Annex 1 – Detailed tables of poverty and population in different land-uses

Poverty per Ecosystem and per country												
	Unsatisfied Basic Needs (%)						*Infant Mortaliy (no. per 1000)*					
	N	Mean	Std	CV	Min	Max	N	Mean	Std	CV	Min	Max
Bolivia												
Savanna	461	41.8	22.9	54.8	0	70	461	60.1	11.3	18.7	47	70
Dry Forest	1520	54.4	25.6	47	0	95	1520	59.1	10.5	17.7	47	86
Montane Grasslands	804	68.4	21.3	31.1	11	95	804	67.8	11.1	16.4	59	86
Montane Forests	759	59.4	18	30.2	0	92	759	60.5	7.1	11.7	47	70
Varzea	5	19	0	0	19	19	5	48.6	11.5	23.7	36	57
Moist Forests	538	56.5	13.3	23.6	0	80	538	63.5	9.2	14.5	36	70
Total Bolivia	4087	56.9	23.1	40.5	0	95	4087	61.8	10.5	17.1	36	86
Brazil												
Savanna	7057	12.8	5.8	45.6	0	24	7057	27.7	8.7	31.5	12	58
Dry Forest	2605	13.5	6.8	50.1	0	24	2605	35	7.9	22.5	20	64
Guianan Mangroves	537	16.6	8.4	50.8	0	24	537	45.2	13.2	29.1	22	80
Varzea	2469	18.3	7.5	40.8	0	66	2469	29.6	5.9	19.9	14	57
Moist Forests	12441	14.5	8.5	58.7	0	66	12441	36.3	12.5	34.3	12	80
Guyananan ecosystems	17	4.5	5.6	123.2	0	11	17	33	0	0	33	33
Total Brazil	25126	14.3	7.7	53.9	0	66	25126	33.3	11.4	34.2	12	80
Colombia												
Savanna	15	10.9	1.7	15.3	6	12	15	27	0	0	27	27
Dry Forest	177	9	1.9	21.3	6	13	177	27	0	0	27	27
Montane Grasslands	22	7.6	3.5	45.5	5	13	22	28.8	3.2	11	21	30
Montane Forests	252	8.4	2.9	34	4	13	252	26.6	4.3	16	21	32
Varzea	6	16	3.1	19.4	12	18	6	39.3	12	30.6	21	47
Moist Forests	411	10.6	2.7	25	0	18	411	23.3	5.4	23.4	18	47
Total Colombia	883	9.6	2.8	29.5	0	18	883	25.3	5	19.7	18	47
Ecuador												
Montane Grasslands	929	11.2	3.4	30.6	4	18	929	37.1	10.2	27.6	18	52
Montane Forests	726	11	3.3	29.8	0	17	726	32.5	4.8	14.8	24	52
Moist Forest	241	9.6	6.1	63.6	0	17	241	32.8	3.4	10.3	32	47
Total Ecuador	1896	10.9	3.8	35.3	0	18	1896	34.8	8.2	23.5	18	52
Perú												
Dry Forest	854	14.1	2.1	14.8	9	17	854	44.2	6.1	13.8	29	50
Montane Grasslands	2548	13.9	2.9	21	5	18	2548	51.8	8.5	16.4	22	63
Montane forests	5173	13.9	2.8	19.9	5	88	5173	50.8	8.3	16.3	32	63
Varzea	314	14.1	2.9	20.8	11	21	314	49.1	4.5	9.1	14	54
Moist Forests	1484	13.7	3.4	25	0	66	1484	43.8	8.7	19.8	14	67
Total Perú	10373	13.9	2.9	20.6	0	88	10373	49.4	8.7	17.6	14	67
ALL COUNTRIES												
Savanna	7535	14.6	10.6	72.7	0	70	7535	29.7	11.8	39.8	12	70
Dry Forest	5156	25.5	23.8	93.2	0	95	5156	43.3	13.7	31.6	20	86
Montane Grasslands	4303	23.5	23.6	100.7	4	95	4303	51.5	13.6	26.5	18	86
Montane Forests	6910	18.4	15.9	86.5	0	92	6910	49.1	11.1	22.7	21	70
Mangroves	537	16.6	8.4	50.8	0	24	537	45.2	13.2	29.1	22	80
Varzea	2794	17.9	7.2	40.5	0	66	2794	31.8	8.5	26.6	14	57
Moist Foress	15118	15.7	11.4	72.6	0	80	15118	37.6	13.2	35.1	12	80
Guyananan ecosystems	17	4.5	5.6	123.2	0	11	17	33	0	0	33	33
TOTAL	**42370**	**18.1**	**15.9**	**87.8**	**0**	**95**	**42370**	**39.9**	**14.5**	**36.3**	**12**	**86**

Population 1960 - 2000 in different ecosystems and countries											
	1960		*1970*		*1980*		*1990*		*2000*		*% Growth*
	N	Sum	N	Sum	N	Sum	N	Sum	N	Sum	
Bolivia											
Moist forest	185	69956	185	82955	185	92154	185	118895	185	162592	132
Savanna	27	12677	27	14441	27	14361	27	19010	27	25690	103
Varzea	4	9	4	14	4	23	4	26	4	34	278
Total	216	82642	216	97410	216	106538	216	137931	216	188316	128
Brazil											
Dry forest	1038	367729	1038	469157	1038	631313	1038	808331	1038	1078350	193
Guayanan ecosystems	23	1118	23	848	23	1630	23	2529	23	5177	363
Mangroves	358	83012	358	82859	358	121217	358	164485	358	195416	135
Moist forest	5108	3618183	5108	3597677	5108	5438640	5108	7739353	5108	9992720	176
Savanna	907	695944	907	777083	907	1081762	907	1437421	907	1776141	155
Varzea	1276	432806	1276	403448	1276	639123	1276	985769	1276	1251908	189
Total	8710	5198792	8710	5331072	8710	7913685	8710	11137888	8710	14299712	175
Colombia											
Dry forest	93	16608	93	47386	93	58570	93	100446	93	136875	724
Moist forest	441	156537	441	265842	441	413035	441	552374	441	794850	408
Montane Forest	222	43040	222	92728	222	130178	222	173547	222	236856	450
Montane Grasslands	24	2521	24	6352	24	7715	24	12429	24	17250	584
Savanna	21	1167	21	2606	21	2919	21	5314	21	7088	507
Varzea	25	3894	25	4813	25	4784	25	7392	25	11689	200
Total	826	223767	826	419727	826	617201	826	851502	826	1204608	438
Ecuador											
Moist forest	295	108076	295	40885	295	83857	295	194639	295	288950	167
Montane Forest	561	409520	561	351791	561	520623	561	644853	561	775353	89
Montane Grasslands	691	1022435	691	1047449	691	1168424	691	1430991	691	1557206	52
Total	1547	1540031	1547	1440125	1547	1772904	1547	2270483	1547	2621509	70
French Guiana											
Mangroves	74	8613	74	12916	74	19778	74	36068	74	50748	489
Moist forest	145	20736	145	30513	145	42973	145	73164	145	103244	398
Total	219	29349	219	43429	219	62751	219	109232	219	153992	425
Guyana											
Guayanan ecosystems	4	249	4	274	4	299	4	274	4	274	10
Mangroves	7	2125	7	2983	7	3160	7	3033	7	3011	42
Moist forest	396	635296	396	784798	396	836708	396	809447	396	824155	30

Savanna	9	638	9	757	9	807	9	759	9	769	21
Swamp Forest	25	7840	25	8233	25	8559	25	8263	25	8559	9
Total	441	646148	441	797045	441	849533	441	821776	441	836768	30
Surinam											
Mangroves	62	134376	62	170325	62	163487	62	198950	62	225918	68
Moist forest	156	46992	156	59166	156	56552	156	57734	156	57778	23
Swamp Forest	178	113851	178	148175	178	141173	178	160249	178	172550	52
Total	396	295219	396	377666	396	361212	396	416933	396	456246	55
Peru											
Dry forest	359	206368	359	284314	359	384047	359	490646	359	593987	188
Moist forest	725	387007	725	551364	725	815035	725	1131371	725	1478183	282
Montane Forest	1395	1124111	1395	1512203	1395	2025954	1395	2592711	1395	3161443	181
Montane Grasslands	645	474776	645	601183	645	764299	645	940904	645	1101914	132
Varzea	267	186652	267	286282	267	436172	267	618036	267	817310	338
Total	3391	2378914	3391	3235346	3391	4425507	3391	5773668	3391	7152837	201
Venezuela											
Guayanan ecosystems	98	8887	98	8750	98	15869	98	25978	98	34785	291
Moist forest	267	261830	267	286935	267	532519	267	842066	267	1090225	316
Savanna	263	148802	263	138383	263	258032	263	430056	263	528646	255
Swamp Forest	9	290	9	229	9	282	9	312	9	346	19
Total	637	419809	637	434297	637	806702	637	1298412	637	1654002	294
All countries											
Dry forest	1490	590705	1490	800857	1490	1073930	1490	1399423	1490	1809212	206
Guayanan ecosystems	125	10254	125	9872	125	17798	125	28781	125	40236	292
Mangroves	501	228126	501	269083	501	307642	501	402536	501	475093	108
Moist forest	7718	5304613	7718	5700135	7718	8311473	7718	11519043	7718	14792697	179
Montane Forest	2178	1576671	2178	1956722	2178	2676755	2178	3411111	2178	4173652	165
Montane Grasslands	1360	1499732	1360	1654984	1360	1940438	1360	2384324	1360	2676370	78
Savanna	1227	859228	1227	933270	1227	1357881	1227	1892560	1227	2338334	172
Swamp Forest	212	121981	212	156637	212	150014	212	168824	212	181455	49
Varzea	1572	623361	1572	694557	1572	1080102	1572	1611223	1572	2080941	234
Total	16383	10814671	16383	12176117	16383	16916033	16383	22817825	16383	28567990	164

Population 1960 - 2000 for different communities and countries											
	1960		*1970*		*1980*		*1990*		*2000*		% Growth
	N	***Sum***	***N***	***Sum***	***N***	***Sum***	***N***	***Sum***	***N***	***Sum***	
Bolivia											
Urban	25	12531	25	14751	25	15591	25	21933	25	29106	132
Rural coloniser	179	65378	179	77747	179	85872	179	110673	179	149421	129
Indigenous	12	4733	12	4912	12	5075	12	5325	12	9789	107
Total	216	82642	216	97410	216	106538	216	137931	216	188316	128
Brazil											
Urban	1302	987269	1302	1004719	1302	1545390	1302	2206968	1302	3008068	205
Rural coloniser	6923	4092625	6923	4206982	6923	6208888	6923	8718632	6923	11027072	169
Indigenous	485	118898	485	119371	485	159407	485	212288	485	264572	123
Total	8710	5198792	8710	5331072	8710	7913685	8710	11137888	8710	14299712	175
Colombia											
Urban	79	13321	79	25812	79	43458	79	57377	79	81793	514
Rural coloniser	653	195207	653	375400	653	555127	653	762253	653	1074943	451
Indigenous	94	15239	94	18515	94	18616	94	31872	94	47872	214
Total	826	223767	826	419727	826	617201	826	851502	826	1204608	438
Ecuador											
Urban	216	846253	216	800742	216	926353	216	1146096	216	1279266	51
Rural coloniser	828	486164	828	414676	828	564874	828	749116	828	880682	81
Indigenous	503	207614	503	224707	503	281677	503	375271	503	461561	122
Total	1547	1540031	1547	1440125	1547	1772904	1547	2270483	1547	2621509	70
French Guiana											
Urban	33	6606	33	9962	33	15290	33	27814	33	39506	498
Rural coloniser	186	22743	186	33467	186	47461	186	81418	186	114486	403
Total	219	29349	219	43429	219	62751	219	109232	219	153992	425
Guyana											
Urban	51	65274	51	86035	51	93118	51	90118	51	92534	42
Rural coloniser	387	580795	387	710931	387	756336	387	731578	387	744154	28
Indigenous	3	79	3	79	3	79	3	80	3	80	1
Total	441	646148	441	797045	441	849533	441	821776	441	836768	30
Surinam											
Urban	52	154798	52	197820	52	189843	52	229340	52	258826	67
Rural coloniser	344	140421	344	179846	344	171369	344	187593	344	197420	41
Total	396	295219	396	377666	396	361212	396	416933	396	456246	55
Peru											
Urban	194	135115	194	182344	194	246724	194	319057	194	394228	192
Rural coloniser	2877	2192619	2877	2984867	2877	4085570	2877	5328830	2877	6596982	201
Indigenous	320	51180	320	68135	320	93213	320	125781	320	161627	216
Total	3391	2378914	3391	3235346	3391	4425507	3391	5773668	3391	7152837	201

Venezuela											
Urban	183	214039	183	244135	183	449924	183	714327	183	916218	328
Rural coloniser	294	128676	294	143285	294	274073	294	440839	294	555724	332
Indigenous	160	77094	160	46877	160	82705	160	143246	160	182060	136
Total	637	419809	637	434297	637	806702	637	1298412	637	1654002	294
All countries											
Urban	2135	2435206	2135	2566320	2135	3525691	2135	4813030	2135	6099545	150
Rural coloniser	12671	7904628	12671	9127201	12671	12749570	12671	17110932	12671	21340884	170
Indigenous	1577	474837	1577	482596	1577	640772	1577	893863	1577	1127561	137
Total	16383	10814671	16383	12176117	16383	16916033	16383	22817825	16383	28567990	164

Poverty indicators per community and per country												
	Unsatisfied Basic Needs (%)						**Infant Mortality (no. per 1000)**					
	N	***Mean***	***Std***	***CV***	***Min***	***Max***	***N***	***Mean***	***Std***	***CV***	***Min***	***Max***
Bolivia												
Urban	427	41.0	24.0	58.7	0	95	427	59.1	10.7	18.1	47	86
Rural	3897	57.7	22.8	39.5	0	95	3897	61.8	10.6	17.1	36	86
Indigenous	226	59.8	11.4	19.1	42	88	226	66.5	5.1	7.7	39	70
Total	4550	56.2	23.0	40.9	0	95	4550	61.8	10.5	17.0	36	86
Brazil												
Urban	1988	15.2	7.2	47.2	0	66	1988	32.7	11.0	33.5	12	71
Rural	24355	14.3	7.7	53.6	0	66	24355	33.3	11.4	34.2	12	80
Indigenous	1158	14.6	9.3	63.8	0	52	1158	34.0	11.9	35.0	14	71
Total	27501	14.4	7.7	53.7	0	66	27501	33.3	11.4	34.2	12	80
Colombia												
Urban	41	9.3	2.5	27.0	6	13	41	23.5	4.7	19.9	21	47
Rural	867	9.7	2.8	28.7	4	18	867	25.1	4.6	18.5	21	47
Indigenous	43	11.0	4.3	39.2	0	18	43	30.0	10.3	34.2	18	47
Total	951	9.7	2.9	29.5	0	18	951	25.3	5.1	20.3	18	47
Ecuador												
Urban	278	9.7	3.8	39.4	0	16	278	35.4	9.0	25.3	24	52
Rural	1456	10.7	3.7	34.6	0	18	1456	34.1	8.1	23.8	18	52
Indigenous	802	11.3	4.4	38.9	0	18	802	35.8	7.2	20.2	18	52
Total	2536	10.8	4.0	36.9	0	18	2536	34.8	8.0	23.0	18	52
Peru												
Urban	498	11.9	3.3	28.1	5	18	498	51.0	6.9	13.6	34	62
Rural	10192	13.9	2.8	20.5	0	88	10192	49.5	8.7	17.5	14	67
Indigenous	664	14.0	2.4	17.1	10	19	664	45.0	6.9	15.4	32	59
Total	11354	13.8	2.9	20.8	0	88	11354	49.3	8.6	17.4	14	67
All countries												
Urban	3232	17.5	14.1	80.3	0	95	3232	39.1	14.4	36.9	12	86
Rural	40770	18.1	15.9	87.8	0	95	40770	39.9	14.5	36.4	12	86
Indigenous	2895	17.0	14.4	84.8	0	88	2895	39.5	12.9	32.7	14	71
Total	46897	18.0	15.7	87.2	0	95	46897	39.8	14.4	36.2	12	86

Annex 2 - Mapping Water quantity-based Ecosystem Services in the Amazon

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The role of WP1 was to provide data-based support to other work packages with respect to the spatial demand for and supply of the key environmental services. This annex describes the work done to better understand current and future environmental services related to water, the key knowns and unknowns both conceptually and geographically (spatially). Of course we can only cover the known knowns and the known unknowns and there may be as yet unknown unknowns which need to be accounted for in additions to the material presented here. The provision of a well regulated quantity and quality of water and the mitigation of water-borne hazards including flooding are key ecosystem services. There is much debate (covered elsewhere in this report) as to what extent these services are determined by climate and landscape and to what extent they are a function of vegetation and ecosystems. There is also much debate in the literature on this issue and the answers are very much dependent on location and scale-specific conditions.

This analysis brings together the best available datasets and modeling tools to quantify water based environmental services at the Amazon scale now and in the future, using this as a means of understanding what the key knowns are and what the key questions in need of further study are likely to be. Of course, water is fundamental to poverty alleviation since it is both a key resource for agriculture and industry but also a key human need for consumption, hygiene and sanitation functions. A number of serious illnesses are associated with poor access to water of sufficient quantity and/or quality for human needs. Whilst the quantification of water availability is achievable to some extent, as we will see, a lack of data on access and consequences of access makes the assessment of the direct impacts of water on poverty more difficult, especially in the humid tropical context of much of the Amazon.

The specific objectives of this analysis were to:

(a) Map state of water supply

(b) Map human impacts on provision of water based ecosystem services (ES)

(c) Review previous research, monitoring infrastructure and data availability for hydroclimatic research relevant to ESPA, and

(d) Integrate and put online the baseline datasets and analyses to support the ESPA programme,

(e) Raise the key remaining questions that need to be answered in support of quantifying water based environmental services and their potential for the alleviation of poverty.

Data, infrastructure and previous work:

In order to compliment the data-based analysis with a review of previous research and data based collection efforts and to provide a baseline of available data and knowledge for ESPA to build upon, thus a review was also taken of :

(a) regional and national hydrological data gathering efforts.

(b) Previous relevant projects and hydrological monitoring/modelling done at the Amazon scale

(c) the hydrological monitoring infrastructure in the Amazon

A review of hydroclimatic data gathering programmes and organisations in the Andes/Amazon

Different multinational and regional research and monitoring programmes have taken place in the Amazon basin recently (over the last 20 years). Their aim has been to provide good quality data to support scientific research to enhance the knowledge of the regional hydrology and climate of the Amazonia as well as the geodynamic, chemical and land cover controls affecting sedimentation and mass transfer processes in the main Amazon tributaries. One of the most comprehensive initiatives is the ORE - HYBAM project (Environmental Research Observatory - Hydrodynamic of the Amazon Basin project). ORE – HYBAM is an international scientific effort between France, Brazil, Bolivia, Colombia, Ecuador, Perú and Venezuela, operating since 2003, which holds close collaboration with other regional initiatives such as the Large Scale Biosphere-Atmosphere Experiment in Amazonía (LBA) and national institutes of research, hydrology and meteorology such as Instituto National de Pesquisas da Amazonia – Brazil (INPA), Servicio Nacional de Meteorología e Hidrología del Perú (SENAMHI), Instituto Nacional de Meteorología e Hidrología del Ecuador (INAMHI), el Instituto de Hidrología y Meteorología y Estudios Ambientales de Colombia (IDEAM), SENAMHI – Bolivia, Universidad Agraría de la Molina and Universidad Nacional de Colombia, among other organizations.

The project was designed to study the hydrology and geodynamics of the Amazon Basin in order to predict extreme events in the context of climate variability and human interventions (ORE-HYBAM 2007). In addition, novel tools such as radar altimetry techniques have been implemented and validated to monitor river stage and discharge in river sections lacking in *in situ* data. MERIS - MODIS imagery processing has also been used to look at sediment load and transport.

SENAMHI in Peru in collaboration with HYBAM has measured river flows and sediment load in the Amazon tributaries of Marañon, Ucayali, Huallaga, Santiago, Nieva and Napo (SENAMHI 2007). Similarly, the INAMHI (2007) in close collaboration with HYBAM in Ecuador has carried out fieldwork to measure sediment yields and transport in the Napo river, as well as river discharge other rivers such as Aguarico, Pastaza and Santiago.

Amongst other regional programmes are the international research initiative Large Scale Biosphere-Atmosphere Experiment in Amazonia (LBA) led by Brazil. The main focus of LBA is to improve the understanding of physical climate, carbon storage and exchange, biogoechemestry, atmospheric chemistry, impacts of land cover and land use change on climate and interactions of the Amazonia with other earth systems. This project has had close collaboration with HYBAM and other various national institutes of hydrology and meteorology for the gathering of high temporal resolution river discharge data, rainfall, evaporation, soil water storage, and sediment yields as well as nutrients exports (LBA 2007). The project is operative since 1995 and is a collaboration between NASA (National Aeronautics and Space Administration), ESA (European Space Agency), INPE, INPA, Ministry of Science and Technology – Brazil and the HYBAM project among other organizations.

Moreover, from 1998 to 1999 the LBA Brazil in Collaboration with NASA carried out the TRMM – LBA experiment as a main component of the TRMM validation program in which data of dynamical, microphysical, electrical and adiabatic heating characteristics of tropical convection in the Amazon basin were gathered (Rutledge 1999). The Global Energy and Water Cycle Experiment (GEWEX), established by the World Climate Research Programme (WCRP), was designed to model the water cycle towards understanding of potential impacts of o climate change in the basin. The programme includes field intensive measurements and modelling with the aim of providing the best available eater balance of the Amazon basin (Marengo 2006).

The Carbon in the Amazon River Experiment (CAMREX) has focused on distributions and transformation of water and bioactive elements (C, N, P and O) in the basin. This information has been used to build models to understand hydrological and biogeochemical cycles and their interactions at different scales (from regional to continental). The project is a joint initiative of the University of Washington (UW, Seattle), the Centro de Energia Nuclear na Agricultura (CENA), NASA, INPA, among other organizations (CAMREX 2007).

EOS – Amazon project linked in the central Andes with the Cornell EOS project (EOS 2007), from 1988 to 1998 produced modelling datasets of the distribution of rainfall and flow accumulations in the river basin as well as used radar technology to understand the geomorphology and hydrology of central Andes glaciers.

The Amazon – Eye (KCL 2007) is one of the latest environmental information systems for the Amazon basin. The system provides easy access to a large set of datasets of terrain, hydrology, climate, land cover change, which in association with a data base of existing and proposed dams in the region, which are been used to support studies that enhance the knowledge of the human and climate change impacts upon biostability and maintenance of environmental services from regional to continental scales in the basin.

Key findings and questions:

Different multinational and regional research and monitoring programmes have taken place in the Amazon recently (over the last 20 years), in order to provide good quality data to support scientific research on the regional hydrology and climate of the basin. ESPA needs to built upon the activities and capacities of these organisations.

Hydrological monitoring infrastructure in the Amazon Basin (OTCA area)

A preliminary flow stations database has been built providing river discharge data for different sub-basins of the different countries comprising the Amazonia. In addition, several virtual gauge stations instrumented from radar altimetry have been also incorporated on the database. The database is composed by about 1000 flow stations places digitized according to infrastructure of flow stations informed by different national institutes of meteorology and hydrology within the OTCA area and from the Global Runoff Data Centre (GRDC 2007) (Figure 1). The national institutes of hydrology in the OTCA area from which data has been collected are: ANA – Brazil (Brazilian Water National Agency), IDEAM - Colombia (Colombian Institute of Hydrology and Meteorology), Hybam (Hydrology and Geochemistry of the Amazon Basin project), SENAMHI – Peru (Peruvian National Service of Hydrology and Meteorology), INMET - Brazil (Brazilian National Institute of Meteorology), among other sources.

The database accounts for 20 year time series of monthly river discharge, for about 70 stations along the main Colombian OTCA - Amazon Rivers (Meta, Putumayo, Guainia, Caqueta, Vaupes and Amazonas, among others). Annual river discharge (only) is reported for about 100 stations along the main Amazon tributaries (Negro, Solimoes, Putumayo, Vaupes, Caqueta, Guainia, Napo, Marañon, Ucayali, Beni, Purus, Madeira, Tapajos, Branco, Orinoco, Maroni and Oyapcok, among others) (Figure 2). Data has been gathered from ANA, Hybam project (ORE-HYBAM 2007) and the GRDC database (GRDC 2007). 21 virtual stations with rating curves derived from radar altimetry and validated against in situ observations with errors of less than 10% (Leon et al 2006) have also been included. This is the most comprehensive georeferenced database available in the public domain but also suffers from the following limitations: most time series are significantly incomplete since an important number of flow stations are not currently in operation, most flow station coordinates are not well placed on their precise location river stream and provide estimates of river discharge rather than measurements, especially for large rivers. The database is available at www.ambiotek.com/ESPA and the stations are also listed in table 5 and are presented in figures 1 and 2.

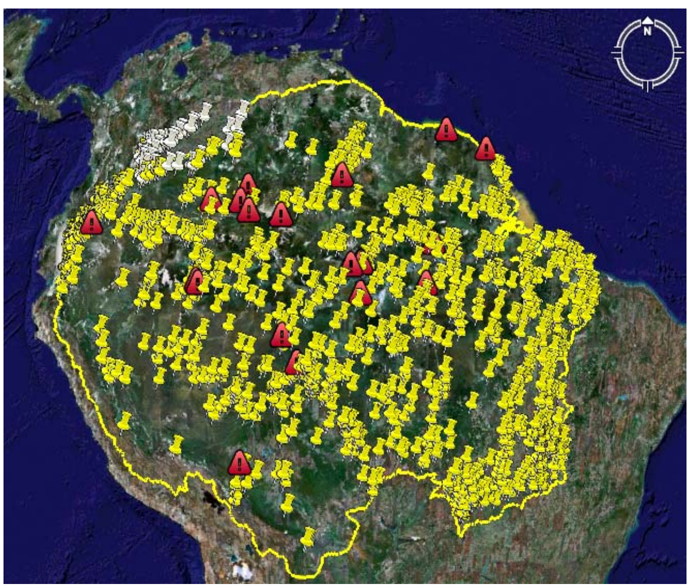

Figure 1. Flow station places in the OTCA area reported in the literature.

Flow station places in the OTCA area reported in the literature. National Institutes of Hydrology and Meteorology and Global Runoff Data Centre - GRDC :

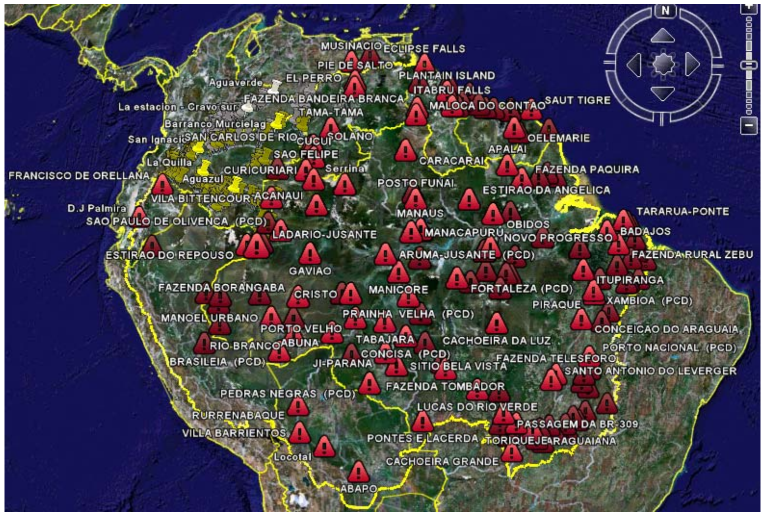

Figure 2. Flow stations from IDEAM (yellow placemarks – monthly time series) and ANA, Hybam Project and GRDC database (red placemarks – average annual discharge) for which data of river discharge is available.

Key findings and questions:

This has been a first attempt to put together a consistent spatially referenced flow stations database for the Amazon. Any evidence based research on water-poverty relationships will need to build upon this work.

Water quantity assessment : methods

Here we describe the key methods used in the quantification of water provision at the Amazon scale and its relationship with human 'management' of ecosystems

Water availability

Though a number of global (Nijssen et al, 2001; Liang et al., 1994; Doll et al, 1999; Doll et al 2003; Hanasaki et al, 2007) and regional scale (Alcamao et al, 2003; Arnell, 1999; Todini, 1996; Vorosomarty et al, 1996; Widden-Nilssen et al., 2007) hydrological models exist and provide information at crude spatial scales on water availability, few of these look in detail at the Amazon. The only of these focused specifically at the Amazon uses 0,5 degree cells (approx. 50km) which is till rather spatially crude for some of the analyses required here, especially on the fringes of the Andes and Amazon. In the absence of publicly available data from previous studies of water resources at the Amazon scale we gathered the best available datasets for climate, terrain and land use and parameterised the FIESTA model (Mulligan and Burke, 2005b; http://www.ambiotek.com/fiesta) to assess water quantity state. The model is a daily-within-monthly timestep, multi-resolution model applicable from remote sensing datasets model for water balance and runoff and is applied here at 1km spatial resolution. The catchment area used is that derived from the Amazon flow network rather than the entire OTCA region (which does not equate to the closed basins that we need for the hydrological analysis).

Human impacts

In order to assess the impacts of human management of ecosystems on water provision we carry out scenario analysis with the FIESTA model using land cover data representing pre-human land cover (based on the UNEP-WCMC global forest watch dataset as amended by Mulligan and Burke, 2005a) and current (MODIS-VCF, http://www.kcl.ac.uk/geodata, Hansen et al. 2006) forest cover to analyse impact on total flow, peak flow and baseflow, seasonally and annually, indicating the water based environmental service provided by forest cover versus other land uses. These impacts are measured spatially across the region but also at the main points at which water is converted into economic resource (irrigation or HEP) : the regions dams.

The FIESTA delivery model

By way of background, the characteristics and processes represented in the FIESTA delivery model are described in figure 3 and the main processes represented in the model are discussed in figure 4.

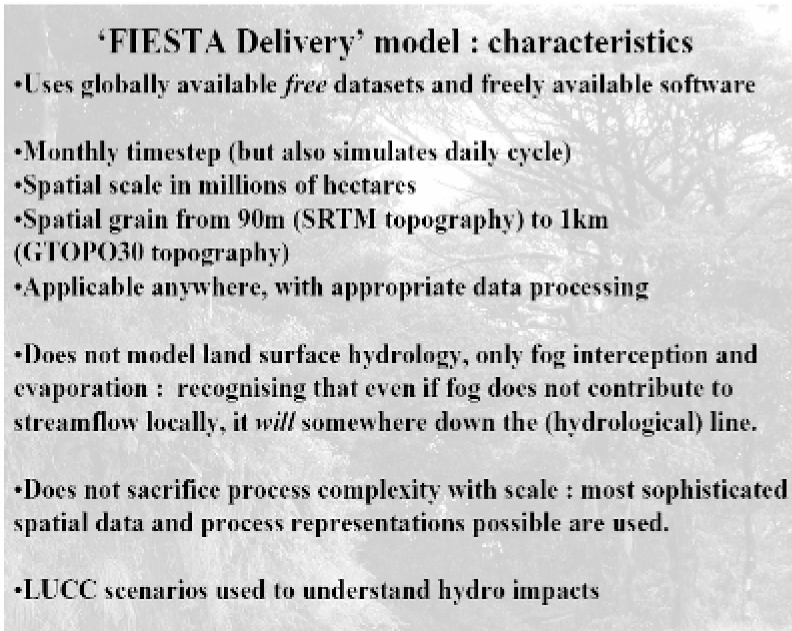

Figure 3 Characteristics of the FIESTA delivery model

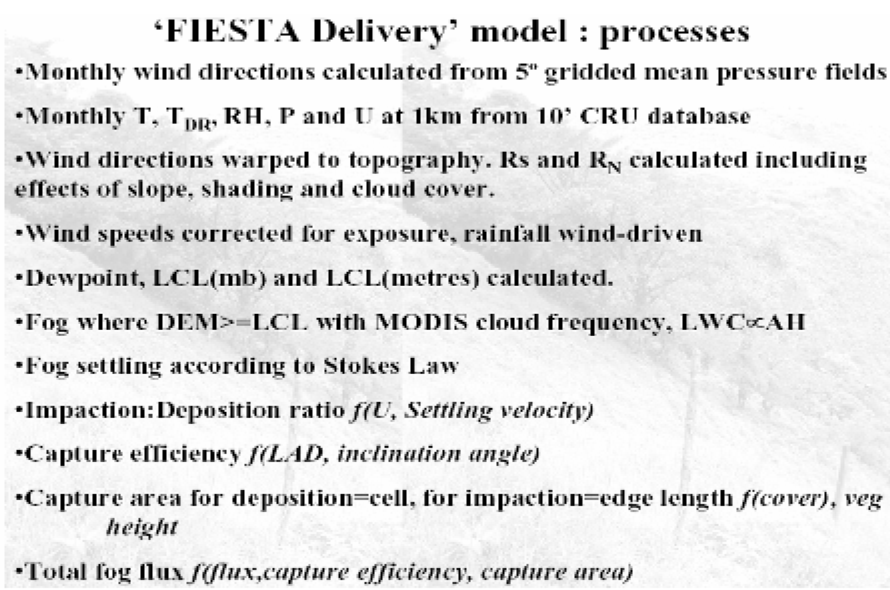

Figure 4 Processes represented in the FIESTA delivery model

The model was parameterized using global datasets generated specifically for FIESTA and available at www.kcl.ac.uk/geodata. Key results describing the hydroclimatology of the Amazon are discussed below.

Because of the range of latitudes across the basin indicates a significant variation in solar radiation inputs altitudinally and latitudinally but also strong seasonality in solar inputs, even in the absence of cloud effects (figure 5).

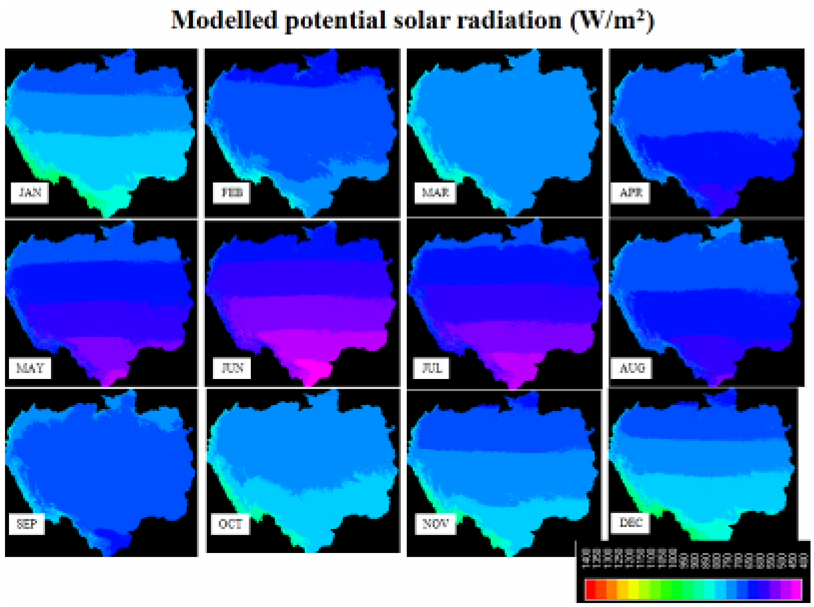

Figure 5 Modelled potential ground level solar radiation receipt (W/m2) across the basin.

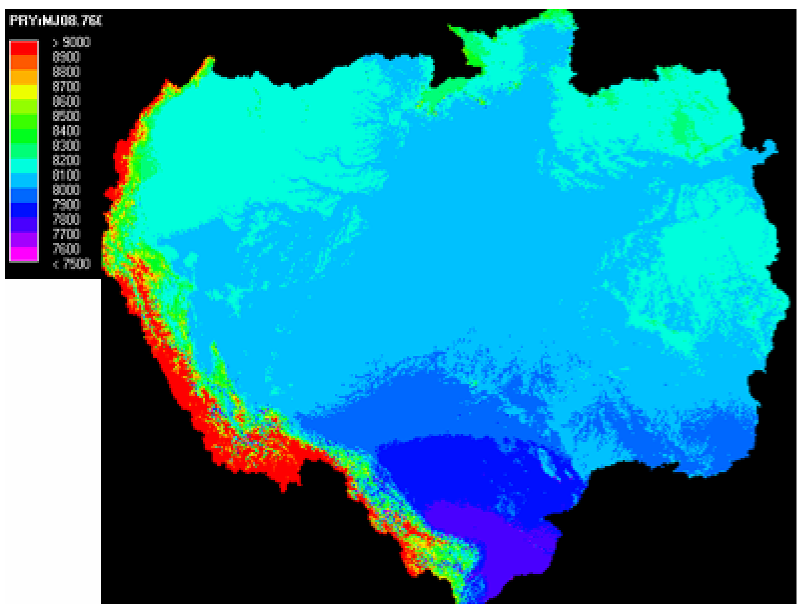

Figure 6 Total annual solar radiation inputs (MJ)

Figure 6 indicates significantly greater potential solar radiation loads in the Andes compared with the Amazon (a function of lesser atmospheric losses). These will in reality be reduced by the higher frequency of cloud cover in the Andes and thus indicate the importance of incorporate cloud frequency in the analysis, as the FIESTA model does. Figure 7 shows the distribution of cloud frequency across the basin, indicating clearly the strong gradient in cloud frequency from NW to SE. Cloud frequency is critical in the mitigation of evapotranspiration (through reducing solar radiation loads) and the cloudiness of the environment will thus have important implications for the impact of land use change.

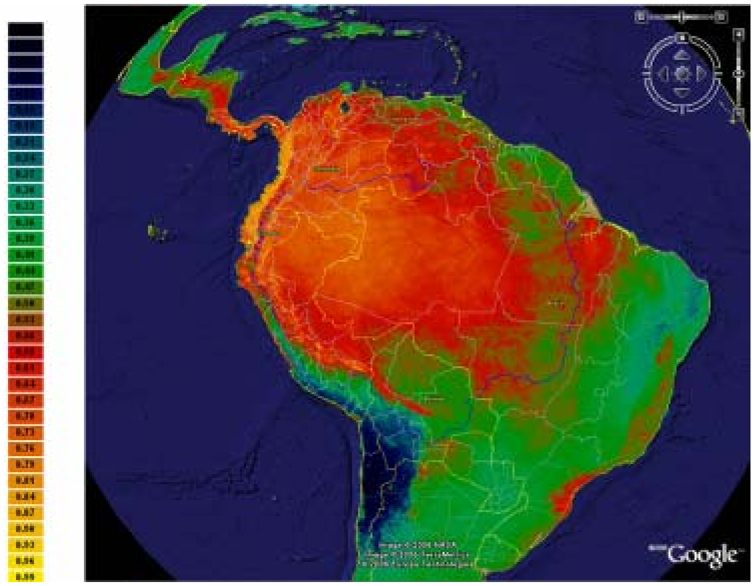

Figure 7 Cloud frequency for South America based on the MODIS cloud climatology (http://www.kcl.ac.uk/geodata)

One of the most important variables to quantify in the assessment of water balance (and thus water based environmental services) is precipitation input. Whilst this is relatively simple at a point, rainfall is highly spatially variable and thus the manner in which spatial estimates are obtained has clear implications for the accuracy of any spatial estimate of water balance. For the application of FIESTA we use the two best available public domain 1km resolution rainfall datasets : WORLDCLIM (Hijmans et al., 2005) which is based on the interpolation of point based rainfall station data and TROPICLIM (Mulligan, 2006) which is a climatology derived from the entire dataset of the tropical rainfall monitoring mission TRMM rainfall radar (1997-2006) and which is available from http://www.kcl.ac.uk/geodata. The two datasets are compared in figures 8 and 9.

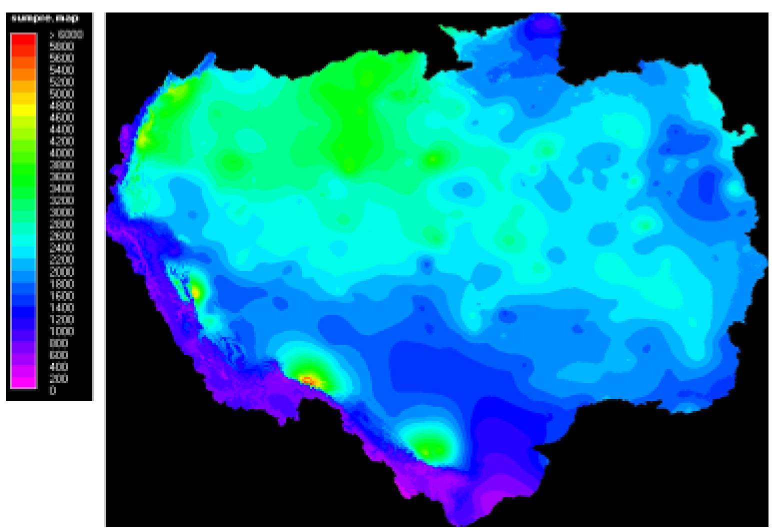

Figure 8 Annual average precipitation inputs for the Amazon based on Hijmans et al (2005)

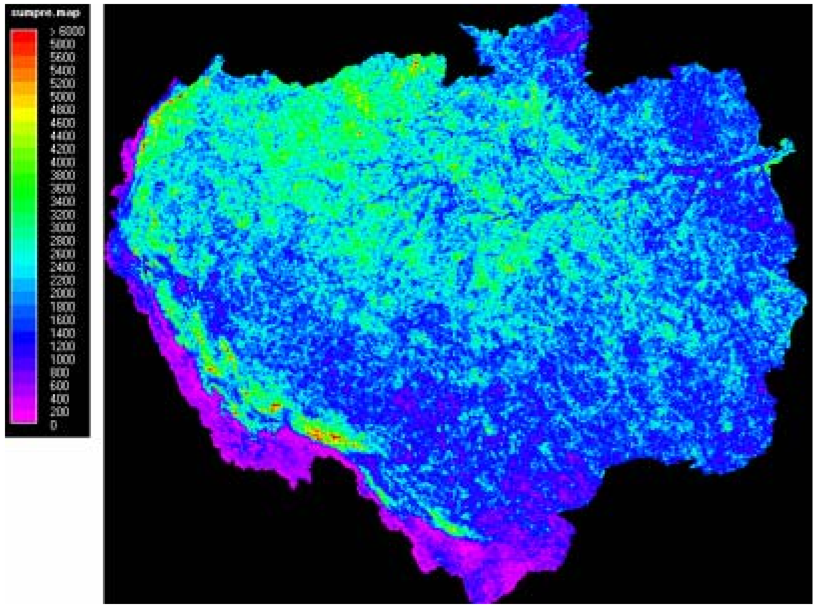

Figure 9 Annual average precipitation inputs based on the TRMM 2b31 Climatology (Mulligan, 2006)

The patterns are similar but there are clear differences in magnitude and spatial detail. The WorldClim data show a much smoother pattern as a result fo the interpolation, whereas the TRMM data shows much greater spatial detail. Locally TRMM rainfall values can be very high much they are much more localized than WorldClim such that areal total rainfall amounts are less with this dataset. Absolute differences between the two climatologies are generally low but in isolated rainfall hotspots the TRMM product produces much higher values (figure 10).

Total annual rainfall is not the only determinant of water availability, even in the tropics, rainfall seasonality can be very significant. Figures 11 and 12 indicate the rainfall seasonality for both datasets. The patterns are again broadly similar but with significant differences in the detail. Clearly the NW section of the basin is virtually aseasonal with respect to rainfall but the S and E of the basin are highly seasonal and particularly dry during May-August.

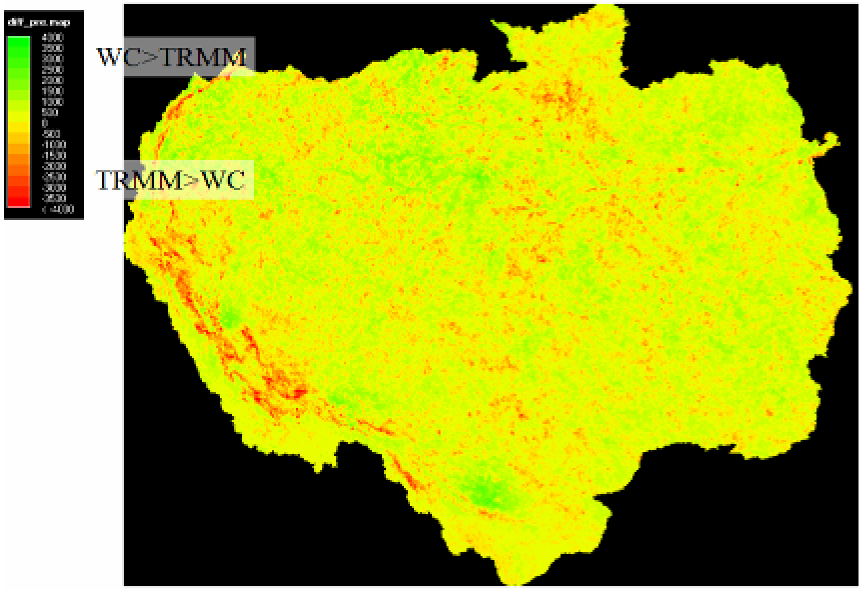

Figure 10 Absolute differences between the WorldClim and the TRMM datasets for rainfall.

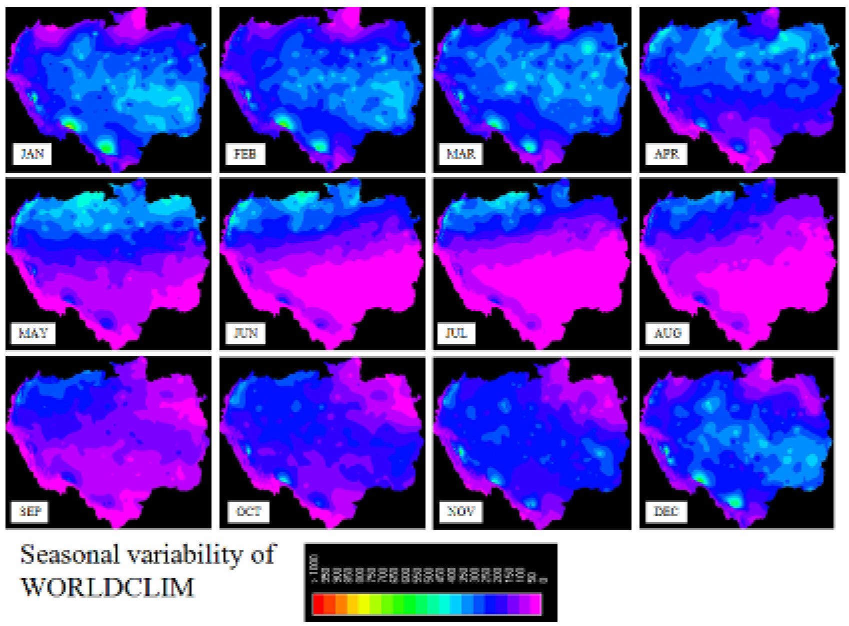

Figure 11 Rainfall seasonality in WorldClim.

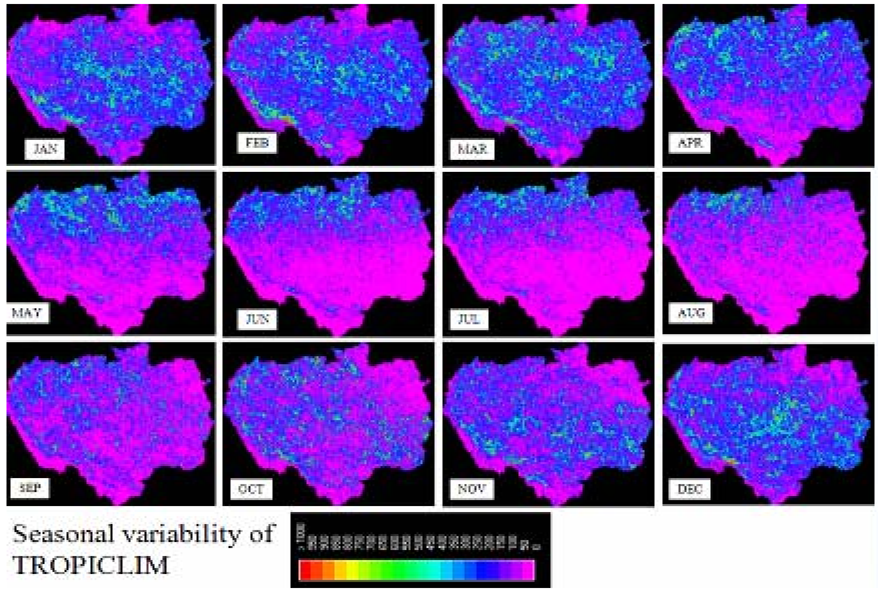

Figure 12 Rainfall seasonality in TropiClim.

The action of rainfall in the terrestrial system is fundamentally determined as much by the rainfall rate as by the rainfall absolute magnitude. The Amazon basin is characterized by a strongly convective (and thus diurnal) pattern of rainfall with little rainfall in the mornings and strong convective bursts in the evenings. This is clearly shown by Figure 13 which results from the analysis of all TRMM/GOES 3b42 data (1997-2006) for 3 hourly precipitation totals. This clearly indicates the high rainfall totals (upto 1300 mm/year) occurring in evening thunderstorms between 1800-2100 hours.

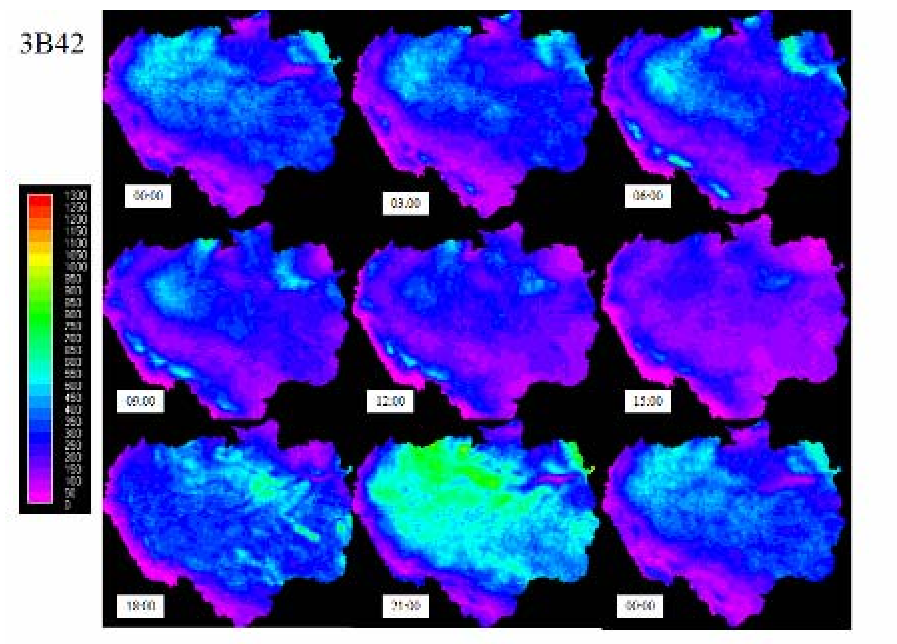

Figure 13 Rainfall diurnality in TropiClim (mm/year in 3 hourly diurnal periods).

In this section we have reviewed the basic hydroclimatology of the Amazon basin and pointed out the main features relevant to understand water based environmental services. We have also indicated the available baseline data and pointed to some of the difficulties in providing aerial estimates for even the most fundamental of hydrological variables such as rainfall. Using the latest satellite derived climatologies, the spatial complexity of inputs is apparent and this necessitates a move away from the traditional coarse resolution approaches (applied commonly at 0.5 degree resolution) to much more spatially detailed approaches. This is now possible given advances in computing power and is certainly something that

ESPA will need to take account of.

Basic water balance of the Amazon basin

Using the two different rainfall climatologies described here to then parameterise the FIESTA model for the baseline (current land use) scenarion, we derive quite a different water balances (figure 14). Point values of water balance are higher for TRMM data but less extensive in coverage than with the WorldClim data. Quantification of ES supply is thus limited by climate data.

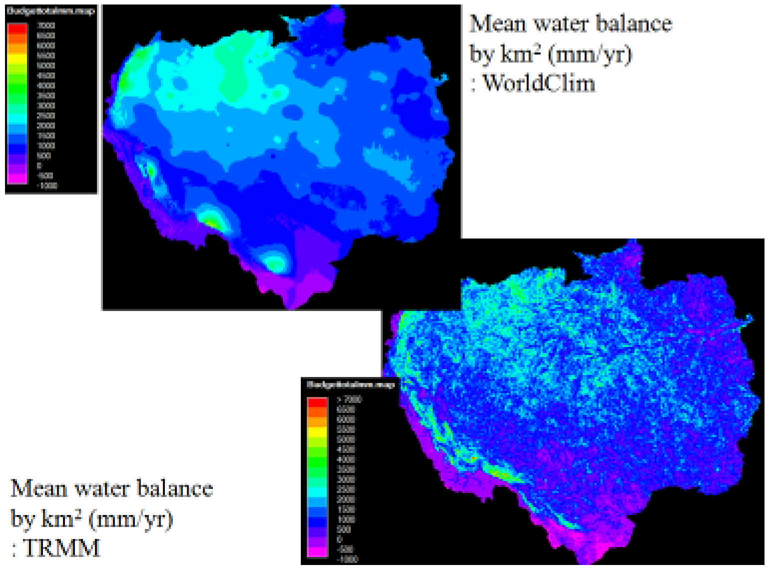

Figure 14 Modelled amazon-wide water balance for the WorldClim and TRMM rainfall inputs (mm/yr).

Given that human use of water tends to be at a point (for agricultural purposes) or aggregated upstream (for transport and HEP), the two rainfall climatologies give quite different patterns of resource availability, hence the need for further work as part of ESPA. These differences are particularly clear when aggregated in classes of elevation. Figure 15 shows mean water balance by classes of elevation for the two rainfall climatologies. Clearly the paucity of stations and reliance on interpolation in the WorldClim data means that the lowlands of the NE Amazon are considered the highest rainfall area, whereas the TRMM data shows that the footslopes of the eastern Andes receive the highest rainfall amounts. If we examine water balances by catchment then differences are also apparent between the two rainfall climatologies.

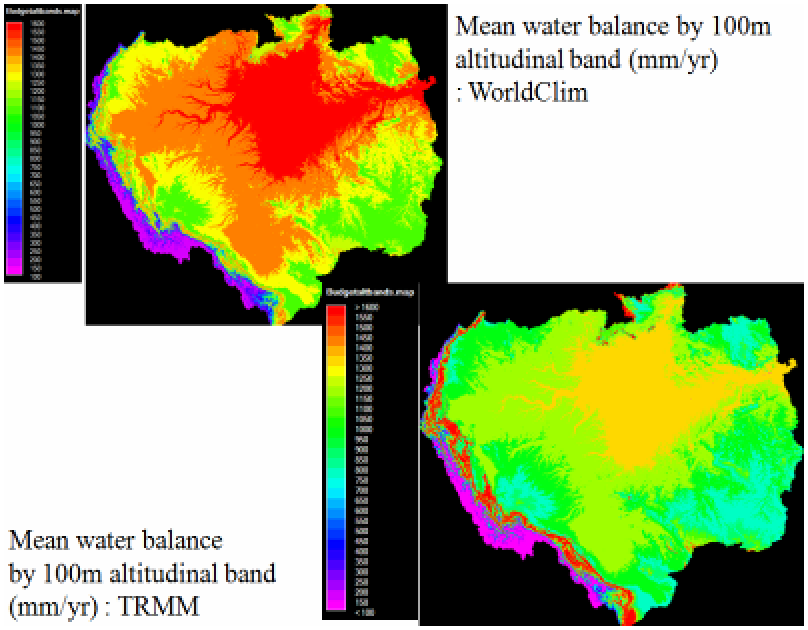

Figure 15 Modelled amazon-wide water balance averaged in 100m elevational bands for the WorldClim and TRMM rainfall inputs (mm/yr).

Seasonally (figure 16) , water balances are positive throughout the year in the Andean flanks and NW of the Basin but seasonal deficits in the S and SE mean that inputs from upstream are important. On a monthly basis rainfall is highly concentrated.

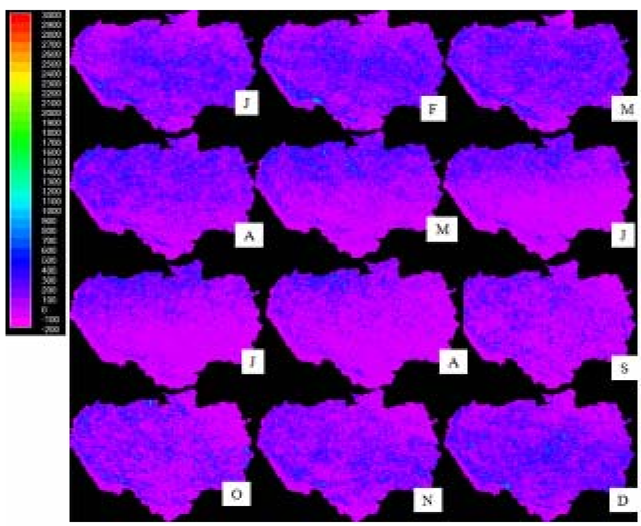

Figure 16 Modelled amazon-wide seasonal water balance for the TRMM rainfall inputs (mm/yr).

Figure 17 shows the minimum monthly rainfall generated runoff (mm) based on the TRMM data. This shows that only a small area in the NW of the basin has rivers fed continuously by rainfall. All other rivers rely on baseflow to maintain flow for at least one month in the year.

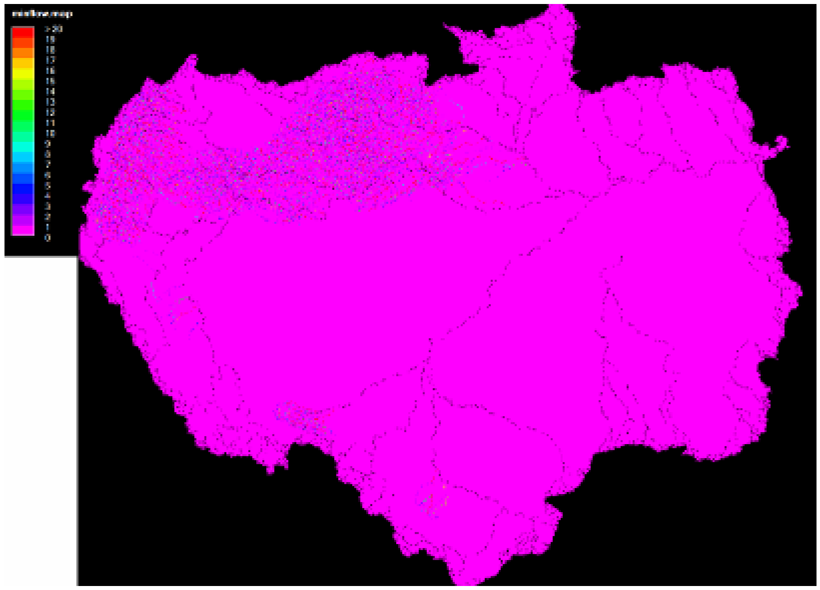

Figure 17 Minimum monthly rainfall generated runoff (mm/yr).

Flow validation

Validation of water balance at the Amazon scale is difficult but the cumulative runoff in the basin for the current (baseline) scenario produces 280 000 cumecs. Other estimates have included Other estimates : 200 000 cumecs (Richey et al., 1989). Korzun (1978) lists the mean annual discharge of the Amazon river at its mouth at 220,000 cumecs, based on a discharge of 157,000 measured at the Obidos narrows. A further 10% of the water discharged by the Amazon enters downstream of Óbidos, very little of which is from the northern slope of the valley. The drainage area of the Amazon basin above Óbidos is about 5 million km², and, below, only about 1 million km², or around 20%, exclusive of the 1.4 million km² (600,000 mile²) of the Tocantins basin.

Key findings and questions:

1. There is still a great deal of uncertainty on the Amazon water balance, depending on the input data used (especially rainfall)
2. The Andes may have the highest water balance per unit area but their small extent means that, on an annual basis, the inputs are dwarfed by rainfall falling on the Amazon
3. The wettest catchments are in the N and W and the driest in the S and E
4. Seasonal deficits in the S and E (and locally bin the N+W) mean that inputs from upstream are significant seasonally, most of the catchment is seasonally dependent on seepage and baseflow.

A review of the literature citing evidence for change in maximum peaks, minimum baseflows and flashiness as a result of land use change from flow data in the region

The impact of climate variability:

A review of the relevant literature on observed changes in flow resulting from land use change for the Amazon concluded that significant variability in flow exists as a results of climate variation and this makes the assessment of land use impacts difficult, also because flow records are often short and interrupted and few controlled (paired catchment) studies exist. The main conclusions are :

Decadal and inter-annual climate variability has affected the discharge of the Amazon river in different parts of the basin.

ENSO phenomena have produced severe drought and strong discharge and rainfall deficits in Western Amazon (of up to 50% - reported at Manaus 1926) with consequent widespread fires (Carneiro 1957; Sternberg 1987;Williams et al 2005), see Table 1 for summary.

Other climate variability phenomena such as the Amazon drought in 2005, the worst in the Southwest Amazon in over a century, have been attributed to anomalous sea surface temperatures of North Atlantic, low humidity, warmer air temperatures (3 to 5C°) and reduced convective development and rainfall, producing catastrophic impacts upon riverside communities (e.g. Iquitos) (Marengo et al 2005).

Table 1 Literature indicating strong ENSO effects on Amazon flows.

Reference	Type of analysis	River side community	Period of analysis	Key findings
	Comparison of river stage levels and rainfall time series	Manaus – Brazil	1920 - 1930	1926 – Niño year of most severe drought of the last century in west-central Amazon. Rainfall deficits of up to 50%. Flow deficits down to 40%. Rainfall surplus to the northeast of the basin.
	Statistical analysis of river stages	Manaus – Brazil	1903 - 1985	Almost statistically significant upward trend of minimum base flows at Manaus over the period 1903 - 1985
	Analysis of climate data (rainfall, air temperatures) Drought 2005	Solimoes and Madeira rivers	2005	Causes of drought were not related to El Niño but to warmer tropical Atlantic. Humidity was lower than normal and air temperatures higher (3 to 5 C°).
Richey *et al.* 1989	Analysis of river discharge time series	Manaus	1903 – 1985	There is statiscally significant change of the river discharge over the period with interannual variability occurring on periods between two and three years.

The impact of land use change

Upstream land use and land cover changes in the river basin, river damming and flow diversion for irrigation purposes are human interventions affecting river discharge, maximum peak and minimum base flows (Costa *et al* 2003). Moreover, land cover changes might affect climate and consequently the hydrological cycle as already informed for some largest catchments such as Yangtze, Mekong and Mississipi (Charney *et al*., 1975; Williams and Balling 1996; Yin and Li, 2001; Goteti and Lettenmaier, 2001; Yang *et al*., 2002; D'Almeida et al 2007). Furthermore, conversion from forest to pasture changes significantly the soil infiltration dynamics and the way water reaches the rivers and streams as well as weakening the ecosystem's ability to pull up significant amounts of water from deep soils (down to about 20m) with implications on evaporation, cloud formation and rainfall (Sternberg 1987; Moraes et al 2005).

Amazon deforestation

In the Amazon deforestation initially greatest in lower Amazonia has widespread further up the river basin towards the Andes including the countries of Colombia, Ecuador, Peru and Bolivia. Large population increase, roads, oil pipelines construction in Ecuador, Illicit crops phenomenon and oil palm cultivation in Colombia, and soybean cultivation in Matogrosso - Brazil have been the main drivers to widespread deforestation recently (Gentry and Lopez-Parodi 1980; Bubb *et al* 2005; NASA 2006). Since the early 1970s to the early 1990s the loss of tropical forest in the region might have gone up to 10% of the basin area (Gentry and Lopez-Parodi 1980; Fearnside 2001; Laurance and Williamson., 2001; NASA 2005; INPE 2005), However, new remote sensing technologies such as MODIS (Moderate Resolution Imaging Spectroradiometer) derived maps of Vegetation Continuous Fields (VCF) are helping to successfully mitigate deforestation in many parts of the basin. Because, these technologies have allowed the implementation of rapid detection deforestation observatories at regional scales to subsequently help focus local forest loss mitigation efforts in the basin (Townshend *et al* 1999; Zeng 1999; Zhan *et al* 2000; Ichii *et al* 2003; Hansen *et al* 2003; NASA 2005; Mulligan and Burke 2005a; Mulligan and Burke 2005b).

Studies of river stage records

Not many studies report the analysis of change in river flows as an effect of deforestation in the OTCA area apart from some insightful examples at the Amazon scale reported at Manaus – Brazil, Iquitos – Peru and the Tocantins basin in Brazil. The scarcity of long term high resolution rainfall and river discharge records coinciding with reliable land cover change analysis over the same periods, at the country scale, has limited the scope of this type of research. Thus, conclusions from the literature on the impacts of deforestation on river flows do not totally agree. While, Sternberg (1987) report no discernable trends towards higher flood peaks at Manaus during the period 1903 – 1955, Gentry and Lopez-Parodi (1980) and Costa *et al.* (2003) propose an increase in the duration of floods with deforestation.

Gentry and Lopez-Parodi (1980), attributed higher flood crests with almost constant base flows of the Amazon river at Iquitos – Peru during the 1970s decade, compared to the 1960s decade, to greatly enhanced deforestation in the upper parts of the river basin in Peru and Ecuador. Whereas, Nordin and Meade (1982) attributed the same changes to normal climate variability. Nordin and Meade also indicate that river stage changes due to alterations of streambed at Iquitos , higher rainfall patterns and carry over storage effects from one year to the next should be considered in these analyses. Similarly, Sternberg (1987) points out the limitations of these analyses based upon river stages records only, because of the uncertainties arising from inter-annual climate variability nonetheless he indicated a potential upward trend of river stage of the Amazon river at Manaus due to deforestation over the period 1903 – 1985 considering that the change in the slope of the low water stage record was almost statistically significant. Chu *et al*. (1994) also points out the significant uncertainty in the absolute amounts of rainfall over the contributing watershed at Taperinha – Brazil making it difficult to achieve consistent rainfall – runoff relationships. Furthermore, Harden (2006) considering the impacts upon fluvial systems at local scales due to reduced storage capacity of Andean landscapes of Ecuador, mainly due to paramo removal, still points out the limitations to extrapolation over regional contexts in which geomorphic adjustments play a role.

Comparison of rainfall – runoff ratios at the Amazon basin scale

Perhaps the most comprehensive study looking at the impacts of deforestation on river flows in the Amazon basin at the large scale is that of Costa et al (2003), which considered rainfall - runoff ratios to avoid potential effects of climate variability upon rainfall, which could affect flow regimes in the basin. By considering a 50 year time series (1949 - 1998) of river flows at Porto National station of the Tocantins river (drainage area of 175 360 km2 in southeast Amazon), rainfall data from the New et al (2000) dataset and land cover change from two periods of great contrasts in deforestation extent (1949 to 1968 with 30% of deforestation and 1979 to 1998 of 50% deforestation), Costa et al (2003), suggests a statistically significant but small increase in the rainfall – runoff ratio (from 0.237 to 0.285 respectively), with negligible rainfall changes between the two periods. This means that land cover changes could have already affected the long-term and seasonal maximum and mean flows of the Tocantins river. However, the rainfall dataset (New et al 2000) still remains as a source of uncertainty due to its coarse nature and thus important rainfall contributing areas might not be well distinguished (D'Almeida et al. 2007).

Comparison of rainfall – runoff ratios: small scale studies

At small catchment scales (1ha.) some studies have reported changes in rainfall – runoff ratios due to land use changes in the Amazon basin. Chaves *et al* (2007) in a paired catchment study in Rancho Grande, Rondonia, studying the impacts on flow regimes of the conversion from forest to pasture, reports the increase in surface stream flow from 0.8% to 17% of rainfall from a forest to a pasture site, which was attributed to changes in soil hydraulic conductivity leading to more frequent overland saturation in pasture soils (Biggs *et al*. 2006). These results coincide with similar studies reported for the Amazon states of Para (Moraes *et al*. 2006) and Manaus (Trancoso *et al* 2007) . These studies highlight the potential impacts of forest conversion to pasture on the regularization of floods, hydrological budgets disruption and sedimentation at larger scales in the Amazon. No studies referring to the change in peak flows, mean and minimum base flows are reported for flow stations in the Amazon tributaries in the countries of Colombia, Ecuador, Venezuela and Bolivia and again most studies have been single point at very few locations in the Amazon basin.

Data-based analysis of the impacts of historic land use change using the FIESTA model

In order to understand better the impacts of ecosystem management on hydrological services we ran two scenarios of the model using the same climate data but different land cover data. The baseline run uses current land cover data as defined by the MODIS VCF product and the historic run uses pre-human land cover data as per Mulligan and Burke (2005a). Figure 18 shows differences in forest cover (fraction) from pre-human times to present (2005). Greatest forest losses have clearly occurred in the Andes and S of the Basin. Forest cover is measured as the fraction of each 1km pixel occupied by trees.

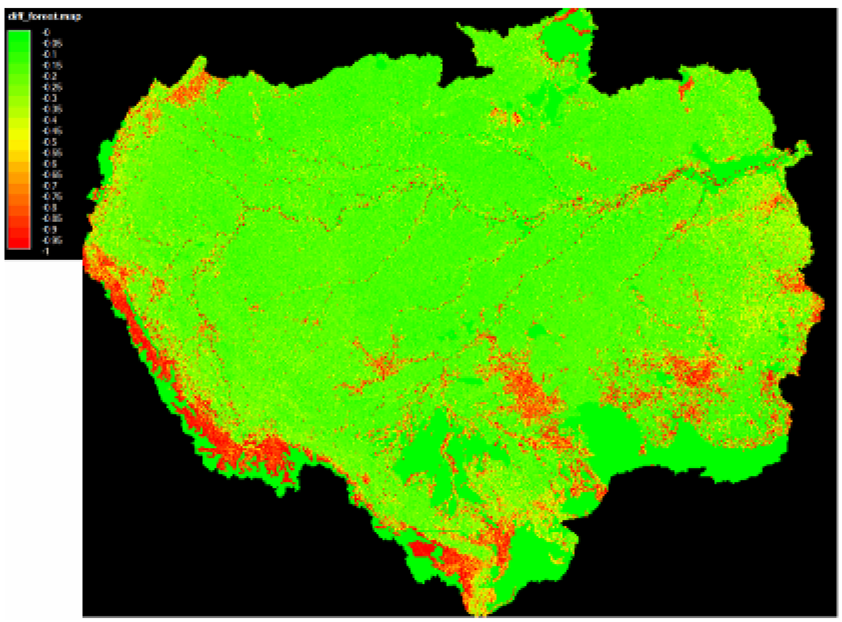

Figure 18 Forest cover change pre-human to 2005 (fraction).

After running the model for both land cover scenarios and comparing the results, we see the impact of historic forest loss on water balance (mm/yr), figure 19. This shows a minimal impact on water balance at this scale with slight increases in water balance in deforested areas, as is to be expected given the reduced evapo-transpiration under non-forested covers. Differences are of the order of a few tens of mm/year. At this scale land cover is thus not very significant in the determination of water balance. The impact of historic forest cover loss on runoff generation is small with minor increases (<1% of original flows) observed in the major rivers draining areas of high forest loss in the south. These results are similar to those presented by Costa et al (2003) on the basis of measurements.

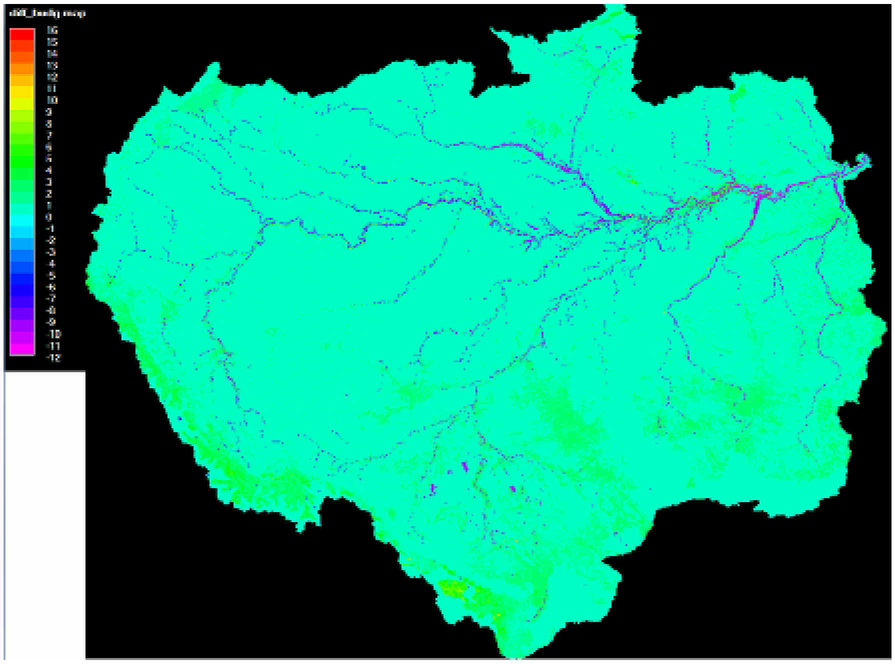

Figure 19 Difference in water balance between pre-human and current (2005) forest covers (mm/yr)

Key findings and questions:

1. Most deforestation historically has taken place along the main channel, along the flanks of the Andes (esp in the N and S) and throughout the 'Arc of deforestation in the S and E'. However, the characteristics of the land uses replacing forest are poorly known.
2. This change has a minimum impact on water balances with local increases in water balance (runoff) of the order of a few mm/year in deforested areas. It was not possible to test this using historical station records for areas which had undergone deforestation though this would be a useful route for ESPA to consider.
3. This change has lead to small increases (<1%) in flow of the major rivers draining these areas so land use does not appear to cause significant changes to water quantity based environmental services at this scale. ESPA should focus on the impact of land use on downstream water quality and impacts on human health.

Impacts of climate change on provision of water based ecosystem services

In order to examine the stability of water resource provision in the Amazon and compare the impacts of historic and current land use with those of climate change, we ran two further simulations using the land cover data of 2005 but climate data generated from the output of two of the most popular GCMs with quite different projections for the climatic future of the Amazon (ECHAM and HADCM3 both using SRES A2 scenarios. Model data were obtained from the IPCC data distribution centre, http://www.ipcc-data.org/). For temperature change the different models show quite different magnitudes of change, though similar patterns. These are shown to the same scale in figure 20. HADCM3 clearly produces extreme warming to the NE of the basin.

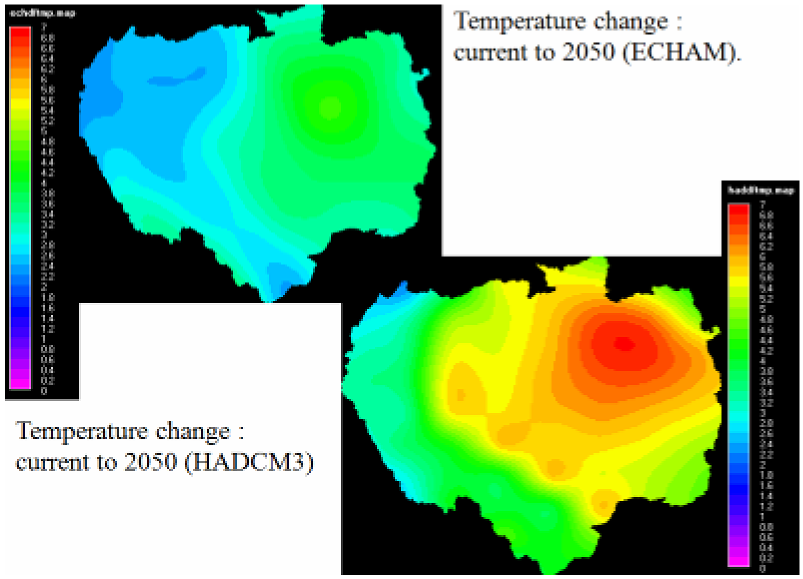

Figure 20 Change in temperature projected by 2050 for HADCM3 SRES a2 and ECHAM SRES a2 for the Amazon basin (°C)

For precipitation ECHAM shows increases in the W and Andes, and decreases elsewhere whereas HADCM3 shows large decreases in the N of the Basin. These are shown to the same scale in figure 21. Applying these inputs to the FIESTA model produces significant changes in a number of elements of the hydrology of the basin (figure 22). Evapotranspiration shows increases throughout the basin, especially in the southern Andes and eastern basin. There is much less change in the N Andes/W Amazon. Water balance shows decreases in the north of the basin and decreases in parts of the southern Andes.

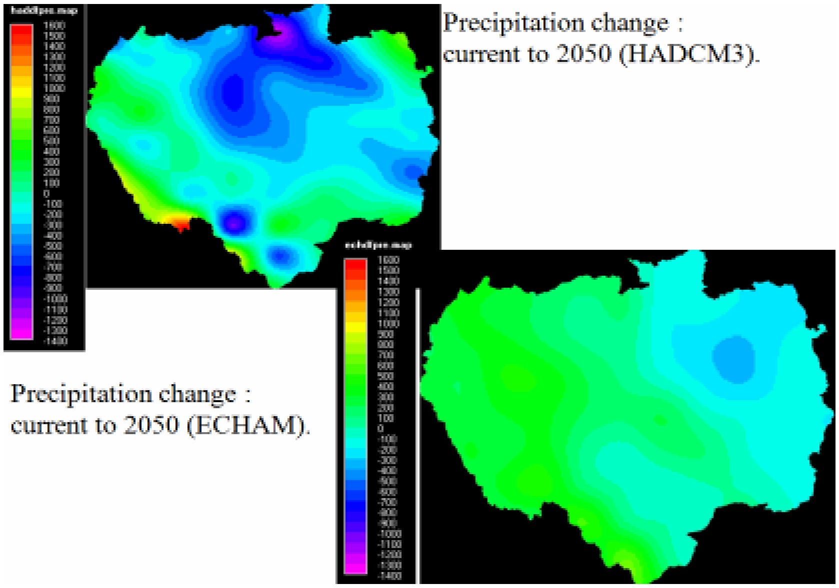

Figure 21 Change in precipitation projected by 2050 for HADCM3 SRES a2 and ECHAM SRES a2 for the Amazon basin (mm/yr)

First we show the results for water balance for the HADCM3 scenario and then for the ECHAM scenario.

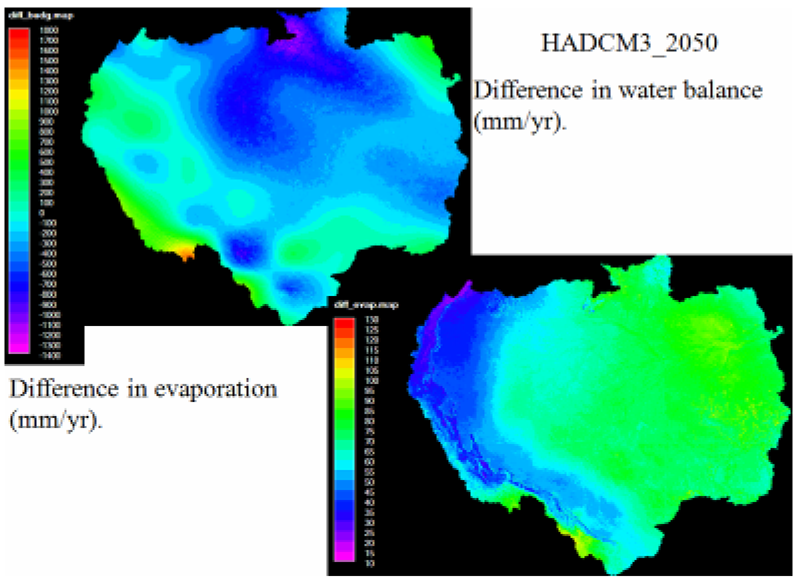

Figure 22 Change in evapotranspiration (lower right) and water balance (upper left) projected by 2050 for HADCM3 SRES a2 for the Amazon basin using FIESTA model (mm/yr)

This change produces significant differences (figure 23) in runoff throughout the basin and shows increases in runoff over Andes (esp. in the S) and significant decreases over the N and SE of the Basin. Moreover, the spatial variability of impacts means that differing responses (positive and negative) between neighbouring watersheds can be observed. 100% increases in runoff generation can be observed in the Andes whilst decreases of upto 90% could occur in the central and northern Amazon. Since rivers tend to flow W-E the increases in the Andes may mitigate flow decreases in the Amazon but given earlier arguments concerning theie relative size, this compensation effect is likely to be minor.

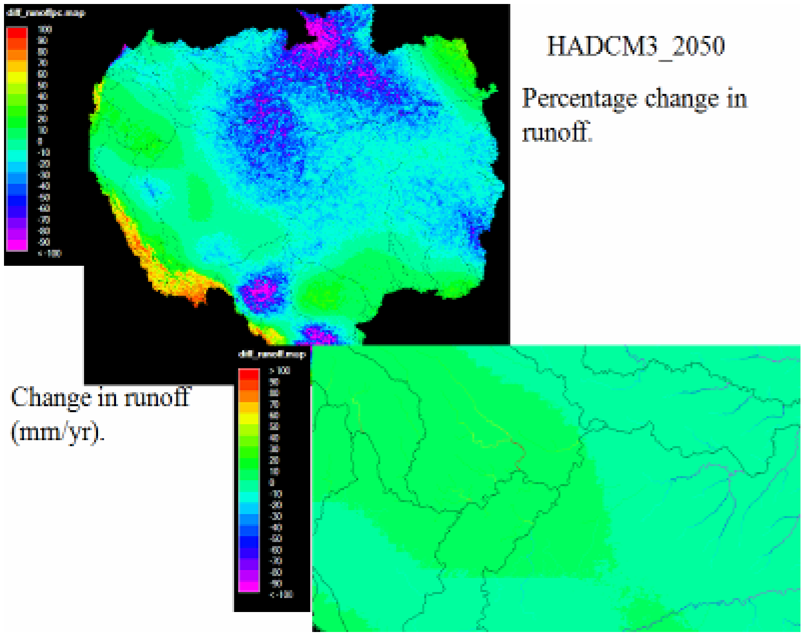

Figure 23 Change in runoff (lower right) and % runoff (upper left) projected by 2050 for HADCM3 SRES a2 for the Amazon basin using FIESTA model (mm/yr)

ECHAM results are broadly similar to those from HADCM3. Water balance shows increases in the west and decreases in the east of the basin. Evapotranspiration shows increases throughout especially in the southern Andes and eastern Basin (figure 24). Percentage change in runoff shows increases in runoff over the southern Andes and significant decreases over the eastern Amazon basin. Change in runoff can show differing responses (positive and negative) between neighbouring watersheds (figure 25).

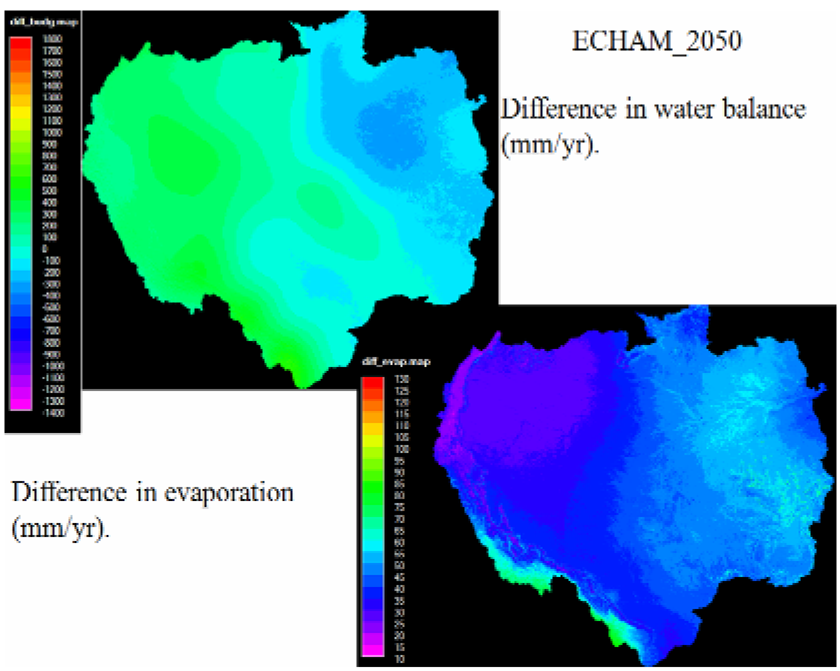

Figure 24 Change in evapotranspiration (lower right) and water balance (upper left) projected by 2050 for ECHAM SRES a2 for the Amazon basin using FIESTA model (mm/yr)

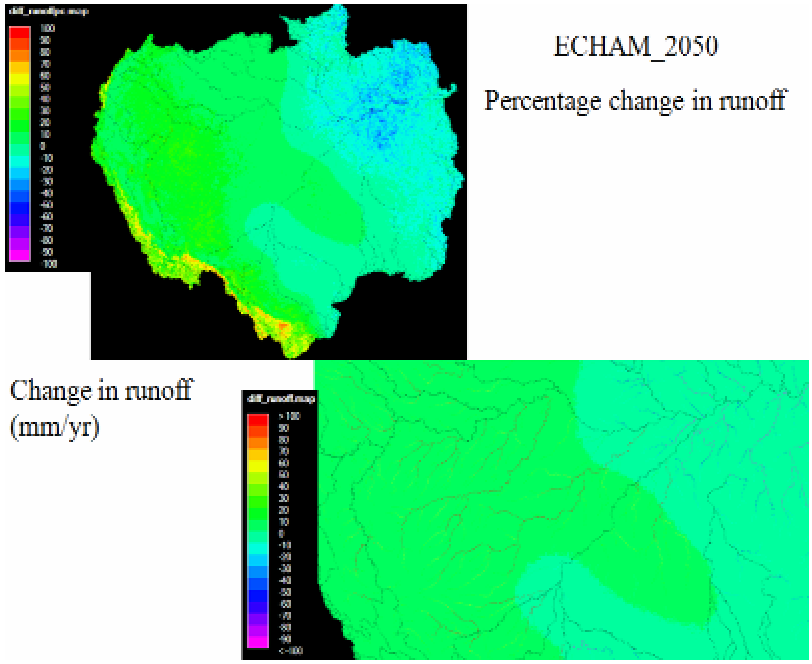

Figure 25 Change in runoff (lower right) and % runoff (upper left) projected by 2050 for ECHAM SRES a2 for the Amazon basin using FIESTA model (mm/yr)

Key findings and questions:

1. Different GCMs (climate models) produce broadly the same pattern but different magnitudes of temperature change for the Amazon. Different GCMs produce different patterns as well as magnitudes of rainfall change. This necessitates a move away from scenario analysis and towards either ensemble approaches or approaches based on sensitivity to change
2. ECHAM SRES A2 indicates warming throughout the basin from 2C in the W to 5C in the E, HADCM3 SRES A2 gives values of 3C in the W to 7C in the E by 2050
3. HADCM2 SRES A2 indicates wetting in the S and W of the Basin of 400-600 mm/yr and drying in the N by 600 to 1000 mm/yr, ECHAM SRES A2 indicates wetting throughout the W and central Amazon by 400-600mm/yr and drying in the E by7 200-400 mm/yr
4. The impacts of climate change on water balance are much greater than those of historic land use change. The impact of climate change on the provision of water-based environmental services (with consequences also for environmental flows) needs to be a key focus of ESPA if poverty alleviation policies based on ecosystem management are to produce sustained relevance and impact in a changing climate.

Water demand

Figure 26 Current and proposed dams in the OTCA region.

Water demand is difficult to quantify in as wet and poorly populated area as the Amazon.

Much of the agriculture is rainfed except in the far SE of the basin, water is required for domestic and industrial uses especially in the large urban centres but also significatly for transportation and for HEP generation. Figure 26 shows current and proposed dams in the OTCA area. At these points a reliable quantity and quality of water is critical.

The following grids lists existing and proposed HEP projects in the OTCA area as an indication of the situation for water service demands in the region and the main issues surrounding the fulfillment of this demand by water engineering.

EXISTING: Dam name	**Country**	**River**	**State**	**Municipality**	**Year**	**Key characteristics**
Tucurui	Brazil	Tocantins	Para	Tucuri	1984	Dam generates 7920 MW and has an area of 2435km^2 covering tropical rain forest and affecting riverside communities. Population of Tucuri increased from 10000 in 1970 to 88000 nowadays stimulated but dam infrastructure and opening up of roads in this part of the Amazon. Amongst the main impacts observed since the creation of the dam are: poor water quality at the discharge point, disappearance of species, reduced fishing catches and fishermen migration upstream the dam (Manyari and Carvhalo 2007).
Isamu Ikeda	Brazil	Tocantins	Tocantins	Ponte Alta do Tocantins	1982	The third hydroelectric in the Tocantins state with a generation capacity of 30 MW.

Serra Da Mesa	Brazil	Tocantins	Goias	Campinacu	1996	Hydroeletric generation of 1275 MW and inundated area of 1.784 km^2. A 15000h park was built to compensate indigenous for the construction of the dam. The park was a joint effort between Furnas Centrais Electricas and Fundacao Nacional do Indio (FUNAI). On the other hand, amphibian species showed a substantial decline before and after the flooding of the reservoir (Brandao, A. and Araujo F, B. 2007).
Balbina	Brazil	Jatapu	Amazon	Jatapu		3150 km2 of rain forest inundated by the dam. The reservoir produces deoxygenated water, which is corrosive to the turbines. Balbina reservoir also flooded two villages, in which lived 107 of the 374 remaining members of the tribe Waimiri-Atroari (McCully 2001).
Guri	Venezuela	Caroni	Bolivar	Bolivar	1978/1986	Second biggest dam of the world in hydropower generation (10200MW – 87 billion KW h) and eight in the volume of water dammed. The project was heavily criticised by the destruction of thousands of squared kilometres of rain forest of reach biological diversity. 1500 Km2 of rainforest submerged. Great problems of green house gas emissions(Methane, CO2)and oxygen depletion due to organic matter discomposing (McCully 2001)

PROPOSED: Dam name	**Country**	**River**	**State**	**Municipality**	**Key characteristics**
San Antonio	Brazil	Madeira	Rondonia	Porto Velho	Projects not licensed yet due to threats to endemic catfish in the basin (Manyari and Carvhalo 2007).
Jirau	Brazil	Madeira	Rondonia	Porto Velho	Projects not licensed yet due to threats to endemic catfish in the basin (Manyari and Carvhalo 2007).
Sao Luis	Brazil	Tapajos	Para	Sao Luis	9000 MW of installed capacity (Switkes 2007).
Belo monte	Brazil	Xingu	Para	Belomonte	11182 MW. First of a series of dams in the Xingu river. The dam would displace a bout 16000 people including 450 indigenous people (Belomonte 2007; Switkes 2007).
Babaquara	Brazil	Xingu	Para	Altamira	Dam not funded by the World Bank since indigenous communities put pressure on the project preventing its construction (McCully 2001).

Bela Vista	Brazil	Xingu	Para	Bela Vista	Belo monte dam system in the Xingu river (Belomonte 2007).
Pimental	Brazil	Xingu	Para		Belo monte dam system in the Xingu river (Belomonte 2007).
Sumapaz (dam about 25km outside the OTCA area, though being a water contributor area)	Colombia		Cundinamarca / Meta		Future expansion of the Bogotá aqueduct with a potential water flow of about 16 $m^3 s^{-1}$ from the Sumapaz Paramo.
Amazon	Brazil	Amazon	Para		Plan of the 1960s to dam the Amazon river, with a potential of 80000 MW of generation capacity, 190000 km^2 of reservoir area and 64 Km dam wall (McCully 2001)

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Annex 3 - Reduction of climatic, hydrological and geomorphic hazards related Ecosystem Services in the Amazon

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Aim

This annex describes the activities carried out in support of providing a review and data-based analysis for reduction of climatic. Hydrological and geomorphic hazards related ecosystem services in the Amazon. Though many of these are related to water quantity, they are distinguished from water quantity in not representing a provisioning service but rather a regulating service. In this first set we examine those associated with water-based environmental hazards (floods and droughts), subsequently we look at those regulating the regional and global climate.

Our aim is to examine first the state of these services and then the potential human impacts upon them. Some evidence from the literature in this regard is presented in the annex 1a.

Methodology

State is assessed using the same runs of the FIESTA delivery model as described previously but analysing the results for the sensitivity of peak flow (floods) and baseflow (fluvial drought potential/impacts on transportation) to vegetation cover change around the current (baseline) value. We do this in order to identify where are the sensitive areas. Human impacts on these services through ecosystem alteration or management are assessed by:

(a) comparing maximum peaks, minimum baseflows and flashiness for pre-human, current and scenario forest cover from model.

(b) reviewing of evidence for maximum peaks, minimum baseflows and flashiness change from flow data in the region (see appendix 1a)

(c) analysing the impacts of climate change scenaria on peak and low flows

Figure 1 is an analysis of runoff sensitivity to forest cover change on a per pixel basis using FIESTA. It indicates areas in which forest cover change has a higher impact on runoff generation. Some parts of the basin have a greater runoff response to land cover change for reasons of climate and landscape. These areas are thus hydrologically sensitive and are clearly indicated.

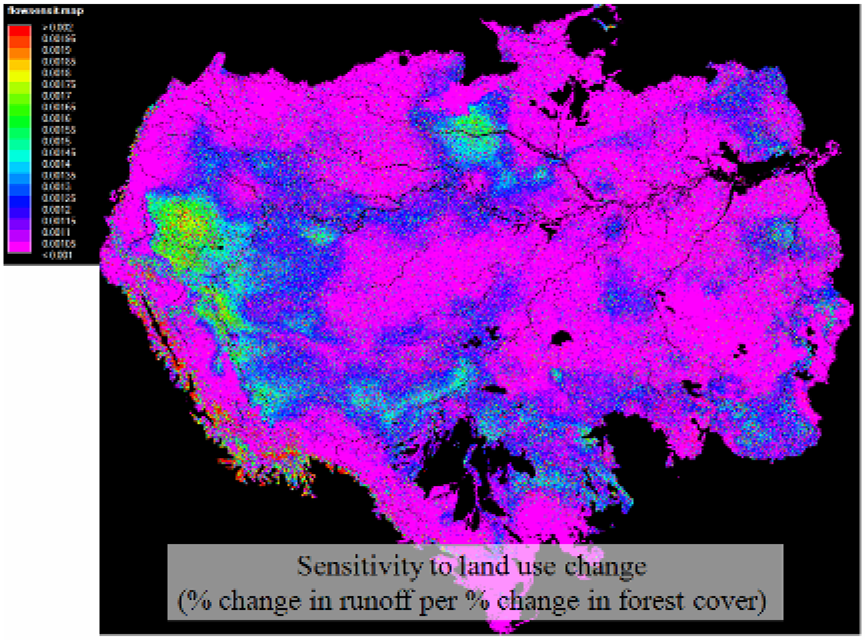

Figure 1 Sensitivity to land use change (% change in runoff per % change in forest cover)

In order to examine the impact of land use change on the potential for flooding (maximum flows) and for fluvial drought with consequences for transportation, fishing and environmental flows (minimum flows), figure 2 indicates by catchment the change in flow resulting from historic forest loss. Historic forest loss has led to small increases in low flows especially in the N and W of the basin and small decreases in high flows especially in the E of the Basin.

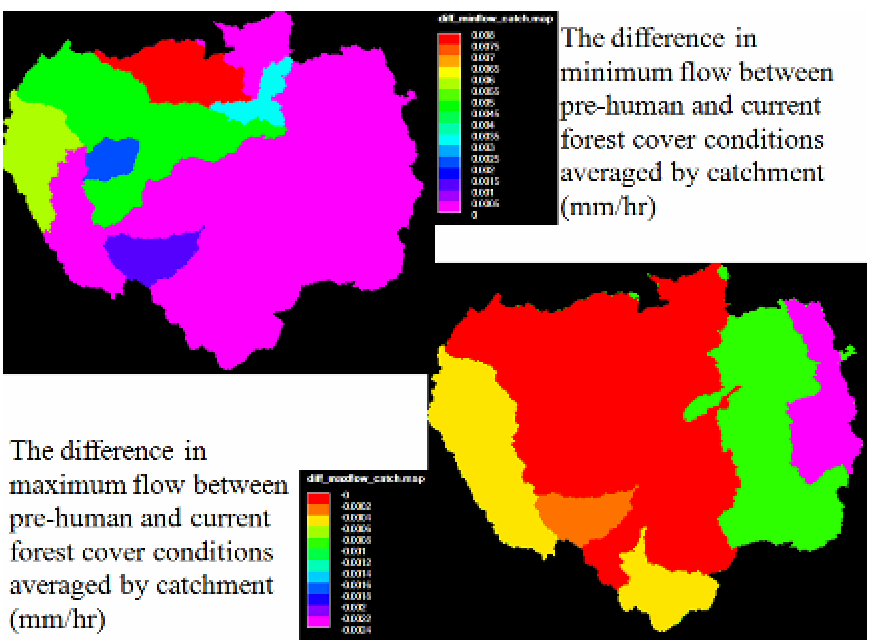

Figure 2 The impact of historic land use change on maximum and minimum flows in the Amazon.

The impact of projected climate change on hazardous flows (floods and droughts) appears to be much greater (figure 3). Climate change scenaria lead to much greater changes in minimum and maximum flows. Under ECHAM minimum flows increase especially in the W of the Basin while they decrease under HADCM3 everywhere except the extreme west. Maximum flows decrease in most of the basin under HADCM3 whilst under ECHAM maximum flows decrease in the E but increase elsewhere.

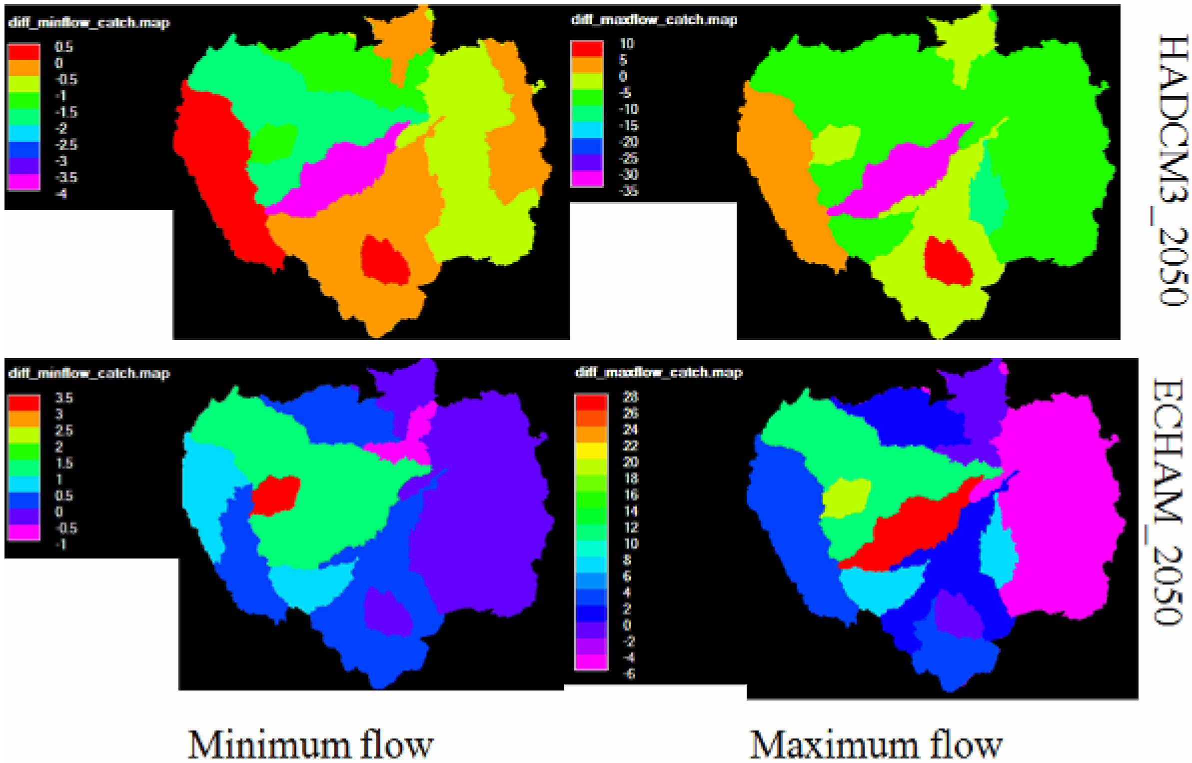

Figure 3 The impact of projected climate change on maximum and minimum flows in the Amazon for HADCM3 SRES a2 and ECHAM SRES a2.

Key findings and questions:

1. Runoff sensitivity to forest cover is low overall but spatially variable through the basin, the precise nature of this variability requires further work.

2. Historic forest loss has led to small increases in low flows especially in the N and W of the basin and small decreases in high flows especially in the E of the Basin. Since the drought of 2005 indicated the importance of these flows to the economy and wellbeing of the region, these events need deeper analysis.

3. Climate change scenaria lead to much greater changes in minimum and maximum flows. Under ECHAM minimum flows increase especially in the W of the Basin while they decrease under HADCM3 everywhere except the extreme west

4. Maximum flows decrease in most of the basin under HADCM3 whilst under ECHAM maximum flows decrease in the E but increase elsewhere. These impacts need further investigation given their potential significance. In particular more advanced field studies are necessary in order to elucidate the significant of these regulating services provided by forests. Though much work has been done on the impacts of forest cover and management on the provisioning services (particularly water quantity, less-so for water quality), the regulating services remain poorly understood. Since these are critical services field analyses with a higher level of detail and control as those reviewed so far are necessary to better understand and validate these model based analyses.

Annex 4 - Regulation of the climate system related Ecosystem Services in the Amazon

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With inputs from:

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Aim

This annex details the reviews and analyses carried out to characterise the spatial variability in regulating services provided by ecosystems with respect to the climate system : in particular the generation of cloud cover and rainfall. Carbon related services are covered in Annex 1d. As indicated in annex 1a cloud cover is an important environmental property which mitigates the impact of high solar radiation loads, thus reducing potential evapotranspiration and keeping water resources available at the land surface. Cloud cover is also, of course, associated with rainfall so that cloud generation is a necessary precursor to rainfall generation.

Methodology

This work will:

(a) Review previous research relating to climate-vegetation feedbacks in the Amazon and the application of models

(b) Assess the relationship between forest cover change with cloud generation and rainfall generation using the MODIS avoidable deforestation dataset Mulligan (2007) (www.kcl.ac.uk/geodata) , the TRMM rainfall climatology Mulligan, (2006a) (www.kcl.ac.uk/geodata), MODIS cloud climatology Mulligan (2006b) (www.kcl.ac.uk/geodata) for the Andes-Amazon for the most extensive historic forest cover change events.

(c) Review national and international climate data gathering efforts as a baseline for future work in ESPA

A review of research examining the impact of land use change on climate regulation in the Amazon

A set of modelling studies have been developed to improve our understanding of the impacts of deforestation on the hydrology of the Amazon. These studies have varied from macroescale (>105 km2) to mesoescale (102-105 km2) as well as one dimensional studies using single column models (SCMs). Macro-scale models (Atmospheric GCMs) have been applied at the Amazon scale and the comparison between scenarios of baseline (current) forest cover and extreme deforestation scenarios made in order to understand the role of land cover in regulating the regional and global climate.

Table 2 presents a summary of the main macroscale models applied at the Amazon scale. Findings with these models indicate an overall decrease of water resources in the Amazon from deforestation, due to reduced evapotranspiration and thus lower cloud generation and rainfall. If the area deforested reaches a given threshold it could lead to a significant drop in rainfall and runoff because of the significant rainfall recirculation in the basin (D'Almeida et al 2007; Leopoldo et al., 1995; Salati and Nobre 1991; Laurance and Williamson 2001). In addition, large scale atmosphere circulations and thus water and energy cycles as well as sensible to latent heat flux could potentially be affected by deforestation and forest fragmentation due to a decline in surface roughness length and an increase in Albedo leading to reductions in surface net radiation (Eltahir and Bras,1996; Berbet and Costa 2003; Nobre *et al*. 1991; Roy and Avissar 2002; Durieux *et al*. 2003; Voldoire and Royer, 2004; D'Almeida 2007).

Mesoscale (regional) models have also been used to model deforestation impacts upon atmospheric circulations at finer scales (D'Almeida 2007; Roy and Avissar 2002). In the Amazon these models predict the alteration of intensity and distribution of precipitation as well as the increase in the seasonality of clouds in areas of high deforestation extent (Avissar and Liu, 1996; D'Almeida 2007; NASA 2004). These effects are attributed to disruption of atmosphere circulations due to induced heterogeneities and gradients in the convective boundary layer depth, soil moisture, surface temperatures and sensible to latent heat flux (Chen and Avissar, 1994; Roy and Avissar 2002; Durieux *et al.* 2003). In addition, it has been suggested that changes in cloud cover are significant for seasonal and diurnal distributions in areas of large forest conversion to pasture (Durieux et al 2003; Roy and Avissar 2002). Over deforested areas, lower level clouds are observed in early afternoons and less convection at night and early morning in the dry season, while convective cloudiness increases at night in the wet season (Roy and Avissar 2002; Durieux *et al.* 2003). However, the wind field in some areas might disperse partially the impacts of these factors (Pielke *et al*., 1991; D'Almeida *et al*. 2007). Overall, results from mesoscale models might vary depending upon climatic conditions of different areas. Therefore, while Eltahir and Bras (1994) report weaker impact (reduction) of deforestation on the water cycle in west-central Amazonia, Chou *et al*. (2002) reports stronger effects.

Results from Single Column Models (SCM) sometimes differ from observations due to the lack consideration of horizontal discontinuities such as thermal instabilities. In the Amazon, the use of SCM to model the Continuous Boundary Layer (CBL) (in Rondonia) underestimates in situ observations (D'Almeida *et al.* 2007). Nonetheless, results from these models indicate greater precipitation over forested areas in Amazonia due to a greater evapotranspiration flux (Rocha, *et al.* 1996; D'Almeida *et al.* 2007). Table 3 presents a list of the main single column models implemented in the Amazon.

As well as direct impacts on the climate, deforestation could potentially affect many other processes relevant to the provision of environmental services and poverty alleviation, including the lands ability to absorb carbon dioxide, the natural flow regimes of the Amazon river and its tributaries, intimately linked to the daily life of riverside communities (Vorosmarty *et al*., 1989; Salati and Nobre, 1991; Victoria *et al*. 1991; D'Almeida et al 2007; Eltahir and Bras, 1994; Bruijnzeel 2004).

Further impacts may occur on the productivity of forests and thus many other processes and feedbacks. Poveda and Salazar (2004) studying the space-time variability of NDVI (normalised difference vegetation index, a measure of vegetation vigour) throughout the Amazon basin report a reasonably well defined pattern of distribution of NDVI for wet and dry periods. They also point out an increase in NDVI variability in wet periods (Niña events), compared to dry periods (El Niño events). These analyses improve the knowledge of hydro-ecological processes as well as provide rules for the spatial scaling of ecosystems response to drought throughout the basin (Poveda and Salazar 2004; Wittmann, et al 2004).

A data based spatial analysis of the role of ecosystems in the provision of climate regulating environmental services in the Amazon

Though there are many modelling studies and a number of localised field and remote sensing data-based studies, there are no whole-Amazon data based studies. In this section we describe the results of a data-based analyses of the impact of historic (satellite measured) land cover change on satellite measured cloud cover and rainfall for the same period. The analyses presented is pantropical though we focus on South America.

One cannot compare land cover with climate and hope to extract the impact of land cover on climate since so many other variables (that have little to do with land cover) control the rainfall and cloud generation processes. Moreover land cover is fundamntally dependent on the prevailing climate, particularly the balance between rainfall and potential evapotranspiration (solar radiation mediated by cloud cover). In order to understand the impact of land use change on climate we therefore have to compare areas with significantly different land cover but in the same climatic environment *i.e.* very near to each other . In this analysis we use three datasets gridded originally at 1km resolution but subsampled for this analysis to 0.25 degree averages of the 1km data. These data represent fractional tree cover change (Mulligan, 2007), rainfall (Mulligan, 2006a) and cloud cover (Mulligan, 2006b).

The analysis compares each cell with its westernmost neighbour for forest cover, rainfall and cloud frequency differences for the period 1997-2006. Figure 1 indicates that across the tropics, neighbour to neighbour differences in land cover canm produce both increases and decreases in rainfall. In some cases neighbouring 0.25 degree cells with lower forest cover than their neighbouring cell have a higher observed rainfall. In some cases these cells have a lower observed rainfall. The pattern is repeated for cells with a higher forest cover than their neighbour. This means that the climatic and geophysical context is critical to whether forest loss leads to a reduction or not in rainfall. In some areas reductions may occur, in others they may not.

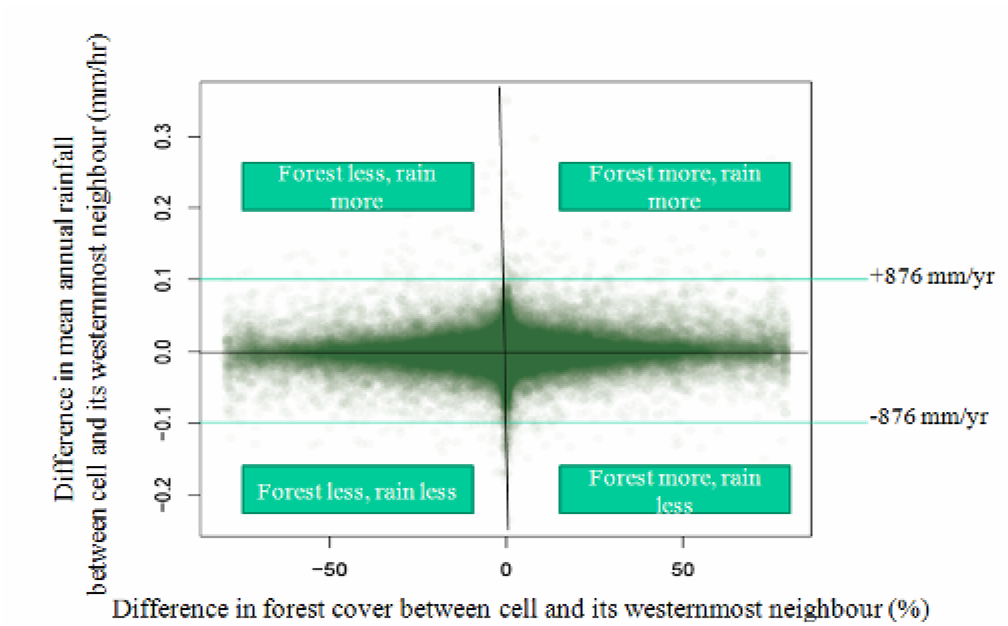

Figure 1 The impact of differences in forest cover on mean annual rainfall (1997-2006)

The same pattern can be observed for rainfall at different times of the day (figure 2).

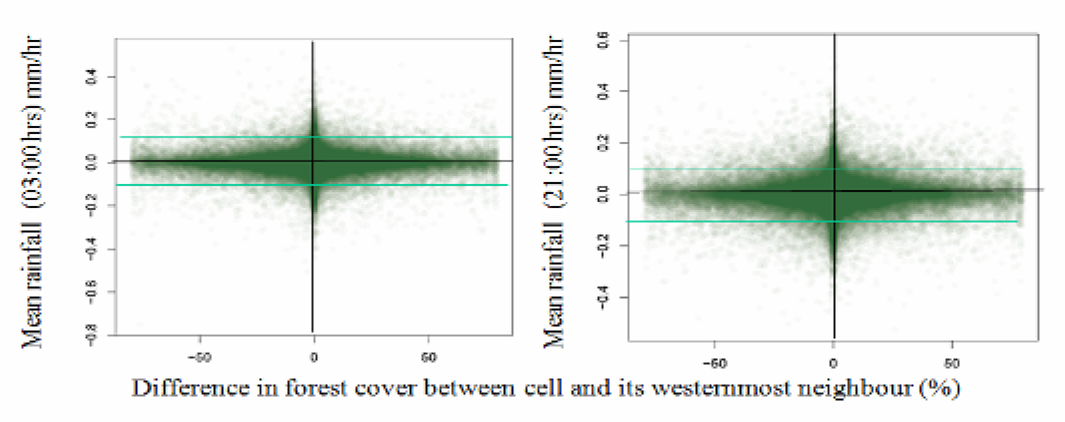

Figure 2 The impact of differences in forest cover on mean annual rainfall (1997-2006)

If we examine these patterns spatially by looking at the percentage change in rainfall between neighbours for areas where the neighbour has less forest (figure 3), we find that forest loss leads to rainfall *increases* >10% (top left) in N and S Andes, S and E Brazil and forest loss leads to large *decreases* in rainfall (>40%) in parts of the central Andes and Pacific (bottom right).

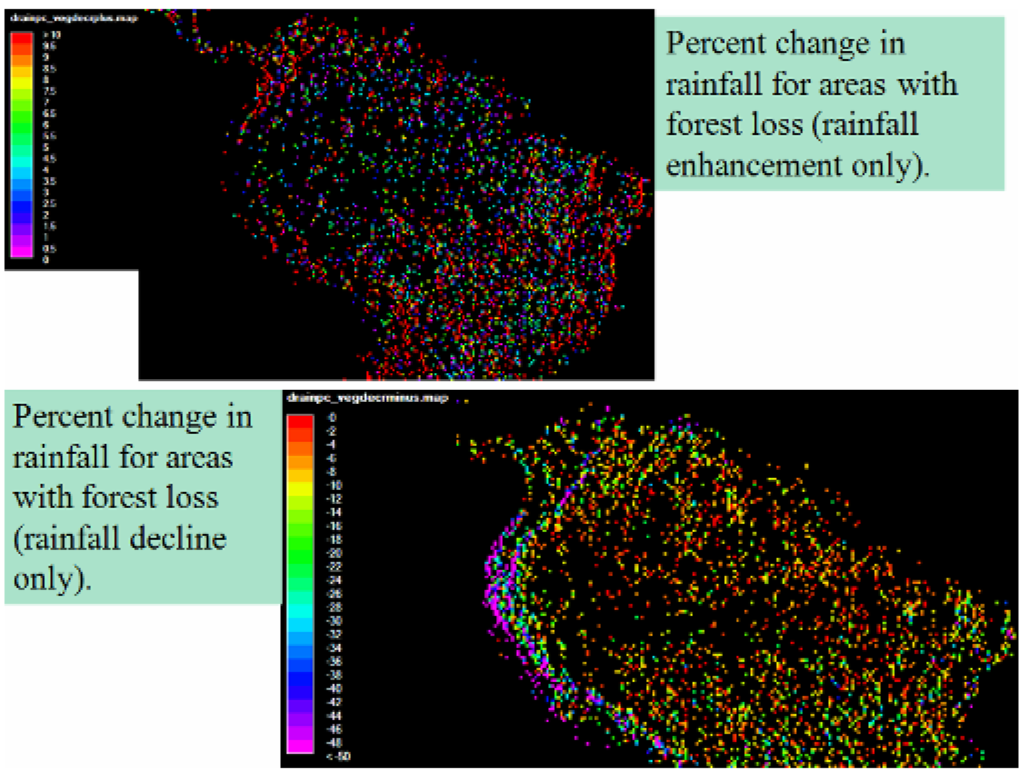

Figure 3 The spatial distribution of rainfall change on forest loss.

If we examine the impact of differences in forest cover on mean annual cloud frequency (2000-2006) in the same way, we see similar patterns (figure 4). Once again, this indicates that Indicates that change between forest and non-forest can lead to increases or decreases in cloud frequency, depending on the context.

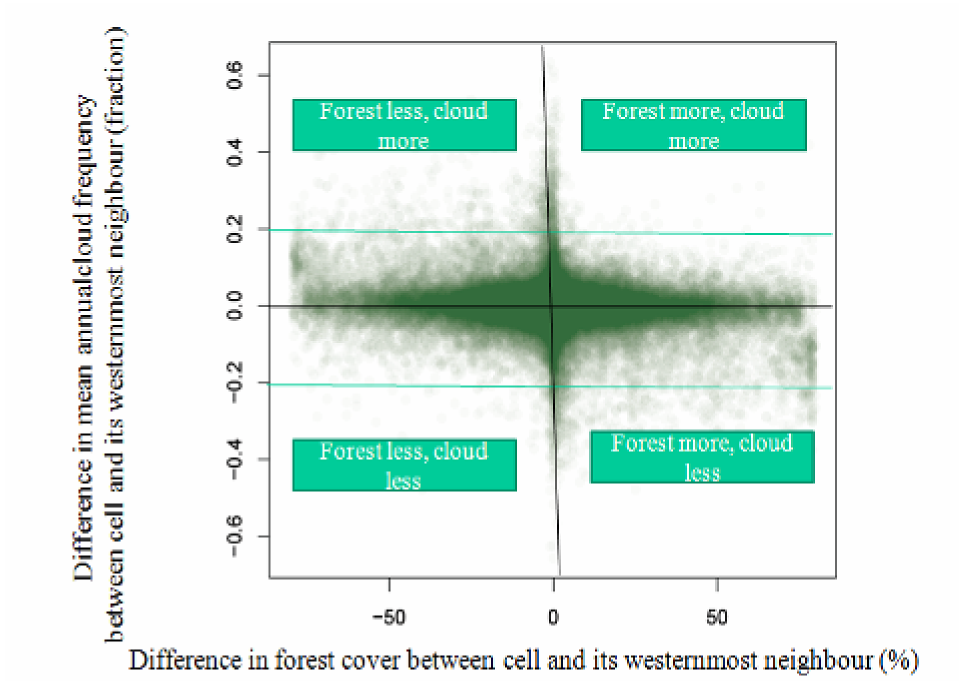

Figure 4 The impact of differences in forest cover on mean annual cloud frequency (2000-2006)

This pattern is, once again, repeated for diurnal and seasonal measurements (figure 5). Forest loss or gain can lead to increases or decreases in cloud frequency depending on the setting. These changes are more pronounced for evening (convective) rainfall. Evening and night-time cloud show land-sea effects *i.e*. some cells have very significant differences in cloud frequency across the range of non-zero land cover differences (especially at the high end). These represent land sea boundaries on west and east aligned coasts where neioghbouring cells represent land and sea.

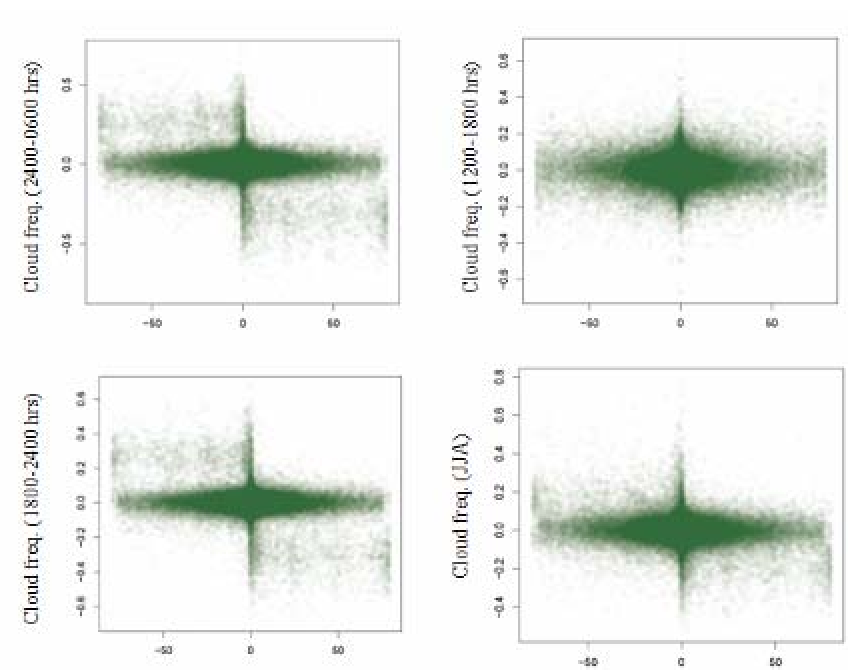

Figure 5 The impact of differences in forest cover on diurnal and seasonal cloud frequency (2000-2006)

Again visualising these patterns of change spatially by mapping percent change in cloud frequency for between cells and their neighbour with lower forest cover (figure 6) , we see large increases (>10%) in cloud frequency on forest loss in some parts of SE Amazon and E Brazil and large decreases (<10%) in cloud on forest loss throughout central and S Andes and E Brazil. The impact of differences in forest cover on both cloud cover and rainfall generation are highly geographically variable across the Andes and Amazon. This may help to explain the observed differences in model and field assessments of the climatic impacts of land cover change.

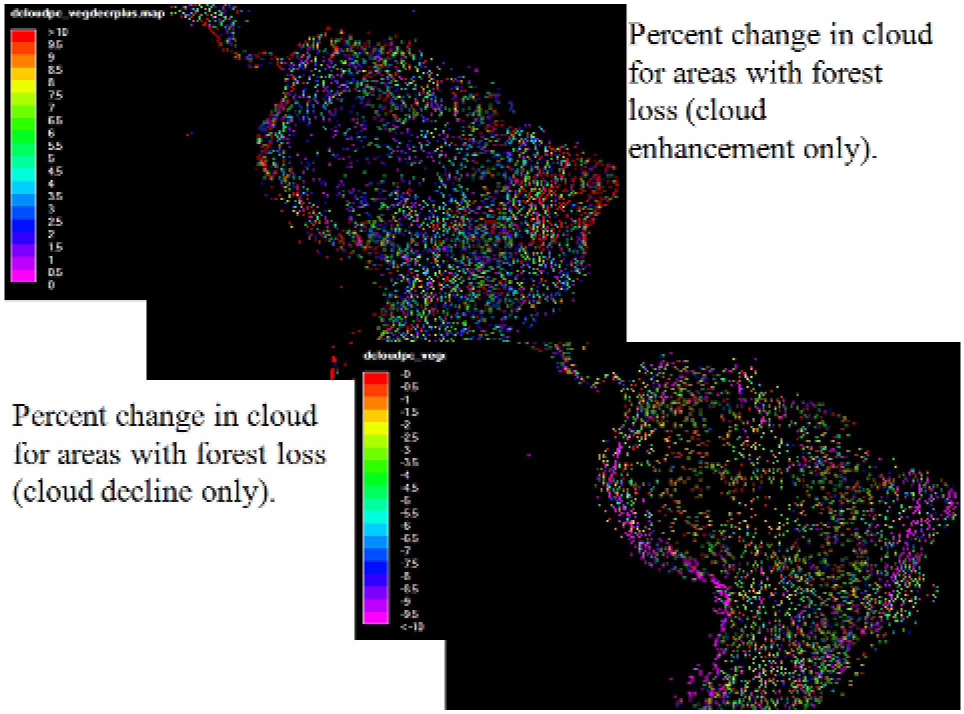

Figure 6 The spatial distribution of cloudiness change on forest loss.

Key findings and questions:

1. There seems to be no consistent relationship between the difference in forest cover and rainfall of neighbouring cells, thus forest loss can be associated with increases or decreases in rainfall. The greater differences between neighbours with similar vegetation covers probably reflects the greater frequency of those areas.
2. Spatial distribution indicates much spatial variation with forest loss leading to rainfall increases of +10% in N and S Andes, S and E Brazil but declines in rainfall in the central Andes and Pacific
3. Similarly change in cloud frequency shows no relationship with change in forest cover (though a land sea effect is apparent, especially for convective (afternoon/evening rains)).
4. Spatial cloud frequency increases significantly on forest loss in some parts of SE Amazon and E Brazil whereas it decreases significantly on forest loss throughout the central and S Andes and E Brazil.
5. Science and policy that connects regulating services with ecosystem management therefore needs to be geographically aware : ESPA needs to focus on large scale studies in this area and not on detailed field investigations. A move awaiting from more modelling into observational analyses is also likely to yield more useful outcomes.

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Annex 5 - Carbon related Ecosystem Services in the Amazon

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Aim

This annex describes work carried out towards better understanding the relevance of carbon storage and carbon sequestration by the Amazon as a global environmental service. The following research was carried out towards this goal:

1. Review and assess potential carbon stocks using MODIS-VCF and sequestration (coupled with existing plot data and published studies of stock sequestration per ecosystem) and examine their fossil fuel emissions offsetting equivalent.
2. Examine the potential impacts of LUCC on carbon stocks and loss of sequestration potential.
3. Produce a bibliography covering publications relating to forest and climate change for the Amazon as a baseline for further analyses during ESPA

Methodology

Different biomass maps exists for the Amazon basin, Brown and Lugo (1992), Fearnside, (1997), Malhi et al., (2006), Euler et al., (2008, *submitted*). The biomass map of Saatchi et al., (2007) was selected for this study since it covers the different ecosystems within the Amazon basin, covers the complete OCTA study area and was available. The biomass value (Mg/ha) is considered here as the initial biomass stock for the model. From this biomass map carbon stock was derived by the assumption that 50 % of the biomass consists of carbon. These data were combined with the TNC ecosystems map (13 classes) and LUCC scenarios for 2050 from Soares-Filho et al. (2006).

Carbon stocks

By coupling the Saatchi et al. (2007) map with the TNC map of ecosystem classes it is clear that some 92.4% of the Amazon biomass is tied up in forests. Assuming that carbon is 50% of biomass this means some 79.96 Pg of carbon are tied up in the Amazon basin forests currently (86 Pg of carbon for all Amazon ecosystems). The Amazon thus represents 21% of all carbon in the world's tropical forests. According to Marland et al. (2007) since the year 1751 roughly 315 Pg (billion metric tons) of carbon have been released to the atmosphere from the consumption of fossil fuels (FF) and cement production. The carbon in Amazon forests is thus equivalent to some 25% of all post industrial FF emissions. Annual average FF emissions from 1970-2004 are some 5.81 Pg.

Using the modelled land cover changes of Soares-Filho et al. (2006) (business as usual scenario, figure 1) and considering only deforestation (not regeneration), some 30% of the existing carbon stocks in the Amazon would be lost by 2050. This would place a further 24 Pg of carbon into the atmosphere (equivalent to 4 years of total global emissions at current rates).

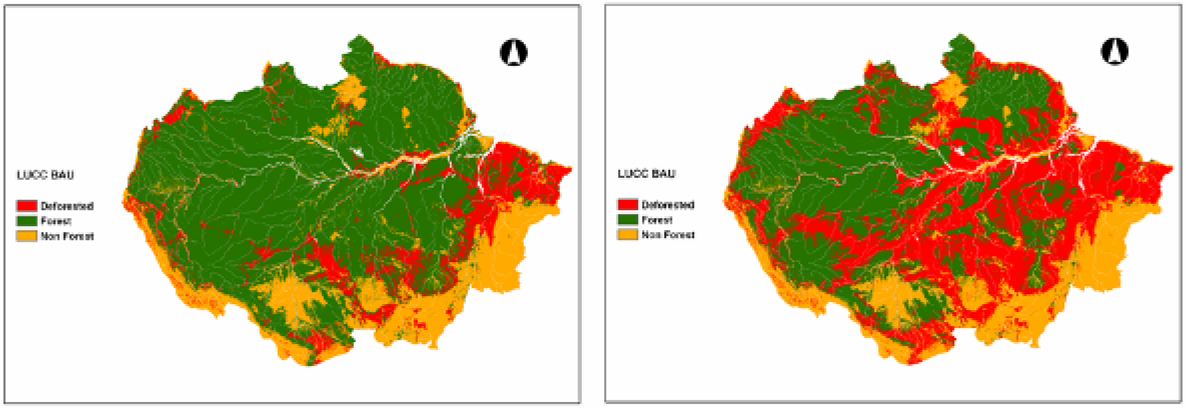

Figure 1 Land cover 2006 and 2050 using the business as usual scenario of Soares-Filho et al. (2006)

In addition to their role as a storage of carbon that is released into the atmosphere upon deforestation, the Amazon forests also have a role in sequestration. Table 1 shows carbon sequestration rates by ecosystem based on a review of the literature. Values are highest for regenerating and plantation forest, followed by *Igapo* and then *Terra Firma* forest

Table 1 Values of carbon sequestration by ecosystem resulting from a review of the literature

ID	Class	Carbon uptake (Mg.ha-1. yr-1)	min	max	Avg	Reference:
1	forest terra firme	2.21	1.14	3.66	3.5	Chambers et al., 2001; Mahli et al., 2004; Clark et al., 2001)
2	forest igapó	2.94	2.45	4.43		Mahli et al., 2004
3	forest varzea	5.42	3.74	6.94		Shongar et al., 2004; Nebel et al., 2001; Malhi et al., 2004
4	forest regeneration	9.26	5.29	13.23		
5	agro-forestry	3.30				Wooner et al., 2000; Mutuo et al., 2005
6	forest plantation	6.60	3.20	10.00		Brown et al., 1996
7	savanna	0.14				
8	cerrado	0.20	0.10	0.20		da Rocha et al., 2002
9	dessert	0.00				Grace et al., 2006
10	grasslands	0.14				

Carbon sequestration rates for Amazon ecosystems vary from 1.14 to 3.66 Mg/ha/yr for terra firme forest (Chambers et al. 2001, Mahli et al., 2004). This produces a total annual sequestration of 2.33 Pg for the Amazon, most of which (2.19) is from the forest ecosystem. This would also be reduced by 30% by 2050 under the Soares-Filho business as usual scenario. The Amazon thus currently sequesters the equivalent of 40% of current annual FF emissions. Combining the loss in Amazon carbon stock (an addition to the atmospheric carbon stock) with the loss of sequestration under the BAU scenario gives an overall net contribution to atmospheric carbon dioxide of 24Pg (stock losses) plus 116.50 Pg (loss of sequestration potential over the 50 years - assuming that forest replacement crops do not grow significant standing biomass but rather have most of their biomass returned to the atmosphere through annual burns or decomposition). This represents an additional 48% on current annual FF emissions as a results of deforestation. Carbon sequestration by the Amazon is this clearly a significant global environmental service.

Key research questions to be addressed by ESPA:

(a) Most studies of the impact of land use change do not consider the impact of changes in sequestration, only of carbon stock losses. There is still much debate as to the role of the Amazon as a global carbon sink (Houghton et al., 2000;Clark, 2002; Laurence et al. 2001) and there needs to be more research to scale up the plot and tower scale studies to Amazon wide estimates capable of tackling the issue of the overall contribution of the basin.

(b) In the light of the potential incorporation of avoided deforestation into the post Kyoto climate change treaty through reduced emissions from deforestation in developing countries (REDD), a mechanism exists for payments for carbon services. Key questions that will need to be answered to ensure that this mechanism works for the poor include (i) how much carbon is sequestered by different ecosystems and how does this vary spatially, seasonally and interannually?, how can areas at risk of deforestation be assessed? and how could a (payments for environmental services) PES scheme contribute?

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Annex 6 - Mapping Spatial Patterns of Supply and Demand of Ecosystem Services in the Amazon Basin: Biodiversity

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Introduction

Biodiversity is important to human welfare as it supports the provision of a range of environmental services. Variation among genes, populations, and species and the variety of structure, function, and composition of ecosystems are necessary to maintain an acceptable and resilient level of ecosystem services in the long term (Millennium Ecosystem Assessment 2005). For example, Fa et al. (2002) estimate that 148.171 t yr^{-1} of wild mammal meat, a non-timber forest product (NTFP), is consumed by people in the Amazon basin. The continued provision of this NTFP at these levels is dependent on maintaining the Amazonian natural ecosystems. Other timber and NTFPs provide food, fibers, construction materials and marketable products that contribute to the subsistence of local people. In addition, the Andes and Amazon regions have been identified as global priorities for biodiversity conservation given the high level of biological diversity, endemism, and anthropogenic threats (Olson and Dinerstein 2002, Mittermeier et al. 1998).

In this context, the main goal of this work is to address the largest and most important knowledge gaps in the supply and demand of ecosystem services (ES) engendered by biodiversity in the Amazon Basin. To accomplish this task, three ecosystem services in the study area were assessed:

- The ES and biological resources provided by biodiversity;
- The provision and beneficiaries of timber and non-timber products; and
- The provision and beneficiaries of tourism and recreation in protected areas.

The main goals of this assessment were to:

Compile existing data on the provision of ES generated by biodiversity and the beneficiaries of these ES flows.

Generate spatially explicit information indicating the distribution of ES flows and the beneficiaries.

Assess the impacts of land use and land cover change (LUCC) and other anthropogenic disturbances on the provision of ES.

The following section details the main methodology followed in the assessment of current and future spatial patterns of ES provision in the Amazon basin. The main findings, along with methodological and conceptual challenges, are summarized in section 3.

Methods

Our analyses focused on mapping spatial patterns of ES provision and consumption. All the analyses were performed on a grid at a spatial resolution of 1 km^2. The methodology has two man components: 1) mapping patterns of ES provision and 2) identification of areas of special interest due to the presence of specific types of ES. The models described below were implemented using spatial analysis tools available in ArcGIS V9.2 .

Mapping Patterns of ES Provision

Terrestrial biodiversity

An index of habitat quality was constructed as a proxy for the quality and quantity of all the ES provided by biodiversity on the landscape. The underlying assumption is that biodiversity status in a place is a function of habitat quality in the place. Better habitat quality in an area means qualitatively and quantifiably better biodiversity-related service provision from that area. Beyond these immediate conclusions a habitat quality model can also be used to identify other conservation targets:

- High quality habitats, especially large blocks of it, are "more likely to have intact ecological processes and be free of invasive exotic species." (Standard 9, TNC and WWF 2006).
- High quality habitat is more likely to contain "critical features of communities and systems that take generations or sometimes hundreds to thousands of years to develop." (Standard 9, TNC and WWF 2006).
- Lower quality habitat areas will indicate areas where the cost of habitat restoration or other conservation actions will be high due to higher levels of habitat damage (Standard 12, TNC and WWF 2006).

This index was used as well as a surrogate for all those environmental services linked with biodiversity which were not able to have a specific analysis due to data constraints and specific data on how these ecosystem services operate in the region. These include supporting services as nutrient cycling, ecosystem stability, and reducing disease risk, among others. For example, research suggest that biodiversity may be important in reducing the risk to certain diseases that are maintained within animal communities and that can transmit to humans (Ostfeld and Keesing 2000), these may include common human diseases in the study region as *Cutaneous leishmaniasis* or Chagas disease. Good habitat quality will mean a higher possibility of offering good habitat to host communities, which in turn may reduce risk exposure to these diseases. Pollination was not included in the analysis due to the scale. This service can be provided by small patches of natural ecosystems (Ricketts et al. 2004) which the analysis will fail to capture due to the scale of 1 km2

The habitat quality index was based on an analysis of threats to habitat and biodiversity performed by The Nature Conservancy, South American Region (Jarvis et al. 2006). Seven sources of threat were considered in the analysis: grazing pressure, recent conversion, accessibility, infrastructure, conversion to agriculture, oil and gas exploration and fire (Table 1). The analysis evaluates the degree of degradation at sites or, conversely, the quality of habitat across the landscape as a function of these threats (Polasky et al. 2007).

For each cell *x* and threat *r* an index of potential degradation in the cell due to the threat was calculated. The index is a function of the relative severity of the threat, the distance between the cell and the locations of threat *r* on the landscape, and the spatial extent of *r*'s impact (Eq. 1).

$$D_{xr} = \sum_{y=1}^{Y} w_r \, f_r\left(\alpha_r, dist_{xy}\right) D_{yr} \qquad \text{Eq. 1}$$

where D_{xr} is the index of the threat *r* to habitat in cell *x*, w_r is the weight of threat *r* vis-à-vis all other threats *r* (if threat $\hat{r}$ is a greater threat to habitat than threat $\tilde{r}$ then $w_{\hat{r}} > w_{\tilde{r}}$), $dist_{xy}$ is the Euclidean distance between *x* and the place of origin of threat *y*, and α_r is a coefficient that modifies the effect of r on x as a function of $dist_{xy}$. The function f_r varies across each *r* (e.g. it can be an exponential function of the form $\exp\left(-\alpha_r \times dist_{xy}\right)$). Finally D_{yr} represents the current intensity of threat *r* from place *y* (e.g. population density, number of fires occurred). Very often $D_{yr} = 0$, i.e., the origin *y* does not produce threat *r*.

Table 1 Sources of threat used in the analysis (Adapted from Jarvis et al. 2006).

Threat to habitat and biodiversity in a grid cell	Description	Data
Grazing Pressure	Density of domestic Livestock on natural pastures in the cell	Density of livestock – cattle, sheep and goats

Recent conversion	Recent natural vegetation loss in the cell	NDVI changes 1998 – 2005
Risk of degradation due to accessibility	Degree of accessibility in the cell to people as a function of travel time across the landscape combined with population density	Roads, railways, rivers, land cover
Infrastructure	Elements of infrastructure not captured in other layers	Dams, airports
Conversion to agriculture	Affectation to natural areas in cells surrounding existing agricultural systems	Distribution of 22 major crops
Fire	Frequency of fires in the cell	Satellite derived fire events 2000 -2005
Oil and gas exploration	Drill sites in the cell	Points of drill sites

The threat index D_{xr} was corrected afterwards to take into account the type of response of each ecosystem to the source of threat, and the severity of the affectation to the ecosystem given the nature of the threat (Jarvis et al. 2006). The combined index of threat in cell x ($\overline{D}_x$) was calculated as the average of the indexes D_{xr} in the cell. The combined index of threat was transformed into a proxy of habitat quality in the cell (Q_x) by assuming that areas under high values of potential threat would present a low quality and quantity of all the ES provided by biodiversity (Equation 2).

$$Q_x = \frac{\overline{D}_x - \max_x(\overline{D}_x)}{\min(\overline{D}_x - \max_x(\overline{D}_x))} \qquad \text{[Equation 2]}$$

Two additional processes were conducted to analyze patterns of provision of biological diversity, these were related with species diversity and habitat diversity. The project team considered important to include these analysis not only because of a global interest on high diversity areas, but also because of the relationships that may exist between diversity and ecosystem functioning. Even though, the relationship between species diversity and ecosystem functioning are still on scientific debate (Loreau et al. 2001), there is some evidence that suggest that species diversity may become increasingly important to ecosystem functioning at large spatial scales (Bond and Chase 2002), and in general there is a consensus that a larger number of species may be essential for maintaining ecosystem stability in changing environments (Loreau et al. 2001). This is an important argument to maintain high diversity areas on the region, and specially considering large conservation landscapes in the Andes/Amazon region.

First, the database of species distributions hosted by NatureServe was processed to create maps of species richness for birds, amphibians and vascular plants. These maps served to compare the general patterns of habitat quality with information on biodiversity at the species level. Second, three maps of diversity of ecological systems were created using a lattice of grids at 20km, 50 km and 100 km. The diversity of ecological systems in a grid cell was evaluated using a Shannon's diversity index (SDI) (Eq.3). SDI equals zero when a cell contains only one type of ecological system and increases as the number of ecological systems in a cell increases or the distribution among types of ecological systems becomes more equitable (McGarigal and Marks 1994).

$$SDI = -\sum_{i=1}^{m} (p_i * \ln p_i) \qquad \text{Eq. 3}$$

where p_i is the proportion of the landscape occupied by ecological system *i*. Similar to the analysis with species distributions, these maps were used to compare patterns of habitat quality with regional patterns of ecosystem diversity.

Timber and non-timber forest products (NTFP)

A literature review was conducted to identify a set of forest species that are important to one or more user groups in the Amazon basin and the Andean region. Current spatial distributions of these species were estimated by mapping look-up tables of species occurrence as a function of South American ecological systems (Sayre et al. 2005). In this way, a binary map depicting presence/absence of each species in a grid cell was generated. The species were grouped according to their end use and user group: 1) medicinal species used by local communities (subsistence), 2) medicinal species for commercial sale, 3) timber species for local use (subsistence), 4) timber species for commercial sale, 5) fruits and nuts (and other food from plants) for local use (subsistence), 6) fruits and nuts (and other food originated from plants) for commercial sale, 7) fibers for local use (subsistence) and 8) game species locally used (subsistence). The numbers of species belonging to each group are listed in Table 2. More information regarding the selection of species and collection of distributional data can be found in Pineda (2008) and Chiriboga (2008).

A forest patch's provision of species in each use group today is a function of its ecological type and past patterns of patch access and use. Several analytical steps were used to estimate the relative current distribution of forest species across the landscape. First, the binary layers depicting the potential distributions of species in a use group in each cell were aggregated. Each cell's use group richness score was normalized by the highest observed cell richness in that use group. Let this normalized value be given by P_{xz}, where z indexes each use group. This index was then used in the model described in Eq. 4 to estimate the spatial provision of ES related to timber and NTFP:

$$AT_{xz} = Q'_x P_{xz} I(adjhours_x - minhours)\frac{(adjhours_x^{\alpha_z+1} - 1)}{(maxhours^{\alpha_z+1} - 1)} \in [0,1] \qquad \text{Eq. 4}$$

where z indexes a use group, $P_{xz} \in [0,1]$ indicates the raw availability of species in group z in x, $Q`_x$ represents habitat quality calculated without the influence of the threat due to accessibility, $adjhours_x$ represents the number of hours it takes to access spatial unit x from the nearest population center considering physical barriers, *minhours* represent a threshold of accessibility, as measured in hours from nearest population center, below which it is assumed that species are not present due to historic harvest pressure and *maxhours* represents the longest amount of time a harvester would travel to harvest in spatial unit *x*. The parameter $\alpha_s \in [0,1]$ controls the variation in supply between *minhours* and *maxhours* (Figure 1).

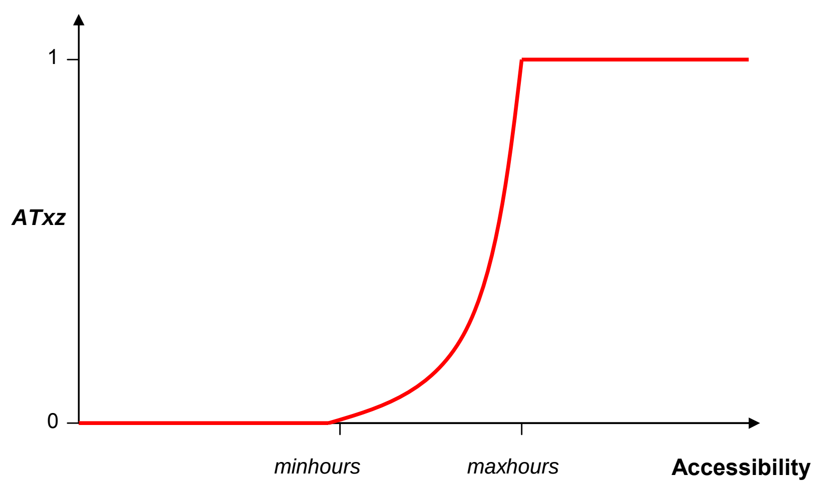

Figure 1 Graphic representation of the variation of ATxz as a function of the distance (in hours) to the closest populated center.

The parameter values used in the implementation of this model are listed in Table 2. Different values were tried for α and the model presented low sensitivity to the variation of this parameter. Comparing models for α = 0.9 and α=0.5, $\Delta AT_x = -0.08$, and for α = 0.5 and α=0.1, $\Delta AT_x = -0.096$. Therefore, a value of 0.5 was chosen for all the use groups. Finally, the calculation of accessibility was made considering populated centers of 1000 inhabitants or more, as these places are assumed to have had an important historical influence in the patterns of current supply of the species considered.

Table 2 Parameters used in the model of provision of timber and NTFPs.

Use group	Number of species	Min hours	Max hours	α
Fruits and nuts - subsistence	39	6	15	0.5
Fruits and nuts - market	18	8	20	0.5
Game spp - subsistence	30	12	15	0.5
Fibers - subsistence	3	6	15	0.5
Timber - subsistence	5	6	15	0.5
Timber - market	10	12	20	0.5
Medicinal - subsistence	37	6	15	0.5
Medicinal - market	12	8	15	0.5

ES related to tourism and recreation

Due to time limitations, it was not possible to obtain consistent data for the whole Amazon basin related to recreational services provided by natural ecosystems. Available information was obtained on visitation rates to Protected Areas, which constitute one of the main target areas for nature based recreation. A map was produced using the patterns of visitation within each protected area.

Demand of ES

The team developed a conceptual model to estimate spatial patterns of demand for the timber and NTFPs identified. The model estimates the potential demand for a product *z* at spatial unit *x* by a harvester *s* based in market *h* (Equation 5).

$$\pi_{xhsz} = p_{zh} I(AT_{xz} > 0) - c_h \left(adjtravelhrs_{xh} + adjgatherhrs_{xz}(AT_{xz}) \right) \quad [5]$$

and

$$\sum_{s=1}^{S} \sum_{z=1}^{Z} \pi_{xhsz} = R_x \quad [6]$$

where p_{zh} is the market price for product *z* in market *h*, c_h is the hourly wage in the next most profitable line of work (e.g., construction, wage labor, etc.), $adjtravelhrs_{xhs}$ indicates the number of hours that it will take *s* to go from *h* to site *x* and back and $adjgatherhrs_{xz}(AT_{xz})$ is a function that indicates the number of hours that it will take *s* to gather product *z* in *x* and is a function of the relative supply of *z* in spatial unit *x* (AT_{xz}). $adjgatherhrs_{xz}(AT_{xz})$ is decreasing in AT_{xz}. Finally, R_x represents the total demand for the set of products *z* associated with market *h*.

Data constraints discussed in the results section prevented full implementation of the model. Instead, the analysis focused on the patterns of provision of ES related to biodiversity, timber and NTFPs in two categories of areas of special interest: 1) indigenous territories and 2) protected areas.

Future scenarios of provision of ES

Future scenarios for the provision of ES were generated based on two main sources of data: 1) a deforestation scenario developed by IPAM for the year 2020 and 2) data regarding road development in the Amazon region (Soares - Filho et al. 2006). These two data sources were used to recalculate the following maps under the projected scenarios of change:

- Habitat quality in the year 2020 (Q_{x2020}) calculated using the projected threat layers of accessibility and areas of recent conversion.
- Provision of timber and NTPFs using habitat quality in the year 2020 (Q'_{x2020}) and the new layer of accessibility based on projected land use and new roads.

To ensure that the scenarios of habitat quality for 2020 were comparable to the current maps, the threat layers used to calculate them were normalized to the maximum values in the 2000 maps.

Provision of ES in main regions of beneficiaries

The study area was regionalized into protected areas, indigenous territories, urban areas, and background areas (zones not belonging to any of the preceding categories) (Figure 2b). In the case of overlap of two or more categories, priority was given to urban areas and indigenous territories. The rationale was that each of these areas represents broad groups of beneficiaries of the services provided by biodiversity in the Amazon/Andes region. Additionally, a map of main habitat types was generated by reclassifying the map of Terrestrial Ecoregions of the World created by the World Wildlife Fund (Olson et al. 2001; Figure 2a). The main habitat types identified were: 1) dry forests, 2) Guayanan ecosystems, 3) mangroves, 4) moist forests, 5) montane forests, 6) montane grasslands, 7) savannas, 8) swamp forests, 9) varzea and 10) other ecosystems (marginal areas of desert and pantanal present in the region). Mean values within each of the combinations of habitat types and regions of use were created for: 1) Q_{x2000}, 2) AT_{x2000} (for the eight groups defined of timber and NTFPs), 3) expected change in Q_x between 2000 and 2020 and 4) expected changes in the provision of timber and NTFPs between 2000 and 2020.

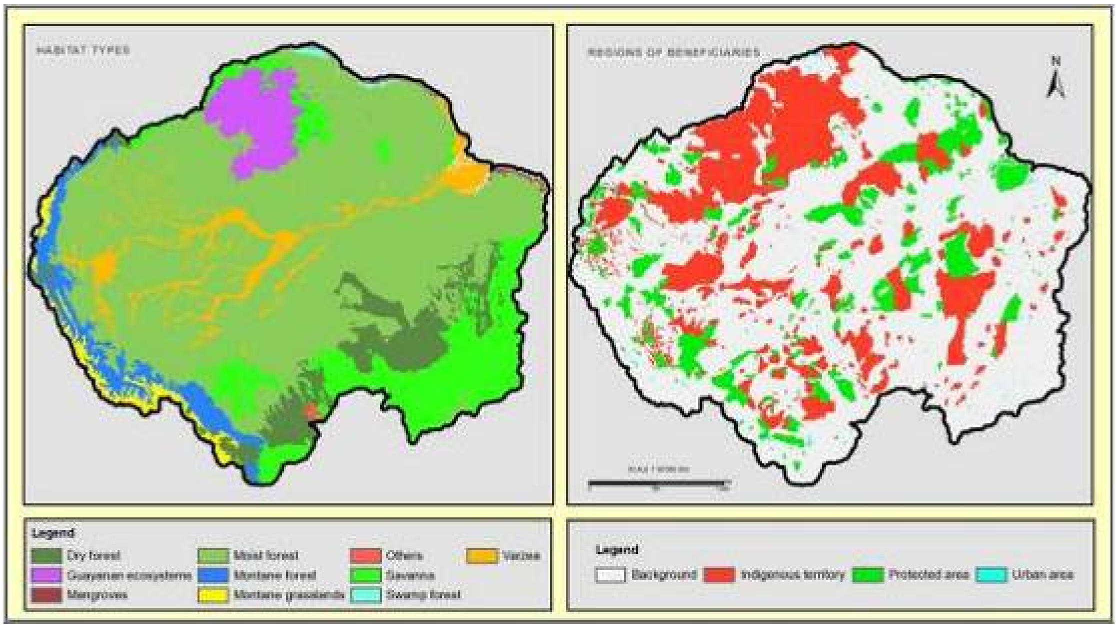

Figure 2 Regions defined to create summaries of habitat quality and provision of timber and NTFPs: a) map of protected areas, indigenous territories, urban areas, and background values, b) main habitat types in the study area.

Results and discussion

Current and future patterns of habitat quality in the Amazon basin

Current and future estimated patterns of habitat quality (Q_x) in the study area are presented in Figure 3. When the study area is disaggregated into regions of beneficiaries, it becomes apparent that habitat quality is greater in indigenous territories for most of the general habitat types defined (Table 3). Additionally, the habitat type that presents on average the highest values of habitat quality corresponds to the Guayanan ecosystems followed by the moist forests. On the other hand, the lowest quality habitat types are dry forests and savannas (Table 3).

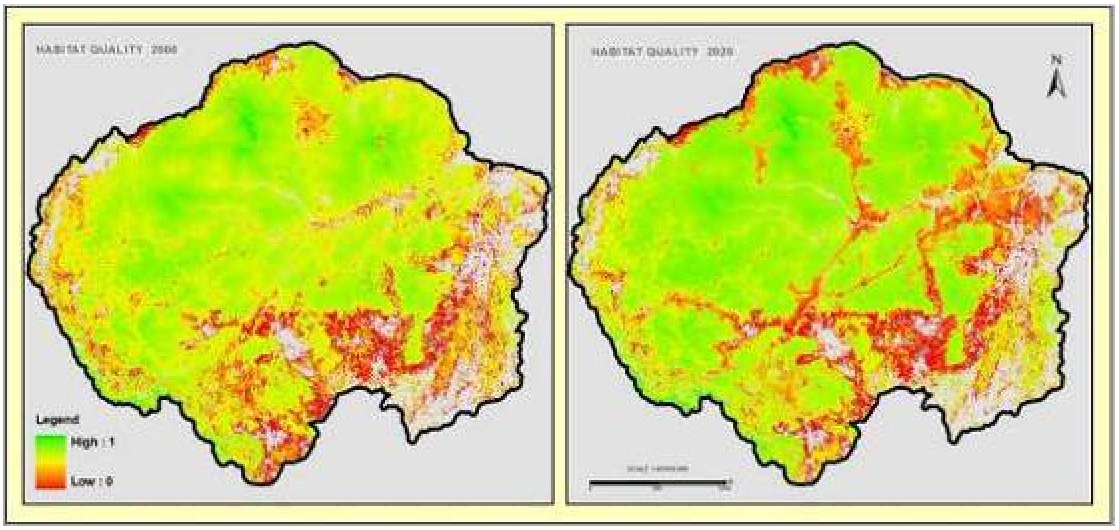

Figure 3 Current patterns and projected changes in habitat quality.

Table 3 Mean values of habitat quality ($Q_x \in [0,1]$) for the year 2000.

	Protected area	Rank PAs	Indigenous territory	Rank ITs	Background	Rank Back.
Dry forest	0.789	6	0.809	6	0.662	9
Guayanan ecosystems	0.867	1	0.878	2	0.840	2
Mangroves	0.763	9	0.879	1	0.766	7
Moist forest	0.842	2	0.851	4	0.808	5
Montane forest	0.804	4	0.785	7	0.767	6
Montane grasslands	0.776	8	0.750	9	0.851	1
Savanna	0.782	7	0.765	8	0.703	8
Swamp forest	0.795	5	0.864	3	0.815	3
Varzea	0.807	3	0.850	5	0.813	4

Other ecosystems	0.719
Urban areas	0.689

The main expected losses in habitat quality are associated to deforestation areas spatially related to new roads projected in the Amazon Basin (Figure 3). When these patterns are disaggregated, the region that would experience more loss in habitat quality corresponds to areas outside indigenous territories and protected areas (background region, Table 4) along with urban areas. At the habitat type level, dry forests, Guayanan ecosystems, and moist forests would experience more habitat quality loss than the other habitat types. In contrast, montane grasslands would experience low levels of loss of habitat quality (Table 4).

Table 4 Mean expected values of change in habitat quality between the years 2000 and 2020.

	Protected area	Rank PAs	Indigenous territory	Rank ITs	Background	Rank Back.
Dry forest	-3.947	2	-2.462	3	-6.234	2
Guayanan ecosystems	-1.471	6	-1.835	4	-5.567	3
Mangroves	-0.599	8	-0.007	9	-2.607	7
Moist forest	-2.917	3	-1.764	5	-5.094	4
Montane forest	-1.017	7	-2.753	1	-1.874	8
Montane grasslands	-0.014	9	-0.009	8	-0.014	9
Savanna	-1.901	5	-2.581	2	-2.674	6
Swamp forest	-2.060	4	-0.147	7	-6.587	1
Varzea	-4.507	1	-0.633	6	-3.036	5

Other ecosystems	-0.252
Urban areas	-5.391

These patterns can be explained in the context of the location of indigenous territories, generally in areas with difficult access and still relatively isolated from the main network of transportation in the Amazon Basin. In contrast, the areas classified as background are closer to the main fronts of deforestation in the region. Even though protected areas present intermediate values in terms of projected loss of habitat quality certain ecosystems in these areas (varzea, dry forests) still could experience significant impacts due to the influence of interrelated processes of increase in accessibility and deforestation in the future.

Current and future patterns of provision of timber and NTFPs

A map of the index of provision of timber and NTFPs was created for each of the eight groups of species defined (See Section 2.1.2). The maps depict both the current patterns of the index and the estimated changes under the scenarios of deforestation and road development used in the present assessment. The complete series of maps is presented in Annex 2. Figure 4 is an example of the maps produced for the group of fruit species locally used for subsistence. A common pattern across the eight groups considered is the spatial concentration of the provision of ES in moist forests and more specifically in the ecological systems present in the western portion of the Amazon Basin (Figure 4).

To facilitate the interpretation of the results, the mean values of the index of provision were summarized for all the groups destined to subsistence (Table 5) and for the market (Table 6). Individual tables are presented in Annex 2. The results disaggregated by region of beneficiaries and type of habitat are similar for both groups of species. In both cases, the highest values of the index of supply are associated with moist forests, closely followed by areas of varzea. Montane grasslands present the lowest values relative to the rest of habitat types considered. At the level of regions of beneficiaries, the index of provision presents the highest values in indigenous territories, followed by protected areas, and finally the background region. From all the combinations of habitat types and regions, the highest values of the index are found in areas of varzea within indigenous territories for both groups of species (Table 5 and Table 6).

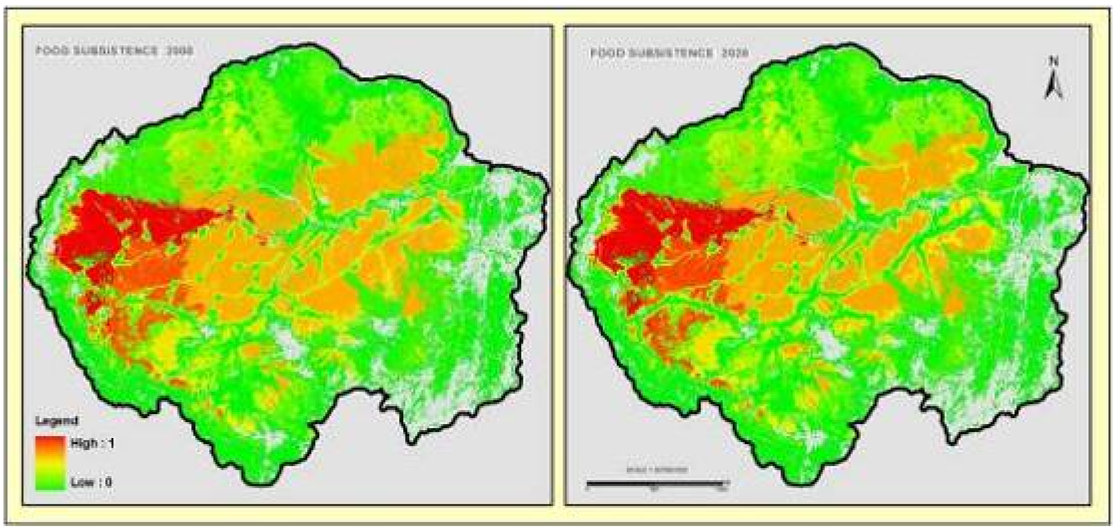

Figure 4 Current patterns and projected changes in the provision of ES ($AT_x \in [0,1]$) related to fruit and nut species for local use (subsistence).

Table 5 Mean values of the index of provision of ES ($AT_x \in [0,1]$) related to species used for subsistence.

	Protected area	Rank PAs	Indigenous territory	Rank ITs	Background	Rank Back.
Dry forest	0.118	4	0.080	5	0.020	6
Guayanan ecosystems	0.112	5	0.112	4	0.104	3
Mangroves	0.013	8	0.034	7	0.005	9
Moist forest	0.369	1	0.367	2	0.314	2
Montane forest	0.171	3	0.235	3	0.056	4
Montane grasslands	0.015	7	0.006	9	0.006	8
Savanna	0.047	6	0.074	6	0.015	7
Swamp forest	0.002	9	0.031	8	0.023	5
Varzea	0.225	2	0.442	1	0.316	1

Other ecosystems	0.008
Urban areas	0.004

Table 6 Mean values of the index of provision of ES ($AT_x \in [0,1]$) related to species destined to the market.

	Protected area	Rank PAs	Indigenous territory	Rank ITs	Background	Rank Back.
Dry forest	0.130	5	0.083	5	0.019	6
Guayanan ecosystems	0.153	3	0.151	4	0.118	3
Mangroves	0.011	8	0.022	8	0.005	8
Moist forest	0.335	1	0.342	2	0.277	1
Montane forest	0.150	4	0.212	3	0.045	4
Montane grasslands	0.019	7	0.007	9	0.002	9
Savanna	0.050	6	0.063	6	0.011	7
Swamp forest	0.008	9	0.022	7	0.020	5
Varzea	0.205	2	0.408	1	0.276	2

Other ecosystems	0.006
Urban areas	0.002

The patterns of loss in the index of provision of ES are summarized in Table 7 for species used for subsistence, and in Table 8 for species destined to the market. Again, the patterns between these two groups are similar. Most of the expected loss in the provision of ES is found in moist forests, followed by montane forests in the case of species for subsistence, and dry forests in the case of species commercialized. Looking at regions of beneficiaries, most of the expected loss is concentrated in background areas, followed by protected areas and indigenous territories for both groups of species. The highest values of loss correspond to moist forests in background areas (Table 7 and Table 8).

Table 7 Mean values of change in the index of provision of ES related to species used for subsistence.

	Protected area	Rank PAs	Indigenous territory	Rank ITs	Background	Rank Back.
Dry forest	-0.825	2	-0.377	4	-0.448	5
Guayanan ecosystems	-0.094	6	-0.248	6	-0.521	4
Mangroves	-0.072	7	0.000	9	-0.023	8
Moist forest	-2.123	1	-1.018	2	-2.819	1
Montane forest	-0.339	3	-1.089	1	-0.649	3
Montane grasslands	-0.006	9	-0.024	7	-0.009	9
Savanna	-0.234	5	-0.355	5	-0.291	6
Swamp forest	-0.046	8	0.000	8	-0.123	7
Varzea	-0.322	4	-0.552	3	-0.814	2

Other ecosystems	-0.007
Urban areas	-0.024

Table 8 Mean values of change in the index of provision of ES related to species commercialized.

	Protected area	Rank PAs	Indigenous territory	Rank ITs	Background	Rank Back.
Dry forest	-1.420	2	-0.631	4	-0.408	5
Guayanan ecosystems	-0.110	7	-0.301	6	-0.706	2
Mangroves	-0.075	8	0.000	9	-0.037	8
Moist forest	-2.145	1	-1.098	1	-2.485	1
Montane forest	-0.407	3	-1.015	2	-0.585	4
Montane grasslands	-0.014	9	-0.012	7	-0.003	9
Savanna	-0.235	5	-0.343	5	-0.235	6
Swamp forest	-0.337	4	-0.002	8	-0.202	7
Varzea	-0.180	6	-0.638	3	-0.637	3

Other ecosystems	-0.006
Urban areas	-0.013

These results provide broad regional patterns for the identification of priority areas in terms of the management of biodiversity with the purpose of securing the future provision of its associated ES. Even though background areas present the lowest current levels of provision of ES, these areas are expected to experience the highest loss under processes of deforestation in the short term. A related argument can be constructed for moist forests which currently present high levels of provision of ES and high levels of expected loss. The human groups that depend of biodiversity-related ES in these areas represent appropriate targets for the development and implementation of research and management initiatives aimed at reducing the loss of habitat quality and securing the flows of goods and services from natural ecosystems. An additional conclusion is that land use regimes in indigenous territories present lower levels of threat to ES provision in the region compared to deforestation and the development of infrastructure.

ES related to tourism and recreation

Data on visitation to protected areas was only available for Peru, Ecuador, and Bolivia (Figure 5). For the protected areas with visitation data, patterns of habitat quality and expected loss in habitat quality were established (

Table 9). The table contains two fields that rank the protected areas according to their habitat quality (Rank $Q_{x\ 2000}$; 1= highest quality) and habitat loss (Rank delta Q_x; 1=highest degree of expected loss). The fields named V_200* contain visitation data for years 2002 through 2006.

Some patterns can be observed in the data presented. The area with the highest average value of habitat quality (El Cajas National Park in Ecuador) also ranks amongst the most visited. Conversely, the areas with lowest values of habitat quality present low rates of visitation (Alto Mayo protected forest and Limoncocha biological reserve). However, the protected areas with the highest rates of visitation (Cotopaxi National Park and Machupichu Historical Sanctuary) have lower biodiversity values than other protected areas with significantly lower rates of visitation.

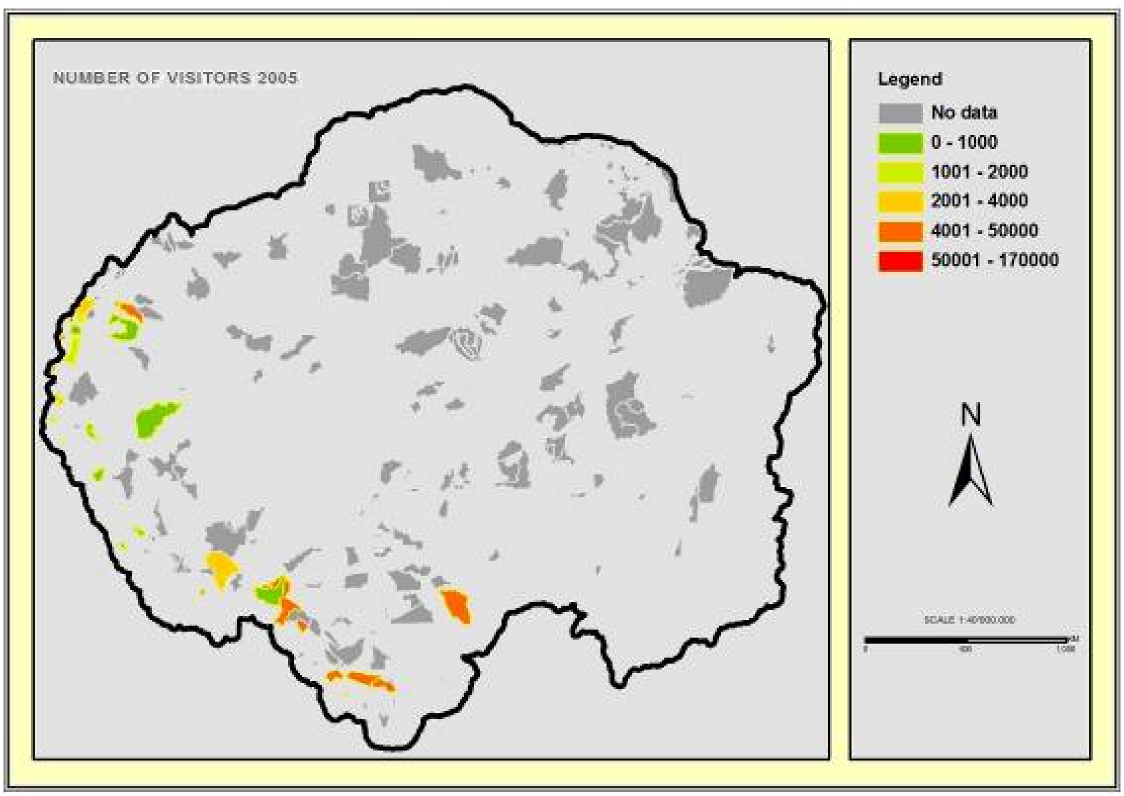

Figure 5 Number of visitors to protected areas in the year 2005.

Table 9 Mean values of habitat quality for the year 2000 and loss of habitat quality (2000 – 2020) in relation to visitation rates in protected areas for the period 2002 - 2006.

[redacted]

The relationship between mean values of habitat quality in the protected areas and the log of the maximum number of visitors it received in the period 2002 – 2006 is depicted in Figure 6. The results present a significant positive relationship ($r^2 = 0.23$, $F = 7.9627$, $p < 0.01$, $df = 28$) between the two variables, with tourist visitation increasing exponentially with habitat quality.

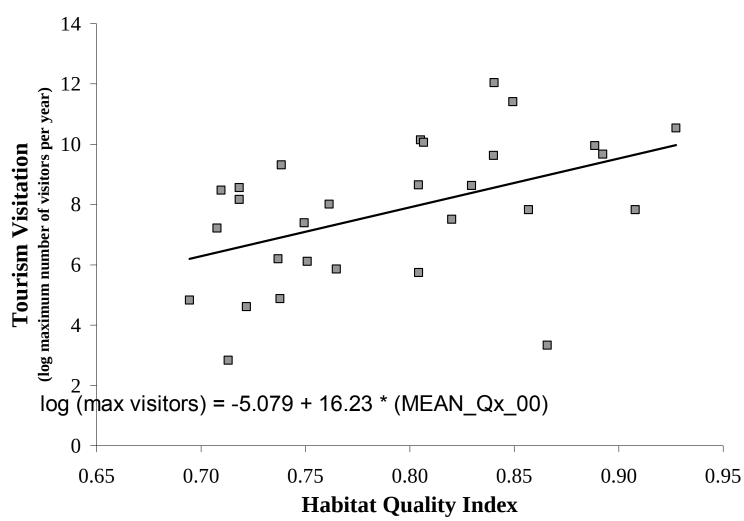

Figure 6 Relationship between habitat quality and the log of the number of visitors per year.

These patterns should be interpreted cautiously as the data are extremely fragmented. Some protected areas may have been omitted and some of the values that report no visitation may represent actually no data. More complete dataset should be collected to draw more appropriate conclusions regarding the relationships between biodiversity, the provision of ES related to tourism and recreation, and the patterns of use of these ES in the Amazon basin. We also know that accessibility is a critical factor related to visitation rates, and further work should include this and other important factors in predicting visitation rates.

Patterns of species richness and ecosystem diversity

The spatial patterns of ecosystem diversity at the three scales selected are depicted in Figure 7. As expected, the highest values are concentrated towards the western and southern portions of the study area. These areas correspond to the transition between Amazonian and Andean ecosystems to the west, and with dry forest and savanna ecosystems to the south.

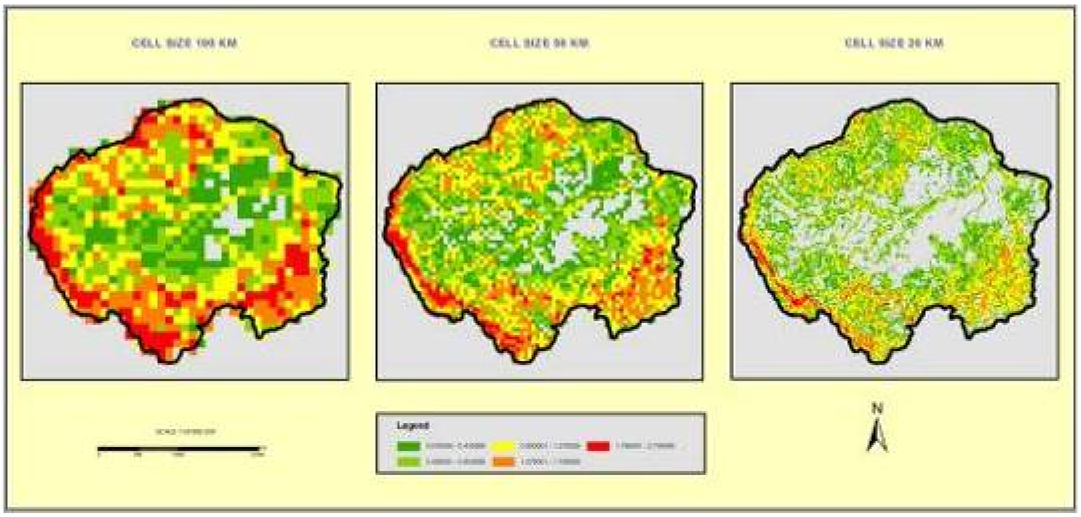

Figure 7 Habitat diversity in the Amazon basin using the Shannon's diversity index

The values of ecosystem diversity disaggregated by habitat type and regions of beneficiaries confirm the patterns observed above (Table 10). The highest levels of ecosystem diversity are associated with montane grasslands, followed by montane forests and savannas. The lowest levels are present in moist forests. Considering regions of beneficiaries, the differences are less evident, with indigenous territories presenting higher values than protected areas and background regions.

Table 10 Mean values of habitat diversity (measured using the Shannon's diversity index) for the different combinations of habitat type and region of beneficiaries.

	Protected area	Rank PAs	Indigenous territory	Rank ITs	Background	Rank Back.
Dry forest	0.661	5	0.631	6	0.760	4
Guayanan ecosystems	0.679	4	0.591	8	0.697	5
Mangroves	0.517	7	0.628	7	0.633	6
Moist forest	0.391	9	0.411	9	0.371	9
Montane forest	0.944	3	0.771	3	1.188	1
Montane grasslands	1.293	1	1.529	1	1.119	2
Savanna	1.055	2	0.896	2	0.813	3
Swamp forest	0.521	6	0.756	4	0.398	8
Varzea	0.431	8	0.637	5	0.573	7

Other ecosystems	1.247
Urban areas	0.788

Patterns of species richness in the study area are depicted in Figure 8. The patterns of species richness vary per group of species (Table 11, Table 12 and Table 13). For example, while the richness of amphibian species is highest in varzea and moist forest ecosystems, mammal species are concentrated in Guayanan ecosystems. A consistent pattern for the three groups of species is that they present the lowest richness in montane ecosystems.

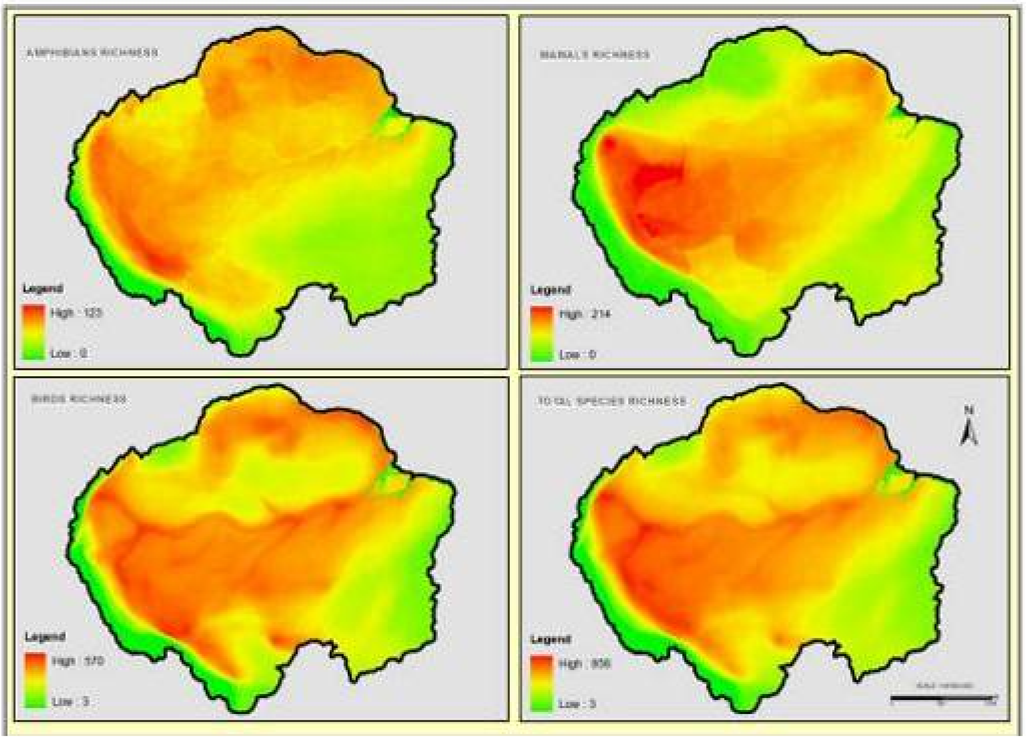

Figure 8 Species richness

Table 11 Mean values of amphibian species richness

	Protected area	Rank PAs	Indigenous territory	Rank ITs	Background	Rank Back.
Dry forest	43	7	47	3	36	5
Guayanan ecosystems	55	3	30	7	34	6
Mangroves	53	4	31	6	33	7
Moist forest	67	1	64	2	67	2
Montane forest	14	8	23	8	8	8
Montane grasslands	7	9	6	9	4	9
Savanna	45	6	42	4	36	4
Swamp forest	52	5	38	5	43	3
Varzea	65	2	80	1	80	1

Other ecosystems	20
Urban areas	41

Table 12 Mean values of mammal species richness

	Protected area	Rank PAs	Indigenous territory	Rank ITs	Background	Rank Back.
Dry forest	137	8	135	8	127	6
Guayanan ecosystems	175	2	177	1	176	1
Mangroves	172	3	148	7	127	7
Moist forest	166	4	162	3	164	4
Montane forest	158	5	157	5	122	8
Montane grasslands	125	9	127	9	80	9
Savanna	144	7	152	6	133	5
Swamp forest	183	1	159	4	175	2
Varzea	157	6	169	2	167	3

Other ecosystems	93
Urban areas	141

Table 13 Mean values of bird species richness

	Protected area	Rank PAs	Indigenous territory	Rank ITs	Background	Rank Back.
Dry forest	396	6	383	6	342	7
Guayanan ecosystems	397	5	449	2	443	4
Mangroves	484	2	315	8	348	5
Moist forest	444	3	429	3	447	2
Montane forest	395	7	422	4	262	8
Montane grasslands	202	9	190	9	139	9
Savanna	388	8	419	5	347	6
Swamp forest	513	1	347	7	445	3
Varzea	443	4	469	1	472	1

Other ecosystems	227
Urban areas	363

Total species richness is higher in varzea, swamp forest, and moist forest ecosystems (Table 14). The lowest values are present in montane ecosystems. These resulting patterns are highly influenced by the distribution of bird species, since this groups has more species than the other two combined (mammals and amphibians) in the dataset used. The dataset represent overall patterns of species in the study region. However, different sources of uncertainty have to be taken into account, such as geographic biases in the collection of presence data (e.g. more sampling efforts in accessible areas) or the omission in the study of certain taxa (Stockwell and Peterson 2002).

Table 14 Mean values of total species richness

	Protected area	Rank PAs	Indigenous territory	Rank ITs	Background	Rank Back.
Dry forest	576	7	564	6	504	7
Guayanan ecosystems	626	5	656	2	654	4
Mangroves	708	2	494	8	508	6
Moist forest	677	3	655	3	677	2
Montane forest	567	8	602	5	392	8
Montane grasslands	334	9	323	9	222	9
Savanna	576	6	613	4	516	5
Swamp forest	748	1	544	7	662	3
Varzea	665	4	719	1	719	1

Other ecosystems	341
Urban areas	546

Methodological issues and knowledge gaps

The development of this assessment presented important conceptual and methodological challenges. As shown in other regional assessments oriented at policy and intervention, the validity of the results is as good as the data sources from which these results were obtained (Nelson et al. 2008). In this context, the methodology and results presented here should be regarded more as a framework to identify further goals for research than as a guide for intervention. The following discussion specifies the main knowledge gaps identified during the execution of the study.

Evaluation of the state of biodiversity

Indexes that synthesize the influence of several factors on the status of biodiversity have been used to provide spatial perspectives at global to regional scales (e.g. Sanderson et al. 2002, Alkemade et al. 2006). This strategy combines the advantages of being relatively easy to implement with the presentation of results in an intuitive format. However, these measures of threat, pressure or habitat quality also share a number of important limitations that should be taken into account when using and interpreting the results of the analyses.

The calculation of habitat quality performed in this study takes into account seven major sources of threat to the integrity of natural ecosystems. Even though these threats cover major processes that affect biodiversity, it is not difficult to think of additional factors that are likely to have important effects in the study area. These could include the effects of climate change on the structure and composition of existing ecosystems, the effects of landscape fragmentation, and associated biotic processes such as local extinctions or the spread of invasive species. The impacts of these sources of habitat degradation should be evaluated, especially as they may affect species and communities that are critical for the sustainment of local livelihoods (e.g. game species).

An additional issue is the static nature of the methodology implemented. Most of the threat factors considered in the calculation of habitat quality present some level of interaction (e.g. recent conversion and conversion to agriculture) which is not explicitly considered in the model. Furthermore, the projection of the index of habitat quality to the year 2020 only included the threats from deforestation and the expansion of the road network. The estimation of future patterns for the other sources of threat is complicated due to the paucity of information, mismatch in the scale of data sources, and lack of appropriate methodological frameworks to generate future scenarios for these factors. In spite of these limitations, the maps of habitat quality generated do provide a robust overview of the status of biodiversity in the Amazon/Andes region.

Limited information and data gaps unable the team to include analysis of other important ecosystem services like nutrient cycling or ecosystem stability. There is a need of better understanding on the links between biodiversity at different levels (i.e. species, ecosystems) and the provision of specific ES. Finally, we need a better understanding on how human disturbances and habitat degradation can affect the supply of different ecosystems services provided by natural ecosystems. We need to have a better idea on resilience and resistance of natural ecosystems to change before they start loosing the capacity to provide different ES.

ES related to timber and NTFPs

The key source of data for the generation of patterns of provision of ES related to timber and NTFPs is the distribution of species across the study region. In this study a simple approach was used to estimate the distribution of the species selected. It was assumed that if a species had been registered in a given ecological system, the species would be potentially present in the whole extension of that ecosystem. In other words, the basic assumption is that the ecological system becomes a valid proxy of the fundamental niche of the species. This approach can lead to commission errors in areas where a given species is considered present but it is not, or omission errors when species are present in an ecological system but have not been registered. Significant improvements to the methodology could be attained by applying niche modeling techniques to generate more accurate estimations of the distribution of key species in the study area (Guisan and Zimmermann 2000).

The selection of used species in the Amazon basin also presented important challenges. The list of species selected should be regarded as a sample of the universe of species actually being used in the region. Data was especially difficult to compile for some of the defined groups of use (

Table 2) such as fibers or game species used for subsistence. Future assessments should consider generating more exhaustive lists of species and to incorporate regional variations in terms of which species are used, the intensity and purpose of their use, and their main markets of destination.

The model used to map the index of provision of ES related to timber and NTFPs required the estimation of a set of parameters for which empirical data was not readily available (Equation 4,

Table 2). For example, the thresholds of accessibility used in the model represent more referential values used to generate regional patterns rather than absolute values defined on an empirical basis. Other studies have acknowledged the subjective nature associated with the definition of such thresholds, as accessibility is a relative concept that varies among cultural groups, types of ecosystems (e.g. montane ecosystems vs. lowland moist forests), and patterns of resource use (Sanderson et al. 2002).

The model proposed in Equation 5 has the advantage of providing a spatially explicit estimation of the demand associated with a species using a consistent scale (i.e. monetary value). However, during the implementation of the methodology it became apparent that the data gaps needed to run the model were too big to be filled within the timeframe of the project. However, the model still can be used to identify two important knowledge gaps related to the demand of ES in the Amazon basin. First, we need a better discrimination of groups of users and their spatial distribution. This would lead to a better discrimination of patterns of resource use in heterogeneous areas such as the background region defined in this study

(Figure 2). In addition, this could facilitate the identification of important market centers for the species identified as critical in the provision of ES. The original idea of the model was to generate data about accessibility and the related costs of transportation associated to species used locally, destined to regional markets, and exported to national or international markets.

A second knowledge gap identified is related to the specific areas that are providing ES for these groups of users. A useful analog would be the delineation of a watershed providing water for a defined group of users (e.g. a city). Of special importance are areas critical for groups of users which are highly dependent on the ES provided by biodiversity (e.g. through game, food or medicinal species used for subsistence). Furthermore, given global trends of economic integration it is important to consider the effects of ex-situ users of goods and services provided by Amazonian biodiversity. The regions of beneficiaries used in this study (Figure 2) constitute a first step towards the disaggregation of spatial patterns of supply and demand of ES in the Amazon basin.

ES related to tourism and recreation

Mapping ES related to tourism and recreation was difficult due the scarcity of consistent data for the countries in the study region. The only dataset available consisted of visitation rates for protected areas in the Amazon basin. There is a clear need for a more sophisticated analytical framework to relate the ES provided by biodiversity with current and potential visitation rates to protected areas. Such model would require basic data on:

1. Visitation rate data, parsed to domestic and international origins.
2. Travel times. Travel times should by adjusted to represent the country of origin for different groups of visitors.
3. Number of activities available in the area.
4. Site quality (e.g. overall landscape diversity, presence of charismatic megafauna).
5. Cultural attractions (e.g. village visits, community management)
6. Infrastructure (accommodations, trails, etc.).
7. Competition (e.g. distance to other parks, degree of similarity with neighboring protected areas).

Furthermore, the potential of regions outside national systems of protected areas should be taken into account. This becomes an important goal given the recent trend towards the implementation of integrated conservation and development projects that promote tourism as a key management strategy to attain the conservation of biodiversity and the alleviation of poverty at the community level. The relationship between provision of tourism and recreation, biodiversity conservation, and improvement of local livelihoods should be defined empirically for the Amazon basin and within each country.

Relationships between biodiversity and the provision of ES

It becomes evident from the results that patterns of habitat quality, provision of ES, species richness and habitat diversity do not necessarily coincide in space. In certain cases, areas with high biological diversity in terms of species richness (e.g. moist forests) also present high levels of provision of ES related to timber and NTFPs. However, these areas do not necessarily present high diversity at the ecosystem level. This condition could be different for other types of ecosystem services such as pollination, water provision, and hydrological regulation. It is likely that the structure and composition of the landscape becomes a critical factor for the sustenance of these services. Establishing the links between biodiversity at different levels (i.e. species, ecosystems) and the provision of ES in the Amazon basin requires further research and the collection of appropriate datasets.

In this context, the results presented suggest that indigenous territories would be a priority target to generate an assessment of the links between the conservation of biological diversity and the management of resources that provide ES. These areas present high levels of habitat quality, species richness, and provision of ES. At the same time, these areas would present low levels of loss of these characteristics in the context of the projected trends in deforestation and infrastructure development. Therefore, these areas present an adequate setting to achieve the protection of biodiversity while continuing the provision of the ES assessed in the present study.

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Appendix 7 - Fish supply and consumption – Methodology and detailed Results

Introduction

Aquatic biodiversity features among the most important components of biodiversity in the Andes/Amazon region. Aquatic fauna represents a significant source of income and proteins for large parts of the rural population (Alonso *et al*, 2008). This section presents a diagnosis of the current situation of aquatic biodiversity focusing on fish resources

Information on aquatic biodiversity in the Andes/Amazon was found to be scarce and primarily local. We, nevertheless, tried to identify regional differences in the patterns fish resource use. The Amazon basin is extraordinarily rich in fish resources (Figure 9), harboring around 2,500 fish species (Gery, 1984; WRI, 2003; Barthem, & Goulding, 2007; Alonso *et al*.,2008). This biodiversity is not uniformly distributed across the Amazonian region (Figure 10). Brazil has the greatest number of species (nearly 2,000), followed by Colombia (1,177), Peru (814), Venezuela (939), and Bolivia (635).

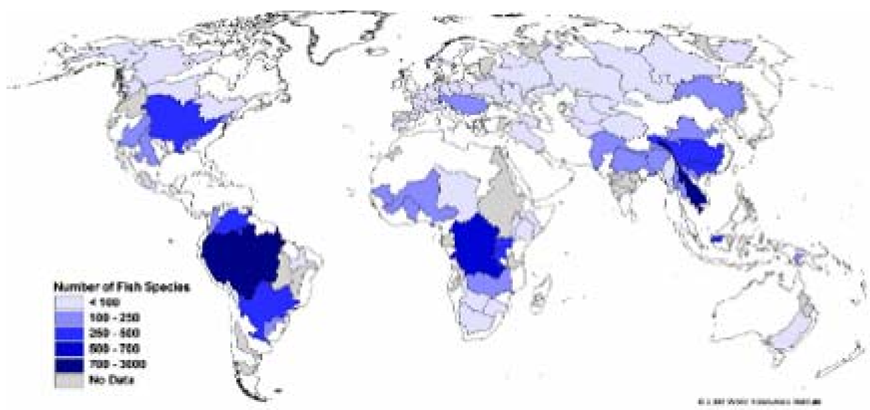

Figure 9 *Number of Fish Species. Source: WRI 2003*

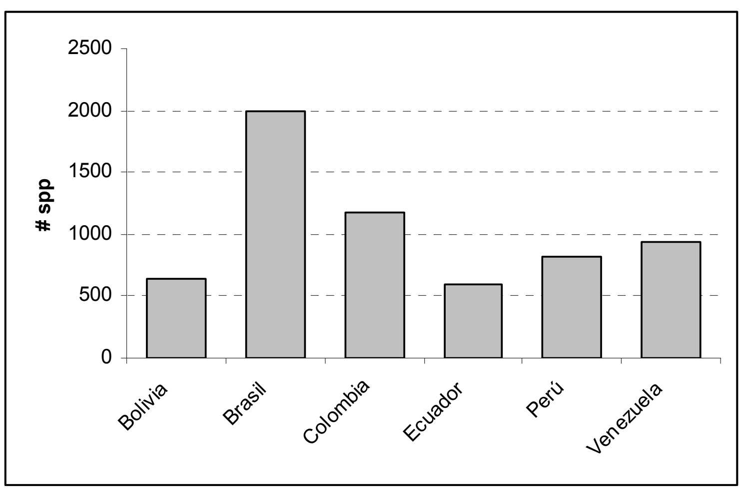

Figure 10 *Fish richness by Amazonian country. Source: TCA (1996).*

In an attempt to characterize the Amazon/Andes fishery resource base we mapped fish species richness into 19 freshwater ecosystems (WWF and TNC 2008), and richness was mapped to each of these (**Figure 11**). The greatest richness was found in Amazon Lowlands (880 species), Rio Negro (616 species) and Orinoco Guyana Shield (610 species). The greatest endemism is found in Amazon Lowlands (880 species), Guyana Shield (145 species) and Tocantins – Araguaia (115 species).

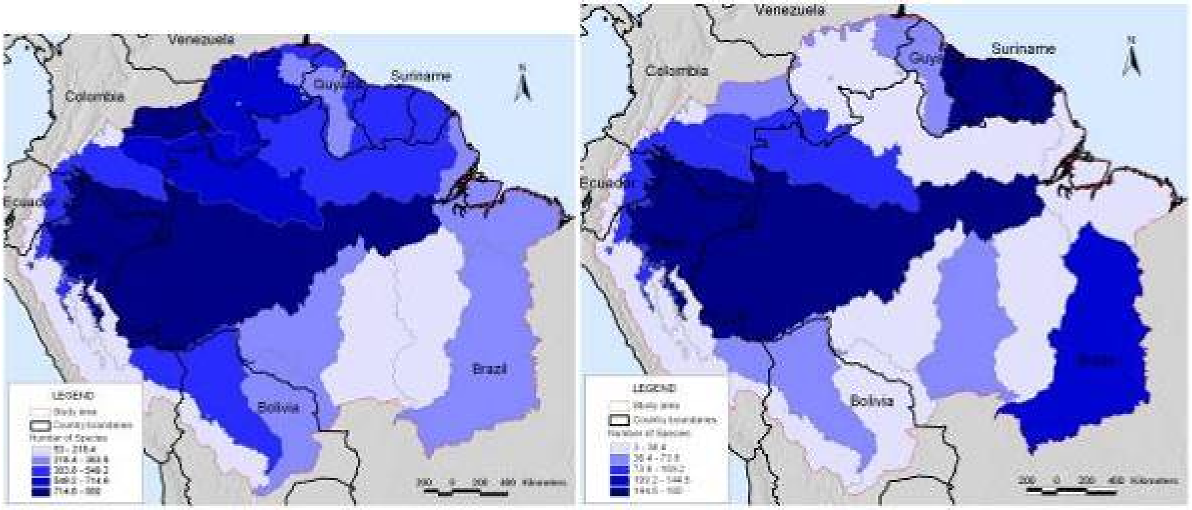

***Figure 11** Fish richness map by freshwater ecoregion (left), and fish endemism map by freshwater ecoregion (right). Source: WWF and TNC, 2008*

Commercial and subsistence fishing relies on an average of 200 species (Gery 1984), and the capture of ornamental fish spans nearly 350 species (WWF, Incoder and Traffic 2006).

In 2005, Brazil accounted for roughly four fifth of the total fish production in the Andes/Amazon region, followed by Peru and Colombia. These three countries also have the highest shares in ornamental fish exports, although Bolivia, Ecuador, Venezuela and Guyana also participate in this market.

In general knowledge gaps exist both on the supply and the demand side of the fish economy.

Supply

Little is known about the ecological characteristics of the regional fish population, such as distribution, feeding and reproductive habits. This limits the development of sustainable management strategies, for example, based on species-specific close seasons. The same applies to the definition of sustainable harvest rates that require better knowledge of population dynamics and growth to determine the number (size) of individuals per species that can caught without compromising future supply.

Demand

There is uncertainty regarding both domestic fish demand from Amazon countries and exports. Moreover, no reliable information exists on the size of the population that depends on fishing, the number of fishing sites and fishing effort for fisher/species/day, with the exception of some specific, regional projects carried out by IIAP, Sinchi, Ibama in the lower and middle Amazon.

Methodology and data

Knowing the number of commercial and non-commercial fish species in the Amazonian biome is not enough if the objective is to draw conclusion on the potential for sustainable livelihoods on the basis of fishery. We, hence, made an effort to estimate the approximate supply and demand of hydro-biological resources on the basis of the available literature and statistics.

Supply

Several studies with limited scope have estimated fish supply in the Amazon using diverse methodologies. For example, Montreuil *et al.* (2003) analyzed species composition and supply in lower Ucayali in the Peruvian Amazon; Riofrio (1998) estimated the supply by relating capture with fishing effort in Pucallpa, as did Tello and Bayley (2001) for the commercial fleet at Iquitos, or Guerra *et al.* (1990) and Granados (1987) who estimated ichthyic biomass or (ichthyo-mass) by acoustic means. All these methods require extensive field work beyond the scope and objectives of this situation analysis.

As a rough approximation we use here district-level commercial catch statistics and an estimate of subsistence fish harvest:

$$Supply = Cf + Sf \quad [1]$$

Where: Cf is commercial fishing measured by statistical data, Sf is subsistence fishing for which there are no official statistics, but is calculated using the following formula:

$$Sf = Cpr * Pop \quad [2]$$

Where: Cpr is the consumption per capita in rural areas based on Figure 12 and Pop is the number of inhabitants using the model of population density (Landscan 2000) and the distribution of rural and urban areas from the GRUMP database.

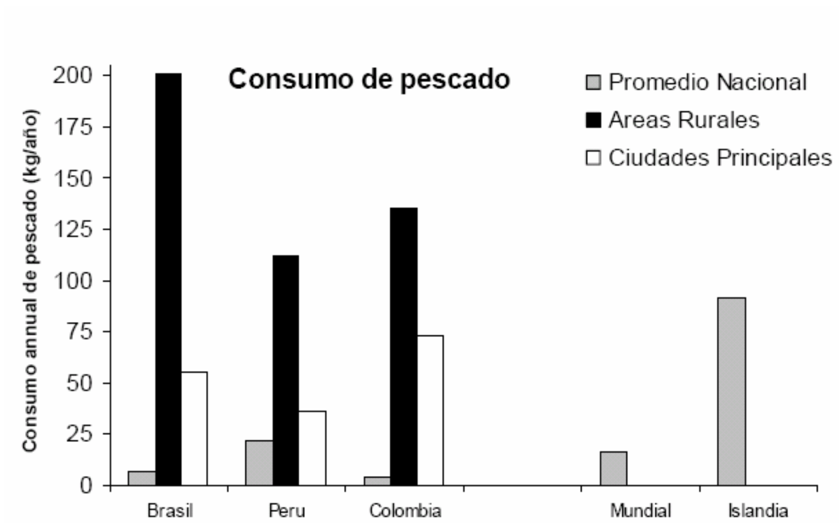

***Figure 12**: Annual fish consumption. FAO (2005).*

Demand

Given the abundance of fish resources, fish consumption is comparatively high in the Amazon region. In Peru, for example, Hanek (1982) determined that the level of fish consumption per capita/year was 36 kg in cities and 101 kg in riverine areas.

Since demand largely depends on resource access, it is largly affected by the spatial distribution of supply. Our approach is to approximate spatial supply distribution based on population density and per capita fish consumption in both rural and urban populations in the Andes/Amazon region.

$$Demand = Capr + Capl \quad [3]$$

Where: *Capr* is total annual fish consumption in rural areas calculated using Equation 3 and *Capl* is the annual fish consumption in urban areas.

Results and discussion

Supply

Catch statistics suggest seasonal variations in fish supply that are directly related seasonal water level variability. During seasonal floods, resources are dispersed throughout the basin and, consequently, fishing is less efficient. Supply falls below demand during this period, principally in cities and fish prices rise. During dry months, supply increases due to the concentration of resources and greater fishing efficiency. Montreuil *et al*., (1991) report that in Peru at least 70% of the capture is recorded during this period and the supply greatly exceeds demand, with a consequent drop in prices. Although this general pattern applies to all fish species, small, but potentially locally relevant differences between species (**Error! Reference source not found.**).

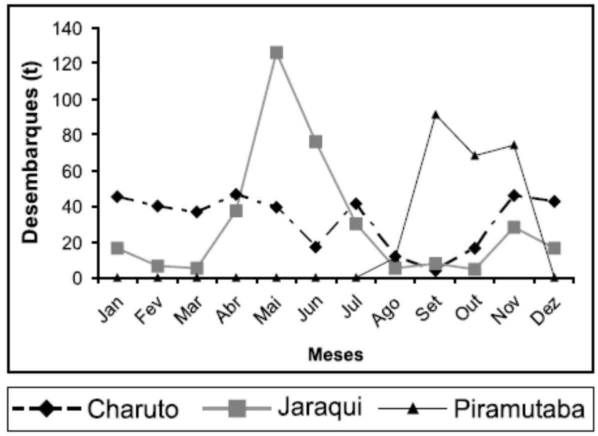

***Figure 13** Monthly landings of the main commercial fish in Manacapuru - Brasil: Charuto (Anodus melanopogon), Jaraqui (Semaprochilodus insigni)s, Piramutaba (Brachyplatystoma vailanti)i. Provársea 2003.*

Catch statistics suggest that the supply of some species has declined during the last three decades leading to the substitution with other species. For instance, the longest available time series for the Ucayali region (Peru), shows that Dorado (*Brachyplatystoma rousseauxii*) catches reduced from 320 tons in1980 to 22.3 tons in 2006. At the same time, species such as the palometa (*Mylossoma duriventris)* and the sardine *(Triportheus spp)*, insignificant in 1980, became the most important commercial fish species along with Bocachico *(Prochilodus nigricans)* in 2006 (**Error! Reference source not found.**). Alonso *et al.* (2008) concluded that capture rates changed due to excessive fishing of some species, after comparing statistics for Colombia, Brazil, and Peru in the years 1994, 1995, 1996, and 2000.

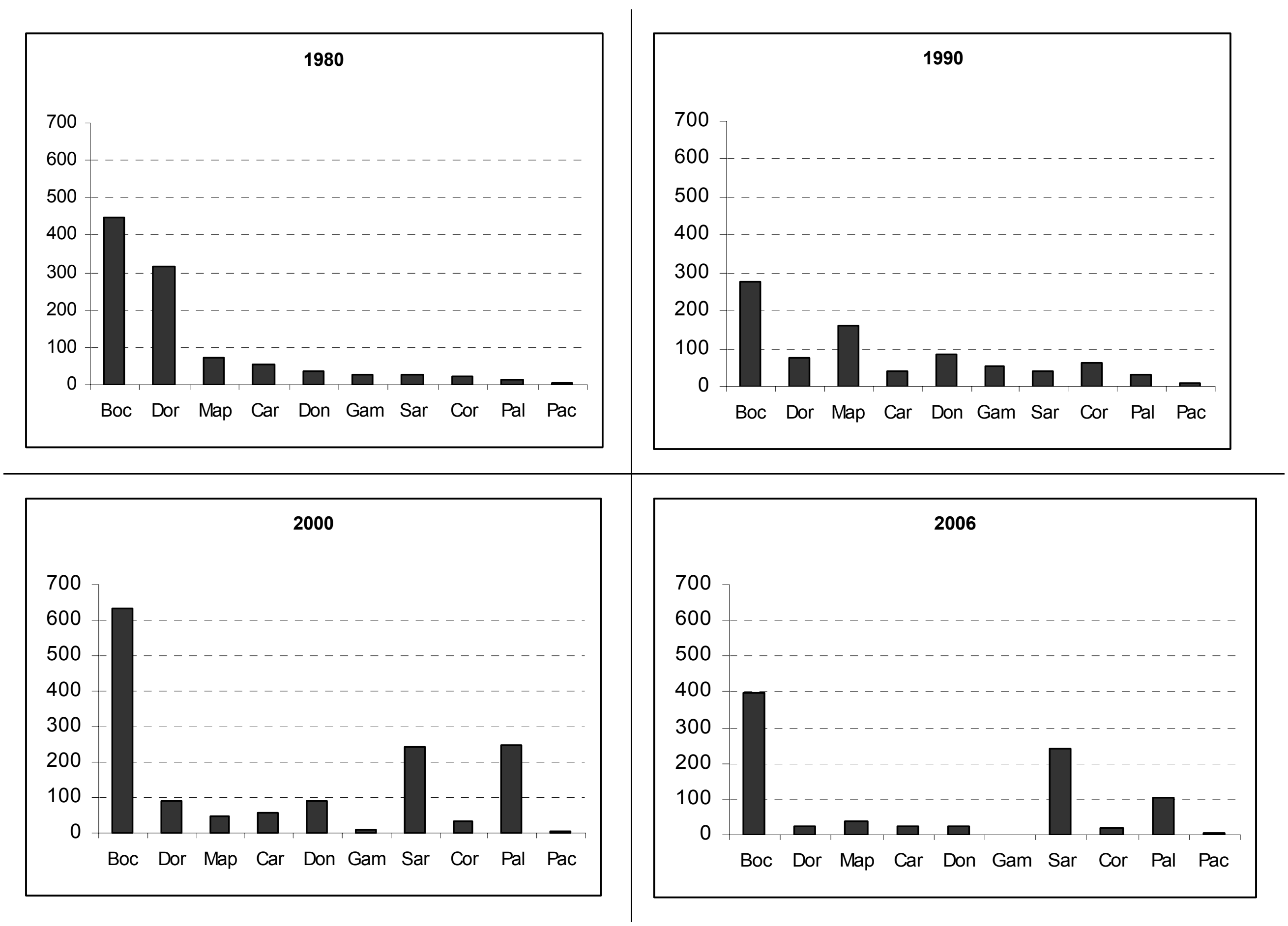

***Figure 14.** Main species unloaded in the Ucayalli, Peru region: Boc BOQUICHICO Prochilodus nigricans, Dor DORADO Brachyplatystoma rousseauxii, Map MAPARATE Hypophtalmus*

edentaus, Car CARACHAMA Pterygoplichthys multiradiatus, Don DONCELLA Psudoplatystoma fasciatus, Gam GAMITANA Colossoma macropomum, Sar SARDINA Triportheus spp. Cor CORVINA Plagioscion squamosissimus, Pal PALOMETA Mylossoma duriventris, Pac PACO Piaractus prachypomus

The available data suggest that in the Amazon region, 365,550 and 220,200 tons/year are fished for subsistence and commercial purposes, respectively (**Table 15**). Based on these figures, the estimated total (566,750 tons/year) is roughly one half of the potential supply estimated by Merona (1993), however, with little information on sustainable harvest rates,

The main areas of supply are towards the lower watershed of the Amazon, the states of Para and Amazonas in the Brazilian Amazon (**Figure 15**), corresponding to 27.7% of the total supply in the region.

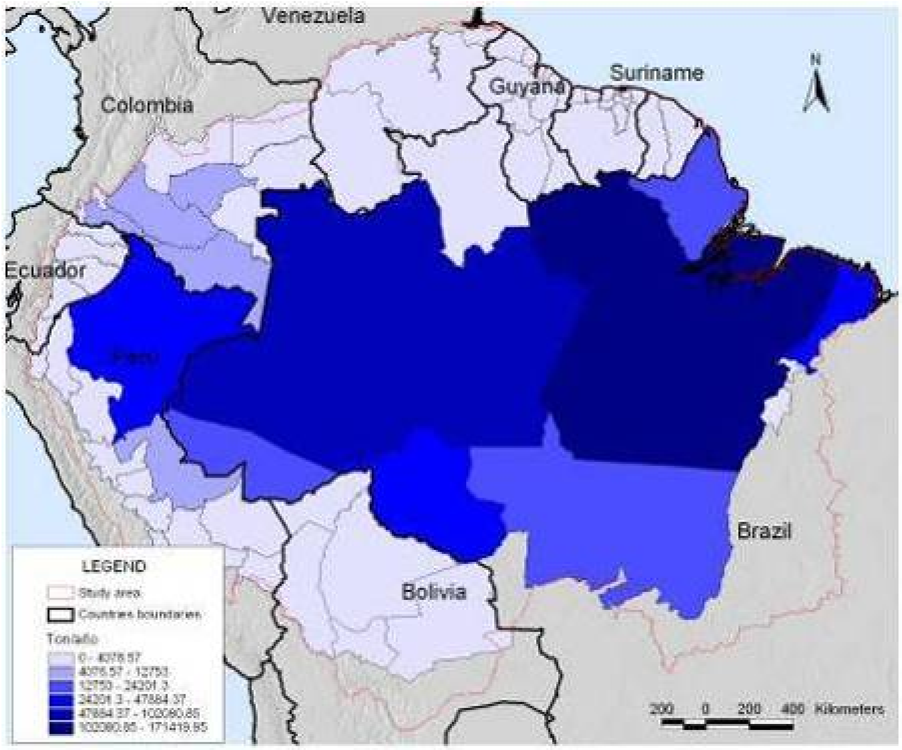

***Figure 15**. Distribution of supply for fish for consumption*

***Table 15** Supply of fish for consumption in the Amazon*

	Commercial Fishing According to Statistics Tons/Year (2005)	Subsistence Fishing Tons/Year (2000)	Total Supply Tons/Year
Bolivia	614	4789	5404
Brazil	162173	220896	383068
Colombia	7896	29203	37099
Ecuador	No data	1673	1673
Guyana	625	3588	4213
Fr. Guiana	No data	1613	1613
Peru	29252	31363	60614
Suriname	No data	1312	1312
Venezuela	623	3728	4351
Total	**201182**	**298166**	**499348**

Demand

Figure 16 illustrates the spatial distribution of demand taking into account the sum of local consumption in rural and urban areas. The states of Para and Amazonas in Brazil stand out as the areas with the highest consumption in the study area.

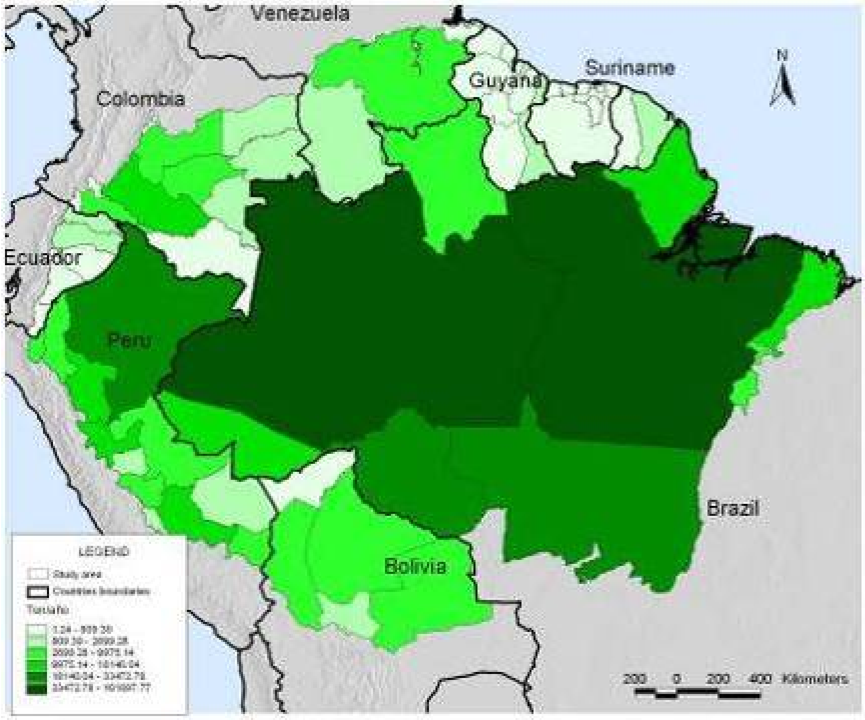

Figure 16 *Distribution of the demand for fish for consumption in the Amazon. Tons/year*

Matching supply and consumption, the blue areas in **Error! Reference source not found.** show excess supply of fish resources allowing commercialization outside the region, whereas green areas represent a deficit of fish in relation to annual per capita intake; light blue areas represent small deficits possibly due to the lack of systematization of fisheries information or areas which are supplied by resources from local aquaculture.

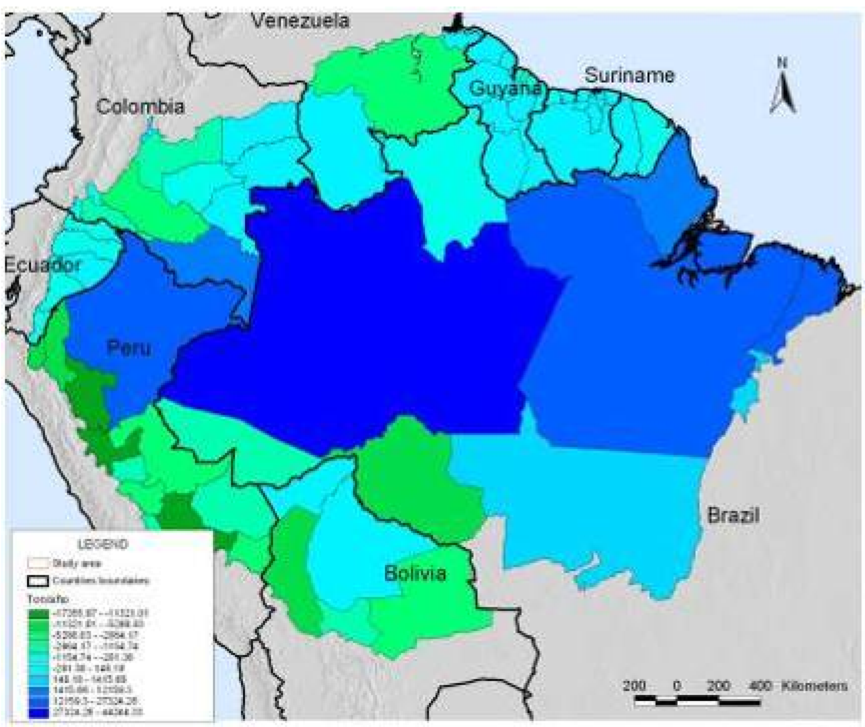

Figure 17 *Relation supply – demand*

Table 16 *Estimate of the relation between supply/demand in the Amazonian countries*

	Consumption in rural areas	Consumption in urban areas	Total local demand	Rel. local supply/demand
Bolivia	4789	11163	15952	-10549
Brazil	220896	68367	289262	93806
Colombia	29203	3892	33095	4004
Ecuador	1673	2485	4158	-2485
Guyana	3588	3044	6632	-2419
Fr. Guiana	1613	475	2088	-475
Peru	31363	48523	79886	-19271
Suriname	1312	2725	4038	-2725
Venezuela	3728	3811	7539	-3188
Total	**298166**	**144485**	**442651**	**56697**

Table 2 provides actual supply/consumption figures and local excess and deficit respectively. In both Brazil and Colombia, supply exceeds national consumption. In Peru, despite an excess of 16,581 tons/year in the Loreto region, there is a deficit in regions closer to the Andes, especially in the departments of Cuzco, Huanuco, Junin and San Martin. Those regions satisfy demand through imports from the Pacific coast or aquaculture. In Bolivia there is a similar situation, and the deficit is supplied by products arriving from Argentina, the Pastaza watershed and Lake Titicaca. The remaining countries have a negative balance, which might well be due to missing information.

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Main commercial fish on Amazon-Andean Region

Orden	Familia	Genus	Common Name
Siluriformes	Pimelodidae	Brachyplatystoma vaillantii	Piramutaba
Siluriformes	Pimelodidae	Brachyplatystoma rousseauxii	Dourada
Characiformes	Prochilodontidae	Semaprochilodus insignis	Jaraqui
Characiformes	Prochilodontidae	Prochilodus nigricans	Curimatã-Curimbata
Siluriformes	Hypophthalmidae	Hypophtalmus fimbriatus	Mapará
Perciformes	Sciaenidae	Plagioscion squamosissioums	Pescada
Characiformes	Characidae	Mylossoma duriventre	Pacu
Characiformes	Curimatidae	Potamorhina latior	Branquinha
Siluriformes	Pimelodidae	Pseudoplatystoma tigrinum	Surubim
Characiformes	Characidae	Brycon melanopterus	Matrinxã
Perciformes	Cichlidae	Cichla monoculus	Tucunaré
Characiformes	Erythrinidae	Hoplias malabaricus	Traíra
Characiformes	Characidae	Colossoma macropomum	Tambaqui
Characiformes	Anostomidae	Anostomoides laticeps	Aracu
Siluriformes	Loricariidae	Pimelodus blochii	Bagre (mandi)
Characiformes	Characidae	Triportheus angulatus	Sardinha
Siluriformes	Pimelodidae	Brachyplatystoma filamentosum	Filhote
Characiformes	Anostomidae	Leporinus fasciatus	Piau
Siluriformes	Loricariidae	Liposarcus pardalis	Acará
Characiformes	Characidae	Piaractus brachypomus	Pirapitinga
Siluriformes	Auchenipteridae	Ageneiosus brevifilis	Mandubé
Osteoglossiformes	Osteoglossidae	Osteoglossum bicirrhosum	Aruanã
Siluriformes	Pimelodidae	Brachyplatystoma flavicans	Dourado
Characiformes	Hemiodontidae	Anodus melanopogon	Charuto
Osteoglossiformes	Arapaimidae	Arapaima gigas	Pirarucu
Rajiformes	Potamotrygonidae	Potamotrygon motoro	Arraia
Characiformes	Serrasalmidae	Serrasalmidae sp	Piranha
Perciformes	Cichlidae	Astronotus ocellatus	Acará-açu
Siluriformes	Loricariidae	Pterygoplichthys sp.	Acari-bodó
Characiformes	Cynodontidae	Cynodon gibbus	Cachorra
Siluriformes	Pimelodidae	Pseudoplatystoma coruscans	Pintado
Perciformes	Cichlidae	Astronotus ocelatus	Apaiari
Siluriformes	Pimelodidae	Phractocephalus hemiliopterus	Pirarara
Siluriformes	Callichthyidae	Hoplosternum litorale	Tamoatá
Siluriformes	Pimelodidae	Pinirampus pirinampu	Barbado
Siluriformes	Pimelodidae	Zungaro zumgaro	Jaú
Characiformes	Erythrinidae	Hoplerythrinus unitaeniatus	Jeju
Siluriformes	Pimelodidae	Paulicea luetkeni	Pacamom
Siluriformes	Doradidae	Platydoras costatus	Bacu
Characiformes	Hemiodontidae	Hemiodus unimaculatus	Jatuarana
Siluriformes	Doradidae	Oxydoras niger	Cuiú-cuiú
Clupeiformes	Clupeidae	Pellona flavipinnis	Apapá
Perciformes	Cichlidae	Crenicichla johanna	Jacundá
Characiformes	Hemiodontidae	Hemiodus microlepis	Avoador
Siluriformes	Loricariidae	Loricariichthys anus	Viola
Siluriformes	Pimelodidae	Pinirampus pirinampu	Piranambu
Characiformes	Characidae	Astyanax fasciatus	Piaba
Perciformes	Cichlidae	Tilapia rendalli	Tilápia
Siluriformes	Pimelodidae	Megalonema platanum	Fidalgo
Perciformes	Sciaenidae	Plagioscion squamosissimus	Corvina
Syngnathiformes	Syngnathidae	Synbranchus marmoratus	Muçum
Siluriformes	Pimelodidae	Goslinia platynema	Barba-chata

Gymnotiformes	Sternopygidae	Sternopygus obtusirostris	Ituí
Characiformes	Characidae	Astyanax bimaculatus	Lambari
Perciformes	Cichlidae	Geophagus proximus	Acaratinga
Characiformes	Cynodontidae	Cynodon gibbus	Cachorro
Characiformes	Hemiodontidae	Anodus elongatus	Cubiú
Siluriformes	Pimelodidae	Pseudoplatystoma fasciatum	Cachara
Characiformes	Hemiodontidae	Hemiodopsis argenteus	Peixe-avoador
Characiformes	Characidae	Brycon microleps	Piraputanga
Characiformes	Curimatidae	Curimata rutiloides	
Siluriformes	Hypophthalmidae	Hypophtalmus edentaus	
Characiformes	Curimatidae	Potamorhina altamazonica	
Characiformes	Curimatidae	Psectrogaster amazonica	
Siluriformes	Loricariidae	Pterygoplichthys multiradiatus	
Characiformes	Cynodontidae	Rhaphiodon vulpinus	
Characiformes	Anostomidae	Schizodon fasciatus	
Characiformes	Characidae	Serrasalmus naltereri	
Siluriformes	Loricariidae	Sorubim lima	

Appendix 8: Freshwater Ecosystem Assessment – Methods and Detailed Results

The freshwater ecosystem assessment uses an approach that is complementary to the assessment of forest and non-forest products is this report (see Jarvis, 2006 and 2008). The objective is to evaluate habitat quality based on the main characteristics of and threats to the ecosystems.

The following threats can be considered most relevant in the Amazon/Andes context:

1. Agro-industry
2. Deforestation
3. Infrastructure (Dams)
4. Pollution from human settlements
5. Oil and gas

Several authors report the potentially high threat of contamination through mining, which uses toxic chemicals to extract minerals (Gomez, 1995b, Sweeting & Clark, 2000; GWP - SAMTAC, 2000; Mann, 2001; Franco & Valdes, 2005; Ibish & Merida 2004; FOBOMADE , 2005). Yet, due to the lack of appropriate spatial data, we do not include this variable in the subsequent analysis. The same applies to nitrogen leakage in animal production systems, which some authors have reported to affect freshwater ecosystem services (Cameron 2000).

Given the nature of the threats and their influence on the hydrologic system we distinguish indirect threats on the hydrologic flow (Deforestation, Agribusiness) and direct threats on the hydrologic flow (Dams, pollution by population and oil & gas wells). The influence of the former depends on a number of variables, such as soil type, topography, the extent and magnitude of the activity, whereas the second, exerts direct influence on water stream flows and related ecosystem services.

To prioritize threats we define a **hierarchy index (wr):**

$$W_r = \frac{\sum_{y=1}^{Y} I_r}{\sum_{r=1}^{R} I_R} \qquad [1]$$

Where I_r is the impact y of the threat r with y = 1 (sedimentation), 2 (contamination), 3 (water cycle), 4 (loss of connectivity)and I_R is the total product score of the sum of each Ir.

The index takes on values from 0 to 4, where high values correspond to high impacts.

Table 17, shows the different variables to be considered to rank the threats over aquatic environments and the hierarchy Index

Table 17 Hierarchy index to aquatic threats

Threat	Sedimentation	Contamination	Natural cycle of water	Loss connectivity	Total	w_r
Agro-industry	1	2	2	2	7	0.175
Deforestation	4	1	3	3	11	0.275
Infrastructure	3	0	4	4	11	0.275
Pollution from human settlements	2	4	0	1	7	0.175
Oil and gas	0	3	1	0	4	0.1
Total					40	

Next we define a degradation potential index ($\overline{D}_{xr}$) for indirect threats according to Polasky *et al* 2007. In the case of direct threats, the estimation of potential degradation varies, according to the type of threat.

Agriculture Conversion

Here we assume that each spatial unit with a high percentage of agro-industry has a high degradation potential. Hence, the magnitude of the disturbance will be given by the relationship between cultivated area (*Ac*) and the area of the spatial unit (*Am*) (see Figure 18 right panel).

$$D_y = \left(\frac{Ac}{Am} \right) \qquad [2]$$

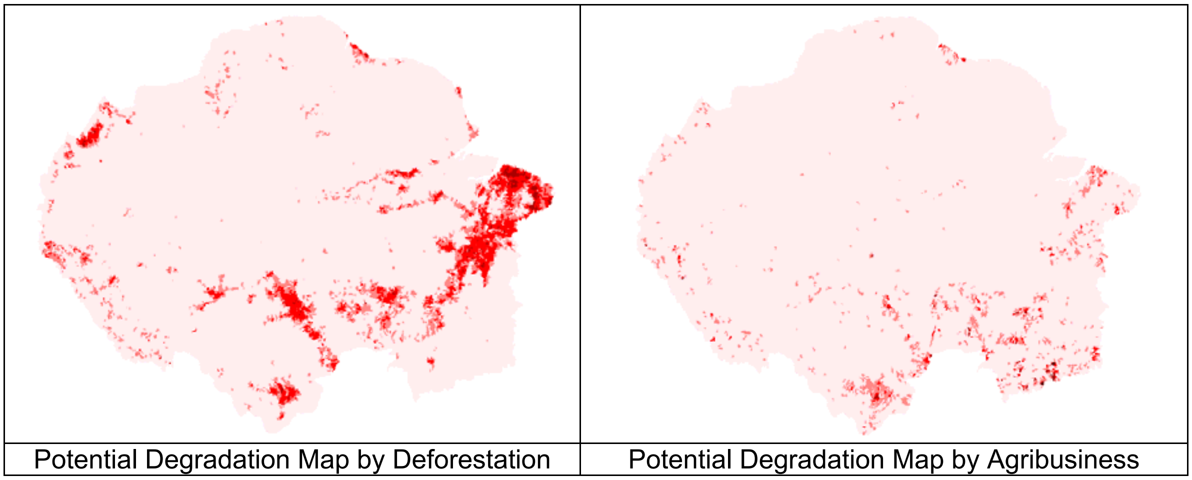


Figure 18 Potential degradation maps from deforestation and agro business threats.

Deforestation

In the case of deforestation we assume that each spatial unit with a high degree of deforestation, will have high levels of degradation, and therefore, the calculation of the magnitude or density of the disturbance will be given by the relationship between deforested areas (*Ad*) and the area of the spatial unit (*Am*) (see Figure 18 left panel). .

$$D_y = \left(\frac{Ad}{Am} \right) \qquad [3]$$

Infrastructure: Dams

Given that dams are the main cause of loss of hydrologic connectivity, i.e. flow and flood pulse regulation. Downstream effects are represented by the difference between the flow rate Q_y volume on the site of the dam (magnitude of the threat) and the flow of the river Q_{rx}, in each spatial unit *x* downstream. Hence, impact is proportional river flow volume.

$$\overline{D}_{xr} = \frac{Q_y}{Q_{rx}} x100 \qquad [4]$$

Pollution from human settlements

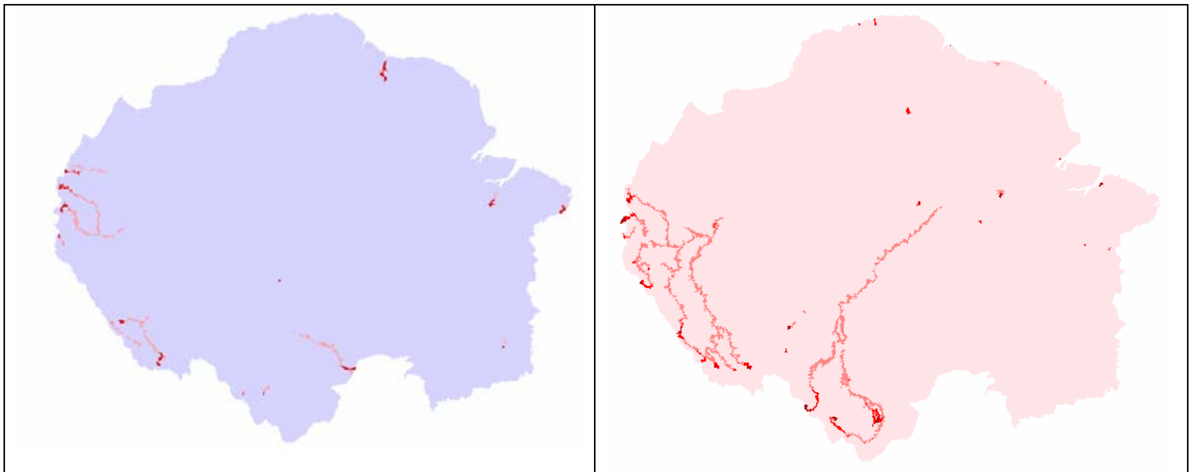
In the case of human settlement pollution, natural water purifying processes need to be taken into account. These processes are affected by flow volume and velocity, the magnitude of the threat (settlement size) and the type of pollution (industrial, residential, chemical, etc.). To simplify we ignore flow velocity and assume pollution type to be constant across the region.

Threat magnitude is calculated based on the average annual per capita water consumption (here 20 liters/day, but variable in reality). This value is multiplied by the number of residents per city (population greater than 5000 inhabitants, Landscan population model, 2000) (Equation 5).

$$D_y = (Hab / Km^2)xQ_y x360$$ [Equation 5]

The magnitude of pollution is then given by the percent of water contaminated (D_y) in relation to the volume of the river flow (Q_{rx} .) As a result we arrive at the amount of contaminated water in spatial unit *x (*illustrated in Figure 19*)*, which declines by the dilution factor, applying a logarithmic function and dividing by the topographic index (λ_x) as suggested in equation 6.

$$\overline{D}_{xr} = \frac{Log(D_y / Q_{rx}\ x100)}{\lambda_x}$$ Equation [6]

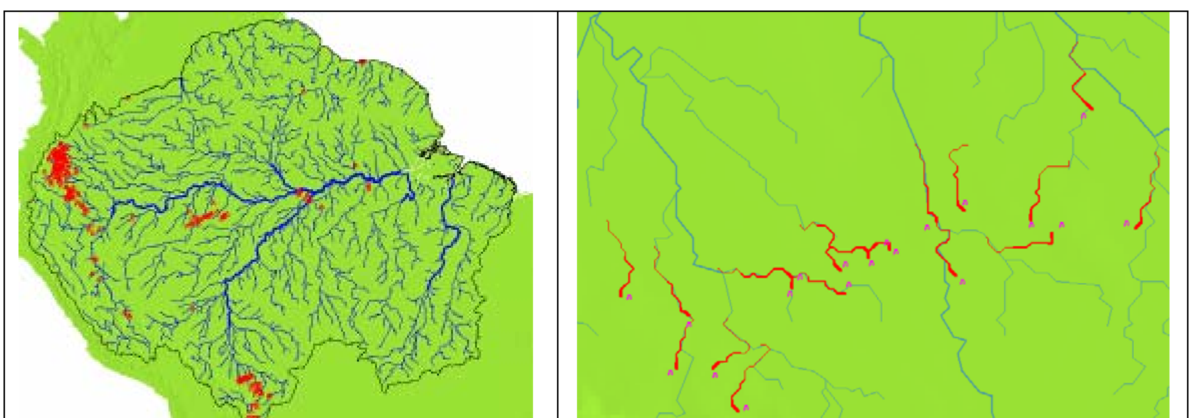


Potential Degradation map by dams	Potential degradation map by pollution of population greater than 5000 inhabitants

Figure 19. Potential degradation maps from dams and pollution.

Oil and gas wells

Alonso *et al* (2008) suggests that the volume of waste water (brine) that originates from the oil industry in the Amazon is about 2.5 barrels of water by one of oil. Yet, we do not know total production of each well. According to expert opinions we assume a potential distance of degradation downstream up to 20 km, where the magnitude of disturbance decreases linearly with distance (Figure 20).



Distribution of oil wells. Source: CIAT	Influence of oil wells on the drainage system, a larger anchor in the drainage (red), the greater magnitude of the threat.

Figure 20 Potential degradation maps from oil and gas pollution.

Habitat Quality

Taking the proposal of Polasky *et al.* 2007, the habitat quality degradation depend on the potential and capacity of ecosystem response to each threat. Bearing in mind that in aquatic ecosystems each micro-basins corresponds to one type of ecosystem, the formula of habitat quality is:

$$Q_z = \sum_{r=1}^{R} L_{jr} N\overline{D}_{zr} \Big/ R \in [0,1] \qquad \text{Equation [7]}$$

Where $N\overline{D}_{zr}$ is the potential degradation standardized by the threat *r* for each sub-basin *z,*

$N\overline{D}_{zr} = \dfrac{\sum_{x=1}^{n} \overline{D}_{xr}}{n}$, where *n* is the total number of spatial units *x* for each sub-basin *z*

L_{jr} is the response capacity of ecosystem *j* to each threat *r* and *R* Is the total number of threats.

Main results

The analysis of habitat quality is a useful tool in assessing the conservation status of aquatic ecosystems. A more detailed analysis, however, needs to extend beyond our results and correlate them with biological population data.

Figure 21 summarizes our analysis and suggests that the basins with greater ecosystems degradation are located at the foothills of Colombia, Ecuador, Peru and Bolivia and the southern river basins of the Brazilian Amazon.

Deforestation and the oil wells in Colombia are the most eminent threats to the Putumayo river ecosystem and the Pastaza river basin close to Rio Bamba.

Rivers near to Iquitos in Peru show great alteration of natural regimes caused by nearby deforestation and waste water pollution from the city. Towards the Andean foothills the rivers Ucayalli, Huallaga and its main tributaries near to Tarapoto, Yurimaguas, Huanuco and Pucallpa are the most affected by the same threats.

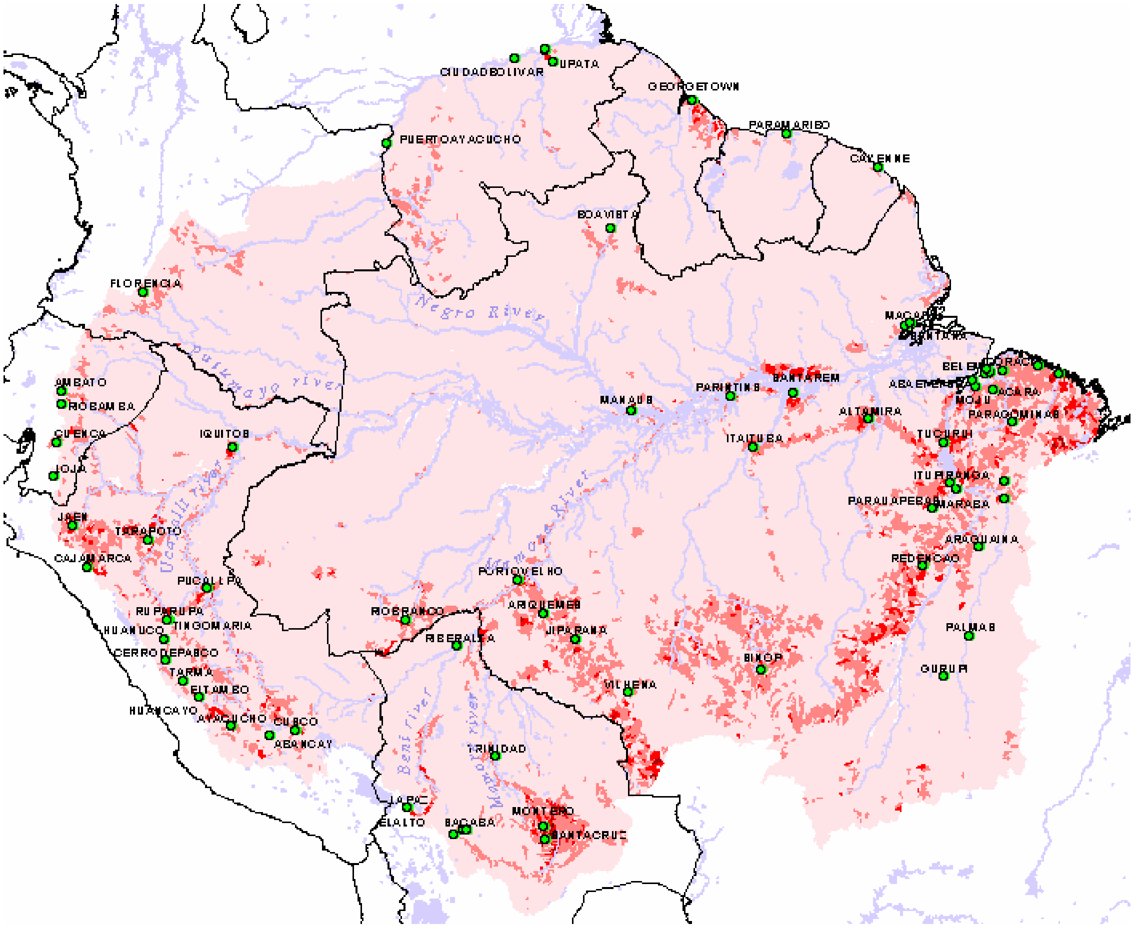


Figure 21 Habitat Quality Map.

In Bolivia the rivers Beni and Mamoré show signs of influences from La Paz in the Andean and piedmont zone the second being mainly affected by deforestation and agribusiness in Montero and Santa Cruz.

In Brazil, the Madeira basin and its tributaries Jiparana, Jamari and Rio Branco in Acre, are the areas most affected. The presence of dams (e.g. Samuel Dam, near Porto Velho) coupled with deforestation and pollution from nearby cities are the largest sources of threats to this river basin.

The upper Tapajos river basin and part of the Xingu and middle - lower Tocantins basins are the areas most affected by forest conversion.

The main arm of the Amazon River and its flood areas are influenced by settlement pollution from Manaus, Santarem and Parantins in Brazil and Iquitos in Peru

In Guyana aquatic ecosystems draining into the Atlantic are affected by deforestation and agro-industry in the Georgetown – Linden corridor.

It is important to stress that the analysis presented in this chapter refers to the potential influence emanating from existing threats on freshwater ecosystems. Whether and to what extent these influences materialize depends on a variety of factors related to both resilience of the affected ecosystems and the management of threats.

Future research should focus on:

- Empirically verifying the suggested influences and their effects on livelihoods in the areas identified in this analysis.
- Understanding why some ecosystems are less resilient to these disturbances than others and deriving related management implications.
- Identifying and documenting management strategies and related policies to reduce the potential impact of threats in the first place.

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Annex 9. Case studies and sources of information

The following two tables provide a detailed description of the twelfe selected case studies.

Management option	Name of experience	Location	Description of ES provided	Initial Situation
(1) Fair trade certification and organic certification	Organic coffee certification and fair trade. CECOVASA (Farmers cooperative)	Puno Province, Peru	Biodiversity protection by avoiding slash and burn in area considered as a biodiversity hotspot. Reduction of erosion and protection of water quality and possibly quantity.	Slash and burn of native forests, use of agrochemicals sources
(2) Ecotourism	La Chonta ecotourism project	Bolivia	Scenic beauty, recreation, and biodiversity protection	A buffer zone to Amboro's National Park was created inside. Llogging is not allowed. Ecotourism was propos income generation to local communities.
(3) Ecotourism	Chalalán : A community-based ecotourism project	Bolivia, Madidi National Park (between 6000 and 200 masl)	Landscape beauty, recreation and biodiversity protection	Extractive practices, slash and burn, migration and low qu quality, inexistence of potable water supply, unemplo unsustainable extraction of wood
(4) Conservation of goods and cultural services provided by ecosystems	The Potato Park: Agro-ecotourism, conservation of native potato varieties and of indigenous peoples' traditional knowledge	Pisaq, Cusco. Sacred Valley of the Incas (3600-4600 masl), Peru.	Agrobiodiversity protection, especially domesticated potato species and medicinal plants. Scenic beauty and landscape protection as space for traditional knowledge sharing, use and dissemination	Area considered potato's centre of origin. Pre-Inca vertical meat exchanged for fruits, vegetables and grains from m Area has important wetlands, high lakes, Inca ruins, condor
(5) Commercialization of non-traditional products to reduce pressure on forests	Coconut fiber for manufacturing automobile parts and conserve the rainforest	Marajó Island, Pará state, Northern Brazil.	Biodiversity protection through agroforestry on degraded lands and sustainable use of non-timber products	Low quality of life. Isolated communities perform slash previously considered as garbage. Lack of conservation and
(6) Extractive reserve and certification of sustainable forest management	Chico Mendes: An agro-extractivist reserve with forest management certification	Brazil, Xapuri, Acre	Conservation of goods provided by native forests through sustainable forest management	Need to protect the territory from invasive logging companie illegal with violence and forest destruction. Working condit were very bad. There was a need to generate alternate s aimed to avoid the destruction of forest through e economically feasible alternatives based on goods provided
(7) Extractive reserve and certification of sustainable forest management	Seringal Porto Dias, Extractive Settlement Project with forest management certification	Municipality of Acrelândia, Acre, Brazil.	Provision of timber and non-timber products (rubber)	Politically and economically marginalized rubber tap deforestation and seeking alternative to properly extract f livelihoods and increase tenure security.
(8) Carbon credits generated from reforestation	Plantar Reforestation Project	Minas Gerais, Brazil (Cerrado)	Carbon sequestration through reforestation	Use of mineral coke, methane emissions by the Plantar co to produce charcoal and to sell certified "green pig iron" to th
(9) Carbon credits generated carbon sequestration	Peugeot / ONF Project: Reforestation project for carbon sequestration	Municipalities of Juruena and Cotriguacu, Northwest Mato Grosso state, Brazil	Carbon sequestration through reforestation	Area under accelerated deforestation. The automobile negatively associated to emission of greenhouse gases.
(10) Carbon credits generated from reforestation and avoided deforestation	Noel Kempff National Park: A CO_2 emissions avoidance (avoided deforestation) project	Chiquitania. Northeastern Bolivia.	Avoidance of carbon dioxide emissions	Expansion of National Park from 634,286 ha to 1,523,446 potential carbon leakage due to displacement of current eco
(11) Carbon credits generated from reforestation and avoided deforestation	Bananal Island Carbon Sequestration Project for social equity	Bananal Island, Tocantins state, Brazil.	Carbon sequestration	Degradation baseline and conversion of land to soybean zone between *cerrado* and the Amazon
(12) Payment for hydrological services: conservation of forests	Payment for Environmental Services for the conservation of the cloud forest	Bolivia, Los Negros River watershed, Department of Santacruz.	Water quantity and quality provision through the conservation of cloud forest	There is a decrease in water level during rainy and dr increment of irrigation channels and the deforestation in the It caused clashes between Los Negros and Santa Rosa Santa Rosa is threatened by agricultural expansion, espec on steeper hillsides. The average of clearing land was 0.5 h

Management option	Name of experience	Donors	Partner / associate organizations	Role of local community	Dependence on exter
(1) Fair trade certification and organic certification	Organic coffee certification and fair trade. CECOVASA (Farmers cooperative)	Conservation International	Starbucks, Green Development Foundation, German Embassy, PNUFID, CBI. For providing credits: Verde Ventures, EcoLogic Finance, Rabobank Foundation, Doen Foundation	Compensated (premium price) for providing a better ecosystem good and associated ES.	Production system and trading are selt on market prices. Receive training in coffee quality improvement.
(2) Ecotourism	La Chonta ecotourism project		SERNAP (Sistema Nacional de Areas Protegidas)	Project partner, compensated for providing recreation	Depends on tourist demand. SERNAI and number of visitors.
(3) Ecotourism	Chalalán : A community-based ecotourism project	Conservation International, IBD, FOMIN	Visitors, travel agencies, national government (Madidi Protected Area), CARE, local municipality	Project partner	Depends on number of visitors, gr projects & improvements obtained thro community revenues.
(4) Conservation of goods and cultural services provided by ecosystems	The Potato Park: Agro-ecotourism, conservation of native potato varieties and traditional knowledge	IIED, Rockefeller Foundation, International Support Committee	Andes Association, International Potato Center	Not clear	Andes Association aims to leave the s to strengthen communities' manageme
(5) Commerce of non-traditional products to reduce pressure on forests	Coconut fiber for manufacturing automobile parts and conserve the rainforest	Daimler-Benz in Brazil. UNICEF	Pará Federal Universiity: POEMA Program. POEMAR, POEMATEC, Bolsa Amazonía. Daimler-Benz (leased equipment), federal government; municipality (land), Bank of Amazonia (small credits to producers' organizations). German DED (infrastructure)	Project partner	Cost of natural fibers for car parts is using synthetic materials. which might g sustainability. Project failed due to ch (Daimler-Benz)
(6) Extractive reserve and certification of sustainable forest management	Chico Mendes agroextractivist reserve with forest management certification	WWF Brazil and others (high cost of RIL based operations has obligated to obtain financial assistance from donors and other organizations)	SEFE, SEATER,CAEX, SEF, COOPERFLORESTA, COOTAF, Xapuri municipality (provides the truck and helps to find wood buyers), AVER who buys the wood to produce furniture	Project partner	Chico Mendes Association pays 1/3 o assistance. SEFE provides training c locals. Community relies on outside Certification system reduced its ad association AMPPAE-CM is large administrative, marketing and decision to the timber project, and covers the c pays community forester's wages.
(7) Extractive reserve and certification of sustainable forest management	Seringal Porto Dias, Extractive Settlement Project with forest management certification	World Bank, The Pilot Program for conservation of the Brazilian Rainforest, ITTO, Rainforest Action Network, Comunidade Solidaria, The National Fund for the Environment CFC, NOVIB, CONANDA, IDB. WWF Brazil.	CTA (Center for Amazonia Workers) All funding is channeled through CTA.	Partner	Rubber Tapper's Association has been out timber harvesting activities and a association has a weak organization political support and has found it dif timber products.
(8) Carbon credits generated from reforestation	Plantar Reforestation Project	-	Plantar Company	Employees	none

(9) Carbon credits generated from avoided deforestation	Peugeot / ONF Project: Reforestation project for carbon sequestration	-	The French National Forest Service and Peugeot-Citroen. Instituto Pro-Natura and ONF International	Employees	none
(10) Carbon credits generated from reforestation	Noel Kempff National Park: A CO_2 emissions avoidance (avoided deforestation) project		Government of Bolivia, American Electric Powers (AEP), Pacific Corp, BP, The Nature Conservancy, FAN (Fundación Amigos de la Naturaleza), and SERNAP	Employees. Compensated for avoiding deforestation. (projects to avoid former activities)	none, as the Park is officially expanded
(11) Carbon credits generated from reforestation	Bananal Island Carbon Sequestration Project for social equity		AES Barry Foundation (thermoelectric company of Wales) and Instituto Ecologica and its partners	Project partner	none on external funding, but on other the government
(12) Payment for Environmental Services	Payment for Environmental Services for conservation of the cloud forest	US Fish and Wildlife Service, UNDP	Fundacion Natura, UNDP, Environmental committees of Los Negros and Santa Rosa municipalities, Los Negros municipality; local inhabitants	Compensated for providing an ES	Dependence on Fundación Natura pa of Los Negros inhabitants (direct ber protecting biodiversity could be maintai US Fish and Wildlife Service

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Annex 10. Previous experiences and advances in research on the topic of ecosystem services in Andean-Amazon countries.

Note: The following list of experiences does not include advances in research on basic information regarding ecosystems, hydrology, rates of capture, environmental valuation, etc. and focuses directly on the experiences oriented towards the topic of ecosystem services.

Country	Institution	Advances and Experience	Contact
Bolivia	Fundación Natura	**Experience in water services** Project aiming to improve water management in Bolivia: Incentives to Promote Sustainable Management in Watersheds and Improve Rural Livelihoods and Payment for Environmental Water Services in the Los Negros River Watershed, located south of the Amboro National Park.	Maria Teresa Vargas mteresavargas@naturabolivia.org
	Fundación de Amigos de la Naturaleza (FAN) – Noel Kempff Mercado	**Experience in climate regulation services, water services, ecotourism, and ecosystem products** Responsible for managing the Noel Kempff Mercado Climate Action Project. Entity coordinating Bolivia's sustainable biotrade program.	Natalia Calderón Angeleri ncalderon@fan-bo.org
	PROMETA	**Experience in water services** Management of watersheds in the Sama Mountain Range Biological Reserve.	Alfonso Blanco ablanco@prometa.org
	Commission for Integrated Water Management in Bolivia (CGIAB)	**Experience in water services** Serves as platform of public and private institutions, as well as university research centers, that work on water-related topics. Established in 2002, the Commission aims to promote the concerted development of public policies on the sustainable management of water resources and water services.	Carlos Crespo Flores crespo54@hotmail.com
	TNC	**Experience in climate regulation services, water services, and ecotourism** Accompanied the processes of the Noel Kempff Mercado Climate Action Project and BOLFOR II.	Mónica Ostria mostria@tnc.org
Brazil	Executive Secretary of Forests and Extractivism (SEFE)	**Experience in ecosystem product services** Subsidy to rubber-tappers in the state of Acre under the Chico Mendes Law.	Carlos Vicente gabsefe@sefe.ac.gov.br

	CIFOR	**Experience in conceptual development of ecosystem services and several projects on multiple services** Has made important advances in conceptual development and has carried out pilot projects in Latin America and Asia. South America Regional Office is in the city of Belém.	Sven Wunder s.wunder@cgiar.org
	PROAMBIENTE	**Experience in ecosystem product services** Experience in designing economical incentives for investing in sustainable production systems, which also secure the provision of ecosystems services.	Shigeo Shiki shigeo.shiki@mma.gov.br
Colombia	CIAT	**Experience in conceptual development of ecosystem services and several projects on water services** Project proposal of payment for environmental services in the Fúquene Lagoon area and review of payment for environmental services in Latin America and its perspectives in the Andean region.	Marcela Quintero m.quintero@cgiar.org
	UNAL MEDELLÍN	**Experience in water services** Research on hydrological issues pertinent to Andean forests and other Colombian ecosystems to determine their capacity to regulate water availability.	Conrado Tobón ctobonm@unal.edu.co
	CI	**Experience in climate regulation services** Support to the CDM projects of Santa Ana and Amoyá River and development of the Munchique-Pinche biological corridor.	Fabio Arjona f.arjona@conservation.org
	ECOVERSA	**Experience in several projects on multiple services** PES-H Venezuela/Colombia project of CIFOR-CI; development of the strategy proposal for payment for environmental services in Colombia; environmental services project with CORPOGUAVIO, among others.	Javier Blanco jblanco@ecoversa.org
	PROCUENCA	**Initial experience in water services and now in multiple services** Forest Project for the Chinchiná river watershed (PROCUENCA-FAO).	Francisco Ocampo direcnacional@procuenca.com
	IAvH	**Experience in water services** Analysis of the feasibility of a payment for environmental services (PES) scheme in the Fúquene Lagoon area; development of a PES program in the Chaina river micro-watershed; coordination of the sustainable biotrade program.	Carlos Moreno (PES) carlosalbertomorenodiaz@yahoo.com José Antonio Gómez (Biotrade) jagomez@humboldt.org.co
	CORNARE	**Experience in several projects on multiple services** Implementation of forest systems in the San Nicolás region.	Maria Patricia Tobón planeprom@une.net.co

	EAAB	**Experience in several water and climate regulation projects** CDM Project of the Santa Ana hydroelectric plant; development of Bogotá's Water Fund; different ecotourism activities.	Sara Usme snusme@acueducto.com.co
	TNC	**Experience in water services** Support to water projects in the Chingaza and Farallones parks.	Aurelio Ramos aramos@tnc.org
	CIPAV	**Experience in ecosystem product services and climate regulation** Developed the Regional Integrated Silvopastoral Approaches to Ecosystem Management Project.	Enrique Murgueitio enriquem@cipav.org.co
Ecuador	Corporation Grupo Randi Randi	**Experience in conceptual development of ecosystem services and how they relate to poverty as well as several various projects on multiple services** Participatory watershed management; watershed inventories and modeling; gender and environment; community conservation; conservation planning for protected areas; and integrated crop management for sustainable development.	Susan Poats spoats@interactive.net.ec
	ECODECISIÓN	Experience in conceptual development of ecosystem services and several projects on multiple services Accompaniment to multiple programs to identify water services in Ecuador and Latin America.	Martha Echavarría mechavar@interactive.net.ec
	FONAG	**Experience in water services** Projects and programs for the rehabilitation, conservation, and maintenance of watersheds supplying water to the city of Quito.	Pablo Lloret pablo.lloret@gmail.com
	ECOCIENCIA/ RISAS	**Experience in conceptual development of ecosystem services and several projects on multiple services** Together with CORPEI, they coordinate Ecuador's sustainable biotrade program. The network of people involved in environmental services (RISAS) is one of the most important points of encounter of experts in environmental services in Latin America.	Macarena Bustamante mbustamante@ecociencia.org
	CEDERENA	**Experience in water services** Development of the Pimampiro PES project.	Silvia Ortega sortega@macas.care.org.ec Robert Yaguache cederena@andinanet.net
	TNC	**Experience in water services** Support to various projects, including the creation of the FONAG.	Silvia Benítez sbenitez@tnc.org

Peru	GTZ-Peru	**Experience in water services** Scheme of payment for environmental water services in the Upper Mayo sub-watershed, San Martin region. Andean Region Watershed Project.	Alonso Moreno Díaz Alonso.Moreno-Diaz@gtz.de
	INRENA	**Experience in several projects on multiple services** Payment for ecosystem services. Experience in the Upper Mayo watershed-San Martin-INRENA-GTZ.	Guillermo Avanzini Pinto gavanzini@inrena.gob.pe
	CI	**Experience in several projects on multiple services** Implementation of mechanisms of payment for ecosystem services and conservation agreements that aim to reconcile conservation and development in the Yuracyacu watershed.	Patricia Zurita p.zurita@conservation.org
	Peru's Commission to Promote Exports and Tourism (PROMPERU)	**Experience in ecosystem product services** Together with the National Environment Council (CONAM), serves as coordinating entity of the sustainable biotrade program.	Lesly Vera Gonzales lvera@promperu.gob.pe
Venezuela	CIDIAT	**Experience in conceptual development of ecosystem services, with emphasis on water services** CIFOR-CI's PES-H Venezuela/Colombia Project.	José Pérez Roas prjose@cidiat.ing.ula.ve
	CI	**Experience in conceptual development of ecosystem services** Viability of implementing payment schemes for environmental services in Venezuela.	Free de Koning f.dekoning@conservation.org
	Ministry of Science and Technology (MCT)	**Experience in ecosystem product services** Together with the Ministry of Environment and Natural Resources (MARN), leads the biotrade program.	Aura Marina Silva asilva@mct.gov.ve

Country	Institution	Advances and Experience	Contact
ACTIVITIES IN SEVERAL COUNTRIES AND/OR KEY EXPERIENCE IN THE AREA OF ECOSYSTEM	CIFOR	**Experience in conceptual development of ecosystem services and several projects on multiple services** CIFOR has conducted four major projects: • Uncovering the scope for environmental service payments in the conservation of the North Andean Corridor • Making Nature count: enhancing payments for environmental service initiatives in Ecuador and Colombia • Stakeholders and biodiversity at the local level: Building on opportunities • Carbon sequestration and sustainable livelihoods	Sven Wunder s.wunder@cgiar.org

	CODESAN	**Experience in water services** Project on Andean watersheds and Andean paramos.	Héctor Cisneros h.cisneros@cgiar.org Rubén Darío Estrada r.estrada@cgiar.org
	WORLD BANK	**Experience in several projects on multiple services** Development of the Regional Integrated Silvopastoral Approaches to Ecosystem Management Project; an eco-market project; analysis of the viability of contributions of the PES to poor communities; and support to several countries in the area of ecosystem services.	Stefano Pagiola spagiola@worldbank.org Juan Pablo Ruiz Jruiz@worldbank.org
	FAO	**Experience in conceptual development of ecosystem services, with emphasis on water services and support to projects** Support to several countries in the area of water ecosystem services and best production practices.	Carlos Marx R. Carneiro Carlos.Carneiro@fao.org
	ICRAF	**Experience in conceptual development of ecosystem services, with emphasis on forest products** Pro-poor agroforestry strategies for local conservation and global benefits.	Brent Swallow b.swallow@cgiar.org
	WWF MPO	**Experience in several projects on multiple services** Guatemala's Sierra de Minas Water Fund; Indonesia's Lombok Island Water Fund; Florida's Pay for Performance Program in the U.S.; and Mexico's Monarch Butterfly Conservation Fund.	Pablo Gutman pablo.gutman@wwfus.org
	IIED	**Experience in several projects on multiple services** Several Markets for Environmental Services case studies; monitoring of biodiversity and the socio-economic impact of the ICMS Ecológico in Brazil; and examination of experiences using auctions and tendering mechanisms to market wildlife products and services as compared with direct negotiations.	Ina Porras ina.porras@iied.org
	WRI	**Experience in conceptual development of ecosystem services and support to several projects** The Corporate Ecosystem Services Review program is a structured methodology for corporate managers to proactively develop strategies for managing business risks and opportunities arising from their company's dependence and impact on ecosystems.	Craig Hanson chanson@wri.org
	Ecosystem marketplace	**Reference site and information exchange between experts** Source of information on markets and payment schemes for ecosystem services; services such as water quality, carbon sequestration and biodiversity.	Ricardo Bayón rbayon@ecosystemmarketplace.com

	Ecology Institute of Mexico	**Experience in water services and climate regulation** Developed Mexico's national program of payment for water services.	Carlos Muñoz carmunoz@ine.gob.mx
	IUCN	**Experience in conceptual development of ecosystem services** Proposal for international payments for ecosystem services.	David Huberman david.huberman@iucn.org
	Katoomba Group - Forest Trends	**Group of international experts in the field of PES** The Katoomba Group is an international network of individuals working to promote and strengthen capacities related to markets and payments for ecosystem services (PES).	Carina Bracer cbracer@forest-trends.org

Annex 11 - Entities offering training and capacity building programs in the ecosystem services area

CATIE – Valuation of ecosystem services (ES), watershed management, forest ES.

CIFOR – Legislation and policy guidelines for PES.

WWF – Forest management.

TNC – Ecosystems valuation and management.

Conservation International – Ecosystems management.

World Bank – ES valuation. Conservation Strategy Fund – ES valuation.

GTZ – Hydrologic services, ES recognition through payment schemes.

GTZ/INWENT – Biodiversity conservation.

FAO – Forest ES.

Universities (see table below)

Academic programs in Andean-Amazon countries which can include topics related to ecosystem services and quality of life				
Country	City	University	Program	E-mail address
BOLIVIA	Tarija	Universidad Autónoma "Juan Misael Saracho"	Forest Engineering	http://coimata.uajms.edu.bo/
	Cochabamba/ La Paz	Universidad Católica Boliviana San Pablo	Environmental Engineering/ Political Science	http://www.ucbcba.edu.bo/
	Cochabamba	Universidad Mayor de San Simón	School of Forestry	http://www.esfor.umss.edu.bo/
	Sucre	Universidad San Francisco Xavier de Chuquisaca	Faculty of Agriculture, Animal Science and Forestry	http://www.usfx.info/agronomia/
	Santa Cruz	Universidad Nur	Agricultural Economics	http://www.nur.edu/50821/wp_m00c0.asp
	Program designed to be offered in the four countries member of CAN	Universidad Andina Simón Bolívar	Master's in Sustainable Development, Climate Change, and Clean Development Mechanisms	http://www.uasb.edu.bo/universidad/maes_ing%20amb%20min_2007%20(2).html
	La paz	Universidad de San Andrés	Graduate course in Territorial Ordinance	http://www.umsanet.edu.bo/
	Valle del Sacta	Instituto Politécnico Universitario	Tropical Agriculture	http://www.ipu.umss.edu.bo/
BRASIL	Porto Alegre	Universidade Federal do Rio Grande do Sul	Environmental Engineering/ Political Science	http://www1.ufrgs.br/graduacao/xInformacoesAcademicas/habilitacoes.php?CodCurso=526
	RS	Universidade Federal de Santa Maria	Forest Engineering	http://www.coperves.ufsm.br/prograd/not.php?id=328
	Rio Grande	Fundacao Federal do Rio Grande	Ph.D. and Master's in Environmental Education	http://www.educacaoambiental.furg.br/
	Paraná	UNIOESTE	Specialization course in Latin America's greatest environmental gateway	http://www.ambientebrasil.com.br/
	Sao Paulo	Universidad de Sao Paulo	Post-graduate course in Environmental Science	http://www.ipu.umss.edu.bo/
	Sao Paulo	CEPEA	Environmental Economy	http://www.cepea.esalq.usp.br/english/
	Salvador	Area1	Environmental engineering / Specialization in environmental management using clean technologies	http://www.area1fte.edu.br/
	Paraná	Universidad Tuiuti do Parana	Licentiate in Environmental Education	http://www.utp.br/cursos/facet/Geografia_Licenciatura.asp
Colombia	Bogotá	UDCA Universidad de Ciencias ambientales	Faculty of Environmental Sciences / Post-graduate course in Social and Environmental Management	http://www.udca.edu.co/contenido/indice.php?id_menu=5&izq=1035
	Medellín	Escuela de Ingeniería de Antioquia	Environmental Engineering	http://www.eia.edu.co/educacion/pregrados/ambiental.htm
	Bogotá	Universidad de La Salle	Licentiate in Natural Sciences and Environmental Education / Environmental and Sanitary Engineering / Specialization in Energy and Environmental Management	http://www.lasalle.edu.co/pregrado/ppregrado_lic_cien_educ_amb.htm
	Bogotá	Universidad de los Andes	Environmental Engineering / Political Science / Master's in Planning and Administration of Regional Development	http://www.uniandes.edu.co/programas/index.php
	Bogotá	Universidad INCCA de Colombia	Specialization in Ecology, Environment, and Development	http://www.unincca.edu.co/
	Bogotá	Universidad Javeriana	Political Science / Ecology	http://www.javeriana.edu.co/
Ecuador	Quito	Universidad San Francisco de Quito	Environmental Economy / Environmental Administration	http://www.usfq.edu.ec/
	Sucumbíos	Universidad Internacional SEK / Estación Científica de Limoncocha en la Amazonía ecuatoriana.	Environmental Sciences	http://www.uisek.edu.ec/default.asp?id=0
		Universidad Agraria	Natural Resource Management	http://www.uagraria.edu.ec/
	Loja	Universidad Nacional de Loja	Forest Engineering and Environmental Engineering	http://www.unl.edu.ec/website/index0.php
	Quito	FLACSO	Socio-environmental Studies / Political Science / Ecological Economy	http://www.flacso.org/ecuador.php
	Quito	Pontificia Universidad Católica del Ecuador	Political Science	http://www.puce.edu.ec/index.php?pagina=cuadrocarreras
Perú	Lima	Universidad del Pacífico	Environmental Economy	http://www.up.edu.pe/portada/
	Tingo María	Universidad Nacional Agraria de la Selva	Natural Resource Management	http://www.unas.edu.pe/
	Lima	Pontificia Universidad Católica dl Perú	Graduate course in Environmental Law	http://www.pucp.edu.pe/content/index.php
	Lima	UNALM	Post-graduate course in Economy of Natural Resources and the Environment	http://www.lamolina.edu.pe/portada/
	Tacna	Universidad Privada de Tacna	Political Science	http://www.upt.edu.pe/Facultades.php
	Arequipa	Universidad Nacional de San Agustín de Arequipa	Ph.D. in Environmental Technologies	http://www.unsa.edu.pe/
	Puno	Universidad Nacional del Altiplano	Master's in Ecology	http://www.unap.edu.pe/web/?id=op_escuelas&tipo=0

Academic programs in Andean-Amazon countries which can include topics related to ecosystem services and quality of life				
Country	City	University	Program	E-mail address
Venezuela	Caracas	Universidad Simón Bolívar	Department of Environmental Studies	http://www.usb.ve/
	Caracas	Universidad Católica Andrés Bello	Environmental Sanitary Engineering	http://www.ucab.edu.ve/ucabnuevo/
	Barquisimeto	Universidad Nacional Experimental "Francisco de Miranda"	Licentiate in Environmental Sciences	http://unefm.edu.ve/
	Mérida	Universidad de los Andes	Faculty of Forestry and Environmental Sciences	http://www.ula.ve/ulaweb/raiz/estudios/index.php?id=2
	Valencia	Universidad de Carabobo	Master's in Environmental Engineering	http://www.uc.edu.ve/Facultades/index.php?opcion=FA

Annex 12 – Policies in the region for water, forest, and protected areas

COUTRY	POLICY DOCUMENTS	ECOSYSTEM SERVICES RECOGNIZED	RELATIONSHIP WITH QUALITY OF LIFE	SOME POLICY INSTRUMENTS WHICH CONTRIBUTE TO ENSURING PROVISION OF ECOSYSTEM SERVICES
BOLIVIA	Water Law of 1906 Environmental Law (Law 1333 of 1992) Law on Drinking Water and Sewage System Services (Law 2066 of 2000) Bill on Drinking Water and Sewage System Services (version 4). Proposed Law on Water Resources (Version 32)	The importance of water in generating well-being for communities is acknowledged and considered as a priority for national conservation; however, water resources are not explicitly referred to an ecosystem or environmental service neither in existing norms nor in norms now under discussion. However, the proposed law on water resources should be highlighted. This legislation includes the following regulatory principles, among others: (a) Water is a vital, limited, vulnerable, and finite resource whose preservation and sustainability are fundamental responsibilities of the State and the civil society and corresponds to national security; and (b) that water is a social and ecological good, with an economic value that depends on how it is used and exploited.	Bolivian norms make clear that "water, in all its forms, is property of the State and constitutes a basic natural resource for all vital processes. Its use not only relates to but also impacts all sectors of development, which means that the protection and conservation of water is a fundamental responsibility of the State and of society." It also establishes "the participation of traditional communities and indigenous groups in processes of sustainable development and rational use of renewable natural resources, taking into consideration their social, economic, and cultural particularities in the environments in which they carry out their activities."	Both environmental laws and water pollution regulations offer the possibility of incentives to maintain environmental quality; however, no pertinent norms have been developed so, in practice, these incentives are non-operational (Gutiérrez, 2006). Even so, the existence of non-normative initiatives, such as that of the Climatic Action Project of the Noel Kempff Park, should be highlighted. This undertaking involves several institutions, including The Nature Conservancy and the Bolivian government, and has generated incentives aiming to reduce carbon emissions that are used to conserve the services provided by these ecosystems Finally, in midst of intense discussions generated by current legislative proposals, the Inter-Institutional Water Council (CONIAG) is expected to serve as a means to achieve consensus about the Policy and the new Water Law for Bolivia, which should categorically address the topic of ecosystem services and how they relate to the quality of life.
BRAZIL	Water Code (Federal Decree 24643 of 1934) Law on Coastal Area Management (Law 7661 of 1988) Law on the National Water Resource Policy (Law 9433 of 1997) Law on the National Environmental Policy (Law enacted in 1981) Law on the National Conservation Unit System (Law 9985 of 2000) Creation of Brazil's National Water Agency (ANA) by Law 9984 of 2000 State Law on Climate Change, Environmental Conservation and Sustainable Development of the Amazon Region (State Law No. 3135 of 2007).	Based on Brazil's Law on Water Resources environmental and water management in the country is integrated and an important series of water-related norms and institutions are in place; however, the concept of ecosystem water services is not explicitly addressed in federal laws. Explicit reference is made to these services in the laws of several states, such as the state of Amazonas that passed a State Law on Climate Change, Environmental Conservation and Sustainable Development of the Amazon Region (State Law No. 3135 of 2007), which acknowledges several ecosystem services and how they relate to the quality of life.	At the federal level, the importance of ensuring the availability of water for current and future generations, at quality levels appropriate for its different uses, is recognized, preventing and defending against critical hydrologic events that could be triggered by misuse of natural resources. It is also proposed that water resource management be adapted to the physical, biotic, demographic, economic, social, and cultural diversity of the different regions of the country. At the state level, the aforementioned law for the Amazon Region establishes, as principle, "sustainable development in which measures aiming to stabilize the effect of greenhouse gases and ensure environmental conservation are adopted, associated with social, economic, and ecological benefits that fight poverty and improve the quality of life for present and future generations." Some of the funding sources for this initiative are related to water charges.	The Water Resource Law foresees six important instruments for water resource management: (i) water resource plans, (ii) classification of water bodies according to types of use, (iii) granting of rights to use water resources, (iv) charging for the use of water resources, (v) compensation of municipalities, and (vi) a water resource information system. These instruments have helped consolidate important programs, such as those of PROAMBIENTE and Floresta Exchange Fund that economically compensate farmers for their good environmental performance. This initiative recognizes the role of the traditional and indigenous populations in the conservation of forest and water sources. Despite the above, some authors like Herman (2006) assert that a modern and coherent system of economic instruments destined to protect water resources does not exist in Brazil. Herman explicitly recommends including aesthetic values and biodiversity associated to water resources as axes and objectives of the Law on the National Water Resource Policy.

	COLOMBIA	Natural Resource Code (Decree-Law 2811 of 1974). Law 79 of 1986 by which water conservation and other provisions are dictated Law 99 of 1993 by which the Ministry of Environment is created Law 142 of 1994 by which the regimen of household public utilities is established and other provisions are dictated Decree 1729 of 2002 by which Part XIII, Title 2, Chapter III of Decree-Law 2811 of 1974 on watersheds is regulated. Policies on Coastal and Wetlands	Colombia recognizes the importance of ecosystem services and is currently working on a national strategy on payment of environmental services, within which water services are considered priority. To guarantee environmental quality and the provision of goods and services provided by Colombian ecosystems, an important series of environmental norms was developed, whose fundamental axis, in the case of hydrologic services, are the watersheds, their conservation and management. Special attention is paid to those ecosystems supplying water: "paramo and sub-paramo areas, water sources, and aquifer recharge areas will be subject to special protection".	Colombian environmental norms establish that "the environment is common heritage." Both State and individuals should participate in its preservation and management because of its public use and social interest. In addition, it is established that "public policies will take into account the right of individuals to "a healthy and productive life in harmony with nature." Hence, the contribution of nature to the quality of life of mankind is clear.	Law 99 of 1993 puts forward that "the State will promote the incorporation of environmental costs and the use of economic instruments to prevent, correct, and restore environmental degradation and conserve renewable natural resources." In fact, Colombia stands out at the international level as having an important series of instruments for managing its water resources, including retributive rates (destined to decontaminate) and water use rates (destined to conserve the resource). Furthermore, transfers are received from the electric sector to protect water basins harboring hydroelectric projects. Compensatory measures, forced investments, and fiscal measures are also in place to help finance conservation actions at the watershed level. Finally, methodological guidelines are also available on territorial ordinance at the watershed level, which allows better natural resource and water management (MMA, 1999).
	ECUADOR	Water Law No. 369 of 1972 Law on Environmental Management (Law 37 of 1999) Creation of the Institutional Water Regimen (Decree 2224, subsequently modified by Decree 3609 of 2003)	Although Ecuador stands out among South American countries because it has a national authority for water-related issues as well as a special water law (Tobar, 2006), it's legislation does not recognize water services nor their relationship to natural ecosystems. Furthermore, although the Law on Environmental Management recognizes the principles contained in the Río Declaration, it does not address the important link between ecosystems and benefits these offer communities. Ecuador's constituent process has now opened a space to discuss environmental issues, thus offering an opportunity to correct identified limitations of current water norms.	"The rational use of nonrenewable natural resources in relation to national interests" is recognized; however, the importance of water services and water per se for communities is not mentioned nor indicated neither explicitly nor tacitly. Nevertheless, the Ecuadorian government has expressed its willingness to comply with the agreements of the Rio Summit and therefore recognizes the important relationship existing between natural ecosystems and the well-being of the communities that depend on them.	The Ecuadorian Environmental Plan is a technical administrative tool that promotes environmental conservation, protection, and management and contains specific objectives, programs, actions, minimum contents, and funding mechanisms as well as review and audit procedures. The Law on Environmental Management also mentions that "contributions and fines related to environmental protection and sustainable use of natural resources, as well as risk insurance and deposit systems, shall serve as instruments to enforce environmental norms. These can also be used to further actions that favor environmental protection." The Law also declares that the State shall establish economic incentives for those productive activities that promote environmental protection and sustainable natural resource management. The respective laws shall determine the modalities of each incentive. Based on this logic, to control the use of water resources and protect and conserve forests and paramos, the municipal council of Pimampiro established a fund for the payment of environmental services in 2001, with the support of the development corporation CEDERENA. The creation of the Water Fund for Quito, with the support of The Nature Conservancy, should also be highlighted. This Fund aims to conserve water services that benefit the inhabitants of the city of Quito and its surroundings.
	PERU	General Water Law (Decree-Law 17752 of 1969). General Sanitation Services Law (Law 26338 of 1994). Organic Law for Sustainable Natural Resource Use (Law 26821 of 1997) Forest Law (Law 27308 of 2001) Water Bill Resolution 060-2007, approved by the Regulatory Body, that adopts INRENA's Institutional Strategy for Payment of Environmental Services (2007-2011)	The current General Water Law does not address the concepts of sustainable resource management (Pulgar-Vidal, 2006). For this reason Peru is currently discussing a Water Bill. However, the current emphasis of this project is to granting water appeal an economic value through market instruments. Accordingly there should be taken this opportunity for discussion to include recognize ecosystem services and their relationship with ecosystem providers. It should be mentioned that although the concept of environmental services is not addressed in hydrologic norms it is addressed in the Forest Law as well as in the concept of payment for ecosystem services.	Although the General Water Law and other norms related to water resources do not explicitly mention how this resource relates to the quality of life, mention is made that "the justified and rational use of water can only be granted in harmony with the social interests and development of the country", which emphasizes the importance of this resource. Nevertheless, it is necessary to explicitly stress this relationship in the future water legislation.	Pulgar-Vidal (2006) mentions that "pertinent policies in Peru have not included economic and social measures that serve as incentives for the conservation and sustainable use of water resources". However, several projects have been carried out through international collaborative efforts and with the support of NGOs that promote the change in attitudes regarding water resources. One of these was the project Payment for Environmental Services in the Upper Mayo Watershed in Moyobamba, carried out by the Andean Region Watershed Project of the German Technical Cooperation (GTZ-Peru) and the Consortium for Sustainable Development in the Andean Ecoregion (CONDESAN). These initiatives have endorsed the creation of an institutional strategy for the payment for environmental services by INRENA (2007-2011). This strategy aims to contribute to the establishment of a regulatory framework and promote mechanisms for funding environmental services (Avanzini, 2007).

	VENEZUELA	Forest Law on Soils and Water (Law 1004 of 1966) Organic Environmental Law (Law 31004 of 1976) Environmental Penal Statute (Law 4358 of 1992) Organic Law on the Rendering of Public Drinking Water and Environmental Sanitation Services (Law 5568 of 2001) Organic Law on Aquatic and Insular Spaces (Law 37290 of 2001) Law on Coastal Areas (Law 37139 of 2001). Water Bill	According to Pérez Roas (2006), “according to the Law on Biodiversity, the State <<Venezuela>> recognizes the services rendered by ecosystems through their biodiversity; **however, it does not describe them.** <<Note: Underlined text is not the author's>> It should also be pointed out that in the proposed Organic Law on Environmental Conservation, **ecosystem** services are defined as all the benefits derived from the environment that directly affect the protection and improvement of the environment and the quality of life of populations. In view of the above, it can be stated that the ecosystem services provided by ecosystems are legally recognized as well as the hydrologic services that these ecosystems provide.	The key relationship existing between quality of life and water services is recognized in the Water Bill, which establishes as fundamental principle that: “water is irreplaceable for life, human well-being, the environment, and social and economic development; constitutes a fundamental tool to eradicate poverty; and should be managed respecting unit of the hydrologic cycle”. It also establishes that “water is a social good. The State shall guarantee the access of the population to water, emphasizing rural and indigenous communities”. Hence, environmental laws related to water resources aim at “guaranteeing conservation, with emphasis on the protection, sustainable use, and recovery of water resources to meet community and environmental needs as well as the demand generated by the country's productive processes”.	The Water Bill declares that “water users will contribute to watershed conservation to guarantee the conservation of both superficial and ground water sources”. The Law on Biodiversity, on the other hand, mentions that actions carried out by municipalities or communities tending to the conservation of biodiversity and environmental services cause countervailing duties, following verification. These tasks shall be economically remunerated in an equitable manner through credit and tax-related incentives. Finally, the Proposed Organic Law on Environmental Conservation establishes that the State shall define economic and fiscal incentives that will be granted to individuals that make investments to preserve the environment as a means to promote the use of clean technology and conservationist practices, among others, and that state and municipal authorities can establish their own pertinent fiscal and economic incentives.

	COUTRY	POLICY DOCUMENTS	ECOSYSTEM SERVICES RECOGNIZED	RELATIONSHIP WITH QUALITY OF LIFE	SOME POLICY INSTRUMENTS WHICH CONTRIBUTE TO ENSURING PROVISION OF ECOSYSTEM SERVICES
FORESTS	**BOLIVIA**	Law 1700 of 1996. Environment Law 1333 of 1992 (Chapter V Of forests and forested lands). Supreme Decree 24453 General regulation of the Forestry Law. Public Policy of the Department of Santa Cruz of 2007 to recognize environmental services of forests.	Law 1700 of 1996 seeks to maintain structure, function and ecological processes through sustainable use of forests and forest lands. It also recognizes the role of forests located on lands used for protection of hydrological services. The Environment Law mentions in Article 51 that the “execution of forestation and agro-forestation plans on national territory, with the goal of soil recuperation, watershed protection, production of firewood and vegetative carbon, industrial and commercial use and other specific activities,” are of public utility.	The forestry legislation highlights the importance of facilitating access for the whole population to forest resources and their benefits. The resources areas of chestnut, rubber, heart of palm and similar products will be conceded with preference for traditional users, peasant communities and local social associations. Another way to guarantee improvement of quality of life for traditional populations via the forestry legislation, is through the creation and support of local social associations and the Community Territories of Origin (TCO for its acronym in Spanish), which make up part of the user community for forest resources and should benefit from the granting of concessions within municipal forest reserve areas. It's also important to mention the BOLFOR II Project which started in 2003 to promote sustainable development of the forest sector. One of its objectives is to provide technical assistance to the local social associations and to indigenous and peasant communities throughout the country.	Within Bolivia's forest policy instruments, it's important to mention voluntary forest certification, given that the country has more than two million hectares of certified forest, which places it among the first in the world for extension of certified tropical forest. The forestry law also establishes incentives for rehabilitation of degraded lands through a discount up to 100% of the Forest Patent, technical assistance and inputs for forest rehabilitation. The forestry legislation also presents other instruments such as the General Management Plan, Annual Forest Operative Plan (which establishes the resource utilization and silvicultural activities that will be carried out during the year, based on the management plan), Property Zoning Plans, and programs for supply and control of raw materials. Actions and measures are established to guarantee the sustainability of the resource, such as harvest cycles of at least 20 years, minimum cut diameters and the use of a population of remnant trees for seed provision to ensure natural regeneration of the forest. The Public Policy for Recognition of Forest Services in the Department of Santa Cruz establishes a mechanism to charge and pay for these services, with the beneficiaries compensating those who own or have rights over the forest.

	BRAZIL	Forest Code Law 4771 of 1965. Public Forests Law Nº 11.284/2006. National Forest Program PNF Decree 3420/2000. Chico Mendes Law of 1999 (Law 1227 of 1999). Decree 6.321/2007 on prevention, monitoring and control of deforestation in the Amazonian Biome. Law of the State of Amazonas No 3135 of 05/06/2007 on climate change, environmental conservation and sustainable development.	The Public Forest Law defines forest services as *"tourism and other actions or benefits derived from the management and conservation of the forests, not characterized or denominated as forest products"*. Likewise it mention aspects related to the use of forest products and services and establishes percentages derived from concessions that should be destined for environmental control activities and sustainable use of forest resources. One of the objectives of the National Forest Program is the valuation of ecosystem services provided by public and private forests. Decree 6321 establishes actions for the protection of areas threatened with degradation and for the rationalization of land use in the Amazonian Biome.	The forestry policy and regulations state that communities, especially local ones, should be guaranteed access to public forests and the benefits derived from their use and conservation. The Climate Change standard of the State of Amazonas mentions the relationship between stabilization of greenhouse gas concentrations and the eradication of poverty.	Among the country's forestry policy instruments are, Forest Management Plans, Environmental Impact Studies, certification for extractive products, monitoring of illegal logging in areas selected for the implementation of Decree 6321 (the areas where deforestation of the Amazonian Biome will be prevented, mitigated and controlled). The Chico Mendes Law of 1999 grants a subsidy to rubber tappers for their role in forest conservation. The Forestry Code establishes that rural properties larger than 50 hectares should designated a parcel as a legal reserve (approximately 80% of the area in the Amazon). For the state of Amazonas, it is important to refer the Climate Change Law and the Bolsa Floresta ("Forest Stock Market") Program. The Climate Change Law establishes economic, financial and non-financial instruments to execute clean energy programs, greenhouse gas emissions reductions, and CDM and REDD projects among others. The state programs also include payment for ecosystem services. It also states that there should be economic recognition of the producers who implement practices that contribute to greenhouse gas emissions reductions, especially those caused by deforestation. Finally, the law mentions the creation of incentives such as tax reduction or exemption for businesses that contribute to emissions reductions (biodigestors, methanol, biodiesel, ecotourism, among others). Through the Bolsa Floresta Program traditional populations are compensated for their role in forest conservation and it offers access to microfinance for communities that begin conservation and sustainable forest management activities. The main beneficiaries of this program are the inhabitants of the conservation units in the State of Amazonas.
	COLOMBIA	National Plan for Forest Development 2000 (PNDF). Forest Policy 1996. Legal Decree 2811 of 1974 (Title X on Terrestrial Flora). Decree 1791 of 1996 which established the Regime for Forest Utilization Law 139 of 1994, Decree 1824 of 1994, Resolution 276 of 2006 and 525 of 1996 of the Ministry of Agriculture on Forest Incentive Certification. Decree 900 of 1997 on Forest Incentive Certification with conservation goals. Climate Change Policy of 2002.	The Forestry Plan and Policy mentions forest services, such as the provision of raw materials, habitat for flora and fauna, protection and regulation of watersheds, contribution to mitigation of erosion, and possibilities for tourism and recreation. The Climate Change Policy presents strategies that the nation should implement to respond to climate change threats, capitalize on opportunities from financing mechanisms and meet the obligations from agreements ratified on this subject.	Forestry norms and policies recognize the need to develop processes where the population linked to the forestry sector participates equally in the preservation, protection, conservation, use and management of forest ecosystems, in order to create a sustainable society.	Among the instruments proposed in the forestry policy and regulations, are programs for compensation for conservation and incentives. One such incentive is the Certification for Reforestation Incentive (CIF), created by Law 139 of June 21, 1994, a recognition by the state of the positive social and environmental externalities of reforestation, which seeks to promote investment in new protective-productive forest plantations on lands apt for forests. Through this incentive the government helps cover some of the start-up costs (50% for introduced species and 75% for native species) for plantations with a density above 1,000 trees per hectare, maintenance of new plantations (50% of costs incurred after the second year, until the fifth year after the establishment for either type of species) and forest management (75% of costs during the first five years). Through the Resolutions 276 of 2006 and 525 of 1996 the Ministry of Agriculture sets the average costs of establishment and maintenance of a hectare of planted and natural forests and the amount it will reimburse through the forestry incentive. In the development of Law 139 of 1994, Decree 900 of 1997 establishes the aspects related to the Certificate of Forestry Conservation Incentive which is a *"recognition for the direct and indirect costs incurred by a property owner for conserving on their property natural forest ecosystems that are little or not intervened"*. This certificate is given for up to a maximum of 50 hectares of forest on a base value of 7 current minimum wages per hectare of forest (this value can be adjusted by the environmental authority). Other instruments are Forest Management Plans and the Plans for Forest Utilization, which describe the systems, methods and equipment used in forests subject to harvest to allow them to be controlled by the environmental authorities. Finally, it is important to highlight that one of the strategies of the Climate Change Policy is the promotion of financial mechanisms. To address this, the policy establishes as an action area the need to design and implement an international cooperation strategy in order to increase and improve technology transfer processes and to obtain financial and technical resources for research and management of activities related to climate change, as well as support formulation of projects under CDM criteria.

	ECUADOR	Law No. 74 of 1981. Book III of the Unified Text of Secondary Environmental Legislation (TULAS). Regulations for sustainable forest management for timber use (Regulation 131), expedited January, 2001. Strategy for Ecuador's Sustainable Forest Development, June, 2000. Working document for Special Legal Project for Ecuador's Sustainable Forest Development, March, 2000.	The country's forestry legislation recognizes the role of forests and vegetation in the protection of soils and wildlife, flood control, watershed protection, and maintenance of scenic beauty, among other things. It also highlights the importance of programs for valuation of services provided, as well as to establish a market for forest and forest plantation services. It also refers to the need to, *"include in the agenda for the Ecuadorian Clean Development Mechanism the potential of native forests, plantations and other ecosystems to capture carbon and carry out the commitments and opportunities provided by the Framework Convention on Climate Change".*	The legislation recognizes that traditional communities have the exclusive right to use non-timber forest products in areas under their control. According to the legislation, other ways to guarantee equality are through participation in decision-making and in the planning, execution and monitoring of forestry and conservation programs. The role of rural, indigenous and black populations within this participatory process is highlighted. According to the Forestry Regime of the nation, sustainable forestry activities are a mechanism to relieve poverty. It is important to highlight that the Forestry Regime in Ecuador proposes a methodology for valuation and compensation for ecosystem services affected by development of activities, which consists of carrying out a diagnostic to identify the level of initial and final use of ecosystem services and, of the affected services, which can be recuperated and which are lost. This methodology emphasizes services that generate income for local communities.	Among the instruments in this legislation are incentives for protected forest lands planted with timber species and for sustainable management and reforestation of public and private forest areas (lines of credit, technical assistance, providing plants and labor); exemption from taxes on rural property with land covered by forests or natural or cultivated vegetation, land planted with timber species or dedicated to forest creation; exemption from tariffs for importing machinery, equipment, tools, or seeds etc…for research, forest cultivation and forest fire control; and private forest lands covered by permanent production forests or those with plans for forestation or reforestation will no be subject to agrarian reform. Other instruments are the Integrated Management Plan and the Forest Use Program, the National Plan for Forestation and Reforestation and the Working Document for the Special Legal Project Ecuador's Sustainable Forest Development and the Strategy for Sustainable Forest Development which recognizes that those who occupy the areas that provide forest ecosystem services should be compensated for them. Additionally, these two documents address topics related to certification for carbon capture. For this country it is important to mention the experience of payments to communities in the municipality of Pimampiro for forest protection, which is supported legally through an ordinance implemented by the municipal government "Fund for the Payment for Environmental Services for the Protection and Conservation of Forests and Paramos in Order to Regulate Water".
	PERU	Forest and Wildlife Law Nº 27308 of 2001. National Forest Strategy 2002-2021 (made official through Supreme Decree 031 of 2004).	The Forestry Law includes in its objectives to make use of forest resources compatible with valuation of forest services. Article 2 of the law defines forest ecosystem services as: *"those that have as their objective soil protection, water regulation, biological diversity conservation, conservation of ecosystems and scenic beauty, absorption of carbon dioxide and in general the maintenance of essential ecological processes".* The law recognizes that forests on protected lands provide services such as soil preservation, maintenance of hydrological equilibrium, ecotourism, non-timber forest products, among others. It also mentions the use of non-timber forest products such as chestnuts, heart of palm, vines, resins, rubbers, medicinal and ornamental plants, raising wildlife in natural environments and concessions for ecosystem services such as ecotourism, conservation of fauna and flora and carbon sequestration.	The law recognizes that forest development benefits the national population. On the other hand, the main objective of the National Forest Strategy is to guarantee rural development, understanding that as the well-being of rural populations through satisfaction of basic needs and equitable access to the benefits of forest utilization.	The Forest and Wildlife Law includes political instruments, such as, Forest Management Plans and Environmental Impact Studies, through which owners of concessions in forests of permanent forestry production should evaluate the existing ecosystem services in the concession as part of the evaluation of environmental impact. The Forestry Law also recognizes a modality for compensation called *"mechanisms for indemnification for the effects of pollution produced by consumption of fossil fuels"* whose funds should be destined for conservation financing, rehabilitation of natural areas and research on wild flora and fauna. It highlights that the state should implement stimulus mechanisms complementary to the benefits granted by Law 27037 (Law for Promotion of Investment in the Amazon). It also promotes the voluntary certification of forest products coming from forests managed for commercial use, establishing a percentage reduction in the rights payments for concessions that have said certification. Article 35 of the Forestry Law, on indemnification for forest environmental services (Num 35.4), indicates that the state will implement mechanisms so that users of water for agrarian, fisheries, mining, industrial, electricity generation, and domestic uses pay for the beneficial impacts of forests on hydrological resources, contributing to maintenance and implementation of forest plans and reforestation programs.

	VENEZUELA	Forest, Soils and Water Law of 1966 Working document for the Forest Law	The working document for the Forest Law mentions that the new vision of forest policy is oriented towards increasing and diversifying the production of forest goods (timber and non-timber) with the goal of reducing pressure on native forests. It also mentions the role of native forests in maintaining ecological equilibrium on the planet.	The forestry legislation establishes that the fruits of forest species for the benefit of the population may be freely used. The working document of the Forest Law recognizes the role of these in the well-being and progress of populations and states the need to establish a management model for forests that favors collective interests.	The Law for Forests, Soils and Waters mentions policy instruments including, exemption from taxes in cases of mobilization or use of forest products destined for development or benefiting peasant communities established by the Agrarian Reform Law. The working document for the Forest Law points to management instruments for forests such as the National Forest Plan, the national forest inventory, territorial zoning, the subsystem of forest information, forestry technical norms, and management plans. The working document also includes national forest certification for timber and non-timber goods that come from native or plantation forests that meet environmental sustainability standards, and presents the benefits of certification, including the granting of credits, technical assistance, technology transfer and support for commercialization of products. The working document also mentions that the state will give incentives and tributary exemptions for the development of ecotourism activities and initiatives presented by traditional communities for community forest management. Article 110 of the document establishes that through decree the terms and conditions for certification will be determined. This will be an acknowledgment by the state of the costs of establishing productive forest plantations and the arboreal component of agroforestry activities.

	COUNTRY	POLICY PAPERS	RECOGNIZED ECOSYSTEM SERVICES	RELATIONSHIP WITH THE QUALITY OF LIFE	SEVERAL POLICY INSTRUMENTS THAT HELP GUARANTEE THE RENDERING OF ECOSYSTEM SERVICES
BIODIVERSITY AND PROTECTED AREAS	**BOLIVIA**	National Biodiversity Strategy Decree 26555 of 19 March 2002. Biodiversity Action Plan. Environmental Law No. 1333 of 1992. Law on Wildlife, National Parks, Game and Fishing Decree-law No. 12301 of the 1975 (Title III). General By-law on Protected Areas, Supreme Decree No. 24781 of 31 July 1997.	The Biodiversity Policy highlights the importance of forest products, particularly chestnut. Chapter VIII of the Environmental Law, which addresses protected areas, specifies that these areas should serve to protect wild fauna and flora, genetic resources, ecosystems, watersheds, scientific, historical, and aesthetic treasures, scientific research, recreation, education, and ecotourism. The By-law on Protected Areas, on the other hand, proposes that each category of protected areas contribute to the preservation of key ecological processes and relates these areas with specific ecosystem services, for example national natural monuments are related to the service of scenic beauty.	The policy and legislation on biodiversity acknowledge the importance of biodiversity conservation for community health and education and guarantee land rights, consolidated as a way of improving the quality of life of communities. The objectives of protected areas proposed by the General By-law include ensuring that the management and conservation of these areas contribute to the improvement of the quality of life of communities.	The policy and legislation on biodiversity point out the need for developing economic instruments that promote biodiversity conservation. Policy instruments for protected areas include the following: management plans; conventions on use of protected areas, which make management plans operational; tourism programs to carry out tourism activities in protected areas; and payment of entrance rates to protected areas, destining the income derived to their conservation and maintenance.

	BRAZIL	Policy on Biodiversity Conservation Decree 4399 of 2002. Political Constitution. Law on National Environmental Policy (Law of 1981). Law on the National System of Nature Conservation Units No. 9985 of 2000 and Decree 4340 of 2002 that regulate several articles of the Law on the National System of Conservation Units. Strategic Plan for Protected Areas (official since the year 2006).	Within its components, objectives, and guidelines, Brazil's Biodiversity Policy of Brazil mentions the need to conserve and maintain the sustainability of ecosystem services, determining the habitats of different species and understanding their importance in the ecosystems, and support the study and valuation of ecosystem services. The importance of establishing conservation support mechanisms is also mentioned. These mechanisms include the payment for ecosystem services provided by protected areas. Chapter VII of Decree 4340 related to the commercial exploration of goods and services, products and by-products in the conservation units establishes that for its authorization the preparation of studies of the economic viability of this utilization is necessary. The Amazon Region Protected Areas (ARPA) Program, created in 2003 by the Federal Government of Brazil and coordinated by the Ministry of Environment, should be mentioned Brazil. Since its creation, this program has supported the creation of 41 new protected areas covering a total of 22.5 million hectares in the Amazon region. To guarantee the sustainability of these areas, the development of economic mechanisms, including the payment for ecosystem services, has been proposed (Secretariat of Biodiversity and Forests, Brazilian Protected Areas 2004/2007).	The Biodiversity Conservation Policy states that the conservation and sustainable use of biodiversity should help eradicate poverty. The group of Sustainable Use Units, covered by the Law on the National System of Nature Conservation Units, tries to harmonize conservation and sustainable management and includes both extractive and sustainable development reserves oriented towards the preservation of nature and the improvement of the quality of life of traditional communities through sustainable management practices. In the case of extractive reserves, it is important to emphasize that these are inhabited and traditional extractive communities exploit these reserves, which have been regulated as territorial spaces under domain of the government and destined to sustainable exploitation and conservation of renewable natural resources by associations of extractive communities through concession contracts (Fundación PRISMA, 2002). With the same objective of harmonizing the conservation of biodiversity and rural household production, while guaranteeing food security, the Program of Socio-environmental Development of Rural Household Production (PROAMBIENTE) was created in 2000 and included as a program of the Federal Government in 2004. PROAMBIENTE is currently managed by the Secretariat of Policies for Sustainable Development of the Ministry of Environment and seeks that program beneficiaries receive technical assistance and different types of compensation for the ecosystem services they provid.	The Policy on Biodiversity Conservation poses the need for developing economic instruments to promote biodiversity conservation and encourage the adoption of an ecological tax on the circulation of goods and services (ICMS) in all states of the country (Complementary Law No. 59/91, known as the Ecological ICMS Law), which aims to "*serve as incentive to promote improved management of protected areas already existing as well as promote the establishment of new conservation areas, including private lands that provide different types of environmental services*". This law was established to compensate those municipalities that promote environmental conservation within their jurisdictions. Article 158 of the National Constitution establishes that the municipalities have the jurisdiction to define, through their legislation, the criteria on how to allocate the income resulting from this tax. The Law on the National System of Conservation Units establishes that each project, considered as having significant environmental impact, shall pay at least 0.5% of the total value of the project as compensation for damages caused. The money collected is used to create or maintain Conservation Units. It also establishes that the companies benefiting from conservation units (power generating companies, water supplying companies) should contribute financially to their protection. In addition, it poses the possibility of having the right to exemption of the Rural Land Tax (ITR) for protected areas, including Private Natural Heritage Reserves (RPPN). Other instruments include management plans, contracts granting real right of use in the case of extractive and sustainable development reserves, and payment for visiting conservation units. The law establishes the percentages destined to the establishment and management of these areas.

	COLOMBIA	Political Constitution of 1991. Decree-law 2811 of 1974. National Code for Renewable Natural Resources. Law 99 of 1993 by which the Ministry of the Environment is created, the public sector responsible for the management and conservation of the environment and renewable natural resources is reorganized, the National Environmental System (SINA) is organized, and other provisions are dictated. National Biodiversity Policy of 1995. Policy on Protected Areas. Ecotourism Policy of 2003. Decree 622 of 1997 (Natural National Parks). Decree 1715 of 1978 (on landscape protection). Decree 1996 of 1999 on natural reserves of the civil society.	The Policy on Biodiversity acknowledges that biodiversity provides the following services: food, fossil fuels, natural fibers, regulation of water cycles and flows, production of oxygen, and regulation of the climate. It also mentions that forests, pastures, and crops are important CO_2 fixers and emphasizes the need to "characterize biodiversity components" and make use of the services provided by biodiversity in relation to crop production. Colombia's Policy on Protected Areas recognizes the role played by these areas in the delivery of services such as protection of watersheds and genetic resources, maintenance of genetic banks for food security, maintenance and moderation of climate, protection of soils against erosion processes, and promotion of ecotourism activities, among others. It also points out that the Ministry of Environment should identify ecosystem goods and services of protected areas. The importance given in Decree-Law 2811 of 1974 to the right communities have to enjoy landscapes that contribute their well-being should be highlighted. To endorse the above, Decree 1715 of 1978 regulates all issues related to landscape protection and establishes that areas must be protected on both sides of roads to make sure that the landscape and its scenic beauty can be enjoyed by all.	The Political Constitution states that among the duties of the State are "the protection of the diversity and integrity of the environment, the conservation of areas of special ecological importance and the promotion of education". To achieve this purpose and guarantee the right of society to a healthy environment, it is necessary to reserve part of the national territory and guarantee, through several mechanisms, the participation of society in biodiversity conservation. In the development of the Constitution's provisions, the Policy on Biodiversity mentions it is necessary to build consensus with communities on how the benefits derived from the use and exploitation of biodiversity will be allocated. It also mentions the importance of promoting the collective granting of land tiles to black and indigenous communities to improve their quality of life as well as the formation of rural reserves, guaranteeing the access to credit, markets, technologies, and education. The Policy on Protected Areas emphasizes that these are fundamental for national development because of the ecosystem goods and services they provide both directly and indirectly to local populations and to regional settlements. Finally, the Ecotourism Policy mentions the role played by this activity in improving the quality of life of local communities.	A series of incentives are in place that aim to encourage users and landown among others, to make decisions that benefit the environment as well as community, for example tax incentives for investors in environmental control enhancement or for projects that promote the reduction of CO_2 emissi reforestation, and forest conservation, among others. The instruments provided in the policies on conservation and protected ar include management plans and tax exemptions (land tax). For example, in case of reserves of the civil society, which are regulated by Decree 1996 of 19 government and territorial entities should create incentives for those landowr who decide to set apart part of their land to conservation and the municipal have the competence to define the amounts and mechanisms to grant land exemptions. Several tools have been developed for the conservation of natural resource protected areas, such as ecological servitudes (legal agreement between tw more landowners in which one agrees to plan the use of resources in favo conservation), co-management (administration and management coordina between several actors), commodatum (one party grants the other, by means contract, the right to use his/her property), among others. Other instruments are investments in ecotourism (these have a tax incer created by Law 788 of 2002), technical and financial incentives for establishment and management of areas of the National System of Protec Natural Areas, entrance fees to protected areas of the National Natural Pa Systems, and the environmental surcharge at tolls (Law 981 of 2005).
	ECUADOR	Law on Environmental Management. No 37. RO/245 of 1999. National Biodiversity Policy and Strategy. Law on Forests and, Conservation of Natural Areas and Wildlife. Law 74 of 1981 (Title II). Book IV of the Standardized Text on Secondary Environmental Legislation (TULAS).	The Political Constitution of the Republic of Ecuador "recognizes the right people have to live in an environment that is healthy, environmentally balanced, and free from contamination. It declares environmental protection, ecosystem conservation, biodiversity, and integrity of the country's gene pool as being of public interest and establishes a national system of natural protected areas, thus guaranteeing sustainable development." The National Biodiversity Policy and Strategy (2001-2010), emphasizes the importance of ecosystem services as water supplies, pest control, capturing of gases (such carbon dioxide), and diversity of landscapes and scenic beauty. Law 74 of 1981 gives the following definition of Natural Areas as National Heritage: "This is a group of uncultivated areas, which in view of their scenic and ecological characteristics, are designed to safeguard and conserve wild flora and fauna in their natural state, while producing other goods and services that allow the country to maintain an adequate environmental balance and provide communities with recreation and entertainment."	The Biodiversity Policy and Strategy highlight that a healthy natural environment affects the quality of life of communities and prevents the proliferation of pests that ravage the country. It also recognizes that the conservation and sustainable use the country's biodiversity, as a source of wealth, creates spaces that alleviate poverty and reactivate and sustain domestic economy, while favoring social development and improvement of the quality of life of communities. Likewise, a proper system of valuation and use of resources and environmental services will benefit important sectors of the population that currently produce marginal crops. The importance of guaranteeing the participation of indigenous and Afro-Ecuadorian peoples as well as local communities in the decentralized management of protected areas and ecosystem services is stressed. Furthermore, when negotiating the payment for ecosystem services, an adequate part of the profits should be invested in the social development of communities living on and neighboring the lands generating ecosystem services.	The Policy on Biodiversity states that incentives and mechanisms will be crea that support the development of sustainable production activities that add valu products, maintain ecosystem services that generate biodiversity, and gene opportunities of employment and development, especially, for local communi According to this policy, the systems of payment for ecosystem services are innovative tool because they could reduce the pressures exerted by other sectors. The approach to comprehensive management of biodiversity is a innovative and priority should be given to services provided by paramos as sou of drinking water and irrigation for Andean communities, floodplains as ar protecting from floods, and hillside forests for watershed protection. Article 68 of Law 74 of 1981 states that, to maintain the national heritag natural areas, ordinance plans will be formulated for each area. Finally, under the Environmental Management Law, environmental managen tools include environmental impact assessments, social participation mechanis and training, among others.

	PERU	Legislative Decree No. 613 of 1990 Environment and Natural Resource Code. Law 28611 or General Environmental Law (October 2005). Law on Biodiversity Conservation and Sustainable Use (Law No. 26839 of 1997) Organic Law for the Sustainable Use of Natural Resources (Law 26821 of 1997). National Biodiversity Strategy. Law No. 26834 of 1997 on Protected Areas.	The Biodiversity Law and Strategy express the need for conserving ecosystems and for maintaining ecological processes that are key to the survival of species. The Law on Protected Areas, in turn, states that these areas serve to ensure the continuity of key ecological processes; maintain products such as flora and fauna, including hydrobiological and genetic resources; maintain the functional conditions of watersheds so as to maintain water collection, flow, and quality; and guarantee the delivery of important cultural services such as recreation and scientific opportunities, among others. The General Environmental Law (Article 94) establishes that: "Natural resources and other environmental components fulfill functions that allow ecosystems and environmental conditions to be maintained, generating benefits that tapped without mediating rewards or compensations. This means that the State shall establish mechanisms to appraise, remunerate, and maintain the provision of these environmental services, trying to achieve the conservation of ecosystems, biodiversity, and other natural resources."	Peru's Environmental and Natural Resource Code proposes that one of the guidelines that should orient the country's environmental policy is "that the control and prevention of environmental pollution, the conservation of ecosystems, the improvement of the natural environment in human settlements, the maintenance of essential ecological processes, the preservation of genetic diversity and the sustained use of species are fundamental elements to guarantee and improve the quality of life of communities." The policy and norms on biodiversity highlight the need to develop mechanisms that efficiently allocate the benefits derived from the use of genetic and biological resources in all plans, programs, actions, or projects related to the commercial use or study of natural resources or biodiversity. The need to guarantee the participation of society in the monitoring of biodiversity is also emphasized.	The instruments proposed by the Law on Protected Areas include the Execu Plan for Protected Natural Areas and the Master Plan for Protected Areas. It should be highlighted that Article 85 of the General Environmental Law, Num 3, specifies that "The National Environmental Authority, in coordination with sectoral and decentralized environmental authorities, prepares and permane updates the inventory of natural resources and environmental services that th provide, establishing their corresponding assessment." The Natio Environmental Authority also encourages public entities of different levels incorporate economic instruments that promote environmentally sound pract in compliance with environmental policies and norms.
	VENEZUELA	Organic Environmental Law. Extraordinary Official Gazette No. 5833 of 22 December 2006. Biodiversity Law of 2000. Law on Special Areas for Sustainable Development Decree 1469 of 2001. Law on Forests, Soils and Waters of 1966.	The Biodiversity Law mentions that is necessary to conserve those ecosystems providing ecosystem services that are susceptible to degradation or destruction by human intervention and "states that the conservation and sustainable use of biodiversity, its restoration, the maintenance of essential processes and environmental services provided by these ecosystems are of public interest". The document of the provisional draft bill of protected natural areas mentions that pertinent regulations are found in the Law on Forests, Soils, and Waters, in the Law on Protection of Wild Fauna, in the Organic Law on Territorial Ordinance, the Organic Law on the Use of Areas under the Special Management Regimen as well as their relevant Ordinance Plans and By-laws. The Provisional Draft Bill on Protected Areas attempts to compile the statutes of these different laws and provide guidelines on this matter in one single document.	The Biodiversity Law, the National Strategy, and the Action Plan (2001) specify that that the distribution of the benefits of traditional and local knowledge to traditional communities should be guaranteed. The Law on Special Areas of Sustainable Development aims to regulate the creation, operation, and suppression of Special Areas of Sustainable Development, with a view to execute plans, dynamize and coordinate governmental initiatives, and encourage the private sector to promote the development of adequate resource production and exploitation, increasing the levels of social welfare and improving the quality of life of communities. These areas are delimited with the objective of carrying out "special integral development plans." To meet this objective, the Law establishes that "incentives and conditions to further the settlement of populations and production activities" in these areas should be developed. The new Environmental Law (2006) and the legislation on indigenous peoples firmly establish the rights of the inhabitants of the country's protected areas to remain in these areas and to participate in their management (Cartaya, 2007) and thus ensure the improvement of the quality of life of these communities.	The Organic Environmental Law specifies, among the objectives of environme management, "the adoption of economic studies and fiscal incentives relate the use of clean technologies and reduction of contamination parameters, as as the recycling of residual elements from production processes and comprehensive use of natural resources." The Biodiversity Law indicates that "actions carried out by municipalities communities that aim to conserve biodiversity and environmental services ca countervailing duties." These tasks shall be economically and equita remunerated through credit and tax-related incentives. Existing legislation also indicates the possibility of a 50% exemption from payment of income taxes due to the execution of specific programs or proje that aim to restore degraded habitats or that are relevant to Venezue endangered, vulnerable, rare, or endemic species. Similar to other countries, Venezuela's legislation emphasizes the role playe management and ordinance plans and environmental impact assessments environmental management tools.