Urbanization and Global Environmental Change

AN IHDP CORE PROJECT

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Opportunities and Challenges for Sustainability in an Urbanizing World:
Selections from the UGEC2010 Conference

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Editorial

Dear friends of the UGEC project,

Transdisciplinarity has been identified as a major pillar of sustainability science. It is widely understood that the knowledge required to deal with intractable problems such as climate change and biodiversity loss cannot be found within the neatly organized walls of a single scientific discipline. This understanding was made even clearer as a result of the 2010 International Conference on Urbanization and Global Environmental Change: Opportunities and Challenges for Sustainability in an Urbanizing World, which took place in October 2010 at Arizona State University. This concept of cross-fertilization of knowledge across distinct disciplines is not limited to the field of sustainability. Recently, national scientific organizations – including the American Association for the Advancement of Science – began exploring the emerging concept of convergence: the idea that engineering, physical sciences and life sciences can come together for solutions to problems in health care, energy and other fields.

Urbanization and global environmental change research can benefit from a closer look into the new ideas connected to the concept of convergence and become a central component in sustainability science. One of the dimensions of sustainability where this convergence of scientific knowledge is critical is in the formation and growth of cities. Urban areas have been and will likely continue to dominate settlement patterns across the globe. About three billion additional urban dwellers are expected to be distributed over 1-2 million square kilometers of new urban land; given existing trends, urban expansion will materialize primarily in the developing world. China and India in particular will have prominent roles in these developments. We must realize that action and results springing from transdisciplinary sustainability science and practice will to a large extent play out in these urban areas.

Both sustainability science and convergence hold many promises for the development of solutions, this movement towards the integration of disciplines requires multiple (and deep) changes: 1) new structures of academic departments and schools, providing incentives for collaboration across departments and promoting the integration of disciplines; 2) alterations in the academic peer review system so that “high(er) risk” research is acknowledged and rewarded; 3) national funding mechanisms and international collaboration for funding; 4) better communication with governments, non-governmental organizations and business; as well as 5) the training of a new generation of scholars – whose daunting task could either be to amass expertise in multiple fields, achieving both breadth and depth of knowledge or adopt a culture of increasingly productive and efficient collaboration across their individual disciplines for solving pressing world problems.

One of the main take home messages from the 2010 UGEC Conference was the need to push harder in order to advance this concept of convergence in the field of urban sustainability. This requires at a first level, a view across different scales, from the individual building to national or regional systems of cities. Also, fields of knowledge that require stronger synthesis include a wide range of natural sciences, social sciences, engineering, architecture, planning and design. In particular, fields such as materials engineering at the smaller scale, (landscape) ecology, complexity science, economics, geography and politics, seem especially critical. In this issue of UGEC *Viewpoints*, we share with you a selection of articles that provide an overview of the diversity of research presented and discussed at the recent 2010 UGEC Conference and ideas of how we can best move forward. Many of the articles speak to the ideas of convergence and transdisciplinarity described here and point ways forward. I hope that this issue inspires further thinking in this regard.

Enjoy the read!

Michail Fragkias
UGEC Executive Officer

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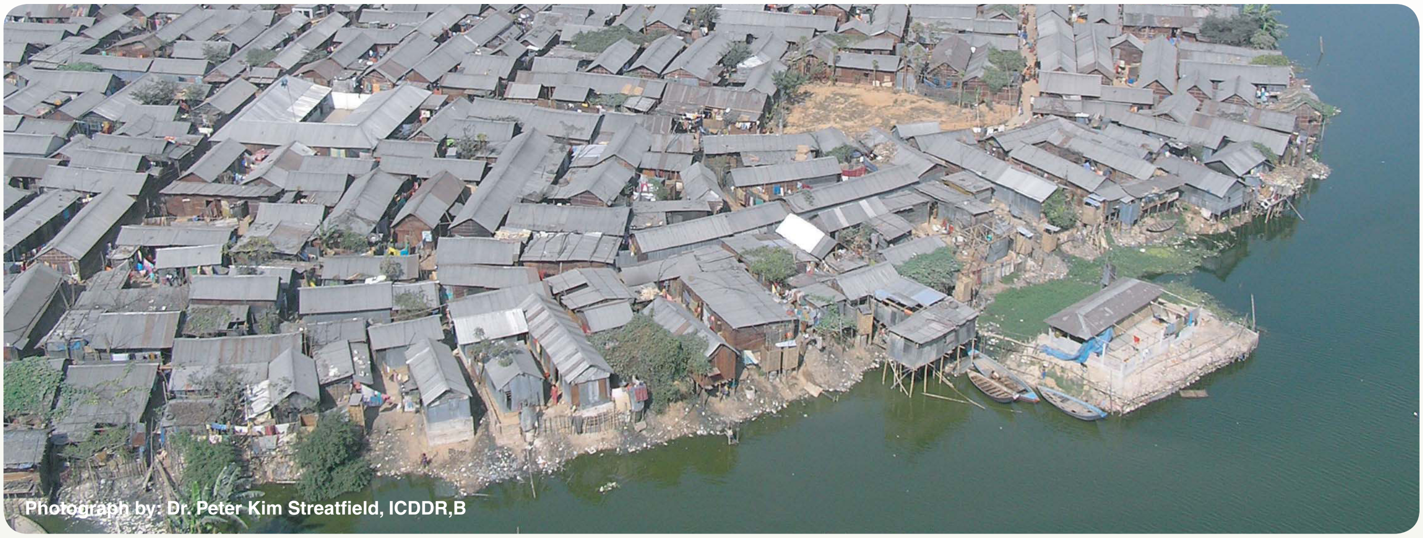


Karail Bastee, Mahakhali, Dhaka, Bangladesh

Remote Sensing Data for the Mapping of Urban Poverty and Slum Areas

Maik Netzband and Atiqur Rahman

Urban focused social science investigates the present-day challenges (threats) to the welfare of the urban population. Social science research mostly relies on interactions with individuals, e.g., through surveys or ethnographic research. Social science studies are attracted to remote sensing (RS) data for observing changes in physical characteristics at a local (e.g., urban studies), regional (forest cover change), or even a global scale. These are the kinds of studies that can be coupled with social science data streams, within surveys or observation of behavior (migration and market activities). But, there is no natural correspondence to grids or even small-scale administrative units. On the other hand, technological requirements seriously reduce the usability of RS data in social science (SS) applications.

Urban RS has proven to be a useful tool for urban planning and urban ecological topics at different scales. But remote sensing in urban areas is by nature defined as the measurement of surface radiance and properties connected to the land use/land cover in cities. Beyond the physical measurement the question remains whether there is (or potentially could be) value in RS for social scientists working on urban topics as well. Is it more than just a pretty picture? And, can it fill spatial gaps in social science data?

Studies concentrating on the challenge of world urbanization still claim an unmet need to link spatial and socio-demographic information. Rindfuss and Stern (1998) discuss the gap between social science and remote sensing research as well as the potential benefits in bridging that gap. As a justification for expensive publicly funded satellite programs, remote sensing scientists argue that remote sensing data are valuable for society. Some social scientists view remote sensing as a tool for gathering information on the context that influences social phenomena or the environmental consequences of various social, economic, and demographic processes. Social science itself can contribute to remote sensing research by validating and interpreting the data as well as investigating the implications of using remote sensing data for confidentiality.

Attempts to address the question of whether the worldwide urbanization process is dealing with poverty have been, thus far, based on limited information. There is little scientific and operational knowledge about this process. Urban growth and land consumption patterns are only beginning to be recognized and regulation is still limited. Thus, the available information is very often inadequate for policy and planning. Due to the microstructure and irregularity of fast growing urban agglomerations as well as their direct adaptation to local conditions and terrain, a generically applicable and operational mapping of these settlements has proven difficult. Sophisticated data and methods of image analysis are thus necessary.

> Population modeling was one of the early applications of remote sensing (de Sherbinin et al., 2002). Although the number of people living in an area can not be seen directly on the remotely sensed data, it can be used as an indirect tool for population estimation by using different methods. There are different branches of population-environment research in which remote sensing data can be effectively used. Remotely sensed data both from aerial photographs and satellite images in combination with Geographic Information Systems (GIS) have scientific value not only in the study of land use/land cover change (e.g., decrease in open green areas, increase in impervious areas), but also for the study of depletion of surface and ground water, increasing air pollution and land surface temperature. Using satellite data can increase accuracy (vis-à-vis ground measurements), will take less time, human power, and reduce the costs of doing research on urban issues.

Identifying spatial patterns of urban poverty

High resolution remotely sensed data sets (e.g., IKONOS, Quick Bird and Cartosat 1 and 2) help to document the growth of urban areas, both quantitatively and, in combination with ancillary data sets, qualitatively. In order to analyze and evaluate intra-urban patterns as well as trends in slums across cities, such data must be taken throughout the various levels of planning processes and must incorporate all existing and documented socio-economic information and environmental issues.

Recent research activities have focused on the identification of the poor in the context of slums, informal settlements, marginal areas and low income neighborhoods, as well as their spatial embeddings in a number of fast growing cities and megacities across the globe (Netzband et al., 2009). The spatial profile that traces poverty in complex, cluttered, uncontrolled, and fast growing urbanized regions is elaborated by means of very high resolution (VHR) remote sensing data, e.g., WorldView 1 and 2 and GeoEye-1 and the associated geospatial techniques. There are several issues in addressing the question of how remote sensing

Figure 1A & 1B | Urban remote sensing applications, A: Central Dhaka, Bangladesh; B: Lo Barnechea, Santiago de Chile

Figure 1A

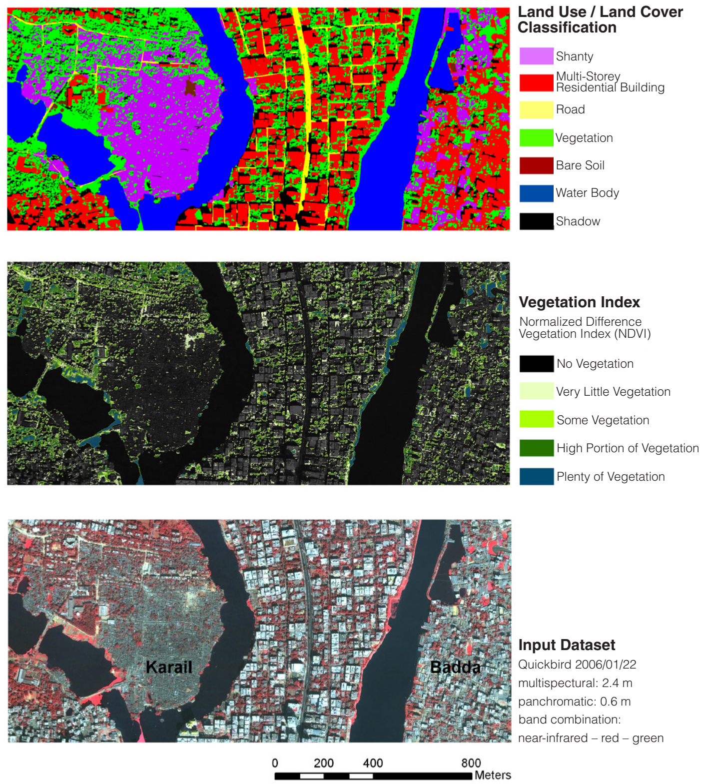


Figure 1B

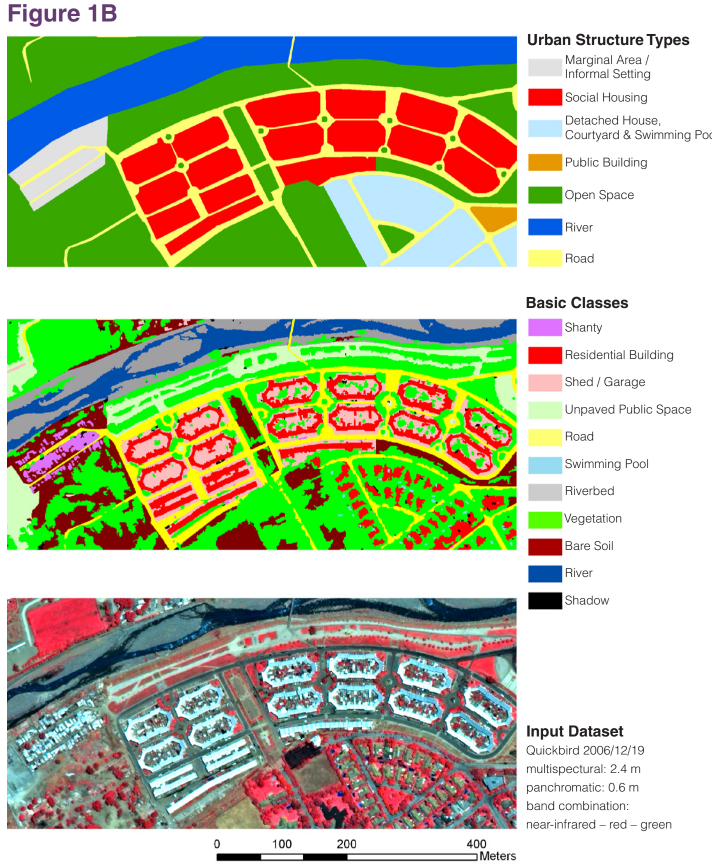
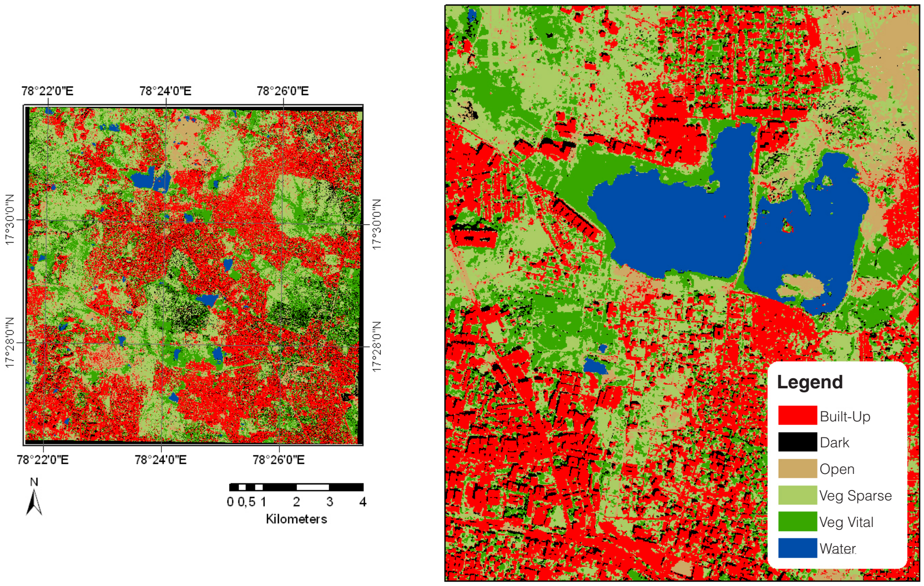


Figure 2 | Example of object-based land cover classification based on multispectral, panchromatic and pan sharpened WV-2 input layers, Hyderabad, India



Data provided by DigitalGlobe as part of the "8-band-challenge", see http://dgl.us.neolane.net/res/dgl/survey/_8bandchallenge.jsp)

can help access the spatial configuration of urban informal settlements and living conditions. These include:

- Examining whether a spatial correlation exists between the results of the different thematic land-use/ land-cover analyses;
- Identifying land-use patterns combined with a vegetation index analysis (NDVI) and Urban Structure Types (UST); and
- Estimating spatial indicators for quality of life and vulnerability to natural hazards such as flooding.

The concept of classifying UST by remote sensing and GIS has proved increasingly important as a baseline for urban spatial research (Banzhaf and Höfer, 2008; Puissant and Weber, 2002; Niebergall et al., 2007; Taubenböck et al., 2006). The UST are characterized as follows: First, they can identify different classes such as types of buildings (residential, commercial, industrial and recreational, etc.), other classes of impervious surfaces (road and railways, parking lots, etc.), and classes of open spaces (woodland, garden allotments, and parks). Secondly, they can typify structures as per their individual compositions, as it takes the composition of two to three of the aforementioned classes to form an urban structure type. Therefore, the amount, connectivity, and distribution of impervious surfaces, green spaces, and other open spaces on an aggregated neighborhood scale are the goal of the quantitative spatial characterization.

After the classification of such single objects, the structural composition in terms of the amount and connectivity of the single objects is aggregated on a neighborhood scale to generate a UST (Banzhaf and Höfer, 2008). The resulting UST layer forms the basis for socio-environmental studies on topics such as socio-spatial differentiation or for socio-ecological investigations on neighborhoods exposed to natural hazards (e.g., flooding and landslides) and also supports socio-economic research on inclusion and exclusion.

In terms of the urban vegetation pattern analyzed with the NDVI, existing vegetation and other open areas are considered positive urban structure elements because of their ecological functions (biodiversity conservation, production of oxygen and cleansing the air from pollutants), as well as their social functions for individual recreational purposes and as social meeting points. Water bodies, as potential carriers of disease and the road system, as a potential air polluter are considered negative urban structures in the sense that their proximity can cause respiratory and infectious diseases. Due to the rapid population growth of megacities lacking appropriate infrastructure measures, multiple health issues result for their inhabitants.

The knowledge of surface temperature is important for urban climatology and human health. Thermal infrared remotely sensed data in the bandwidth of 10.4-12.5 µm, available from Landsat-7 (TM and ETM+) and ASTER satellites, which has 60m and 80m resolution respectively, can be used to identify urban heat islands (Rahman, 2007). Thermal infrared data acquired over urban areas during the day and at night can be used to monitor the heat island effect associated with urban areas, as well as atmospheric pollution.

Sliuzas and Kuffer (2008) analyze the spatial heterogeneity of poverty using selected high resolution remote sensing based spatial indicators such as roof coverage densities and a lack of proper road network characterized by the irregular layout of settlements. Based on these indicators, the heterogeneity of several deprived neighborhoods have been identified and different types of poverty areas delineated. Other approaches by Gamba et al. (2007) analyze VHR images of disaster events to develop efficient methods for building detection.

These methods also estimate damages on the basis of pre and post event images in order to map the presence, location and status of buildings in order to provide a statistical basis for planning instruments. Such approaches exemplify the possibilities of VHR images for poverty mapping and demonstrate the scale of VHR needed to gain detailed information. In other words, data aggregation may hide the spatial variation of the urban structure, and thus, of poverty.

Final thoughts

This contribution attempted to show some potential benefits of bridging the gap between spatial analysis and remote sensing in social science by characterizing the deprivation of quality of life for the urban poor, who are strongly influenced by their physical environment. Studies concentrating on the challenge of world urbanization and its links to global environmental change often refer to a need for combined spatial, physical and socio-demographic information. Geospatial technology and RS can help to fill some of these gaps. For example, RS can help identify vulnerable groups and their spatial urban environment, which if acted upon, could support the search for equity in megacities. Methods are improving, but cross-disciplinary skills still need better integration and forethought. One major actor within the growing international network, the "100 Cities Project" at Arizona State University (http://cesa.asu.edu/urban-systems/100-cities-project/), has sought to understand how urban remote sensing can best be utilized by researchers and practitioners in developing urban models, planning, and policy formulation for the sustainable development of urban areas.

Waste water inflow into lake, Hyderabad, India

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Night view of city landscape in Shenzhen, China

The Impacts of Urbanization on Cultivated Land Change in China

Xiangzheng Deng and Karen C. Seto

China's urban population is expected to increase by approximately 300 million over the next 40 years. Currently, the country is not only one of the most populous nations, it also has the largest total urban population. With the transition from a planned to a market-oriented economy and the gradual shift of the population and economy from the agricultural sectors to the industrial and service sectors, the expansion of urban areas and the built environment in China has accelerated. This trend is expected to continue for several decades as the country undergoes an urban and economic transition that has already been experienced by all industrialized countries. Urbanization is correlated with economic growth and an improvement in livelihoods and standards of living. However, it has also resulted in numerous environmental problems such as rapid resource extraction, water and air pollution, and high levels of energy use and greenhouse gas emissions (Chen, 2007; Güneralp and Seto, 2008).

Land is a central factor in economic development and urbanization processes. It allows for an increase in the built environment to house the geographic shift of population from rural to urban areas (Deng et al., 2008). Around the world, there is evidence that rapid economic growth is usually accompanied with the conversion of cultivated land to urban uses, i.e., for industry, infrastructure, and housing (Ramankutty et al., 2002; Seto et al., 2000). High income countries in East Asia, North America and Europe all lost significant amounts of arable land during their economic and urban transitions. As China enters into an era of unprecedented rates of urbanization, it raises research and policy questions around the impact of urban growth on agricultural land. Are the rates of cultivated land loss in China similar to those that occurred in other countries during their economic transitions? Or, is agricultural land loss occurring at a more rapid pace? Are the most productive agricultural lands being lost to urban expansion? How will the loss of cultivated land affect the ability of the country to feed itself? Moreover, urbanization is expected to result in significant changes in the demand for meat and dairy products because urban diets demand more meat than rural diets. Thus, urbanization has two affects on agricultural land. Directly, urban expansion can envelop cultivated land. Indirectly, urban diets have a larger agricultural land requirement for feed grain. The issue of agricultural land loss is not only an issue of domestic food security for China, but it also has significant implications for international food prices and global agricultural markets.

Urbanization in China

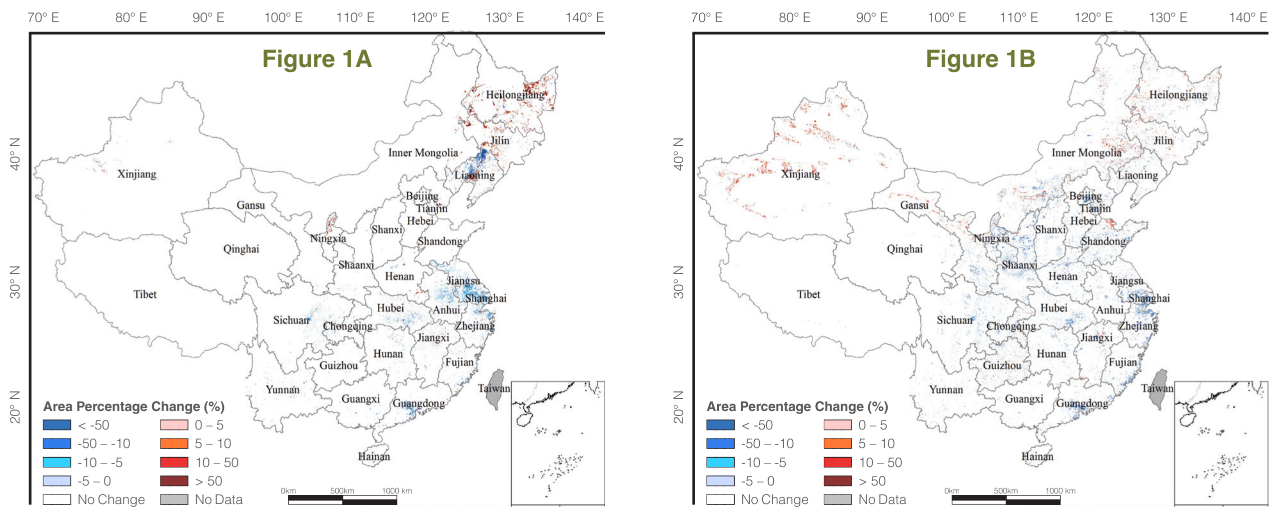
China is experiencing the largest flow of rural to urban migration in the world (Zhang and Song, 2003). The percentage of the urban population has increased dramatically over the last thirty years: 18% in 1978, 30% in 1995, 39% in 2002 and 46% in 2008 (NSBC, 1996, 2003, and 2009). However, urbanization is not taking place uniformly across the country. The eastern and coastal provinces and municipalities have developed at a much faster pace than its interior counterparts, leading to severe income and development disparities among regions (Chen, 2002). The coastal province cities such as Shanghai, Beijing, Shenzhen and Guangzhou already have populations near or exceeding 10 million.

Cultivated land changes in China

The central debate around cultivated land is whether urbanization is resulting in the net loss or increase in cultivated land. A remote sensing analysis of changes in cultivated land from the late 1980s to the mid 2000s shows unexpected results (Liu et al., 2003; Liu et al., 2010). From the late 1980s to the late 1990s, the analysis shows that cultivated land increased during this period (Figure 1A). In the late 1990s, the total area of cultivated land in China was about 141.14 Mega hectares (Mha), with the paddy field area of 35.65 Mha and dry land area of 105.49 Mha. The cultivated land shows an increase of 2.99 Mha or 2.17% from the late 1980s; the dry land increased by about 2.85 Mha or 2.78% and paddy fields increased by about 0.14 Mha or 0.4%. The net change of cultivated land shows an imbalance between the loss and gain of cultivated land. About 3.2 Mha cultivated land was converted to other land use types, including 1.5 Mha to built-up area. However, 6.2 Mha cultivated land was converted from other land use types, which was much larger than the loss of cultivated land. The area of cultivated land increased in Northern China, most of which were converted from forests and grassland. Southern China showed a decrease of cultivated land due to the expansion of urban areas (Figure 2A).

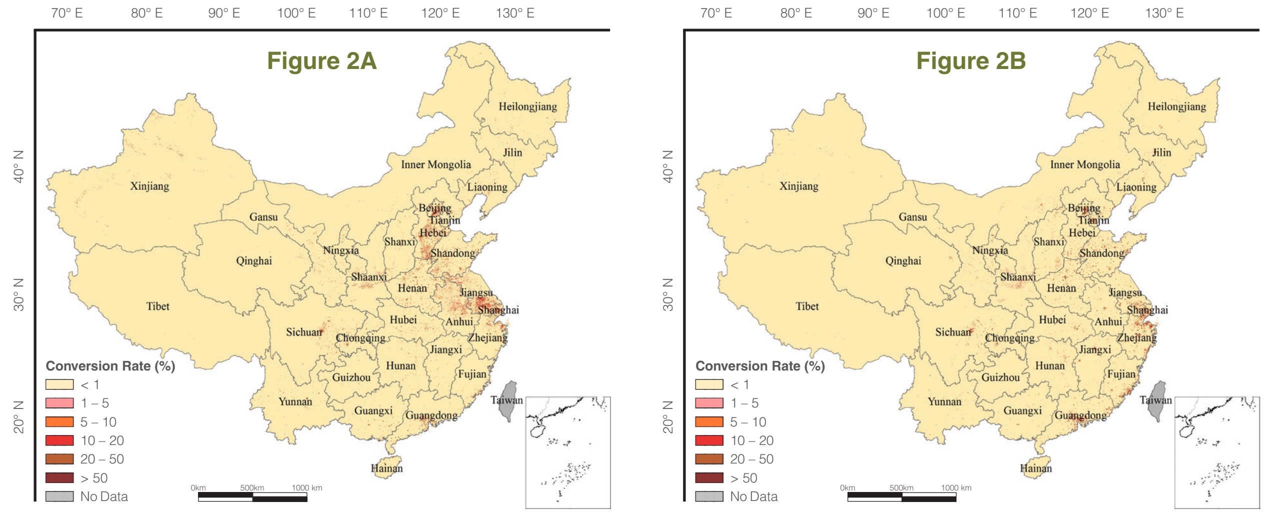
Changes in cultivated land exhibit a different trend from the late 1990s to the mid 2000s (Figure 1B), with an overall decline, especially of paddy field area in Southern China. The remote sensing analysis shows that cultivated land decreased by 0.69 Mha from the late 1990s to the mid 2000s, with 0.95 Mha of paddy field gained and 0.26 Mha dry lands lost. The decline in cultivated land was mainly due to urban expansion (Figure 2B), while the increase was from the reclamation of unused land and the alluvial flat land along the reaches of rivers or along the shores of lakes. The overall impact is that the quality of cultivated land declined. Traditional farming regions such as the southeastern coastal area and north China plain are undergoing a decreasing trend of cultivated land, with paddy field area decreasing more significantly. Meanwhile, there is a slight increase of cultivated land in the farming-grazing transition zone, the farming-forest transition zone, and wetland across Northeast China, Northwest China and North China. These results put earlier regional scale analyses into perspective. Although agricultural land loss may be

Figure 1A & 1B | Remote sensing based area percentage change of cultivated land within a one by one square kilometer grid pixel across China, A: 1988-2000; B: 2000-2005



Data Source: Data Center for Resources and Environmental Sciences, Chinese Academy of Sciences and the National Key Programme for Developing Basic Science of China (2010CB95094)

Figure 2A & 2B I Remote sensing based conversion rate of cultivated land onto built-up area within a one by one square kilometer grid pixel across China, A: 1988-2000; B: 2000-2005



Data Source: Data Center for Resources and Environmental Sciences, Chinese Academy of Sciences and the Key Project in the National Science and Technology Pillar Program of China (2006BAC08B00)

significant in one region of the country (Seto et al., 2000), the net gain or loss at the country scale is more important.

Impacts of urbanization on cultivated land in China

There are opposing views regarding the impacts of urbanization on cultivated land in China. Some scholars argue that urbanization leads to the decrease of cultivated land and endangers national food security (Döös, 2002; Chen, 2007; Wu et al., 2011). Other researchers argue that rapid urbanization, accompanied by the population shift from agricultural sectors to non-agricultural sectors, plays an active role in promoting the conservation of cultivated land because the land consumption per capita is much lower in urban areas than that in rural areas (Jia et al., 1997). At the same time, there are also discrepancies regarding the impacts of different types of urbanization (e.g., suburban, high-density) on cultivated land (Ji, 2001; Deng et al., 2008).

Zhu and Huang (2007) explored the impact of urbanization on cultivated land based on land-use remote sensing data from 14 provinces of eastern China. Their study shows that economic growth plays a key role in cultivated land changes and the impacts of urbanization on cultivated land depend on the mode of urbanization. With the effects of other factors controlled, the expansion of townships and cities consume much less cultivated land than does rural village development, which implies that urbanization may have even reduced the rate of cultivated land loss.

Although this debate has inspired considerable research, there are still some shortcomings in recent studies. For example, some studies fail to consider both rural and urban built-up areas, while other studies have failed to control for other factors such as agricultural productivity. The spatial and temporal scales of current studies could also be improved. Ideally, the spatial scale of any analysis would be able to distinguish fallow from productive fields, crop type, and non-productive spaces in agricultural areas such as dikes, ditches, and berms. On the temporal domain, the time series of satellite images should be able to distinguish between agricultural phenologies and changes in cropping cycles. If urbanization continues to place direct pressure on agricultural land, we may see changes in the types of crops grown in and around urban areas. We expect to see significant increases in fertilizer and pesticides to increase yield, especially if there is a national-level decline in agricultural land. Increasingly, studies will need to examine not only the sheer amount of agricultural land loss, but the types of agricultural land being converted, changes in agricultural productivity, and changes in inputs.

Concluding remarks

The impact of urbanization on agricultural land in China is far from conclusive. More long-term empirical-based research is needed to help clarify the issues that underscore this debate. Furthermore, since other factors may also lead to the decrease of cultivated land, it is necessary to investigate the impacts of urbanization on other factors such as diet changes and food prices, which may indirectly influence cultivated land change. We agree with the view that the mode of urbanization plays a large role in the way cultivated land is impacted. High-density urbanization that increases land use efficiency may even reduce the rate of cultivated land loss. Since the land consumption per capita is different among large and small cities, it is necessary to further investigate the effects of expansion of various cities with other factors controlled. A related point is that as agricultural land expands into other regions, it could have deleterious effects on other ecosystems such as grasslands, forests, and drylands. We have already begun to see this during the 1990s. Ultimately, the challenge going forward is to develop analytical tools that allow us to examine the relationships between urbanization, agricultural land, and other land systems.

Workers on the rice field in Dali, China

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Economic development in Accra, Ghana

Transforming Accra towards a Sustainable Future: Comprehensive Land Use Planning and the Greater Accra Urban Simulation System (GAUSS)

Tyler J. Frazier

The urbanization of Sub-Saharan Africa is occurring more rapidly than in any other region in the world, at a historically unprecedented absolute rate of increase, within an institutional framework desperately lacking in resources. In step with its Sub-Saharan location, Ghana is experiencing unprecedented urbanization with currently 50% of its 23 million people living in urban areas; that share is expected to become 65% by 2030. The lion's share of this growth is taking place in the administrative and commercial center, Accra, which has a population of more than three million people. It is exhibiting a growth rate in excess of 4% per year and is expected to double its population within 16 years.

While Accra has often been considered the proud "superstar" of West Africa with its foundations of infrastructure development beginning with Dr. Kwame Nkrumah, it is an illusion to view the capital city without considering that most service provision levels are failing when compared to the standards of developed nations. Inadequate financing and poor management coupled with rapid growth have led to: water supply coverage declining from 85% in 1990 to 60% in 2004; solid waste collection coverage of only 70%, even though the expenditure is an enormous part of most local government budgets; and unregulated septic collection and disposal by hundreds of vacuum trucks dumping waste on a daily basis directly into the Gulf of Guinea at Korle Gonno. The transportation network is consistently failing and is considered amongst the most dangerous in the world, the electricity sector is strained, threatening to reduce GDP by as much as 0.9 percent per year, and public health, education and safety all require significant attention. Weak local governments throughout Accra have met evolving demands for public services with ad-hoc assistance arrangements rather than as part of a consistent and targeted capital improvement plan. These District Assemblies lack basic taxing authority, as evidenced by their inability to generate revenue from property taxes in Osu where real estate values have increased to the point where they are commensurable to some European cities. The World Bank has estimated Accra's capital expenditures at approximately $2.7 USD per capita as compared to an estimated need of $80 USD per capita. The effect of inadequate public service provisions is an environment which implicitly promotes urban poverty rather than poverty reduction. Provisions for public transportation, water and sewer, stormwater, electricity, health, education and safety services are an integral part of the environment needed in Accra and the cities of Ghana to achieve the primary objective of the Growth and Poverty Reduction Strategy and Millenium Development Goal, to achieve middle-income status.

While the problems faced by local and regional governments throughout Greater Accra are daunting, developing and maintaining a spatial decision support system to assist these governments is equally intimidating. One major issue facing urban modelers as we forecast land use change is how much data do we need? Robert Solow once stated that simplifying assumptions is the essence of model-building, while the philosopher of science Russell Hanson noted that if one progressed from a five-inch balsa wood model of a Spitfire airplane to a 15-inch model without moving parts, to a half-scale model, to a full-size entirely accurate one, you would not end up with a model of a Spitfire but with a Spitfire itself. Even Lewis Carroll remarked that a map on the scale of one-to-one would serve no purpose. So how much data is needed to create this spatio-temporal map and where do we draw the boundary of simplicity for this increasingly complex and uncertain West African city? How can we incorporate three-dimensional satellite imagery and the complete inventory of building envelope signatures which can be used to derive existing land uses for millions of structures? Or, what use is there in recording the origins and destinations of every individual transportation decision made throughout Accra on a daily basis? And this only concerns macroperspective observations, for without detailed surveys of households, businesses and institutions, this externally captured data lacks the detail needed to describe the microenvironment and its disaggregate, individual agents. The science of the city has come a long way from Lowry's gravity models, Leontieff's work on spatial input-output models, and the "7 Deadly Sins" described by Doug Lee in his 1973 Journal of the American Planning Association (JAPA) article, *Requiem for Large-Scale Models*. Modern geographic information systems, such as ArcGIS or QGIS provide a powerful medium for integrating static and dynamic physical and human geographic information with: statistical modeling platforms such as R or Stata; database systems such as MySQL or PostgreSQL; and extensible programming languages such as Python or Java for specification, parameterization and programming individual agent behavior and environmental constraints, as well as coupling equally sophisticated transportation models.

But simply accepting that the hyperdynamics of Greater Accra amounts to a complex system, arguably rivaling the microcosmos of the human body or the macrocosmos of the universe is only the beginning. How do we go about obtaining all this data we need and what responsibility do we have, once we have it? In his book *Far-Fetched Facts*, Richard Rottenburg provides a fascinating and thoughtful ethnographic analysis of developmental relations between rich countries in the north and poor countries in the south and Hans-Jörg Rheinberger, author of *Toward a History of Epistemic Things*, elaborated upon this parabola of development aid in terms of the central conflict of interests: the necessity for donor countries to control money flows, and the political goal of self-determination on the part of recipients. The incongruences of these transnational institutions have been illustrated on a pan-African scale by Dambisa Moyo in *Dead Aid* or one only has to cross Zion Street at Korle Lagoon to find a 20 million USD, World Bank funded wastewater treatment facility idly awaiting wastewater to treat. The relevance of this conflict becomes clear when attempting to collect data in Accra, where the concept of the public domain has great strides to make before it becomes a reality. A second and equally important issue is related to statistical disclosure limitations and the right of confidentiality for all human beings, wherever they may reside. The work of Jerry Reiter at Duke

Fishing boats along the shoreline of Accra, Ghana

City sprawl, Accra, Ghana

University and Andrea Alfons at Technische Universität Wien is central to synthetically generating large scale data sets which spatially retain the statistical parameters of original survey samples, while also maintaining the rights of individual privacy.

While urbanization's impact is clear and poverty reduction should be the primary focus, how do we reconcile the need for Greater Accra to be an economic development engine with the equally important concern for environmental degradation resulting from ad hoc, arbitrary and private land use transformations? An additional complication is contextual – the dual title system – where central Accra uses the British system for subdividing and registering property, while the massive urban sprawl resulting from forest and agricultural lands transitioning to low density, single family residential homes, occurs under the authority of traditional rulers such as the Asante or Fante and their customary land title system. How do we introduce comprehensive planning, zoning and development permitting, within a context that often subjectively favors indigenous institutions and criticizes "foreign" practices without exercising objective judgment? How do we synthesize modern land use planning practices for transforming towards a more sustainable future with the vernacular of indigenous institutions, rooted in hundreds of years of culture and history? The vernacular of each local and regional jurisdictions' approach to governance will always exist, but is it really necessary to "reinvent the wheel?" In some cases the price of modernity may be the need to significantly transform or reinvent the institutions themselves.

Creating and developing the Greater Accra Urban Simulation System (GAUSS) required more than a series of two week visits and a return home expecting to make a meaningful contribution. In order to understand the deeper, often hidden, meaning found alongside the interconnecting pathways of Accra, it was necessary to become a resident for a lengthy period of time. Modeling the urban dynamics of Accra required more than negotiating with local scientists and engineers to unlock the connections, data and their means for the practical application of advanced theory. Creating GAUSS required a real understanding of the daily risks encountered in millions of people's lives, and the complexity that arises from the billions of interactions for which there will never exist a satellite system or realtime network capable of recording the data necessary to create this one-to-one map of Accra. At some point all of our simulations reach a quantitative limit and it becomes necessary to take a step back, invoke qualitative understanding, and use the same common sense which is most likely akin to the local knowledge found in Cantonments, Agirigano or Kokomlemle in the first place. GAUSS continues to be a journey through an incredibly complex realm lying at the crossroads of the developing and developed world, the public and the private sectors, between academia and professional businesses, and more important than any synthetic dataset, location choice coefficient or scenario run is a personal understanding of the families and individuals living in Accra and the commitment necessary to make a lasting and meaningful contribution towards the transformation of their sustainable future.

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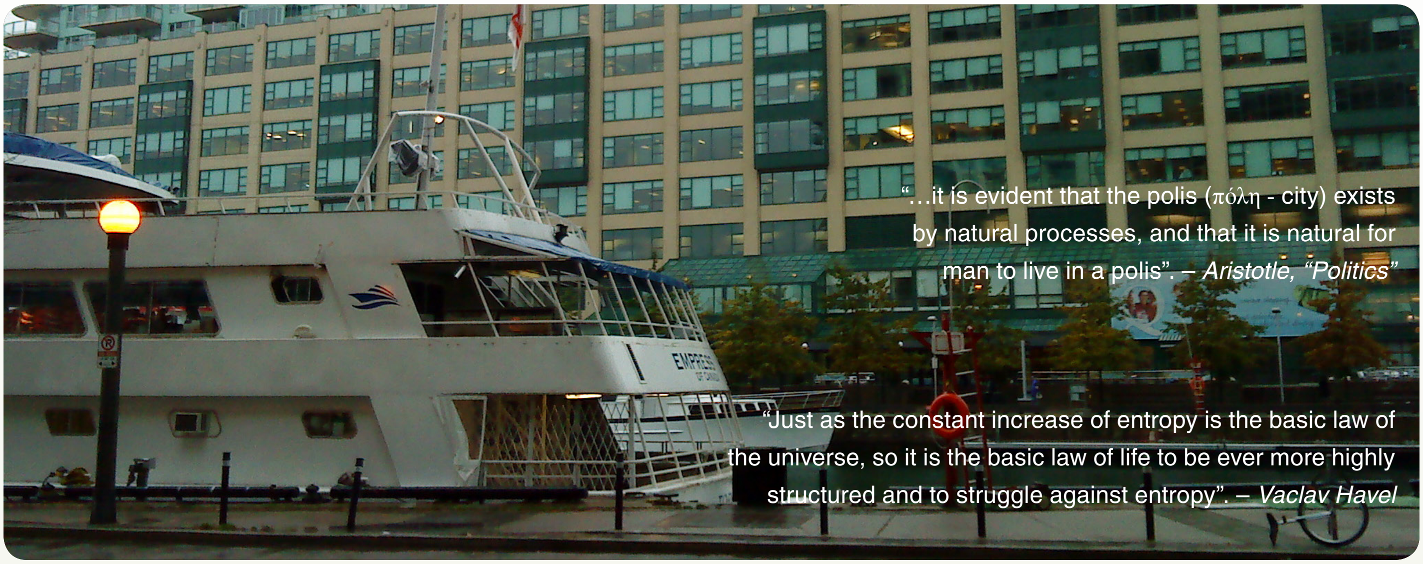


City of Toronto, Canada

City Systems, their Growth and Sustainability: An Urban Biogeochemistry Approach

Anastasia Svirejeva-Hopkins, Yuri G. Puzachenko and Robert B. Sandlersky

Over the next 100 years most population growth will take place in urban areas. Humans have become a major driving force of the Earth system; growth in urban pollution and greenhouse gas emissions from urban areas could lessen the resilience of urban systems and irreversibly affect the state of the Earth system. Earth system analysis is one of the main challenges to science in the decades to come and its main task is to provide tools for managing global change in order to secure an acceptable long-term co-evolution of nature and civilization (Schellnhuber, 1998). Scientists have increasingly been calling for solutions for major challenges of Earth system analysis in relation to social systems (Lucht, 2009).

In this article, urbanization is considered a global ecological process, and urban areas (UA) as a spatial component of the biosphere and of the Earth system, in general. UA "modify" the surrounding landscape by changing the fluxes of matter and energy. The urban area is viewed as an open thermodynamic system, maintaining its structure through the conversion of energy. During its evolutionary process including growth (increase in size) and structural development (increase in the system's organization), the system-city fluctuates from one state to another and its exergy grows and becomes the highest when the system is farthest from an equilibrium state that has local maximum of entropy. We estimate numerically this state (and the degree of non-equilibrium) by recalculating standard satellite data, deriving and combining global maps of entropy, information gain and exergy, as well as proposing a new approach for the study of urban sustainability questions. For this, we introduce the index (anthropogenic heat flux/exergy) as the measure of the degree of disturbance in urban areas at certain geographical locations, which, recalculated per capita, reflects the level of urban infrastructure in cities of different regions.

Thermodynamics, urban ecosystems, entropy, exergy and the AHF/EX index

According to one of Vernadsky's axioms constituting the base of his empirical generalization method, developed for studying complex systems such as the biosphere, there is a constant exchange of matter and energy between living and inorganic components; these fluxes support the existence of the biosphere itself. Since it is an open thermodynamic system, it also requires the permanent inflow of solar energy, which since the very beginning of the Earth's existence has controlled the global biogeochemical cycles (Svirezhev and Svirejeva-Hopkins, 2008). Vernadsky describes the function of living matter in the biosphere as transferring solar radiation into other types of energy (chemical, heat, mechanical, etc.).

The main interaction in thermodynamics is that between the system and its environment. During the process that establishes this equilibrium, the former can perform work (i.e., the transfer of energy) to the latter. This super-system (system and environment) can arrive at a number of different final states (with respect to its energy and entropy, in particular). Namely this distance (and the degree of non-equilibrium) can be estimated by the difference of entropies, or Kullback information, which shows the increment of information (information gain) or order in a non-equilibrium system in relation to the system in the state of equilibrium (Jorgensen and Svirezhev, 2004).

From an ecological point of view, urban areas are heterotrophic systems maintained by external inflows of energy and materials. However, the urban ecosystem (including people and other living and non-living things and the space constructed by them) differs very much from any natural heterotrophic ecosystem. In fact, a city has a more intensive metabolism per area unit, requiring a significant inflow of artificial energy. Thermodynamically, any urbanized area is an open system that is far from thermodynamic equilibrium with its environment (Svirejeva-Hopkins, 2008). In an urban system, ecological factors like plants (autotrophs), soil, animals, etc., are affected by humans (heterotrophs). Human decisions are also affected by various ecological factors. Urban structural organization then determines the parameters of the thermodynamic system and its many specialized sub systems and forms of energy transfer.

Exergy (*Ex*) could describe and measure sustainability of the system; it determines how far the system is from thermodynamic equilibrium with respect to its surrounding environment. This means that in moving from thermodynamic equilibrium, the system accumulates exergy. Exergy grows in the process of self-development of a complex system and is the highest when the system is farthest from an equilibrium state, while at the same time, entropy has a local minimum (Jorgensen and Svirezhev, 2004). In other words, exergy enables the expression of information entropy in physical terms.

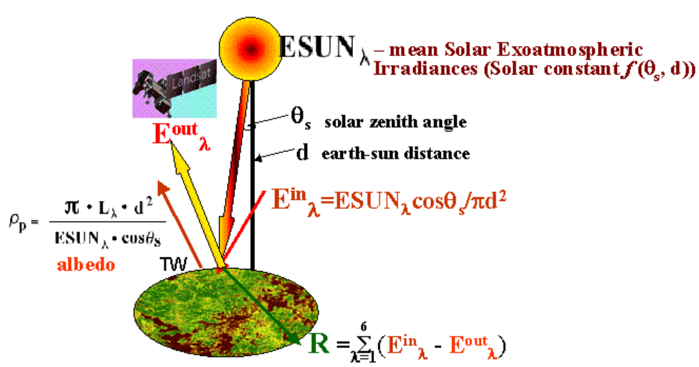
Spatially, cities constitute a mosaic of open, built-up and vegetated spaces, which creates high internal gradients of entropy, exergy and heat flux. Urban areas are also known as the biggest producers of the anthropogenic heat-flux (AHF, or thermal pollution). We propose to use the ratio index *AHF/Ex* to measure the degree of disturbance in urban areas at certain geographical locations. This index, recalculated per capita, reflects the level of urban infrastructure in cities of different regions. Globally, the index allows the analysis of the transformation of solar radiation by urban landscapes, whereas satellite measurements provide an overall picture. At more detailed scales, the index will help us to answer the question of how to organize cities and optimally allocate a growing population so that urban areas cause minimal disturbances to the biosphere (and to the Earth system), while urban structural elements provide the optimal mesoclimate.

Mapping thermodynamic parameters of an ecosystem and indices for cities

Generally, the function of living matter is determined as an increment of *Ex*, or the ability to conduct useful work. We compare the structure of energy fluxes and transformation of *Ex* in the ecosystem with some measurable elements of its structure. This is done with the help of remote sensing multi-spectral measurements of reflected solar radiation (Puzachenko et al., 2011) (Figure 1). Reflected solar radiation is determined through recalculations of brightness of satellite data (in dimensionless digital number (DN) units, proportional to the amount of radiation detected by the sensor) into energetic units – the flux of energy in time step (Watt/m^2). As a result, we obtain the numbers of reflected solar radiation for each spectral channel. The degree of deviation of real spectrum of absorption from equilibrium is estimated as Kullback information (Jorgensen and Svirezhev, 2004), which is the measure of difference between two compared distributions and is a parameter of open non-equilibrium thermodynamical systems.

Figure 1 | Calculating thermodynamic parameters using remotely sensed information: incoming solar energy - $\boldsymbol{E^{in}}$, reflected solar radiation - $\boldsymbol{E^{out}}$, $\boldsymbol{R} = \boldsymbol{E^{in}} - \boldsymbol{E^{out}}$ - absorbed solar radiation, ***TW***-heat flux

Temperature of the Earth's surface:
$T = K_2/\ln(K_1/L_6 + 1)$
K_2 and K_1 – sensor calibration constants
L_λ – at-sensor radiance
λ - spectral range (λ=6 for long-wave (thermal)), L_6=**TW**



In summary, the following thermodynamic characteristics of ecosystems are calculated (Jorgensen and Svirezhev, 2004): $\boldsymbol{E^{in}}$ – incoming solar energy (Wt/M²); $\boldsymbol{E^{out}}$ – reflected solar radiation (Wt/M²); ***R*** – absorbed energy (Wt/M²); ***K*** – Kullback information (nit); $\boldsymbol{S_{out}}$ – Entropy of reflected energy (nit); ***Ex*** – Exergy of solar energy (Wt/M²); ***U*** – inner energy (increment) (Wt/M²) – accumulation of absorbed energy, including Carbon accumulation; TW – heat flux from the surface (Wt/M²), ***T*** – surface temperature (˚C); ***STW*** = TW*S_{out} – the combined energy, showing the transfer of incoming energy into the heat flux ***TW*** and entropy (S_{out}).

The Figures 2A and 2B show the maps of information gain and entropy. Information gain illustrates the effectiveness of a system from the information point of view, reflecting the degree of inner complexity and organization in the system. The areas where it is the highest have large information, and entropy values are the lowest. Exergy (*Ex*) is calculated by the fluxes in spectrums and the Kullback information, *K*:

$$Ex = E^{out}\left(K + 1\mathrm{n}\left(\frac{E^{out}}{E^{in}}\right)\right) + R$$

Kullback information is calculated as:

$$K = \sum_{\lambda=6}^{6} p_i^{out}\, 1\mathrm{n}\left(\frac{p_i^{out}}{p_i^{in}}\right)$$

Where $p_i^{in} = \frac{E_i^{in}}{E^{in}}$ is a portion of input radiation in band *i* from total incoming radiation and

$p_i^{out} = \frac{E_i^{out}}{E^{out}}$ portion of output radiation in band *i* from total outgoing radiation.

Figure 2A & 2B I (A) Information gain (nit). Averaged for 2002, measured every 16 days for 720x360 pixels and (B) Entropy (nit). Resolution: 0.5x0.5˚ Both are calculated and mapped by Puzachenko et al. (2011), using MODIS satellite data (http://modis.gsfc.nasa.gov) for 2002

Figure 2A

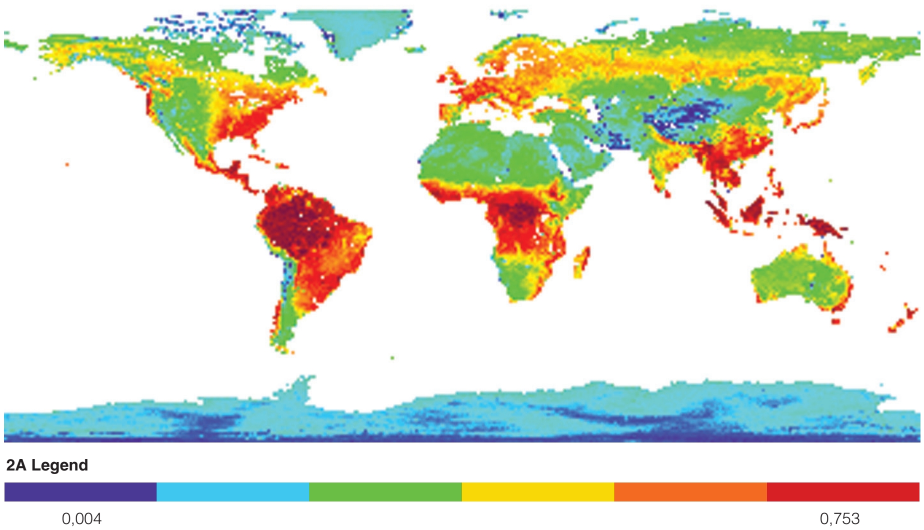


Figure 2B

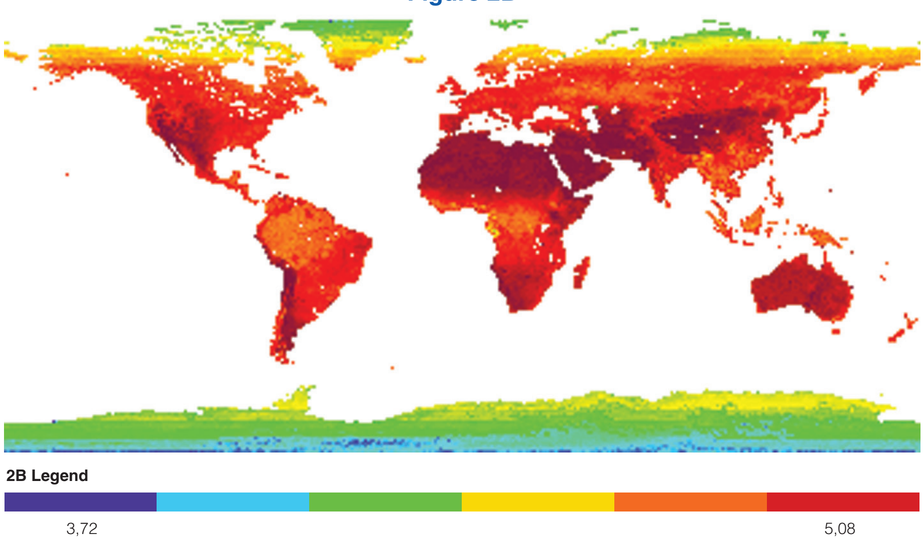


Figure 3 I Annual average exergy W/km² and 23 largest UA locations (Demographia, 2009).

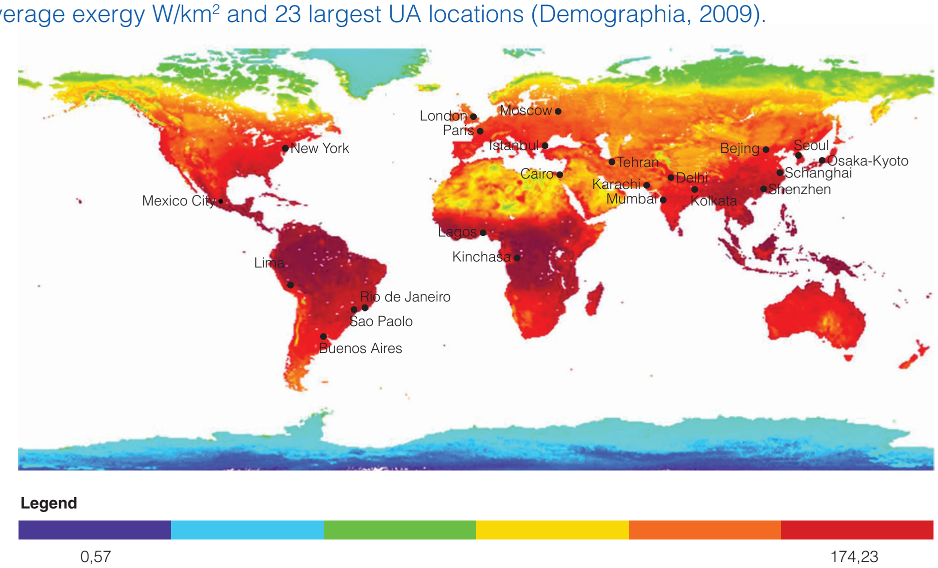


Figure 3 shows the global map of annual average exergy in the year 2002 with the 23 largest urban areas. The highest values of exergy are attributed to the tropical forest zones with the highest biomass density.

We then overlay this map with the map of Anthropogenic Heat Flux (*AHF*) for 2005, or thermal pollution (http://www.cgd.ucar.edu/tss/ahf/). Globally, *AHF* is very small (about 0.03 W/m²) but, for example, over the continental United States and Western Europe, it is 0.4 and 0.7 W/m² respectively. Table 1 shows the values of exergy and *AHF* for the selected urban areas. We propose to use the index *AHF/Ex* to show the degree of urban system disturbance. We also calculate the index "per million inhabitants" that better reflects the level of a city's infrastructure/energy efficiency. The lower the index, the less disturbed is the system.

Downtown Toronto, Canada

Preliminary analysis shows that New York is quite energy efficient, especially when the *AHF/Ex* index value is compared to Seoul, considering that their populations are the same. The Osaka-Kobe urban area is also similar to Seoul in terms of index value, while Mumbai's value is the lowest. All but two cities (New York and Osaka-Kobe) with a population over 11 million belong to developing and countries in transition, which typically signifies a lesser degree of control over urbanisation. We find that there is no relationship between population size and energy and thermodynamic characteristics of cities and attribute the thermodynamic characteristics to the structural characteristics of urban areas. Exergy of cities mainly depends on their geographical location. Tropical cities have larger values of exergy in comparison with temperate and subtropical cities, as they are situated in more unstable and environmentally sensitive zones. The largest heat flux is produced by cities of developed countries, particularly those that are concentrated in the temperate zone (with the exception of New York), while the smallest values naturally exist in the least developed cities (e.g., Kinshasa, Lima, Lagos). Similarly, when we recalculate the index of disturbance per million inhabitants, we find that the least disturbance is found in undeveloped countries and the greatest levels of disturbance are in cities of developed countries (Paris, London, Osaka), most likely due to the long history of human impacts. Only one city from of the developed countries, New York, is in the least disturbed state, while BRIC countries (Brazil, Russia, India, and China) have medium values.

Conclusions

We further develop ecosystem theory in order to view urban areas as a spatial anthropogenic component of the biosphere and focus centrally on the concept of exergy. The method allows for the construction of maps of exergy at various scales using standard satellite data. The multi-spectral measurements of thermodynamical parameters of the biosphere provide much information about the state of a system. Practically speaking, this technology makes direct estimation of entropy and information possible – reflecting real processes in structural-functional organization of ecosystems (including urban systems) and the biosphere as a whole.

The *AHF/Ex* index shows how disturbed the system is in terms of anthropogenic intervention and allows for a quick comparison between cities, as well as relatively easy future scenario building with the aim of achieving urban sustainability. Mapping the index globally provides a basic visual understanding of the state of cities across the different regions and the differences between the Northern and Southern hemispheres. This preliminary analysis shows that dense human settlements located in tropical forest zones are the main contributors to the energetic non-equilibrium, while the more dispersed urban areas in the temperate zones are more energy efficient and cause less disturbance to the Earth system. The results are certainly scale sensitive, therefore, it is planned as a future step to produce higher resolution maps in order to assess the thermodynamical states of a city, as well as to produce seasonal maps of the mosaic of states within its boundaries.

Table 1 | 23 largest urban areas (Demographia, 2007), Index values.

UA	Population (Mln)	Exergy W/m^2	AHF W/m^2	Index ($*10^2$)	Index Per Mln Inhab.
New York	19,712	174.2	1.60	0.92	0.05
Seoul	19,500	139.47	6.30	4.52	0.23
Sao Paolo	18,700	174.2	2.50	1.44	0.08
Mexico City	18,100	174.2	4.00	2.30	0.13
Osaka-Kobe	17,25	174.2	6.30	3.62	0.21
Mumbai	17,000	174.20	0.40	0.23	0.01
Cairo	16,25	104.75	2.5	2.39	0.15
Delhi	15,250	139.47	1.00	0.72	0.05
Shanghai	14,24	174.20	1.60	0.92	0.06
Shenzhen	14,000	174.20	0.60	0.34	0.02
Moscow	13,250	139.47	0.60	0.43	0.03
Kolkata	13,217	139.47	1.00	0.72	0.05
Beijing	12,405	139.47	2.50	1.79	0.14
Buenos Aires	12,000	139.47	4.00	2.87	0.24
Istanbul	11,100	139.47	0.30	0.22	0.02
Rio de Janeiro	10,900	174.20	1.00	0.57	0.05
Paris	10,400	139.47	6.30	4.52	0.43
Karachi	8,700	139.47	0.20	0.14	0.02
Lagos	8,350	174.20	0.20	0.11	0.01
London	8,278	139.47	4.00	2.87	0.35
Kinshasa	7,850	174.20	0.10	0.06	0.01
Tehran	7,800	104.75	4.00	3.82	0.49
Lima	7,500	139.47	0.10	0.07	0.01

Lucht (2009) has suggested that: "The urgency of the sustainability challenge on the international table lies in the observations that neither climate change nor the land use change process are anywhere close to being complete: in fact the largest changes will take place in the next decades, within the lifespan of current generations. As a consequence, the Earth as a system will operate in a fundamentally new regime, a comprehensively no-analogues state before the end of this century". Addressing the dynamic nature of urban sustainability problems, our method provides an approach for two emerging points in urbanization and global environmental change research, namely space and form as well as biodiversity and energy. Thermodynamics allows us an easy way for quantitative description of the disturbance level in the Earth system, caused by uncontrolled urbanization. However, it cannot answer the question about the actual ways of degradation, i.e., it only shows the possibility of degradation and estimates the value of the entropy overproduction (energy of disorder) that can eventually destroy the system – but it cannot show the pathways along which this destruction will really occur.

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The town of Bageshwer encroaching upon highly productive and irrigated cultivated land along the valley floor

Urban Growth and Food Security in the Himalayas

Prakash C. Tiwari and Bhagwati Joshi

The Himalaya represents ecologically fragile, economically underdeveloped and the most densely populated mountains on the planet. The nature of the terrain imposes severe limitations on the scale of resource productivity, as well as on the efficiency of infrastructural facilities (ICIMOD, 2008). As a result, biomass-based subsistence agriculture constitutes a main source of rural food and livelihood. Owing to the constraints of a subsistence economy, a large proportion of the adult male population migrates out of the region in search of employment. In recent years, natural resources have been depleted and climate change has stressed the traditional agro-ecosystem through higher mean annual temperatures and the melting of glaciers and snow, altered precipitation patterns, and more frequent and extreme weather events in the Himalaya (Aase et al., 2009; ICIMOD, 2008; Cline, 2008; Tiwari, 2010).

Furthermore, rapid urbanization has declined food production through the loss of productive agricultural land, destruction of the forest, biodiversity and the depletion of water resources. Long-term impacts of these changes are likely to increase vulnerability of regional population to food insecurity through the substantial decrease in production and availability of food (Poudel, 2008; FAO, 2008). The main objective of this article is to analyze urban growth trends and to examine its impact on food security in the fast growing and densely settled urban areas within Uttarakhand, Himalaya.

Study region and methodology

The present study was carried out in Uttarakhand – the newly established State in the Indian Himalaya. The State encompasses a 53,066 km^2 geographical area of which 64% is forest, 14% lies under snow and glaciers, and only 13% is cultivated land. Sharing international borders with China in the north and Nepal to the west, Uttarakhand is home to the headwaters of some of the major river systems and to the largest glaciers of South Asia. Located in varying geographical transacts ranging from the narrow foothill belt in the south to the Lesser, Great and Trans Himalayan ranges in the north, Uttarakhand is divided up into 13 districts of which ten extend across the Himalayan mountains and three are located in their foothill zone (Figure 1). The State is home to about six million people, 26% of whom live in the 86 fast-growing and emerging urban centres (Office, 2001). Tourism is a rapidly-growing economic sector and has become an important driving force of increasing urbanization within the State.

Figure 1 I The 13 districts of Uttarakhand

Source: National Atlas of India Prepared by National Thematic Mapping Organization of India.

Fast-growing and densely-settled urban complexes, one each from ten mountainous districts of Uttarakhand, were selected for inclusion in a comprehensive assessment of the impacts of urbanization on food security. Loss of agricultural land and the depletion of water resources have been regarded as important impacts of growing urbanization, adversely affecting food security. Urban and agricultural land use changes have been detected through digital interpretation of satellite data of years 1980 and 2010. Information pertaining to the status and availability of water resources was generated through hydro-meteorological monitoring. Detailed information with respect to food availability, access and utilization, irrigation, food productivity and demand, rural income patterns and food purchasing power etc., have been collected through comprehensive socio-economic surveys using exclusively designed questionnaires. Occurrences of food deficit based on local food production have been interpreted by developing estimates of production and demand (Tiwari, 2010 and 2008).

Urbanization in Uttarakhand

During recent years, Uttarakhand, Himalaya has experienced rapid, unregulated and unplanned urban development mainly in response to population growth, enhanced transport connectivity, growth of tourism, improved access to markets, and to the lack of appropriate and effective land use policy. In addition to the emergence and growth of a large number of new urban centers, existing towns are rapidly increasing in size and area. More recently, comparatively less accessible areas have also begun the process of urbanization, mainly due to enhanced road connectivity, changes in the rural economy, e.g., the gradual shift from primary resource development practices to secondary and tertiary sectors, and the growth of tourism. Consequently, there has been a tremendous increase in the density, intensity and complexity of urban settlements. This is clearly indicated by the fast growing urban population in the state, particularly after 1971. In Uttarakhand, urban population increased from 16.36% in 1971 to 20.7 % in 1981, 22.97 % in 1991, and 25.59 in 2001. As per the Census of India (Office, 2001), the State registered a 56.38% growth in urban population during 1971–1981, however, decadal urban population growth declined slightly during 1981–1991 (42.20%) and between 1991–2001 (32.81%). Nevertheless, the growth of urban population in Uttarakhand during 1971–1981 and 1981–1991 was much higher than the national decadal growth of the urban population in India (46.39% and 36.24% respectively) (Table 1).

Table 1 I Trends of urban growth in Uttarakhand

Census Years	Total Popoulation	Urban Population	% Urban Content	% Decadal Urban Growth
1901	1,979,866	154,424	7.80	–
1911	2,142,258	179,332	8.37	16.13
1921	2,115,984	191,660	9.06	6.87
1931	2,301,019	195797	8.51	2.16
1941	2,614,540	270503	10.35	38.15
1951	2,945,929	400631	13.60	48.0
1961	3,610,938	495995	13.74	23.80
1971	4,492,724	734856	16.36	48.16
1981	5,725,972	1149136	20.07	56.38
1991	7,113,483	1634084	22.97	42.20
2001	8,479,562	2170245	25.59	32.81

Source: Census of India (2001)

Food security

Food security in Uttarakhand, Himalaya mainly depends on (i) local agricultural production and (ii) food purchasing power of the population (Barrett, 2010; ICIMOD, 2008; FAO, 2008). Recently, a variety of changes have emerged in the traditional agricultural resource use structure mainly in response to population growth and the resultant increased demand of natural resources (such as

Steep sloping cultivated land of Almora, the rapidly growing second largest town of Uttarakhand, Himalaya

Table 2 I Impacts of urban growth on agricultural resources

District	Urban Area	Impacts of Expansion of Urban Land Use (1971 – 2010)		
		% Loss of Agricultural Land	% Loss of Forest	% Decline in Irrigated Land
Uttarkashi	Uttarkashi	05.37	03.17	15.22
Chamoli	Gopeshwer	04.71	05.14	21.07
Rudrapryag	Rudrapryag	05.27	05.22	17.73
Pauri Garhwal	Srinagar	10.15	06.49	05.22
Tehri Garhwal	New Tehri	06.22	03.54	04.34
Pithoragarh	Pithoragarh	12.97	09.63	11.91
Bageshwer	Bageshwer	11.36	07.92	15.44
Champawat	Champawat	07.14	03.44	07.15
Almora	Almora	11.21	02.21	09.71
Nainital	Lake Region	09.12	02.06	07.92

Source: Generated through research

land, food, fodder, fuel wood, etc.) and the rapid urbanization of rural landscape. As a result, critical natural resources such as arable land, forests, biodiversity, water etc., have steadily depleted and have significantly led to the decline in agricultural productivity.

Our study indicates that the most densely settled and rapidly growing urban centres of Uttarakhand, Himalaya have been fast encroaching upon productive agricultural land in their surrounding rural regions. All ten urban areas selected from ten mountainous districts of Uttarakhand have caused huge transformations to the cultivated land within urban centres as well as in their peri-urban zones, leading to the intensification of land use. Rural areas surrounding these urban centres have lost their prime agricultural land ranging between 4.71% to as much as 12.97% due to the expansion of urban land use in the urban fringe over the last 30 years. The highest encroachment of cultivated land (12.97%) was recorded in Pithoragarh which is the largest township of Uttarakhand, Himalaya, followed by Bageshwer (11.36%) and Almora (11.21%), which are not only densely settled towns within the region, but are also seats of district level administration. Additionally, urban growth has also contributed to the degradation of 2.06% - 09.63% of the natural forest and reduced the proportion of irrigated land between 4.34% and 21.07%, due to hydrological disruption and the resultant depletion of water resources around different towns (Table 2).

The results of this investigation reveal that the loss of fertile agricultural land, the decrease in supply of biomass manure and the reduction of irrigated area caused by forest depletion and the development of urban structures contributed to a 19% to 55% decline in agricultural productivity in the ten urban zones. Consequently, rural settlements situated along the fringe of these urban complexes are currently facing a food deficit between 65% and 95% (Table 3). Undoubtedly, urbanization has contributed significantly to socio-economic betterment of the region through the development of infrastructure, generation of employment opportunities in various emerging sectors such as tourism, trade, and services, etc. However, the depletion of forest resources and the decline in the agricultural economy has decreased off-farm employment opportunities in traditional forestry and agricultural sectors in the urban areas of Rudraprayag (by 42%) and in Almora (by 87%), reducing rural income. As a result, rural households in peri-urban zones have lost 7% to 12% of their food purchasing power (Table 3). This will have long-term impacts on local food security, particularly affecting the poor and socially marginalized communities, which constitute nearly 75% of total population.

Conclusions

It can be concluded that urban growth is very speedy in Uttarakhand and has resulted in the collapse of traditional agricultural and food systems and the loss of off-farm employment opportunities in peri-urban zones. It has also contributed to increased vulnerability of the poor and socially marginalized mountain communities, leading to food insecurity. Since urbanization is

Table 3 | Impacts of urban land use expansion on agricultural and food systems

District	Urban Area	% Decline in Local Food Production	% Increase in Local Food Deficit	% Loss of Rural Livelihood Opportunities	% Decline in Food Purchasing Power
Uttarkashi	Uttarkashi	31.17	71.00	67.00	07.00
Chamoli	Gopeshwer	35.22	65.00	74.00	11.00
Rudrapryag	Rudrapryag	21.14	74.00	42.00	09.00
Pauri	Srinagar	41.45	76.00	61.00	05.00
Tehri	New Tehri	19.00	85.00	65.00	12.00
Pithoragarh	Pithoragarh	37.23	86.00	45.00	08.00
Bageshwer	Bageshwer	44.17	79.00	87.00	11.00
Champawat	Champawat	31.77	67.00	64.00	07.00
Almora	Almora	55.00	95.00	81.00	12.00
Nainital	Lake Region	39.00	85.00	73.00	06.00

Source: Generated through research

one of the important drivers of socio-economic advancement and infrastructural development, it would not be possible to arrest present trends of urbanization, nor to discontinue the expansion of urban land use onto the rural landscape. However, the process of rapid urbanization could be transformed into sustainable patterns of urban development through optimal land use regulations and planning, and increasing rural income and community food-purchasing capacity through the creation of adequate and viable employment opportunities in various urban sectors, particularly in peri-urban zones.

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Sydney, Australia

Operational Framing of Climate Change Adaptation at the Local and Regional Scales

Hartmut Fünfgeld and Darryn McEvoy

Conceptual frameworks for adaptation planning can play a vital role in providing meaningful guidance in support of adaptation processes by creating a shared body of knowledge on climate change impacts and appropriate responses, helping to improve a feeling of ownership among diverse stakeholder groupings and clarifying how adaptation responsibilities are distributed across administrative and institutional boundaries. For such frameworks to be effective, however, their conceptual foundations need to be robust and transparent, while at the same time, grounded in the operational needs and realities of policy and decision making processes. In this article, the authors argue that for adaptation frameworks to be widely applicable and effective there will need to be a careful balance between providing top-down guidance on climate change impacts and adaptation policy context on the one hand; and integrating bottom-up information on local narratives of climate change adaptation and vulnerability, coherence with mitigation objectives, and the potential costs and benefits of adaptation, on the other.

"Doing adaptation" at the local and regional scales

Adapting to climate change is increasingly considered part of the core business of sub-national governments and non-governmental organisations in developed countries; often in absence of clear national policies that regulate how the responsibilities for responding to climate change impacts will be shared. In countries such as Australia, South Africa, the United Kingdom and the United States, a number of local governments have embarked on the development of strategies and action plans designed to respond to climate change impacts and risks (see: Preston et al., 2010; Roberts, 2010; Bassett and Shandas, 2010). However, robust guidance remains lacking for actors at the local and regional level on how to best design and implement effective adaptation measures.

The challenge of effectively framing adaptation at an operational level (i.e., developing a framework that can deliver tangible, effective adaptation outcomes) strongly resonates with more fundamental questions about the meaning and interpretation of adaptation as a policy and decision-making process. Developing a shared understanding of the purpose, objectives and methods used for local planning is an important enabling condition for effective adaptation to occur. This involves striking a workable balance between top-down perspectives that involve knowledge and understanding of climate change projections and national-level policy response mechanisms and the bottom-up integration of local context and being responsive to the specific vulnerabilities and adaptation needs of communities.

Often, however, fundamentally different framings of adaptation exist which hamper the institutionalisation of balanced and inclusive adaptation processes. Disagreement, or lack of understanding about different framings, if left unaddressed, could evolve into a major barrier to effective adaptation. The project "Framing multi-level and multi-actor adaptation responses in the Victorian context" (Framing Adaptation)[1] is exploring the suitability of existing adaptation frameworks and approaches for local and regional level decision-making in Victoria, Australia. In collaboration with state and local government partners, the project is developing and field-testing an operational framing of adaptation that can act as a decision-making "roadmap". This article summarises some of the key early findings from the project (Fünfgeld and McEvoy, forthcoming).

Approaches for local adaptation

Taking framing considerations into account, an operational adaptation framework - and the assessment methodologies used - needs to be clear about its underlying concepts. This is critical because adaptation approaches differ in that they:

- Pursue different goals;
- Are underpinned by different theoretical foundations;
- Rely on different forms of input data;
- May elucidate different information on the possible impacts of climate change;
- And ultimately lead to different adaptation responses.

A limited number of dominant concepts have been discerned as underpinning the existing approaches to adaptation thinking, all of which overlap to a certain degree. The following three broad approaches are commonly used:

A **hazards-based approach** takes the perspective that the climate and climate change are the origin of threats that can affect a system in the form of perturbations and stress; producing specific, localised impacts (Turner et al., 2003). Framing local adaptation in the context of a hazards approach, therefore, tends to focus on the assessment of possible impacts (e.g., increased flooding) from a specific climate-related hazard (e.g., an increase in average rainfall), and devising response measures that will reduce or manage these impacts. Hazard-based approaches typically rely on the use of a climate impact assessment to obtain a better understanding of biophysical and/or socio-economic impacts.

A **risk-based approach**, while being closely related to hazards theory and hazard-based approaches, differs in that it explicitly embraces notions of uncertainty and risk perception. In business management, risk has been defined as the effect of uncertainty on objectives (Australian/New Zealand Standard, 2009). Risk-based approaches to climate change adaptation therefore emphasise individual and/or collective perceptions of risk emanating from climate-related hazards. Although risk can be quantified using various formulas, qualitative, perception-based data often supplements risk assessments.

Vulnerability-based approaches place emphasis on understanding the degree to which ecological, social, or coupled socio-ecological systems are susceptible to the adverse effects of climate (McCarthy et al., 2001; Turner II, 2010). Exposure, sensitivity and adaptive capacity are core concepts underlying vulnerability-based approaches. *Exposure* refers to a system being subject to experiencing climate-related hazards. *Sensitivity* is about a system's responsiveness to a climatic hazard, where it is assumed that the higher the sensitivity of a system, the higher the impact will be resulting from a particular hazard. *Adaptive capacity* refers to a system's ability to reduce exposure and/or sensitivity.

Selecting a suitable approach

The challenge, and an objective of the *Framing Adaptation* project, is to devise a framework for local adaptation that enables policymakers and practitioners to put these approaches, and their underlying concepts, into operation and integrate them in a more meaningful way into day-to-day processes of planning, decision-making, and project implementation. Each of the three approaches can provide useful avenues for climate change adaptation planning, depending on local context and adaptation objectives. Ultimately, frameworks that are relevant to the operational level need to provide flexible guidance on which approaches (and their associated assessment methodologies) are best suited for which purpose, and how they can be combined meaningfully at the design stage of local adaptation processes.

In a situation of constrained time and financial resources, the strategic choice of a particular adaptation approach will be highly influential in setting the agenda and course of action at

1 See www.vcccar.org.au for further details

an operational level. Policy developers and decision-makers need to be equipped with information that allows them to ascertain the meaning and relevance of the underlying concepts for the purposes and expected outcomes of an adaptation activity, and to query if a particular type of approach can be effectively applied to a specific project. Typical triggers and reasons for selecting a particular adaptation approach are:

- **Adhering to policy requirements or recommendations:** New policy, legislation, or broad top-down guidance on the objectives of local climate change adaptation is likely to give implicit or explicit preference to particular approaches for adaptation planning. Local adaptation actors may be encouraged or even legally required to use a particular approach.
- **Evolving sectoral standards:** In administrations or sectors where adaptation is regulated insufficiently, opinion leaders and early adopters may be at the forefront of providing the research and development input into the establishment of particular approaches for climate change adaptation in a particular sector, geographical area, or level of government.
- **Alignment with internal organisational processes:** Where organisations have the choice, they are likely to use an adaptation approach that fits in best with their organisational objectives and established processes. For example, organisations that already have corporate risk management systems in place may intuitively lean towards integrating climate change into existing systems, whereas a social vulnerability perspective may be more difficult to incorporate.
- **Prevailing individual/professional trajectories:** In many situations, adaptation will be placed on the agenda and driven by influential individuals (such as community leaders, CEOs, governmental department heads, leading consultancies, etc.) that consider climate change impacts part of their mandate, responsibility or core business. In the early stages of adaptation planning, such champions are well positioned for determining the approach to be used. Their choice may be significantly influenced by individual professional background, disciplinary traditions, or performance-based needs.

These and other significant reasons that determine the course of action for adaptation planning need to be considered as critical to the outcomes of adaptation planning processes and, where possible, be made explicit and reflected upon at an early stage of adaptation planning by all stakeholders involved in the process.

An emergent typology

The *Framing Adaptation* project will assess the strengths and limitations of different adaptation approaches through iterative field-testing of operational frameworks in local and state government case studies in Victoria. Through this research and testing, the project will be able to provide guidance on maximising the effectiveness of different adaptation approaches for "typical" adaptation challenges.

In a second step, the project team plans to develop a typology of operational-level adaptation, where local adaptation needs are matched with the most suitable approaches and methods. Such a typology will balance the incorporation of top-down guidance on climate change impacts and overarching adaptation priorities with bottom-up information on the local context, social narratives of climate change, and quantitative and qualitative methods for costing the impacts of climate change.

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Fruit and vegetable sellers on the streets of Mumbai, India

India: Patterns of an Urbanizing Nation

P K Joshi, Richa Sharma, Brij Mohan Bairwa and Vinay Sinha

The first urbanized empire, the Harappan civilization, existed during the Bronze Age (3500 to 1200 B.C.E) and was marked by an astonishing level of complex development, while the second urbanization phase occurred during the Iron Age (1200-550 B.C.E.) in the Gangetic plains (Gangal et al., 2010). Due to the pace and scale of urbanization, it would be appropriate to term this era as the “Urban Age”, for today more than half of human civilization resides in urban areas and the United Nations (UN) has projected that by 2030, 60% of the world’s population will be urban. Although most developed nations have stabilized over time, developing nations are still urbanizing. By 2030, Asia and Africa will have the highest number of urban dwellers, accounting for seven out of every ten urban residents worldwide. India, in particular, has witnessed tremendously high rates of urbanization over the past forty years. By 2021, India is expected to house six mega cities (Bangalore, Chennai and Hyderabad) including the present three (Delhi, Mumbai and Kolkatta).

Cities serve as powerful engines of growth and although urbanization can be a good indicator of progress, particularly of developing nations, it has important social, cultural, and environmental implications at both regional and global scales. Some of the associated negative consequences include the development of urban heat islands, altered regional hydrology patterns with changes in peak flows and rainfall run-off values, adverse impacts on ecosystem services, scarcity of urban services and housing facilities, poor infrastructure, etc.

Furthermore, as 87% of Earth’s land cover has been altered because of anthropogenic activities like urbanization, investigation and analysis of land use land cover (LULC) patterns and their change thus becomes an important tool for gathering information about the urban growth process, its drivers and outcomes. The monitoring, measurement and assessment of urban growth along temporal and spatial domains is an essential prerequisite for city planners, economists, environmentalists, ecologists, resource managers and policymakers in defining a more viable path of development. In this regard, multi-temporal satellite data serves as a significant data-gathering tool for such LULC change information.

In our study, we used multi-temporal DMSP-OLS cloud-free data (1999-2009) to study the urban footprints of twelve large Indian cities (Taubenböck et al., 2009). These images were used to generate one stable light image per year and were used to systematically study the patterns and process of urbanization in India (Batty and Howes, 2001; Chand et al., 2009). We believe that the knowledge generated from this study, described here, will aid in the development of a well-managed path of growth for Indian cities, which is imperative for building a sustainable urban society.

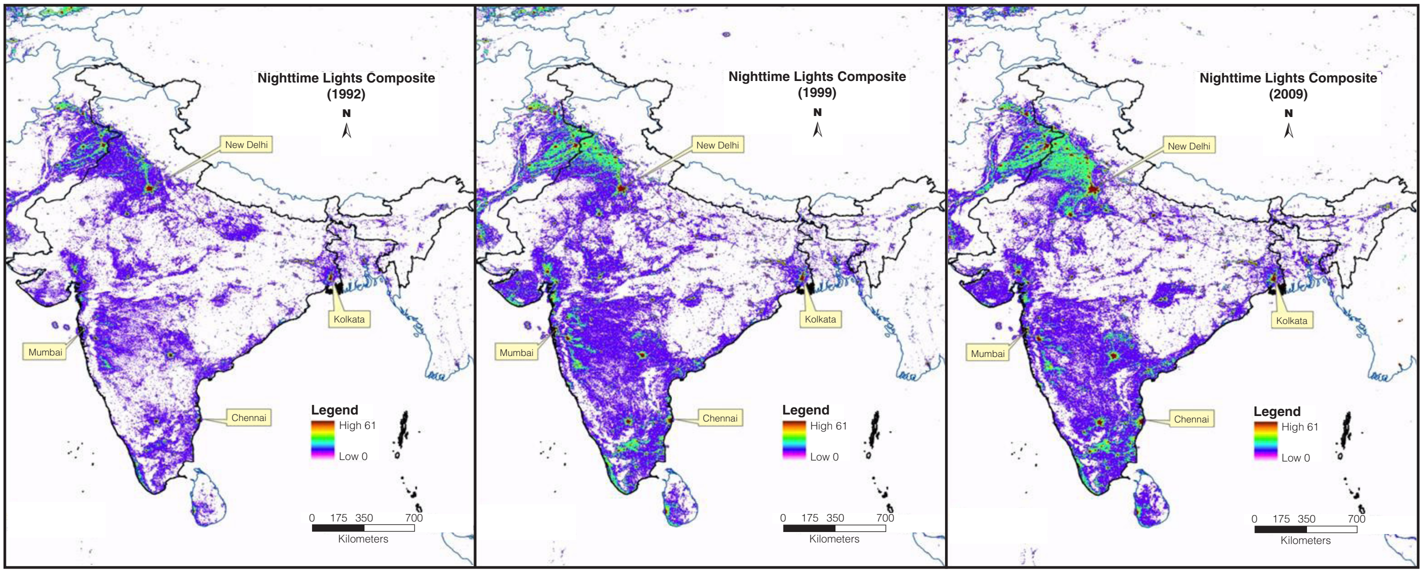
Patterns of urbanization

In 1995, abrupt changes took place in the North-Western Plains and down south around Mumbai and Bangalore. During 1996-97 remarkable urban expansion occurred around Delhi, Surat, Hyderabad, Bangalore, Kolkatta and Mumbai, with even more extensive expansion occurring in 2007. The three *mega cities* have shown unique patterns of urbanization; Delhi is characterized by radial growth and Kolkatta and Mumbai exemplify elongated and disaggregated growth. The *incipient cities* (Hyderabad, Chennai, Ahmedabad and Banglore) demonstrate complex and unstructured sprawls. Three of the *urban agglomerations* (Jaipur, Kanpur and Lucknow) experienced a tremendous change in 2007 while the other two (Pune and Surat) sprawled out in 1996 and 2000 respectively. Recently, these have shifted from mono to polycentric cities exhibiting complex, unstructured growth patterns, while giving rise to satellite cities. These medium sized cities were found to be the fastest growing urban areas.

Urban morphology of Delhi

This study has illustrated not only the multi-level hierarchical succession of India's giant urban centers from urban agglomerations to incipient cities and mega cities, but has also described the urban morphology in India, accounting for these area's urban footprints. For example, India's capital of Delhi has been urbanizing at an inconceivable pace and has witnessed tremendous changes in the LULC practices over the past four decades. This demonstrates the evolution of the regional urban pattern; for instance, large tracts of agricultural land in northern Delhi have been taken over by small and large concrete structures accounting for low and high density construction over the course of the 1970s to 1990s. Similar changes have been recorded in the southwestern parts of the city, including a very large patch of sparse vegetation and scrubland which was gradually converted to built-up area. Within a decade from 1999, large parts of Delhi that were less dense became denser. Additionally, vast tracts of agricultural land were taken over by scrubland. A broad overview (1977-2009) of the directional analysis of the changes in land use and land cover practices in the city suggests that the conversion of scrub and bare soil to low density construction has taken place in the south and south-eastern parts of the city. North and northwestern Delhi exhibit a changing trend from agricultural to built-up lands of

Figure 1 I DMSP OLS data for India, showing the variation in human dimensions over space and time



Source: DMPS – OLS data

lower density. Extreme southeastern parts of the city have been dominated by the transformation of land from sparse vegetation to built-up area of lower density. High density construction has occurred replacing the scrub and bare soil in the extreme eastern and south eastern parts, while in central to eastern Delhi the same change has occurred with low density built-up area.

The study reveals that there has been tremendous loss of agricultural areas, bare soil and scrubland at the hands of built-up areas (high and low density). An attempt to relate the density of the built-up area with population density and land surface temperature with population densities in Delhi for the year 2001 indicates that population growth has contributed to the elevated land surface temperatures and thus, has affected the micro-climate of Delhi. It was also found that the tremendous and complex urbanization patterns of Delhi have contributed to a 1-2^{o} C rise in mean surface temperature over the span of just four years (2001-2005); these population and urbanization trends are contributing to the development of the Urban Heat Island phenomenon within the city (Mallick et al., 2009).

Final thoughts

Urban areas and the environment interact bi-directionally with global environmental change serving both as a driver and outcome of complex political, social, economical, cultural and physical interactions within urban areas. As illustrated in the above findings, urbanization in India has been increasing, creating the need for more efficient and sustainable plans in order to manage the urban growth with regard to social, political, economic and environmental contexts. Unfortunately, India is overburdened and under-planned despite the pace of its urbanization. In order to overcome these challenges, better integrated sustainable plans and policies must be developed. Instead of converting metropolises into mega cities, a greater focus should be put on developing smaller towns as magnets for rural populations. This will ultimately help in curbing the source of increased pressure on urban centers; in India, urbanization occurs not because of urban pull but is due to the rural push.

Some headway is, however, being made through various initiatives to curb the patterns of unsustainable growth that continues in India. One example is Providing Urban Amenities in Rural Areas (PURA), one of the sustainable strategies initiated by former President of India, Dr. A. P. J. Abdul Kalam. This strategy aims at bringing urban amenities to rural communities so as to prevent rural to urban migration. Apart from such preventive measures to reduce the burden on cities, living conditions in the existing urban areas must be improved. This includes working towards improved transportation facilities, better water and sanitation facilities, improved sewage and solid disposal services and well-managed infrastructure as proposed under the Jawaharlal Nehru National Urban Renewal Mission (JNNURM). While planning for an urban area, the focus should lie not only on the planning for a well-managed city but on a *sustainable city* (Monto and Malhotra, 2011). This includes consideration of the relationship between the state and dynamics of environmental resources and services (ecological environment); the livability of urban infrastructures for *all* citizens without causing any harm to the urban environment (built-up environment); promoting public participation (political environment); promoting equal rights to support livelihoods of local communities with special emphasis on the marginalized sector of society (social environment); and long-term development of communities without increasing the ecological footprint of the city (economic environment). Thus, urban planning needs to become an integrated process as cities cannot serve as *islands of reform* in isolation, due to their complex interaction with global political and economic domains and peri-urban, sub-urban and rural areas.

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Urbanized landscape along the outskirts of Bangalore, India

Patterns, Process, Causes and Consequences of Urban Growth

H. S. Sudhira

The evolution of human-social organisation into towns and cities has resulted in large urban agglomerations and metropolitan cities along with unprecedented urbanisation, especially in developing countries like India, which poses enormous challenges for planning and policy making. Urbanisation in India has never occurred as rapidly as it has in the recent times. In India, the urban population is currently growing at around 2.3% per annum. The number of urban agglomerations and towns in India has increased from 3,697 in 1991 to 4,369 in 2001. It is projected that the country's urban population will increase from 28.3% in 2003 to about 41.4% by 2030 (United Nations, 2004). This increased urban population and growth is a consequence of unplanned population growth and migration. By 2001, there were 35 urban agglomerations with a population of more than one million, which increased from 25 urban agglomerations in 1991.

Of the 4,000-plus urban agglomerations that exist today, about 38% reside in just 35 urban areas, thus indicating the magnitude of urbanisation prevailing in the country. This clearly indicates magnitude of concentrated growth and urban primacy, which also has led to urban sprawl. The forthcoming 2011 Census will further ascertain the trend of this growth. As one of the fastest growing economies in the world, India faces stiff challenges in managing this urban growth and sprawl and ensuring the effective delivery of basic services within these urban areas. This article suggests a holistic framework based on recent research to address the challenges posed by urbanisation with the aim to enhance the understanding of our cities and aid in the formulation of better policies and mechanisms for managing them.

Patterns

The efficiency of urban settlements largely depends on how well they are planned, developed economically and how efficiently they are managed. A starting point for this is the development of appropriate indicators for measuring and quantifying urban growth. There are scores of metrics or indicators that report the status of a phenomenon of interest. These indicators serve multiple purposes: they serve as benchmarks, as measures to plan, evaluate, review and communicate. Indicators are typically classified as performance indicators, issue-based indicators, and need-based indicators. Among the major approaches for developing indicators are: the policy-based approach, thematic/ index approach and systems approach (Asian Development Bank, 2003). Thus, there are various indicators that have evolved along with different approaches and frameworks: policy-driven, theme-or-index driven, systems, performance, needs-based allocation and benchmarking.

Additionally, the availability of satellite remote sensing data has paved the way for monitoring urban growth spatially and systematically over time. Typically, the degree of urban growth is ascertained by quantifying the amount of paved surface or built-up area in a given region obtained from the classification of remotely sensed data or other geospatial data (Torrens and Alberti, 2000; Galster et al., 2001). A comprehensive set of indicators combining certain spatial metrics and other key dimensions that reflect a city's characteristics has evolved. Through a combination of thematic and systems approach, these are grouped under four themes: a) Demography and Economy; b) Environment and Resources; c) Mobility; and d) Planning and Governance.

The effectiveness of planning and governance is assessed based on the level of various services and certain spatial metrics. Governance itself determines the level of services in the outgrowth, while planning addresses the forecasts of such future outgrowth. It is in this context that understanding the *process* gains importance. In order to understand their dynamics, it is important to link the key patterns (metrics) with numerous processes across various sub-systems by identifying their causes. Even within the realm of land-use change studies, the linking of pattern and process in landscapes is being widely investigated.

Slum in India

Processes and causes

The interactions among numerous entities and sub-systems within urban systems generate complex dynamics that can often be intractable in comprehension and too terse as a system of equations. At an aggregate level, the effects of the dynamics are evident from the growth of urban centres by the rise in city size and its spatial extent. At the level of a particular urban centre, the dynamics are evident from the varying socio-political settings, economic activities and resource use. It is of special interest to study these dynamics to understand if they depict any underlying pattern and process in the course of their evolution. Pumain (2004) suggests that at least three time scales have to be considered for describing the main processes of evolution of urban systems:

1. the short-time process of innovation and competition, as it may be seen at the actor level;
2. the mean-time process (usually a few decades) of specialisation as related to economic cycles at the level of each town and city; and
3. the long-time process of the emergence and slow transformation of the urban hierarchy (in general, several centuries) at the level of the whole system of cities.

Acknowledging the effect of *scale* is essential for studying the dynamics of urban systems. In the short-time process, the interactions of actors and the activities in urban areas generate dynamics within the city, influencing travel times, market dynamics, etc. At the actor level, the choice and allocation of requisite proportion of resources especially in urban governance evolves as a consequence of these interactions. In the mean-time (near to short-term), the consequences of the dynamics are evident by changes in land-uses, like the reduction in open spaces and green-cover, change in pollution levels, etc. The evolution of towns and cities can also be studied in the mean-time scale over years ranging from decades to a century. The rise in size of towns and cities in terms of population and spatial extent are important determinants of urban growth at this scale. In order to analyze the long-time process, appropriate data spanning over several centuries will be required.

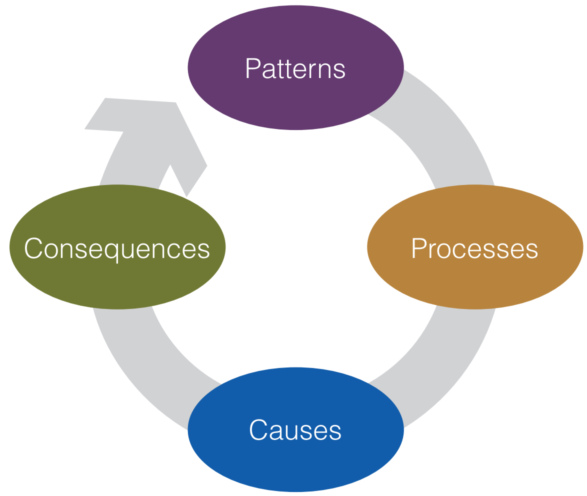
Furthermore, the process of urban growth is driven by a multitude of activities involving planning policies and regulation, governance structures, population dynamics, economic activities, ongoing and future development prospects, etc. In these circumstances, the dynamics manifested by the interaction of these entities occur non-linearly. Hence, analysing the causes of these dynamics requires different methods that are capable of synthesising the non-linearities in the system. However, it will certainly be interesting to address whether the development of outgrowths follow planning or vice versa. Forrester (1969) attempted to model urban dynamics based on complexity involving dynamic relations represented by stocks and flows that determined the various volumes of activity within the city, which were synthesised from knowledge and observation of causal factors. While the systems approach can be a good starting point, agent-based models are useful to understand, explain and forecast future scenarios through simulations that can allow the testing of various hypotheses in addition to just visualising them. Through analysis of the causes of urban spatial expansion, the externalities can be modelled as agents in a geospatial environment, like location of jobs, housing, access to services, level of economic activity, etc.

Consequences

With an understanding of the patterns, processes and causes of urban growth, the consequences of this growth can be explored which are reflected by the patterns, thus eventually aiding in the design of a spatial planning support system (SPSS). For effectively managing the challenges posed by urban growth – testing, building and visualising different scenarios – it is imperative to design and develop a robust SPSS. An ideal SPSS would not only aid in managing, but also in planning, organising, coordinating, monitoring and evaluating the system in question. SPSS includes instruments relating to geoinformation technology that primarily have been developed to support different aspects of the planning process including problem diagnosis, data collection, mining and extraction, spatial and temporal analysis, data modelling, visualisation and display, scenario-building and projection, plan formulation and evaluation, report preparation, enhanced participation and collaborative decision-making (Geertman and Stillwell, 2004). The sequence of patterns, process, causes and consequences sets the agenda for research on urban systems (Figure 1).

An important aspect in enhancing the comprehension of the evolution of city systems is an integrated understanding of different sub-systems that manifests the overall outcomes. The integrated understanding should complement spatial planning acknowledging the city's functions and its economic activities coupled with the availability of resources and environmental considerations. All of these point towards leveraging complexity science to build such an understanding of urban systems. The knowledge gained from complexity science on urban systems shows that the typical characteristics of self-organisation, path dependence and adaptation are all prevalent. Additionally, it is noted that addressing urban growth is closely embedded with how spatial planning confronts the challenges inherent in the evolution of cities that are associated with urban economics and transportation (Batty, 2008). Certainly, the call for "city planning as a new science" (Batty, 2008) holds merit. Thus, there is promise for future research to address urban growth through the holistic framework for facilitating policy, planning and decision-making while integrating different sub-systems that underpin the evolution of cities.

Figure 1 | Holistic research agenda linking patterns,processes, causes and consequences



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Rio de Janeiro, Brazil

Sea Level Rise and Flood Risk in Rio de Janeiro City: Challenges of Global Climate Change

Andrea Ferraz Young

Extreme events such as intense rainfall have proven to be a growing problem in many areas of the world, including the city of Rio de Janeiro, Brazil. The negative consequences associated with sea level rise and flooding are expected to become even worse in the coming decades due to the effects of climate change. Therefore, identifying zones of vulnerability to climate change within the city has important implications for the livelihood of its inhabitants and also for urban planning. Here, we describe the impacts of sea level rise associated with intense rainfall events in Rio de Janeiro and using Geographic Information System (GIS), identify the main areas affected by floods. We characterize such areas with respect to their biophysical and urban dimensions and conclude by discussing more broadly the importance of social-environmental assessments for adaptive management.

With respect to extreme events like flooding, level of risk is associated with a society's susceptibility to environmental changes. This susceptibility is not only a result of a single event, but is also a consequence of social processes, which in turn, are related to the urban structure formed by political decisions implemented over the course of time. The Rio de Janeiro metropolitan region is one of the largest and most complex urban agglomerations of the Brazilian Coastal Zone, with an estimated population of 11,812,482 inhabitants. The city of Rio de Janeiro, the hub of the metropolitan region, has approximately 6,093,472 inhabitants (PNAD, 2008).

In general, areas poorly suited for urban use such as wetlands, steep hillsides, outcrops and rocky shores, estuarine channels, rivers and forest remnants have suffered the effects of intense urban expansion. This development has occurred in isolation, without taking into account the concept of the ecological and how this system is affected. According to Coelho Netto (2007), "the landscape of Rio de Janeiro in the 21st century depicts the historical process of city growth at a site marked by mountain massifs surrounded by fluvial-marine plains, sandbanks and coastal lagoons. From the mid-twentieth century the city underwent a process of accelerated growth, expanding its formal and informal constructions in the lowlands and on hillsides replacing the ecosystems of the Atlantic Forest. The advance of forest degradation has resulted in increasing instability of the hillsides. The increase of sediment supply during and after heavy rainfall has been responsible for the increased frequency and magnitude of floods, enhancing the socio-environmental disasters during the rainy season, mainly in summer."

Urbanization and pressures on natural resources

In Rio de Janeiro, urban form and land use are influenced by the pressures of population growth and economic productivity, generating increased resource demands for land, water and energy. The combined effects of these pressures make the city increasingly vulnerable to climate change. Furthermore, the city is confronted by serious problems of social, political and economic inequality. The lack of water supply, of sewerage and street paving, illegal occupations, insalubrious housing density, etc., all contribute to the precarious living conditions of the metropolitan population. These problems are further intensified in the most popular areas, suburbs and slums.

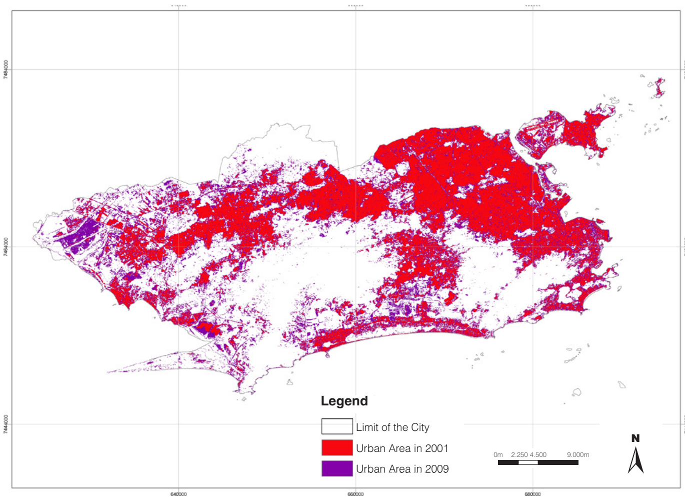
Over time, the city's growth has created a number of deleterious circumstances; the urbanization process has resulted in soil sealing, the removal of vegetation, disintegration of the soil's surface layers, and the pollution of waterways and air. Essentially, the entire natural system has been altered. Unsustainable patterns of urbanization along with the increasing demand for water, energy and land - which will only be exacerbated by climate change - will provide new challenges, particularly with respect to the equitable distribution of resources.

In order to understand the urban expansion of Rio de Janeiro, a survey was completed using satellite imagery (Landsat 5 and Landsat 7 ETM + - orbit point 217-076) making it possible to observe the process of urban expansion in the city between 2001 and 2009 (Figure 1). An edge effect around the majority of consolidated urban areas in 2001 is easily observable, as well as the trend of expansion to the west of the city in 2009.

The consequences of sea level rise

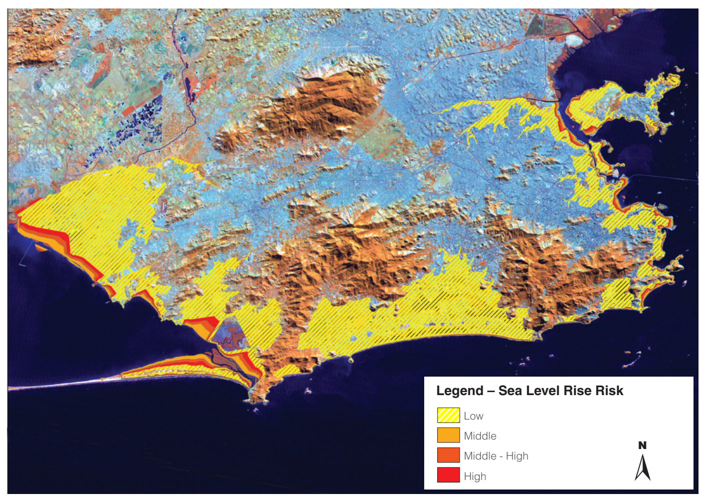
According to Muehe and Neves (2007), a series of impacts caused by climate change can dramatically affect the city of Rio de Janeiro, which will manifest in "changes in morphology and dynamics of beaches, water quality in lagoons, bays and estuaries, balance of the hillsides, and in the survival of mangroves and other plant species."

Figure 1 I Urban expansion in the city of Rio de Janeiro (2001-2009)



Source: Landsat 5 and Landsat 7 ETM + - orbit point 217-076 – resolution 30mx30m

Figure 2 I Vulnerable zones based on sea level rise risk



Source: Based on the Digital Terrain Model (through the interpolation and analysis of topography)

"The human-led occupation of the land which took place in another time, under other environmental conditions, may not respond adequately to new meteorological and oceanographic conditions […] [initially one must consider that] the main causes of sea level rise are the thermal expansion of ocean water (eustatic rise) and the melting of continental glaciers. […] Then, it is necessary to emphasize that the level of oceans varies from year to year, in cycles of about 20 to 30 years, with variations from 10 to 50 cm in width, depending on location and time" (Muehe and Neves, 2007).

For purposes of urban planning and decision-making processes, it is important to recognize not the gradual increase, but the occurrence of variations associated with the *meteorological tide*[1]. In addition to the meteorological tide, states Muehe and Neves (2007), there are the *astronomical tides*, which "can reach amplitude of about 1.30m, ranging in magnitude for different points of Guanabara Bay, Sepetiba Bay and ocean beaches. Some researchers like Rosman et al. (2007) mention that despite attempts, simulations of sea level rise are questionable, precisely because it is a dynamic system that varies according to astronomical tides and mainly to meteorological ones.

Moreover, Mendonça and Silva (2007) point out that "the coastal geomorphology of Rio de Janeiro is diversified and extremely modified by many factors of natural origin and human intervention. The coastal areas have dynamic characteristics and their own specificities that will certainly respond in different ways to the sea level rise." Bearing this information in mind, we have identified the lower-lying areas of the municipality that would be more susceptible to the sea level rise through the Digital Terrain Model (DTM) generated from interpolation methods (Figure 2).

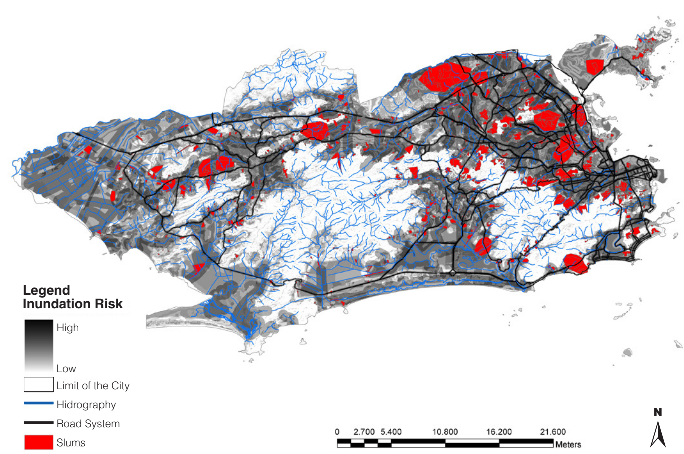
The orange zones correspond to sea level rise due to the meteorological tide. The red zones represent the increase in sea level considering the meteorological and astronomical tides (assuming the most critical situation). The most affected areas of the city include locations in the east and in parts of the south and west.[2] In terms of population, the total number affected (located at an average altitude of up to 1.50 m) would be approximately 60,320; more specifically, in the west this number would remain around 5,412, with 35,557 in the south and around 20,000 in the east. At the average altitude of up to three meters 402,849 people would be affected.

Currently, low-lying areas of lagoons and inlets, as well as terraces or fluvial-marine plains already represent areas that are at risk of flooding. Although with coastal erosion, vulnerability increases with the degree of exposure to wave, more negative effects than those envisaged with the erosion of the shoreline[3] will be felt by a rise in groundwater level, in the flooding of low-lying areas and consequently in the blockage of drainage channels and lowland rivers that have difficulty draining to the sea under normal conditions. This results in flooding conditions during periods of heavy rainfall, during "spring tides"[4] and periods of rise due to the meteorological tide. In other words, any of the scenarios of sea level rise will bring serious problems, but over large spatial extents and with a greater number of people affected. Furthermore, the variation of the average sea level due to climate change and the impact this has on mangroves[5] is another concern. In this regard, the main function of these ecosystems would be altered, as they stabilize and protect the shoreline to prevent its erosion and the silting of adjacent water bodies. Due to the position of mangroves in the intertidal zone, these ecosystems will inevitably be affected significantly by changes in sea level.

Risk of flooding

Due to the geomorphologic, geological and hydrological characteristics of Rio de Janeiro and human intervention in the natural water cycle and changes in land use, there are a variety of risks related to flood events. Floods are natural phenomena that occur mainly during the summer rains between December and March,

Figure 3 | Vulnerable zones based on flood risk



Source: Based on integrated analysis of topography, hydrographic system and land use data

1 In the open sea the tidal wave would be little affected by climate changes or by a rise in average level of about 30cm to 1m. In the inner parts of bays and of the estuaries that flow into those bays, however, this rise in sea level would make a tidal wave hit higher points, causing reversals in the direction of the rivers' drainage.

2 The most affected portions of the East would be the harbour and Governor's Island. In the South, which is constituted by a vast area that spreads from Jacarepagua Lagoon to Barra da Tijuca, the Aterro do Flamengo appears to be the most affected area. Within these regions are the Galeão and Santos Dumont airport, Marina da Gloria, as well as the whole cove (small bay) of Flamengo and Botafogo. The western part of the city includes the regions of Bangu, Campo Grande, Santa Cruz and Guaratiba (in Sepetiba Bay).

3 Erosion is a function of water movement by waves and currents, thus it would be necessary to distinguish different environments in terms of exposure. The shorelines can be classified as exposed, semi-exposed and sheltered.

4 Twice each month the earth, moon and sun align. This occurs once when the moon is between the earth and sun (new moon), and once when the earth is between the moon and sun (full moon). The gravitational pull of this alignment results in a greater distortion of the water envelope. This makes for higher than average tidal ranges. These are called "spring tides".

5 The remnants of mangroves of Rio de Janeiro are distributed throughout three main systems: Guanabara Bay, Jacarepaguá Lagoon System (Barra da Tijuca and Sepetiba Bay), in addition to a small area of Grumari beach and a narrow strip on the margin of Rodrigo de Freitas Lagoon (as a result of replanting).

during which intense rain events are a common occurrence in the late afternoon and are often extended for three or four days by the duration of cold fronts. With respect to the different types of flood processes that may affect communities and improvements in the area of the municipality of Rio de Janeiro, one of the scenarios of risk that deserves to be highlighted here is that which results from processes affecting large urban areas of the coastal plain. The mapping of vulnerable areas to floods in Rio de Janeiro reveals more clearly the situation of the city (Figure 3). In order to identify these areas subject to damage from flood events, data on land use, protected areas, the hydrographic network, soil suitability, the road system and topography (Digital Terrain Model) were integrated through GIS.

Concluding remarks

Many of the socio-environmental problems that exist in Rio de Janeiro are linked to the urban structure. Urban growth in Rio de Janeiro has resulted from a set of systematically interrelated processes that have transformed the landscape over time, endangering the population, as the city is unable to absorb the impacts which arise from extreme events. The predominant style of development has contributed to irrational uses of the land, turning valley bottoms into avenues, protected areas into urban lots, wetlands and coastal plains into poorly designed neighborhoods, all disrespecting the landscape and its natural features. The challenges inherent in these problems concern the development process of urban space and therefore, the different political and economic systems that influence it and/or the urban living conditions and social structures that inform ways of life and interclass relationships. In the face of continuing urban vulnerability and climate change challenges, there is an urgent need to strengthen social-environmental assessments for adaptive management, in order to better understand the types of climate hazards to which various population groups and systems are vulnerable, the causes of vulnerability, and their location. In this context, strategies towards mitigation and adaptation should address the issues identified in integrated social-environmental assessments.

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Mexico City, Mexico

Built Landscapes of Urban Regions: An International Comparison

Stephen M. Wheeler and Jayoung Koo

Built landscapes—homogenous patches of urban form at the neighborhood scale or larger—are the building blocks of today's large and rapidly growing metropolitan regions. A better understanding of urban form and its impacts at this scale can help citizens and policymakers manage growth, preserve ecosystem function, enhance livability, reduce motor vehicle use, and otherwise meet sustainability goals. As Seto and Christensen (2010) suggest, such knowledge may also be important in order to reduce greenhouse gas emissions and adapt to climate change.

Over the past year, our team has developed and compared built landscape typologies for 18 metropolitan regions internationally. We did not start this process from scratch, of course; urban morphology has a substantial history, as our work builds on past morphological research by figures such as Kevin Lynch, Michael Southworth, Anne Vernez Moudon, Dolores Hayden, Rob Krier, Spiro Kostof, A.E.J. Morris, Edmund Bacon, and John Reps. Bacon (1967), Kostof (1991, 1992), Reps (1965), and Morris (1979) have produced excellent illustrated descriptions of pre-modern urban landscapes. Lynch's 1981 analysis of urban form values and elements remains invaluable. More recently, Southworth and Owens (1993) analyzed neighborhood patterns in several suburban California cities, Moudon (1994) laid out an initial framework for urban typology of North American cities, and New Urbanist-affiliated writers such as Duany and Talen (2002) have explored the concept of a "transect" of urban forms—an ideal series of place types from the center of a city to its fringes, which are increasingly used at regional planning workshops within the United States. Hayden (2004) and Campoli and MacLean (2007) have produced attractive pictorial guides to urban form using aerial photos. Wheeler (2008) and Wheeler and Beebe (forthcoming) used GIS to map built landscape forms in seven U.S. urban regions.

Many writers on urban morphology have been more descriptive than analytic, however, and the idea of systematically mapping urban form and developing comprehensive, comparative typologies is relatively recent. GIS technology and the availability of aerial and street-view photographs through services such as Google Earth have made the process easier. For the current project we used Google Earth to catalog current types of built form for our 18 international metropolitan regions. The regions studied include Atlanta, Amsterdam, Bangkok, Beijing, Bogotá, Boston, Cairo, Johannesburg, Lagos, Mexico City, Moscow, New Delhi, Paris, Rio de Janeiro, Sacramento, Sydney, Tokyo, and Zagreb. These relatively large and typical metropolitan regions are a convenience sample that we feel can provide an initial comparison of the types of urban form existing on six continents. To some extent each metropolitan region is uniquely adapted to its context, and certainly cultural, institutional, and geographical settings are very different. However, it is quickly apparent that there are many similarities as well.

Table 1 I International built landscapes typology summary

	Typology	Atlanta	Amsterdam	Bangkok	Beijing	Bogota	Boston	Cairo	Johannesburg	Lagos	Mexico City	Moscow	New Delhi	Paris	Rio de Janeiro	Sacramento	Sydney	Tokyo	Zagreb	Total
V	Apartment Blocks	X	X	X	X	X	X	X		X	X		X	X	X	X	X	X	X	16
O	Civic Center	X		X	X	X	X					X	X	X		X		X		10
R	Commercial Strip	X					X						X			X				4
O	Country Roads		X	X								X		X				X	X	6
O	Degenerate Grid	X		X	X		X		X							X	X			7
V	Downtown Core	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	16
O	Garden Apartments				X				X		X	X	X				X	X		7
R	Garden Plots		X									X								2
R	Garden Suburb	X					X	X					X			X				5
C	Heavy Industrial		X		X		X	X		X	X	X	X				X	X	X	11
R	Hillside Upscale					X					X	X			X				X	5
O	Incremental Infill	X		X			X				X		X	X		X		X		8
O	Industrial	X		X	X	X	X				X				X	X	X	X		10
O	Informal Housing			X		X		X	X	X			X		X					7
V	Light Industrial	X	X	X	X		X	X	X	X	X	X	X	X		X		X	X	15
O	Long Blocks			X				X			X	X	X	X			X	X		8
U	Modern Hutong				X															1
R	Office Park	X	X		X		X	X					X			X				7
O	Old Town		X		X			X			X		X	X					X	7
R	Qausi-Grid								X				X			X				3
O	Organic Blocks		X				X			X	X				X			X	X	7
C	Rural Sprawl	X			X		X	X	X	X	X	X	X		X	X	X	X		13
V	Shopping Center	X	X	X	X		X		X	X	X	X	X	X	X	X	X	X	X	16
U	Storage Landscape											X								1
R	Streetcar Suburb	X		X			X		X							X				5
C	Suburban Grid					X	X	X	X	X	X		X		X		X	X	X	11
O	Suburban Lollipops	X	X				X	X	X								X		X	7
V	Suburban Tract	X	X	X	X	X	X	X	X	X	X	X		X		X	X	X	X	16
O	Superblock	X			X		X				X	X		X		X		X		8
R	Trailer Park	X					X									X				3
O	Upscale Enclave					X	X	X	X	X		X				X			X	8
R	Upscale Grid	X				X				X			X				X			5
C	Urban Grid	X	X	X		X	X	X		X	X	X	X	X	X		X	X		14

V=Very Common, C=Common, O=Occasional, R=Rare, U=Unique

We analyzed street patterns, block size and layout, building scale and placement on the lot, apparent land uses, and natural landscape elements of neighborhood forms in each region. We then developed illustrations comparing built landscape forms, including figure-ground diagrams of streets and blocks at 1,000' x 1,000' (Figure 1). Lastly, we merged the 18 separate typologies into a master list that shows the frequency with which each built landscape pattern occurs across these urban regions.

We discovered more than five dozen built landscape patterns, but many had similar characteristics, allowing us to narrow the list to 33 main types across these 18 regions. Of these, only nine could be considered common or very common. Our main findings include the following: 1) Suburban tract-style development is now found in almost every metropolitan area, but with considerable variation; 2) Superblock high-rise residential landscapes are common except in the United States; 3) Upscale housing and rural sprawl landscapes are found in most cities; and 4) "Big box" freeway retail landscapes are not found widely outside of the U.S. The remainder of our article provides a summary of our main findings on urban form and we also conclude by relating these findings to prospects for improved sustainability (Table 1).

The Spread of Suburban Tracts

Suburban tract-style development—single family housing blocks with wide streets and little land use mix—can be found in almost every metropolitan area, but with considerable variation in size and shape. In some regions these developments are for the wealthy while in other regions they are densely occupied by low-income groups. Most tracts are found in satellite cities and/or suburban locations. The spread of tract development is worrisome

Figure 1 | Selected built landscape types in different international metro areas (1,000ft x 1,000ft)

from a sustainability point of view since the relatively low-density, single-use character of this form encourages motor vehicle use.

The Prevalence of Superblock Apartment Housing

Le Corbusier and his colleagues in the modernist movement appear to have succeeded—the superblock style of multifamily housing is common throughout the world except in the U.S. But even more common is apartment housing within gridded or semi-gridded neighborhood street patterns. This latter form has the advantage of not interrupting street connectivity, now seen as important to diffuse traffic and facilitate multiple modes of travel.

Upscale Housing and Rural Sprawl

Upscale, low-density housing forms were present in every urban region, usually near the urban fringe or on hillsides. Most regions also contain "rural sprawl"—development on lots of one to ten acres. This form has grown rapidly in the United States in recent decades, and works against urban sustainability by consuming large amounts of land, promoting high levels of motor vehicle use, and reducing habitat quality. Rural areas were also at times colonized by lower-income development featuring unpaved, informal roads and piecemeal building construction.

Lack of Clear Urban Boundaries

Most regions did not have clear boundaries to urban development. Often, fingers of development extend along country roads outside of metropolitan areas, or upscale enclaves and rural sprawl development fragment formerly agricultural land. Since planners usually aim to limit urban growth, this lack of clear boundaries indicates that urban planning has been less than fully successful in most countries.

"Big box" Landscapes Limited Outside the United States

Large-scale commercial landscapes are universally present in urban areas but the "big box" freeway retail form is still found mainly in the United States. This may indicate that regular freeway use is less common in other countries (and that freeway networks are less extensive), or that land around freeway exists is more strictly controlled.

Gridded Urban Cores

Almost all cities feature some form of gridded street patterns towards their centers. Older districts tend to feature smaller blocks and narrower streets, frequently with some irregularity in block sizes and shapes. Newer business districts often feature larger blocks and wider streets, but also contain more open space and vegetation within blocks, perhaps indicating growing desires to green cities.

Informal Housing

We found informal settlements in all developing world cities except Beijing, where the strength of state control may prevent or quickly redevelop them. Informal settlements in many places were not quite as expansive as might be expected given their reported populations; this may be due to their high density.

Conclusion

This research represents an initial cut at a comparative study of built landscapes internationally. A next step will likely be quantification in GIS of land areas covered by each development type and the addition of historical layers. Beyond that, it would be useful to correlate information about typical household energy consumption, travel, and greenhouse gas emissions with different types of built form. We believe that such spatial comparisons can improve understandings of how urban forms and functions are evolving globally. Decision-makers should be able to integrate lessons from other metropolitan regions to their own local and regional contexts to improve urban environmental performance. In rapidly developing regions, knowledge of the experience of past urban forms elsewhere can help prevent inappropriate choices and lead toward forms that can meet sustainability goals.

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Urban agriculture in downtown Juiz de Fora, Brazil

Local and Global Changes in an Urbanizing World: The Connections of Urban Agriculture within Cities

Camille Lanzarotti Nolasco

As cities expand, agricultural land decreases in size, putting even greater pressure on food production to accommodate urban dwellers, who depend almost entirely on local markets for food purchases (FAO-FCIT and RUAF, 2009). Global changes in the physical environment, economy, institutional structures and civil society will have significant impacts on urban areas (UN-Habitat, 2009) and modify agri-food systems; this requires new solutions, which in turn, will ultimately alter these systems significantly from what they are today. In this time of change and insecurity, it is necessary to improve our understanding of the connections between urbanized space, food production, environment and people within urban systems at all levels. Studies that aim to understand the connections between urban agriculture as part of this urbanizing world are thus extremely necessary.

The role of urban agriculture in Brazil

For the first time in history, more than half of the world's population lives in cities (UNFPA, 2007). In Brazil, urbanization has acquired a characteristic of expansion that differs from the model of high concentration in large metropolitan areas (Carvalho, 2003). This outward expansion leads to a number of negative consequences including the loss of land along the urban periphery used for food production, the increase in water demand for human consumption and other uses, and the increase of solid and non-solid waste generated in the city, among others. With this expansion of cities, agricultural lands are lost and even greater pressure is put on the food production system relied upon by urban inhabitants (FAO-FCIT and RUAF, 2009).

Urban agriculture (UA) closely affects and is affected by processes of urban growth and plays an important role in the provision of fresh food for urban citizens. It contributes to increased food security by improving not only production and supply, but it also diversifies nutrition, diet, eating habits and values, in addition to improving human health in poor communities and reducing the risk of disease. In terms of environmental benefits, UA promotes increased reuse and recycling of waste, lessens the negative human impacts on biodiversity, improves the conservation of natural resources and agrobiodiversity (i.e.,

City of Juiz de Fora, Minas Gerais, Brazil

the preservation of native crops with high nutritional value) and promotes ecological awareness. UA also contributes to the economy through job creation and disincentivizes marginal jobs for youth, adults and elderly, which often generate insecurity and violence. It also makes fresh food rich in micronutrients available at competitive prices in the local markets.

In Brazil, urban agriculture involves a range of different stakeholders and occupies a great diversity of land space within its cities, but it is not generally regulated. The incorporation of the spatial dimension of urban agriculture into development plans and legislation is needed to further maintain and encourage the activity and to reconcile the demands of urban growth. Thus, UA is not only important for food security in times of economic crises, but is also an essential component of strategies for building healthy and sustainable cities (FAO-FCIT and RUAF, 2009).

Urban agriculture and global environmental change

In the coming years, environmental and climate changes will result in impacts that involve both decreased availability and increased water scarcity. Increased rainfall has already caused flooding and landslides in some areas of Brazil, i.e., the recent events of January 2011 within the mountainous region of Rio de Janeiro, southeastern Brazil. This region is a major producer of fresh vegetables that supplies the consumer market in major cities of Rio de Janeiro and Minas Gerais, two of the most populous states in Brazil. These extreme events resulted in a shortage of fresh vegetable supply and due to their absence in markets, affected the dietary habits of a large portion of consumers. Increases to the global average temperature will further exacerbate food production cycles and quality of life for people, increasing insecurity.

Furthermore, there is a broad set of challenges resulting from global environmental changes including increasing urbanization, globalization and future technological changes, as well as economic and behavioral changes, all which can affect food security. Global changes affecting the physical environment, economy, institutional structures and civil society have a significant impact on urban areas (UN-Habitat, 2009) and can alter agri-food systems, demanding new solutions which in turn, will change them dramatically. A greater emphasis will be placed on urban and peri-urban agriculture due to their multifunctionality (i.e, in addition to production functions, urban agriculture can offer a wide variety of ecological functions including biodiversity, nutrient cycling, and micro-climate control and cultural functions such as recreation, cultural heritage, and visual quality) (Fresco, 2009). Knowing that global changes do not affect everyone equally and vary in kind and scope across the globe (Hulme, 2009), it is necessary to improve our understanding of the connections between urbanized space, food production, environment and people within urban systems at multiple scales.

Understanding agri-food systems

Agri-food systems can be categorized as a "tragedy of the commons", as was described by Garrett Hardin (1968). Certainly, there exists a common need for food, but the challenge is to sustain the very ecosystems which are necessary for supporting food production. In an era of rapid change, uncertainty and growing risks, the developing world faces a number of limitations with respect to agriculture; their policies and practices are woefully inadequate for achieving long-term sustainability. The driving forces of urban growth, demographic shifts, the greater demand for food production, globalization and technological change have led to a reorganization of food systems from farm to plate. Efforts must be made to build healthy and equitable food systems that contribute to the social and economic development of communities. The good news is that the scientific community is now beginning to take recognition of the fact that changes must be made to current agri-food systems.

Concerns have recently emerged regarding food safety, sanitation, nutrition and the increasing demand for a re-location of systems aimed at the agri-food supply for urban consumers. Agri-food systems can be understood by human-environment interactions, which explains why current approaches of agricultural science and technological innovation fail to provide sustainable outputs, particularly at large scales and to a large number of the poor in developing countries. There has been little progress in understanding the changes in agri-food systems through interdisciplinary and integrated forms of study which are necessary for this understanding and for designing effective responses to human-environment interactions related to food and agriculture in a changing world. To address these challenges one must take into account not only knowledge and traditional practices, but also the dynamics and governance issues at various scales, including national, regional and global. Thus, it is necessary to take into account how the interests of various actors, among both political elites and civil society, influence the form of participatory research and development through their cultural "baggage" (Thompson and Scoones, 2009).

Present challenges require a new "look" at this relationship between culture and the agri-food system. According to Proctor (1998), the cultural dimension should be thought of as a process of shared meaning and a way to make sense of reality itself, an adjective that describes social processes. Cultural processes of signification are part of all human practices and it is necessary to identify what kinds of shared meanings are connected with human practices associated with global environmental change. The individual meanings appear in a context of shared meanings, where culture is shared and individuals relate to cultural networks. Therefore, when thinking about the agri-food systems and their relationship to global change we must first "identify" these systems. What are their cultural foundations? What actors, interests and historical, political and economic contexts are involved?

Conclusion

In this sense, research that aims to understand the dimensions of urban agriculture may raise rich connections. Nolasco (2009), for instance, found that the UA areas improve local food security, generate income, and preserve several cultivated plant species, which in turn, benefit indigenous animal species. UA areas are places considered to be of great importance to those involved, for the conservation of natural resources and local biodiversity, for maintenance of traditional knowledge and can therefore, be used as a tool in the development of sustainable cities. Other studies that consider the connections between urban agriculture as part of this urbanizing world are extremely necessary. These studies could help to understand the balance that is necessary between the space needed to support vital biological processes within cities' limits (including food production, green spaces, biodiversity, health and quality of life of urban dwellers) and the space necessary for functional urban structure.

Urban agriculture has a strong potential to be used in the development of sustainable cities given the non-sustainability of actual agri-food systems, the high concentration of people in cities and greater demand for food, in addition to the necessary preservation of environmental quality. However, much remains to be investigated, especially in relation to the connections it has with the urban metabolism and natural surroundings. Only with further study and greater knowledge will it be possible to see the real contribution of UA for a better future in this urbanizing world.

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View of Andes and Santiago, Chile from Cerro San Cristobal

Building Green Cities: The Urban Green Growth Management Model (U2G2M)

Cristiane Carvalho, Benjamín Infante, Ricardo Jordán

One of the main challenges of sustainable development in Latin America and the Caribbean concerns how to address the often complex issues that derive from urban processes such as rapid urbanization and increased migration. As a result, cities within this region are confronted by changes in land use patterns, increased natural risk vulnerability, pollution, environmental degradation, poverty, social fragmentation and crime, to name a few (Jordán and Simioni, 2003). In parallel, these processes are compounded by pressures of global climate change, further exacerbating these complex issues.

For almost 20 years, since the 1992 United Nations Conference on Environment and Development (Rio Summit), such issues have primarily been addressed by the traditional sustainable development approach, based mainly on the principles included in the Rio Declaration (Report, 1992). Presently, a new strategy for sustainable development is being set forth under the Green Economy Initiative, launched in 2008 by the United Nations' Environment Programme (UNEP) amid the global financial crisis, which aims to revive economies through the creation of lasting employment while also tackling environmental challenges that, if left unaddressed, will jeopardize the ability of future generations - rich or poor - to enjoy a proper life (UNEP, 2010). Part of this new approach is included in the recently published UNEP 2011 Green Economy Report entitled "Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication", in which a "green" economy is defined as one that is low carbon, resource efficient, and socially inclusive, with the potential to be a new engine of growth, a net generator of decent jobs, and a strategy to eradicate poverty (UNEP, 2011).

Although at first it may sound like a paradigm shift, UNEP asserts that the concept of a green economy does not replace that of sustainable development, but comes amidst a growing recognition that achieving sustainability rests almost entirely on the economy, and that the current "business as usual" or "brown economy" model has not substantially addressed issues such as social marginalization, environmental degradation, and resource depletion. One of the key messages stated within the UNEP Green Economy Report chapter on cities is that there is indeed *"the need for a fundamental change in urban development in order to facilitate the transition towards a green economy through a low-carbon, resource-efficient path"* (UNEP, 2011). This "fundamental change" in urban development points towards the building of "green" cities. A green city would be, in essence, an urban green economy, combining greater productivity and innovation capacity through investment in resource efficient technologies of sectors such as urban infrastructure, transport, housing, buildings, fresh water supplies, sewage, and energy.

This new economic vision recognizes the need for a strong political consensus on the costs and benefits of a transition to a green economy, and sees it as a critical element in effective fiscal policy reform that could be technically supported through the development of a robust evaluation framework. This framework would include a sound set of indicators to help assess the interactions between the environment and the economy, and at the same time evaluate policy progress (UNEP, 2010a). In the same vein, it is our belief that this challenge can be addressed in part through the definition of a management model based on the identification and implementation of measures aimed directly at addressing specific sustainability gaps in urban management. These gaps will act as pathways for a transition to an urban "green" economy aimed at achieving sustainability and eradicating poverty in cities in Latin America and the Caribbean.

The urban green growth management model

Here, the Urban Green Growth Management Model (U2G2M) is presented as a tool that allows for a systemic and integrated approach to urban management. It does so by complementing aspects of both urban economy and urban ecology and can be used by decision makers at the national, regional or local level, effectively contributing to a successful greening of cities through the development of urban green economies in Latin America and the Caribbean.

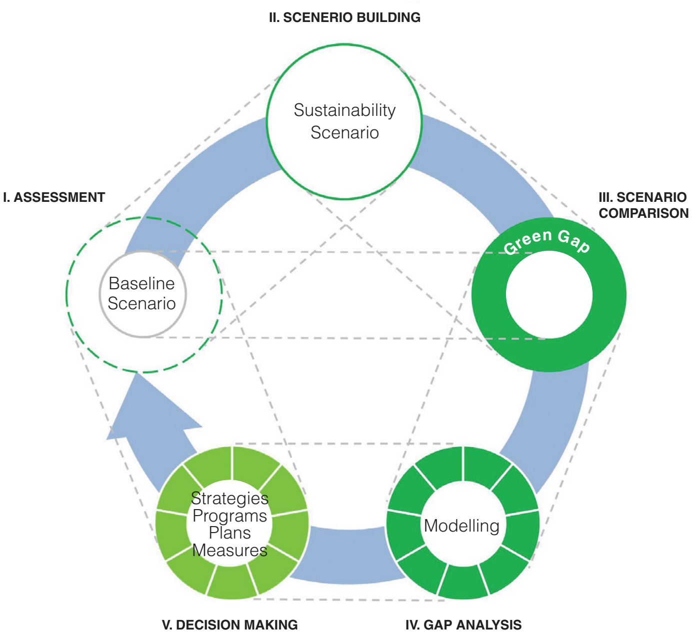
Given that urban areas are not just about the physical and built environment, but also institutions, governance, and social processes (Seto et al., 2010), the U2G2M considers the analysis of the interaction between the physical, built and social environment in which urban processes take place. The U2G2M works both as an assessment and management tool, helping to implement effective solutions to the main challenges of urban sustainability facing cities in Latin America and the Caribbean, and at the same time allows for measuring the economic, social and environmental aspects of sustainability policies through the decision-making process.

Given that appropriate indicators are widely known to be an essential part of any management strategy aimed at achieving development goals, the U2G2M incorporates the use of composite indicators of sustainability. Composite indicators are a simplified representation that seeks to summarize a multidimensional concept into a simple (one-dimensional) index based on an underlying conceptual model. These can be quantitative or qualitative depending on the requirements of the analyst. There are different categories of composite indicators, including indicators based solely on the natural sciences (e.g., Living Planet Index), accounting indicators (e.g., Socio-economic Dynamics, Index of Sustainable Economic Welfare, Genuine Progress Indicator, Ecological Footprint), and synoptic indicators (e.g., Human Development Index, Environmental Performance Index, Environmental Sustainability Index) (UN-ECLAC, 2009).

The idea behind the U2G2M is that every city will have a "green" gap in terms of its present state of sustainability and its goal of becoming a green city. The implementation of a series of green growth actions through a green stimulus programme directed to specific urban sustainability goals will ultimately lead to filling such a gap. Thus, the main objectives of the U2G2M are to first, identify the green gap and secondly, to select the set of actions that will fill it most effectively.

The methodological design of the U2G2M is comprised of five main phases: i) Assessment; ii) Scenario building; iii) Scenario comparison iv) Gap analysis, and v) Desicion making (see Figure 1). First, a sustainability assessment is created based on a set of composite indicators used to describe the current sustainability of the city, thus establishing a "baseline scenario" that is used to measure the city's state of sustainability. Next, during the scenario building phase, a series of sustainability scenarios are modelled, which are based on a set of different standards for each of the same composite indicators used during the assessment phase; one of these scenarios is ultimately selected as a sustainability goal. These urban sustainability scenarios differ only by the standards of sustainability assigned to each, and can themselves be considered different sustainability paradigms, modelled according to specific strategic goals. Once the desired sustainability scenario has been selected, a comparison is made between its values and those of the baseline scenario (scenario comparison), therefore identifying the green gap between the two, expressed as the difference between the values of its indicators. Once the gap has been identified, it is then analyzed in further detail in order to identify the specific individual sustainability gaps that aggregate the whole of the green gap. Finally, this leads to the decision making phase in which a combination of green growth actions including strategies, programs, plans, projects and measures are modelled over the baseline scenario until there is balance between its values and those of the desired urban sustainability scenario, thus identifying the actions needed to achieve such a goal.

Figure 1 | Urban green growth management model



Given the fact that the green gap and each of the individual gaps comprising the whole have an associated numerical value, decision makers will know exactly how much it will cost to fill the gap in terms of financing and trade-offs. As previously stated, this can be an effective tool for decision makers who are looking for ways to establish urban sustainable development strategies based on cost-benefit analysis. Moreover, the U2G2M also has the advantage of providing a quantitative measure of the strategy's success throughout the implementation period by analysing the evolution of the size of the green gap - whether it decreases, remains the same, or actually increases. It can also be used as a method of comparison between cities, as it substantively formulates an understanding of their "green" competitiveness.

Final considerations

Taking into account that decisions on matters of sustainability are made not only on the basis of technical but also political grounds, and that public sector capabilities are based mainly on regulatory and investment initiatives, the proposed model acknowledges the fact that the final decision in the overall strategy for transitioning to a green economy will ultimately be made based on cost-benefit and cost-effectiveness analysis, and that in most cases governance, institutional capacity and financing are and the main drivers of the implementation of such strategies. Nevertheless, technical support in the form of dynamic management models such as the U2G2M can provide useful information about the different options considered and the direct and indirect consequences of those decisions.

Because the U2G2M represents a tailored, context-specific urban management model that can be adapted to any geographical, social or environmental context, it can be used in many locations for the purpose of developing urban green economies and building green cities. As such, UN-ECLAC is currently studying in parallel the application of the U2G2M in intermediate cities within the Brazilian Amazon, Colombian Caribbean, and northern Chile.

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Urbanization and Global Environmental Change
AN IHDP CORE PROJECT

The Urbanization and Global Environmental Change (UGEC) project is a science project that targets the generation of new knowledge on the bi-directional interactions and feedback loops between urban areas and global environmental change at local, regional and global levels. It follows a multi-disciplinary approach and utilizes an innovative framework for the comprehensive understanding of the driving and resulting economic, political, cultural, social and physical processes. An important feature of this core project is the explicit commitment to translate abstract knowledge about GEC into local decision-making contexts. The project is expected to provide a platform for close interaction between practitioners, political decision-makers and researchers and targets a stronger coordination and collaboration between academics, political decision-makers and practitioners working on urban and environmental issues. The UGEC project is currently engaged in ongoing efforts to expand its regional and thematic networks.

Our website provides links to the UGEC Science Plan, information on how researchers can join our network as project associates, and how research projects and agencies can get their projects endorsed by UGEC (www.ugec.org). You can assist us in achieving our goals by forwarding this newsletter to any potentially interested party. Visit www.ugec.org for more information.

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The International Human Dimensions Programme on Global Environmental Change (IHDP) is an international, interdisciplinary science programme, dedicated to promoting, catalysing and coordinating research, capacity-development and networking on the human dimensions of global environmental change. It takes a social science perspective on global change and works on the interface between science and practice. IHDP is a joint programme of the International Council for Science (ICSU), the International Social Science Council (ISSC) and the United Nations University (UNU).

IHDP was founded by the International Council for Science (ICSU) and the International Social Science Council (ISSC) of UNESCO in 1996, and has been a key programme of the United Nations University (UNU) since January 2007. Financed by a broad range of agencies from different countries, IHDP's research programme is guided by an international Scientific Committee made up of reputable scientists from various disciplinary and regional backgrounds.

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ARIZONA STATE UNIVERSITY

The Global Institute of Sustainability is the hub of Arizona State University's (ASU) sustainability initiatives. The Institute advances research, education, business practices, and the University's operations for an urbanizing world. Its School of Sustainability, the first of its kind in the US, offers transdisciplinary degree programs that explore and advance practical solutions to environmental, economic, and social challenges.

With over 30 years of environmental research conducted by ASU's Center for Environmental Studies, in 2004, it evolved into the Global Institute of Sustainability established by Julie A. Wrigley. In 2007, the School of Sustainability was formed, offering undergraduate and graduate degrees in sustainability.

The Institute has a comprehensive sustainability research portfolio with a special focus on urban environments. More than half of the world's population lives in cities: global sustainability cannot be achieved without making cities sustainable.

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