Journal of Cleaner Production 149 (2017) 502–510

Contents lists available at ScienceDirect

Journal of Cleaner Production

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

How scholars and the public perceive a “low carbon city” in China

Bofeng Cai [a], Yong Geng [b, *], Weishan Yang [c, **], Pingzhong Yan [d], Qianli Chen [e, f], Dong Li [g, ***], Libin Cao [a]

[a] Center for Climate Change and Environmental Policy, Chinese Academy for Environmental Planning, Beijing 100012, China
[b] School of Environmental Science and Engineering, Shanghai Jiao Tong University, Shanghai 200240, China
[c] Institutes of Science and Development, Chinese Academy of Sciences, Beijing 100190, China
[d] LAPC, Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing 100029, China
[e] School of Management, XinJiang Agricultural University, Urumqi 830052, China
[f] College of Public Administration, NanJing Agricultural University, NanJing 210095, China
[g] Beijing Tsinghua Tongheng Planning & Design Institute, Beijing 100085, China

ARTICLE INFO

Article history:
Received 18 November 2016
Received in revised form
27 January 2017
Accepted 15 February 2017
Available online 16 February 2017

Keywords:
Low-carbon city
China
Scholar
Public
Perception

ABSTRACT

China is actively promoting low-carbon city development. Understanding the perception of a low-carbon city by the entire society is vital for effective policy implementation. However, the essence of a “Low Carbon City” is not consistently understood by the society. In this article, big data mining and a bibliometric approach were adopted to establish several indicators so that scholars (based on literature) and the public (based on social network) perceptions on low carbon cities can be uncovered. The major findings are as follows: The numbers of literature and social networking posts with “low carbon” & “city” as key words have increased during the period 2010–2016 and reached a peak in 2013. The literature mainly defines low-carbon cities from a macro-economic aspect. However, the public express their concerns with respect to the quality of life or how their behaviors could be affected. Cities with high *PPI* (Publication Popularity Indicator) or *WPI* (Weibo Popularity Indicator) values are mainly clustered in the three Chinese main economic regions (Jing-Jin-Ji region, Yangtze River delta region and Pearl River delta region). Cities with high *CPII* (Comprehensive Popularity Intensity Indicator) values are not always clustered in the three main economic regions but are located dispersedly. This implies that cities can make great progresses in low carbon development irrespective of their economic levels and spatial locations. Three cities (Shuangyashan, Chongzuo and Guyuan) had zero *PPI*, *WPI* and *CPII* values, reflecting that they have not been considered for low carbon development by the scientific community or the public. It is obvious that some cities have been ignored in the context of low carbon development or they have not taken any initiatives with respect to low carbon development. The *CPII* used in this paper could be a useful indicator for monitoring and evaluating the perception of low carbon development at the city level.

1. Introduction

China, as the highest emitter in both greenhouse gases (12.45 billion tons CO_2eq in 2012 (JRC and PBL, 2015)) and fossil fuel combustion-related CO_2 (9.15 billion tons in 2015 (BP, 2016)), continues to contribute a substantial share of the annual carbon emission growth due to its fast economic development and urbanization (Jackson et al., 2015; Le Quéré et al., 2015). Carbon emission reduction has become a key strategy to mitigate environmental and climate-associated damages (IPCC, 2014). Under such a circumstance, to pursue low carbon development will undoubtedly benefit China’s own wellbeing and the global society. After the 2015 Paris agreement on climate change was approved, the Chinese government submitted its Intended Nationally Determined Contributions (INDC) to the United Nations Framework Convention on Climate Change (UNFCCC), which was signed in April 2016, and made a commitment to achieve carbon emissions peak by 2030, or sooner as best efforts allow.

* Corresponding author.
** Corresponding author.
*** Corresponding author.
E-mail addresses: caibofeng@gmail.com (B. Cai), ygeng@sjtu.edu.cn (Y. Geng), Yangws@caep.org.cn (W. Yang), missfield@gmail.com (P. Yan), chenql@xjau.edu.cn (Q. Chen), ldzgy@qq.com (D. Li), caolb@caep.org.cn (L. Cao).

http://dx.doi.org/10.1016/j.jclepro.2017.02.122
0959-6526/

Cities as administrative units are the most populous areas and also have the most intensive industrial activities and infrastructure construction. Existing studies have shown that cities are responsible for a large proportion of carbon emissions in China and globally (Cai and Zhang, 2014; Dhakal, 2009, 2010; IEA, 2009). Major emitting countries have been wisely shifting their efforts to cities in order to substantially reduce their emissions (The World Bank, 2010; OECD, 2010). The concept of a "Low Carbon City" has boosted cities with respect to acting in the most cost-effective manner for mitigating the effects of climate change. During such a rapid urbanization process, Chinese cities are facing with the severe challenges on climate mitigation. China's National Development and Reform Commission (NDRC) launched the first and second batches of "Strengthening Low Carbon Development in Pilot Areas", covering 6 provinces and 36 cities to promote low carbon practices. In September 2015, in the First Session of the U.S.-China Climate-Smart/Low-Carbon Cities Summit, 9 Chinese cities jointly initiated the establishment of the Alliance of Peaking Pioneer Cities (APPC) to support the national peak of carbon emissions around 2030.

Low carbon development at the city level has become more popular in China. Scholars began to pay more attentions on the relevant research perspectives. For instance, the potential influence of Chongqing's low carbon development plan on energy consumption and carbon emissions up to 2020 has been analyzed based on different policy scenarios (Liu et al., 2012). Several evaluations on China's low carbon development practices have been conducted in the selected cities in order to identify to what extent such practices can affect urban development as well as recognizing the major gaps in the development pathways (Su et al., 2012, 2013). Also, some scholars developed several evaluation indicators to assess the performance of a low carbon city (Wen and Gao, 2013; Zhu et al., 2015). Their main approach is to adopt a scenario analysis, aiming to predict energy demands and corresponding carbon emissions at the city level.

In order to better promote low carbon development at the city level, it is important to identify the key contexts and scopes of one low carbon city. Although the Chinese government has actively advocated and encouraged several pilot cities to explore a feasible model on developing low carbon cities and the Chinese academia have made significant efforts on investigating how to better pursue low carbon development at the city level, an integrated framework that combines low carbon development plan, implementation, monitoring and evaluation has not been established. Also, in addition to those pilot cities, other cities and the whole scientific community are keen to understand how they can initiate their own efforts toward low carbon development.

However, few research attempts have been made to explore the perceptions on low carbon cities and evaluate the related performance. Therefore, it is critical to investigate how a city can smoothly move toward a low carbon city by considering the local realities. Several studies analyze the perception of scholars and the public on low carbon issues by using questionnaires and interviews (Chen et al., 2015; Hartikainen et al., 2014; Howell et al., 2014; Mabon and Littlecott, 2016; Mabon et al., 2014; Suk et al., 2016). But only one is related with China and only focuses on the carbon capture and storage (CCS) issue with a very narrow aspect on low carbon development (Chen et al., 2015). China is the largest carbon emission country and is facing a great pressure to mitigate climate change. Therefore, it is necessary to initiate more research efforts on understanding the current barriers on low carbon development at the city level so that appropriate mitigation policies can be raised. Under such a circumstance, this study adopts a big data mining approach coupled with bibliometric analysis to quantify the perception of a low carbon city, with the aim of determining how social, geographical, political, economic and/or other factors affect the implementation of a low– carbon city. In this study, big data refer to the huge volume of data that were searched and analyzed from accessible databases, including hundreds of thousands of publications and social networking sites containing millions of daily posts. A big data mining approach can rapidly acquire valuable information relevant to a research topic while saving time and manpower. Both social networking sites (representing the public) and professional databases (representing academics) are used to extract perceptive knowledge so that the general but different overviews of low carbon city perceptions in China can be obtained. The structure of this paper is as follows: after this introduction section, Section 2 describes the methods and data sources, Sections 3 presents the research results and Sections 4 draws research conclusions and proposes policy implications.

2. Methods and data

2.1. Methods

A combination of big data mining method and bibliometric analysis was employed based on published peer-reviewed articles and social media information. Bibliometric analysis has been widely adopted in academia for evaluating scientific activities (de Jong et al., 2015; Han et al., 2014; Tian et al., 2008; Yeo et al., 2015; Yu et al., 2016; Zhong et al., 2016; Amador et al., 2017). However, bibliometric analysis has a disadvantage of concentrating on the specific fields of certain communities (mainly academia) (Gu et al., 2017; Thomas et al., 2017; Gao et al., 2016; Zhong et al., 2016), neglecting the opinions of the general public and government. In order to solve such a problem, the information derived from both academic literature and Weibo (China's most popular social networking website) are analyzed to identify the awareness on low carbon city from the perspective of both scholars and the public in China (Li and Long, 2015; Cai et al., 2015).

Literature derived from peer-reviewed journal databases represent the popularity and attitudes attributable to the professional community, while information extracted from Weibo represents both the government and public's perspectives on low carbon cities (Both national and local governments have Weibo accounts in China).

"City" in this study refers to Chinese prefecture-level cities (PLC). A prefecture-level city is the second level of the administrative structure, between provinces and counties. There are 283 prefecture-level cities in China (National Bureau of Statistics of the People's Republic of China, 2011). Four municipalities directly under the central government (Beijing, Shanghai, Tianjin and Chongqing) are province leveled administrations, but included in this study because they are also administratively recognized as cities in China.

First, a Publication Popularity Indicator (*PPI*) was designed to represent the popularity and attitudes toward a low-carbon city of the professional communities, defined in equation (1).

$$PPI_i = \sum_j paper_j \quad (1)$$

PPI_i represents the popularity of city i in the literature; each city (i) mentioned in the abstract of paper j was counted as one, irrespective of the times it was mentioned in the same abstract. PPI_i is the aggregated number of total appearances of city i in all literature.

Second, the Weibo Popularity Indicator (*WPI*), representing both the government and public perspectives on low carbon city, is defined in equation (2).

$$WPI_i = \sum_j Weibo_j \quad (2)$$

WPI_i represents the popularity of city i on Weibo; each city (i) mentioned on Weibo j was counted as one, irrespective of the number of times it was mentioned; WPI_i is the aggregated number of total appearances of city i in all Weibo posts.

Comprehensive Popularity Intensity Indicator (*CPII*), normalizes and integrates PPI_i and WPI_i, and represents the comprehensive and comparable popularity of city *i*. The *CPII* is defined in equation (3).

$$CPII_i = \frac{PPI_i/(\sum PPI) + WPI_i/(\sum WPI)}{GDP_i} \quad (3)$$

where $\sum PPI$ is the overall sum of the city's popularity on the literature, $\sum WPI$ is the overall sum of the city's popularity on Weibo, and GDP_i is the gross domestic production of city *i*.

One city's GDP is significantly related to its popularity with respect to low carbon issues in both the literature and Weibo sites. Based on our investigation and interviews with experts, one city's GDP could directly affect the propaganda and infrastructure investment of its low carbon strategy and planning. Meanwhile, the GDP level is also associated with data transparency (especially energy data), which can significantly influence the carbon emission data disclosure and therefore influence a city's low carbon popularity. Thus, GDP is selected as one indicator for processing *CPII* to compare cities on the extent of their popularity.

2.2. Data sources

Literature data were obtained from two sources: the Wanfang Database (http://www.wanfangdata.com.cn, Chinese publication) and Scopus (https://www.scopus.com, English publication); social media data were extracted from Sina Weibo (http://weibo.com). The literature abstracts and Weibo texts were used in the analysis.

Considering the consistent time frame for both professional and public data (Weibo was launched at the end of 2009, and there were also few publications on low carbon cities before 2009), this research focuses on data between 1st Jan., 2010 and 5th May 2016.

Key words containing "low carbon" & "city" were used to search all relevant literature abstracts within the database. A total of 8290 Chinese language articles and 284 English language articles (containing "low carbon" & "city" & "China" in the abstracts) were found. The same method was applied to the Weibo online database, and 51,081 Weibo posts were found. Weibo data were captured through a network-based program developed using Python. The original information was saved as JSON data, including the message sequence number, publishing date and time, contents, and user information. The original data were further processed to build up a low carbon city-oriented dataset.

3. Results

3.1. Changing trends concerning low carbon city"

The number of both literature and Weibo posts referring to low carbon cities first increased from 2010 to 2013 and reached the peaks in 2013, then decreased afterwards (Fig. 1), reflecting similar interests from both the public and professional communities.

The published articles unexpectedly increased by 100% in 2013, namely from 1133 articles in 2012 to 2436 articles in 2013, while the corresponding Weibo posts only increased 23%, namely from 9914 in 2012 to 12,234 in 2013. Such a reality may be explained by the fact that academic communities are more sensitive on governmental initiatives and policies than the general public. Also, since it usually takes months for one paper submission to its final publication, it may be rational to assume that dynamic changes occurred in 2012, boosting the rapid increase of relevant literature.

The most likely event taking place nationwide was a provision issued by National Development and Reform Commission (NDRC) in November 2012. NDRC released the second batch of Chinese low carbon city pilot projects, including 28 new pilot cities on the basis of the first batch of 8 cities issued in July 2010. At an international level, the Rio+20 summit held in December 2012 also contributed to the recognition of low carbon development by the Chinese government and academic communities.

3.2. Key words frequency analysis of "low-carbon city"

After analyzing the overall literature and Weibo posts, the most

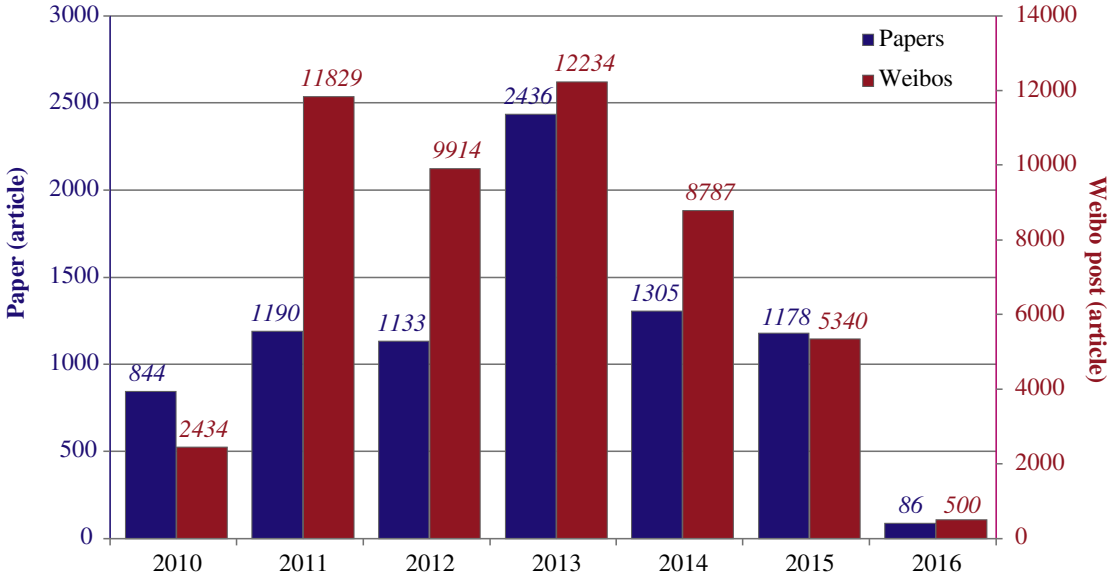

Fig. 1. Changes in literature and Weibo posts.

frequently used key words in publications and Weibo posts were ranked, and their differences were compared to determine the preference and the disparity between these two groups of stakeholders. Such an analysis can also help identifying the hotspots of low carbon city.

The top 5 key words from the literature include “Development”, “Economic”, “Construction”, “Ecology” and “Emission” (Fig. 2). The key words “Development”, “Economic” and “Construction” may imply that China is at its early stage of developing low carbon cities and pays a lot of attention on the related costs and benefits of developing low carbon cities. This indicates that although the concept of low carbon city is attractive and promising, the possible investment and economic return from such an initiative deserves more considerations. Key words of “Ecology” and “Emission” refer to the importance of a synergy between low carbon development and environmental quality. The term of “Emission” not only represents greenhouse gases but also represents other atmospheric pollutants (SO_2, NO_X, etc.). The top 5 key words from Weibo posts include “Green”, “Environmental Protection”, “Travel”, “Development” and “Life” (Fig. 3). This indicates that the general public concern the quality of life, in particular, the living environment rather than economic development. It also reflects that the general public regard low carbon development as one key strategy of environmental protection. Different from academia, the general public care more for the improvement of environmental quality as it is related with their health and life quality, rather than low carbon development per se since carbon emission is more intangible and has less direct impact on their life.

In the top 20 most frequently used words list, five words appeared in both the literature and Weibo posts, including “Development”, “Green”, “Economic”, “Construction” and “Ecology”, reflecting common concerns related to low-carbon city in China by both academic communities and the general public. In the top 200 most frequently used key words list in the literature, two cities appeared, namely “Beijing” (ranked 91st) and “Shanghai” (ranked 109th). This is not surprised since they are the two largest Chinese cities in terms of population and GDP. However, in the Weibo list, more city names appeared than in the literature. Both Beijing and Shanghai still rank as the top two cities positioned as 55th and 48th, respectively. Guangzhou (88th), Xi’an (114th),

Fig. 2. Word cloud of frequently used words in the literature. Note: The size of a word indicates its frequency in terms of scale.

Fig. 3. Word cloud of frequently used words in the Weibo posts. Note: The size of a word indicates its frequency in terms of scale.

Hangzhou (156th), Xiamen (179th), Chongqing (182nd), Tianjin (190th) and Wuhan (200th) also appear in this ranking list. Such a difference may be due to the fact that the general public like to point out the actual names of the cities, while academic communities prefer to discuss the general model of low carbon city and seldom mention the detailed city names in their research.

In the Weibo list, another feature is that some frequently used key words associate with the daily life. For instance, No Car Day (35th), Vehicle Restriction (87th), and Car Plate Number (99th), are included in this list, indicating that the general public concern related to low carbon city has a strong association with routine lifestyle. This suggests that the low carbon city strategies and policies could be more understandable and acceptable by the general public if they are closely linked with the daily life.

3.3. Popularity analysis of “low carbon city”

Fig. 4 shows the popularity and spatial pattern of low carbon city perception from the academic communities and the public perspectives. The cities’ *PPI* and *WPI* values were highly relevant. Cities with high *PPI*/*WPI* values mainly come from the three main Chinese economic regions (Jing-Jin-Ji region, Yangtze River delta region and Pearl River delta region) (Fig. 4). Top Chinese cities (Shanghai, Beijing, Tianjin, etc.) in terms of *PPI* attracted special public attention.

Among the top 20 most popular cities in the literature, 17 were in the first or second batch of national pilot low carbon cities, indicating that related national initiatives have very strong policy influence. Other three cities include Zhengzhou (capital of Henan, the most populous province in China), Nanjing (capital of Jiangsu, one of the richest economic provinces in China) and Chengdu (capital of Sichuan, the wealthiest western province in China).

Among the top 20 most popular cities on the Weibo posts, all the cities except Zhengzhou (replaced by Zhuhai) are the same as that in the literature. This indicates that although Weibo represents the popularity expression of the general public, it is still strongly influenced by the governmental initiatives.

In the literature list of the most popular cities on low carbon development, 45 cities were only mentioned once, but 8 cities appeared in the published literature more than 100 times (*PPI*

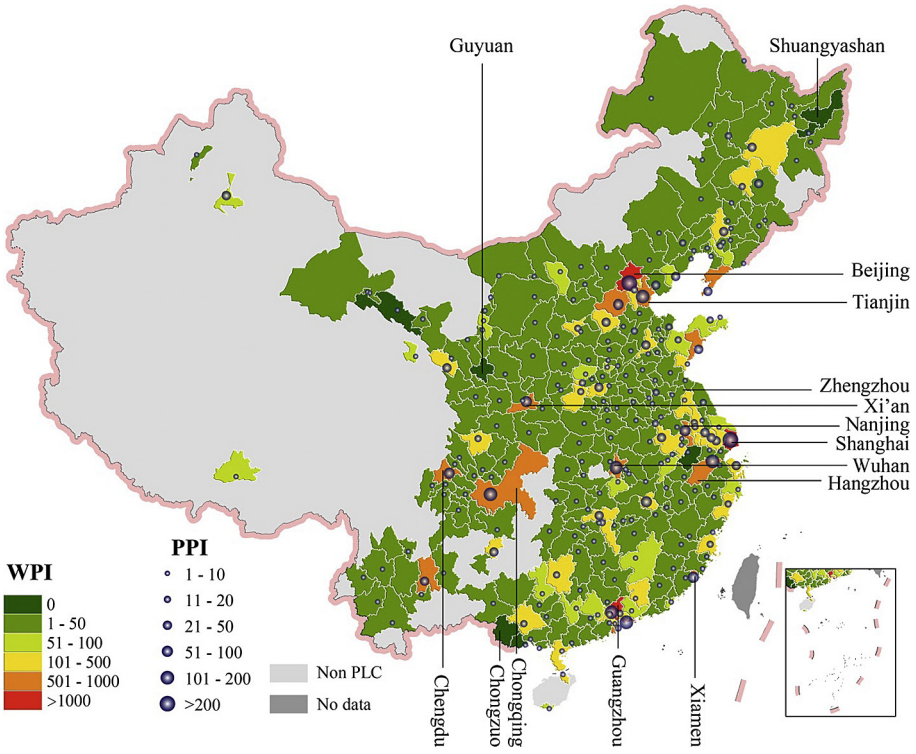

Fig. 4. *PPI* and *WPI* indicators of cities in the publications and Weibo posts. Note: PLC refers to prefecture-level cities.

>100). In the Weibo list, 5 cities were only mentioned once, and 4 cities were mentioned more than 1000 times (*WPI* >1000). These results indicate that the popularity of low carbon development is extremely imbalanced among the Chinese cities. Shuangyashan, Chongzuo and Guyuan were the only three cities that were neither mentioned in the Weibo nor referred to in any literature. It is obvious that some cities were ignored in the context of low carbon development or they have not taken any initiatives with respect to low carbon development. Therefore, in terms of promoting low carbon development in the Chinese cities, policy makers should not only focus on those big cities but also pay more attention to those medium and small cities because they lack recognition of the importance of low carbon development.

3.4. Key impact factors on one city's popularity

Statistical analysis was conducted to quantitatively measure how one city's economy (measured by GDP) and population affect its popularity on low carbon development. Both GDP and population's relevance to *PPI* and *WPI* of cities were analyzed and shown in Figs. 5 and 6. The *R*-squared values show that GDP had significant relevance to the city's popularity both in the literature and Weibo posts. A city's popularity on low carbon development had a weaker relationship with its population than with GDP because both literature and Weibo posts were proposed from nation-wide sources, and its popularity somehow hardly reflected the contribution from that city's residents. However, GDP had a strong relationship with one city's popularity because cities with higher GDP values could invest more into R&D and propaganda on low carbon development and also residents in such cities usually have higher life standards and demands on low carbon lifestyles. In addition, cities with higher GDP values usually host more universities and research institutions, where academic communities pay more attention on low carbon development.

3.5. Comprehensive evaluation of low carbon popularity in Chinese cities

As defined, the popularity of low carbon development for a specific city partially reflects the inputs and achievements of low carbon development of that city, which is substantially affected by its GDP. The *PPI* and *WPI* can barely represent a city's real and fair low carbon popularity due to significant GDP differences among cities. Therefore, the *CPII* indicator, normalized and integrated from *PPI* and *WPI* and then weighted by GDP, is a reasonable indicator to comprehensively evaluate and compare the low carbon popularity of cities.

Fig. 7 shows the top and bottom 10 cities in the *CPII* ranking list. Significantly different from *PPI* and *WPI* indicators, megacities, such as Beijing, Shanghai, Tianjin and Guangzhou, which were ranked in the top 10 in terms of *PPI* and *WPI* values, are not presented in the *CPII* ranking list. Guangyuan, Zhuhai, Guiyang and Baoding are ranked in the top 4. All of these four cities are middle sized cities, indicating that some middle sized cities have made significant efforts on low carbon development than those megacities.

Xi'an is the only city listed in the top 10 list of *CPII* ranking list and also in the top 10 lists of both *WPI* and *PPI*. Baoding in the top 10 list of *CPII* is also included in the top 10 of the population. None of the top 10 list of *CPII* appears in the top 10 list of the GDP. Such results demonstrate that the top *CPII* cities have not taken the advantages of either GDP or population. Seven of the top 10 cities in the *CPII* list are national low carbon pilot cities. This demonstrates again that national initiatives have strong influence on the popularity and concrete actions at the city level.

Guangyuan in Sichuan province of western China has sufficiently and successfully integrated post-earthquake reconstruction with low carbon development (Hao et al., 2015, 2016). Zhuhai is progressively developing its own low carbon pattern under the implementation of the "low carbon city pilot project released by NDRC. This city also actively engages in the international

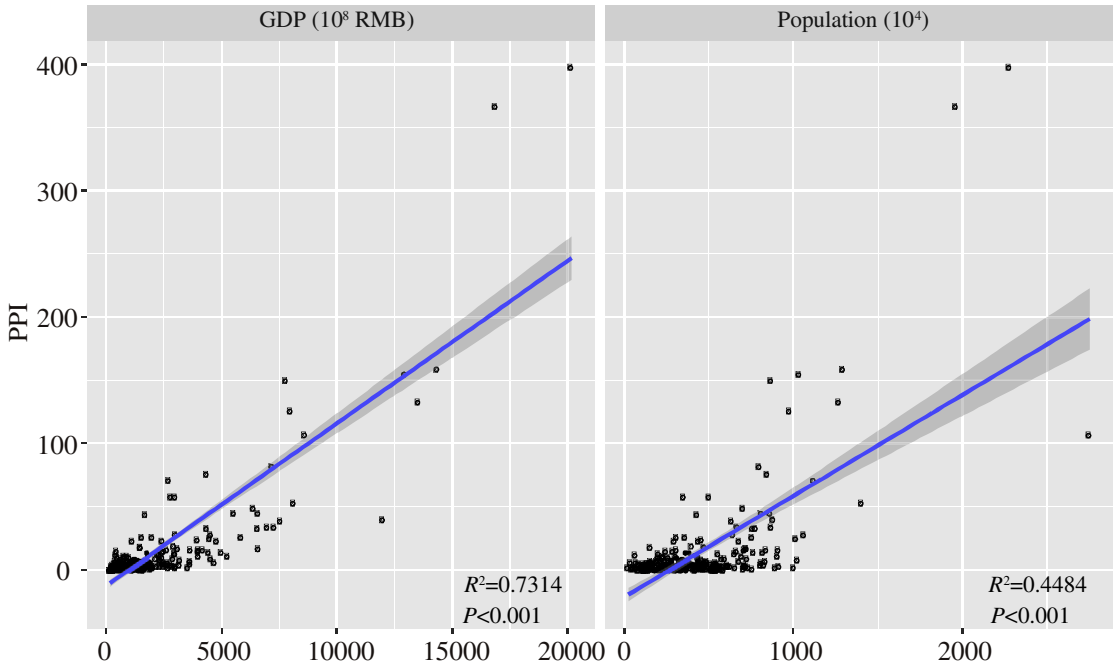

Fig. 5. Correlation between *PPI* and GDP/population of cities. Note: Observation number = 287. Dots refer to cities and grey areas refer to the 95% significance level.

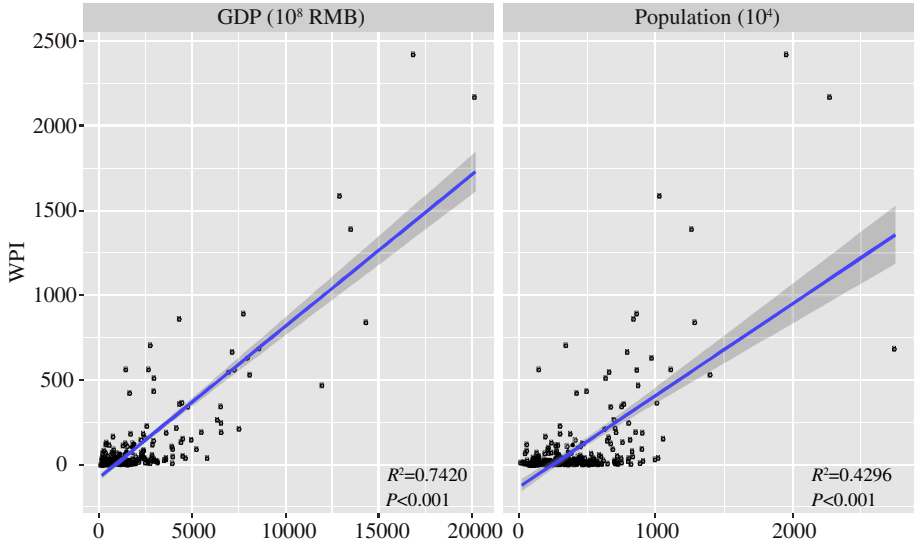

Fig. 6. Correlation between *WPI* and GDP/population of cities. Note: Observation number = 287. Dots refer to cities and grey areas refer to the 95% significance level.

cooperation through its participation of the Europe-China Eco-Cities Link project. Guiyang is the capital city of Guizhou province in the western China and has selected *Ecological Civilization* as its long term development strategy. This city benefits from hosting the famous *Ecological civilization International Forum* (starting from 2009) and learned a lot innovative actions on low carbon development from international communities. Baoding in the Inner Mongolia of northern China is a steel/iron dominated heavy industrial city. By actively supporting the photovoltaic industry and energy efficient technologies, this city has made great efforts on transforming its energy and economic structure with and has been selected by the WWF (World Wide Fund) as one low carbon pilot city.

Among the bottom 10 cities of *CPII*, three (Chongzuo, Yulin and Hechi) are from Guangxi province of southern China, one of the least developed provinces in China. Four of them (Shuangyashan, Suihua, Songyuan and Liaoyuan) are from Northeast China, which is the heavy industrial base of China and is now facing great challenges in economic transition. This phenomenon further demonstrates that healthy and sustainable economic development are the basis for low carbon development. Interestingly, three cities (Chongzuo, Shuangyashan and Guyuan) scored zero in *CPII*, indicating that these cities are in the very low stage of low carbon development. Both central and provincial governments should investigate the underlying reasons so that appropriate policies can be prepared to promote low carbon development in such backward cities.

Fig. 8 shows the spatial patterns of *CPII* indicators, which are significantly different from those of *PPI* and *WPI* indicators. Cities with high *CPII* values do not mainly come from the three main

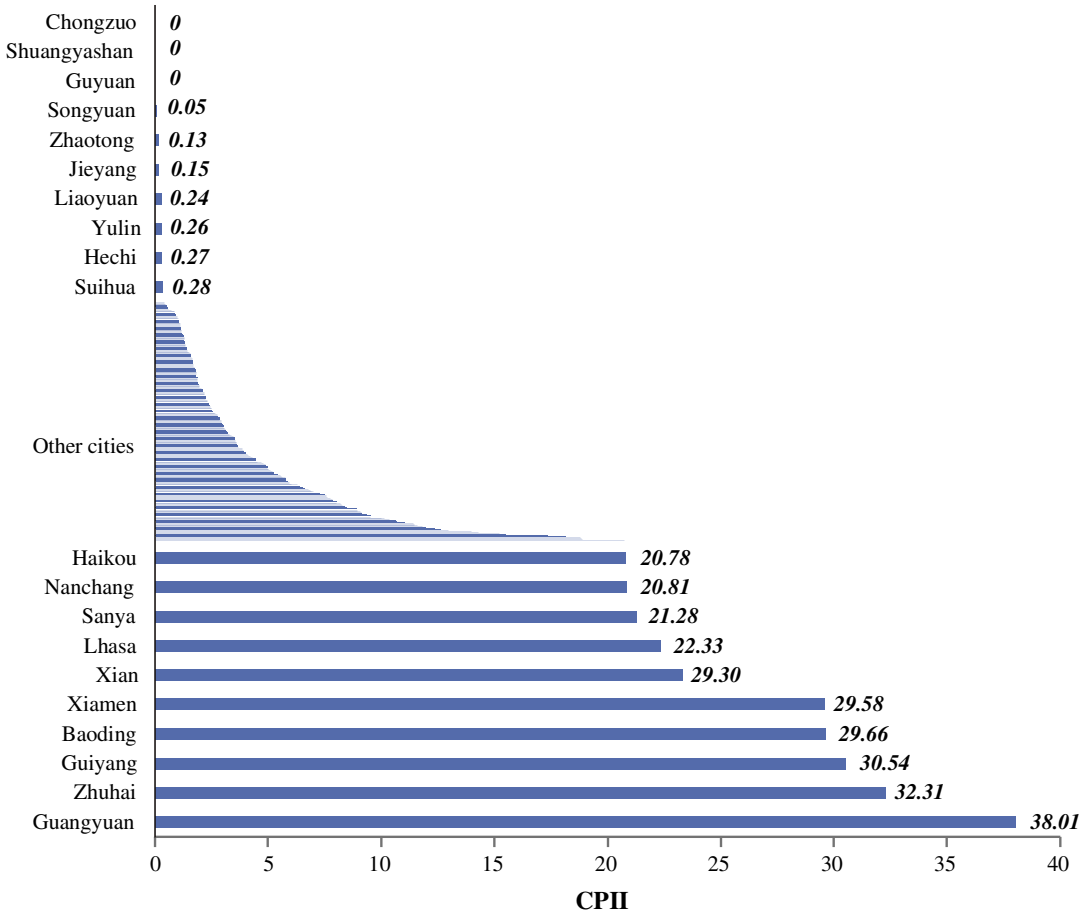

Fig. 7. *CPII* ranking of cities. Note: The figure only indicates the 10 top and bottom cities by name and the *CPII* value.

economic regions of China, but are distributed randomly. Some cities (such as Lhasa in Tibet) in the western China also have high *CPII* values, implying that cities can make positive progress on low carbon development irrespective of their economic levels and spatial locations.

4. Conclusions and policy implications

Low carbon development at the city level is essential for China so that smooth urbanization and industrialization can occur. In this regard, better understanding on low carbon development by the whole society is vital so that effective mitigation policies can be raised.

Under such a circumstance, this paper investigates how scholars and the public perceive low carbon city using a combined method of data mining approach and bibliometric analysis. The results present that the perceptions changed during the research period and reached a peak in 2013, which was presumably induced by China's new low carbon city pilot program and the Rio +20 summit launched in 2012. According to key words frequency analysis, the academic communities had different understandings on low carbon city than the public. The former group mainly concern with the macro economy, based on frequently used key words such as "Development", "Economy" and "Construction", while the general public expressed their own concerns related to "Green", "Travel" and "Life"; reflecting that they care more on the quality of life and environmental quality. Cities with high *PPI*/*WPI* values mainly come from three main economic regions (Jing-Jin-Ji region, Yangtze River delta region and Pearl River delta region). However, cities with high *CPII* values are distributed dispersedly, implying that cities can make great progress on promoting low carbon development irrespective of their economic levels and spatial locations. Three cities had zero *PPI*, *WPI* and *CPII* values, indicating they have not been considered for low carbon development by the academic communities or the general public. In the top 20 ranking lists of most popular cities of both publications and Weibo posts, 17 were low-carbon pilot cities of NDRC. In the top 10 ranking *CPII* list, 7 cities were low carbon pilot cities of NDRC. Such results indicate a very strong policy motivation for boosting low carbon development at the city level in China.

In order to further improve better policy design on low carbon development at the city level in China, several suggestions are proposed based upon the analysis findings.

Firstly, the perception on low carbon development for different cities should be monitored and evaluated regularly. Low carbon development is a long term strategy for one city and should not be ended by one single project. It is crucial to summarize the lessons and experiences by assessing the overall performance of pilot cities so that these lessons and experiences can be shared by other cities.

Secondly, special attention should be made for the least concerned cities. Several cities had zero *PPI* and *WPI* values, reflecting that both the academic communities and the public do not care for these cities' low carbon development. This also indicates that due to China's imbalanced development, different cities need different policies to encourage their low carbon development. In this regard, it is critical to consider the local situations so that their concerns can be better addressed.

Thirdly, more capacity-building efforts should be made so that

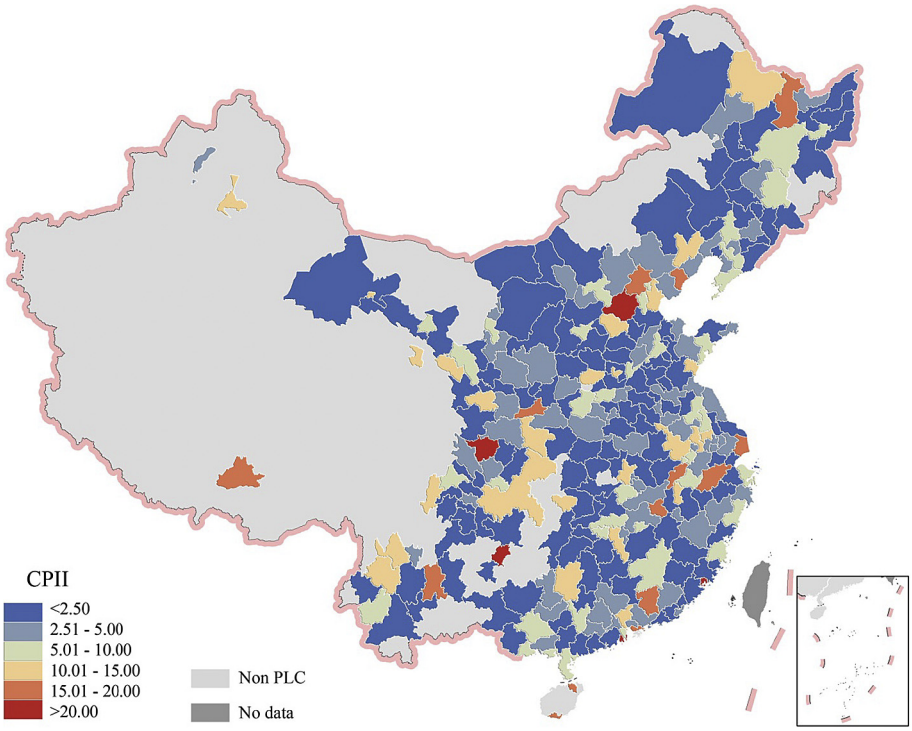

Fig. 8. Distribution of *CPII* in Chinese cities. Note: PLC refers to prefecture-level cities.

the general public can improve their awareness on low carbon development. Feasible channels include newspaper, websites, pamphlets, TV promotions and regular workshops so that advanced low carbon development experiences and technologies can be shared and learnt by more Chinese cities. Particularly, these capacity building activities should be delivered in an appropriate way. Otherwise, the general public may be misguided for their low carbon behaviors. For instance, most consumers believe that electric vehicles have much less emissions compared with conventional vehicles. Unfortunately, from life-cycle perspective, electric vehicles may induce higher CO_2 emissions in some regions where electricity is mainly generated by coal-burning power plants, particularly in the northern China (Huo et al., 2010; Geng et al., 2013). Consequently, careful screening on these efforts is necessary so that accurate information can be delivered to different stakeholders.

In summary, this study adopted a combination method (combination of bibliometric analysis and big data mining) to explore the perception on low carbon city from the perspectives of both scholars and the public. Compared with traditional literature reviews and bibliometric analysis methods, this new approach can help better and more effectively understand the perceptions of both scholars and the public. The outcomes provide valuable policy insights to those policy makers so that more appropriate mitigation policies can be released. However, a data mining approach can extract a tremendous amount of information related to policy measures. However, the method and data used in this study have the following limitations: (1) A Weibo account cannot fully represent the general public's perceptions since any persons or organizations (governmental agencies, academic communities, enterprises, and non-governmental organizations) can register their own Weibo accounts, but their perspectives on low carbon development were not included in our results. Thus it will be necessary to include these in the future studies. (2) Some detailed data on Weibo users were not further analyzed (such as genders, ages, education backgrounds, etc.), which may influence the in-depth perception. Thus, the future studies may consider these factors so that more broad and valuable information can be obtained. (3) This study investigated 287 Chinese cities by using the same indicators. But due to different economic levels, geographical locations and industrial structure, it is rational to categorize these cities by considering these factors; (4) This study only focuses on the special period of 2009–2016. But with the rapid development, the dynamic changes of such perceptions from both academic communities and the general public should be always monitored. Also, more channels to get such information should be explored beyond traditional academic databases and Weibo posts, such as questionnaires survey and face-to-face interviews so that more concrete perspectives on low carbon development can be obtained from different stakeholders.

Acknowledgements

The research was funded by the National Natural Science Foundation of China (71673107, 71690241, 71325006, 71461137008).

References

Amador, D.S., Maria, C.D., Rama, R., Jose, A.G., 2017. Bibliometric analysis of publications on wine tourism in the databases Scopus and WoS. Eur. Res. Manag. Bus. Econ. 23, 8–15.
BP, 2016. BP Statistical Review of World Energy.
Cai, B., Zhang, L., 2014. Urban CO_2 emissions in China: spatial boundary and performance comparison. Energy Policy 66, 557–567.
Cai, B., Wang, J., Long, Y., Li, W., Liu, J., Ni, Z., Bo, X., Li, D., Wang, J., Chen, X., Gao, Q., Zhang, L., 2015. Evaluating the impact of odors from the 1955 landfills in China using a bottom-up approach. J. Environ. Manag. 164, 206–214.
Chen, Z.A., Li, Q., Liu, L.C., Zhang, X., Kuang, L., Jia, L., Liu, G., 2015. A large national survey of public perceptions of CCS technology in China. Appl. Energy 158, 366–377.
de Jong, M., Joss, S., Schraven, D., Zhan, C., Weijnen, M., 2015. Sustainable–smart–resilient–low carbon–eco–knowledge cities; making sense of a

multitude of concepts promoting sustainable urbanization. J. Clean. Prod. 109, 25–38.
Dhakal, S., 2009. Urban energy use and carbon emissions from cities in China and policy implications. Energy Policy 37, 4208–4219.
Dhakal, S., 2010. GHG emissions from urbanization and opportunities for urban carbon mitigation. Curr. Opin. Environ. Sustain. 2, 277–283.
Gao, C., Sun, Y., Geng, Y., Wu, R., Chen, W., 2016. A bibliometric analysis based review on wind power price. Appl. Energy 182, 602–612.
Geng, Y., Ma, Z., Xue, B., Ren, W., Liu, Z., 2013. Co-benefit evaluation for urban public transportation sector-A case of Shenyang, China. J. Clean. Prod. 58, 82–91.
Gu, D., Li, J., Li, X., Liang, C., 2017. Visualizing the knowledge structure and evolution of big data research in healthcare informatics. Int. J. Med. Inf. 98, 22–32.
Han, M.Y., Sui, X., Huang, Z.L., Wu, X.D., Xia, X.H., Hayat, T., Alsaedi, A., 2014. Bibliometric indicators for sustainable hydropower development. Ecol. Indic. 47, 231–238.
Hao, Y., Su, M., Zhang, L., Cai, Y., Yang, Z., 2015. Integrated accounting of urban carbon cycle in Guangyuan, a mountainous city of China: the impacts of earthquake and reconstruction. J. Clean. Prod. 103, 231–240.
Hao, Y., Cai, Y., Zhang, L., Su, M., Yang, Z., 2016. Identification of low-carbon strategies for post-earthquake development in the city of Guangyuan based on an inexact two stage stochastic programming approach. Habitat Int. 53, 413–429.
Hartikainen, H., Roininen, T., Katajajuuri, J.-M., Pulkkinen, H., 2014. Finnish consumer perceptions of carbon footprints and carbon labelling of food products. J. Clean. Prod. 73, 285–293.
Howell, R., Shackley, S., Mabon, L., Ashworth, P., Jeanneret, T., 2014. Engaging the public with low-carbon energy technologies: results from a Scottish large group process. Energy Policy 66, 496–506.
Huo, H., Zhang, Q., Wang, M.Q., Streets, D.G., He, K., 2010. Environmental implication of electric vehicles in China. Environ. Sci. Technol. 44 (13), 4856–4861.
IEA, 2009. Cities, Towns&Renewable Energy. IEA.
IPCC, 2014. Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York,USA.
Jackson, R.B., Canadell, J.G., Le Quéré, C., Andrew, R.M., Korsbakken, J.I., Peters, G.P., Nakicenovic, N., 2015. Reaching Peak Emissions. Nature Climate Change.
(JRC) European Commission, Joint Research Centre, (PBL) Netherlands Environmental Assessment Agency, 2015. Emission Database for Global Atmospheric Research (EDGAR).
Le Quéré, C., Moriarty, R., Andrew, R.M., Canadell, J.G., Sitch, S., Korsbakken, J.I., Friedlingstein, P., Peters, G.P., Andres, R.J., Boden, T., 2015. Global carbon budget 2015. Earth Syst. Sci. Data 7, 349–396.
Li, D., Long, Y.A., 2015. Crowd-sourcing data based analysis framework for urban planning. China City Plan. Rev. 24 (1), 49–57.
Liu, G., Yang, Z., Chen, B., Su, M., 2012. A dynamic low-carbon scenario analysis in case of Chongqing city. Procedia Environ. Sci. 13, 1189–1203.
Mabon, L., Littlecott, C., 2016. Stakeholder and public perceptions of CO2-EOR in the context of CCS – results from UK focus groups and implications for policy. Int. J. Greenh. Gas Control 49, 128–137.
Mabon, L., Shackley, S., Bower-Bir, N., 2014. Perceptions of sub-seabed carbon dioxide storage in Scotland and implications for policy: a qualitative study. Mar. Policy 45, 9–15.
National Bureau of Statistics of China, 2011. China City Statistical Yearbook. China Statistics Press, Beijing.
OECD, 2010. Cities and Climate Change. OECD Publishing, Paris.
Sina, 2016. Sina Weibo.
Su, M.R., Chen, B., Xing, T., Chen, C., Yang, Z.F., 2012. Development of low-carbon city in China: where will it go? Procedia Environ. Sci. 13, 1143–1148.
Su, M., Li, R., Lu, W., Chen, C., Chen, B., Yang, Z., 2013. Evaluation of a low-carbon city: method and application. Entropy 15, 1171–1185.
Suk, S., Lee, S.-Y., Jeong, Y.S., 2016. A survey on the impediments to low carbon technology investment of the petrochemical industry in Korea. J. Clean. Prod. 133, 576–588.
The World Bank, 2010. Cities and Climate Change: an Urgent Agenda.
Thomas, E., Nicholas, B., Tarig, A., Arfon, G.M.T.P., Jolene, W., Wyn, G.L., 2017. The 100 most cited manuscripts in emergency abdominal surgery: a bibliometric analysis. Int. J. Surg. 37, 29–35.
Tian, Y., Wen, C., Hong, S., 2008. Global scientific production on GIS research by bibliometric analysis from 1997 to 2006. J. Inf. 2, 65–74.
Wen, L., Gao, Q., 2013. Comprehensive evaluation of low-carbon city in China using intuitionistic fuzzy set theory. Int. J. Environ. Prot. Policy 1, 68–75.
Yeo, W., Kim, S., Park, H., Kang, J., 2015. A bibliometric method for measuring the degree of technological innovation. Technol. Forecast. Soc. Change 95, 152–162.
Yu, H., Wei, Y., Tang, B., Mi, Z., Pan, S., 2016. Assessment on the research trend of low-carbon energy technology investment: a bibliometric analysis. Appl. Energy 184, 960–970.
Zhong, S., Geng, Y., Liu, W., Gao, C., Chen, W., 2016. A bibliometric review on natural resource accounting during 1995–2014. J. Clean. Prod. 139, 122–132.
Zhu, J., Liu, X., Pang, W.H., 2015. Scenario analysis for the energy demand and carbon emissions in low carbon city. Ecol. Econ. 130–138.