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Low carbon development and local sustainability from a carbon balance perspective

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ABSTRACT

Urbanization raises great challenges for global sustainability and natural resources. With the increasing carbon constraints in the context of climate change, the capacity of carbon sequestration becomes an important resource to address regional sustainable development. However, there is still a lack of an integrated methodology to evaluate urban sustainability within a local urbanization process from a carbon cycle perspective. This paper presents a new way of understanding regional sustainability, which assumes that the status of carbon balance is closely related to low carbon management and local sustainability. The concept of carbon neutral coefficient (CNC) is proposed based on the estimation of carbon emissions and sinks, which emphasizes the fundamental role of carbon sinks in achieving low carbon development and improving local sustainability. Taking Chongming Island (China), the largest alluvial island in the world, as a case study, carbon emissions and sinks are calculated respectively according to an integrated carbon inventory and local coefficients. From 2005–2013, a temporal-spatial variation of CNC was observed on Chongming Island, owing to the different growth rate of carbon emissions and sinks. Furthermore, a spatial variation of change of CNC was detected, caused by the imbalanced spatial distribution of carbon emissions and sinks. Remote Sensing based analysis shows that the change of land use and cover which was induced by human activities can greatly influence local carbon balance and sustainable development. It is also found that the CNC results can help explaining the positive impacts and limitations of ecological environment policies in Chongming Island during the same period. Consequently, the approach of carbon balance analysis serves as an additional tool for monitoring policy effectiveness, which contributes to the debate of sustainable carbon management for local sustainable development.

1. Introduction

Urbanization has placed huge pressure on resource management globally (Shen et al., 2005; White et al., 2010; Su et al.,2011; Agudelo-Vera et al., 2012; Pan, 2014). Sustainable urbanization is becoming a great challenge, especially for developing countries (Bai et al., 2012; Li et al., 2016; Shahbaz et al., 2016). China is in a critical phase of socio-economic transition and its urbanization strategy has always been a great concern for the rest of the world. Nowadays urbanization and climate change are inextricably linked, with bi-directional interactions that are complex, multifaceted, and often nuanced (Seto and Satterthwaite, 2010). The relationship between carbon cycle and sustainability has been an important subject of interest among scholars in the history of intellectual concern since the start of the Global Carbon Project (GCP) in 2001. The GCP aims to develop a complete picture of the global carbon cycle, which includes both natural and anthropogenic sources of carbon dioxide together with the interactions and links to climate and human activities. The annual carbon budgets were released by the GCP since 2007 (Le Quéré et al., 2014). The key issues of carbon cycle studies include temporal-spatial patterns of carbon emissions and sinks, the dynamic processes and mechanisms among different sources, and carbon management strategies. Additionally, the concept of carbon footprint is firstly developed to estimate the total set of greenhouse gas (GHG) emissions caused by an organization, event, product or person. Then a collective carbon footprint on a national or global level can be developed (Hertwich and Peters,

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2009). The carbon cycle mainly emphasizes the dynamic changes of carbon emissions and sinks, while the concept of carbon footprint usually refers to the absolute effect or impact.

The existing studies on carbon cycle are mainly at large scales such as global, national, regional or urban scale (Keeling et al., 1996; Cao and Woodward, 1998; Cox et al., 2000; Li, 2000; Fang et al., 2001; Schimel et al., 2001; Sitch et al., 2003; Chapin et al., 2009; Piao et al., 2009; Ciais et al., 2011; Yu et al., 2012; Yan et al., 2014; King et al., 2015; Wang et al.,2016). Schimel et al. (2001) points out that the global carbon exchange by terrestrial ecosystems was largely balanced in 1980s, and became a net carbon sink in 1990s. Piao et al. (2009) analyzed the terrestrial carbon balance of China during the 1980s and 1990s. They find that northeast China is a net source of CO_2 to the atmosphere whereas southern China accounts for more than 65 per cent of the carbon sink. Although global carbon balance presents an integrated picture for the whole world, local carbon cycle can provide detailed evidences by using high resolution datasets from local statistic bureaus and satellite images. For instance, the impact of local cropland and scattered trees along the streets and rivers can be better estimated, which is usually ignored in global and national carbon budgets.

In the 21st Conference of Parties held in Paris in 2015, China announced that it would peak its total carbon emissions by 2030 or earlier in the "intended nationally determined contribution" (INDC). With increased constraints of carbon emissions in the context of climate change, low carbon development is closely related to regional sustainable development. Therefore, effective carbon management plays a crucial role in creating a sustainable society, although we still know less about the carbon cycle and metabolism at a local level, especially in developing areas. Meanwhile, there is lack of integrated methodology to comprehensively evaluate the impact of historic and ongoing policies on sustainable development from the carbon cycle perspective. The gap between plan and practice also broadens due to the absence of a systematic approach for performance evaluation of plans. For instance, a disconnection between low carbon planning and practice often leads to a paradoxical development, deviating from the initial low carbon goal.

This study explores the conceptual model of the linkage between local carbon metabolism and sustainability. The aim is to provide local policy makers a quantitative tool of carbon balance analysis for local sustainability assessment, which can contribute to spatial-temporal optimization in the process of urbanization. This study also aims at a further understanding of the underlying principles of regional sustainability by means of RS technology, which can provide a theoretical basis for decision makers to achieve a sustainable carbon resource management.

2. Methodology

2.1. Basic concepts and assumptions

The urban population in 2015 accounted for 54% of the total global population, which is expected to rise to 66% worldwide (UN-habitat, 2016). A sustainable urbanization is crucial to achieve low carbon development and improve global sustainability. Carbon cycle plays an important role in the process of social-economic development with urbanized areas as both a driver and recipient of environmental change. This study explores how to measure local sustainability from the perspective of carbon cycle, emphasizing the irreplaceable role of carbon sinks.

There are already many studies on carbon cycles at large scales (global, national, regional or urban level). However, there are few carbon cycle studies at county and town level due to data scarcity. It is quite common that data associated with carbon cycle is either absent or scarce at smaller scales. Therefore, RS-based analysis can be a helpful addition for obtaining data at county and town levels. Besides, local carbon cycle can be easily affected by policies at different levels, especially for areas relying highly on surrounding regions.

The capacity of carbon sequestration already becomes a unique resource with the recognition of human-induced climate change (IPCC, 2006). Gaps between carbon emissions and sinks for different areas may possibly be linked with the scale and intensity of environmental impacts at multiple levels. Therefore, carbon balance is an ideal concept to analyze the relationship between carbon metabolism and sustainability. As the basic units, counties and towns are of great importance to implement low carbon strategies at local level. Local carbon balance analysis can identify local contributions to climate change, which is an effective tool to link local actions with global effects.

Frankly speaking, it is difficult to achieve carbon balance at small spatial scales because urbanized areas usually have more emissions rather than sinks. However, regional diversity can be revealed by the relative ratio of carbon emissions and sinks since human activities have different impacts on the local carbon cycle. For instance, improved living standards in urbanized areas will increase carbon emissions and impacts of urbanization will change land use (e.g. from cropland to construction land). On the other hand, industrial development and technical progress can improve energy efficiency while at the same time reducing carbon emissions. The capability to protect carbon sinks is also enhanced. More particularly, the linkage between the carbon cycle and sustainability can be described as follow**s**.

It is assumed that the concept of carbon balance is consistent with sustainable development for three reasons. Firstly, sustainable development emphasizes on the balance of nature, society, and economy, while carbon balance also focuses on the balance between human induced emissions and natural sinks. Secondly, sustainability is influenced by natural, social, and economic factors, with the natural factor being of fundamental importance. Carbon balance analysis also addresses the important role of carbon sinks. It is then argued that the balanced development of different aspects is potentially connected to the complicated linkage between carbon emissions and carbon sinks. Thirdly, analysis of carbon balance can help to identify priorities for local carbon management, which contributes to low carbon development as an important part of sustainable development. Therefore, carbon balance can partly reveal the state of specific regions in a quantitative way.

Consistent with the concept of strong sustainability (which assumes that the economic and natural capital is not always interchangeable and some ecological functions cannot be duplicated by humans or human made capital), the carbon balance analysis can also identify the most critical requirement of coordinated development, which is the basis for the maintenance of ecological bottom line. Therefore, it is a possible way to assess low carbon development and regional sustainability through a carbon balance analysis. Furthermore, urbanization implicated a spatial-temporal redistribution of population and industry, which leads to a transformation between carbon emissions and sinks in different areas. Therefore, the change of land use and cover can also be linked to the spatial differentiation of local carbon balance.

The overall methodology is shown in Fig. 1.

2.2. Estimation of carbon emissions and sinks

CO_2 is the main contributor to the local carbon cycle. Due to data availability, in this study the analysis of carbon cycle is limited to the CO_2 emissions and sinks. IPCC provides the basic approach to estimate carbon emissions and sinks at a national level, which is accepted worldwide. In 2011, National Development and Reform Commission (NDRC) of China released the Guideline for Green-