The Study of the Physical Environment and Natural Hazards in Latin America: Progress and Challenges

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ABSTRACT
The decade of the 1980s witnessed a decline in the work of North American physical geographers which was compensated by the active engagement of Latin American and European researchers. The fields of climatology and quaternary studies experienced impressive progress with the introduction of quantitative analysis and modern geodating techniques. A central subject in climatological and natural hazard research was El Niño-Southern Oscillation whose implications for the global tropical circulation was intensively investigated and better understood after the occurrences of ENSO in 1982-83 and 1986. Of particular relevance has been the emergence of the environmental history paradigm which traces back the effects of major climatic crises on the basis of historical sources and places events in social, economic, and cultural history in the context of environmental stress. Here resides the major potential for future investigations in physical processes and natural hazards, not in isolation, but in close connection with human responses and cultural adaptation.

The 1980s were a decade of mixed signs for research on physical environments and natural hazards in Latin America. Even though there was a healthy development in geophysical investigations pertaining to changes in the biosphere, ocean dynamics and crustal mobility, the activity of North American physical geographers in Latin America declined remarkably. Unlike in previous decades, investigations by Americans in geomorphology, field climatology, fluvial geomorphology, soils and biogeography are scarcely represented in this inventory.

There are three apparent explanations for this situation: 1) a paradigm shift from strict investigations of natural environments to a more integrative approach to man-nature interaction; 2) shortage of research funds or their prioritary destination to disciplines like meteorology, geology or geophysics with which geography finds itself in tough competition; and 3) hazardous field work conditions that render individual research in some areas of Central and South America not only slow and cumbersome, but even dangerous. Fortunately for the progress of the natural sciences, the relative withdrawal of the North American physical geographers has been compensated by a vigorous involvement of Latin American geographers, particularly in Brazil, Argentina, Venezuela, Chile and Mexico, where the research fronts in urban and regional climatology, geomorphology and biogeography were noticeably pushed forward during the 1980s. In addition, the Anglo-American withdrawal has served to highlight the activity of French geographers working out of the Institute of Andean Studies in Lima and of the Germans working under the consortium of German universities in La Paz, Bolivia. The flow of production that has resulted from these two international endeavors is remarkable and should serve as a model for a more aggressive cultural involvement of Americans in Latin America. The feasibility of such involvement can be documented by the American participation in the specialization courses offered by CEPEIGE in Quito which, although not exclusively under North American auspices, has enabled geographers to work in the Central Andes and come up with a good collection of investigations.

THEMATIC MAIN LINES OF PHYSICAL GEOGRAPHY RESEARCH

The review of the materials produced during the 1980 decade, not only by Anglo-American researchers but also by their Latin American and European counterparts, reveals almost immediately a clear "trichotomy." Many of the publications from the Latin American

geomorphologists, climatologists, hydrologists and biogeographers adhere in their methodology to the British and North American tradition. This is not only a reflection of the scientific value of the methodologies developed during the 1960s and 1970s but also the byproduct of the fact that a good number of physical geographers were trained in the United States, Canada and the United Kingdom, and of the widespread **[end p. 19]** use of bibliographic sources in English. Particularly the works emerging from the Universidade Federal de Sao Paulo, Rio Claro, are indicative of this trend. The studies of Maria J. Zani dos Santos on rainfall variation in the sugar fields of Sao Paulo using the Thornthwaite and Mather hydric balance formula (1985) and the investigation of the variability of precipitation in the state of Sao Paulo by means of central limit theorem assumptions (1987) lean towards application of quantitative methods, which is also evident in the probabilistic studies of southern Brazilian precipitation by Vania L. di Lascio (1985) and in the investigation of humid and dry spells in Rio Claro by Brino and Tavares (1982). A quantitative approach was also used by Lucy M. Calderini and Philadelphio Machado (1982, 1983) in their work on cumulative discharges of the Tieté river and drainage pattern attributes and by M. Araya and F. Sandoval on drainage geometry in central Chile (1985).

Other studies based on quantitative analysis application reveal also the growing desire to describe in empirical terms trends and patterns that in the past were expressed only qualitatively. When describing soil erosion under heavy downpours in Barinas, Rondón, Aguilar and Ponte (1985) utilize convincingly Wischmeir's soil loss equation and Rodríguez (1980) examines the fitting of monthly rainfall in Caracas to a Gaussian distribution; Ryder and Antonini (1985) have applied Wentworth's formula to map critical slopes in the province of Tunguragua (Ecuador); cluster analysis is the methodological tool employed by Hugo Romero (1985) in the determination of climatic regions in Chile, while Marilene dos Santos Aouad (1983), in a similar approach, classifies the climate of Bahia and J. M. Guevara (1981) uses regression equations (and surprisingly no run tests) to prove the manifested increase in air temperatures in Caracas, which he attributes to enlarged build-up in urban areas. While honest and enthusiastic, a good many of these works overemphasize description and method and fail to provide a process-oriented explanation of the findings obtained through the application of the novel analytical techniques. Let us hope that once the initial admiration for the precision of quantitative methods subsides this necessary step is taken and the early infatuation with method will be complemented by emphasis on process explanation.

There was not much pure geomorphological work conducted by North American geographers in Latin America, and even the contributions from geomorphologists of the region were relatively scarce. Exceptions to this generalization are the investigations by the Frenchmen Battistini and Bergoing (1983), Beaudet et al. (1986), and Bergoing (1987), who focused mostly on the description and structural characteristics of Costa Rican landforms without getting into processes or environmental history. From the rather reduced published work on Mexico, the contribution by Laura E. Madeny (1987) on river discharge, stream load and precipitation in Tabasco deserves mention. In Brazil, the country's foremost geomorphologist, Antonio Christofoletti (1981), wrote a textbook on fluvial geomorphology with many examples from the area. In Uruguay, D. Panario (1988) studied Quaternary diastrophic movements and recent landform developments. Somewhat more active were Chilean geomorphologists; José Araya (1985) studied coastal forms on the southern tip of the continent and in central Chile and fluvial morphology and channel

behavior in the vicinity of Santiago; B. Andrade (1985) investigated coastal flats in south-central Chile, G. Abele (1984) explored mass wasting and glacial forms in central Chile, Canto and Paskoff (1983), as well as Castro (1985) concentrated on coastal processes and accumulations. Particularly active in Chile was Wilfried Endlicher from Germany studying erosive processes and land degradation in the subhumid fringe of Chile (Endlicher 1988; Endlicher and Mäckel 1985).

There was an unusual surge in interest in glaciological studies of the Andes, probably in response to the many questions that had been raised in the 1970s. Not only the extension of Quaternary glaciations in poorly surveyed areas was of concern in these investigations but also the impact of climate variability on ice accumulations and moraine depositions. A major thrust of the German group operating from La Paz, Bolivia, was directed at the study of glacial modelling and ice fields in the Cordillera Real. In a paper on the physio-ecological characteristics of the tropical Andes by Lauer and Erlenbach (1987) the priorities and agenda of contemporary German geography in the cordilleras of South America were expounded. Within this framework, Lauer and Rafiqpoor (1986, 1990) investigated the characteristics of early Pleistocene glaciations in the foothills of the Apolobamba Cordillera and detected mighty glaciations fed by humidity advection from the eastern lowlands of Bolivia. In a slightly different setting, Finsterwalder and Jordan (1989) thoroughly mapped the region around the Illampú mountain tracing the changes that had occurred in glacial extension since Carl Troll's survey between 1928 and 1935. Also with the purpose of ascertaining changes in climate and glacial intensity in the most arid segment of the Andes, Ochsenius (1986) demonstrated that the Puna glaciation of the early Pleistocene was powerful but remained confined to the high reaches of the Andes, never descending below 4200 meters. Interested in the glaciers' extension in the Puna-Altiplano block, Abele (1987) momentarily abandoned his concentration on the central Chilean mountain **[end p. 20]** morphology (1984) and looked for geomorphological evidence of a wetter/cooler morphoclimatic system in northern Chile; he found nothing to substantiate that contention. Bruno Messerli (University of Bern) has joined the club and is actively searching for climatic/geomorphological clues of glacial climate and surface forms in the Llullaillaco area, northern Chile.

American glaciological investigation, methodologically different from the German research, has relied on geochronology and ice core characteristics to advance hypotheses about climate pulsations and corresponding atmospheric circulation. Studying the content of oxygen isotopes within ice cores from the Quelccaya ice cap in southern Peru, Thompson (1980) and Thompson et al. (1984) have been able to propose the existence of dry climate variations associated with El Niño episodes, while Birkeland, Rodwell and Short (1989) have looked for traces of late Pleistocene glacier withdrawal in the Andes of central Peru that they have dated back to 12,100 years B.P. using radio-carbon dating. Around the same time, the high summits of the Cordillera Neovolcánica of Mexico experienced an increase in precipitation that led to a short-lived mountain glacier advance (Heine 1983), a circumstance that points out to important Holocene paleoclimatic variations in the tropical belt of the Americas that were not well recognized until now.

LANDFORM EVOLUTION, CLIMATE CHANGE, AND BIOGEOGRAPHIC CONTROVERSY

Obviously, the underlying concern of most of these investigations has been climate change rather than descriptions of ice accumulations and of glacial morphology. With the aim of elucidating this question in southernmost South America, which after all received the brunt of past glacial onslaughts, Villagrán (1988), Markgraf (1987), and Heusser and Rabassa (1987) have been looking at vegetation changes induced by climate change in southern and central Chile. While Heusser (1983) and Porter (1981), along with Pino (1981) and Lauer and Frankenberg (1984), contend that altiglacials produced cool/humid climate conditions along the temperate margins of South America and consequently the establishment of a temperate humid forest (Heusser 1983) whose aggressiveness has persisted until recent times (Veblen and Markgraf 1988), investigators like Markgraf (1987, 1989) and Villagrán (1987, 1988) posit that the climate of these regions was actually drier due to circulation conditions in the high latitudes not much different from the present. Departing from an actualistic climatic model of the temperate west coast of South America and regression analysis of the major climate controls of the area, Caviedes (1990) sustains that drops in sea temperature of no more than 2^{O} or 3^{O} C in the mid-latitudinal Pacific Ocean suffice to increase substantially rainfall levels in temperate South America and to trigger the vegetational shifts that Villagrán and Markgraf reject.

Evidences from tropical Latin America lend support to the position that purports sensible climatic changes on the South American continent and its rimlands during the cooler periods of the Quaternary. In one of the best works on the Quaternary in the Caribbean, Carlos Schubert (1984) documents sea level changes and palaeoforms in Santo Domingo that explicitly point to the existence of climate change even within the warm tropics. Further, P. Usselman (1983), one of the French geographers formerly associated with I.F.E.A., Lima, when investigating the geomorphology of the Pamplonita river in northeastern Colombia, recognizes that some of the observed fluvial forms must have been shaped by processes operating under much cooler conditions such as might have reigned during a cold phase of the Quaternary. The scale and spatial variations of the posited climate changes become crucial also for the explanation of animal migration patterns and extinction as well as plant adaptation during the Quaternary of South America. Research in this area advanced during the 1980s, but was also punctuated by controversy. C. Ochsenius (1985) elaborated that postglacial times were marked by extreme climate dryness which brought about the extinction of large animals, particularly in the fringe of South America that borders on the Altiplano. The proposition of Caviedes and Iriarte (1989) that the proven dryness of the Atacama Desert even during the cooler/wetter periods of the Pleistocene prevented southward expansion of mammals that are especially abundant in the Altiplano but conspicuously absent from contiguous southern Atacama has also tied together palaeoclimatic research and zoogeographic reconstructions.

Traditional biogeography, on the other hand, continued to expand and enrich the field with inventories. Soren Wiurm-Andersen and O. Hamman (1986) produced a detailed list of mangroves on the Galapagos Islands, Quintanilla (1983a) offered a synthetic picture of the islands' vegetation and, on the mainland of Ecuador, Misael Acosta Solís continued with his prolific and insightful work. His descriptions of the lowland savannas of Ecuador (1982) and of surface forms and vegetation formations that resemble the "puna" are among the most valuable contributions from national geographers (1985). In other areas of Latin America, Guillermo Quintanilla maintained his accustomed pace in descriptive work by adding monographs on

comparative flora (1983b), vegetation maps of **[end p. 21]** temperate central Chile (1981) and the volume on biogeography that appeared in the collection of ***Geografía de Chile***, one of the most ambitious geographical projects undertaken by a Latin American country during the 1980s. Thomas Veblen and his collaborators (Veblen and Lorenz 1988; Veblen et al. 1989a; Veblen 1989; Veblen et al. 1989b) have been conducting active research on the interface fringe of glacier retreat, southern beech forests and Patagonian steppes. Their studies proficiently document recent vegetational and climatic change in this transitional belt of mid- to high-latitude maritime southernmost South America. Also well represented is descriptive biogeographical research in Brazil: M. Goulding published ***Man and Fisheries on an Amazon Frontier*** (1981), which complements the information provided by Nigel Smith's ***Man, Fishes, and the Amazon*** (1981). Detailed mapping of vegetation, animals, and soils in Sergipe was carried out by Franco (1983), and a systematization of the ***agreste*** in northeastern Brazil and their utilization was attempted by Melo (1980).

ATMOSPHERIC INTERACTION AND CLIMATE FLUCTUATIONS: THE IMPACT OF EL NIÑO - SOUTHERN OSCILLATION

Unlike geomorphological and biogeographical research, climate analysis and interpretation were very successful during the 1980s. There is no doubt that the environmental changes in the Latin American hemisphere are of far-reaching relevance: the depletion of the ozone layer over the Antarctic and contiguous southernmost South America will probably induce global climate alterations, starting with Latin America due to its proximity to the "ozone hole;" fire deforestation in the Amazon basin is claimed to have contributed to the increase of carbon dioxide in the atmosphere elsewhere; also, some investigators fear that the alleged global warming of the last decade may reach catastrophic proportions if the cooling machine of the tropical oceans fails and the Humboldt (Peru) Current in the eastern Pacific loses its cooling effect. Another major area of concern was El Niño-Southern Oscillation phenomenon, now recognized as a major contemporary semi-periodic climatic variability that struck with unusual intensity in 1982-83 and less severely in 1986 and which was felt first and foremost off the coast of western South America.

Still, the development of descriptive climatology was not overshadowed by these major subjects. As with other physical disciplines, most of the work was explorative and descriptive, lacking theoretical and analytical zest. Early in the decade, the rainfall regimes of South America and the rain generating mechanisms of the continent were outlined by Caviedes (1982b) who also hinted at some genetic linkages with the general circulation over the continent. In a similar interpretative direction, but focusing on Chile, were the contributions of Peña (1987) and Romero (1981, 1985), trying to discern the marine, continental and local controls of the Chilean climates. A remarkable insight into the influence of the westerlies and oceanic controls on the climate of the southernmost tip of the continent was that of Weischet (1985) who showed that these controls are so determinant as to create a "cooler" and agronomically less favorable climate than their western European correlates at the same latitude. In Argentina the works by Rodríguez (1990) and Minetti and Sierra (1989) clarify some points concerning the association between climate in southernmost South America and the general circulation over the South Atlantic and South Pacific as well as over the subtropical fringe of the continent, after a pioneer

work by Pittock (1980) had aroused awareness that much more detailed regional study was necessary before generalizations about climate dynamics in South American mid-latitudes could be attempted. At the end of the 1980s, a closer than suspected association between the climate controls in Chile and Argentina (Minetti and Sierra 1989) emerged as one of the most significant findings in Latin American regional climatology.

Climatological research in Brazil was oriented towards investigating rainfall and temperature variations in the different regions of the country and their relationships with the upper atmospheric circulation pattern over tropical South America and the contiguous tropical Atlantic. Interesting studies by Buchmann et al. (1986) have shed light on the manner in which fluctuations of the tropical jet increase pluviosity in southern Brazil during certain anomalous years but cause precipitation deficits over the central Amazon basin and northeastern Brazil. Tropospheric circulation conditions that promote or inhibit summer rainfall in the center of the continent were investigated by Virji (1981), Virji and Kousky (1983) and Kousky and Kagano (1981). These studies as well as those conducted in Argentina and Chile have greatly expanded our present understanding of the circulation mechanisms over most of extratropical South America and the central part of the continent occupied by Brazil.

Unfortunately, there is still not enough information and research about the way in which most of the central Andean countries are affected by these circulation conditions. The French researchers from IFEA, Francou and **[end p. 22]** Pizarro (1985) as well as J. Ronchail (1989), worked in that direction and tried to discern periods of heightened or lowered precipitation in the Altiplano region of Peru/Bolivia and associate them with general atmospheric anomalies over the tropical Andes or with onslaughts of mid-latitudinal air masses. In a different approach, Künzel and Kessler (1986) investigated the cyclicity of rainfall over the Bolivian Altiplano by looking at the level variations of Lake Titicaca. They found 2.4 year peaks that seem to react to the pulsations of the Quasi-Biennial Oscillation over the South Pacific Ocean.

Studies on synoptic climatology for most of Peru, Ecuador and central to southern Colombia are practically nonexistent, a situation that prevents tying the circulation mechanisms of the central and northern Andes with those of the temperate and Brazilian segments of the continent. Nevertheless, one of the contributions to Colombian descriptive climatology is the exhaustive compilation of monthly averages of rainfall and temperature from 980 stations by Eslava, López and Olaya (1985), although the work contains no references to variability in time or relationships with synoptic weather situations. Only Venezuela musters detailed studies on regional climatology contributing to close the "information gap" in the central Andean atmospheric circulation picture. A conventional characterization of the Venezuelan climates by J. M. Guevara (1985) can be used as departure point for more detailed and analytical treatment of dynamic climatology in the country. In fact, the study of Ricardo R. Ponte (1982) on precipitation distribution in the western Andes of Venezuela in which he associates spatial and temporal variations of rainfall with locational shifts of the Intertropical Convergence Zone with oceanic controls from the Caribbean Sea and with relief controls over convective rain goes in that direction. Further, in an endeavor to place the climate of that country in the context of the climatic rifts that characterize the rest of the continent, Caviedes (1982c) established correlations of rainfall in Caracas with other continental stations to find that years with precipitation deficits

coincide with El Niño in northern Peru while rainy years tend to occur in phase with positive rainfall departures in the equatorial Atlantic.

The realization that climate controls from the northern equatorial Atlantic and the Caribbean Sea dominate in great part the interannual precipitation and temperature variations over the northern edge of the continent has sparked renewed interest in tropical circulation north of equatorial South America. Riehl (1984) forwarded evidence that rainfall and river discharges in Colombia react negatively when El Niño is experienced off Ecuador and Peru, and Hastenrath (1990) established relationships between runoff of northern South American rivers and the Southern Oscillation. Pursuing the reasons for these negative associations, J. C. Rogers (1988) found that during years with high Southern Oscillation indices (SOI), rainfall in the southern Caribbean and northern South America is higher than in periods of low SOI, when positive high troposphere anomalies dominate the Caribbean region and Venezuela as consequence of oceanic warming in the tropical Pacific. These and other studies that have dealt with the atmospheric circulation characteristics of the northern tropical Atlantic and Caribbean region (Douglas and Englehart 1981; Gray 1984) leave no doubt that there is a linkage between climate variations in the Caribbean and Central America and one of the major climatic oscillations of the present time: El Niño phenomenon.

THE IMPACT OF EL NIÑO, 1982-83

It seems now that there is hardly a decade during which this notorious climatic variability has not upset the natural balance of Latin America. Already El Niño 1972-73 was recognized by ecologists, geophysicists and geographers as a recurring climatic fluctuation with serious environmental and human repercussions (Caviedes 1975; Parsons 1981). During the 1980s El Niño did not miss its appointment: in 1982-83 it struck with the greatest intensity of this century. On the central Pacific islands and the Galapagos Islands El Niño caused numerous casualties in fish, sea mammals and coastal bird communities before reaching the west coast of the continent (Schreiber and Schreiber 1984). When the warm water advection and its associated storm systems (Caviedes and Endlicher 1989) reached the coast of southern Ecuador and northern Peru, torrential rains destroyed dwellings, roads and irrigation works and eroded fertile farmland (Caviedes 1984). Around the same time; that is, late spring of 1982 and early summer of 1983, anomalies in the atmospheric circulation over the Andes had caused a devastating drought in the Peruvian-Bolivian Altiplano (Francou and Pizarro 1985) that decimated llama herds and potato yields and caused social hardships. Across the continent the upset circulation conditions triggered higher-than-normal summer/fall precipitation and floods all over the Paraná-Paraguay river basin and southern Brazil (Valdéz y Ereño 1984). Concurrently, a severe drought in northeastern Brazil confirmed the theory that these catastrophes on the east side of the continent are related to El Niño episodes in the tropical Pacific. As these events occurred in South America, the distant effects of El Niño intensified bad winter weather in the western United States and winter rainfall in the **[end p. 23]** southeast of North America while causing failure of the summer monsoon in Indonesia and India and prolonged droughts in sub-Saharan Africa as well as in Australia (WMO 1984).

The occurrence of El Niño 1982-83 and the impact of its primary effects on South America

prompted a hitherto unparalleled research thrust into this phenomenon and its sequels. The collection of papers edited by D. Pauly et al., ***The Peruvian Upwelling Ecosystems: Dynamics and Interactions*** (1989), which contains 31 contributions that span from ocean dynamics to fish, mammals and sea bird populations along the Peru Current, is destined to become the primer on the South American west coast ecosystem and the most accurate document on the fluctuations of that ecosystem in response to El Niño occurrences. Equally revealing and comprehensive is the special issue of ***Investigación Pesquera*** entitled "Taller Nacional Fenómeno El Niño 1982-83" (Instituto de Fomento Pesquero 1985) which contains twenty-seven papers on climate and ocean oscillations along Chile associated with El Niño 1982-83, plus a vast array of contributions dealing with faunal and ecological changes in that country. Recognition is due also to the effort of David Enfield who collected 29 papers presented at the AGU Chapman Conference on El Niño, Guayaquil 1986 and published them in volume 92 (1987) of the ***Journal of Geophysical Research*** under the title "El Niño: An AGU Chapman Conference."

These works, not to mention the stream of publications that came from the fields of physical meteorology, oceanography and geophysics, contributed not only to expand our knowledge of the phenomenon's implications but pushed forward existing research frontiers in Latin America and opened up new ones. One of the latter is the connection of El Niño-Southern Oscillation phenomena with hydroclimatic variability in South America and the Caribbean. Perhaps the most comprehensive study on the multiple effects of ENSO events on the South American continent is Patricio Aceituno, "On the interannual variability of South American climate and the southern oscillation" (1987, 1988) in which he reviews the connections of these oscillations with thermal regimes, precipitation anomalies, pressure and wind fields as well as continental river runoff. This survey will probably serve as departure point for other general studies of ENSO impact on Latin America. Of equal significance are the investigations that have sought to relate Southern Oscillation variations with snow accumulations in South America (Cerveny et al. 1986) and with thermal variations along the west coast of the continent (Walsh and Cerveny 1990).

Attention is drawn in Aceituno's study, as well as in Riehl's short piece on the effects of El Niño on southern Colombian rivers (1984) and in Valdéz and Ereño's (1984) survey on the effects of El Niño 1982-83, to the sizeable variations in river discharge during these abnormal events. With the purpose of furthering understanding of the impact of El Niño on the surface hydrology of the continent, as far as availability of records allows, Waylen, Caviedes, and their students have started a major program of identifying discharge variations in time series. They have discovered that northern Peru river discharges can be subdivided in three subpopulations: in El Niños, Anti-Niños and normal years, each of them offering unique characteristics that are statistically discernible (Waylen and Caviedes 1986). Spatially they observed a great influence of El Niño episodes on rivers in northern Peru but an actual reversal of this condition to the south so that the rivers bordering on the Peruvian-Bolivian Altiplano actually recorded lower discharges in connection with El Niños (Tapley and Waylen 1988). Expanded studies into Argentina uncovered a similar tendency in the rivers of the northwest while the rivers arising from the eastern slopes of the central Argentine Andes experienced higher floods during El Niño, responding very much to the climate controls of the mid-latitudinal Pacific Ocean during ENSO events. In the southern regions of Argentina the response to El Niño becomes more erratic thus

inviting further studies (Bright 1990). In their analysis of discharge characteristics of the Aconcagua river in central Chile Waylen and Caviedes (1990) not only identified the processes underlying particular flow types but they associated them with established ocean-atmosphere conditions in the Southeast Pacific, mostly of El Niño or Anti-Niño signature.

It cannot be emphasized enough that these advances in the study of El Niño as a major climatic-ecological variation unveiled the global implications of the phenomenon under contemporary climatic conditions while at the same time forcing scholars to search for traces of past climatic anomalies and for historical references to environmental crises allowing thus to place cultural transitions and social crises within the context of changing environmental circumstances.

THE EMERGENCE OF A NEW MAN-ENVIRONMENT PERSPECTIVE ON LATIN AMERICA

Already at the end of the 1970s the realization that past El Niño occurrences seem to have had an impact on certain cultural adjustments observed particularly amongst coastal Peruvian civilizations had brought together geoscientists **[end p. 24]** and archaeologists (Moseley 1987). The 1980s witnessed a dramatic expansion of this newly emerging perspective. Past El Niño occurrences have been traced through their catastrophic imprints on cultivated fields, irrigation works and dwellings of pre-Hispanic coastal communities. Catastrophic flash-flood descriptions by Craig and Shimada (1986), Wells (1987), De Vries (1987) and several others have revealed the persisting presence of this phenomenon in proto-historical times and its enormous influence on the development of pre-Hispanic agrarian communities. Not only environmental variations in the arid coastal setting of Peru were considered but also population and cultural changes in the South American highlands. In an enlightening paper P. Usselmann (1987) argues convincingly that the cultural adaptation of pre-Hispanic populations to mountain environments was remarkably accentuated by climatic fluctuations. The arrival of the Spaniards and their disregard for the adaptation techniques that Andean communities had developed provoked serious environmental deterioration and social dislocation from which Andean Peru has still not recovered.

In the different setting of central Mexico, Metcalfe et al. (1989) investigated the implications of Late Holocene climate change on human occupation of the Michoacán highlands while Street-Perrot et al. (1989) looked at the impact of deforestation on soil erosion and surface modelling after the introduction of maize cultivation. In all these research cases the study of the physical milieu has not been separated, as it was in the past, from its bearings on environmental history and human landscape occupation.

The intense search for traces of El Niño in the past and for indications of social and cultural dislocations that were exemplified in these works are but illustrations of the reconstructing physical environments paradigm and the environmental history approach (cfr. Kendall E. Bailes "Environmental History: Critical Issues in Comparative Perspective" 1985), which is becoming the newest and most stimulating development in the study of Latin American humanized landscapes. This research avenue has created, in addition, a need to dig into historical sources and surrogate information on past climatic anomalies that, so far, had been overlooked. One of

the first attempts to make a complete compilation of references to past El Niño occurrences from historical and instrumental sources is that of Quinn, Neal and Antunez de Mayolo (1987). In northern Peru they were able to trace such occurrences back to 1541. Against this basic series one might check others to reconstruct climatic variabilities elsewhere in South America. Historical records from central Chile (Taulis 1933; Oficina Meteorológica de Chile 1968) and northeastern Brazil (Serra 1973) that make reference either to torrential rains and catastrophic floods or to severe droughts in years identified as influenced by past El Niños or Anti-Niños have allowed us to trace these phenomena back to the mid-1500s and to connect them with anomalies in other places of the southern hemisphere (Caviedes and Waylen, 1990). Past El Niños are now known to have caused high numbers of shipwrecks on the coast of temperate Chile and also on the distant coast of Cape Province, thus confirming the impact of El Niño not only on the South Pacific but also the South Atlantic (Caviedes 1985). The phenomenon is also being considered as the catalyst for Polynesian eastward navigation against prevailing winds and ocean currents in the eastern Pacific (Finney 1985). Furthermore, extensive and detailed lists on hurricane occurrences in the tropical Atlantic and Caribbean Sea (Reading 1990) have permitted to investigate hurricane frequency and time series attributes in order to correlate low frequency of occurrence with high Southern Oscillation indices (Anti-Niños in the South Pacific) and high frequency with El Niño phenomena, proving thus that the circulation over the tropical Atlantic and Caribbean Sea is not disassociated from its Pacific counterpart (Caviedes, 1991).

A similar historical-cultural leaning and emphasis on the use and interpretation of conventional and indirect historical sources coupled with a contemporary search for physical evidence is found in the work that Karl Butzer and his associates are doing in central and northern Mexico (see article on "Agriculture in Mexico: Historical Perspectives" in this volume). In Puebla and Sonora Diana Liverman (1990) has effectively documented the differential implications of climate crises (droughts) on agricultural innovation and economic prowess among cultivators, revealing thus the social implications of natural catastrophe occurrences. Works like these, as well as David Robinson's current studies on past famines and harvest failures in Middle America, help to establish that much-needed connection between social and climatic history that will allow the insertion of Latin America into world climatic history. To this date, one of the best surveys matching historical references and climatic crises in Mexico is that of Metcalfe (1987), in which a vast body of surrogate information has been compiled with the purpose of sketching the main lines of the climatic history of the country from 1450 to 1977.

Still, gaps remain in both the spatial and time coverage of environmental reconstruction for other regions of Latin America. Instrumental series on climate, geomorphic processes and river discharge in South America (Peru, Bolivia and Paraguay) and almost all of Central America have yet to be analyzed, as well as the surrogate sources **[end p. 25]** for climatic history in Argentina, Ecuador, Colombia and Venezuela. Once an assessment of this sparse body of information is made the climatic and social history of Latin America is likely to reveal details that will enrich the interpretation of obscure periods in political and social history.

NATURAL HAZARDS: INVENTORY AND INTERPRETATIVE WORK

Among the major natural disasters of the 1980s is not only El Niño of 1982-83, but also the

1985 eruption of the Ruiz volcano in Colombia, which alerted the world anew to the vulnerability of settlements in high risk mountain environments and to the destructive power of lahar masses. The latter received ample media coverage but no follow-up by Colombian or North American geographers, notwithstanding the fact that the region in which the catastrophe occurred is densely populated and remains threatened by a repeat eruption (Herd 1986). The Mexico earthquake in September of 1985 (8.1 degrees on the Richter scale) was just an example of the extent to which lives and property can be destroyed when anti-seismic construction regulations are not complied with and if public and official hazard awareness and preparedness are underdeveloped: again no geographic investigations arose from this catastrophe.

Gilbert, the mighty hurricane of October, 1988, was another reminder of the destructive power of natural catastrophes on the densely populated islands of the Caribbean and the Middle American mainland. One of the most powerful in this century, Gilbert attracted a good deal of attention from geographers and a special issue of ***GeoJournal*** contains a series of contributions on this hazard. In it the physical attributes of the phenomenon and meteorological conditions that led to the hurricane onslaught are studied by Meyer-Arendt (1991), while Skeeter Dixon (1991) documents the damages inflicted on agriculture, tourist facilities and construction in Yucatan. Howard Richardson and David Nemeth (1991) trace the drifting of locusts from Africa to the Antilles on the westward air currents that precluded Joan's inception. Excellent additional studies on Gilbert are those by Lawrence and Gross (1989), detailing its development and path, and by Avila and Clark (1989) who associate that hurricane with the genesis and development of an "African wave" similar to the one that facilitated the trans-Atlantic locust journey described by Richardson and Nemeth.

Besides these contributions, the 1980 decade saw the appearance of important documentation on Latin American natural hazards. Volume 6 of ***GeoJournal*** contains insightful information on drought and destitution in north-central Chile in an article authored by Schneider (1982), drought and subsequent social adjustment in northeastern Brazil were analyzed by M. Brooks (1982), the synoptical characteristics of cold waves and their damages to coffee fields in Brazil were explored by M. Y. Une (1982), T. Veblen (1982) dealt with the long-term effects of volcanism and mass wasting triggered by earthquakes on the renewal and permanence of forest stands in southern Chile, while T. L. Hills (1982) examined the concept of vulnerability and its implication for chronic poverty, deprivation and social injustice in Latin America. Unfortunately, in spite of being one if the few comprehensive volumes of this nature, this issue of ***GeoJournal*** seems to have gone almost unnoticed by Anglo-American geographers.

In contrast with the lax interest of Anglo-American scientists in hazards besetting contiguous Latin America earth researchers from that sub-hemisphere have shown a keen interest in the description and assessment of the impact of some natural hazards on the society and economy of their native countries. In an original study on wind-driven dust storms in northern Mexico, Jáuregui (1989) established pertinent linkages between synoptic meteorology, progressive desiccation, and dust storm damages of agricultural land and settlements while the devastations caused by storm surges related to hurricane activity on Jamaica were outlined by Naughton (1984). On the continent, L. D. Morales (1987) made a valuable contribution to the localization of seismic activity in Costa Rica, pinpointed the most vulnerable locations and related them to

particular geostructural situations. Carlos Ferrer (1982) produced an interesting paper on site-specific risks in the Venezuelan city of Merida where not only floods but also earthquakes and the ensuing mass waste movements contribute to making this a risky environment. Espinoza et al. (1985) explored the aggravating circumstances that increased landslides in middle Chile, and Gray and Ruiz (1990) surveyed the damage caused in certain sectors of the city of Mendoza by the earthquake of January 26, 1985.

In Brazil, with the exception of the paper by Hilgard O'Reilly Sternberg (1987) that questioned that deforestation in the Amazon basin has increased flooding in recent times, most of the research effort into natural hazards has been focused on the prolonged drought of 1981-84 in the country's northeast that coincided with an El **[end p. 26]** Niño development in the Pacific. Placing these droughts into a historical perspective a valuable survey on the social impact of these northeastern droughts from the seventeenth through the nineteenth centuries was provided by J. Alves (1982), while Guerra (1981) offered an interpretation of social adjustments to and official strategies for drought situations. Andrade and Pébayle (1987) gave an account of the damages caused by the said drought in the interior of Sergipe, S. Jost (1984) commented on the famine that was claimed to be triggered by the 1981-1984 drought and Aguiar (1985) takes a critical look at the state's endeavors to alleviate the situation during that period and claims that the social consequences of droughts were no worse than those of the perennial injustice and deprivation in the country.

Outside Brazil, the question of environmental crises and socioeconomic dislocations due to recent droughts was addressed by Durán (1987) for the Argentine pampas and Romero (1989) offered a synthetic view of the 1987-88 winter droughts in Chile.

Aside from these works that emphasize the physical aspects of natural hazards in Latin America and shed some light on the socioeconomic implications of disasters, a survey of the literature produced on natural hazards during the 1980s is not complete without mentioning two publications authored by anthropologists and sociologists that testify to the social scientists' growing interest in social and institutional responses to catastrophic environmental crises. Following his studies on the obliteration of Yungay by an avalanche in 1970, Anthony Oliver Smith (1986) wrote an exciting book on social resilience, sense of place and post-catastrophic adjustments in rural populations hit by natural disasters. His reasoning as to why people return to places deemed dangerous hinges enormously on place perceptions that we geographers tend to covet, but do not necessarily stress sufficiently. The other work is ***Desastres Naturales y Sociedad en América Latina*** (1985), edited by the noted Argentine sociologist Jorge Hardoy assisted by María Caputo and Hilda M. Herzer, which deals with several natural hazard occurrences in South America. The accent is on the social and economic implications of the droughts that affected different segments of the Altiplano from 1981 to 1983, the drought in northeastern Brazil (1981-1984), the floods and avalanches that accompanied El Niño 1982-83 in Ecuador and Peru and the floods in the La Plata river basin that followed the maturity phase of the 1982-83 ENSO events. Although not particularly rich in theory on social stress related to natural disaster situations, this collection of case studies reveals a concern for structural pre-disaster conditions that aggravate the sequels of catastrophic occurrences. If not of great help in mitigating disasters, this book raises awareness among Latin American intellectuals about certain

social and institutional shortcomings caused by governmental incapacity or social insensibility that exacerbate the deleterious effects of natural hazards beyond their strict impact on ecosystems and human activities (Caviedes 1985b).

To summarize this survey of the literature on natural hazards produced during the 1980s, one might say that while still insisting on description and neglecting interpretation current research offers many indications that this field is alive and will continue to thrive in the decade ahead. The commitment demonstrated by the geographers and social scientists to investigate not only the physical sequels of catastrophes but also the human adjustments and institutional responses to environmental crises promises, in the long run, more socially-relevant results. It is only to be hoped that the involvement of Anglo-American researchers increases as overall environmental awareness rises in Latin America.

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