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Water resources issues in South America

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South America has some of the richest water resources in the world. It is second only to Asia in total annual river discharge, but since its land area is less than half that of Asia, it far exceeds all other continents in cubic metres of runoff per square kilometre: almost double that of Asia. Annual water resources in South America average around 582,500 m^3 km^{-2}, whilst no other continent yields more than 300,000 m^3 km^{-2}.

The second vital statistic for water resources in South America is the per capita resource. Total per capita resources are more than double those of North America and second only to sparsely populated Australia. Moreover, ambitious programmes of dam-building have more than doubled stable river-flows over the last 40 years, whilst South America's nearest rivals, North America and Australasia, have only achieved increases of some 60%. Not all these dams, however, are primarily for water supply. Hydroelectricity has been a major reason for dam developments such as the mighty Itaipú on the borders of Brazil and Paraguay, which was the largest in the world before the Chinese Three Gorges. With so much water surplus, to date there has been little need to use these dams for public water supplies.

Nature and geography also favour South America as a whole with more naturally stable river regimes, which give a more constant supply of water and are easier to manage than regimes with a high percentage of flood events. It ranks top equal with Europe and Africa with 36% of annual discharge occurring as stable flows—slightly above the world average of 31%—whereas Asia with only 26% suffers more from larger amounts of water occurring in less harnessable flood flows. The greater variability of annual river regimes in Asia is fed by annual monsoons, Himalayan snowmelt and typhoons in the Pacific and the Bay of Bengal. In contrast, South America is not prone to monsoons and hurricanes are very rare in the southern hemisphere—hurricane "Catarina" that hit the coast of southern Brazil in 2004 in Santa Catarina and Rio Grande do Sul provinces, was the first at this latitude, 30°S. However, South America does experience snowmelt floods from the Andes, and many areas are dependent on these for their water supplies.

There is, however, one major inter-annual fluctuation that affects South America more than Southeast Asia: the El Niño-Southern Oscillation (ENSO). Roughly every 7 years, a reversal in the airflow over

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the equatorial Pacific appears to create a reversal in the surface currents of the ocean, bringing warmer water to the west coast of the Americas and stifling the cold Humboldt Current that normally runs north from the Antarctic along the coast and out into the equatorial Pacific, which reduces oceanic evaporation and rainfall along the west coast. When it occurs, ENSO brings devastating rains to Colombia, Bolivia, Ecuador and Peru, causing landslides, mudflows and catastrophic floods that engulf whole villages. The total amount of damage caused by El Niño of 1997–1998 in the Andean region was estimated at US$7,543 million, including $72 million in Venezuela. There is some indication that ENSO events are increasing in intensity, and that its impact is ranging wider than the tropical west coast, affecting countries east of the Andes as far south as Argentina. The extreme El Niño of 1982 caused severe damage in the Río Paraná basin and the 1993 El Niño severely affected the Río Salado basin in Argentina (Scarpati et al. 2002a and b, 2004, 2007a and b).

General statistics can thus hide many problems due to regional differences and developing trends. Figure 1 shows the spatial distribution of water resources based on the latest data from the Climatic Research Unit at the University of East Anglia in England (Jones, in press). Most of the great surplus of water resources lies in the Amazon basin. The Amazon is the world's largest river in terms of discharge. Indeed, it is so large that there are only 9 rivers in the world with actual discharges greater than the probable error of measurement of the Amazon's discharge, estimated at an enormous 17,500 $m^3\ s^{-1}$. The Amazon basin is also underpopulated, with barely 1 person per square kilometre over most of the area, compared with 10–100 times this density along most of the Pacific coast and throughout the 750–1,000 km broad belt of land extending down the Atlantic coast from the Amazon delta to central Argentina, even excluding the big cities. Only Patagonia, the Atacama Desert and the southern half of the High Andes are similarly underpopulated, and these have significantly fewer water resources.

In common with most of the rest of the world, South American water resources face threats from four major trends: population growth, urbanization, climate change and rising water pollution. The population of South America currently stands at 300 million. United Nations estimates suggest that

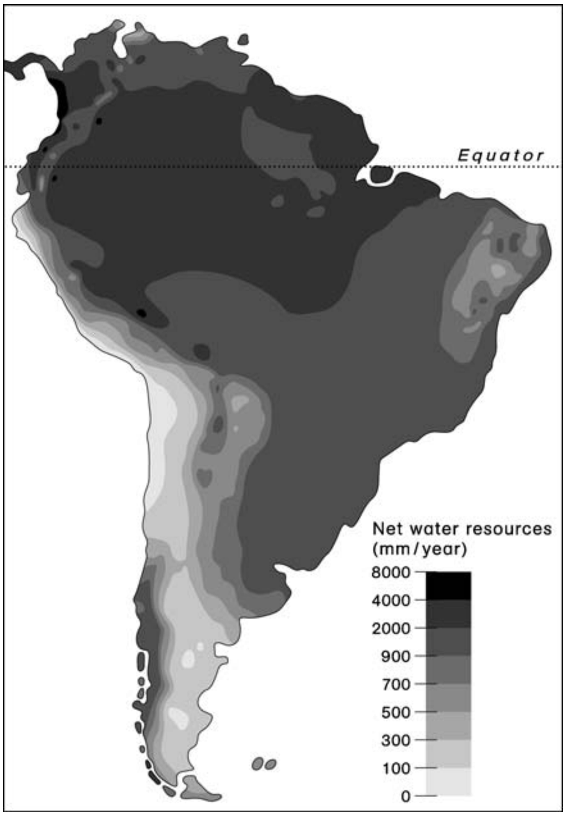

Fig. 1 Available water resources in South America, based on CRU archives (Jones in press)

the populations of Brazil, Argentina and Chile will rise by over a fifth between 2000 and 2030, and those of the countries in the northwest of the continent from Bolivia to Venezuela by as much as one third. In addition to these increases, South America is experiencing the beginning of a major drift of population from the countryside into the cities. The increasing concentration of the population in urban areas is one of the worst problems facing the world in general. Per capita water consumption rises dramatically in urban areas. Consumption in cities is typically 300–600 l per person per day (l $cap^{-1}\ day^{-1}$), compared with under 30 l in rural areas of South America. In 2000, 30% of the population of Argentina was urbanised, but UN calculations indicate that this could rise to 50% of a much larger overall population by 2030. Over 60% of Brazil's population is already urbanised and UN projections suggest that this will rise to over 70% by 2030. This is leading to rapid expansion of the major cities of Latin America. The population of Cochabamba, Bolivia's third largest city, is predicted to rise from 800,000 now to 3.3 million in 2025 (Martin and Laurie 1999). Recent trends show that a significant proportion of the new urban dwellers are likely to live in informal settlements, *favellas*, with no proper water supply or sanitation. This may limit water demand, but at the expense of health and environmental pollution: a tenth of all child mortality in Bolivia, which has one of the highest rates of child mortality in the world, is linked to unsafe water supplies.

In fact, recent events in Bolivia have shown that illegal tapping of public water mains is a thriving business. After a number of street protests, the city authorities in La Paz's shanty town suburb of El Alto actually decided to condone the activity in 2005 and end the contract of the French water supply company Suez Lyonnaise. Suez claimed to have increased access to public water supplies, as required by contract, by laying pipelines along the streets, but was charging more for connection than the urban poor could afford. After previous riots and deaths in Cochabamba, the Bolivian government ousted the US-Dutch-owned company Bechtel in 2000 for failing to fulfil its contract to provide affordable mains water supply to the poor areas of the city: the new charges were equivalent to some 20% of people's annual incomes. These events highlight what could almost be regarded as another potential threat: foreign ownership of water supplies in Developing Countries.

The long-term strategy of the World Bank, the International Monetary Fund and the Inter-American Development Bank has been to encourage privatisation and public-private partnerships (PPPs). Grants from these institutions are made conditional on full or partial privatisation of water and sanitation services in the belief that investment capital and professional management by large international bodies will overcome the problems created by decades of underfunding and poor management. As a result, large European and North American multi-national companies are increasingly prowling the globe for investments in water utilities, and thus far their history has not been one that has generally been seen as successful in the host countries: the Tanzanian government's revocation of Biwater's contract in Dar-es-Salaam in 2005 is another recent example. Much of the problem seems to lie with the wording of many of the water supply contracts, which do not tie the companies down sufficiently and fail to provide incentives for achievements or fines for failures. These commercial companies sign the contracts to make money for foreign shareholders, not altruistically to serve the local public or to support loss-making supply systems if this can be avoided. There may even be elements of corruption compounding the problems: the French company Vivendi was charged with corruption in Buenos Aires.

Climate change is also very much a matter for concern in South America. In general, climate change scenarios produced by the UK HadCM2 model based on increasing levels of greenhouse gases suggest that by the 2080s riverflows in South America will exhibit some of the widest variations experienced on any continent, with some substantial regions experiencing over 50% reductions and others with increases of over 50%. Only Asia is expected to show a similar range of responses, but since the land area of Asia is 2.5 times that of South America, the range across South America will be compressed into much shorter distances. According to hydrological modelling undertaken by Arnell and King (1997), the main regions of reduced water resources are likely to be the north coast, from western Venezuela to just south of the Amazon estuary, and most of Argentina. The gains are likely to be south of 48°S, Brazil west of Recife in Pernambuco, Rio do Norte, Pariba, Ceara and Piauí provinces, and again south of Sao Paolo, Uruguay and Paraguay, and finally along the Pacific coastal strip from the southern tip of Peru (18°S) to the Panama border. However, this modelling does not take account of increased glacier melt rates. There is abundant evidence that the Andean glaciers are melting and retreating at an accelerating rate (Leiva et al. 2007; Espizua and Maldonado 2007). The latest evidence from Peru indicates that the melt rate of Andean glaciers like the Pastoruri has doubled in the past two decades, and projections suggest that all Peru's glaciers will have disappeared by 2020. The meltwaters are already forming new proglacial lakes, which present another hazard when they eventually burst through their natural dams, a hazard aggravated by continuing earthquake activity in the region. Initially, the meltwaters enhance riverflows, but as the glaciers disappear so the accumulated snowfall of millennia is lost. With the final demise of the glaciers, riverflows will decline in the surrounding agricultural regions during the critical spring-time period for crops, leading to depopulation in the mountains and exacerbating the social and resource problems of the coastal cities. At best, if snowfall regimes are simply replaced by the equivalent amount of rainfall, then the timing of river discharges will change, and patterns of agricultural activity attuned to meltwater dominated regimes will have to change or else more water reservoirs will need to be built to redistribute the timing of flows. If, on the other hand, there is a change in the overall amounts of annual precipitation, then more drastic measures may be needed. There is already some evidence that rainfall in the Amazon headwaters has been reduced by up to 20% in recent years and it has been suggested that this may be related to advancing deforestation, which increases the albedo (reflectivity) of the ground, reducing heating, convection and evapotranspiration. In this case, climate change may have a more local cause than global warming.

The papers in this Special Issue analyze a number of these issues, beginning with recent trends in riverflows and the estimated impacts of climate change. Analyzing recent trends in riverflows, Vich, López and Schumacher, rather reassuringly, find that only about 1 in 5 of the 210 gauging stations studied in Argentina show significant trends, and only one actually shows significantly reduced discharges thus far. Andrade and Scarpati follow this with an investigation into recent changes in flood risk in Buenos Aires Province. They conclude that these changes are aggravated by human activity, especially poor planning controls for urban developments, and the lack of systematic updating of flood information.

Seoane and López analyze the sensitivity of riverflow to changes in precipitation in two Argentinian rivers with a view to the likely impacts of climate change on hydroelectric generation. Using climate change scenarios from a number of different General Circulation Models, they conclude that annual mean and minimum discharges are likely to decrease largely as a result of decreased discharges during the low flow season.

The next three papers focus on aspects of water resources related to agriculture. Munka, Cruz and Caffera look at changes in rainfall erosivity in Uruguay since the 1930s. This is important not only for agricultural management and the potential loss of soil fertility, but also because of the high turbidity in rivers draining these areas and its effect on public water supply as the main source of water throughout the country is its rivers. They find significant regional differences, with erosivity during the critical period of bare soil and limited vegetation cover in winter and early spring decreasing in the northeast, but increasing in the southeast. They also find that trends are not always unidirectional, with differences between one decade and another in some areas.

Forte Lay, Kruse and Aiello investigate the reciprocal effects of recent increases in the area of land planted with soya beans and changing groundwater levels in the Pampas. Groundwater is the principal source of water in the Pampas, but predicting groundwater levels is complicated by minor topographic undulations and the limited number of groundwater monitoring wells. Some depressions can become waterlogged and stunt growth of the crop. The best areas for soybean yields are in the north and northeast, partly because of natural advantages, but also partly because of more tested agricultural practices. Expansion in the south is more recent and less well tested. Forte Lay and colleagues aim to try to produce guidelines for more efficient practices based on the relationships found between groundwater, soil moisture and crop growth.

Salmuni, Velasco, Fresina and Flores investigate the use of satellite remote sensing as a means of estimating the demand for irrigation in arid and semiarid parts of Argentina. Increasing demand for water for irrigation in the lower San Juan River basin is driving a need for better surveillance of the expanding area under irrigation. They report the results of two common approaches: unsupervised land classification based purely on computer algorithms, and supervised classification based on cross-referencing with ground truth from aerial photography and ground surveys. Given the cheap availability of satellite imagery, they conclude that this approach is more cost effective than traditional methods.

The last two papers take up the theme of water quality and health risks. Arreghini, de Cabo, Seoane, Tomazin, Serafini and de Iorio investigate the sources of changes in water quality in a natural, unpolluted stream, showing how concentrations vary with stream discharge using an instantaneous unit hydrograph model. They see this knowledge as a key essential for defining background water quality in order to determine the extent of anthropogenic influences.

Finally, Garcia outlines the possible effects of water pollution from urban-industrial sources in the city of Tandil on human health risks. They establish a GIS model incorporating levels of pollution and measures of human quality of life. Concern has been expressed about the levels of nitrates in private wells, but Garcia finds that levels in the public water supply are more worrying, with the poorer communities suffering the worst water quality.

The papers in this issue were commissioned following the conference sponsored by the International Geographical Union's Commission for Water Sustainability, held in Buenos Aires in 2005 and organized by Commission Secretary Professor Olga Scarpati. More information on the activities and publications of the Commission can be found on the website: http://water-sustainability.ph.unito.it. Interested parties can also register with the Secretary on olgascarpati@yahoo.com.ar for information about future conferences.

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