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Environmental Impacts of Urban Sprawl in Santiago de Chile on the Andean Piedmont

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Environmental degradation caused by urbanization of the Andean piedmonts and related pre-mountain systems can be observed along both Chilean and Argentinean slopes, with a consequent decrease in vegetation productivity, biomass and soil moisture, and generation of heat islands. This leads to degradation of Andean environmental services such as water infiltration and flood control. Fragmentation of vegetation patches and corridors are among the other main impacts on the natural environment. These land cover and land use changes have in turn increased the frequency and magnitude of natural hazards, and the concentration of air, water and soil pollution. Unfortunately, this makes large Latin American cities examples of unsustainable development.

Urban sprawl seems to be directly related to the increase in total imperviousness areas, runoff coefficients, and the interruption of the ecological integrity of the Andean watershed. Significant impacts can also be observed on the social environment, as the recent urbanization process has substantially increased social segregation and socioecological fragmentation in cities. Urban planning and regulations have not explicitly taken account of the environmental effects of urbanization on mountains in Chile. Urban development urgently needs to be strategically assessed in social and environmental terms, and not only as a relevant component of economic growth. The introduction of ecological planning and consideration of environmentally sensitive areas as a relevant form of regulation are proposed here.

The process of urban sprawl

Chile has experienced a more rapid, persistent and comprehensive process of economic development in the last 20 years. The country has generally been considered a successful model of socioeconomic progress that should be followed by other Latin American countries. However, it is quite a different issue to consider this primarily economic growth in terms of sustainable development.

One of the most prominent features of the recent development process has been the increasing urbanization of the population and urban sprawl. Eighty-seven percent of Chile's population lives in cities and towns, according to the 2002 census. Urbanization is beginning to have severe impacts on mountainous ecosys-

FIGURE 1 Encroaching urbanization in the Andean Santiago piedmont (Arrayan watershed). While expansion of the city used to take place mainly in the plains, it is now moving up into environmentally fragile areas. (Photo by Alexis Vásquez and Virna Apablaza)

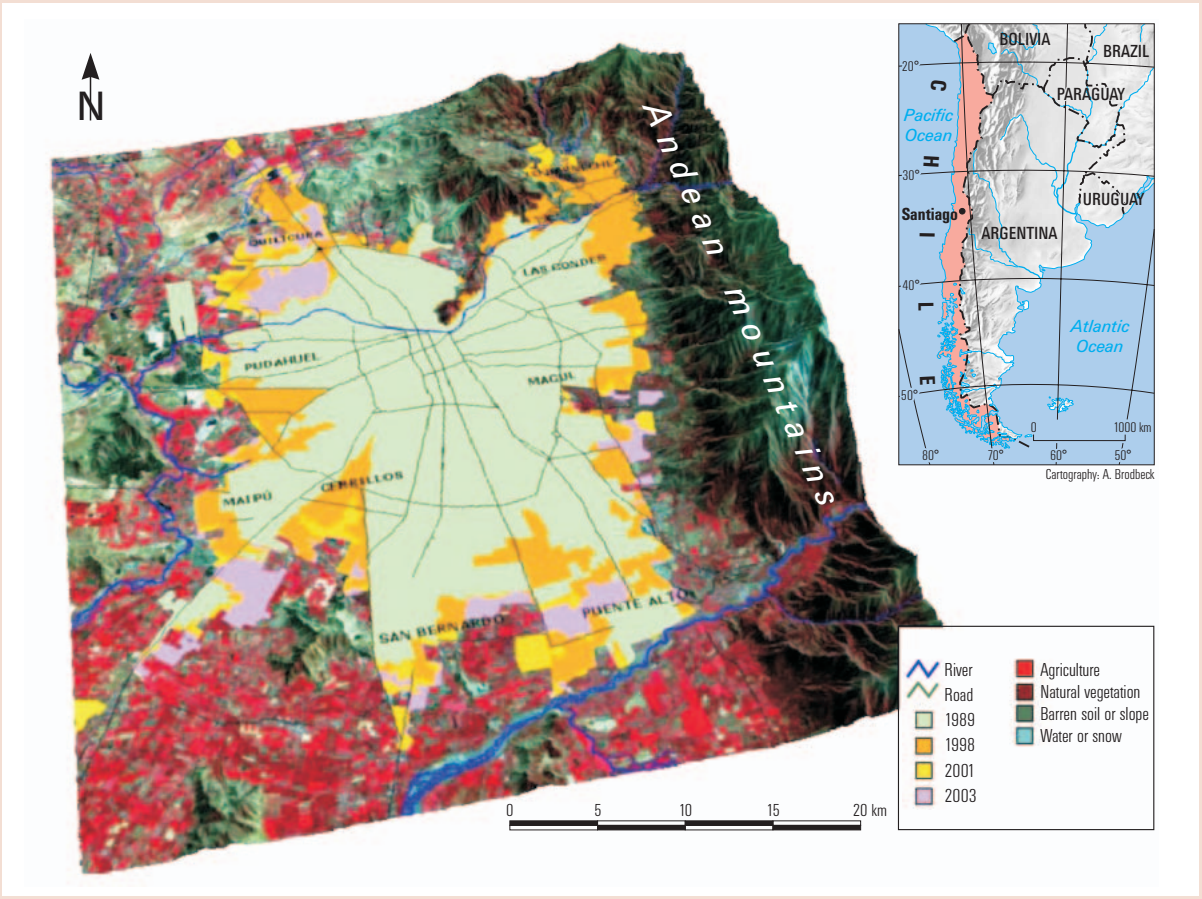

FIGURE 2 Changes in land cover in the Santiago de Chile area from 1989 to 2003. Urban sprawl has resulted in loss of agricultural land and other natural cover. (DTM by authors, location map by Andreas Brodbeck)

tems, especially in the case of such large metropolitan areas as Santiago, the capital city, which has 6 million inhabitants.

Urbanization of Andean slopes and piedmonts in Chile and Argentina—the countries that share the southern Andes—has begun only recently (Figure 1). The physical and ecological restrictions of the southern Andes, and the preference of European colonizers for occupying the floodplains for agricultural use rather than the mountain slopes, generated a different spatial and temporal pattern of urbanization by comparison with the central Andean countries, ie Ecuador, Peru and Bolivia.

Detecting urban sprawl in Santiago

A multi-temporal ecological landscape analysis based on remote sensing and geographical information systems was used to investigate patterns of urbanization, land use change, and the environmental and socioeconomic impacts caused by urban development in the main Chilean metropolis. This analysis of recent urban sprawl in Santiago shows that around 44% of the country's total population is concentrated in the city (Figure 2).

Residential density decreased from 111 inhabitants per ha in 1989 to 85.8 in 2003. Altogether, the metropolis has occupied close to 65,000 ha of previously prime agricultural land and natural vegetation cover, at an average annual growth rate of 1700 ha. While in previous decades urban expansion advanced mainly on flat areas located on the alluvial floodplains of the Mapocho and Maipo rivers, in the last 15 years urban sprawl has progressed up into the Andean piedmont.

Environmental factors such as better air quality, found above 850 m where the top of the thermal inversion layers are located, were a reason for the upper classes to escape polluted areas at lower altitudes. Landscape quality—in terms of panoramas, vegetation and clear skies—

FIGURE 3 Upper class housing in the Macul watershed, Santiago piedmont. (Photo by Alexis Vásquez and Virna Apablaza)

has provided a continuing impulse for urbanization of mountainous areas, characterized by private housing developments (Figure 3), gated communities especially built for the richest people, with some remaining poor people who previously and illegally occupied the area.

Lack of environmental regulations and enforcement, and the social segregation process that have characterized urbanization in Latin America in recent decades, are the main reasons for the negative impacts of urban sprawl on Andean piedmont environments.

Environmental impacts of urban sprawl

Table 1 presents a series of environmental impacts caused by urban sprawl in Santiago, using selected indicators. Fourteen thousand hectares of prime agricultural land (land types I–IV) located in the Mapocho and Maipo floodplains were lost between 1989 and 2003. Another 5500 ha in land types V–VIII, especially on the steep slopes of the Andean piedmont, have disappeared as the result of urban land use. Environmental impacts are obvious in the loss of 6789 ha of land with high vegetation productivity, 4224 ha of land with high soil moisture content, and 6654 ha with high concentrations of biomass.

The process of urbanization is reducing environmental services such as water infiltration and recharge (in a Mediterranean area where average annual rainfall amounts to less than 300 mm on fewer than 20 days annually, and severe drought occurs at least once every 10 years). At the same time, surface temperatures have increased between 2 and 4°C over an area of 6458 ha, resulting in a large urban heat island. Heat islands caused by urbanization are beginning to replace cooler piedmont areas that have traditionally acted as a source of airflow which cleans the heavily polluted city atmosphere during the night.

Total imperviousness areas (TIA) and urbanization

In the most urbanized areas of the Andean piedmont, such as the Macul watershed, 40% of the total area is already taken up by urban land uses. TIA has already reached 23%, producing large floods on rainy days. This watershed was affected by a large flash flood in May 1993 that destroyed hundreds of homes and killed more than 100 people (Figure 4).

The growth of imperviousness areas must be considered one of the most devastating environmental impacts of urbanization in semi-arid Mediterranean Andean landscapes. Urbanization is responsible for increasing surface runoff, decreasing groundwater recharge, and

FIGURE 4 Devastation resulting from the flash flood of 3 May 1993 in Macul watershed. (Photo by Francisco Ferrando)

TABLE 1 Land use change in Santiago de Chile between 1989 and 2003. (Source: authors' data)

Change in area (ha) / Environmental features		1989–1998	1998–2003	Total
Agricultural land converted to urban landscape, by land type				
I	Prime agricultural land	2533.4	1312.5	3845.9
II		1739.1	2320.2	4059.3
III		2895.3	2678.0	5573.3
IV		147.7	404.3	552.0
VI	Mostly sloping areas	2664.3	1168.2	3832.5
VI		113.7	1167.1	1280.8
VIII		264.8	191.2	456.4
Change in areas with high vegetative productivity				
Decrease		4744.3	2045.4	6789.7
No change		7866.2	7404.6	15270.8
Increase		1031.5	957.1	1988.6
Areal change according to soil moisture content				
Decrease		2615.8	1608.7	4224.5
No change		9258.2	7287.0	16545.2
Increase		1768.0	1511.3	3279.3
Areal change according to biomass concentration in soils				
Decrease		4511.1	2142.9	6654.0
No change		8126.2	7344.9	15471.1
Increase		1004.7	919.1	1923.8
Areal change in relation to surface temperatures				
Decrease < 4°C		17.7	35.9	53.6
Decrease 2–4°C		74.6	70.4	145
No change (variations > 2°C)		4367.2	1143.0	5510.2
Increase 2–4°C		4609.4	1849.1	6458.5
Increase < 4°C		4573.2	7208.7	11781.9
Urban growth		**13642.1**	**10407.1**	**24049.2**

polluted water sources. Other Santiago Andean watersheds, such as the Chicureo, Arrayan, Lower Maipo and Lower Mapocho, have not yet been heavily urbanized, due to steeper slopes and difficult accessibility. The Pirque watershed, located in the southernmost part of the city, has the lowest rate of urbanization and greater permeable cover as a consequence of regulations that have prevented urbanization south of Maipo River, given its ecological and agricultural suitability. An international World Bank tribunal in Washington, DC is currently considering a demand for financial compensation from a transnational company that charges the Chilean government with failing to allow urbanization of this watershed in 1998.

Ecological planning and environmentally sensitive areas

In view of the negative environmental impacts of urban sprawl in Andean mountainous areas, the scientific community and environmentalists are urging more pro-active and effective land regulations on government officials, in order to save the most sensitive areas remaining in and around Santiago. Ecological planning has never been explicitly considered in strategic environmental impact assessments of urban policies and projects in Latin America, where the process of urbanization is currently progressing at the highest rate in the world.

An environmentally sensitive area (ESA) is a portion of the landscape that contains natural or cultural features important to the functioning of the ecosystem, and that can be negatively impacted by human activity. An ESA can include physical, biological or cultural features. The main objective of ESA assessment and mapping is to contribute to proactive land use planning through the designation of sensitive areas. ESA types include wetlands, riparian zones, rare or endangered species, wildlife habitats, flood-prone areas, unstable slopes, and groundwater aquifer recharge zones. Ecological planning now calls for excluding from urbanization all the larger and more complex vegetation patches located in the Andean piedmont. These sensitive areas are a combination of vegetation cover and diversity, corridor configuration, and conservation of prime agricultural lands.

The free market that has supported Chilean economic growth has also included land resources in Chile, reducing the role of the government in regulating and controlling urban sprawl. The time is right to carry out a process of control, with a necessary re-interpretation of the real meaning of sustainable development, in relation to urban development and conservation of mountain peoples and resources.

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