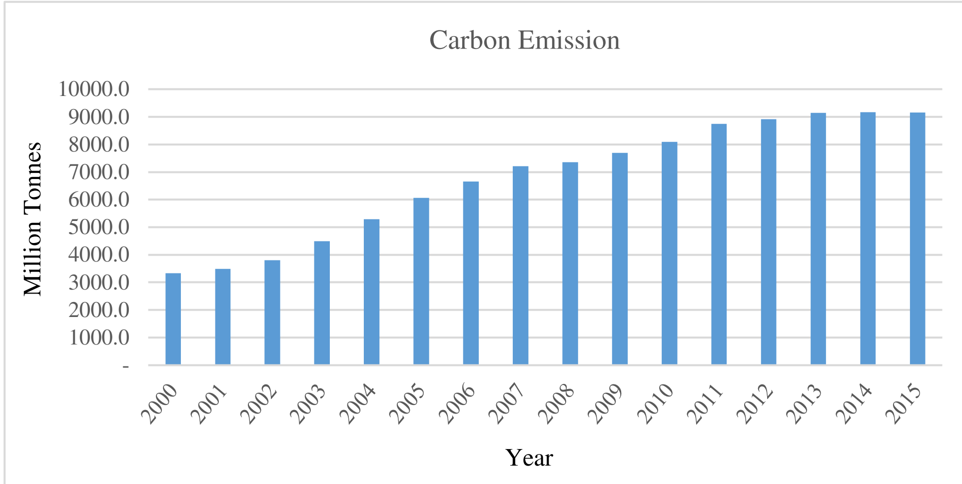
Recently, in growing literature of human activities to counter air pollution and environmental degradation, the role of the forest has been neglected in environment and health studies. Planting of new forests can help to reduce the amount of CO_2 emission in the atmosphere, through combining with sun's energy via the process of photosynthesis and subsequently resulting to its conversion into trunks, branches, leaves, and roots and remains stored as biomass until it is degraded back to the environment (Palmer 2012). Minnemeyer et al. (2017) argued that stopping deforestation in the world could reduce 7 billion CO_2 dioxide emissions annually, and 42% of total emission reductions could be achieved through reforestation of all grazing land in forested eco-regions. In addition, forests are carbon sinks and hence afforestation, reforestation,[1] and forest restoration (ARR) activities effectively remove carbon emission from the atmosphere (Ahmad 2017). Human activities like deforestation are among the major causes for the increased level of carbon in the atmosphere (The Guardian 2011; Waheed et al. 2018). The increasing pace of greenhouse gas emissions (specifically the CO_2 emission) has been implicated in a number of health problems and issues in different countries (Looi and Chua, 2007; Morin et al, 2013; Beatty and Shimshack 2014; Chaabouni et al. 2016). The effect of air pollution on human beings affects the labor productivity, which subsequently has an impact on industrial production, domestic output, and economic growth (Yazdi and Khanalizadeh 2017). This narrative highlights the idea that if air pollution through CO_2 emissions can be controlled by planting more forests then health issues can also be minimized. When afforestation and investments on forests are encouraged, the CO_2 level could be decreased in atmosphere which can father help to minimize health issues and health expenditures.

Over the last two decades, China has been taking necessary measures to reduce deforestation while promoting reforestation and afforestation. As a result, China stands at fifth position in the world with 207 million hectares of forest land (FAO 2010). China has allocated 725 billion Yuan (US$113 billion) into 20 new programs for afforesting of 56 million hectares of land. China intends to afforest half of its available land in less than one decade (Wolosin 2017). Figure 2 highlights the change in forest area and afforestation for China from 1980 to 2012, which reports the continuous increase in forest area.

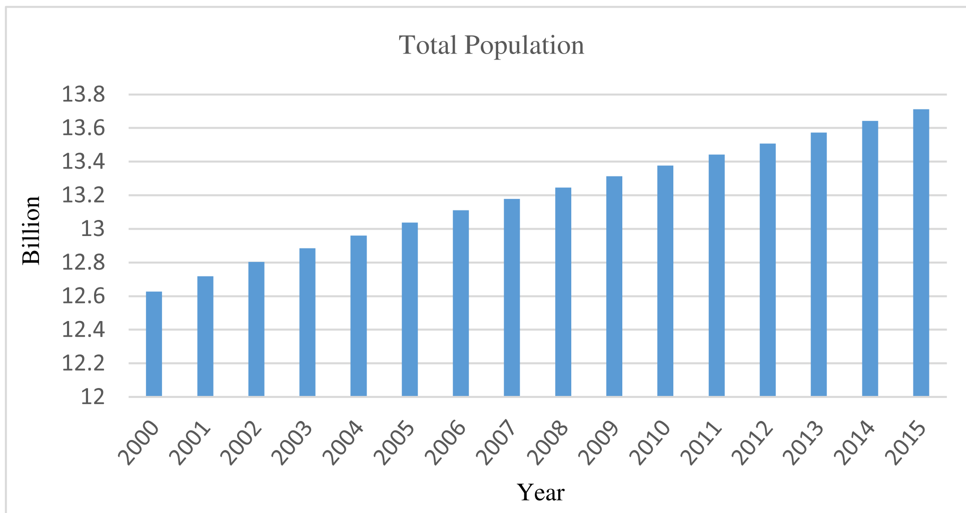
The present study aims to investigate the role of afforestation to reduce the health problems caused by CO_2 emissions in different Chinese provinces. As China is continuously facing exaggerating pace in health issues and health expenditures, it has become more than urgent need for China to identify the factors that contribute in inducing health issues and to make counter policies and reforms to protect human development. The present study adds in multifold directions to the existing

[1] Reforestation specifies to plant new trees in existing forest land. Afforestation indicates to form new forests on non-forest land.

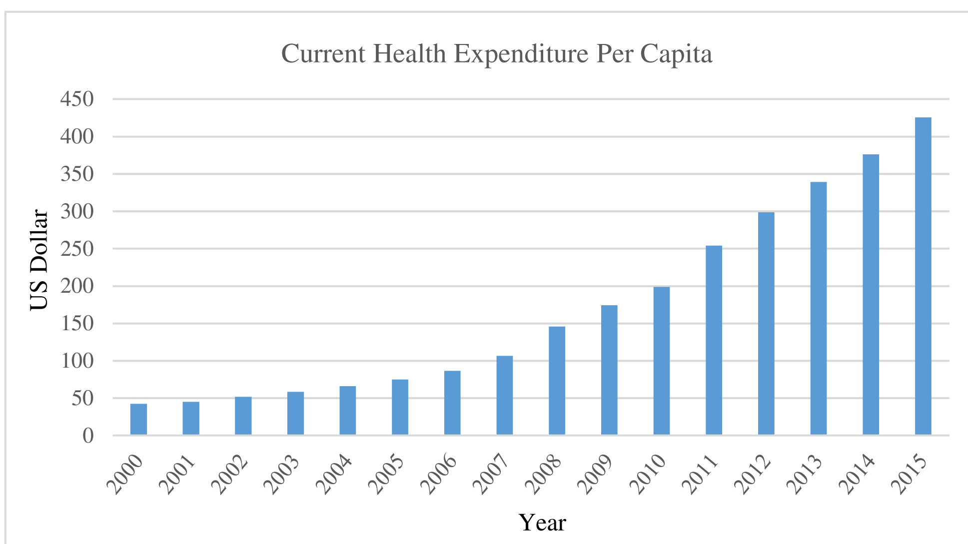
Fig. 1 Carbon emission of China, total population of China, health expenditures of China Source: World Bank, (2015)



(a) Carbon emission of China



(b) Total population of China



(c) Health expenditure

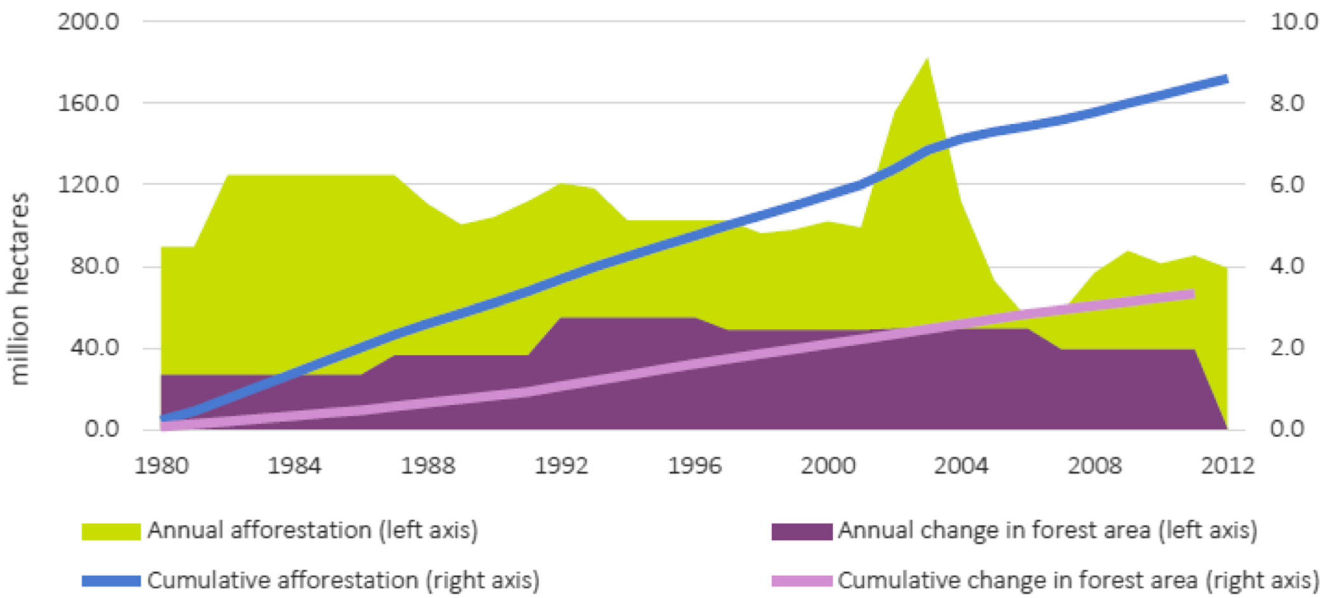


Fig. 2 Forest area and afforestation change. Source: Wolosin (2017)

literature through the following: firstly, this is the pioneer study that examines the role of CO_2 emission on health issues for the case of China. Recently, some of the studies have shown that CO_2 emission is posing a risk to human health which increases health expenditures and minimizes economic growth (Narayan and Narayan 2008; Janke et al. 2009; Beatty and Shimshack 2014; Chaabouni and Zghidi 2016; Yazdi and Khanalizadeh 2017). These studies investigated the health expenditures and CO_2 unidirectional and bidirectional aspects and have reported the various routes through which CO_2 emission affects human health (Tox Town 2017; CCOHS 2017; Fernandoa and Lin Hor 2017; Dong and et al., 2018). Another study reported on how health issues and diseases lower economic growth and industrial growth (Chaabouni and Zghidi 2016).It is definite that the increase in health issues and illnesses compels the government to spend on human health treatment plans to protect human development and economic development of the country. Therefore, health issues and the factors that contribute to the health issues must be dealt with if significant economic growth is to be witnessed in China.

Secondly, a significant contribution of this study is the inclusion of afforestation in health studies literature. Previously, forestry scientists and researchers have conducted limited studies regarding environment and economy (e.g., Brown et al. 2004; Achard et al. 2004; Stern 2006; Routa et al. 2011; Thuy et al. 2014; Waheed et al. 2018). This study attempts to fill the gap by incorporating the role of forests in controlling health issues and minimizing disease (Vittor et al, 2009). Plants including trees act as carbon sink and carbon source; (i) plants utilize carbon in the atmosphere to produce oxygen and carbohydrates during photosynthesis process, (ii) while in the decomposition process, the carbohydrates are again broken down into carbon and energy which is released back into the environment (Thuy et al. 2014; Griggs, 2017; Waheed et al. 2018). Deforestation activities also increase carbon in atmosphere especially when forests are set on fire on purpose (e.g., people living near forests forced to leave homes, or commercial purposes) (Beatty and Shimshack, 2014; Chaabouni and Zghidi 2016; Griggs, 2017; Joyce, 2017; Lathrop, 2017; Yazdi and Khanalizadeh 2017). Reforestation and afforestation helps to mitigate CO_2 emission from atmosphere, which further assists in reducing health issues in the country. Further, Appendix Figs. Fig. 4, Fig. 5, and Fig. 6 present the disease per province, CO_2 emission, and afforestation for the years 2005, 2010, and 2015. These figures demonstrate that higher CO_2 emission tends to boost the diseases, whereas higher afforestation activities cause a decline in health issues which supports our argument. With regard to all of these concerns, the study aims to examine the role of forests in control of health issues.

Thirdly, this is the pioneer study to investigate the role of other greenhouse gases, sulfur dioxide, and nitrogen dioxide, on health. The World Health Orgnization (2018) has reported that the greenhouse gas emissions and climate change affects social and environmental aspects of health such as clean air, safe drinking water, sufficient food, and secured shelter which further leads to increase in health issues and mortality rates of young people and children (Feldscher 2011; NIEHS 2017). In addition, greenhouse gases affect the public health in a number of ways including causing a heat wave and other climate-sensitive diseases, distorting the air quality, especially to the vulnerable population (EPA 2018). The World Health Organization (2018) has estimated that climate change is expected to cause 250,000 annual deaths from 2030 to 2050. Given all these concerns, the study included sulfur dioxide and nitrogen dioxide emission in an econometric model to examine its impact on health issues in China. The study aims to provide significant policy implications for government and policymakers to make effective regulations regarding health and environmental change.

Background literature

Recently, number of researchers have provided empirical studies and policies regarding health expenditures and CO_2 emission (Gerdtham and Jonsson 1992; Jerrett et al. 2003; Field et al. 2014;Yazdi and Khanalizadeh 2017; Ebi et al. 2017; Gao et al. 2018), whereas some of the researches (Stern 2006; Routa et al. 2011; Thuy et al. 2014; Zhou et al. 2017; Waheed et al. 2018 etc.) have dealt with forest and carbon emission. In general, previous literature has mainly focused on two strands; first strand explains the nexus between health expenditures and environment which reports that climate change induces an increase in health issues and diseases, which require higher spending on health treatment plans. On the other side, health issues and diseases decrease economic growth and industrial development (Yazdi and Khanalizadeh 2017). The second strand demonstrates the role of forest in mitigating CO_2 emission and controlling global warming. The forests can act as positive indicator in mitigating CO_2 emission and producing forest biomass energy, if forests are properly managed with sufficient investment (Routa et al. 2011; Waheed et al. 2018). Wang (2007) applied Granger causality method to determine the relationship of air pollutants: nitrogen oxides (NO_x), sulfur dioxide (SO_2), carbon monoxide (CO), total suspended particulates (TSP), and particulate matter smaller than 10 μm (PM_{10}) on respiratory diseases of residents in Beijing. The results indicated that nitrogen, sulfur, and CO_2 emission act as main culprits for respiratory diseases for the residents of Beijing. Chaabouni and Zghidi (2016) conducted an empirical investigation between carbon emission, health expenditures, and economic growth as income-wise classification of countries. The study selected 51 countries as three groups such as low-income group, middle-income group, and upper-income group over the period of 1995–2013. The empirical findings reveal that carbon emission leads to increase health expenditures for middle-income and upper-income group countries, while human health plays important role for economic growth, and it limits the impact on increasing deterioration of environmental quality. Concerning the Middle East and North African (MENA) countries, Yazdi and Khanalizadeh (2017) studied the effects of air pollution on economic growth and healthcare expenditures by employing Pedroni cointegration and autoregressive distributed lag (ARDL) techniques over the period from 1995 to 2014. The results argued that income, CO_2 emission, and PM_{10} (particulate matter smaller than 10 μm) induce an increase in health care expenditures for MENA countries. The study proposed that policy makers should focus on environment issues for better human development in the region.

Schlamadinger and Marland (1999) empirically proved the role of deforestation activities to increase the carbon emission. The study recommended that forest harvesting and growing of trees are the best alternatives to mitigate CO_2 emission from the atmosphere. In addition, recently, a number of studies have documented that global warming and unbalanced environment is due to cutting down of trees and plants (e.g. Brown et al. 2004; Achard et al. 2004; Stern 2006; Routa et al. 2011; Thuy et al. 2014; Zhou et al. 2017; Waheed et al. 2018). Thuy et al. (2014) econometrically documented the significance of forests with regard to environment and climate change for Indonesia and Vietnam. The empirical estimations demonstrated that forests assist to mitigate the carbon. Zhou et al. (2017) documented that forestry and carbon forest projects play vital role in climate change. The study highlighted that China has stimulated the investments on carbon forest projects; however, the carbon forests of China has reached 3.5 million hectare in 2016. With regard to Pakistan, Waheed et al. (2018) empirically confirmed the negative association between forest area and carbon emission, suggesting that Pakistan can control its carbon emission by increasing investments on forest areas and by stopping deforestation activities.

Niu et al. (2011) investigated the long run relationship between coal consumption, oil consumption, economic growth, and carbon emission for eight Asian countries including four developing countries (China, India, Thailand and Indonesia). The empirical results argued that coal and oil consumption significantly contribute in increasing CO_2 emission in atmosphere. Alkhathlan and Javid (2015) examined the empirical nexus between oil consumption, economic growth, and CO_2 emission for Saudi Arabia; the empirical results confirmed that oil consumption induces to increase CO_2 emission. Dong et al. (2017, 2018b) identified specific factors that contribute in mitigating CO_2 emission for China. The study used data from 1965 to 2016 and employed autoregressive distributed lag (ARDL) and vector error correction model (VECM) for empirical estimations. The empirical results confirmed that negative association of natural gas consumption and renewable sources towards CO_2 emission in short-run and long-run estimations. The study further recommended that gas consumption and renewable can act as better alternative to fossil fuels and coal for the case of China.

The brief overview of literature depicts that only limited studies have examined the role of forests in mitigating carbon emission and carbon-health nexus. However, it is inconclusive to fully consider the role of forests with carbon emission and health issues. Forests act as carbon sink and play positive role in mitigating carbon from atmosphere, which further help to minimize health issues. The present study analyzes the role of forests in dampening the negative effects of carbon emission on health issues for Chinese provinces. To the best of our limited knowledge, this is the pioneer study to examine the impact of afforestation and carbon emission to reduce health issues and diseases.

Data and methodology

The study uses unbalanced panel data of 30 Chinese provinces from 1996 to 2015. We have excluded the data stream of Tibet, Macao, and Hong Kong due to the unavailability of data. The provincial level data of all studied variables are extracted from the National Bureau of Statistics of China (http://data.stats.gov.cn/english/). The main motive is to examine the role of CO_2 emission and afforestation in health issues. However, we have divided the data into five separate models to check the robustness of CO_2 emission and afforestation. Model-1 is given below:

$$Health_{it} = \beta_0 + \beta_1 CO_{2\,it} + \beta_2 AF_{it} + \varepsilon_{it} \quad (1)$$

where $Health_{it}$ is the health issues which uses the definition of number of visits in health institutions (100 million person-times) for province i at time t. $CO_{2\,it}$ presents the carbon emission for province i at time t, which is calculated by Intergovernmental Panel on Climate Change (IPCC, 2006) methodology.[2] AF_{it} represents the afforestation that is the proxy of total area of afforestation square kilometers (sq. km). ε_{it} is the error term.

$$Health_{it} = \beta_0 + \beta_1 CO_{2\,it} + \beta_2 AF_{it} + \beta_3 NO_{2\,it} + \varepsilon_{it} \quad (2)$$

Model-2 is the extension of model-1, which further incorporates the nitrogen dioxide emission ($NO_{2\,it}$) to analyze its impact on health and to reconfirm the significance of carbon emission and afforestation. Nitrogen oxide emission in waste gas (ton) is used for the proxy of nitrogen emission:

$$Health_{it} = \beta_0 + \beta_1 CO_{2\,it} + \beta_2 AF_{it} + \beta_3 SO_{2\,it} + \varepsilon_{it} \quad (3)$$

Model-3 adds the nitrogen emission ($NO_{2\,it}$) with sulfur emission ($SO_{2\,it}$) and robust check the role of carbon emission and afforestation. We use sulfur dioxide emission in waste gas (ton) as a proxy of sulfur emission:

$$Health_{it} = \beta_0 + \beta_1 CO_{2\,it} + \beta_2 AF_{it} + \beta_3 NO_{2\,it} + \beta_4 SO_{2\,it} + \varepsilon_{it} \quad (4)$$

In Model-4, we combine the carbon emission, nitrogen emission, sulfur emission, and afforestation to empirically investigate their role in health issues.

$$Health_{it} = \beta_0 + \beta_1 CO_{2\,it} + \beta_2 AF_{it} + \beta_3 NO_{2\,it} + \beta_4 SO_{2\,it} + \beta_2 Pop_{it} + \beta_2 Oil_{it} + \beta_2 Gas_{it} + \varepsilon_{it} \quad (5)$$

On the other hand, model-4 is extended by augmenting the population (Pop_{it}), oil consumption (Oil_{it}), and gas consumption ($Coal_{it}$). For provincial level data of population, we used the data of resident population (10,000 persons). Oil consumption is consumption of crude oil (10,000 tons), and gas consumption is the consumption of natural gas (100 million cubic meters). Following the Waheed et al. (2018), Sarwar et al. (2017), Shahbaz et al. (2017), and Ozturk and Acaravci (2010), we use log specification for all studied variables to standardized the variables. The descriptive statistics of all studied variables are reported in Table 1. The mean, standard deviation, and minimum and maximum values confirm that there is no evidence of outlier in variables.

Health represents the health issues, CO_2 is the carbon emission, AF presents the afforestation, and NO_2 and SO_2 show the nitrogen emission and sulfur emission. Pop is the population, Oil and $Gas$are oil consumption and gas consumption.

Result and discussion

Table 2 highlights the estimations of five quantile regression models. These five models check the robustness to verify the reliability of empirical analysis. In model 1, CO_2 emission has a consistent and positive relationship with health issues, implying that health issues are increasing in China with higher exposure to CO_2 emission while the coefficient of afforestation is significantly negative, inferring that health issues tend to decrease with higher afforestation rate while controlling other confounding factors. In model 2, we have augmented the nitrogen oxide in model 1. Empirical estimations of model 2 confirm the significant positive impact of CO_2 emission and significant negative relationship of afforestation, which validates the previous findings. The coefficient of nitrogen

Table 1 Descriptive statistic

Variable	Mean	Std. Dev.	Min	Max
Health	0.561	0.827	− 1.661	2.094
CO_2	30.565	0.918	27.063	32.545
AF	4.563	1.378	− 0.342	6.759
NO_2	13.209	0.726	11.035	14.404
SO_2	13.201	0.899	9.738	14.510
Pop	8.148	0.760	6.248	9.292
Oil	5.563	3.077	− 4.605	9.060
Gas	2.098	2.053	− 4.605	5.166

[2] $CO2_t = \sum_{i,j} CO2^t_{ij} = \sum_{i,j} E^t_{ij} \times O_j \times EF_j$, for further details, visit IPCC (2006) report.

Table 2 Quantile regression estimations

Health	Model 1	Model 2	Model 3	Model 4	Model 5
CO_2	0.888***	0.810***	0.861***	0.743***	0.182**
AF	− 0.076**	− 0.082**	− 0.081***	− 0.044	− 0.135***
NO_2		0.104		0.342	− 0.219
SO_2			0.035	− 0.175	− 0.012
Pop					1.162***
Oil					− 0.002
Gas					0.029
Const	− 26.608***	− 25.527***	− 26.205***	− 24.486***	− 10.927***

Health represents the health issues, CO_2 is the carbon emission, *AF* presents the afforestation, and NO_2 and SO_2 show the nitrogen emission and sulfur emission. *Pop* is the population, *Oil* and *Gas* are oil consumption and gas consumption. On the other hand, *Const* represents the constant term

***, ** represents the significance level at 1% and 5%, respectively

emission is insignificant which shows that health issues are not related to nitrogen emission. The estimations of model 3 confirm the findings of model 1 and model 2, where CO_2 emission is statistically significant and positive, and afforestation is significant and negative. The results of nitrogen and sulfur emission are insignificant in model 3, suggesting that nitrogen and sulfur emission have no harm to human health in China. The empirical estimations of model 4 have confirmed the earlier responses of CO_2 emission, nitrogen emission, and sulfur emission. Surprisingly, afforestation turns out to be insignificant, which implies that afforestation is not a useful strategy to control the CO_2 emission.

Lastly, model 4 is extended by incorporating population, oil consumption, and gas consumption. Empirical results of CO_2 emission are still statistically significant and positive, and afforestation is significant and negative, indicating that higher CO_2 emission is responsible for health issues, but this unpromising effect can be naturalized by increasing the afforestation activities. The coefficients of nitrogen emission, sulfur emission, oil consumption, and gas consumption are insignificant in model 5. On the other hand, the population has a statistically significant and positive relationship with health issues, mentioning that higher population increases the health problems. Furthermore, CO_2 emission has a more significant positive effect on the 90th quantile of health issues. In this quantile, health issues significantly rise by 0.29% with an increase of 1% CO_2 emission. The linear regression coefficient also underscores this influence. The quantile regression outcomes point out that afforestation rate has a significantly negative impact on the 90th quantile of health issues while this association is relatively little weak in the 10th and 75th quantiles. Health issues at 90th quantile are diminishing by about 0.19% with 1% increase in afforestation rate. Similar to CO_2 emission estimate of ordinary least square (OLS), afforestation coefficient is undermining in ordinary least square estimation.

Surprisingly, ordinary least square and first three quantile estimates of NO_2 exert a negative connection with health issues significantly. Similarly, SO_2 has a significantly negative association with health issues at 75th and 90th quantiles. The coefficients of the population are significantly and nearly equal to 1.1, presenting a more significant impact on health issues at the 75th quantile where health issues are raised by 1.168% with 1% increased rate of population. This coefficient at 50th and 75th quantile is almost similar to the ordinary least square estimate. The effect of gas consumption on health issues at 25th quantile is significantly reasonable where 0.12% higher prevalence of health issues results from 1% increasing use of natural gas while this effect remains inconsistent at 50th and 75th quantile. The ordinary least square regression coefficient of gas is significantly underestimated. The impact of oil on health issues is insignificant at all quantile as well as in the linear regression model. Further, Appendix Fig. Fig. 3 mentions the quantile regression in graphical form. The quantile regression graph demonstrates the influence of CO_2 emission, afforestation, and other studied variables on health issues which indicate the magnitude of coefficients varies across quantile, and the size of the coefficients at various quantile differs considerably from the coefficients of ordinary least square even taking into account the confidence intervals around all coefficients. All graphs are accurately validating quantile regression outcomes shown in Table 3.

Discussion

Overall, long-run outcomes of quantile regressions confirm afforestation, carbon emission, and population are significant predictors of health issues in China. In the five quantile regression models, the effectiveness of carbon emissions on health issues ranges from 0.18 to 0.89, where the coefficients of carbon emission are positive in all quantiles. Studies have stated that CO_2 depreciates environment quality by enhancing air pollution, thus raising health issues (Wolfe et al, 2005; Karine and Branco n.d.; Narayan et al. 2010; Young and Norgard 2006). Other studies have also linked CO_2 emission to health issues due to the fact that health diseases, such as lung cancer, heart disease, stroke, chronic bronchitis, lower respiratory infections, and premature mortality among others, are directly related with the exposure to the high

Table 3 Quantile regression extended in quantiles

Health	OLS	Q10	Q25	Q50	Q75	Q90
CO_2	0.152**	0.158	0.181	0.182***	0.179**	0.289***
	− 3.09	− 1.53	− 1.79	− 3.92	− 3.33	− 6.55
AF	− 0.140***	− 0.121***	− 0.160***	− 0.135***	− 0.116***	− 0.189***
	(− 12.22)	(− 5.48)	(− 7.70)	(− 11.05)	(− 8.65)	(−17.12)
NO_2	− 0.308**	− 0.488**	− 0.461*	− 0.219**	− 0.0455	− 0.0994
	(− 3.32)	(− 2.68)	(− 2.58)	(− 3.01)	(− 0.48)	(− 1.17)
SO_2	0.0597	0.176	0.183	− 0.0124	− 0.201**	− 0.237***
	− 0.94	− 1.33	− 1.5	(− 0.25)	(− 3.09)	(− 4.28)
Pop	1.178***	1.156***	1.156***	1.162***	1.168***	1.116***
	− 32.48	− 21.23	−20.69	− 45.05	− 29.47	− 27.47
Oil	0.00081	− 0.00186	0.00196	− 0.00151	− 0.00253	− 0.011
	− 0.16	(− 0.25)	− 0.21	(− 0.31)	(−0 .38)	(− 1.61)
Gas	0.0719***	0.112***	0.119***	0.029	0.0237	0.0407**
	− 4.55	− 3.65	− 3.93	− 1.94	− 1.27	− 2.81
Const	− 10.07***	− 9.716***	− 10.65***	− 10.93***	− 10.68***	− 12.02***
	(− 10.64)	(− 4.74)	(− 5.32)	(− 12.15)	(− 10.39)	(− 14.72)

Health represents the health issues, CO_2 is the carbon emission, *AF* presents the afforestation, NO_2 and SO_2 show the nitrogen emission and sulfur emission. *Pop* is the population, *Oil* and *Gas* are oil consumption and gas consumption. On the other hand, *Const* represents the constant term. OLS is the ordinary least square estimation. Q10, Q25, Q50, Q75, and Q90 are the quantile 10, quantile 25, quantile 50, quantile 75, and quantile 90, respectively. *t*-statistics in parentheses

$*p < 0.05$; $**p < 0.01$; $***\ p < 0.001$

concentrations of polluted air from emissions (Badamassi et al. 2017; Kamila et al. 2014). This evidence suggests that countries with severe environmental problems might face severe public health issues; for example, cardiovascular problems and respiratory problems (Rodopoulou et al. 2014; Su et al. 2011; Zhang and Batterman 2013). This relationship is also aligned with past studies which reported that poor environment quality had a significantly positive connection with health outcomes concerning cardiovascular diseases (Abbade 2018). The estimations of Badamassi et al. (2017) also validate our findings, showing that carbon emission increases health problems with positive and significant signs. It implies that air pollution adversely impacts human health through damaging environment quality; this has a negative influence on labor productivity. Quantile regression analysis also validates this impact, revealing a positive and significant relationship between afforestation and health issues. Furthermore, this outcome in quantile regression implies that health issues are rising with the time as CO_2 being emitted justifying our key objective.

In four out of five quantile regression estimations, the coefficients of afforestation are statistically significant and negative, ranging from 0.044 to 0.135. Furthermore, quantile regression results reveal that an increasing trend in the magnitude of the coefficients of afforestation across the quantile predicts that with the passage of time, health issues are significantly diminishing as afforestation rate in China is rising. This outcome is justifying the key objective of our study. Thus, it is confirmed that higher deforestation activities tend to increase health issues, via direct effects such as rainfall reduction and increased temperatures. The influence on rainfall happens because deforestation decreases the natural recycling round by which plants absorb vapor from the ground and discharge it into the atmosphere, where it returns in the form of rain. The effect on temperature happens through the association between deforestation and greenhouse gases. As forest areas play an essential role in the absorption of pollutant gases, deforestation reduces the natural ability of the forest to absorb CO_2 through photosynthesis which subsequently causes global warming. A number of studies (Bernstein et al. 2008; Skoufias et al. 2011) have confirmed that deforestation lowers rainfall and raises temperature levels. It has also been reported that the survival of mosquitoes is mostly determined by the levels of temperature and humidity which in turn affects human health (Karine and Branco n.d.). Generally, the higher level of air pollution causes global warming, which directly results in chronic diseases such as lung cancer, heart disease, stroke, chronic bronchitis, cataracts, lower respiratory infections, premature mortality, and low birth weight, among others (Kamila et al. 2014; Badamassi et al. 2017).

Models 2 and 4 depict an overall inconsistent relationship between NO_2 and health issues, but this relationship is significantly strange (negative) at the first three quantile. The coefficient of sulfur emission appeared inconsistent in all models. Moreover, sulfur emission has also inconsistent relation with health issues at the first three lower quantiles while this connection is surprising in the last two quantiles. The last two results are widely contradicted to various past studies (Narayan and Narayan 2008; Yazdi et al. 2014: Badamassi et al. 2017) which elaborate a positive and significant relationship between health problem and NO_2 and SO_2.

The coefficients of populations are significant and positive, which suggest that higher population leads to higher health challenges. Similarly, results are observed at all quantiles with almost same magnitude, because population growth exploits nature to fulfill present needs. As a result, humans are destroying natural resources including forests (Science Daily, 2014). Most developing countries with a high population growth rate need quick action to attain improved living standards. This high population is at more risk of deteriorating environmental resources such as soil, forests, water, and air (Science Daily, 2014). It implies that sustainable development warrants a lower population growth rate. It also implies that human health is at a higher risk of airborne diseases especially as the population becomes denser. An increase in population growth rate is likely to cause urban crowding and environment changes that result in infectious diseases such as tuberculosis, malaria, dengue fever, and cholera (Health News n.d.) to mention a few. Aligned with this outcome,Mittal and Mittal (2013) has reported more health issues are related to higher population rate because higher population raises the demand for agricultural products. Consequently, expanding agriculture sector reduces forests, and over-usage of pesticides and fertilizers make the soil infertile thus harming the human health indirectly. Moreover, the increase in population demands more construction of houses, more transport resources, and higher fossil fuel consumption, resulting in more air, water, and land pollution. In concise, population growth results in different kinds of pollution which destroy the physical environment that subsequently produces more health issues.

Gas and oil consumption have no significant relationship with health issues in all models. This outcome is mainly contradicted to various past studies which justify that partial or full combustion of any fuel (oil, coal, and gas) cause multiple types of illnesses through CO_2 emission in the air, like Pneumonia, headache, and acute and chronic bronchitis (K Saritha Rani 2014; Sirag et al. 2016; Badamassi et al. 2017). However, higher gas consumption has significantly increased health issues at 10th and 25th quantiles with a reasonable magnitude. This conclusion is in line with K Saritha Rani (2014) and Sirag et al. (2016).

Conclusion and policy implications

The present study empirically analyzes the consequences of CO_2 emission and afforestation on human health. For this purpose, the yearly data of 30 Chinese provinces over the period of 1996–2015 have been used. Our research aims to contribute to the literature of environment and health economics that models the determinants of health issues in the case of China. Notably, this research introduces the role of forest to improve the environmental quality which directly impacts the human health. We suggest a model that analyzes the CO_2 emission, afforestation, and health issue gradient while controlling other confounding factors. The study explains the quantile regression, on the five levels of quantiles (such as, 10th quantile, 25th quantile, 50th quantile, 75th quantile, and 90th quantile), which permits comparing how CO_2 emission and afforestation may more influence health issues in different quantiles. Among empirical findings, CO_2 emission has a statistically consistent and positive impact on health issues while afforestation has a negative effect on health issues. The coefficients of CO_2 emission and afforestation rate for the 10th, 25th, 50th, 75th, and 95th quantile regression imply that with higher CO_2 emission, health issues are rising. On the contrary, the significant increase in forest assists to control the health issues in China. This empirical finding owes to the fact that higher afforestation activities serve to upgrade the environmental quality, which resultantly lessens the health problems. In empirical results, the population is the most effective factor influencing health issues, as confirmed by all quantile levels.

Increasing health expenditures is not an appropriate solution to decrease health issues because such expenditures are potentially at the cost of (1) improving environmental value to a certain standard and (2) expenses on other sectors, like education. It implies that if the significant share of health expenditure goes to resolving public health issues caused by environmental quality deterioration, fewer funds will be available to cater for scaling up environment quality and if such expenditures continuously rise, it is likely to cause more burdens on government budgets.

The empirical results urge economists and policymakers to propose policy measures which will improve environmental quality and reduces the health issue burden. To start with, the local and provincial authorities in cooperation with the central government should take quick actions to maintain and adequately manage the forests regularly. CO_2 emission can be controlled through public investment in the forest sector, e.g., forest management, reforestation, afforestation, and cleaning activities that involve the residents to look after the forest and provide rewards and incentives to them for their services in forest management. Furthermore, the government should legislate strict rules to deforestation and limited licenses to deforestation, if necessary, should be issued on a condition to double planting of trees relative to cutting them down.

Secondly, the most effective method to reduce CO_2 emission is to bring a change in the energy mix by switching from non-renewable to renewable energy sources. China should take some immediate actions in transportation like the Netherlands where coal or oil has been replaced with wind energy as the fuel source that power the trains and ultimately reduce air pollution. Furthermore, the government should ensure that all industries will use treatment plants to control air and water pollution. Last but not the least, the government should provide better living conditions to the urban and rural population, through planting green belts, parks, and better sewerage system to mention a few. This policy implication will help to control the population-based health issues.

Appendix

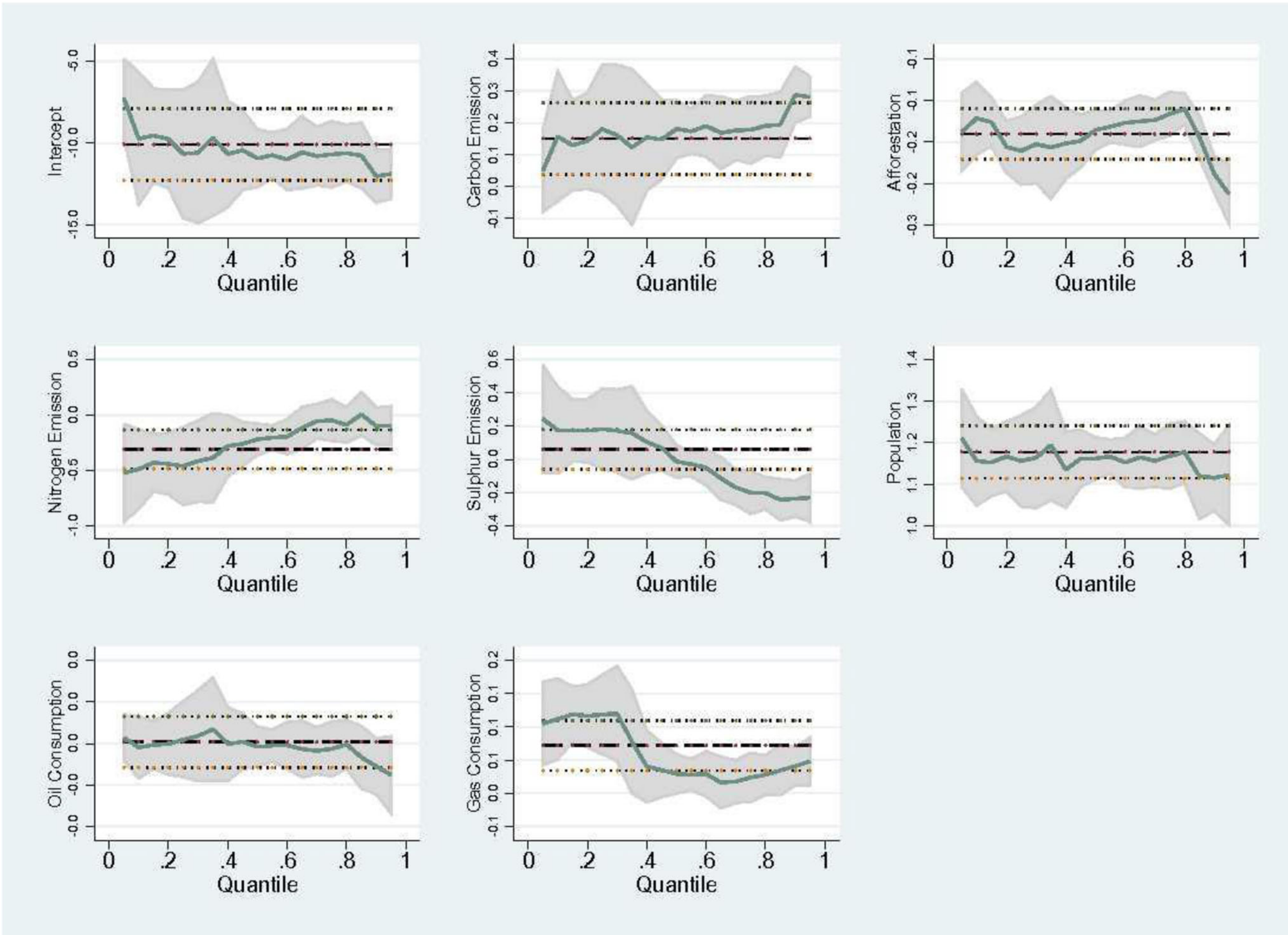


Fig. 3 Quantile regression plot

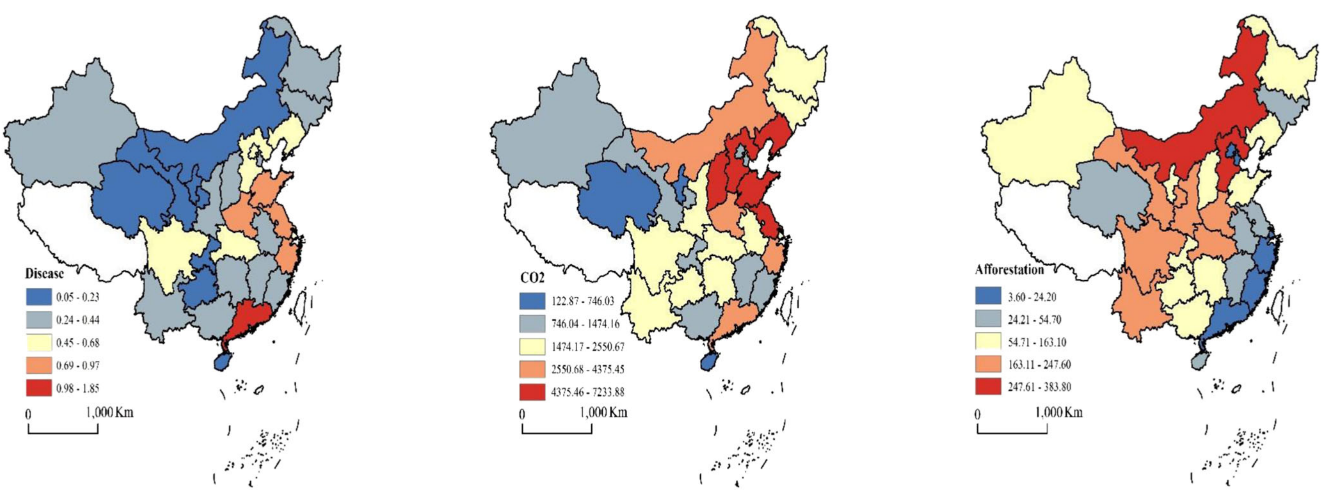


Fig. 4 Health issues, carbon emission, and afforestation of China in 2005

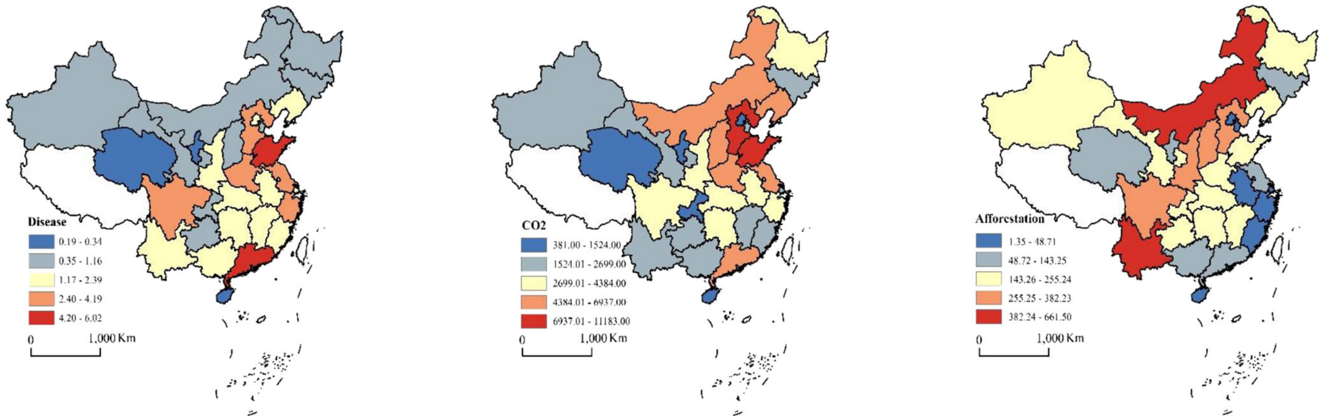


Fig. 5 Health issues, carbon emission, and afforestation of China in 2010

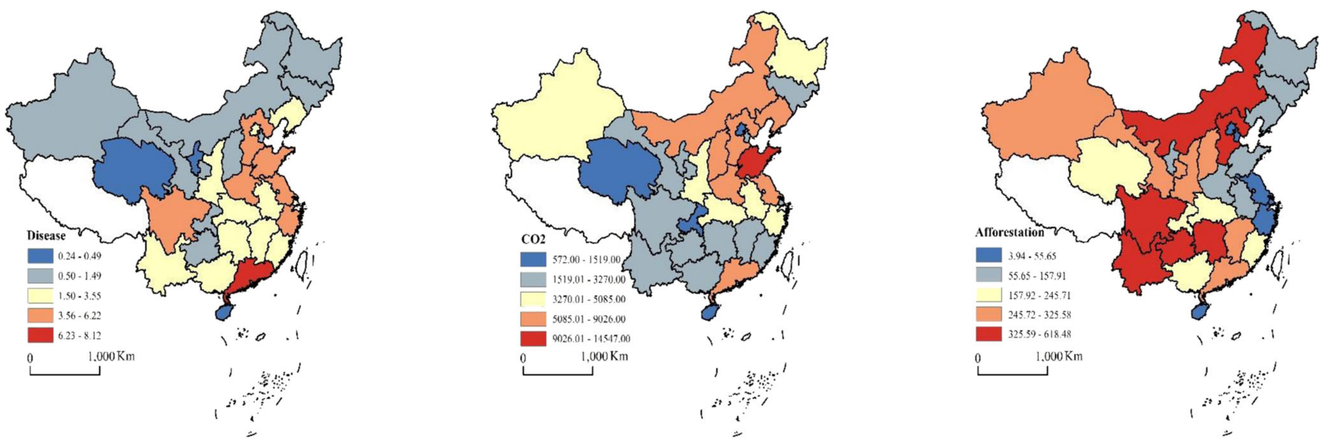


Fig. 6 Health issues, carbon emission, and afforestation of China in 2015

References

Abbade EB (2018) The relationships between obesity-increasing risk factors for public health, environmental impacts, and health expenditures worldwide. Manag Environ Qual: An International Journal 29(1):131–147. https://doi.org/10.1108/MEQ-08-2016-0058

Achard F, Eva H, Mayaux P, Stibig H, Belward A (2004) Improved estimates of net carbon emissions from land cover change in the tropics for the 1990's. Glob Biogeochem Cycles 18(2):GB2008

Ahmad O. (2017). How forests help tackle carbon emissions: lessons from India, China and South Korea. Retrieved November 16, 2018, from https://www.thethirdpole.net/en/2017/11/16/forests-tackle-carbon-emissions-india-china-south-korea/. Accessed 16 Jul 2018

Alkhathlan K, Javid M (2015) Carbon emissions and oil consumption in Saudi Arabia. Renew Sust Energ Rev 48:105–111

Badamassi A, Xu D, Leyla BH (2017) The impact of residential combustion emissions on health expenditures: empirical evidence from sub-Saharan Africa. Atmosphere 8(9):157. https://doi.org/10.3390/atmos8090157

Beatty T, Shimshack J (2014) Air pollution and children's respiratory health: a cohort analysis. J Environ Econ Manag 67:39–57

Bernstein L, Bosch P, Canziani O, Chen Z, Christ R, & Riahi K (2008). IPCC, 2007: climate change 2007: synthesis report. IPCC

Brown S, Dushku A, Pearson T, Shoch D, Winsten J, Sweet S, & Kadyszewski J (2004). Carbon supply from changes in management of forest, range, and agricultural lands of California. Winrock International for California Energy Commission

CCOHS. (2017). Canadian center for occupational health and safety; carbon dioxide. Retrieved 06 07, 2018, from https://www.ccohs.ca/oshanswers/chemicals/chem_profiles/carbon_dioxide.html. Accessed 7 June 2018

Chaabouni S, & Zghidi N (2016). On the causal dynamics between CO2 emissions, health expenditures and economic growth. Sustain Cities Soc, 1–19

Chaabouni S, Zghidi N, Mbarek M (2016) On the causal dynamics between CO2emissions, health expendituresand economic growth. Sustain Cities Soc 22:184–191

Dong K, Sun R, Hochman G, Zeng X, Li H, Jiang H (2017) Impact of natural gas consumption on CO2 emissions: panel data evidence from China's provinces. J Clean Prod 162:400–410

Dong F, Yu B, Hadachin T, Dai Y, Wang Y, Zhang S, Long R (2018a) Drivers of carbon emission intensity change in China. Resour Conserv Recycl 129:187–201

Dong K, Sun R, Dong X (2018b) CO2 emissions, natural gas and renewables, economic growth: assessing the evidence from China. Sci Total Environ 640(641):293–302
Ebi K, Ogden N, Semenza J, Woodward A (2017) Detecting and attributing health burdens to climate change. Environ Health Perspect 085004:1–7
EPA (Enviornmental protection Agency). (2018). Health effects . Retrieved June 11, 2018, from https://www.epa.gov/sites/production/files/signpost/cc.html. Accessed 11 June 2018
FAO (2010) Global Forest Resources Assessment 2010. Food and Agriculture Orgnization of United Nations, Rome
Feldscher K (2011). Greenhouse gases pose threat to public health. Retrieved june 11, 2018, from https://www.hsph.harvard.edu/news/features/bernstein-greenhouse-gases-health-threat/. Accessed 11 June 2018
Fernandoa Y, Lin Hor W (2017) Impacts of energy management practices on energy efficiency and carbon emissions reduction: a survey of Malaysian manufacturing firms. Resour Conserv Recycl 126:62–73
Field HE (2009) Bats and emerging zoonoses: henipaviruses and SARS. Zoonoses Public Health 56(6–7):278–284
Field C, Barros V, Mastrandrea M, Mach K, Abdrabo M-K, Adger W, Anokhin Y (2014) Climate change 2014: impacts, adaptation, and vulnerability. Cambridge University Press, New York, USA
Gao J, Kovats S, Vardoulakis S, Wilkinson P, Woodward A, Li J, Gu S, Liu X, Wu H, Wang J, Song X, Zhai Y, Zhao J, Liu Q (2018) Public health co-benefits of greenhouse gas emissions reduction: a systematic review. Sci Total Environ 627:388–402
Gerdtham U-G, Jonsson B (1992) International comparisons of health care expenditure—conversion factor instability, heteroscedasticity, outliers and robust estimators. J Health Econ 11(2):189–197
Griggs M (2017) Humans are responsible for the vast majority of wildfires in the US. Retrieved from Popular Science: https://www.popsci.com/humansare-responsible-for-vast-majority-wildfires-in-us. Access 15 May 2018
Health News. (n.d.). World Population Day 2017—impact of overpopulation on health in India. Retrieved from http://www.thehealthsite.com/news/overpopulation-in-india-is-a-serious-health-threat-i715/
IPCC (2006) IPCC Guidelines for National Greenhouse Gas Inventories. Institute for Global Environmental Strategies (IGES), Hayama, Japan
IPCC (2014) Contribution of working group III to the fifth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, United Kingdom, New York USA.
Janke K, Propper C, Henderson J (2009) Do current levels of air pollution kill? The impact of air pollution on population mortality in England. Health Econ 18:1031–1055
Jerrett M, Eyles J, Dufournaud C, Birch S (2003) Environmental influences on healthcare expenditures: an exploratory analysis from Ontario, Canada. J Epidemiol Community Health 57(5):334–338
Joyce C (2017) What's The Leading Cause Of Wildfires In The U.S.? Humans. Retrieved from National public Radio: https://www.npr.org/sections/thetwo-way/2017/02/27/517100594/whats-the-leading-causeof-wildfires-in-the-u-s-humans. Accessed 17 May 2018
Kamila S, Kappen J, Rysankova D, Hyseni B, Putti RV (2014) Clean and improved cooking in sub-Saharan Africa. Washington, DC, USA, World Bank
Karine D, & Branco S (n.d.). Deforestation and infant health : evidence from an Environmental Conservation Policy in Brazil
Lathrop J (2017). Humans Responsible for More Wildfires than Lightning, Longer Fire Season and Expansion of ‘Fire Niche. Retrieved from UMass Amherst researchers and team document human threat in wildfires: https://www.umass.edu/newsoffice/article/humans-responsible-more-wildfires. Accessed 5 June 2018
Looi LM, Chua KB (2007) Lessons from the Nipah virus outbreak in Malaysia. Malays J Pathol 29(2):63–67
Minnemeyer S, Harris N, & Payne O (2017). Conserving forests could cut carbon emissions as much as getting rid of every car on earth. Retrieved June 07, 2018, from http://www.wri.org/blog/2017/11/conserving-forests-could-cut-carbon-emissions-much-getting-rid-every-car-earth. Accessed 7 June 2018
Mittal R, & Mittal CG (2013). Impact of population explosion on environment. WeSchool “Knowledge Builder” - The National Journal, 1(1)
Morin CW, Comrie AC, Ernst K (2013) Climate and dengue transmission: evidence and implications. Environ Health Perspect 121(11–12):1264–1272
Narayan P, Narayan S (2008) Does environmental quality influence health expenditures? Empirical evidence from a panel of selected OECD countries. Ecol Econ 65(2):367–374
Narayan S, Narayan PK, Mishra S (2010) Investigating the relationship between health and economic growth: empirical evidence from a panel of 5 Asian countries. J Asian Econ 21(4):404–411
News D US (n.d.). Population growth threatens public health, Report says. Retrieved from http://www.unisci.com/stories/20011/0108014.htm. Accessed 14 May 2018
NIEHS (National institute of Enviornmental health Sciences (2017). Climate and human health. Retrieved June 11, 2018, from https://www.niehs.nih.gov/research/programs/geh/climatechange/health_impacts/index.cfm. Accessed 11 June 2018
Niu S, Ding Y, Niu Y, Li Y, Luo G (2011) Economic growth, energy conservation and emissions reduction: a comparative analysis based on panel data for 8 Asian-Pacific countries. Energy Policy 39(4):2121–2131
Ozturk I, Acaravci A (2010) CO2 emissions, energy consumption and economic growth in Turkey. Renew Sust Energ Rev 14(9):3220–3225.
Palmer D. (2012). To what extent could planting trees help solve climate change? Retrieved June 07, 2018, from https://www.theguardian.com/environment/2012/nov/29/planting-trees-climate-change. Accessed 8 June 2018
Rodopoulou S, Chalbot M-C, Samoli E, DuBois DW, San Filippo BD, Kavouras IG (2014) Air pollution and hospital emergency room and admissions for cardiovascular and respiratory diseases in Doña Ana County, New Mexico. Environ Res 129:39–46
Routa J, Kelomaki S, Kilpelainen A, Peltola H, Strandman H (2011) Effects of forest management on the carbon dioxide emissions of wood energy in integrated production of timber and energy biomass. Global Chnage Biol Bioenergy 3:483–497
Saritha Rani K . (2014). Environmental effects of burning fossil fuels, 2(3), 63–67
Sarwar S. Chen W. Waheed R (2017) Electricity consumption, oil price and economic growth: Global perspective. Renew Sust Energ Rev 9–18
Schlamadinger B, Marland G (1999) Net effect of forest harvest on CO2 emissions to the atmosphere: a sensitivity analysis on the influence of time. Tellus Ser B Chem Phys Meteorol 51(2):314–325
Sciene Daily (2014) Devastating human impact on the Amazon rainforest revealed . Retrieved from Science Newsfrom research organizations: https://www.sciencedaily.com/releases/2014/05/140522104856.htm. Accessed 8 June, 2018
Shahbaz M. Sarwar S. Chen W. Malik MN (2017) Dynamics of electricity consumption, oil price and economic growth: Global perspective. Energy Policy 256–270
Shao L, Li Y, Feng K, Meng J, Shan Y, Guan D (2018) Carbon emission imbalances and the structural paths of Chinese regions. Appl Energy 215:396–404
Sirag A, Nor NM, Law S, Abdullah NR, Lacheheb M (2016) The impact of health financing and CO2 emission on health outcomes in sub-Saharan Africa: a cross-country analysis. Geo J 82(6):1247–1261
Skoufias E, Vinha K, & Conroy H (2011). The impacts of climate variability on welfare in rural Mexico

Stanley F, Farrant B (2015) Climate change and children's health: a commentary. Children (Basel) 2(4):412–423

Stern N (2006). Stern review: the economics of climate change. HM Treasury. Cambridge University Press, UK

Su C, Franck U, Pan X (2011) Association between ambient air pollution and the hospital emergency room visits for respiratory diseases: a case-crossover study. Epidemiology 22(1):S205

The Guardian . (2011). How do trees and forests relate to climate change? Retrieved June 07, 2018, from https://www.theguardian.com/environment/2011/feb/11/forests-trees-climate. Accessed 10 June 2018

Thuy PT, Moeliono M, Locatelli B, Brockhaus M, Gregorio MD, Mardiah S (2014) Integration of adaptation and mitigation in climate change and forest policies in Indonesia and Vietnam. Forests 5(8): 2016–2036

Tox Town. (2017). Environmental health concerns and toxic chemicals carbon dioxide. Retrieved 06 07, 2018, from https://toxtown.nlm.nih.gov/text_version/chemicals.php?id=6. Accessed 12 June 2018

Vittor AY, Pan W, Gilman RH, Tielsch J, Glass G, Shields T, … Flores S (2009). Linking deforestation to malaria in the Amazon: characterization of the breeding habitat of the principal malaria vector, Anopheles darlingi. The American Journal of Tropical Medicine and Hygiene, 81(1), 5, 12

Waheed R, Chang D, Sarwar S, Chen W (2018) Forest, agriculture, renewable energy, and CO2 emission. J Clean Prod 172:4231–4238

Wang Y (2007) A randomized community intervention to improve complementary feeding practices. Peking University Health Science Center, Beijing Retrieved june 2018

Wolfe ND, Daszak P, Kilpatrick AM, Burke DS (2005) Bushmeat hunting, deforestation, and prediction of zoonotic disease. Emerg Infect Dis 11(12):1822–1827

Wolosin M (2017). Large-scale forestation for climate mitigation: lessons from South Korea, China, and India. Climate and Land use Alliance

World Development Indicators. (2015). World Bank Database. Retrieved from http://data.worldbank.org/

World Health Orgnization. (2018). Climate change and health. Retrieved June 11, 2018, from http://www.who.int/news-room/fact-sheets/detail/climate-change-and-health. Accessed 11 June 2018

Yazdi SK, Khanalizadeh B (2017) Air pollution, economic growth and health care expenditure. Economic Research-Ekonomska Istraživanja 30(1):1181–1190

Yazdi S, Tamhmasebi Z, & Mastorakis N (2014). Public healthcare expenditure and environmental quality in Iran. In recent advances in applied economics, Proceedings of the 6th International Conference on Applied Economics, Business and Development, Business and Economics Series (Vol. 16, pp. 126–134)

Young A, Norgard C (2006) Assessing the quality of courses from the students' perspective. Internet High Educ 9(2):107–115

Zhang L (2017). China: new law replacing pollution discharge fee with environmental protection tax. Retrieved from Global Legal Monitor: http://www.loc.gov/law/foreign-news/article/china-new-law-replacingpollution-discharge-fee-with-environmental-protection-tax/. Accessed 14 April 2018

Zhang K, Batterman S (2013) Air pollution and health risks due to vehicle traffic. Sci Total Environ 450:307–316

Zhou W, Gong P, Gao L (2017) A review of carbon forest development in China. Forests 8(295):1–11

Affiliations

Muhammad Umar Farooq[1,2] **· Umer Shahzad**[3] **· Suleman Sarwar**[4,3] **· Li ZaiJun**[5]

[1] Government College University Faisalabad, Faisalabad, Pakistan

[2] Center of Economic and Research, Shandong University, 27-Shanda nanl lu, Jinan, Shandong, China

[3] School of Economics, Shandong University, 27-Shanda nanl lu, Jinan, Shandong, People's Republic of China

[4] Finance and Insurance Department, University of Jeddah, Jeddah, Saudi Arabia

[5] Research Institute of Central Jiangsu Development, Yangzhou University, Yangzhou 225009, Jiangsu, China