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Environmental consequences of exurban expansion in an agricultural area: the case of the Argentinian Pampas ecoregion

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Abstract Exurban land use growth has been documented for at least thirty years in various regions around the world. Land use planners and land use/land cover change researchers have been concerned about the low-density residential developments scattered on a natural or agricultural matrix, due to their ecological and environmental impacts. In this paper, exurban sprawl in the Pampas ecoregion (Buenos Aires province, Argentina), is characterized and assessments are taken of the magnitude of two important consequences: agricultural land conversion, and excess CO_2 emission resulting from commute. The exurban developments concentrate between 50 and 70 km from Buenos Aires city, mainly at walking distances from compact towns, from 1 to 6 km of main roads, and no further than 25 km from them. Most of the exurban developments are located on the higher elevations in the study area (25 to 30 m above sea level). Even though exurban land use covers a very small proportion of land, the results show a tendency for conversion of land in the highest soil productivity capacity classes. While the best agricultural lands accounted for 29% of the land in the study area, it accounted for 54% of the exurban development. Preference of exurban land use conversion for good quality agricultural soils is observed even in those counties with a scarcity of good soils. However, there are great differences among counties in the relative proportion of land converted to exurban land use in each soil productivity capacity class. At the county level, from 0 to 100% of the highest production capacity lands have been converted to exurban uses, regardless of the proportion of land in each soil productivity capacity class for individual counties. Excess CO_2 equivalents emission was calculated for both the actual and the potencial number of households in the exurban developments. According to the automobile marque, range and fuel type, the actual

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emission ranges from 81,065 to 190,446 tons/year, and the potential from 296,643 to 696,908 tons/year. The excess emission per household is higher than that produced by domestic energy consumption within the Buenos Aires city during the same time period. The amount of CO_2 emitted in a year by personal vehicle transportation, in the study area, is equivalent to that captured by 16,000 ha of temperate forests or 27,600 ha of temperate grasslands during the same time period.

Keywords Gated cities · Greenhouse gas emissions · Land use change · Leapfrog development · Buenos Aires Province

Introduction

The pattern of random, unplanned growth of urbanized areas, commonly known as sprawl, has become the most common form of land use/land cover change around cities throughout the world (Hammer et al. 2004). Even though urban sprawl is considered by some landscape architects and planners as an opportunity to emphasize qualities such as attractiveness, pedestrian-friendliness, or stimulating regional economic growth (Burchell et al. 2000), according to a considerable amount of studies, it creates numerous environmental and social problems, both within cities and in their surroundings. Urban expansion may threaten natural and agricultural landscapes through direct land use/land cover change, as well as through various indirect effects. The most visible indirect effects are increased traffic congestion; degradation of air and water quality; deterioration of wildlife habitat quality; changes in hydrological regimes; increased flow of pollutants into waterways; loss of species and natural landscapes; exotic species invasions; increased social disparity. The worldwide deterioration of natural and human systems due to the expansion of the urban population and urbanized areas occurs at all geographic scales (Botkin and Beveridge 1997; UN 2006).

This state of affairs has triggered a considerable amount of research aimed at the study of causes and consequences of this phenomenon, including the development of methods and indicators for the assessment of urban sprawl (Hasse and Lathrop 2003; Hammer et al. 2004; Herold et al. 2005); studies of the dynamics of the phenomenon (Berling-Wolff and Wu 2004; Yu and Ng 2007); the ecological effect of urban expansion on wildlife (Blair 1996, 2004; Theobald et al. 1997; McKinney 2002); various aspects related to loss and fragmentation of agricultural lands (Fischel 1982; Brabec and Smith 2002; Carsjens and van der Knaap 2002); urban management and the effects of land use policies (Conway and Lathrop 2005; Marcotullio and Boyle 2003; Wasilewski and Krukowski 2004). The literature includes a discussion regarding the driving forces of urban sprawl, among which the more cited are increases in numbers of households, housing preferences, industrial restructuring, geo-morphological patterns and processes, infrastructure investment (Alberti et al. 2003); land and real estate markets pressures (Ottensmann, 1977; Morello et al. 2003); changes in economic scenarios, in social conditions, and local government policies (Wasilewski and Krukowski 2004; Morello et al. 2003).

Most of the studies focus on land use changes in the urban rural fringe; that is, the advancement of the urban borders in the metropolitan areas with the eventual incorporation of existing small urban centers to form a dense agglomeration. Only recently, disjoint or leapfrog development has become a matter of concern to researchers and planners (Hammer et al. 2004; Nassauer et al 2004; Theobald, 2001, 2005). This form of scattered sprawl consists of the development of urban patches within the existing matrix, and may have even more dramatic effects on the matrix fragmentation than edge land cover changes (Franklin and Forman, 1987;

Theobald et al., 1997), since they drive changes at a disaggregate scale. Leapfrog land use change has increased since the 1990's; and it occupies far larger extensions than urban and suburban areas. For example, Theobald (2005) reports for the US, that exurban land conversion has been growing at a rate of about 10–15% per year, which exceeds the rate of urban development, and occupies five to ten times more area than urban and suburban lands.

Since 1995 we have been studying urban fringe expansion and its consequences in agricultural land loss in the Buenos Aires metropolitan area, which occupies the best agricultural lands of Argentina (Morello and Solbrig, 1997). In a study of urban growth during seven periods between the censuses from 1869 to 1991, we found that at all time intervals, urban growth occurred on prime farmland rated as capability class II, according to the US Soil Conservation Service land capability classification (Morello et al., 2000a, b). Our findings did not differ greatly from those of Nizeyimana et al. (2001) for the conterminous USA, notwithstanding the differences in extension and resolution.

However, in our previous research we did not take into account the urban patches located beyond the urban-rural fringe, whose rate of establishment started to increase by the 1970's. In this paper we report for the first time for Argentina, the environmental consequences of exurban growth in Buenos Aires Province. We focus our study on two spatial scales: land cover and land use changes, mainly the loss of agricultural lands, on a local scale, and CO_2 emission caused by personal vehicle commute, at the regional scale.

The first exurban developments were established in the 1930's, beyond the urban fringe of Buenos Aires metropolitan area, and up to the 1980's their increase in number was slow. They belonged to the high and medium income families, and functioned as weekend country clubs for the inhabitants of Buenos Aires city. Starting in the 1970's, some families moved on a permanent basis to their weekend homes, as a consequence of the increasing lack of safety in the city. During the 1990's, exurban land use change increased considerably, as it happened in other regions of the world (Carrión-Flores and Irwin 2004; Nassauer et al. 2004; Robinson et al. 2005; Theobald 2005). In Buenos Aires province, the private towns became a social and economic event of unusually great proportions. A large number of higher income city dwellers moved to the private enclaves on a permanent basis; and many young couples chose the country clubs at the time of buying their first house. In a short time, the number of exurban developments and their population grew at an alarming rate, with urban patches of low density spreading all over the Pampas ecoregion.

Exurban development is largely of the single-family residential type, characterized by a high ratio of green area to constructed area; low population density; detached individual units with no hedges around them; dendritic (i.e. based on cul-de-sacs) street networks differing widely from the standard grid-based street networks of compact cities; sports infrastructure; private security services; and utility infrastructure, including sewer system, energy supply, telephone, television, provided by the private developers. The most important differences among the types of developments are the rate of green to constructed area, and their specialty. According to the former, the private exurban developments are classified as gated neighbourhoods, with the lowest rates and higher population density; country clubs, with intermediate values, and farm clubs with 1 ha parcels (Szajnberg 2000). With regards to the specialty, there are nautical clubs, aeroclubs where the inhabitants arrive in their own planes, golf and tennis clubs, equestrian clubs, and those offering a variety of sports. Recently, a new type has appeared; this is the mega-development, which occupies hundreds of hectares and comprise a set of neighbourhoods which differ among them with regards to type of buildings, landscape design and sports or cultural specialty.

In Argentina there exists a fair amount of research that tackles exurban growth from various points of view, such as the organizative, the social, and even the legal aspects (Pirez

1999; 2002; Szajnberg 2001; Vidal-Koppman 2001; Torres 2001); however, there are no reports on its environmental impacts.

Several drivers of exurban land use change have been reported, such as: fragmentation of local governments, large-lot zoning, urban disamenities associated with higher density areas (Carrión-Flores and Irwin 2004), advances in communications and information technologies (US Congress Office of Technology Assessment, 1995), improvement of the transportation network (Pirez 1999; Vidal-Koppman 2001), reduction of car prices during the period of exchange parity (one argentinian peso = 1 dollar) (Vidal-Koppman 2001), real state market pressure together with the lack of public planning policies (Pirez 1999), social or cultural factors, such as the search for privacy and safety, or individual choices related to income level or way of life (Pirez 1999); the search for a better quality of life, and the return to the kind of social relations that prevailed before overpopulation within the city (Thuillier 2005).

The ecological or environmental consequences of exurban growth in Buenos Aires province has not been studied. Field observations show that among the most noticeable environmental effects are the loss of agricultural lands, invasion by exotic species, deterioration of riverine vegetation, disappearance of endangered native ecosystem fragments and species; water, air and soil pollution; changes in topography and natural drainage; loss of biological corridors. Some of these, for example, the loss of agricultural lands, have been mentioned in the literature but without scientific verification (Pirez 2002).

At the present time, the most pressing impact of exurban land use in the Pampas ecoregion appears to be agricultural land loss. The excess emission of greenhouse gases caused by commute in personal vehicles is not recognized by people, not even by government officials.

The studies of exurban land use/land cover change have benefited from the recent shift from a regional approach to a residential plot level analysis (Theobald et al. 1997; Irwin and Bockstael 2002, 2007; Hasse and Lathrop 2003; Irwin et al. 2003; Carrión-Flores and Irwin 2004; Stone 2004; Stone and Bullen 2006). In the Pampas ecoregion, the assessment of agricultural land directly transformed by exurbanization requires a farmland parcel level analysis, since exurban growth produces land use/land cover changes in relatively large land tracts of agricultural or farm lands within the rural matrix. The farms become parcelized by the developers, and the parcel owners form a collaborative organization such that the urban development functions as a unit.

Land-cover change has a significant influence on carbon storage and fluxes in terrestrial ecosystems. The concentration of greenhouse gases in the atmosphere has been increasing since the start of industrialization in the 19th century, and more rapidly during the second half of the 20th century (NAS 1992). This observation has become a genuine matter of concern for the informed public. Despite uncertainty about the relationship between increased CO_2 concentration and rising global temperatures (Wang and Oppenheimer 2005; Wang and Chameides 2007), a consensus has emerged that there is a direct relation between these two facts (NAS 2001). The main contributor to increasing atmospheric CO_2 concentration is fossil fuel combustion (IPCC 2007) for power generation, transport, industry, and domestic use. The concern for the greenhouse warming of non-biological origin has triggered technological research aimed at decreasing or mitigating it. Energy companies and other industries are applying techniques and devices to reduce greenhouse gas emissions (EPA 2000; Herzog 2001). Motor vehicles emission is the least amenable to control, since low quantities of greenhouse gasses (carbon dioxide, methane, and nitrous oxide) and other contaminants are released at many points scattered over large land tracts. With the present technology, this emission can only be reduced by decreasing fuel consumption and the commute distances travelled by individuals. The first step is problem recognition, followed by the evaluation of its magnitude. This paper approaches the problem estimating the excess carbon dioxide emission caused by commute in personal vehicles from the exurban enclaves to the capital city (Buenos Aires city).

The objectives of this work are: a) to determine the areal extent of land converted to exurban uses, and the distribution of exurban developments in relation to highways, roads, and compact cities, in the Pampas ecoregion; b) to assess the areas and proportion of land converted to exurban developments in each soil productivity capacity class using remote sensing and GIS technology; c) to estimate the excess CO_2 emission due to daily transportation from the exurban developments to Buenos Aires city core in personal vehicles.

Methods

The study area

The study area was defined as a set of 32 counties in Buenos Aires Province where at least one exurban development was present. It falls within two of the subregions of the Pampas ecoregion: the Rolling Pampa and the Flooding Pampa. The Pampas ecoregion is a sedimentary basin with its crystallized basement covered by several strata of loessic sediments during the Holocene. Those sediments are the parent material of most of the agricultural soils in the Province (SAGyP-INTA 1989). The Pampean ecoregion is divided in subregions, according to the general topography, which affects the present drainage system and soils, each of them supporting different economic activities. The climate is temperate, and mild due to the temperature moderating effect of the ocean; thus, snowfall is absent, and large diurnal or seasonal temperature amplitudes do not occur (10–12º between the coldest and warmest months). This, together with evenly distributed rainfall allows for year-round cropping.

The Rolling Pampa, where the most productive agricultural lands of Argentina are located, is one of the five extensive areas of loessic fertile soils of the world. It has enough rainfall to produce sustained high yields of soybeans, wheat, sunflower and corn, representing 52% of the national agricultural production value. The traditional crops, maize and wheat, as well as cattle raising, have been superseded by soybean in the last decades, when international soybean prices increased in the 1980's. The native grassland has been converted to croplands; and only very few, isolated relics remain. In this subregion, the capital city Buenos Aires and its extended metropolitan area, the Great Buenos Aires Region, are located. Urban growth, mainly metropolization, has triggered a fierce conflict with agriculture, and considerable extensions of farmland have been irreversibly lost (Morello et al. 2000b).

The Flooding Pampa is formed largely (80%) by a low plain, covered by natural grasslands. Its flat topography, lack of a well developed drainage system, and low hydraulic conductivity of soils, determine the occurrence of floods in late winter and spring, while droughts are frequent in summer. Agriculture is impeded by flooding, soil salinity and low fertility. The main economic activity is cattle raising on its'natural grasslands. In a lower proportion, managed pastures and fodder are included in cattle raising practises. In the northern portion, there are important milking activities. Crops are limited to a few hillocks sticking out on the plain.

Data sources and methodology

Our approach focuses on urban properties that can be measured directly and relatively easily, i.e. urban land cover as seen on a satellite image and defined by its morphology. The extent of exurbanization was determined by generating an exurban layer from the Landsat seven TM scenes adquired in december 2002 and January 2003 and provided by the

National Spacial Commission (CONAE). An urban layer of all compact urban settlements in the study area was obtained from the same images. Roads, highways and contour layers were provided by the Military Geographic Institute of Argentina (IGM). The digitized county map was provided by the National Statistics and Censuses Institute (INDEC). Soil productivity ratings, and soil landscape units were obtained from the attributes tables and the vector maps published in the Soil Atlas of Argentina (Maccarini and Baleani 1995), and in the Soil Map of Buenos Aires Metropolitan area (Morello et al., 2000a). Exurban land use preferences for particular geographic locations were obtained by analysis of the data resulting from overlays of exurban land use maps and the other layers (roads, highways, altitude, compact urban setllements). The level of soil productivity capacity, presently under exurbanization, was obtained by analysis of the data resulting from overlays of exurban landuse maps and the soil productivity layer.

The personal vehicle CO_2 yearly emission was obtained by computing the distances travelled between each exurban town and the city of Buenos Aires per year. The rate of CO_2 emission per kilometer per vehicle was obtained from the Society of Motor Manufacturers and Traders of Great Britain web page (SMMT 2002).

All GIS computations and coverage overlays in raster format were performed using IDRISI (Eastman, 1999); vector maps were handled using ArcView3.2 (ESRI 1999).

Mapping exurban land use

Image processing and GIS technology were used to obtain and analyze the data. Country clubs, farm clubs and mega-developments were included in the study. Gated neigborhoods were discarded because of their small extension and population make them less aggresive to the environment. Also, many of them are within the metropolitan area, and in many cases they have become the only green areas within the compact urban mesh. Even though they are private dwellings, they may offer some ecological services to their surroundings, such as CO_2 capture, increased water infiltration, and wildlife habitat.

All the exurban developments that were visible on the Landsat seven TM scenes, were digitized manually on screen in ArcView3.2. The national digital geographic data base comprising roads, water courses, contour lines, localities, and rail roads were used to help locate the exurban neighbourhoods. The landscape designs, and the lot plans of each urban project were used to facilitate their delimitation. The designs and distribution of parcels are provided by the real state sales promotion agencies and the developers in the Web, specialized magazines and newspapers. Exurban developments are distinguished from compact cities by their urban morphology: the former have irregular designs, mostly with dendritic street networks, while compact cities show a standard grid-based street network with 100 m long blocks.

The exurban land use map was rasterized to facilitate spatial tabulations. The resulting 25 m grid resolution image was reclassified to produce a Boolean map assigning values of one to the exurbanized cells and 0 to background cells.

Assessing geographic preferences of exurbanization

The compact middle sized and small cities were digitized manually on screen, and rasterized as described for the exurban developments. The roads and highways vector layers were also rasterized.

Distance maps were obtained for each geographical object (compact cities, roads and highways) to obtain an image of continuous values representing the Euclidean distance between each cell and the nearest of a set of target features representing a geographical object. A map of distance classes for each object was obtained by reclassification.

The raster layer of exurban developments was multipled by each of the distance classes map to obtain a set of new maps in which each urban pixel had a value of its distance to the object under study. The frequency of exurban pixels within each distance class was obtained for each geographical object layer.

Assessing exurbanization preferences for terrain elevation

A digital elevation model (DEM) was obtained from the contour lines of the study area, with a horizontal and vertical resolutions of 50 and 5 m, respectively. The DEM was reclassified to obtain a map of elevation categories. The proportion of exurban area on each elevation class was obtained by cross tabulation between the Boolean exurban layer and the terrain elevation layer.

Assessing soil productivity capacity distribution

The map of soil landscape units covering all of Argentina (included in the Atlas) has been developed by the Natural Resources Research Center (CIRN) and the Soils Institute, with the technical assistance of ESRI's representative in Argentina (Aeroterra) (Maccarini and Baleani 1995). The map consists of soil polygons described by a set of attributes of importance to agricultural production, including surface form and several soil characteristics (35 variables). The soil layer and the associated attributes table are based on existing soil survey maps recompiled at 1:500,000 scale. The Atlas also contains various climatic, demographic, hydrological, contour, political boundaries, localities, roads, railways, and other layers, compiled at 1:250,000 scale.

One of the soil variables, in the attributes table, is the cartographic productivity index (IPc), developed from the productivity index (Riquier 1970), which multiplies nine factors based on soil characteristics that are correlated with yield (climate, drainage, soil depth, texture, salinity, alcalinity, organic matter, cationic exchange capacity, and erosion). The productivity index assesses the proportion of the potential yield for the most common crops adapted to the local conditions, and grown under a particular technology. The index varies from 0 to 100; the higher the value, the higher the quality of the land for agricultural production. Soil component rating values for each polygon were then weighted by percentage composition to determine a single rating value (Ipc) for each soil mapping unit. The ratings were finally grouped into the following seven categories: very high (100–80), high (80–70), moderately high (70–60), moderate (60–50), low (50–30), moderately low (30–10) and very low (10–0). A soil productivity layer was extracted from the soil landscape units map, and converted to raster format.

The distribution of the soil productivity capacity in the study area was tabulated as the percentage of the total area in each soil productivity capacity class. The distribution of soil productivity capacity in each county was determined by intersecting the county boundaries map with the soil productivity layer, and the proportion of each soil productivity capacity class was tabulated as the percentage area of each county.

Assessing the areal extent of agricultural land converted to exurban land use

The area of soil mapping units converted to exurban land use that fall into each soil productivity category were determined by overlaying the exurban land use layer with the soil productivity layer. By means of cross tabulation between these maps in which a tabulation is kept of the number of cells in each combination, the relative proportion of land converted to exurban land use in each soil productivity capacity class was estimated. From the same data set, the relative proportion of land in each soil productivity capacity class that was converted to urban land use was estimated.

By means of cross tabulation between the soil productivity layer and a point map of exurban land use, in which each point is in the grographic center of an exurban development, the percentage of the total number of exurban units in each soil productivity capacity class is obtained.

The above analyses were also performed for each of the 32 counties by intersecting the county boundaries layer with the soil productibity layer. The results are the proportion of land converted to exurban land use in each soil productivity capacity class in each county.

A general discussion of the relationships between the distribution of potential soil productivity and urban land use is provided for various counties.

Assessing carbon dioxide emission

The estimate of CO_2 emission was based on the present and potential numbers of households in the exurban developments, the distance between each exurban unit and the geographical center of the capital city, and individual vehicle gas emission in grams per kilometer.

The number of households in the exurban units was obtained from the advertisements published in the mass media by the developers and real state companies. For those exurban developments for which this information is not given, the number of already built houses was used as a surrogate. The number of vacant residential plots was used as a surrogate for the future number of households.

The distances, in a straight line from the geographical center of Buenos Aires city to each exurban enclave, was measured with a GIS. A distance map from the city central point was obtained, as well as a point map showing the center of each exurban neighbourhood. The latter was rasterized and reclassified to obtain a Boolean layer. The distances were obtained by a cross tabulation of both maps.

The distances travelled in kilometers per year were calculated supposing that only one vehicle per family commutes per day, in five days a week during 11 months a year; that is, holidays were not counted.

Values for CO_2 emission were obtained from the SMMT (SMMT 2002) with a calculator that allows choices for vehicle specifications (marque, range, fuel type, transmission, door plan, trim, engine capacity), and yields the amount of CO_2 emitted in grams per kilometer. The number of vehicles of each marque and other specifications in the exurban developments is not available; thus, a range of emission values was obtained, from the highest to the lowest car emissions from the vehicles commercialized in Argentina. It is assumed that the engines are in good shape since malfunctioning engines emit higher levels of greenhouse gases. Four values were obtained: present and future CO_2 emission from the most and the least polluting vehicles.

For comparison, the amount of carbon dioxide emitted is converted to equivalent areas of various plant coverages found in the Pampas ecoregion, such as forests, wheat and pastures. The CO_2 capture rates for temperate zone ecosystems and crops were obtained from the literature (NAS, 1992; Hanan et al., 2005). This approach is not intended to suggest that planting forests or crops around the city will mitigate emission through CO_2 photosynthetic capture, since atmospheric CO_2 transport depends on a set of variables and there is not a straight foward relationship between CO_2 emission and capture in situ. In addition, for comparison, the CO_2 emission caused by domestic electricity is calculated on a household basis for northern Buenos Aires metropolitan area, with data on electricity consumption provided by the local electricity distributing company. The northern metropolitan area was chosen because electricity consumption is higher than in the southern neighbourhoods.

Results

Geographic preferences of exurbanization

There are 223 exurban developments, scattered over 32 counties (Fig. 1). The number is larger than that reported by Pirez (1999, 2002), of 139 units distributed in 19 counties. The paper by Pirez includes all types of private neighborhoods, and includes only the counties surrounding Buenos Aires city. In our reseach, those counties were not taken into account because they belong to the gated neighbourhoods type, with the lowest rates of green to constructed areas, and the highest population densities.

This study area comprises 2,304,318 ha, and the exurban land use area 39,187 ha; that is, only 1.7% of the total area has been converted to exurban use. These results differ from previous reports (Pirez, 1999), where 23,991 ha of exurban land use were identified in an areal extent of 800,000 ha, showing a rate of occupation of 3%. The data used by Pirez came from the literature, and we have found large differences between values reported by developers and owners, and the extensions measured by us on the GIS map. We cannot assure that our larger figures reflect urban growth, because data sources, method of analysis and spatial scales differ from those in previous works.

Extension of exurban developments varies between 20 and 1,300 ha, with parcel extensions from 1,000 m^2 to 1 ha. The amount of units and their extension varies in each county (Table 1); and these two variables are not associated. For example, Coronel Brandsen county has only four exurban units, and their total area is three times that of the 14 exurban units in Escobar county.

Most of the exurban neighborhoods (91% of the units and 78% of the exurban land use area) are located within a distance of 20–80 km from Buenos Aires city. Their higher

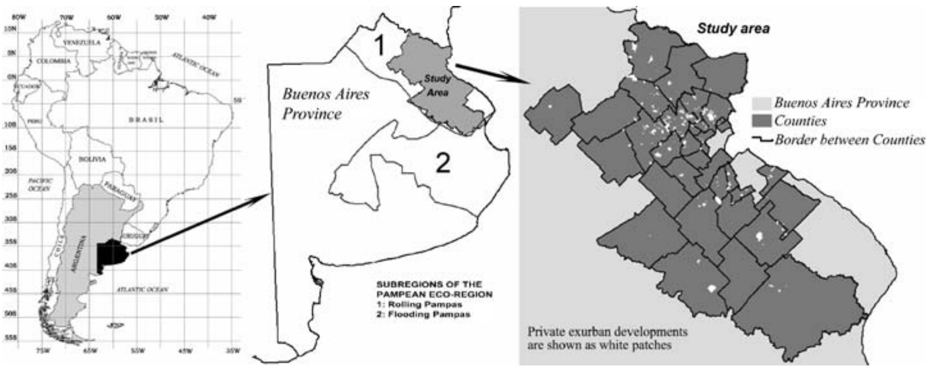

Fig. 1 Map of the study area showing in shaded tones the counties in which at least one exurban development (white polygons) is present

Table 1 Number of exurban developments, exurban land use area for individual counties, and proportion of the county area converted to exurban land use

Name	Exurban Area (ha)	Number of units	% of county area(1)
Berazategui	798	5	3.62
Campana	783	4	0.79
Cañuelas	758	6	0.63
Carmen de Areco	441	1	0.41
Chascomús	676	3	0.16
Coronel Brandsen	2684	4	2.41
Escobar	948	16	3.14
Esteban Echeverría	1301	12	10.71
Exaltación de la Cruz	3910	14	6.15
Ezeiza	1936	6	8.15
General Rodríguez	2093	8	5.75
Ituzaingo	270	2	7.11
José C. Paz	186	1	3.71
La Matanza	50	1	0.15
La Plata	621	8	0.69
Lobos	92	1	0.05
Lujan	3774	24	4.89
Malvinas Argentinas	359	5	5.72
Marcos Paz	406	1	0.96
Mercedes	456	2	0.43
Merlo	128	1	0.12
Monte	2465	2	1.34
Moreno	847	6	4.56
Pilar	5101	52	13.26
Presidente Perón	575	3	4.76
San Andrés de Giles	408	2	0.36
San Fernando	236	4	0.24
San Isidro	20	1	0.38
San Miguel	276	5	3.32
San Vicente	70	1	0.11
Tigre	3787	16	9.61
Zárate	2791	6	2.34
Totals	39246	223	1.70

(1)=(Land area under exurban land use*100/county area)

concentration is between 50 and 70 km, where 25% of the units and 27% of the area is located (Fig. 2); however, in number of units, the highest concentration is within 35 and 70 km.

It is evident that the exurban developments have spread out in recent years. In a previous paper (Pirez 2002; with data obtained in 1999), the private enclaves concentrated within 40 km from the city, and a few distant units were found 70 km to the North. By the end of 2002, the farthest away are at 140–160 km from the city.

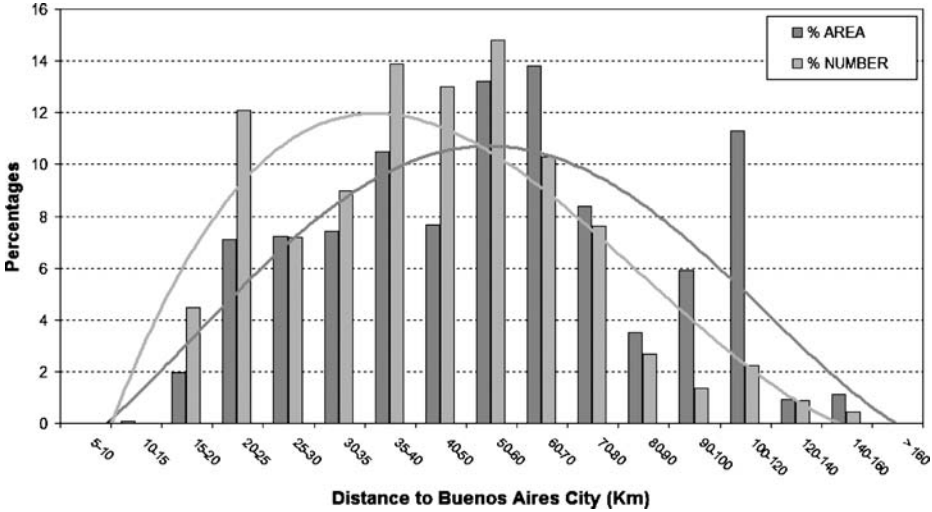

Fig. 2 Distance between the exurban developments and Buenos Aires city

Most of the exurban neighbourhoods (72%) are near compact urban areas (Fig. 3), the farthest away from a town is at 40 km, and 52% are at less than 3 km, a walking or bicycling distance. These compact cities, most of them small towns, provide basic services to the private enclave dwellers, such as car mechanics, repairmen for small appliances, last minute food shopping. People that work by the hour in the private neighborhoods (gardeners, maids, etc) live in these small compact cities.

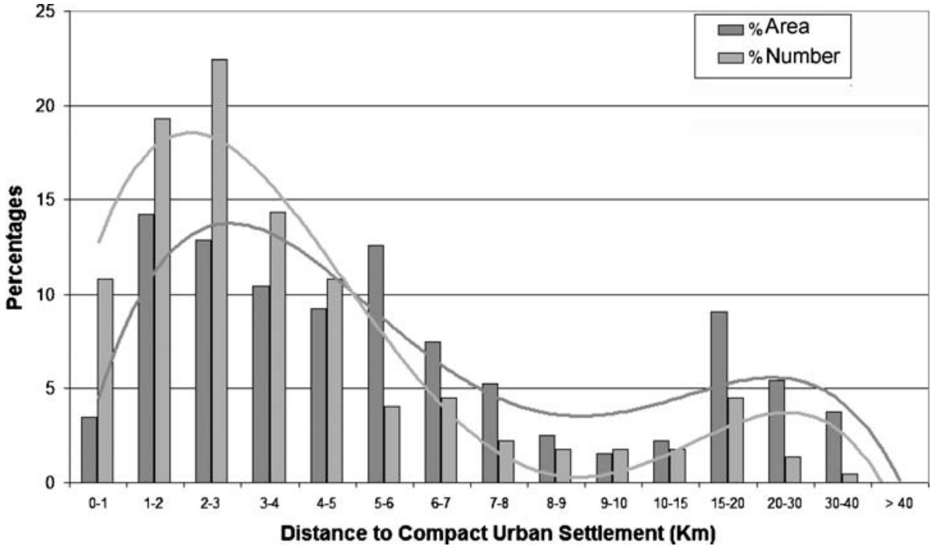

Fig. 3 Location of exurban developments in relation to compact urban settlements

These results are in agreement with those of Pirez (2002), who pointed out the situation of inequality between those living "outside" and those from "inside" the private neighborhoods. Part of the differences in life quality and well being arise from the fact that private enclaves have utility services that are lacking in the compact towns next to them. This happens because the infrastructure planning and construction in the exurban developments is also private, and is provided with the parcels on the market, while outside it is a public service of very low quality.

Only 2.65% of the exurban land use area is in contact with highways; 1.87% with national routes (Fig. 4), and 6.65 % with local roads, some of them constructed to access

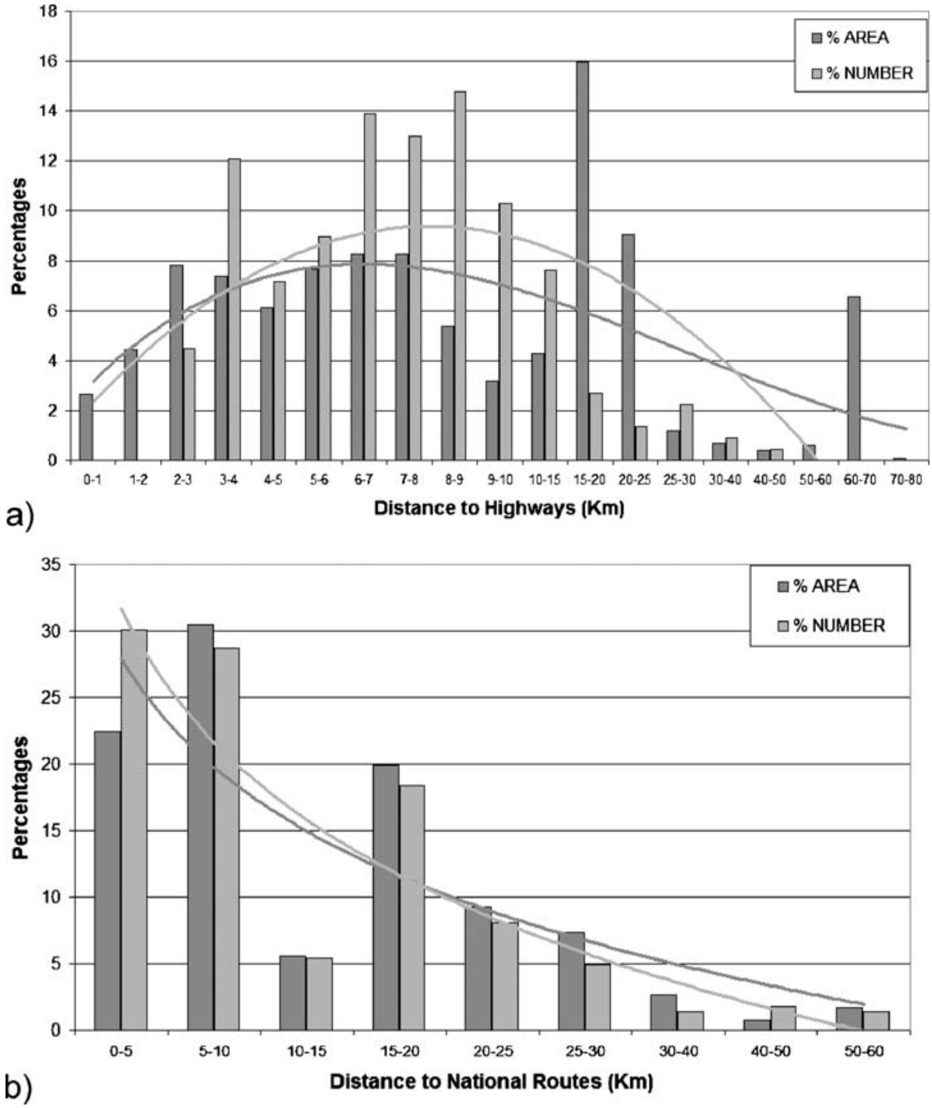

Fig. 4 Location of exurban developments in relation to roads: (a) highways; (b) national routes

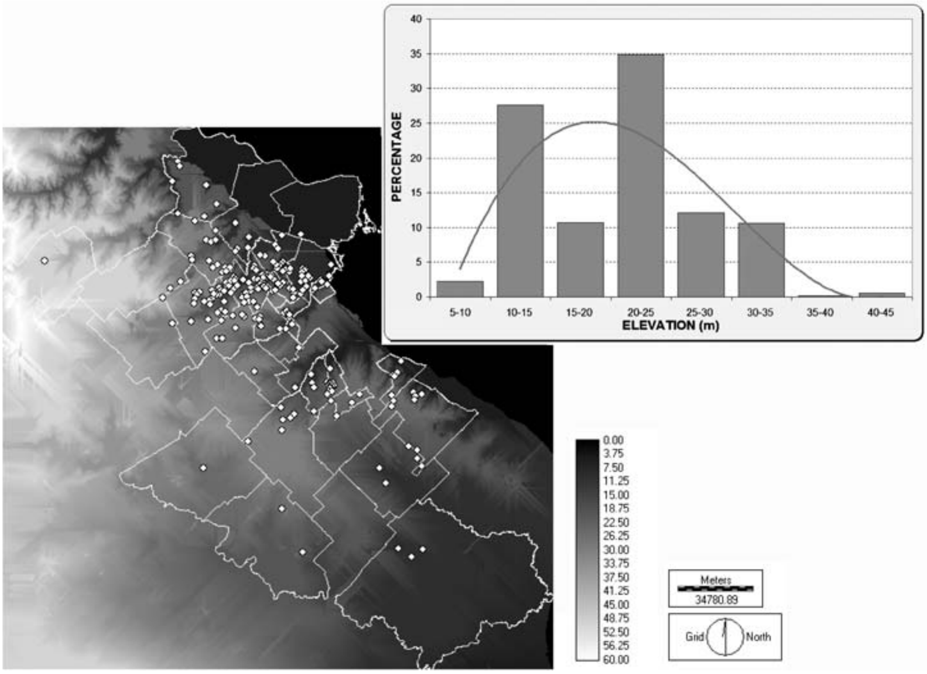

Fig. 5 The location of exurban developments in relation to elevation. Exurban developments are shown on the DEM

the new developments. The difference in the last two values is due to the higher density of local roads. The highest proportion of the exurban land use area (85%) is between 1 and 6 km from a main road, and the farthest is at 25 km. The highest concentration of units is found between 3 and 10 km from the highways. Even though highways facilitate commute to the city, a preference for sites far from the noise of the traffic is observed.

Exurban developments show a preference for higher altitudes: 58% of their area lies between 20 and 35 m above sea level, the highest elevations in the study area (Fig. 5). These are also the best agricultural lands, since in this ecoregion there is a strong correlation between elevation and soil variables related to its productivity capacity (loess depth, drainage, soil organic matter, etc). Only 2% of the exurban enclaves are located in the lowlands next to the main rivers. Most of these are nautical clubs, which deserve special attention because they change topography and natural drainage systems, increasing the risk of flooding in their surroundings and even in lands far from the coastal line.

Conversion of agricultural lands to exurban land use

At the regional level, the most abundant soil types are those of very low productivity capacity (IPc 3 to 10), and of low to moderate (IPc 30–60) (Table 2). The former are in the flooding valleys of main rivers, and in the Flooding Pampa lowlands, to the southwest of the study area. Only 17% of the land area falls in high and very high productivity capacity classes (70–100); while 20% fall in the very low soil productivity capacity class, in the flooding valleys.

Table 2 Proportion of land area in each soil productivity class for the entire study area and for the exurban land use area, and proportion of land in each soil productivity class converted to exurban land use

IPc class	% of the study area(1)	% of exurban land use area	% IPc class under exurban land use(3)
0–10	19.67	12.44	1.11
10–30	7.71	15.75	3.58
30–50	22.63	7.80	0.60
50–60	20.86	10.21	0.86
60–70	12.52	30.86	4.32
70–80	8.93	10.35	2.03
80–100	7.68	12.59	2.87
TOTAL			1.75

(1) Area of land in a given productivity class*100/area of land in study area. (2) Area of land in a given productivity class*100/area of land in study area under exurban land use. (3) Area of land under exurban land use in a given productivity class*100/ area of land in the soil productivity capacity class. (1) = (Land area under exurban land use*100/county area)

A small fraction of land in each soil productivity capacity class has been converted to exurban land use (Table 2). The highest proportion of exurban land change affects the moderately high soil productivity capacity class (60–70%), followed by the moderately low (30–10) class.This is not a consequence of relative proportions of the soil classes, since they are not the most abundant in the study area. Approximately 23% of the lands under exurban use are on the most productive soils.

Counties differ in their potencial for agricultural production; that is, spatial distribution of the productivity capacity among counties is heterogeneous. They can be categorized in three groups of productivity capacity: high, with more than 50% of their area with IPc values higher than 60; medium, with 20–50% of their area with IPc higher than 60; low, with less than 20% of the land in the moderately high to very high soil productivity capacity classes (Table A-1 in appendix). The latter are those located next to the Parana River Delta and in the Flooding Pampa Subregion. The counties with best soils are those of the Rolling Pampa Subregion.

Half of the counties belong to the first group (high productivity capacity). In this group, four counties stand out for their high and very high quality soils (IPc values higher than 70%); two of them (San Andrés de Giles and Carmen de Areco) have a very small proportion of their land area converted to exurban use; while in the other two (Lujan and Exaltación de la Cruz) more than 5% of their territory is under exurban land use (Table 1). Pilar county (Table A-1), which is taken as an example in all studies of exurban growth for its extremely fast urban development in the 1990's, had more than 80% of its territory with good agricultural soils, in the moderately high soil productivity capacity class, now mostly irreversibly converted to exurban land use.

In the counties with the highest productivity potential, exurban development shows a high preference for the best soils (Table A-2), even though non-agricultural lands are available, as it happens in Exaltación de la Cruz, José C. Paz, Mercedes and Merlo. In these three counties, 4.18% of the area converted to exurban land use falls into the moderate to very high productivity capacity classes (IPc form 50–100). Preference for good quality agricultural soils for conversion to exurban land use is observed even in those counties with a scarcity of good soils, as in Marcos Paz, Zárate, Cañuelas and Lobos (Table A-2 in appendix). In the latter, for example, there is only one exurban unit (Table 1), and it is located on the best soils present in the county, even though these occupy only 7 % of the county's territory (Table A-1).

Among the four counties with a high proportion of good agricultural soils, in Lujan (Nº11) 57% of the highest production capacity lands have been converted to exurban uses; and in Exaltación de la Cruz (Nº5), 42%. On the other hand, in Carmen de Areco, the best agricultural lands have been preserved from exurban land use change (Table A-2), even though 65% of the lands fall into the high and very high soil productivity capacity classes (Table A-1).

These results show that there are cultural and management differences among counties. Carmen de Areco County, for example, has a long farming tradition. The results contradict the assertion that exurban development occurs preferably on low price lands (Pirez 2002). The myth of low land prices in the Rolling Pampa Subregion due to soil unproductivity prevails; but it is untrue. The farmers selling their land is not a consequence of soil productivity capacity but of the real state agent's buying pressure, which reduces agricultural production returns, in comparison to urban development. The reduction in profitability of agricultural production as compared to the relatively high price of housing land increases the farmers' interest in selling land for nonagricultural purposes (Carpenter and Lynch 2003; Wasilewski and Krukowski 2004). Local governments consider urban land use conversion a factor of economic development, and they stimulate the speculation in land transactions in order to increase their budget revenue.

The low soil productivity capacity counties are either in the coastal area and hold a higher number of exurban units, or in the Flooding Pampa, with fewer exurban units of greater extensions.

Two different situations coexist in the study area: the conversion of agricultural lands on the highlands and the modification of topography and natural drainage on the low quality soils of the lower altitude areas. Both situations generate adverse environmental consequences, but agricultural land loss is more important for the national economy.

Excess emission of carbon dioxide

By the end of 2004 there were 26,427 households in the exurban towns; the potential number is 81,547. Supposing only one household member commutes to the central city in his/her car, during a year of 48 weeks and 5 work days in the week, there are 240 round-trips per year per family. Thus, taking into account the distances to each exurban unit, and the number of households in each one; 555,236,400 km were travelled annually by the end of 2004, and 2,031,801,168 km will be travelled when the potential occupation of the present exurban developments is realized.

The annual rates of carbon dioxide emission by the least and the most polluting vehicles are 146 and 343 g CO_2 equivalents/km, respectively[1]. Thus, the excess present emission for these extreme cases is between 81,065 and 190,446 tons/year. In the near future, the values would be 296,643 and 696,908 tons/year.

These figures represent the amounts emitted in excess of that arising from circulation within the city, because it was calculated from the centre of each exurban neighborhood to

[1] Burning of fuels results in the emission of several gases among which the most abundant carbon dioxide (CO_2), methane (CH_4) and nitrite (NO_2), and in less amounts ethane (C_2H_6), propane (C_3H_8) and butane (C_4H_{10}). Emission values are expressed as CO_2 equivalents, which are obtained by transforming the other gases to equivalent amounts of CO_2 (IPCC 1996)

the geographical centre of Buenos Aires city. It is assumed that travelling within the city does not change significantly whether the driver lives within the city boundaries or outside.

The values are rough estimates because, in addition to the suppositions already mentioned, velocity of circulation, petrol octane rating and engine condition are not taken into account; all these factors affect the rate of gas emission. Neither the increase in transportation of manufactured products, fuel and construction materials from the city to the exurban developments, nor that of the fresh food (mainly vegetables, eggs, poultry, etc) from the rural lands outside the metropolitan fringe to the city, are taken into account. The distance between Buenos Aires city and the horticultural farms is increasing as a consequence of exurban expansion.

The real magnitude of the commute contributing to greenhouse gas emissions is appreciated when it is compared to that of electricity production for domestic uses. According to the statistics provided by one of the companies in charge of electricity distribution in Argentina, during 2004, 6735 GWh were sold to 2,322,560 households in the northern portion of Buenos Aires metropolitan area. Thus, the average annual consumption was 2900 KWh per household.

The rate of greenhouse gas emissions in the generation of electricity depends on several variables, such as type of fuel, technology efficiency, and general conditions of the power plant. An emission ranging from 0.69 to 1.27 Kg of CO_2 per KWh produced has been reported (USDE-USEPA 2000). If we take the median of 0.98 Kg CO_2/KWh, the average emission per household in northern Buenos Aires was 2842 Kg CO_2/year for 2004. The excess emission per household caused by commuting is over 3000 Kg CO_2/year for the least polluting vehicle to over 7200 Kg CO_2/year for the most polluting vehicle. This shows that greenhouse gas emissions caused by commuting is higher than that due to domestic electricity consumption at present, and will be much higher when the potential occupation of exurban enclaves is realized.

A temperate forest in optimal conditions (water and nutrients non limiting growth), captures annually 14 tons of CO_2 per hectare (NAS 1992); thus, from 1580 to 15,580 ha of forests would be needed to capture the CO_2 emitted by private transportation in our study area. The world mean of CO_2 net assimilation rate[2] for forests is 0.82 ton CO_2/ha/year, which would increase the extension of forest-sinks to 27,000 and 231,800 ha. In the Pampas ecoregion, dominated by grasslands and crops, 27,600 and 237,600 ha of these ecological systems would be needed, considering that the average capture rate for grasslands and wheat in temperate regions is 0.8 ton CO_2/ha/year (Hanan et al. 2005). These numbers greatly exceed the total extension of lands converted to exurban development. These estimations should be considered only for comparison; by no means we suggest that planting forests, grasslands or wheat will mitigate locally the estimated emission. The source and sink relationship between emission and capture by the vegetation cover is not direct nor simple. Gases flow in the atmosphere, thus meteorological variables, such as wind flow at various heights should be considered.

[2] Net assimilation rate of CO_2 is the amount of CO_2 stored in the plant biomass; it is the difference between the amount of CO_2 captured in photosynthesis and that released in respiration, both processes occur in plant cells.

Discussion

Exurban land use growth has been documented for at least thirty years in various regions around the world. Low-density residential developments of this type have been a concern of land use planners and land use/land cover change researchers, for their effect on loss of agricultural land, the high costs of service provision, the over reliance on transport by personal vehicles, and the consequences on wildlife and ecological services.

Even though, at present, the exurban land use beyond the fringe of Buenos Aires Metropolitan area covers a negligible proportion of land, the results show a tendency for conversion of land in the highest soil productivity capacity classes. While the best agricultural lands (those falling in the moderately high to very high soil productivity capacity classes) accounted for 29% of the land in the study area, it accounted for 54% of the exurban development. This estimate suggests that prime agricultural land is more vulnerable to urbanization.

At a higher resolution analysis, the results show great differences among counties. The proportion of land under exurban use is greatest in counties in the Rolling Pampa subregion, which is the most productive zone in Argentina. While the absolute magnitudes of land converted to exurban use were not necessarily the largest, these counties lost from 77 to 100% of their land in the high and very high soil productivity capacity classes. Thus, although the land with the most productive soils represents a small fraction of the total land area in several counties, it also experiences the highest level of urbanization.

The analysis at various spatial levels may be useful to demonstrate that, while each single land use change results in a negligible impact, the accumulation of these individual changes within a landscape or region, as it occurs in the Rolling Pampa, may constitute a major impact.

In our study of agricultural lands conversion to exurban use, all the estimates are conservative, since the conversion to complementary uses associated with exurban development, such as shopping malls, games arcades and other recreational facilities, and the health and education infrastructure, have not been computed. Impervious surface increment, informal land parcelling and land occupation by illegal activities, causing peripheral urban growth around the private enclaves has not been evaluated.

The over reliance on transport by personal vehicles that accompanies exurban development results in the excess emission of CO_2. There is a lack of available information needed for the estimation of greenhouse gas emissions. It has not been possible to obtain demographic statistics for the exurban neighborhoods, neither for the amount nor type of automobiles or the number of daily trips per household. The public administration has the technology and the technicians for capturing basic data; however, since the emission of CO_2 is not perceived as a problem, this information is not considered in the censuses. In spite of the limitations of the estimations, the results give an idea of the magnitude of the CO_2 emissions, and bring up a question that deserves attention from the planners and decision makers.

The tendency of the real state market continues. A local newspaper reported in December 2005 that “in 2005, twenty-three new private neighbourhoods were established”; another newspaper reported in January 2006 that in a radius of 150 km from Buenos Aires city, 35 private urban projects of farm clubs were underway, encouraged by the economic recovery during 2005. Thus, further land use conversion is expected in the future, with the accompanying consequences of loss of agricultural lands and increases in CO_2 emission resulting from commute in personal vehicles.

Land-use change is driven by human actions, and it will initiate changes that impact humans. Such is the case with agricultural land conversion to exurban use, generating a chain of responses that turn into driving forces at a higher level. In Buenos Aires Province, the interactions between choices and decisions of various agents (county governments, developers, farmers and migrants from the city) are largely responsible for promoting sprawl. Buenos Aires city and its surroundings have grown beyond its capacity to provide the amenities associated with a high quality of life. The stresses associated with crowding, such as higher crime rates, pollution, traffic congestion, poor services, have pushed households to the rural area. The individual choice to move outside the city could easily be achieved for several reasons, including the liberal economy (Morello et al. 2003), the feasibility of buying agricultural lands at relatively lower prices, and other incentives to developers. The individual decisions of farmers to sell their lands to developers has resulted in decreasing agricultural production returns as compared to urban development returns. The low profitability of agricultural production originates both in land speculation and in land and soil deterioration caused by the proximity to Buenos Aires city and its demands for resources and waste disposal sites (Morello et al. 2001). Land use planning decisions at the county governmental level are made within the framework of long term master plans, which regulate the economic activities, and the allotment of resources and land. None of the Master Plans in the study area incorporate agricultural protection programs or strategies. On the contrary, since county governments gain increased budget revenue from land conversion, and reduce costs of infrastructure construction and maintenance (which is financed by the developers first, and by landowners later), many changes in the Master Plan and exceptions to land use assignments are introduced to allow agricultural land conversion to exurban use. Even though this general description of the reciprocal relationship between the developers and the government officials is as yet incomplete, it highlights the complex net of interactions among agents that turns policymaking into a real challenge.

The agricultural lands conversion to urban uses cannot be tackled from one viewpoint. Simultaneous actions should be taken at the individual, the societal and the public policy levels, both within the city and in the rural surroundings. A comprehensive regional approach that addresses zoning, transportation, environmental degradation, and economic development is needed to control and manage land use change.

From the rural point of view, a good Master Plan with intelligent zoning regulations based on scientific knowledge, with adequate mechanisms to ensure the enforcement of such policies, could help control urban sprawl. The observance of the land use change policies may be achieved by requiring approval by the provincial government for any significant conversion of agricultural land for urban purposes (e.g. Wasilewski and Krukowski 2004). Agricultural land protection programs including purchase of development rights, transfer of development rights, or down-zoning (Brabec and Smith 2002; Conway and Lathrop 2005), do not exist in Argentina, and they will not exist as long as society and government officials remain unconvinced that agricultural land loss is a problem.

The individual preferences for open spaces and lower density areas contribute to exurban expansion, but the effects could be mitigated by a system of economic incentives and disincentives. Frequently, local or provincial governments indirectly subsidize development, through, for example, mortgage interest deduction and road construction; thus, the private costs of land development are distorted below the social costs. Punishments such as higher prices for public services in exurban developments, parking restrictions and increased costs in the city core, higher toll prices, push households from exurban areas.

Highways and expressways encourage sprawl. The number of new highway kilometers rose significantly in Buenos Aires province since the 1990's, and is still rising. This has stimulated migration to exurban developments and also commercial strip development along the highways, increasing impervious surfaces. It has been shown that low-density development increases road density on a per housing unit basis, and contributes to forest fragmentation (Miller et al. 1996; Forman and Alexander 1998), and this effect is also seen in the agricultural matrix.

This brings us to the question of excess CO_2 emission. Whether an urban inhabitant chooses a private or public transportation system to commute between home and work depends on the availability of a public transportation system (Alberti et al. 2003). A dependable public transportation system is lacking beyond the urban-rural fringe in Buenos Aires province. Buses are old, uncomfortable, insecure, and take longer travel times than necessary because of the large number of intermediate stops. The railway system could be a good option if it were properly maintained, and run as scheduled. In reviewing methods of reducing greenhouse gas emissions from the transportation sector, the Panel on Policy Implications of Greenhouse Warming (NAS 1992), focused on three areas: vehicle efficiency, alternative transportation fuels, and transportation system management. Most interesting for Buenos Aires are the ideas on transportation system management (TSM), which could and should be applied here. TSM involves activities such as the construction of new mass transportation facilities, high-occupancy-vehicle lanes, and land use planning strategies. The improvement of the railway and bus systems, together with restrictions to parking in the city core, would be of great help in reducing personal vehicle commute. Among the land use planning strategies, the restriction of uses that generate excessive numbers of trips, is a feasible option for Buenos Aires. As the panel suggested, exurban developers could be required to provide for mass transportation, and comply with trip reduction ordinances (Suhrbier and Deakin 1988 cited by NAS 1992), though the latter should be enacted since they do not exist in the provincial legislation. In Argentina, a public reaction cannot be expected because greenhouse gas emissions is not perceived as a problem and, even though a national inventory for 1994 has been published in the international literature (UN 2005), the results have not been locally publicized; and most citizens ignore the importance of our contribution to the global situation.

Exurban development has been credited with stimulating regional economic growth (Stone 2004) through a high rate of home ownership. This is not the case in Buenos Aires province. In a recent research in which concordance values derived from Procrustes analysis are used as an indicator of sustainability, counties with a relatively high proportion of land in the higher soil productivity capacity classes showed unexpected poor social conditions (Matteucci 2006). In a closer inspection, some of these counties have suffered agricultural lands conversion to exurban use. Even though the county government receives higher budget revenues than counties with lower rates of exurban growth, this benefit is not always transferred to the local population.

Land use/land cover changes may have great impacts in the long term. Besides matrix fragmentation, loss of agricultural land, and deterioration of soils in agricultural remnant patches, exurban development stimulates commercial strip development, as well as conversion of open spaces into streets, driveways, parking lots, within the gated neighborhoods. These land use changes, in turn, result in growth of impervious land covers, with negative implications for environmental quality, such as increased storm water runoff, enhanced stream channel erosion, and decreased ground water recharge (Corbetts et al. 1997). Impervious materials influence regional climate and air quality, and the pollutants transported from impervious surfaces degrade streams, rivers, and lakes (Stone 2004).

The most dramatic change will probably occur in the long term with the infilling around the exurban developments, an inescapable process if actions are not taken in the present time.

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Appendix

Table A-1 Proportion of land in each soil productivity capacity class for individual counties

		PERCENTAGE OF COUNTY AREA IN EACH SOIL						
ID	COUNTY	0–10	10–30	30–50	50–60	60–70	70–80	80–100
1	Presidente Perón	0.00	0.00	0.00	0.00	100.00	0.00	0.00
2	Malvinas Argentinas	0.00	0.57	0.00	0.00	99.43	0.00	0.00
3	San Miguel	0.00	0.00	9.38	0.00	0.00	90.62	0.00
4	Moreno	0.00	1.26	8.88	0.00	89.85	0.00	0.00
5	Exaltación de la Cruz	0.00	10.44	0.00	0.00	1.33	60.66	27.57
6	San Andrés de Giles	0.00	10.56	0.00	0.00	11.63	45.97	31.83
7	Ezeiza	0.00	0.00	0.00	11.64	53.09	35.27	0.00
8	Pilar	4.30	11.01	3.66	0.00	66.05	0.33	14.65
9	La Matanza	0.26	0.00	21.60	0.58	77.56	0.00	0.00
10	Ituzaingo	0.00	27.32	0.00	0.00	72.68	0.00	0.00
11	Lujan	0.13	15.79	0.14	16.76	1.40	28.49	37.29
12	Carmen de Areco	0.00	22.54	0.00	12.17	0.00	28.21	37.08
13	San Isidro	0.00	42.45	0.00	0.00	57.55	0.00	0.00
14	José C. Paz	0.00	0.00	44.39	0.00	55.61	0.00	0.00
15	Mercedes	1.67	22.81	0.00	29.61	12.85	4.27	28.38
16	Merlo	59.90	0.00	0.00	0.00	40.10	0.00	0.00
17	Marcos Paz	16.65	0.00	0.00	45.69	37.66	0.00	0.00
18	Zárate	58.72	4.08	0.00	0.00	0.00	36.94	0.26
19	San Vicente	14.92	0.00	49.88	4.30	30.90	0.00	0.00
20	Escobar	42.39	28.23	0.00	0.00	19.29	0.00	10.09
21	General Rodríguez	10.37	0.36	22.88	41.13	16.44	6.36	2.47
22	Esteban Echeverría	0.00	0.00	0.00	21.00	79.00	0.00	0.00
23	Campana	71.43	6.14	0.00	0.00	0.02	8.66	13.76
24	Cañuelas	4.06	0.00	29.97	50.91	15.06	0.00	0.00
25	Tigre	29.11	59.87	0.00	0.00	11.01	0.00	0.00
26	Lobos	6.73	3.67	35.29	47.04	7.19	0.00	0.00
27	Coronel Brandsen	27.08	0.00	63.22	6.96	2.74	0.00	0.00
28	Monte	24.66	0.00	9.26	64.37	1.71	0.00	0.00
29	Chascomus	14.47	8.32	58.37	18.84	0.00	0.00	0.00
30	San Fernando	57.87	42.04	0.00	0.00	0.00	0.00	0.00

(1) = (Area of soil productivity class * 100 /area of county)

Table A-2 Relative proportion of land converted to exurban land use in each soil productivity capacity class for individual counties

ID	COUNTY	Percentage of exurban land use area in each IPc class[2]						
		0–10	10–30	30–50	50–60	60–70	70–80	80–100
1	Pte Peron	0.00	0.00	0.00	0.00	100.00	0.00	0.00
2	Malvinas Argentinas	0.00	0.00	0.00	0.00	100.00	0.00	0.00
3	San Miguel	0.00	31.75	0.00	0.00	68.25	0.00	0.00
4	Moreno	0.00	1.02	0.00	0.00	98.98	0.00	0.00
5	Exaltación de la Cruz	0.00	0.00	0.00	0.00	0.00	57.77	42.23
6	San Andrés de Giles	0.00	22.36	0.00	0.00	0.00	77.64	0.00
7	Ezeiza	0.00	0.00	0.00	0.00	100.00	0.00	0.00
8	Pilar	0.00	9.85	4.24	0.00	72.80	0.00	13.10
9	La Matanza	0.00	0.00	0.00	0.00	100.00	0.00	0.00
10	Ituzaingo	0.00	42.17	0.00	0.00	57.83	0.00	0.00
11	Lujan	0.00	1.67	0.00	4.21	7.70	29.90	56.52
12	Carmen de Areco	0.00	26.21	0.00	73.79	0.00	0.00	0.00
13	San Isidro	0.00	22.75	0.00	0.00	0.00	77.25	0.00
14	José C. Paz	0.00	0.00	0.00	0.00	100.00	0.00	0.00
15	Mercedes	0.00	0.00	0.00	0.00	0.00	1.03	98.97
16	Merlo	0.00	0.00	0.00	0.00	100.00	0.00	0.00
17	Marcos Paz	0.00	0.00	0.00	41.97	58.03	0.00	0.00
18	Zárate	46.13	17.61	0.00	0.00	0.00	29.58	6.68
19	San Vicente	0.00	0.00	0.00	0.00	100.00	0.00	0.00
20	Escobar	53.43	7.52	0.00	0.00	36.99	0.00	2.06
21	General Rodriguez	0.80	0.00	2.32	71.47	25.41	0.00	0.00
22	Esteban Echeverria	0.00	0.00	100.00	0.00	0.00	0.00	0.00
23	Campana	0.00	63.81	0.00	0.00	0.00	0.00	36.16
24	Cañuelas	0.00	0.00	0.00	13.04	86.44	0.00	0.00
25	Tigre	0.00	94.03	0.00	0.00	0.00	5.97	0.00
26	Lobos	0.00	0.00	0.00	0.00	100.00	0.00	0.00
27	Coronel Brandsen	34.73	0.00	54.77	10.50	0.00	0.00	0.00
28	Monte	42.31	0.00	0.00	57.68	0.00	0.00	0.00
29	Chascomus	71.72	0.00	28.28	0.00	0.00	0.00	0.00
30	San Fernando	55.96	44.04	0.00	0.00	0.00	0.00	0.00

(2) = (Area of exurban land use of a given soil productivity class *100/area of county under exurban land use)

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