A new frontier for landscape ecology and sustainability: introducing the world’s first atlas of urban agglomerations

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At the moment, the world’s future seems more uncertain than ever before: the COVID-19 pandemic still raging after almost 3 years, with political interventions frequently derailing science-based solutions; the largest war in Europe since World War II still continuing after months of brutal shelling and killing, with much of the world watching and panicking; climate change devastating people and ecosystems from coastal areas to drylands, with more imminent disasters looming on the horizon... At least one thing seems certain, however. History has shown that the world seems to continue urbanizing no matter what else happens (Fig. 1). Cities have been the engines of growth, innovation, and globalization, as well as the epicenters of environmental pollution and extreme social inequity. Thus, urbanization is both part of the problem and part of the solution for sustainable development. Achieving urban sustainability, although it will not solve all the other problems, is certainly vital to our current and future wellbeing. Landscape ecology has contributed greatly to the study of cities (Forman 2008, 2014; Wu 2008, 2010; Milovanovic et al. 2020), but global urbanization has entered a new phase of cities becoming not only more and bigger but also coalesced over broad regions—forming “urban agglomerations”—which represent a new frontier for landscape ecology and landscape sustainability research. Nowhere else on Earth has urbanization been more dramatic than in China during recent decades; this editorial was motivated by the publication of an important new compendium on the topic: “The Atlas of China’s Urban Agglomerations” (Fang 2020). I believe that such atlases can greatly facilitate the scaling-up of landscape studies so as to better meet the scientific and societal needs of a rapidly urbanizing world.

What are urban agglomerations?

The world’s urbanization began to accelerate at the beginning of the Industrial Revolution in the late eighteenth century (Fig. 1). In 1950, about 30% of the 2.5 billion people on Earth lived in cities. The global population increased to 6.67 billion in 2007,
when the world for the first time had more people living in urban than in rural areas (Figs. 1, 2a). Today there are 7.9 billion people on Earth, about 57% of whom (some 4.5 billion) live in urban areas. By 2050, the world’s total population is expected to be 9.8 billion, with the global urbanization level rising to 68% (i.e., 6.7 billion urbanites) and the rural population declining to 3.1 billion (United Nations Population Division 2019). Currently, the most urbanized regions include Northern America (82%), Latin America and the Caribbean (81%), and Europe (74%), but the fastest urbanizing regions are found in Asia and Africa (Fig. 2a). In particular, China’s urbanization during the past four decades has been unprecedented in the world’s history: its urbanization level doubled from 17.90% in 1978 (the beginning of Reform and Opening Up period) to 35.88% in 2000, reached 50% in 2011, surpassed the global urbanization level (53.01%) in 2013, and jumped to 64.72% in 2021 (Fig. 2a). Gu et al. (2011) projected that China’s urbanization level would reach 70% in 2035 and 75% in 2050. The urbanization level for less developed regions of the world is projected to reach 65.6% by 2050, which will still be much lower than that for more developed regions (86.6%). But the urban population for less developed regions (5.56 billion) will be about five times that of more developed regions (United Nations Population Division 2019).

Urbanization not only produces more and bigger cities, but also accelerates the formation of urban agglomerations in which cities are increasingly connected physically and functionally (Fig. 2b). The latter is a prominent feature that characterizes the global urbanization pattern in recent decades (Batty 2008; Gu 2011; Wu 2014; Fang and Yu 2017; Kii 2021). The term, “urban agglomeration”, has been defined variously in the literature. According to Fang and Yu (2017), the concept of urban agglomeration is related to several other terms, including the English urban planner Ebenezer Howard’s (1898, 1902) clusters of garden cities, the Scottish biologist, sociologist, and planner Patrick Geddes’ (1915) conurbation, and the French geographer Jean Gottmann’s (1957) megalopolis, as well as other terms like city clusters, megaregions, and polycentric urban regions. In particular, Gottmann (1957)

Fig. 1 The urbanizing trends of the world and selected countries (China, India, Japan, and USA) during the past 500 years (modified from Our World in Data at https://ourworldindata.org)
observed that “the super-metropolitan character” of the vast region stretching from Boston to Washington “called for a special name”. After careful deliberation, he redefined the word “megalopolis” to denote “a chain of metropolitan areas, each of which grew around a substantial urban nucleus”.

Fig. 2 The urbanizing trends of the world and selected regions between 1960 and 2020. A Increases in the percent urban populations for the world and selected regions, and B the world’s cities and urban agglomerations in 2030 (United Nations Population Division 2019).
The United Nations defined “urban agglomeration” as “the population contained within the contours of a contiguous territory inhabited at urban density levels without regard to administrative boundaries” (https://population.un.org/wup/General/FAQs.aspx). However, the term has been used inconsistently among countries due to different socioeconomic settings and the hierarchical nature of the concept (as with watersheds, landscapes, or human-environment systems, which can be classified hierarchically based on speed, scale, and scope). A large number of recent studies of urban agglomerations have come from China (Gu 2011; Wu et al. 2014; Fang 2015; Zhao et al. 2015; Fang and Yu 2020; Bian et al. 2020).

There are multiple definitions of urban agglomeration in the Chinese literature, all of which are related to, but distinct from, the United Nations’ definition. Fang and Yu (2017) defined urban agglomeration as an “economically highly integrated cluster of cities” that are connected through “transportation and other infrastructure networks”. According to Fang and Yu (2017), an urban agglomeration consists of “one or more highly urbanized and commercialized large cities” and a number of medium and small cities with unique functions (e.g., manufacturing, technological, and commercial); the central and peripheral cities are socioeconomically connected; and the formation and development of urban agglomerations are driven by forces such as economic globalization, specialization of production and consumption, and institutional networks of governments and economies.

Urban agglomerations of different sizes now play an instrumental role in promoting economic, technological, and sociocultural developments at the international, national, and regional levels. Some well-known urban agglomerations include: the Nairobi Metropolitan Region in Africa; the Yangtze River Delta Region and the Pearl River Delta Region in China; the Delhi Megalopolis in India; the Greater Tokyo Area in Japan; the Paris Metropolitan Area in France; the Greater London Area in UK; the New York Metropolitan Area, the Greater Chicago Metropolitan Area, the San Francisco Bay Area, and the Arizona Sun Corridor in the USA. In the next 28 years, about 2.2 billion more people will likely be added to cities, with 90% of the increase coming from Africa and Asia. Thus, more and faster growing urban agglomerations are expected in the developing world where environmental and socioeconomic challenges are already mounting due to population pressures, social instabilities, and governance failures. This new urbanization pattern certainly poses grand challenges for sustainable development at regional and global scales (Forman and Wu 2016; United Nations Population Division 2019; McPhearson et al. 2022).

Introducing the world’s first atlas of urban agglomerations

Sixty-five years has passed since Gottmann’s (1957) call for investigating the structure, function, and dynamics of megalopolises. But not until the early 1990s did urban agglomeration-related studies begin to accelerate substantially in number (Fang and Yu 2017). During recent decades, China’s urbanization has not only led the world in speed and scale on the ground, but has also increasingly appeared in the pages of journals and books. A milestone publication is, “The Atlas of China’s Urban Agglomerations (2020), edited by Chuanglin Fang, a leading urban geographer. This atlas is the world’s first of its kind and provides the most comprehensive and detailed information on China’s rapidly developing urban agglomerations in map format (Fig. 3). The atlas was the culmination of 15 years of studies by a team of more than 50 researchers. Altogether, the atlas contains more than 300 maps that cover the environmental, economic, and social dimensions of China’s urban agglomerations between 1980 and 2016. These maps were created based on an enormous amount of data from numerous sources, including remote sensing data, statistical yearbooks, urban and regional planning documents, governmental documents, and field survey data.

The atlas consists of four sections: I—Overview of China’s urban agglomerations, II—Key development of five national-level urban agglomerations, III—Steady development of eight regional-level urban agglomerations, and IV—Guiding and incubating six local-level urban agglomerations (Fig. 3). Section I provides information on the environmental settings, strategic positions, demography and urbanization levels, economic development, spatial pattern and development stages, social development levels, and environmental pollution and measures for China’s urban agglomerations. Each category has a wealth of detail in terms of both the thematic topics
and the spatial resolution. For example, the natural environment part is composed of captioned maps of the spatial distribution, topography, landform, geology, remote sensing imagery, earthquake fault zones, natural disasters, water systems, monthly temperature, annual precipitation, climate types, land use, soils, vegetation, and ecological risk assessment for all China’s urban agglomerations. Sections II, III, and IV present national-, regional-, and local-level urban agglomerations individually with further details, each consisting of a wide range of thematic maps: spatial domain, digital elevation, remote sensing image, economic density, population density, population migration, knowledge flow network, spatial configuration, transportation network, and spatial patterns of PM$_{2.5}$ and O$_3$. The atlas ends with two appendices of data sources/mapping procedures and major scientific publications as supporting materials for the atlas.

For the first time, the essential environmental, economic, and social datasets of a variety of sources for all urban agglomerations in China are compiled and synthesized into one book in a methodologically consistent, scientifically rigorous, and artistically elegant manner. The atlas provides extremely valuable data for ecological, geographic, sustainability studies of Chinese cities and global urban agglomerations. This is especially true for urban researchers, landscape ecologists, and landscape sustainability scientists. The atlas is nicely accompanied by the book, “China’s Urban Agglomerations” (Fang and Yu 2020), which provides a systematic and historical review of urban agglomeration-related studies, and an in-depth account of the spatiotemporal transformations, selection and development plans, and socioeconomic functions of China’s urban agglomerations during the past 35 years. Consistent with the atlas but with greater detail in terms of text, the book describes the overall design and implementation of China’s hierarchically structured urban agglomeration system, which consists of 5 national-, 9 regional-, and 6 local-level urban agglomerations (the so-called 5+9+6 model). Going beyond the atlas, the book also discusses the challenges, strategies, and evaluation measures to achieve sustainable urban agglomerations in China.
A new frontier for landscape ecology and landscape sustainability science

Gottmann (1957) thought it was “too early to assess the full meaning of a study of Megalopolis”, but he was certain that “the study must first be carried out” because “Megalopolis heralds a new era in the distribution of habitat and economic activities”. His prophecy is fulfilled. Today, urban agglomerations have indeed produced some of the most spectacular landscapes that signify human ingenuity and dominance over nature. While they provide a variety of social and economic benefits to the global community, their profound impacts on the environment and increasing structural and functional complexity are worrisome to many. Yet, the process of urban agglomeration is still accelerating, which will undoubtedly exert greater influences on the ecology and sustainability of landscapes, regions, and the world as a whole. Gottmann (1957) proposed that megalopolis research must address the basic questions about its formation, driving processes, functions, internal organizations, and across-system interactions. In particular, Gottmann (1957) highlighted four major problems with megalopolises to be studied and solved: traffic difficulties, slums, water supply, and local government. From the reviews by Fang and Yu (2017, 2020), it is clear that these problems have been studied extensively around the world, but they are yet to be solved adequately (“wicked problems”). To ensure sustainable urban agglomerations, they must be studied systematically with interdisciplinary and transdisciplinary approaches. Towards this end, landscape ecology and landscape sustainability science can certainly help (Wu 2013, 2021; Opdam et al. 2018; Frazier et al. 2019; Liao et al. 2020). Indeed, here I argue that urban agglomeration presents a new and exciting frontier for landscape sciences.

Batty (2011) projected that “the entire world will be urbanized by 2092”, or that “by the end of the century everyone will be living in cities”. He eloquently articulated that, cities grow outward, incorporate smaller cities, join bigger cities, form clusters, and become increasingly connected across regions, continents, and the entire world. Then, this growing and coalescing process of urbanization will eventually lead to something of a phase transition in percolation, producing the ultimate global “giant cluster” of cities across the size hierarchy, in which “all cities will be connected, but there may remain stubborn pockets of resistance in failed states” (Batty 2011). Will the world eventually become one all-connected gigantic city? Probably not. I certainly hope not, as we know from landscape ecology that overconnected landscapes are not sustainable because they have too much sensitivity and too little resilience to disturbances. Think about the spread of the COVID-19 pandemic and the numerous lockdowns and restrictions to contain it. Think about the profound homogenizing influences of urbanization on biological and cultural diversity. Think about the spatially stretched-out ecological footprint of each city and country!

To make urban agglomerations sustainable, we need to understand and gauge how connected (or disconnected) cities and their clusters ought to be in a country and across the globe. More isn’t always better.

To move forward with the study of urban agglomerations, it is important to continue addressing Gottmann’s (1957) suggested questions. They are fundamental. But in order to achieve sustainability goals, they must be addressed in a broader context that considers biodiversity, ecosystem function, ecosystem services, and human wellbeing. The pattern-process-scale-design paradigm of landscape ecology (Forman 1995; Wu and Loucks 1995; Turner et al. 2001; Wu 2006; Nassauer and Opdam 2008) can provide a comprehensive ecological foundation for this endeavor.

The eight core questions and ten approaches for landscape sustainability science (Wu 2021) are equally pertinent to the study of the structure, function, and sustainability of urban agglomerations. For example, it is essential for both fields to understand, on the one hand, how the composition and configuration of regional landscapes or urban agglomerations affect system-level performance and sustainability, and on the other hand, how landscape patterns are influenced by environmental conditions (e.g., climate, topography, and ecosystems) and socioeconomic drivers (e.g., demography, institutions, and globalization). The landscape pattern-ecosystem services-human wellbeing nexus is central to both fields. Collaborations from ecological, geographical, and design sciences are not only desirable but also imperative if our regions, including urban agglomerations, are to be sustainable (Wu 2019).

Urban agglomerations are in fact coupled urban–rural landscape systems. Cities depend on rural areas for basic material needs (e.g., food, water,
and energy), while rural areas need cities for economic opportunities (e.g., investments and markets) and education and health services. As UN-Habitat (2019) pointed out, “the reciprocal and repetitive flow of people, goods and financial and environmental services (defining urban–rural linkages) between specific rural, peri-urban and urban locations are interdependent; they are the reality of socio-spatial arrangements, creating places with distinct yet interwoven, socially constructed identities”. Cities cannot survive without constantly engulfing resources from other ecosystems near and far. Thus, urban and rural systems coexist now and will probably do so forever. Therefore, to sustain urban regions, rural areas must be (re)vitalized and integrated. As Liu and Li (2017) put it: “Cities and villages are an organic whole. Both must be developed sustainably to support each other”. The United Nations recognizes that “Integrated policies to improve the lives of both urban and rural dwellers are needed, strengthening the linkages between urban and rural areas and building on their existing economic, social and environmental ties” (United Nations Population Division 2019). One of the targets of Sustainable Development Goal 11 (“the urban goal”) is to “support positive economic, social and environmental ties” (United Nations Population Division 2019). One of the targets of Sustainable Development Goal 11 (“the urban goal”) is to “support positive economic, social and environmental ties” (United Nations Population Division 2019). One of the targets of Sustainable Development Goal 11 (“the urban goal”) is to “support positive economic, social and environmental ties” (United Nations Population Division 2019). One of the targets of Sustainable Development Goal 11 (“the urban goal”) is to “support positive economic, social and environmental ties” (United Nations Population Division 2019).

Landscape approaches make it explicit that urban agglomerations are not merely “city clusters”; rather, they are land mosaics that consist of cities, towns, rural areas, human-made infrastructures, and natural ecosystems. Urban agglomerations are “powerful” landscapes, and their dynamics are having profound impacts on the environment and society. Thus, it makes perfect sense to have urban agglomerations as a new frontier for landscape ecology and landscape sustainability science. Exciting and important outcomes are expected from this cross-disciplinary fertilization. The Atlas of China’s Urban Agglomerations and similar works can certainly help advance this line of research in the years and decades to come.

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