

1. Project Title

Can Cities Reduce Global Warming? Urban development and the carbon cycle in Latin America

Principal Investigator: Patricia Romero
Depto. de Política y Cultura
UAM-Xochimilco Calzada del Hueso 1100
Col. Villa Quietud 04960
Mexico, DF
Email: rolp7543@cveyate.uam.mx

2. Executive summary

This proposal requests that **IAI** provides \$US 30,000 to organize two workshops aimed at establishing a new set of coordinated case studies. These case studies will address the linkages among three dimensions of urban development in Latin America (namely economic, socio-demographic, and institutional) and two components relevant to the carbon cycle: energy and land uses. The proposed project, which we conceive as a first phase of a longer term networking and research effort, will take one year and involve the participation of investigators and students from the Metropolitan Autonomous University (UAM-Xochimilco) in Mexico, the University of Chile, and the Universities of Mendoza and National of Luján in Argentina.

This project will pose questions about the interactions between urban development and the carbon cycle in Latin American cities. For example, how do specific pathways of urban development interact to influence land and energy use in the three cities? What is the influence of three underlying factors, namely economic and socio-demographic dynamics and institutional settings (e.g. liberalization, deregulation, and urban policies) in the use of energy by the cities' sectors (industrial, service, transport, domestic)? Fuel consumption and land-use changes are the most important sources of cities' impacts in the carbon cycle; what is the pattern of causation, and what are the feedbacks with economic, demographic and institutional dynamics?

We will use two system approaches to answer the questions above: flow accounting analysis (metabolism approach) and underlying driving forces/direct causes model. The former will be used to assess the carbon impacts of fossil fuel consumption and of land-use changes and the areas linked to them through interchanges of two carbon-relevant components: fuels and food. The latter will serve to explore three development dimensions and/or driving forces of such activities or proximate causes (economic dynamics, socio-demographic components, and institutional settings).

3. Introduction and objectives

Cities are contradictory front-runners of development in terms of economic growth, industrial transformation, quality of life, lifestyle changes, economic and demographic dynamics, and environmental impacts. They are key drivers of climate change and changes

in the global carbon cycle. Their activities release carbon directly, through the consumption of fossil fuels, and indirectly, such as through electricity consumption in the production of cement. Urbanization as land cover does not seem to be central to carbon, because cities only occupy a tiny part of earth's land surface (Lambin et.al. 2001). Cities' carbon relevance relates more to their effects on land change elsewhere through transformations of urban-rural linkages or urban ecological footprint, defined as the "area of productive land... needed to sustain" a defined urban population, an area located not only near by the city but also in remote places (Rees and Wackernagel 1996: 227). The carbon relevance occurs because land-use changes have reduced the amount of carbon stored in soils and impacted, hence, the distribution of carbon among land and the atmosphere (Houghton and Skoles 1990). The conversion of forests and other "natural" land to irrigated farm-land changes the albedo and heat capacity of the land.

Most carbon-related literature considers national or sector-level analysis, for example estimating net carbon balances from fossil fuel use or land-use changes. Scholars have also examined the impacts of climate change on specific sectors, such as agriculture and forest, energy or industry. Other studies have considered relationships between carbon emissions and aggregate measures of economic growth, technology and population (Richards 1990, Greening *et al* 1999, Lukkanen and Kaivo-oja 2002).

Very few studies, however, have had a perspective on how specific pathways of *development*¹ in Latin American cities interact with land and energy use as two components of the carbon cycle. This issue is implicitly addressed in themes III and IV of "IAI Science Agenda", but this project aims to develop it further by explicitly focusing on the linkages between urban development and the carbon cycle at three analytical levels:

- a) Flow-accounting assessment of some carbon impacts generated by the use of fuels and land in the three cities and the areas linked to them through the interchanges of energy and food.²
- b) Analysis of three development dimensions and/or driving forces of fuels and land use (proximate causes): economic dynamics, socio demographic components, and institutional settings.
- c) Systems modeling of the feedbacks among proximate causes and driving forces.

For the achievement of these long-term goals, this project proposes to organize two workshops *to establish a network of researchers sharing a common approach and methodology, data bases, research targets, and research results as well.*

4. Approach

¹ Usually by defining development the emphasis is on economy, i.e. the productive sectors providing commodities, employment, consumption, and wealth, and the incentives and policy strategies aimed at promoting investment as well. Another – social – dimension of development focuses on humans, their quantity and their quality of life measured in terms of life expectancy, education and equity. Yet another dimension highlights the natural resources and the environment (Board on Sustainable Development 1999). We use here a three pillars approach to development and distinguish between economic, social, political and environmental - carbon - inter-related processes.

² „Energy and material flows through human settlements are conceived as urban metabolism, in which material inputs are transformed into useful energy, physical structure and waste“ (Decker, E.H et al., 2000: 687). This process constitutes the main dimension of cities ecological footprint we will analyse in this project.

Both the workshops and the coordinated case studies will need to address questions specific to the socioeconomic and political context of each city. In addition, we will address the following questions by considering all of the case studies together:

1. How do specific pathways of urban development influence land- and energy use in the three cities?
2. What is the influence of three underlying factors, namely economic and socio-demographic dynamics and institutional settings such as liberalization, deregulation, and urban policies in the use of energy by the cities' sectors (industrial, service, transport, domestic)?
3. If both consumption of fuels and changes in land-use are the most important human direct causes of cities' impacts in the carbon cycle, which is then the pattern of causation and what are the feedbacks with economic, demographic and institutional dynamics?
4. If managing carbon were to become an explicit goal in the development policies of Latin American cities, what are the most feasible strategies for meeting the "requirements for a sustainable earth system"? (Raupach et al 2003)? Which interactions with other ecological and socioeconomic processes should be considered?

Two approaches belonging to a systemic pattern of explanation³ will be drawn on to answer those questions: flow accounting analysis (metabolism approach), and underlying driving forces/direct causes model (Fischer and Amann 2001, Krausmann, F. et al. 2001, Geist and Lambing 2001, Romero Lankao 2003). From the rich set of variables developed within the socioeconomic metabolism approach, three will be used here to represent the carbon impacts of changes in land use and flows of fuels into, within and out Latin American cities and "their areas": Total Material Requirement, Total Domestic Output, and Human Appropriation of Net Primary Productivity.⁴

We intend to test at the analytical level of the underlying forces, if the economic, social and political dimensions of development (Footnote 1) drive the changes in the uses of land and energy. We want to see if rather than only operating at local scales, those dimensions also function at national or even international scales.

On the economic dimension, recent dynamics of the three cities will be explored, such as impacts of current waves of globalization, liberalization and deregulation (also known as *structural reform*) on energy use by the industrial, commercial, service, agriculture and

³ „At least two major pathways of explanation have emerged to explain patterns of causation“ in the analysis of issues of sustainable development: „single factor causation versus irreducible complexity“ (Geist and Lambing 2001).

⁴ Total Material Requirement (TMR) of fossil fuels and biomass appears as the sum of Direct Material Input (DMI) and Hidden Flows. The Direct Material Input equals to domestic extraction plus imports of fossil fuels and biomass. Hidden Flows are estimated as background processes to the DMI, and usually amount to the same or more than DMI. Total Domestic Output relates to the outflow of wastes and emissions in question, from which CO₂ releases seem to play a dominant quantitative role. Human appropriation of net primary productivity (HANPP) is used to assess land-use changes in ecosystem's patterns and processes, and defined as the difference between Net Primary Production (NPP) "of the potential vegetation and the NPP remaining in ecosystems after harvesting /.../ HANPP results in reduced energy availability in ecosystems and is associated with a reduction of standing crop and, hence, of carbon storage in ecosystems" (Krausman *et al* 2001).

transportation sectors. Indicators will be constructed to represent the carbon impacts of regional economic dynamics, namely gross domestic product (GDP) and outflow intensity of the regional economy (DPO/GDP),⁵ energy use and carbon emissions by different sectors. We will then build key ratios, e.g. carbon intensity of energy use, energy intensity of GDP, outflow intensity of GDP. We will keep in mind that regional economic statistics can be limited by two facts: (a) data are not always available or reliable, and (b) some activities (e.g. subsistence agriculture) occur outside of the formal market economy.⁶

The second – social – dimension relates to urban demographic dynamics. It refers also to other carbon-relevant social indicators related to land-use, energy consumption and transportation characteristics, such as urban density, passenger cars and vehicles/1000 people, and annual car km/capita (Kenworthy and Laube 1996: Table 2). Population is important, not only in terms of the total population, but also in terms of differentiated living standards and access to carbon-relevant technologies, such as cars and household appliances.

The third dimension refers to the institutional settings.⁷ Some aspects of institutions that are relevant to carbon emissions vary between locations (e.g. effectiveness of land-use planning), and some aspects are common to cities around the world (e.g. transportation strategies). Institutions should be understood in terms of recent structural and political reforms in Latin America, such as the rolling back of the state, cuts in public expenditure, privatization, and decentralization (Harris, R. 2000, Schaefer, R.K. 2003). Besides the characterization of national development policies and their influence on urban economic dynamics, the following institutional components will be explored, with the goal of shedding light on their effects on land-use changes, transportation modalities, environmental intensities and carbon emissions by local economic activities:

- a) Transportation and infrastructure policy strategies, i.e. whether they are transit- or car-orientated, and whether they emphasize infrastructure for cars, or for public and alternative transport (e.g. bikes);
- b) Regional land use planning, i.e. whether it has promoted heavily zoned and segregated urbanization patterns, and urban sprawl;
- c) Instruments and strategies explicitly aimed at reducing the material intensity of regional economic and transportation activities, e.g. taxes and subsidies for investments in clean technologies, improvement of fuels used by industry and automobiles (Romero 2001).

5. Plan and Timetable

We will organize two workshops. In the first workshop, we will establish protocols, analytical tools, datasets, initial targets, and longer-term research strategies. In the second

⁵ Domestic processed output (DPO) refers to the total amount of materials used and processed in a domestic economy (i.e. which are the product from DMI), when they flow back to the environment as emissions, wastes, and deliberate disposals.

⁶ The shadow economy, estimated to amount to half or more of Mexican economy, includes activities that evade taxes, elude official regulatory requirements, do not appear in statistics, and/or are as such illegal.

⁷ O’Riordan and Jordan (1999) define institutions as the “multitude of means for holding society together, for giving it a sense of purpose, and for enabling it to adapt. Institutions apply both to structures of power and relationships as found in organizations with leaders, membership, resources and knowledge, and to socialized ways of looking at the world as shaped by communication, culturally ascribed values, and patterns of status and association.”

workshop, we will exchange results and discuss draft reports of case studies. We will invite colleagues from other projects (START, APN see Table 2) and some policy makers to both meetings. We will also agree on next steps aimed at strengthen the long-term collaborative efforts of the group (Table 1). This proposal seeks funding for three case studies in Latin America: Santiago (Chile), Mexico City (Mexico) and Buenos Aires (Argentina). In addition, we expect to strengthen our collaborative research networking with other case studies, four of them already funded by APN (Indonesia, Philipines, India and Thailand), while others (Colombia, South Africa, Japan) are sponsored by or incorporated into the project on “Urbanization, emissions and the global carbon cycle” (NCAR, GCP and Packard Foundation)

Table 1: Plan and Time Table

Activity	1	2	3	4	5	6	7	8	9	10	11	12
First meeting Mexico city to plan and agree on protocols, data targets, and research strategies												
Case studies: analysis of cities’ carbon-relevant metabolism, of its proximate and underlying forces												
Synthesis meeting , in Santiago, Chile to exchange research findings and discuss draft reports of case studies												
Drafting of synthesis paper												
Reporting to IAI												

6. Relation to IAI Science Agenda

Our project is related in two ways to topics within themes III and IV of IAI Science Agenda, such as “comparative studies of regional air pollution”, “greenhouse gases and their impact on climate change”, and “rapid urbanization and sustainability”. First, we will build on previous research on urbanization, greenhouse emissions, climate change, and sustainability.⁸ Second, we will analyze one issue not fully and explicitly explored in earlier proposals, namely the relationship between three dimensions of urban development in Latin America and two relevant dimensions of the carbon cycle (land and energy uses). Our effort can shed light not only on our research questions, but also on broader issues such as

- a) urbanization’s impacts and feedbacks to the dyad climate-carbon (see Field and Raupach 2003),
- b) functioning of key global, national and more local human drivers of land and energy use, namely globalization, liberalization, economic dynamics, and institutional settings,
- c) modeling of feedbacks among underlying drivers and two carbon relevant proximate causes (consumption of fuels and changes in land-use)

⁸ See for instance Richards 1990, Greening *et al* 1999, Lukkanen and Kaivo-oja 2002.

7. Regional Collaboration

Our project will contribute in three ways to the collaborative research networking of the Americas. We will establish a well-coordinated set of case studies on urban development and the carbon cycle. We will integrate those studies with the ones underway within other American programs and institutional umbrellas – e.g. “Urbanization, emissions and the global carbon cycle” sponsored by START, NCAR, GCP, and the Packard Foundation. Finally, we will connect and coordinate our set of studies to other global environmental programs (see section 11 in this document)

8. Contribution of each Co-PI

We summarize in Table II the contribution to our proposal, not only of each Co-PI, but also of researchers from two projects: “Integrating Carbon into developing strategies of cities – establishing a network of case studies of urbanization in Asia-Pacific”, financed by APN, and “Urbanization, emissions and the global carbon cycle”, sponsored by START, NCAR, GCP and the Packard Foundation. An “X” means a relatively larger contribution than a “+”, while (X) means that involvement depends on independent funding.

Table 2: Scientific Involvement

Country	Writing proposal	Case study	Thematic review	Two workshops and write-up	Other
Mexico	X	X ¹	X	X	Project steering group, hosts first workshop
Chile	X	X ²	X	X	Project steering group, hosts second workshop
Argentina	X	X	X	X	
Colombia		(X) START	+	+	
South Africa		(X) START	+	+	
Japan, China, Korea		(X) START ³	+	+	
Australia		GCP ⁴		+	Advisory group GCP
Thailand		(X) APN		+	
Philippines		(X) APN		+	
Indonesia		(X) APN		+	
India		(X) APN		+	

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1. The PI is also involved in the activities of START and has applied for a “seed grant”, but the final decision has not been made yet.

2. In the case of Chile, besides our Co-PI we have one researcher participating in the START project and willing to collaborate in the networking efforts of this group.

3. We have two colleagues working in Japan, participating in START and willing to integrate in the broader network.

4. Global Carbon Project, executive director

9. Capacity Building

Our project seeks to build capacity through three mechanisms: a) collaborative planning, research and synthesis, b) communication with local policy makers, and c) training of

graduate students. The following strategies will allow us to achieve the exchange of technical and analytical skills, and of scientific information within the region:

- workshops and other working meetings;
- networking activities with other projects within the Americas;
- publishing results in peer reviewed journals; and,
- an outreach process with policy makers, in which issues of urban development and the carbon cycle are given new consideration in the development of urban policies.

10. Policy Relevance

Managing carbon is already an implicit goal in the development policies of Latin American cities – e.g. transportation, infrastructure and land use planning. By discussing our research strategies and results with policy makers we can contribute to making that goal explicit, and to reshaping policies that negatively affect the carbon cycle (e.g. institutional incentives to the use of cars, or to urban sprawl). We can also enrich our research approach by learning from the experiences and challenges facing policy makers. We can contribute to public discussions at the national and international level of a crucial issue: the most feasible carbon-management strategies in terms of their “requirements for a sustainable earth system” (Raupach et al 2003), and the trade offs of such strategies with other ecological and socioeconomic processes as well. We intend to contribute through key global programs (e.g. GCP) to the international analysis and management of the interplays among cities, globalization, and carbon.

11. Related research work

The PI is author of a concept note and a chapter on regional development and the carbon cycle (Romero Lankao 2003a and b). She is co-author of the Framework and Implementation Plan of the Global Carbon Project (Raupach *et al* 2003). These activities provided the impetus for this proposal. Dr. E. Puliafito and the IEMA Institute have been involved since 1990 in urban air pollution monitoring and dynamic modeling. He will implement a mathematical model of the complex city-carbon cycle interactions. A. Leon’s research relates to the land-use change process, and rural-population vulnerability to drought in the semi-arid region of Chile, an area severely affected by the desertification process. Desertification, which affects almost half of Chile’s territory, is a carbon-related issue as it decreases the ability of the soil to sequester carbon. Other research includes the potential for decreasing vulnerability through the utilization of seasonal climate forecasts, and the institutional aspects that promote/hinder disaster prevention in Chile. We present in Appendix II the CVs for members of the other two projects participating in our networking efforts.

Our project is related to the following international research programs and networks:

- a) The research area “Pathways of Development and the Carbon Cycle” within GCP, a joint project of IHDP, IGBP and WCRP,
- b) The project “Integrating Carbon into developing strategies of cities – establishing a network of case studies of urbanization in Asia-Pacific”, financed by APN,

- c) The project “Urbanization, emissions and the global carbon cycle”, sponsored by START, NCAR, GCP and the Packard Foundation, and
- d) Research on urbanization within the project Industrial Transformation and IHDP’s Urbanization Program.

12. Summary statement

This proposal intends to

- a) Establish a well-coordinated network of case studies addressing the linkages between urban development in Latin America and the carbon cycle, and related to the research activities of the Global Carbon Project and IHDP,
- b) Develop a common and comparable methodology including two tools: flow accounting analysis and the underlying drivers /direct causes model. The former will be used to assess the carbon impacts of fossil fuel consumption and of land-use changes. The latter will serve to explore three development dimensions and/or driving forces of such activities or proximate causes (economic dynamics, socio demographic components, and institutional settings).
- c) Build capacity through three mechanisms: i) collaborative planning, research and synthesis among researchers, ii) communication with policy makers, and iii) training of graduate students, and
- d) Submit research findings to peer-reviewed journals

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