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South American Natural Ecosystems, Status of

Philip M. Fearnside
National Institute for Research in the Amazon (INPA), Brazil

Abstract

The term ecoregion, as used in this article, refers to “natural” ecological systems, or terrestrial and aquatic areas as they were when Europeans first arrived in the New World. The original extent of natural ecoregions is presented, grouped by bioregion, major habitat type, and major ecosystem type. The definitions of these terms, given in the Glossary, are taken from Dinerstein *et al*. (1995); the rating codes are given in the footnotes to the table. Indications of the extent of remaining natural ecosystems, the threats to their continued existence, and the status of protected areas are discussed, together with priorities for conservation.

Keywords

Amazon
Biodiversity
Biological diversity
Biomes
Conservation
Deforestation
Ecosystems
Environment
Environmental impact
Rainforest
Savannas
Species diversity
Tropical forest

Wetlands

Glossary

Bioregion

One of six biogeographic divisions of South America consisting of contiguous ecoregions. Bioregions are delimited to better address the biogeographic distinctiveness of ecoregions.

Ecoregion

A geographically distinct assemblage of natural communities that share a large majority of their species and ecological dynamics, share similar environmental conditions, and interact ecologically in ways that are critical for their long-term persistence.

Ecosystem

A set of interacting living and nonliving components in a defined geographic space. Ecosystems include both plant and animal communities and the soil, water, and other physical elements of their environment.

Major ecosystem type

Groups of ecoregions that share minimum area requirements for conservation, response characteristics to major disturbance, and similar levels of β diversity (i.e., the rate of species turnover with distance).

Major habitat type

Groups of ecoregions that have similar general structure, climatic regimes, major ecological processes, β diversity, and flora and fauna with similar guild structures and life histories.

Original Extent of Terrestrial Ecosystems

Ecosystems can be classified in many ways, making the number of categories vary widely depending on the use intended. Here, the system adopted by Dinerstein *et al.* (1995) is used. This divides the continent into 95 terrestrial “ecoregions,” exclusive of mangroves. These are grouped into four “major ecosystem types:” tropical broadleaf forests, conifer/temperate broadleaf forests, grasslands/savannas/shrublands, and xeric formations. Within each of these categories are varying numbers of “major habitat types,” such as tropical moist broadleaf forests. These are further divided into nine “ bioregions.” Amazonian tropical moist forests, for example, is a bioregion.

The 95 ecoregions, with their hierarchical groupings, are presented in Table 1. Also included are the ratings for conservation status, biological distinctiveness, and biodiversity priority derived by Dinerstein *et al*. (1995). This study made a systematic survey of the status of natural ecosystems in Latin America and the Caribbean (LAC) and applied a uniform methodology to assigning priorities to these ecosystems for conservation efforts. The work was done for the United States Agency for International Development (USAID) by the WWF–US Biodiversity Support Program (BSP). The document is based on three workshops, plus consultations with relevant organizations and individual experts (the list of contributors contains 178 names).

Table 1.

Terrestrial ecoregions of South America

a.

Conservation status codes: 1, critical; 2, endangered; 3, vulnerable; 4, relatively stable; 5, relatively intact.

b.

Biological distinctiveness codes: 1, globally outstanding; 2, regionally outstanding; 3, bioregionally outstanding; 4, locally important.

c.

Biodiversity priority codes: I, highest priority at regional scale; II, high priority at regional scale; III, moderate priority at regional scale; IV, important at national scale.

Major ecosystem type	Major habitat type	Bioregion	Ecoregion name	Ecoregion number	Countries	Original area (km^2)	Conservation status a x Conservation status codes: 1, critical; 2, endangered; 3, vulnerable; 4, relatively stable; 5, relatively intact. a	Biological distinctiveness b x Biological distinctiveness codes: 1, globally outstanding; 2, regionally outstanding; 3, bioregionally outstanding; 4, locally important. b
Tropical broadleaf forests	Tropical moist broadleaf forests	Orinoco tropical moist forests	Cordillera La Costa montane forests	17	Venezuela	13,481	3	2
			Orinoco Delta swamp forests	18	Venezuela, Guyana	31,698	4	3
			Guianan Highlands moist forests	20	Venezuela, Brazil, Guyana	248,018	5	2
			Tepuis	21	Venezuela, Brazil,	49,157	5	1

Major ecosystem type	Major habitat type	Bioregion	Ecoregion name	Ecoregion number	Countries	Original area (km^2)	Conservation status[a]	Biological distinctiveness[b]
		Amazonian tropical moist forests			Guyana, Suriname, Colombia			
			Napo moist forests	22	Peru, Ecuador, Colombia	369,847	4	1
			Macarena montane forests	23	Colombia	2366	3	2
			Japurá/Negro moist forests	24	Colombia, Venezuela, Brazil	718,551	5	1
			Uatuma˜ moist forests	25	Brazil, Venezuela, Guyana	288,128	4	3
			Amapá moist forests	26	Brazil, Suriname	195,120	4	3
			Guianan moist forests	27	Venezuela, Guyana, Suriname, Brazil, French Guiana	457,017	4	3
			Paramaribo swamp forests	28	Suriname	7760	3	3
			Ucayali moist forests	29	Brazil, Peru	173,527	2	1
			Western Amazonian swamp forests	30	Peru, Colombia	8315	4	1
			Southwestern Amazonian moist	31	Brazil, Peru, Bolivia	534,316	4	1

[a] Conservation status codes: 1, critical; 2, endangered; 3, vulnerable; 4, relatively stable; 5, relatively intact.

[b] Biological distinctiveness codes: 1, globally outstanding; 2, regionally outstanding; 3, bioregionally outstanding; 4, locally important.

Major ecosystem type	Major habitat type	Bioregion	Ecoregion name	Ecoregion number	Countries	Original area (km^2)	Conservation status a x Conservation status codes: 1, critical; 2, endangered; 3, vulnerable; 4, relatively stable; 5, relatively intact. a	Biological distinctiveness b x Biological distinctiveness codes: 1, globally outstanding; 2, regionally outstanding; 3, bioregionally outstanding; 4, locally important. b
			forests					
			Juruá moist forests	32	Brazil	361,055	5	2
			Várzea forests	33	Brazil, Peru, Colombia	193,129	3	1
			Purús/Madeira moist forests	34	Brazil	561,765	4	4
			Rondônia/Mato Grosso moist forests	35	Brazil, Bolivia	645,089	3	2
			Beni swamp and gallery forests	36	Bolivia	31,329	4	4
			Tapajós/Xingu moist forests	37	Brazil	630,905	3	4
			Tocantins moist forests	38	Brazil	279,419	2	4
		Northern Andean tropical moist forests	Chocó/Darién moist forests	39	Colombia, Panama, Ecuador	82,079	3	1
			Eastern Panamanian montane forests	40	Panama, Colombia	2905	2	1
			Northwestern Andean montane forests	41	Colombia, Ecuador	52,937	2	1
			Western Ecuador moist forests	42	Ecuador, Colombia	40,218	1	2
			Cauca Valley montane forests	43	Colombia	32,412	1	1
			Magdalena Valley montane forests	44	Colombia	49,322	1	1

Major ecosystem type	Major habitat type	Bioregion	Ecoregion name	Ecoregion number	Countries	Original area (km^2)	Conservation status a Conservation status codes: 1, critical; 2, endangered; 3, vulnerable; 4, relatively stable; 5, relatively intact. [a]	Biological distinctiveness b Biological distinctiveness codes: 1, globally outstanding; 2, regionally outstanding; 3, bioregionally outstanding; 4, locally important. [b]
			Magdalena/Urabá moist forests	45	Colombia	73,660	2	3
			Cordillera Oriental montane forests	46	Colombia	66,712	3	1
			Eastern Cordillera Real montane forests	47	Ecuador, Colombia, Peru	84,442	3	1
			Santa Marta montane forests	48	Colombia	4707	3	2
			Venezuelan Andes montane forests	49	Venezuela, Colombia	16,638	2	1
			Catatumbo moist forests	50	Venezuela, Colombia	21,813	1	4
		Central Andean Tropical moist Forests	Peruvian Yungas	51	Peru	188,735	2	1
			Bolivian Yungas	52	Bolivia, Argentina	72,517	2	2
			Andean Yungas	53	Argentina, Bolivia	55,457	3	3
		Eastern South American tropical moist forests	Brazilian Coastal Atlantic forests	54	Brazil	233,266	1	1
			Brazilian interior Atlantic forests	55	Brazil	803,908	2	2
	Tropical dry broadleaf forests	Orinoco tropical dry forests	Llanos dry forests	74	Venezuela	44,177	2	4

Major ecosystem type	Major habitat type	Bioregion	Ecoregion name	Ecoregion number	Countries	Original area (km^2)	Conservation status[a]	Biological distinctiveness[b]
		Amazonian tropical dry forests	Bolivian Lowland dry forests	76	Bolivia, Brazil	156,814	1	1
		Northern Andean tropical dry forests	Cauca Valley dry forests	77	Colombia	5130	1	4
			Magdalena Valley dry forests	78	Colombia	13,837	1	4
			Patiá Valley dry forests	79	Colombia	1291	1	4
			Sinú Valley dry forests	80	Colombia	55,473	1	4
			Ecuadorian dry forests	81	Ecuador	22,271	1	1
			Tumbes/Piura dry forests	82	Ecuador, Peru	64,588	2	1
			Marañion dry forests	83	Peru	14,921	2	3
			Maracaibo dry forests	84	Venezuela	31,471	2	4
			Lara/Falcón dry Forests	85	Venezuela	16,178	2	4
		Central Andean tropical dry forests	Bolivian montane dry forests	86	Bolivia	39,368	1	3
Conifer/temperate broadleaf forests	Temperate forests	Southern South American temperate forests	Chilean winter rain Forests	87	Chile	24,937	2	2
			Valdivian temperate	88	Chile,	166,248	3	1

[a] Conservation status codes: 1, critical; 2, endangered; 3, vulnerable; 4, relatively stable; 5, relatively intact.

[b] Biological distinctiveness codes: 1, globally outstanding; 2, regionally outstanding; 3, bioregionally outstanding; 4, locally important.

Major ecosystem type	Major habitat type	Bioregion	Ecoregion name	Ecoregion number	Countries	Original area (km^2)	Conservation status a x Conservation status codes: 1, critical; 2, endangered; 3, vulnerable; 4, relatively stable; 5, relatively intact. a	Biological distinctiveness b x Biological distinctiveness codes: 1, globally outstanding; 2, regionally outstanding; 3, bioregionally outstanding; 4, locally important. b
			forests		Argentina			
			Subpolar *Nothofagus* forests	89	Chile, Argentina	141,120	3	3
	Tropical and subtropical coniferous forests	Eastern South American tropical and subtropical coniferous forests	Brazilian *Araucaria* forests	105	Brazil, Argentina	206,459	1	3
Grasslands/savannas/shrublands	Grasslands, savanas, and shrublands	Orinoco grasslands, savannas and shrublands	Llanos	110	Venezuela, Colombia	355,112	4	3
		Amazonian grasslands, savannas, and shrublands	Guianan savannas	111	Suriname, Guyana, Brazil, Venezuela	128,375	4	3
			Amazonian savannas	112	Brazil, Colombia, Venezuela	120,124	4	3
			Beni savannas	113	Bolivia	165,445	2	3
		Eastern South American grasslands, savannas, and shrublands	Cerrado	114	Brazil, Paraguay, Bolivia	1,982,249	3	1
			Chaco savannas	115	Argentina, Paraguay, Bolivia, Brazil	611,053	3	2
			Humid Chaco	116	Argentina,	474,340	3	4

Major ecosystem type	Major habitat type	Bioregion	Ecoregion name	Ecoregion number	Countries	Original area (km^2)	Conservation status[a]	Biological distinctiveness[b]
					Paraguay, Uruguay, Brazil			
			Córdoba montane savannas	117	Argentina	55,798	3	4
		Southern South American grasslands, savannas, and shrublands	Argentina monte	118	Argentina	197,710	4	3
			Argentina Espinal	119	Argentina	207,054	4	3
			Pampas	120	Argentina	426,577	2	3
			Uruguayan savannas	121	Uruguay, Brazil, Argentina	336,846	3	3
	Flooded grasslands	Orinoco flooded grasslands	Orinoco wetlands	128	Venezuela	6403	4	3
		Amazonian flooded grasslands	Western Amazonian flooded grasslands	129	Peru, Bolivia	10,111	4	3
			Eastern Amazonian flooded grasslands	130	Brazil	69,533	3	3
			Sa˜o Luis flooded grasslands	131	Brazil	1681	2	4
		Northern Andean flooded grasslands	Guayaquil flooded grasslands	132	Ecuador	3617	2	3
		Eastern South American flooded	Pantanal	133	Brazil, Bolivia, Paraguay	140,927	3	1

[a] Conservation status codes: 1, critical; 2, endangered; 3, vulnerable; 4, relatively stable; 5, relatively intact.

[b] Biological distinctiveness codes: 1, globally outstanding; 2, regionally outstanding; 3, bioregionally outstanding; 4, locally important.

Major ecosystem type	Major habitat type	Bioregion	Ecoregion name	Ecoregion number	Countries	Original area (km^2)	Conservation status[a]	Biological distinctiveness[b]
		grasslands						
			Paraná flooded savannas	134	Argentina	36,452	2	3
	Montane grasslands	Northern Andean montane grasslands	Santa Marta paramo	137	Colombia	1329	3	1
			Cordillera de Mérida paramo	138	Venezuela	3518	4	1
			Northern Andean paramo	139	Ecuador	58,806	3	1
		Central Andean montane grasslands	Cordillera Central paramo	140	Peru, Ecuador	14,128	3	1
			Central Andean wet puna	141	Bolivia, Argentina, Peru, Chile	183,868	3	2
			Central Andean wet puna	142	Chile	188,911	3	2
			Central Andean dry puna	143	Argentina, Bolivia, Chile	232,958	3	2
		Southern South American montane grasslands	Southern Andean steppe	144	Argentina, Chile	198,643	4	4
			Patagonian steppe	145	Argentina, Chile	474,757	3	2
			Patagonion grasslands	146	Argentina, Chile	59,585	3	3

[a] Conservation status codes: 1, critical; 2, endangered; 3, vulnerable; 4, relatively stable; 5, relatively intact.

[b] Biological distinctiveness codes: 1, globally outstanding; 2, regionally outstanding; 3, bioregionally outstanding; 4, locally important.

Major ecosystem type	Major habitat type	Bioregion	Ecoregion name	Ecoregion number	Countries	Original area (km^2)	Conservation status a x Conservation status codes: 1, critical; 2, endangered; 3, vulnerable; 4, relatively stable; 5, relatively intact. a	Biological distinctiveness b x Biological distinctiveness codes: 1, globally outstanding; 2, regionally outstanding; 3, bioregionally outstanding; 4, locally important. b
Xeric formations	Mediterranean scrub	Central Andean Mediterranean scrub	Chilean matorral	148	Chile	141,643	2	1
	Deserts and xeric shrublands	Orinoco deserts and xeric shrublands	La Costa xeric shrublands	168	Venezuela	64,379	2	4
			Arayua and Paría xeric Scrub	169	Venezuela	5424	2	3
		Northern Andean deserts and xeric Shrublands	Galapagos Islands xeric scrub	170	Ecuador	9122	3	1
			Guajira/Barranquilla xeric scrub	171	Colombia, Venezuela	32,404	2	3
			Paraguná xeric scrub	172	Venezuela	15,987	2	3
		Central Andean deserts and xeric shrublands	Sechura Desert	173	Peru, Chile	189,928	3	3
			Atacama Desert	174	Chile	103,841	3	3
		Eastern South American deserts and xeric shrublands	Caatinga	175	Brazil	752,606	3	3
	Restingas	Northern Andean restingas	Paranaguá restingas	176	Venezuela	15,987	2	2
		Amazonian restingas	Northeastern Brazil restingas	177	Brazil	10,248	1	1
		Eastern South American	Brazilian Atlantic coast restinga	178	Brazil	8740	1	1

Major ecosystem type	Major habitat type	Bioregion	Ecoregion name	Ecoregion number	Countries	Original area (km^2)	Conservation status[a]	Biological distinctiveness[b]
		restingas						

[a] Conservation status codes: 1, critical; 2, endangered; 3, vulnerable; 4, relatively stable; 5, relatively intact.

[b] Biological distinctiveness codes: 1, globally outstanding; 2, regionally outstanding; 3, bioregionally outstanding; 4, locally important.

The classification system is hierarchical, starting with four “major ecosystem types” (e.g., Tropical Broadleaf Forests), which are divided into 10 “major habitat types” (e.g., Tropical Moist Broadleaf Forests). These are crossed with six bioregions (e.g., Amazonia) and divided into 95 ecoregions (e.g., Rondônia/Mato Grosso moist forests). The system allows the priority of some ecoregions to be promoted upward based on uniqueness and regional representation, even if indicators of diversity and vulnerability are not so high.

The effort was unusual in emphasizing protection of areas with high β diversity (a measure of the turnover of species along ecological gradients), as well as the more commonly used α diversity (species diversity within a habitat). In the case of mangroves, the diversity assessed is ecosystem diversity, including aquatic animal life. This avoids mangroves receiving the unjustly low diversity ratings that tend to result when assessments are restrained to terrestrial organisms, especially trees.

Although the ecoregions identified in Table 1 refer to “natural” (pre-Columbian) ecosystems, it should be emphasized that these had already been subject to millennia of influence by indigenous peoples prior to the arrival of Europeans. This influence continues today, together with much more rapid alterations from such activities as deforestation and logging done by nonindigenous residents. “South America” is taken to include the three Guianas (different from usage by the Food and Agriculture Organization of the United Nations (FAO)) and to exclude Panama (however, in the case of ecoregions that extend into Panama, the area estimates in Table 1 include the Panamanian portions). The ecoregions are mapped in Figure 1. The ecoregion numbering corresponds to Table 1 and also to the report by Dinerstein *et al.* (1995); the numbering presented here is not continuous, since the report also includes ecoregions in Mexico, Central America, and the Caribbean. Extensive bibliographic material on the delimitation of the ecoregions and on the state of knowledge about them can be found in Dinerstein *et al.* (1995).

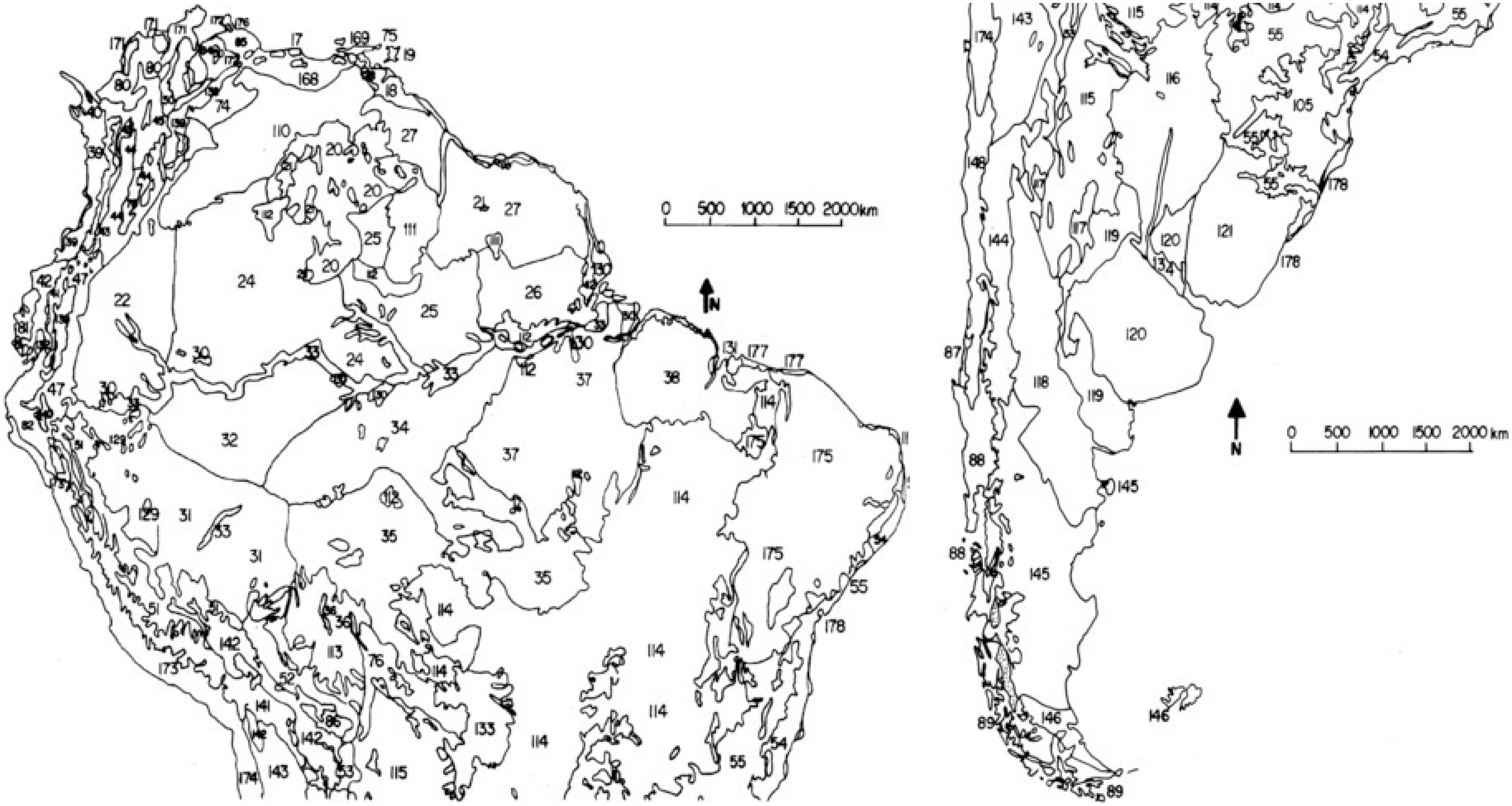

Figure 1. Ecoregions for pre-Columbian vegetation of South America. Numbers correspond to Table 1.

Mangroves occur along the coasts of Brazil, the three Guianas, Venezuela, Colombia, Ecuador, and northern Peru. Dinerstein *et al*. (1995) divide them into five complexes: Pacific South America, Continental Caribbean, Amazon–Orinoco–Maranha˜o, Northeast Brazil, and Southeast Brazil. Each complex is further subdivided into 2–5 units, corresponding to distinct segments of coastline. Mangroves are essential to maintain populations and ecological processes in surrounding marine, freshwater, and terrestrial ecosystems.

Present Extent of Terrestrial Ecosystems

Unfortunately, information is not available on the present extent of each of the 95 ecoregions listed in Table 1. Information on the extent of tropical forests in approximately 1990 is available from the FAO Tropical Forest Resources Survey (FAO, 1993). These data are tabulated by country in Table 2. More recent FAO reports (e.g., FAO, 2015) provide national data for forests and for woodlands, but without distinguishing between the various groups of ecosystems (such as tropical forest). Forest types are separated in national reports for some countries, including Brazil (FAO, 2014). Nontropical areas are covered by a variety of national surveys (Harcourt and Sayer, 1996). National data are important because decisions regarding land-use policies and conservation are taken at the national level – not at the levels of bioregions or ecosystem types. Over half of the South American continent is represented by a single country: Brazil (Figure 2).

Table 2.

Area of tropical forest present in 1990 (km^2)

a.

Includes cerrado, caatinga, and chaco.

Country	Tropical rain forests	Moist deciduous forest	Dry deciduous forest a x Includes cerrado, caatinga, and chaco. [a]	Very dry forest	Desert Desert	Hill and montane forest	All forests a x Includes cerrado, caatinga, and chaco. [a]
Bolivia	0	355,820	73,460	0	40	63,850	493,170
Brazil	2,915,970	1,970,820	288,630	0	0	435,650	5,611,070
Colombia	474,550	41,010	180	0	0	24,900	540,640
Ecuador	71,500	16,690	440	0	0	31,000	119,620
French Guiana	79,930	30	0	0	0	0	79,970
Guyana	133,370	31,670	0	0	0	19,120	184,160
Paraguay	0	60,370	67,940	0	0	270	128,590
Peru	403,580	122,990	190	2690	1840	147,770	679,060
Suriname	114,400	33,280	0	0	0	0	147,680
Venezuela	196,020	154,650	2220	1	0	103,900	456,910
Total	4,389,320	2,787,330	433,060	2691	1880	826,460	8,440,870

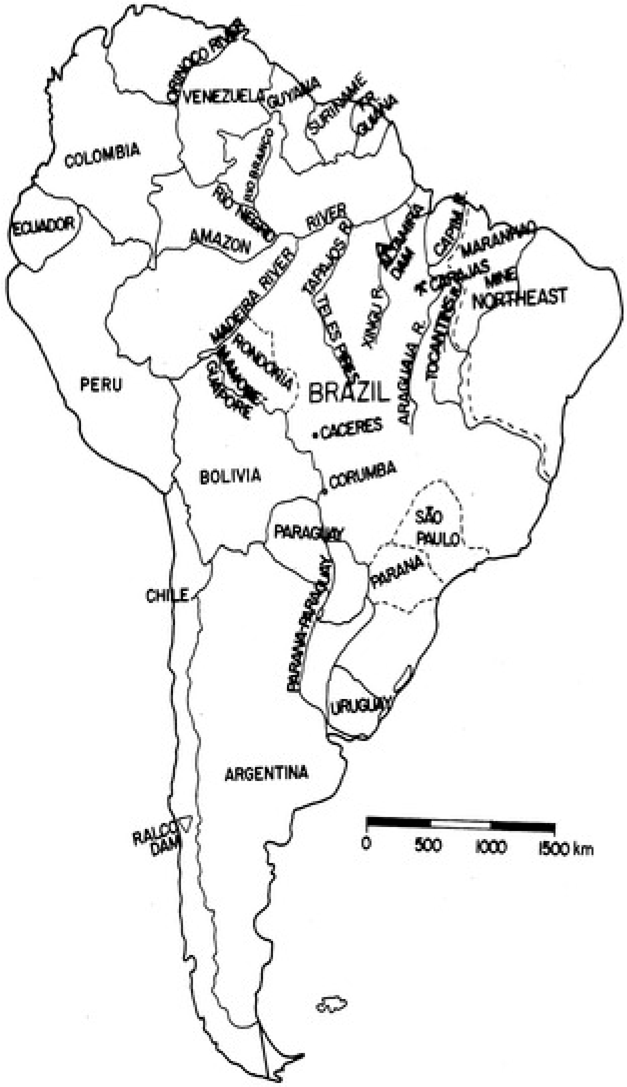

Figure 2. Locations mentioned in the text.

An idea of the extent of existing ecosystems can be gained from measurements of land cover in 1988 made using 1×1 km resolution data from the AVHRR sensor on the NOAA satellite series (Stone *et al.*, 1994). These are tabulated in Table 3.

Table 3.

Land cover in South America in 1988

Country	Closed tropical moist forest	Recently degraded TMF	Closed forest	Degraded closed forest	Woodlands	Degraded woodlands	Savanna, grasslands	Degraded savanna, grasslands	Scrublands, Shrublands	Desert, bare soil	Water	Snow, rock, ice	Other	Total
Argentina	1.2	0.0	96.8	0.6	645.4	15.7	755.4	232.8	894.8	37.9	34.0	31.4	35.7	2779.8
Bolivia	323.5	12.7	409.2	24.6	345.1	102.2	87.7	86.2	4.8	16.5	11.9	0.1	1.1	1089.4
Brazil	3522.3	519.7	3686.0	1692.2	1555.9	330.0	740.0	179.4	0.0	0.0	80.9	0.0	124.0	8388.5
Chile	0.0	0.0	134.1	29.1	75.2	29.8	101.1	14.0	86.9	186.8	7.0	16.6	3.8	684.5
Colombia	581.6	5.4	622.5	11.4	116.3	14.5	255.5	64.0	0.0	0.0	3.1	0.0	22.8	1110.1
Ecuador	115.5	1.7	121.0	1.7	33.7	4.3	41.9	13.3	3.2	2.5	0.6	0.0	0.8	223.1
French Guiana	78.8	0.0	79.8	2.4	0.6	0.0	0.2	0.0	0.0	0.0	0.1	0.0	1.0	84.1
Guyana	159.4	2.0	171.6	2.4	5.4	0.3	18.4	1.5	0.0	0.0	1.2	0.0	3.7	204.3
Paraguay	0.3	0.0	8.9	0.2	209.1	50.7	104.0	26.5	0.0	0.0	0.6	0.0	1.1	401.1
Peru	620.8	19.1	654.7	19.1	88.0	78.8	139.0	97.4	64.3	88.0	8.3	0.7	5.6	1244.1
Suriname	126.0	2.5	128.5	10.0	0.5	0.3	1.2	0.4	0.0	0.0	1.1	0.0	3.3	145.2
Uruguay	1.4	0.0	2.1	0.0	0.9	0.0	154.1	11.0	0.0	0.0	3.0	0.0	5.9	177.0
Venezuela	379.1	0.2	415.5	9.9	33.9	40.2	243.3	82.0	27.2	0.0	11.4	0.0	8.4	871.8
Unclassified														313.0
Total	5909.9	563.4	6530.7	1803.7	3109.8	666.9	2642.0	808.5	1080.6	331.7	163.2	48.9	217.2	17,716.1
Continent (%)	33.4	3.2	36.9	10.2	17.6	3.8	14.9	4.6	6.1	1.9	0.9	0.3	1.2	
Category (%)		8.7		21.6		17.7		23.4						100.0

Note: All values in thousands of km^2 or percent. “TMF” includes tropical moist, semideciduous, and gallery forests, “ Grasslands” includes those seasonally flooded, “Closed Forest” includes TMF, montane forests, cool and temperate deciduous forests, and tropical seasonal forests, “Degraded Grasslands” includes agriculture, “Desert, Bare Soil” includes inland salt marsh communities, and “Other” includes wet vegetation and mangroves. More recent land-cover maps for South America are available, but without tabulation by country (

Eva *et al*., 2004; Arino *et al*., 2008; Tateishia *et al*., 2008 x
Eva. et al., 2004
Arino et al., 2008
Tateishia et al., 2008

Eva *et al*., 2004; Arino *et al*., 2008; Tateishia *et al*., 2008).

It should be emphasized that many ecosystems can be heavily disturbed by logging and other activities without the change being evident on satellite imagery. This is true for Landsat TM imagery (30×30 m resolution) used for deforestation estimates in Brazil, and the limitations are much greater for 1×1 km AVHRR data.

Brazil is the country with the most extensive satellite information on forest cover and its loss. Unfortunately, information on nonforest vegetation types such as cerrado is much less complete. Considerable confusion arises between the FAO classification and others such as the one adopted here because FAO classifies cerrado, caatinga, and chaco as "forests." FAO classifies areas with only 10% crown cover as "forests" if the trees are 5 m high or if it has "trees able to reach these thresholds *in situ*" (FAO, 2012, p. 3).

Brazil's Legal Amazon region originally had 4 million km^2 of forests, the rest being cerrado and other types of savannas. Agricultural advance was slow until recent decades because of human diseases (especially yellow fever and malaria), infertile soil, and vast distances to markets. These barriers have progressively crumbled, although a range of limiting factors restricts the extent and the duration over which many uses of deforested areas can be maintained (Fearnside, 1997a). Deforestation in the region has been predominantly for cattle pasture, with critical contributions to the motivations for the transformation coming from the role of clearing as a means of establishing land tenure and in allowing land to be held and sold for speculative purposes (Fearnside, 2005, 2008).

Fearnside, 2005, 2008 x
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The Atlantic forests of Brazil (ecoregions 54 and 55) have been almost completely (>95%) destroyed, mainly for agriculture, silviculture, and real estate development. Most of what remains of this extraordinarily rich ecosystem is in protected areas, but unprotected areas continue in rapid retreat. These forests are recognized as major "hot spots" of biodiversity (

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In Andean countries, clearing by small farmers has predominated in driving deforestation, in contrast to the predominant role of medium and large cattle ranchers in Brazil. Migration from densely populated areas in the Andean highlands (*altiplano*) has led to settlement in lowland forests areas, with consequent upsurges in clearing (e.g., Rudel and Horowitz, 1993).

Savanna ecosystems have suffered heavy human pressure. The pampas of Argentina and the Uruguayan savannas of Uruguay and Southern Brazil (ecoregions 120 and 121) have largely been converted to agriculture. The Brazilian cerrado, originally covering 2 million km^2, is the largest ecoregion in South America, as well as holding the largest number of species of any of the world's savannas. The cerrado was largely intact until the mid-1970s. Clearing, especially for soybeans and planted pasture, reduced the cerrado to 55% of its original area by 2002 according to MODIS imagery (Klink and Machado, 2005). An official estimate for 2015 (projected from 2013 data) corresponds to only 44% of the cerrado biome remaining uncleared (FAO, 2014,p. 20). The advance of clearing has proceeded at an accelerating pace, speeded by infrastructure projects and an array of government subsidies.

The temperate and coniferous forests of the Southern Cone have been under severe pressure from logging. These forests are usually logged by clear-cutting in a manner similar to their counterparts in the North American temperate zone. This contrasts with the “selective” logging (highgrading for a few species) that characterizes timber extraction from the diverse forests of the tropical region.

Human Use of Converted Areas

Conversion of natural ecosystems to agroecosystems and secondary forests creates landscapes that maintain biodiversity to varying degrees. “Shifting cultivation” as practiced by indigenous peoples and by traditional nonindigenous residents (*caboclos*) in Amazonian forests maintains a substantial part of the original biodiversity. This contrasts with the effect of the vast expanses of cattle pasture that have replaced this, either directly or following a phase of use in pioneer agriculture by small farmers who have recently arrived from other places.

In densely settled areas along the coast of Brazil and in the southern portions of the country, agricultural use has gone through a series of “cycles,” such as sugarcane and coffee. The productivity of many areas has been damaged by soil erosion and other forms of degradation. Cattle pasture is often the land use replacing these crops. Plantation silviculture has grown steadily since the 1970s and covered more than 82,276 km^2 by 2012 (FAO, 2014, p. 23). Soybeans (207,000 km^2 in 2008) have also made large advances.

In Argentina and Uruguay, cattle ranching and wheat and rice farming are major land uses. Natural vegetation is better represented in areas with little agricultural potential, such as mountain and polar areas and arid and semiarid zones.

Human Use of Remaining Natural Habitats

Areas that remain under natural vegetation cover, rather than being converted to other land uses through clearing, are also subject to human use and alteration. Selective logging in tropical forests, for example, leaves much of the basic structure of the ecosystem intact, but also can lead to significant changes that can set in motion a sequence of events leading to complete destruction of the ecosystem. Logging leaves a substantial amount of dead biomass in the forest, including the crowns and stumps of harvested trees and all of the biomass of the many additional trees that are killed by damage sustained during the logging process. Openings created in the canopy allow sunlight and heat to penetrate to the forest floor, drying out the fuel bed more quickly than in unlogged forests. Climatic variations such as those provoked by the El Niño phenomenon make logged forests especially susceptible to entry of fires. Ample opportunities for fires are provided as fields are burned to prepare land for planting and as cattle pastures are burned to control invading weeds. The fires burn slowly through the understory, charring the bases of trees as they go. Many of these trees then die, leading to a positive-feedback process whereby more dead biomass and canopy openings are provided and subsequent fires begin with greater ease, killing still more trees. This can degrade the entire forest within a few years (Nepstad *et al.*, 2001).

Tropical forests are also used for “extractivism,” or the collection of nontimber forest products (NTFPs) such as rubber and Brazil nuts. This does relatively little damage to the forest, although extractivists do have an impact through hunting and through clearing for subsistence crops. The extractivist population can also play a protective role in defending the forest against encroachment by more aggressive actors such as ranchers and loggers. This is the basis of the extractive reserve system in Brazil (see Anderson, 1990).

Savannas are often grazed by cattle without cutting trees. Cerrado (ecoregion 114), “ lavrado,” or Guianan savannas (ecoregion 111), the Pantanal wetlands (ecoregion 133), and the llanos of Venezuela (ecoregion 110) are among the savannas often used in this way. Increasing fire frequency, virtually all a result of human-initiated burning, can lead to shifts in species composition and to a drain of nutrients.

Aquatic ecosystems are traditionally exploited by fisheries. This alters the relative abundance of the species present. Use of watercourses as recipients for sewage and other pollutants also affects aquatic life in many ways.

Threats to Remaining Natural Habitats

Terrestrial Ecosystems

Deforestation

Deforestation is the dominant transformation of forested ecosystems that threatens biodiversity. In Brazil, which holds most of the continent's remaining forests, ranching is the dominant use for land once deforested. In the 1990s, soybeans began to enter forested regions, representing a new force in this process (Fearnside, 2001a).

Soybeans had already been a major factor in transformation of the cerrado since the 1970s. The most important effect of soybeans is not loss of forest directly planted to the crop, but the extensive infrastructure of waterways, railways, and highways that are built to transport soybeans and the inputs needed to grow them. The cycle of deforestation that has repeatedly occurred along Amazonian highways can be expected to accompany these new access routes (Fearnside, 2007).

Population growth is a fundamental contributor to deforestation and other forms of natural habitat loss. In recent years, however, the redistribution of population through migration has overshadowed the impact of absolute growth in population size. These include migrations from the semiarid Northeast of Brazil to Amazonia, from Paraná to Rondônia, from the highlands of Bolivia, Peru, and Ecuador to the Amazonian lowlands and, in the case of Ecuador, to the Pacific lowlands as well.

Deforestation rates in Brazilian Amazonia have undergone major swings since regular satellite monitoring began in 1988. These have been in response to shifts in the country's economy, with peaks in 1988, 1995 and 2005. Deforestation rates declined significantly from 2005 to 2012 and oscillated around the lower plateau through 2015. Most of the most recent decline was in the 2005-2008 period, when virtually all of the change can be explained by falling commodity prices (Assunção *et al.*, 2012). Slower clearing since 2008 reflects government repression programs, which owe their added effectiveness to a 2008 ruling by the Brazilian Central Bank making absence of pending environmental fines a condition for loans from government banks (Fearnside, 2015). This is a fragile and easily reversed protection, and underlying drivers of deforestation, such as road construction, population and investment, are all increasing.

Logging and Charcoal Manufacture

Logging is an increasingly important factor in Amazonia, and the catalytic role of this activity in increasing the flammability of the logged forest gives it potential impact far beyond its direct damage. So far, logging in Brazil has been dominated by domestic demand for sawn wood, plywood, and particleboard, which is almost entirely supplied from tropical forests rather than from silvicultural plantations (which produce wood for pulp and, to a lesser extent, charcoal). However, global markets for tropical timber are presently dependent on supplies from Asian forests that will soon come to an end if current rates of exploitation continue. In the 1990s, Asian logging companies began buying land and/or obtaining concessions in such countries as Brazil, Guyana, and Suriname, and pressure from global timber markets can be expected to increase in the future. Asian loggers are also the principal forces in clear-cutting the Valdivian and *Nothofagus* forests of Chile (ecoregions 88 and 89).

In eastern Amazonia, demand for charcoal for pigiron smelting in the Carajás area is a potential threat to forests. Carajás, with the world's largest deposit of high-grade iron ore, is expected to be mined for 400 years at the present rate of exploitation. Wood from native forests is inherently cheaper as a source of biomass for charcoal production as compared to plantation-grown sources. Charcoal manufacture has an impact on the forest both through direct removal (including officially sanctioned forestry management systems) and by increasing the profitability of logging and deforestation (see Anderson, 1990).

Deforestation impacts are magnified by fragmentation and edge effects (Laurance and Bierregaard, 1997). This division of the remaining natural habitat into many small islands surrounded by cattle pastures or other highly modified land uses, together with forming edges with increased entry of light, wind, and foreign organisms, results in many changes in the remaining natural ecosystems. Most of these changes are forms of degradation, such as greatly increased mortality in the trees that provide the dominant component of forest structure. Vine loads on trees near edges also increase, leading to further increase in mortality and susceptibility to windthrow (Laurance *et al.*, 2014a).

Other Threats

Climate change represents a major long-term threat to many South American ecosystems (Fearnside, 2015). In addition to higher temperatures, continued global warming would cause dramatic increases in the frequency and severity of droughts in Amazonia both due to the El Niño phenomenon that is triggered by warming of surface water in the Pacific Ocean (Lehmann, 2015) and due to even faster increases in the frequency of sea-surface temperature anomalies in the Atlantic Ocean such as the one that caused a disastrous drought in 2005 (Cox *et al.*, 2008).

The extent to which projected climate changes constitute threats to Amazonian forests is uncertain. Early simulations indicated catastrophic dieoff with double the pre-industrial atmospheric CO_2 concentration (2 × CO_2) (Cox *et al.*, 2004) have now been joined by a revised model by the same modeling group indicating the forest resisting up to 4 ×CO_2 without major dieoff (Good *et al.*, 2013). The principal change is ascribed to incorporating CO_2 “fertilization” effects, reducing the water demands of trees and increasing their growth and resilience (Huntingford *et al.*, 2013). However, key features of Amazonian forests are omitted from the models, such as the impact of lianas, which benefit more than trees from increased CO_2, as well as being favored by predicted drier conditions. Lianas are increasing in Amazonian forests, presumably as a result of the higher atmospheric CO_2 concentrations already present, and are killing trees, especially in the dryer areas near forest edges (Laurance *et al.*, 2014a,b). Forest fires, which are also expected to increase due both to climate change and to increased human presence, is another factor not included in the models; fires kill trees irrespective of CO_2 fertilization.

Removal of fauna through hunting is a virtually universal consequence of proximity of human settlements to natural habitats. The removal of fauna can affect seed dispersal, pollination, and other processes needed for maintaining plant and animal communities. Introduction of exotic species also represents a threat to natural ecosystems. Exotic species are a particularly severe problem in the Valdivian and *Nothofagus* forests of Chile (ecoregions 88 and 89).

Mangrove ecosystems are subject to some unique threats. Shrimp culture in mangrove areas has had severe impacts on the coast of Ecuador. Mangroves in Maranha˜o have been subject to pressure for charcoal manufacture. In Sa˜o Paulo state mangroves have often suffered from oil spills and are also losing ground to real estate development. This has also affected restingas (ecoregions 176–178).

Aquatic Ecosystems

Dams

Hydroelectric dams have major impacts on river ecosystems by blocking fish migration, by eliminating rapids and replacing well-oxygenated running water with reservoirs that usually have anoxic water in their lower layers. The composition of fish present changes radically and undergoes a succession of changes as reservoirs age. Anoxic water released through the turbines severely reduces fish and freshwater shrimp productivity in the rivers downstream of the dams (Fearnside, 2001b).

In Brazil, the 2010 Plan, released in 1987, listed more than 300 dams for eventual construction in Brazil, independent of the expected date of completion. Of these, 65 dams were in the Amazon region. Economic difficulties have caused projected construction dates to be successively postponed, but the ultimate number of dams has remained essentially unchanged (Fearnside, 2016). Most contentious is the Babaquara Dam (renamed the “Altamira Dam”) on the Xingu River, which would flood greater than 6000 km^2 of forest, much of it in indigenous areas (Fearnside, 2006).

In Chile, the dams planned in Patagonia, together with their transmission line to Santiago, are expected to have major environmental impacts. In Uruguay, at least five major dams are planned for construction in the next few years. Brazilian-financed dams are moving forward in Peru, Bolivia, and Guyana.

Waterways

Industrial waterways, known as *hidrovias* in Brazil, greatly alter aquatic habitats. No less than seven waterways are under construction or planned for soybean transport on barges: the Paraguay–Paraná (*Hidrovia do Pantanal*), the Madeira River waterway, the Tocantins-Araguaia waterway, the Teles Pires–Tapajós waterway, the Capim River waterway, the Mamoré–Guaporé waterway, and the Rio Branco and Rio Negro–Orinoco waterways. Waterway construction involves blasting rock obstructions, cutting sharp curves, and dredging sediment from the river beds. The Corumbá–Cáceres stretch of the *Hidrovia do Pantanal*, if built, would lower the water level in the Pantanal wetlands (ecoregion 133), threatening one of the world's most renowned concentrations of wildlife.

Other Threats

Other threats to aquatic habitats include sedimentation from soil erosion and landslides. This is severe, for example, in rivers draining steep areas of former Atlantic forest in the coastal mountains of Brazil. Mining for gold, tin, and diamonds in Amazonia can also inject large amounts of sediment into streams and rivers.

Destruction of varzea forest (ecoregion 33) in Amazonia can affect aquatic life through loss of important fish breeding areas and food sources for fruit- and seed-eating fish. Destruction of varzea lakes and overfishing represent additional threats.

Status of Protected Areas

The choice and design of reserves depend on the financial costs and biodiversity benefits of different strategies. In Brazil, rapid creation of lightly protected “paper parks” has been a means of keeping ahead of the advance of barriers to establishment of new conservation units, but emphasis must eventually shift to better protection of existing reserves (Fearnside, 1999).

Creating reserves that include human occupants has a variety of pros and cons (Kramer *et al.*, 1997). Although the effect of humans is not always benign, much larger areas can be brought under protection regimes if human occupants are included (Fearnside, 2003). Additional considerations apply to buffer zones around protected areas. A “fortress approach,” whereby uninhabited reserves are guarded against encroachment by a hostile population in the surrounding area, is believed to be unworkable as a means of protecting biodiversity, in addition to causing injustices for many of the human populations involved.

Priorities for Conservation

Indigenous peoples have the best record of maintaining forest, but negotiation with these peoples is essential in order to ensure maintenance of the large areas of forest they inhabit (Fearnside and Ferraz, 1995). The benefits of environmental services provided by the forest must accrue to those who maintain these forests. Development of mechanisms to capture the value of these services will be a key factor affecting the long-term prospects of natural ecosystems.

In the case of deforestation in Amazonia, a variety of measures could be taken immediately through government action, including changing land tenure establishment procedures so as not to reward deforestation, revoking remaining incentives, restricting road building and improvement, strengthening requirements for environmental impact statements for proposed development projects, creating employment alternatives, and, in the case of Brazil, levying and collecting taxes that discourage land speculation. A key need is for a better informed process of making decisions on building roads and other infrastructure such that the full array of impacts is taken into account.

Environmental services represent a major value of natural ecosystems, and mechanisms that convert the value of these services into monetary flows that benefit the people who maintain natural habitats could significantly influence future events in the region (Fearnside, 1997b). Environmental services of tropical forests include maintenance of biodiversity (Fearnside, 1999), carbon stocks (Nogueira *et al*., 2015), and water cycling (Arraut *et al*., 2012). The water cycling function, although very important for countries in the region, does not affect other continents as the first two services do. At present, avoiding global warming by keeping carbon out of the atmosphere represents a service for which monetary flows are much more likely to result from international negotiations. Activities under the United Nations Framework Convention on Climate Change (UN-FCCC) are at a much more advanced stage of negotiation than is the case either for the Biodiversity Convention or for the “Non-Binding Statement of Principles” and possible future convention on forests.

In the case of carbon, major decisions regarding credits for tropical forest maintenance are pending in ongoing negotiations (Fearnside, 2012a,b). Regardless of what is decided, global warming is a permanent consideration that can be expected to receive increasing weight in decision making. The threats to natural ecosystems in South America are many, and recognition of the multiple environmental services provided by them is a key factor in ensuring that substantial areas of each of these ecosystems continue to exist, thereby maintaining their biodiversity.

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See also

Deforestation and Land Clearing. Fires, Ecological Effects of. Grazing, Effects of. Indigenous Peoples and Biodiversity. Rainforest Loss and Change

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