9

Land Use Changes and their Synergies with Climate Change

César Freddy Suárez, Luis Germán Naranjo, Juan Carlos Espinosa, and Javier Sabogal

The tropical Andes have been a center of human development for over 10,000 years and are considered one of the world's 12 major centers of origin of plants cultivated for food, medicine, and industry (Saavedra and Freese 1986). The long presence of human cultures has caused variable impacts on the region's landscapes and biodiversity. Therefore, understanding the current responses of Andean ecosystems to climate change requires an examination of the processes responsible for these transformations.

In the wake of transformation and replacement of ancient cultures by western civilization, traditional land use systems have also changed, modifying soils, causing loss of plant and animal species, and removing much of the original land cover (Young 2008). Despite the long occupation of the tropical Andes by humans, most of the extensive alterations of natural habitats in the northern Andes have taken place since the beginning of the 20th century (Corrales 2001). Intensification of land and natural resource use continues today, resulting in further habitat loss, fragmentation, and degradation (Palminteri and Powell 2001).

In this chapter we present an overview of the transformation of Andean ecosystems through history and examine the relative importance of different land use change processes to ongoing ecosystem transformation, biodiversity and the possible interactions between these processes and regional climate change.

Historic Land Use Change in the Tropical Andes

When Europeans first arrived in the tropical Andes, they met different cultures along the mountains. Barié (2003) estimates that ca. 243 ethnic-linguistic groups occurred in the Andean region, several of them with influence over large distances. Before the arrival of the Spaniards, most of the Andes were ruled by two dominant nations: the Muisca culture in the northern Andes and the Inka empire, which extended from southern Colombia to northwestern Argentina (Lumbreras 1999, Mann 2005). Although the impact of the different cultures on their environments varied across the region, with the exception of snow peaks and natural barriers of the highlands, practically every type of ecosystem had some kind of occupation in pre-Columbian times (Fernández-Armesto 2002). Cultural activities were characterized by hunting, pottery, fishing, small-scale agriculture (quinua-*Chonopodium quinoa*, cañiwa-*Ch. Pallidicaule*, corn and potatoes-*Solanum tuberosum*), and the domestication of camelids (llama-*Lama glama* and alpaca-*Lama pacos*) and guinea pigs (*Cavia porcellus*).

This heterogeneous spatial pattern of land use was drastically modified during the XVI century, soon after the arrival of the Europeans. After the severe reduction of the indigenous population during the first decades of occupation (Crosby 1986, Denevan 1992), the progressive concentration of land ownership (Aramayo et al. 2004) due to the new social structures introduced by the invaders facilitated the expansion of livestock grazing, large concentrations of human settlements in some areas, and the relocation of entire ethnic groups, often into areas hitherto sparsely occupied (Corrales 2001).

These processes continued during the colonial period and the first republican stages of the Andean countries, and intensified as the young nations initiated their integration into international markets with the export of natural resources and intensified agricultural production to satisfy the needs of a growing population. Intensive production of sugar cane, cocoa, tobacco, and coffee and extensive ranching were among the first large-scale modifiers of the original landscapes of the inter-Andean valleys and the surrounding slopes, mainly in Colombia and Ecuador (Corrales 2001). In Bolivia, the increase in mining, the introduction of livestock (bovine, equine, sheep, and goat) and new crops, combined with new pasturing practices, caused an imbalance in the Andean ecology (Aramayo et al. 2004).

Anthropogenic disturbance and loss of *Polylepis* forests, formerly dominant across a large part of the high (>3500 m) central Andes, are held responsible for the population decreases in more than one half of the plant species (Kessler 2006) and ca. 26% of the bird fauna of the more humid habitats (Fjeldså 2002) mainly through fires and overgrazing of habitats (Ellenberg 1958; Kessler 2000, 2002).

During the first decades of the 20th century, the expansion of the agricultural frontier was responsible for significant transformation of some Andean landscapes. For instance, the colonization of large sectors of the Colombian Andes driven by the expansion of coffee cultivation caused the deforestation of vast landscapes between 1000 and 1500 m, and the introduction of exotic grasses favored the expansion of cattle ranching in many areas (Rivera et al. 2007). In Colombia alone, almost 500,000 ha of natural Andean ecosystems were transformed just between 1910 and 1925 (Corrales 2001).

Landscape Transformation of the 20th Century

The first developments of market driven agricultural systems in the Andean countries set the stage for the implementation of large scale transformations of entire landscapes during the second half of the 20th century. The implementation of the Green Revolution in the northern tropical Andes brought significant economic investments promoting the industrialization of agricultural sectors. As growing monocultures and extensive cattle ranching occupied the fertile inter-Andean valleys, smallholding subsistence farmers were displaced towards peripheral landscapes with the resulting replacement of the original mountain ecosystems (Rivera et al. 2007). Cattle grazing on the steep slopes of the tropical Andes and the intensification of monocultures of barley, potato, onion, and garlic also have taken a heavy toll on cloud forests and *páramos* of the northern Andes (Corrales 2001). In the southern tropical Andes, on the other hand, the 80's agricultural reforms in Bolivia have changed land tenure (Morales 1991) expanding croplands and pastures, and causing major degradation (Aramayo et al. 2004).

Early in the 20th century, the Colombian Andes had the highest percentage of area under agricultural uses among the countries of the tropical Andes, mostly cattle ranching, potatoes (especially in the páramo zones), and coffee, bananas, sugar cane, and flowers in the inter-Andean valleys. Although many of these uses have been in place for decades, there are regions with high land change dynamics such as the Andean-Amazon corridor (upper Putumayo and Caquetá watersheds and Macarena) and the southern Pacific piedmont, due to the deforestation initiated by coca production (Armenteras et al. 2006).

According to Arellano et al. (2000), the main causes of ongoing expansion of the agricultural frontier in Ecuador are demographic growth, social inequity, and the intensification of agriculture techniques. These same authors analyzed the relationship between poverty indices and deforested areas in Carchi Province (El Ángel basin, northern Ecuador) and found that the highest deforestation rates coincide with high poverty levels and population density.

In Peru, the primary Andean crops are potatoes, corn, wheat, and Andean cereals such as quinoa, maca, tarwi and kiwicha (Torres Lozada 2004). In the livestock sector, bovines, pigs and South American camelids (Alpaca, llama and vicuña) are characteristic of small productive units (less than 3 ha),. Studies carried out by Bussink and Hijmans (2000) and Frias (1995) in the Cajamarca province found that the area planted with tubers was decreasing and the area under pasture increasing.

In Bolivia, studies of land use changes in the Yungas and the Alto Beni region of La Paz show increases of 30% in agriculture lands and 20% in anthropogenic secondary vegetation during the period 1987-2001 (Killeen et al. 2005). The area planted with quinua increased until 1990, while since then this trend slowed and there is even evidence of a slight decrease (Crespo Valdivia 2000). As this same author points out, after the first half of the 1980's the amount of land planted with potatoes (the most important cash crop for Bolivian farmers) has also decreased in the Altiplano, while the production of cacao, coffee, cotton, and sugar has increased.

After the 1980's agricultural expansion in some areas of the tropical Andes slowed down due to the increase in agricultural imports in all countries of the region (Corrales 2001, Hervé and Ayangma 2000, Sarmiento et al. 2002). However, the rate of transformation of natural ecosystems in some areas continued unabated, as the less favored sectors of the population sought income alternatives. The expansion of illicit crops, mainly opium poppy and coca, has occurred in vast sectors of the tropical Andes, affecting some of the most fragile ecosystems. According to the United Nations Office on Drugs and Crime (2008a), coca plantations increased by 16% in Colombia, Peru, and Bolivia in 2007. In Colombia alone the increase of these crops caused the deforestation of 170,000 ha between 2001-2007 (United Nations Office on Drugs and Crime 2008b).

On the other hand, mining could be one of the most severe threats now faced by Andean ecosystems, as it represents a growing productive activity with high importance for public finances and corresponding support by governments. Current mining exploitation rights in Peru, Ecuador, and Colombia cover ca. 14% of the total paramo area in these countries, but an additional 14% of these ecosystems is subject to illegal mining (Guerrero 2009)

All of these landuse changes have produced ecosystem losses and degradation throughout the tropical Andes (Table 9.1), with the heaviest toll below 1000 m elevation.The connectivity between high-Andean ecosystems and the lowlands has been severely affected in many places, resulting in multiple threats to biodiversity and the loss of ecosystem services. An example of those effects is mentioned by Weigend et al. (2006) in their examination of the economic importance of ecosystem services provided by 23 relict forests in NW Peru.

Table 9.1. Ecosystem conversion by altitudinal range in the tropical Andes.

Elevational range	% area transformed
< 1000	34.0
1000-2000	28.4
2000-3000	23.8
>3000	11.4

Source: Vegetation map of South America. Eva, H.D et al. 2002

The IPCC's Fourth Assessment Report points out that global CO_2 emission from deforestation and agricultural development correspond to ca. 20% of the total anthropogenic emissions (IPCC 2007). In the Americas emissions from deforestation in Amazonia represent the most important percentage (Achard et al. 2004, DeFries 2002, Houghton 2003). A look at recent trends in the Andean countries reveals that Ecuador had the highest rate of deforestation during 2000 – 2005 (1.7%), and Venezuela the largest area deforested from 1990 to 2005 (4,313,000 ha) (Table 9.2, FAO 2005). Since the statistics of the FAO do not discriminate between types of forests, it is difficult to calculate the impact of deforestation of Andean forests. In Colombia, the most recent estimates indicate a deforestation rate of 118,000 ha/year of which 56,000 ha are in the Andes (Instituto de Hidrología, Meteorología y Estudios Ambientales 2008). This shows the importance of preserving the current natural cover to prevent greenhouse gas (GHGs) emissions due to deforestation and degradation.

Table 9.2. Changes in Forest Cover in Andean countries between 1990 and 2005.

	Area			**Annual Change**			
	1990	**2000**	**2005**	**1990-2000**		**2000-2005**	
	1000 ha			**1000 ha/year**	**%**	**1000 ha/year**	**%**
Bolivia	62.795	60.091	58.740	-270	-0,4	-270	-0,5
Colombia	61.439	60.963	60.728	-48	-0,1	-47	-0,1
Ecuador	13.817	11.841	10.853	-198	-1,5	-198	-1,7
Peru	70.156	69.213	68.742	-94	-0,1	-94	-0,1
Venezuela	52.026	49.151	47.713	-288	-0,6	-288	-0,6

Source: Evaluación de los Recursos Forestales Mundiales 2005: Tablas Mundiales 2005, Food and Agricultural Organization - FAO.

According to the northern and central Andes ecosystem map (Josse et al. 2009), 24% of the Andean region is anthropogenically altered land (agriculture, degraded vegetation), with Venezuela and Colombia being the countries with the highest percentage. Bolivia has the highest proportion of highland vegetation, whereas forest cover for all countries is between 35 and 41% (Table 9.3). Bolivia, Ecuador, and Peru emit three times more CO_2 through land use changes than by burning fossil fuels (Table 9.4) due to the demand for forest resources and the conversion of forest to agricultural and grazing lands (PNCC 2003).

Table 9.3. Land Use Cover Distribution (%) in the Andean Region.

Land cover classes	**Bolivia**	**Colombia**	**Venezuela**	**Ecuador**	**Peru**
Agriculture, degraded vegetation	3.26	59.05	50.98	43.23	12.60
Forest cover	37.29	35.11	35.99	41.25	36.72
Highland shrub, grass and bogs	51.10	4.38	16.66	35.35	6.38
Other montane vegetation	4.12	1.16	3.83	6.10	5.13
Glaciers	0.29	0.03	0.003	3.62	0
Lakes and others water bodies	3.93	0.37	0.25	1.08	0.07

Source: Adapted from Josse et al. (2009).

Table 9.4. Emissions of greenhouse gases (GHG) in the tropical Andean countries

Country	**Proportion of GHG in CO_2[e] of Annex 1 countries**	**Proportion of GHG in CO_2[e] of all countries**	**Proportion of CO_2 emitted by fossil fuel combustion**	**Proportion of CO_2 emitted by silviculture and land use changes**
Bolivia[a]	0,39	0,22	21,11	77,10
Colombia[b]	0,96	0,54	71,8	21,5
Ecuador[c]	0,50	0,28	28,8	69,5
Perú[d]	0,63	0,36	21	66
Venezuela [e]	1,14	0,65	76,8	14,9
sum	**3,62**	**2,05**		

Source: First National Climate Change Communication. [a] PNCC 2003; data to 2000. [b] Instituto de Hidrología, Meteorología y Estudios Ambientales 2001; data to 1994. [c] Ministerio del Ambiente de Ecuador 2000; data to 1990, [d] CNCC 2001; data to 2000. [e] Ministerio del Ambiente y de los Recursos Naturales 2005; data to 1999. Annex 1 countries refer to industrial countries as defined in the Kyoto protocol.

The production of biofuels has recently become a major driver of land use change in the Andean countries, and laws or programs that promote mixing bioethanol and biodiesel with commercial fuels are in place in Bolivia[1], Colombia[2], Ecuador[3], and Perú[4]. Main energy crops currently promoted in the region include sugar cane, oil palm, and soy. However these crops require special characteristics of precipitation, temperature, soils, topography, elevation, and

[1] Bolivia, Law 3207 (September 30, 2005).

[2] Colombia, Ministerio de Minas y Energía, Resolución No. 180687 de 2003; Ministerio de Ambiente, Vivienda y Desarrollo Territorial, Resolución No. 1289 de 2005.

[3] Ministerio de Agricultura, Ganadería, Acuacultura y Pesca, Ministerio del Ambiente, Ministerio de Electricidad y Energía Renovable y Ministerio de Minas y Petróleo de Ecuador (2007), "Biocombustibles". Available at: www.comunidadandina.org/desarrollo/biocombustibles_ecuador.pdf.

[4] Ministerio de Energía y Minas de Perú (2007), "Situación Actual y Perspectivas de los Biocombustibles en el Perú". Available at: www.comunidadandina.org/desarrollo/biocombustibles_peru.pdf.

hydrologic regime that the Andes can offer only in a few zones, especially in the inter-Andean valleys under 1500 m and on flat terrain adjacent to the lowlands. The use of corn, sugar beet, coffee waste, and wheat as energy crops has largely been neglected in Andean countries but may have potential in highland areas.

All of these land uses and drivers (cattle ranching, mining, agriculture, land tenure) have fragmented and isolated ecosystems in the Andean region, impacting biodiversity and its underlying processes. The positive relationship of species density and the size of forest patches has been demonstrated repeatedly (e.g., Kattan et al. 1994, Fernández and Sork 2007, Marsh and Pearman 2007). Andean forest fragmentation may hinder the natural or induced migration of species (Bustamante and Grez 1995) and may also affect microclimates (Didham and Lawton 1999).

The Future: Land Use, Climate Change and Biodiversity in the Tropical Andes

Given the multiple dimensions of the contemporary environmental crisis at multiple scales (MEA 2005) and the pressing need to adapt to climate change, it is pertinent to examine some of the possible relationships between land use change, habitat loss and fragmentation, and biodiversity vulnerability to climate change. Ecosystem modeling using time series of climate variables can be a powerful tool to reveal expected responses of biodiversity to climate changes at the landscape or ecosystem level (Cuesta-Camacho et al. 2008). Spatial modeling can also show how available habitat for a given species can increase or decrease as a consequence of climate change (see Graham et al., Chapter 21, this volume), provided that ecosystem fragmentation does not prevent its movement across landscapes.

A recent study carried out for the eastern Cordillera Real of Colombia, Ecuador, and Peru revealed that climatic changes could impact the distribution of life zones and vegetation types: whereas different types of dry shrub and forest could increase by up to 23-72% by 2050, wet montane forests could decrease by up to 11 - 83% during the same period (Hernández et al. 2010), which will surely increase fragmentation of those ecosystems occupying narrow elevational belts.

On a geologic time scale some species were capable of adjusting their distribution in response to natural climate change, literally running away from extinction (Jablonski 2001, 2008). However, this may no longer be possibile for many species in the near future (Myers and Knoll 2001, Travis 2003). Current ecosystem fragmentation obstructs movement, and fragmentation could disrupt population connectivity within species leading to extirpations and possibly extinctions, thereby altering community composition (Root et al. 2003),. Habitat specialists, especially those of relatively poor colonizing ability, are least able to keep pace with climate change (Travis 2003), and if favorable climate were constrained to areas that are heavily disturbed by land use, this would act as a bottleneck for their long-term survival (Higgins 2007).

The resilience of biodiversity to support agricultural systems must be considered under climate change. Hydrology, soil formation, pollination, seed dispersal, and predator-prey relationships become altered by land conversion processes (Primack and Ros 2002, Van Noordwijk et al. 2004), and these changes alter ecosystem processes and their resilience to environmental change. This has profound consequences for services that humans derive from ecosystems (Chapin et al. 2000). Since these functions depend on future deforestation and degradation, and on how much of the current remaining forests will be in place or even expand (Cramer et al. 2004), it is now more urgent than ever to control further transformation of the remaining natural ecosystems in the region and to prevent direct impacts on biodiversity and on the continued provision of ecosystem services.

Literature Cited

Achard, F., H. D. Eva, P. Mayaux, H.-J. Stibig, and A. Belward. 2004. Improved estimates of net carbon emissions from land cover change in the tropics for the 1990s. Global Biogeochemical Cycle 18:GB2008.

Aramayo, C., F. Fonturbel, S. Palomeque, and R. Rocha. 2004. La region altoandina de Bolivia. In Ecología, medio ambiente y desarrollo sostenible: algunos ejemplos prácticos, edited by F. Fonturbel, C. Ibañez, and C. Aramayo. CD-ROM. La Paz: Editorial Publicaciones Integrales.

Arellano, P., S. Poats, M. Proaño, and C. Crissman. 2000. Pobreza rural y deterioro ambiental en la cuenca del rio El Angel, Carchi – Ecuador. Quito: Consorcio para el Desarrollo Sostenible de la Ecorregión Andina. Available at: http://www.condesan.org/memoria/Docspolitics.htm#Pobreza%20Rural.

Armenteras, D., G. Rudas, N. Rodriguez, S. Sua, and M. Romero. 2006. Patterns and causes of deforestation in the Colombian Amazon. Ecological Indicators 6:353-368.

Barié, C. G. 2003. Pueblos indígenas y derechos constitucionales en América Latina: un panorama. Mexico City: Instituto Indigenista Interamericano, Comisión Nacional para el Desarrollo de los Pueblos Indígenas, and Editorial Abya-Yala.

Bussink, C. B., and R. J. Hijmans. 2000. Land-use change in the Cajamarca catchment, Peru, 1975-1996. Pp. 421-428 in Enriching the portfolio: CIP's global and regional partnerships. CIP Program Report 1999-2000. Available at: http://www.cipotato.org/publications/program_reports/99_00/enriching.asp.

Bustamante, R., and A. Grez. 1995. Consecuencias ecológicas de la fragmentación de los bosques nativos. Ambiente y Desarrollo 11(2):58-63.

Chapin III, F. S., E. S. Zavaleta, V. T. Eviner, R. L. Naylor, P. M. Vitousek, H. L. Reynolds, D. U. Hooper, S. Lavorel, O. E. Sala, S. E. Hobbie, M. C. Mack, and S. Díaz. 2000. Consequences of changing biodiversity. Nature 405:234-242.

Corrales, E. 2001. Andes del norte: principales tendencias socioeconómicas y su relación con la biodiversidad. Appendix C in Visión de conservación de la biodiversidad en los Andes del Norte, edited by S. Palminteri and G. Powell. Cali, Colombia: WWF, FUDENA, and Fundación Natura.

Comisión Nacional de Cambio Climático. 2001. Comunicación nacional del Peru a la Convención de las Naciones Unidas sobre cambio climático: primera comunicación. Lima: Consejo Nacional del Ambiente. 155 pp. Available at: http://unfccc.int/resource/docs/natc/pernc1.pdf.

Cramer, W., A. Bondeau, S. Schaphoff, W. Lucht, B. Smith, and S. Sitch. 2004. Tropical forests and the global carbon cycle: impacts of atmospheric carbon dioxide, climate change and rate of deforestation. Philosophical Transactions of the Royal Society of London B, Biological Sciences 359:331-343.

Crespo Valdivia, F. 2000. Incidencia de las reformas estructurales sobre la agricultura boliviana. Serie Desarrollo Productivo 98. Santiago de Chile: Naciones Unidas. 55 pp. Available at: http://www.eclac.org/publicaciones/xml/3/5753/LCL1455P.pdf.

Crosby, A. W. 1986. Ecological imperialism: the biological expansion of Europe, 900-1900. New York: Cambridge University Press.

Cuesta-Camacho, F., M. Peralvo and A. Ganzenmüller. 2008. Posibles efectos del calentamiento global sobre el nicho climático de algunas especies en los Andes Tropicales. Chapter 4 in Páramo y Cambio Climático 23 – Serie Páramo, edited by P. Mena and G. Maldonado. Quito: Grupo de Trabajo en Páramos del Ecuador/EcoCiencia.

DeFries, R. S., R. A. Houghton, M. C. Hansen, C. B. Field, D. Skole, and J. Townshend. 2002. Carbon emissions from tropical deforestation and regrowth based on satellite observations for the 1980s and 1990s. Proceedings of the National Academy of Sciences of the United States of America 99:14256-14261.

Denevan, W. M. 1992. The native population of the Americas in 1492. Madison: University of Wisconsin Press.

Didham, R. K., and J. H. Lawton. 1999. Edge structure determines the magnitude of changes in microclimate and vegetation structure in tropical forest fragments. Biotropica 31:17-30.

Ellenberg, H. 1958. Wald oder Steppe? Die natürliche Pflanzendecke der Anden Perus. Umschau 1958:645-681.

Eva, H. D., E. E. de Miranda, C. M. Di Bella, V. Gond, O. Huber, M. Sgrenzaroli, S. Jones, A. Coutinho, A. Dorado, M. Guimarães, C. Elvidge, F. Achard, A. S. Belward, E. Bartholomé, A. Baraldi, G. De Grandi, P. Vogt, S. Fritz, and A. Hartley. 2002. A vegetation map of South America. European Commission, Joint Research Centre. Available at: http://www.cobveget.cnpm.embrapa.br/resulta/relat/vegetation.pdf

FAO. 2005. Evaluación de los recursos forestales mundiales 2005: tablas mundiales 2005. Food and Agricultural Organization. Available at: http://www.fao.org/forestry/site/32006/sp

Fernández-Armesto, F. 2002. Civilizaciones, la lucha del hombre por controlar la naturaleza. Bogotá: Taurus.

Fernández-M., J. F., and V. L. Sork. 2007. Genetic variation in fragmented forest stands of the Andean Oak Quercus humboldtii Bonpl. (Fagaceae). Biotropica 39:72-78.

Fjeldså, J. 2002. Polylepis forests – vestiges of a vanishing ecosystem in the Andes. Ecotropica 8:111-123.

Frias, C. 1995. Pobreza campesina. Sólo un problema rural? Cajamarca: economía, espacio y tecnología. Lima: Intermediate Technology Development Group. 153 pp.

Guerrero, E. 2009. Implicaciones de la minería en los páramos de Colombia, Ecuador y Perú. CONDESAN – Proyecto Páramo Andino. Available at: http://www.infoandina.org/site.shtml?x=27822.

Hernández, O. L., C. F. Suárez, and L. G. Naranjo. 2010. Análisis de vulnerabilidad al cambio climático en la Cordillera Real Oriental (Colombia, Ecuador y Perú). Pp. 65-82 in Experiencias de adaptación al cambio climático en ecosistemas de montaña en los Andes del Norte, edited by C. L. Franco-Vidal, A. M. Muñoz, G. I. Andrade, and L. G. Naranjo. Santiago de Cali: Fundación Humedales and WWF Colombia. Available at: http://assets.panda.org/downloads/cambio_climatico_archivo_web_final.pdf.

Hervé, D., and S. Ayangma. 2000. Dynamique de l'occupation du sol dans une communauté agropastorale de l'altiplano bolivien. Revue de Géographie Alpine 88(2):69-84.

Higgins, P. A. T. 2007. Biodiversity loss under existing land use and climate change: an illustration using northern South America. Global Ecology and Biogeography 16:197-204.

Houghton, R. A. 2003. Revised estimates of the annual net flux of carbon to the atmosphere from changes in land use and land management 1850-2000. Tellus, Series B, Chemical and Physical Meteorology 55:378-390.

Instituto de Hidrología, Meteorología y Estudios Ambientales. 2001. Colombia. Primera comunicación nacional ante la convención marco de las Naciones Unidas sobre cambio climático. Bogotá: Instituto de Hidrología, Meteorología y Estudios Ambientales. 267 pp. Available at: http://unfccc.int/resource/docs/natc/colnc1.pdf.

Instituto de Hidrología, Meteorología y Estudios Ambientales. 2008. Resumen técnico del módulo uso de la tierra, cambio en el uso de la tierra y silvicultura del inventario nacional de GEI años 2000 y 2004. Bogotá: Instituto de Hidrología, Meteorología y Estudios Ambientales. 11 pp. Available at: http://www.cambioclimatico.gov.co/documentos/lulucf.pdf.

IPCC. 2007. Couplings between changes in the climate system and biogeochemistry. In Climate change 2007: the physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, edited by S. Soloman, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, and H. L. Miller. Cambridge: Cambridge University Press.

Jablonski, D. 2001. Lessons from the past: evolutionary impacts of mass extinctions. Proceedings of the National Academy of Sciences of the United States of America 98:5393-5398.

Jablonski, D. 2008. Extinction and the spatial dynamics of biodiversity. Proceedings of the National Academy of Sciences of the United States of America 105(Suppl. 1):11528-11535.

Josse, C., F. Cuesta, G. Navarro, V. Barrena, E. Cabrera, E. Chacón-Moreno, W. Ferreira, M. Peralvo, J. Saito and A. Tovar. 2009a. Ecosistemas de los Andes del norte y centro. Bolivia, Colombia, Ecuador, Perú y Venezuela. Lima: Secretaría General de la Comunidad Andina, Programa Regional ECOBONA-Intercooperation, CONDESAN-Proyecto Páramo Andino, Programa BioAndes, EcoCiencia, NatureServe, IAvH, LTA-UNALM, ICAE-ULA, CDC-UNALM, and RUMBOL SRL.

Kattan, G. H., H. Álvarez-López, and M. Giraldo. 1994. Forest fragmentation and bird extinctions: San Antonio eighty years later. Conservation Biology 8:138-146.

Kessler, M. 2000. Observation on a human-induced fire event at a humid timberline in the Bolivian Andes. Ecotropica 6:89-93.

Kessler, M. 2002. The "Polylepis problem": where do we stand? Ecotropica 8:97-110.

Kessler, M. 2006. Bosques de Polylepis. Pp. 110-120 in in Botánica económica de los Andes centrales, edited by M. Moraes R., B. Øllgaard, L. P. Kvist, F. Borchsenius, and H. Balslev. La Paz: Universidad Mayor de San Andrés.

Killeen, T. J., T. Siles, L. Soria, and L. Correa. 2005. Estratificación de vegetación y cambio de uso de suelo en los Yungas y Alto Beni de La Paz. Ecología en Bolivia 40(3):32-69.

Lumbreras, L. G. (ed.). 1999. Historia de América Andina. Quito: Universidad Andina Simón Bolívar, Libresa. 605 pp.

Mann, C. C. 2005. 1491, new revelations of the Americas before Columbus. New York: Vintage Books.

Marsh, D. M., and P. B. Pearman. 2007. Effects of habitat fragmentation on the abundance of two species of leptodactylid frogs in an Andean montane forest. Conservation Biology 11:1323-1328.
Ministerio del Ambiente de Ecuador. 2000. Inventario Nacional de Gases de Efecto Invernadero Sector Forestal 1994. Quito: Ministerio del Ambiente. 47 pp. Available at: http://www.planetaverde.org/mudancasclimaticas/index.php?ling=por&cont=contribuicoes&codpais=6.
Ministerio del Ambiente y de los Recursos Naturales. 2005. Primera comunicación nacional en cambio climática de Venezuela. Caracas: Ministerio del Ambiente y de los Recursos Naturales, Programa de las Naciones Unidas para el Desarrollo, and Fondo Mundial para el Medio Ambiente.
Millennium Ecosystem Assessment. 2005. Ecosystems and human well-being: synthesis. Washington, DC: Island Press.
Morales, J. A. 1991. Reformas estructurales y crecimiento económico en Bolivia. Instituto de Investigaciones Socio Económicas, Universidad Católica Boliviana. 39 pp. Available at: http://www.iisec.ucb.edu.bo/.
Myers, N., and A. W. Knoll. 2001. The biotic crisis and the future of evolution. Proceedings of the National Academy of Sciences of the United States of America 98:5389-5392.
Palminteri, S., and G. Powell (eds). 2001. Visión de conservación de la biodiversidad en los Andes del Norte. Cali, Colombia: WWF, FUDENA, and Fundación Natura.
Primack, R., and J. Ros. 2002. Introducción a la biología de la conservación. Barcelona: Editorial Ariel.
Programa Nacional de Cambios Climáticos. 2003. Inventario nacional de emisiones de gases de efecto invernadero de Bolivia para la década 1990-2000 y su análisis tendencial. La Paz: Ministerio de Desarrollo Sostenible y Planificación, Viceministerio de Medio Ambiente y Recursos Naturales.
Rivera, C. C., L. G. Naranjo, and A. M. Duque. 2007. De "María" a un mar de caña. Imaginarios de naturaleza en el Valle del Cauca entre 1950 y 1970. Cali: Universidad Autónoma de Occidente.
Root, T. L., J. T. Price, K. R. Hall, S. H. Schneider, C. Rosenzweigk, and J. A. Pounds. 2003. Fingerprints of global warming on wild animals and plants. Nature 421:57-60.
Saavedra, C., and C. Freese. 1986. Prioridades biológicas de conservación en los Andes tropicales. Parks/Parques/Parcs 11:8-11.
Sarmiento, L., J. K. Smith, and M. Monasterio. 2002. Balancing conservation of biodiversity and economic profit in the high Venezuelan Andes: is fallow agriculture an alternative? Pp. 283-293 in Mountain biodiversity: a global assessment, edited by C. Körner and E. M. Spehn. London: Parthenon Publishing.
Torres Lozada, V. 2004. La agricultura peruana en los tiempos del TLC. Lima: Confederación Campesina del Perú. 16 pp. Available at: http://www.aprodeh.org.pe/tlc/documentos/victor_torres.pdf.
Travis, J. M. J. 2003. Climate change and habitat destruction: a deadly anthropogenic cocktail. Proceedings of the Royal Society of London B, Biological Sciences 270:467-473.
United Nations Office on Drugs and Crime. 2008a. World drug report 2008. United Nations Publication Nº E.08.XI.1. Vienna: United Nations Office on Drugs and Crime. 305 pp.
United Nations Office on Drugs and Crime. 2008b. Censo de cultivos de coca 2007. Bogotá: United Nations office on Drugs and Crime. 101 pp.

Van Noordwijk, M., J. G. Poulsen, and P. Ericksen. 2004. Quantifying off-site effects of land use change: filters, flows and fallacies. Agriculture, Ecosystems and Environment 104:19-34.

Weigend, M., N. Dostert, and E. Rodriguez-Rodriguez. 2006. Bosques relictos de los Andes peruanos: perspectivas económicas. Pp 130-145 in in Botánica económica de los Andes centrales, edited by M. Moraes R., B. Øllgaard, L. P. Kvist, F. Borchsenius, and H. Balslev. La Paz: Universidad Mayor de San Andrés.

Young, K. R. 2008. Stasis and flux in long-inhabited locales: change in rural Andean landscapes. Pp. 11-32 in Land-change science in the tropics: changing agricultural landscapes, edited by A. Millington and W. Jepson. New York: Springer.