DRYLANDS POPULATION ASSESSMENT II

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1. Introduction

Almost half of the world's land area is defined as perennial desert or drylands, ecosystems that are extremely vulnerable to over-exploitation and inappropriate land use. In Africa alone, 45% of the population, or an estimated 325 million people, live in dryland areas. The problem of degradation of these lands and the resulting hardship faced by their inhabitants is the focus of the United Nations Convention to Combat Drought and Desertification.

This report is the second phase of a collaboration between the UN Development Programme's Office to Combat Desertification and Drought (UNSO) and the World Resources Institute (WRI) to 1) assess the extent of (dry) land covered by the CCD on a country by country basis, and 2) assess the population levels within these same zones. These statistics were used to explore new ways to support the goals of the Convention. One way to assess and monitor ecosystems is through the development of indicators of condition of and pressures on an ecosystem. In order to assess future vulnerability, it is also important to look at indicators of social response; the policies adapted to address environmental problems, their implementation and effectiveness. Indicators quantify information so its significance is more readily apparent, and simplify information about complex phenomena to improve communication (WRI, 1995). In the context of the Convention, indicators can be used to illustrate the magnitude of the problem facing inhabitants of dryland areas, establish a reference point from which progress can be measured, and create a basic framework within which activities to combat desertification can be prioritized.

This report briefly describes a GIS analysis that combines climate and population data to quantify the number of people living in dryland areas. For each country in Africa and Latin America, estimates of dryland area and population are presented and results are analyzed by continent. Due to data limitations, results are only presented for a few countries in South and Southeast Asia. This is followed by a discussion of some data issues and limitations associated with the results. This assessment considers only two factors, population and climate, and is therefore not a suitable basis for ranking countries according to need or risk of desertification. The final section proposes some specific areas for future development of dryland indicators. The paper was revised based upon comments received from 15 experts who attended a workshop on "Assessing Desertification: Developing a New Global Indicator," July 14, 1998, at WRI, and on-going discussions between WRI and UNSO.

2. Background

Results of a global analysis of population in dryland areas were published in the 1997 report "Aridity Zones and Dryland Populations: An Assessment of Population Levels in the World's Drylands" produced by UNSO. This 1997 report made use of the global aridity zones defined in the 1992 World Atlas of Desertification (WAD) and more detailed climate data for Africa. The current analysis was conducted using the same methodology as the previous report, with improved climate and population data for Africa, Latin America and part of Asia. Improvements in spatial resolution and accuracy of the input data made it possible in this analysis to summarize results at the country level. This is an important step which will allow for future indicator development such as the stratification of dryland populations using socioeconomic data available at the national or administrative district level, information on agricultural systems and productivity, or other spatial data such as land use and land cover, population growth, or climate variability.

3. GIS Analysis

The GIS analysis is a simple overlay of aridity zones on population data, and calculation of the number of people living in each zone in each country. Results of the analysis are highly dependent on the aridity zones used, and therefore heavily influenced by the climate data and method used to delineate the zones (see Technical Notes Annex for details).

Population

For all three regions, population data were compiled from the latest available censuses - resulting in reference years ranging from 1970 to 1993 for Africa, 1981 to 1995 for South Asia, and 1990 to 1996 for Latin America. The data were standardized to 1995 levels and compared to UN estimates. In a few cases adjustments were made to the growth rates to bring the 1995 estimates closer to UN figures. For Africa and Asia modeled datasets were developed that more accurately represent the spatial distribution of people (Deichmann, NCGIA, 1996). The model redistributes the total population within each district, taking into account the location of existing infrastructure, as well as lakes, protected areas, and other sparsely populated areas. The modeled surfaces developed for Asia and Africa have a spatial resolution of 2.25 min (approx. 4.5 km). The population data for Latin America were developed at the International Center for Tropical Agriculture (CIAT, 1997). The data were not modeled, and so do not have the same level of spatial accuracy as the raster datasets. However, the lack of modeling is offset by the fact that data were compiled at a smaller administrative unit than for the other regions. Data for most countries in Latin America were available at the *municipio* level.

Climate

For climate data, a new generation of high resolution raster databases including mean monthly precipitation (PPT) and evapotranspiration (PET) were used. Improvements in the climate data include a greater density of data points and an advanced algorithm used to interpolate the climate surfaces. Records from a greater number of weather stations were used because the criteria for inclusion was reduced from 20 years continuous record for the WAD to a minimum of 5 years continuous PPT averages for the new climate surfaces. Most of the weather data were collected between 1920 and 1990. The interpolation method used incorporates latitude, longitude, and elevation. The incorporation of a continuous, spatially varying dependence on elevation is a critical factor in the accuracy of these data. The spatial resolution of the climate surfaces varies: 3 min (approx. 5 km) for Africa, 5 min (approx. 9 km) for Latin America, and 2.5 min (approx. 4.5 km) for South Asia. For Africa, the same high resolution climate data were used for the 1997 Assessment by UNSO and for this assessment.

Aridity can be defined in several different ways, but most simply it is a moisture deficit. In this analysis, moisture deficit, or an aridity index, is determined by the ratio of mean annual precipitation (total moisture) to mean annual potential evapotranspiration (moisture loss). This index is then reclassified into six aridity zones according to the ranges defined by UNESCO (1977) and described in the following table:

Aridity Zone	Aridity Index	Length of Growing Period (days)	Typical Crops
Hyper-arid	<0.05	0	No crops, no pasture
Arid	0.05-0.20	1-59	No crops, marginal pasture
Semi-arid	0.20-0.50	60-119	Bulrush millet, sorghum, sesame
Dry sub-humid	0.5-0.65	120-179	Maize, bean, groundnut, peas, barley, wheat, teff
Moist sub-humid	0.65-1	180-269	Maize, cotton, sweet potato, finger millet
Humid	>1	>270	Cassava, coffee, banana, enset, tea, sugar cane

This method of delineating arid zones is consistent with the WAD and the previous Dryland Populations Assessment.

The next three sections of this report present results by continent for Latin America, Africa and South and Southeast Asia. Maps and tables present the distribution of land and population by aridity zone for each of the continents considered. The tables provide land area and population summaries by country. The same set of maps and tables is provided for each continent, along with discussion of results. For the purposes of this study, drylands refer to dry sub-humid arid and semi-arid lands, as defined under the Convention to Combat Drought and Desertification. This definition is meant to encompass areas which are potentially vulnerabe to desertification or drought, and therefore excludes arid and cold extremes. References to productive lands includes humid and drylands.

4. Latin America

Twenty-six percent of the land area in Latin America is classified as dryland. These areas are home to 28 percent of the population on the continent. Figure 4.1 reflects the distribution of land and population by aridity zone. Within Latin America, focusing on productive lands by excluding hyper-arid and cold zones does not affect these percentages much. Twenty-seven percent of all productive lands are classified as dryland, while 29 percent of the population on productive lands live in drylands.

Figure 4.1 Aridity Zone Area and Population: Latin America

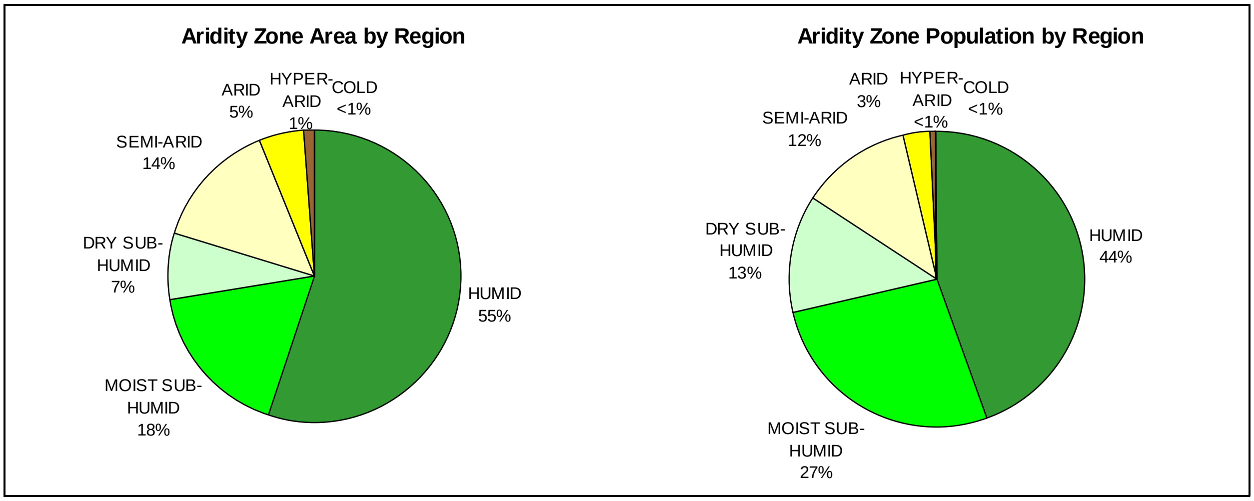


Table 4.1 provides the distribution of land area by aridity zone, while Table 4.3 provides a summary of the land area in drylands by country. Argentina, Mexico, Brazil, Bolivia, and Peru have the largest dryland area of the Latin American countries. In terms of percentage of a country's land area that is dryland, as reflected in Table 4.3, only Argentina, Mexico, Paraguay, and Bolivia exceed 40 percent.

Table 4.2 provides a breakdown of a country's population by aridity zone, while Table 4.4 provides a summary for population on all drylands and all productive lands. Mexico, Brazil, Peru, Argentina, and Chile are the countries with the largest dryland populations, all over 13 million. The countries with the highest percentage of the population in drylands are Bolivia, Peru, Mexico, and Chile, each with between 62 and 57 percent in drylands.

The average population density within dryland areas in Latin America is 23 persons per square kilometer. Map 4.2 provides a graphic summary of the distribution of the population within drylands in Latin America.

Table 4.1 Land Area (Km²) per Aridity Zone

	HUMID	MOIST SUB-HUMID	DRY SUB-HUMID	SEMI-ARID	ARID	HYPER-ARID	COLD	Total
Argentina	246,943	632,706	443,765	964,512	478,700	0	12,587	2,779,423
Belize	21,627	663	0	0	0	0	0	22,289
Bolivia	428,890	202,693	147,542	230,197	78,426	0	0	1,087,750
Brasil	6,305,664	1,313,730	393,568	529,150	0	0	0	8,542,150
Chile	358,505	53,003	13,441	49,057	148,979	114,711	12,851	750,608
Colombia	1,105,154	23,923	4,884	8,897	0	0	0	1,142,858
Costa Rica	51,252	129	0	0	0	0	0	51,381
Ecuador	162,409	64,680	16,158	5,546	176	0	0	248,969
El Salvador	17,690	2,765	0	0	0	0	0	20,455
Guatemala	101,620	7,044	83	0	0	0	0	108,746
Guyana	211,240	0	0	0	0	0	0	211,240
Guyane	83,629	0	0	0	0	0	0	83,629
Honduras	88,063	23,922	0	0	0	0	0	111,985
Mexico	231,594	424,926	276,659	764,930	254,217	6,734	0	1,959,427
Nicaragua	88,725	39,251	0	0	0	0	0	127,976
Panama	74,270	703	0	0	0	0	0	74,974
Paraguay	82,180	121,906	71,552	124,697	0	0	0	400,334
Peru	663,708	264,289	107,980	130,193	65,551	60,240	0	1,291,961
Suriname	146,747	0	0	0	0	0	0	146,747
Uruguay	56,680	120,355	0	0	0	0	0	177,036
Venezuela	587,281	253,413	24,359	46,874	0	0	0	912,086
Aridity Zone Total:	**11,113,870**	**3,550,101**	**1,499,990**	**2,854,052**	**1,026,050**	**181,685**	**25,438**	**20,252,025**
% of Total Area:	**54.9%**	**17.5%**	**7.4%**	**14.1%**	**5.1%**	**0.9%**	**0.1%**	

Table 4.2 Population per Aridity Zone (numbers are in thousands)

	HUMID	MOIST SUB-HUMID	DRY SUB-HUMID	SEMI-ARID	ARID	HYPER-ARID	COLD	Total
Argentina	1,401	21,214	3,924	6,673	2,574	0	75	35,862
Belize*	207	6	0	0	0	0	0	213
Bolivia	947	1,583	1,976	2,163	62	0	0	6,730
Brasil	103,170	30,921	11,377	10,922	0	0	0	156,393
Chile	4,067	1,267	2,883	4,263	852	541	125	14,000
Colombia	31,073	2,316	827	90	0	0	0	34,307
Costa Rica	3,293	2	0	0	0	0	0	3,295
Ecuador	4,267	4,613	1,550	439	2	0	0	10,870
El Salvador	5,130	363	0	0	0	0	0	5,493
Guatemala	7,303	1,708	17	0	0	0	0	9,029
Guyana	772	0	0	0	0	0	0	772
Guyane*	147	0	0	0	0	0	0	147
Honduras	3,631	1,439	0	0	0	0	0	5,070
Mexico	14,765	22,484	29,483	19,386	3,947	63	0	90,128
Nicaragua	880	3,253	0	0	0	0	0	4,133
Panama	2,594	37	0	0	0	0	0	2,631
Paraguay	1,807	2,516	31	38	0	0	0	4,391
Peru	1,936	4,863	2,756	5,044	5,784	1,935	0	22,317
Suriname*	427	0	0	0	0	0	0	427
Uruguay	376	2,620	0	0	0	0	0	2,997
Venezuela	2,384	13,296	1,263	3,538	0	0	0	20,481
Aridity Zone Total:	**190,578**	**114,500**	**56,086**	**52,555**	**13,219**	**2,539**	**201**	**429,684**
% of Total Population:	**44.4%**	**26.6%**	**13.1%**	**12.2%**	**3.1%**	**0.6%**	**0.0%**	

* Based on national data from UN World Population Prospects: The 1996 Revision

Table 4.3 Land Area Summaries Km² (numbers are in thousands)

	TOTAL AREA	PRODUCTIVE LAND	DRYLAND	DRYLAND / PRODUCTIVE LAND	DRYLAND / TOTAL AREA
Paraguay	400	400	196	49%	49%
Chile	751	623	211	34%	28%
Bolivia	1,088	1,088	456	42%	42%
Ecuador	249	249	22	9%	9%
Mexico	1,959	1,952	1,296	66%	66%
Argentina	2,779	2,767	1,887	68%	68%
Peru	1,292	1,232	304	25%	24%
Venezuela	912	912	71	8%	8%
Brasil	8,542	8,542	923	11%	11%
Colombia	1,143	1,143	14	1%	1%
Guatemala	109	109	0	0%	0%
Belize	22	22	0	0%	0%
Costa Rica	51	51	0	0%	0%
El Salvador	20	20	0	0%	0%
Guyana	211	211	0	0%	0%
Guyane	84	84	0	0%	0%
Honduras	112	112	0	0%	0%
Nicaragua	128	128	0	0%	0%
Panama	75	75	0	0%	0%
Suriname	147	147	0	0%	0%
Uruguay	177	177	0	0%	0%
Total:	**20,252**	**20,044**	**5,380**		

Table 4.4 Population Summaries (numbers are in thousands)

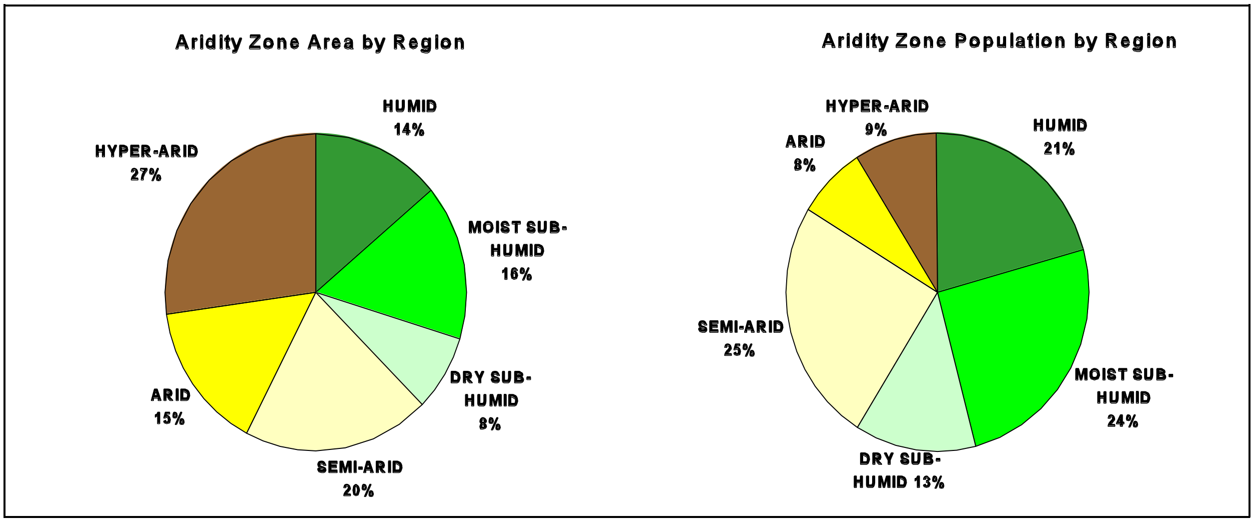
	TOTA L POP	PRODUCTIVE LANDS POP	DRYLANDS POP	DRY POP / PL POP	DRYPOP / TOTALPOP
Bolivia	6,730	6,730	4,201	62%	62%
Peru	22,317	20,382	13,583	67%	61%
Mexico	90,128	90,065	52,815	59%	59%
Chile	14,000	13,332	7,998	60%	57%
Argentina	35,862	35,786	13,170	37%	37%
Venezuela	20,481	20,481	4,801	23%	23%
Ecuador	10,870	10,870	1,990	18%	18%
Brasil	156,393	156,390	22,299	14%	14%
Colombia	34,307	34,307	918	3%	3%
Paraguay	4,391	4,391	69	2%	2%
Guatemala	9,029	9,029	17	0%	0%
Belize*	213	213	0	0%	0%
Costa Rica	3,295	3,295	0	0%	0%
El Salvador	5,493	5,493	0	0%	0%
Guyana	772	772	0	0%	0%
Guyane*	147	147	0	0%	0%
Honduras	5,070	5,070	0	0%	0%
Nicaragua	4,133	4,133	0	0%	0%
Panama	2,631	2,631	0	0%	0%
Suriname*	427	427	0	0%	0%
Uruguay	2,997	2,997	0	0%	0%
Total:	**429,684**	**426,939**	**121,861**		

* Based on national data from UN World Population Prospects: The 1996 Revision

5. Africa

Africa is the only continent with a significant proportion of hyper-arid land, at 27 percent, compared with roughly two and one percent for Asia and for Latin America, respectively. Therefore, whether or not hyper-arid areas are included in statistics on dryland populations have the most profound effects on numbers for the African continent.

Figure 5.1 Aridity Zone Area and Population: Africa



As Figure 5.1 reflects, 43 percent of the land area on the African continent falls within arid, semi-arid, or dry sub-humid aridity zones, and are therefore classified as drylands. These areas are home to 46 percent of the population on the continent. For Africa, if we exclude the hyper-arid areas, and focus on productive lands, 59 percent of all productive lands are dryland, supporting fifty percent of the population.

Table 5.1 provides the distribution of land area by aridity zone, while Table 5.3 provides a summary of the land area in drylands by country. Sudan, South Africa, Ethiopia, Namibia, Chad, and Mali have the greatest dryland area of countries on the African continent. Table 5.3 also provides a summary of the percentage of a country's land area that is dryland. In Botswana, The Gambia, Zimbabwe, Eritrea, and Burkina Faso, 95 - 100 percent of the land area is classified as dryland. If one focuses instead on the percentage of productive land (which excludes hyper-arid areas) that is dryland, Morocco, Tunisia, Egypt, Niger, and several others would stand out as countries where 100 percent of the productive lands are classified as dryland.

A similar examination can be performed of population distribution in drylands areas. Table 5.2 provides a breakdown of population by aridity zone for each country, while Table 5.4 provides a summary for population on all drylands and all productive lands. Nigeria, South Africa, Morocco, Algeria, Sudan, and Ethiopia have the largest populations living in drylands, each with in excess of 30 million people living in these areas. If one examines the percentage of the population living on drylands, a different set of countries would be highlighted - Botswana, The Gambia, Djibouti, Eritrea, among others.

The average population density within dryland areas on the African continent is 25 persons per square kilometer (see Map5.2). Countries with the most densely populated drylands are Cape Verde, Burundi, Egypt, Togo and The Gambia, all with over 100 persons per square kilometer.

Table 5.1 Land Area (Km²) per Aridity Zone

	HUMID	MOIST SUB-HUMID	DRY SUB-HUMID	SEMI-ARID	ARID	HYPER-ARID	Total
Algeria	0	5,196	28,834	180,146	202,143	1,903,692	2,320,011
Angola	97,817	690,470	175,838	262,563	21,976	3,539	1,252,204
Benin	0	69,971	30,090	15,956	0	0	116,017
Botswana	0	0	0	494,624	84,939	0	579,562
Burkina Faso	0	13,711	58,508	188,993	14,535	0	275,747
Burundi	3,138	22,617	1,313	0	0	0	27,068
Cameroon	355,144	56,578	21,373	32,469	2,752	0	468,315
Cape Verde	0	0	0	0	2,036	855	2,891
Central African Rep	223,599	359,393	26,625	13,250	0	0	622,867
Chad	0	50,530	122,196	253,950	306,605	541,134	1,274,416
Comoros*	2,048	0	0	0	0	0	2,048
Congo	338,385	4,848	0	0	0	0	343,233
Congo, Dem Rep	1,655,616	618,190	64,171	0	0	0	2,337,976
Cote d'Ivoire	121,169	202,066	13	0	0	0	323,248
Djibouti	0	0	0	266	18,336	3,158	21,760
Egypt	0	0	0	0	45,890	938,267	984,157
Equatorial Guinea	27,094	0	0	0	0	0	27,094
Eritrea	0	0	0	41,769	74,117	5,016	120,902
Ethiopia	102,973	218,694	159,276	342,378	309,291	432	1,133,044
Gabon	265,850	0	0	0	0	0	265,850
Gambia, The	0	0	7,461	3,374	0	0	10,835
Ghana	58,012	138,924	42,831	0	0	0	239,768
Guinea	158,307	80,646	6,909	0	0	0	245,862
Guinea-Bissau	17,523	16,581	0	0	0	0	34,104
Kenya	13,090	64,428	48,219	239,472	219,553	0	584,763
Lesotho	1,747	12,269	14,231	2,243	0	0	30,491
Liberia	96,291	0	0	0	0	0	96,291
Libya	0	0	0	12,439	163,281	1,443,873	1,619,594
Madagascar	270,964	190,161	45,009	87,149	0	0	593,283
Malawi	3,532	51,600	60,355	3,020	0	0	118,507
Mali	0	28,080	61,659	269,476	309,156	585,955	1,254,326
Mauritania	0	0	0	25,776	291,737	726,197	1,043,711
Mauritius	1,997	0	0	0	0	0	1,997
Morocco	0	177	11,419	180,080	159,468	55,475	406,618
Mozambique	29,649	349,510	213,831	195,670	0	0	788,661
Namibia	0	0	0	410,696	336,198	79,422	826,316
Niger	0	0	0	77,922	482,953	626,752	1,187,627
Nigeria	162,918	282,884	135,335	298,647	33,420	0	913,204
Rwanda	5,918	14,244	5,156	0	0	0	25,318
Sao Tome & Principe	1,013	0	0	0	0	0	1,013
Senegal	0	22,914	29,921	116,230	28,415	0	197,480
Sierra Leone	72,625	0	0	0	0	0	72,625
Somalia	0	0	0	122,820	418,855	94,750	636,425
South Africa	194	78,477	150,672	571,952	406,998	13,383	1,221,675
Sudan	347	142,692	161,197	782,155	631,069	795,550	2,513,010
Swaziland	0	3,759	8,594	4,967	0	0	17,320
Tanzania	20,250	349,026	350,994	225,534	0	0	945,804
Togo	1,752	46,884	8,642	0	0	0	57,278
Tunisia	0	46	3,961	38,674	70,160	42,375	155,216
Uganda	9,597	171,065	41,876	19,740	81	0	242,358
Western Sahara**	0	0	0	0	27	267,378	267,406
Zambia	6,572	384,156	241,383	122,022	0	0	754,133
Zimbabwe	1,078	7,985	55,843	324,919	2,017	0	391,842
Aridity Zone Total:	**4,125,198**	**4,748,768**	**2,393,737**	**5,962,356**	**4,636,009**	**8,127,204**	**29,993,271**
% of Total Area:	**13.8%**	**15.8%**	**8.0%**	**19.9%**	**15.5%**	**27.1%**	

* Comoros includes island of Mayotte, ** territory

Table 5.2 Population per Aridity Zone (numbers are in thousands)

	HUMID	MOIST SUB-HUMID	DRY SUB-HUMID	SEMI-ARID	ARID	HYPER-ARID	Total
Algeria	0	1,263	8,793	14,581	1,741	1,688	28,066
Angola	948	6,356	851	2,572	52	13	10,792
Benin	0	4,904	355	146	0	0	5,405
Botswana	0	0	0	1,396	43	0	1,439
Burkina Faso	0	226	2,128	7,957	162	0	10,472
Burundi	745	5,091	231	0	0	0	6,067
Cameroon	9,751	480	894	2,060	1	0	13,187
Cape Verde	0	0	0	0	374	12	386
Central African Rep	2,044	1,167	37	13	0	0	3,261
Chad	0	893	1,873	2,188	1,369	0	6,323
Comoros*	612	0	0	0	0	0	612
Congo	2,423	164	0	0	0	0	2,586
Congo, Dem Rep	31,401	12,991	1,002	0	0	0	45,394
Cote d'Ivoire	8,663	5,024	0	0	0	0	13,686
Djibouti	0	0	0	1	593	6	600
Egypt	0	0	0	0	7,916	54,167	62,083
Equatorial Guinea	399	0	0	0	0	0	399
Eritrea	0	0	0	2,306	826	37	3,168
Ethiopia	10,721	25,142	10,137	7,706	2,672	0	56,377
Gabon	1,071	0	0	0	0	0	1,071
The Gambia	0	0	940	170	0	0	1,110
Ghana	6,167	8,715	2,449	0	0	0	17,331
Guinea	6,065	1,237	42	0	0	0	7,344
Guinea-Bissau	635	432	0	0	0	0	1,067
Kenya	3,286	13,924	4,672	4,655	601	0	27,138
Lesotho	37	510	1,298	181	0	0	2,027
Liberia	2,121	0	0	0	0	0	2,121
Libya	0	0	0	938	3,851	598	5,387
Madagascar	10,924	2,226	413	1,297	0	0	14,859
Malawi	379	3,507	5,448	335	0	0	9,668
Mali	0	380	1,205	7,501	1,615	77	10,778
Mauritania	0	0	0	216	1,512	534	2,262
Mauritius	1,117	0	0	0	0	0	1,117
Morocco	0	29	1,963	19,771	4,092	660	26,515
Mozambique	986	6,797	6,511	2,947	0	0	17,241
Namibia	0	0	0	1,245	240	58	1,543
Niger	0	0	0	4,070	4,905	164	9,139
Nigeria	41,756	27,347	9,610	32,171	809	0	111,693
Rwanda	1,342	3,463	378	0	0	0	5,183
Sao Tome and Principe	133	0	0	0	0	0	133
Senegal	0	796	432	6,424	657	0	8,308
Sierra Leone	4,192	0	0	0	0	0	4,192
Somalia	0	0	0	3,325	5,521	630	9,476
South Africa	31	8,931	6,404	25,022	1,009	9	41,407
Sudan	12	594	1,520	9,881	10,795	3,858	26,660
Swaziland	0	281	429	147	0	0	857
Tanzania	1,381	13,022	10,117	5,493	0	0	30,012
Togo	106	2,702	1,278	0	0	0	4,085
Tunisia	0	2	386	5,424	3,028	143	8,983
Uganda	788	16,769	1,867	261	0	0	19,684
Western Sahara**	0	0	0	0	0	241	241
Zambia	39	3,810	3,214	1,000	0	0	8,064
Zimbabwe	55	381	4,018	6,713	14	0	11,180
Aridity Zone Total:	**150,195**	**179,556**	**90,894**	**180,248**	**54,397**	**62,895**	**718,185**
% of Total Population:	**20.9%**	**25.0%**	**12.7%**	**25.1%**	**7.6%**	**8.8%**	

Table 5.3 Land Area Summaries Km^2 (numbers are in thousands)

	TOTAL AREA	PRODUCTIVE LAND	DRYLAND	DRYLAND / PRODUCTIVE LAND	DRYLAND / TOTAL AREA
Botswana	580	580	580	100%	100%
Gambia, The	11	11	11	100%	100%
Zimbabwe	392	392	383	98%	98%
Eritrea	121	116	116	100%	96%
Burkina Faso	276	276	262	95%	95%
South Africa	1,222	1,208	1,130	93%	92%
Namibia	826	747	747	100%	90%
Senegal	197	197	175	88%	88%
Kenya	585	585	507	87%	87%
Morocco	407	351	351	100%	86%
Djibouti	22	19	19	100%	85%
Somalia	636	542	542	100%	85%
Swaziland	17	17	14	78%	78%
Tunisia	155	113	113	100%	73%
Ethiopia	1,133	1,133	811	72%	72%
Cape Verde	3	2	2	100%	70%
Sudan	2,513	1,717	1,574	92%	63%
Tanzania	946	946	577	61%	61%
Lesotho	30	30	16	54%	54%
Chad	1,274	733	683	93%	54%
Malawi	119	119	63	53%	53%
Mozambique	789	789	410	52%	52%
Nigeria	913	913	467	51%	51%
Mali	1,254	668	640	96%	51%
Zambia	754	754	363	48%	48%
Niger	1,188	561	561	100%	47%
Benin	116	116	46	40%	40%
Angola	1,252	1,249	460	37%	37%
Mauritania	1,044	318	318	100%	30%
Uganda	242	242	62	25%	25%
Madagascar	593	593	132	22%	22%
Rwanda	25	25	5	20%	20%
Ghana	240	240	43	18%	18%
Algeria	2,320	416	411	99%	18%
Togo	57	57	9	15%	15%
Cameroon	468	468	57	12%	12%
Libya	1,620	176	176	100%	11%
Central African Rep	623	623	40	6%	6%
Burundi	27	27	1	5%	5%
Egypt	984	46	46	100%	5%
Guinea	246	246	7	3%	3%
Congo, Dem Rep	2,338	2,338	64	3%	3%
Western Sahara**	267	0	0	100%	0%
Cote d'Ivoire	323	323	0	0%	0%
Comoros*	2	2	0	0%	0%
Congo	343	343	0	0%	0%
Equatorial Guinea	27	27	0	0%	0%
Gabon	266	266	0	0%	0%
Guinea-Bissau	34	34	0	0%	0%
Liberia	96	96	0	0%	0%
Mauritius	2	2	0	0%	0%
Sao Tome & Principe	1	1	0	0%	0%
Sierra Leone	73	73	0	0%	0%
Total:	**29,993**	**21,866**	**12,991**		

* Comoros includes island of Mayotte, ** territory

Table 5.4 Population Summaries (numbers are in thousands)

	TOTAL POP	PRODUCTIVE LANDS POP	DRYLANDS POP	DRY POP / PL POP	DRY POP / TOTAL POP
Botswana	1,439	1,439	1,439	100%	100%
Gambia, The	1,110	1,110	1,110	100%	100%
Djibouti	600	594	594	100%	99%
Eritrea	3,168	3,131	3,131	100%	99%
Tunisia	8,983	8,841	8,838	100%	98%
Niger	9,139	8,975	8,975	100%	98%
Burkina Faso	10,472	10,472	10,246	98%	98%
Morocco	26,515	25,854	25,825	100%	97%
Cape Verde	386	374	374	100%	97%
Namibia	1,543	1,485	1,485	100%	96%
Zimbabwe	11,180	11,180	10,744	96%	96%
Mali	10,778	10,701	10,321	96%	96%
Somalia	9,476	8,847	8,847	100%	93%
Senegal	8,308	8,308	7,512	90%	90%
Algeria	28,066	26,378	25,115	95%	89%
Libya	5,387	4,789	4,789	100%	89%
Chad	6,323	6,323	5,430	86%	86%
Sudan	26,660	22,801	22,195	97%	83%
South Africa	41,407	41,397	32,435	78%	78%
Mauritania	2,262	1,729	1,729	100%	76%
Lesotho	2,027	2,027	1,480	73%	73%
Swaziland	857	857	575	67%	67%
Malawi	9,668	9,668	5,783	60%	60%
Mozambique	17,241	17,241	9,458	55%	55%
Zambia	8,064	8,064	4,215	52%	52%
Tanzania	30,012	30,012	15,610	52%	52%
Nigeria	111,693	111,693	42,590	38%	38%
Kenya	27,138	27,138	9,928	37%	37%
Ethiopia	56,377	56,377	20,515	36%	36%
Angola	10,792	10,780	3,476	32%	32%
Togo	4,085	4,085	1,278	31%	31%
Cameroon	13,187	13,187	2,955	22%	22%
Ghana	17,331	17,331	2,449	14%	14%
Egypt	62,083	7,916	7,916	100%	13%
Madagascar	14,859	14,859	1,710	12%	12%
Uganda	19,684	19,684	2,128	11%	11%
Benin	5,405	5,405	501	9%	9%
Rwanda	5,183	5,183	378	7%	7%
Burundi	6,067	6,067	231	4%	4%
Congo, Dem Rep	45,394	45,394	1,002	2%	2%
Central African Rep	3,261	3,261	50	2%	2%
Guinea	7,344	7,344	42	1%	1%
Cote d'Ivoire	13,686	13,686	0	0%	0%
Comoros	612	612	0	0%	0%
Congo	2,586	2,586	0	0%	0%
Equatorial Guinea	399	399	0	0%	0%
Gabon	1,071	1,071	0	0%	0%
Guinea-Bissau	1,067	1,067	0	0%	0%
Liberia	2,121	2,121	0	0%	0%
Mauritius	1,117	1,117	0	0%	0%
Sao Tome and Principe	133	133	0	0%	0%
Sierra Leone	4,192	4,192	0	0%	0%
Western Sahara**	241	0	0	0%	0%
Total:	**718,185**	**655,290**	**325,406**		

* Comoros includes island of Mayotte, ** territory

6. South and Southeast Asia

As Figure 6.1 reflects, 23 percent of the land area in South and Southeast Asia is classified as dryland. These areas are home to 32 percent of the population in this part of Asia. As noted in the introduction, much of Asia is not included in this analysis due to data limitations.

Figure 6.1 Aridity Zone Area and Population: South and Southeast Asia

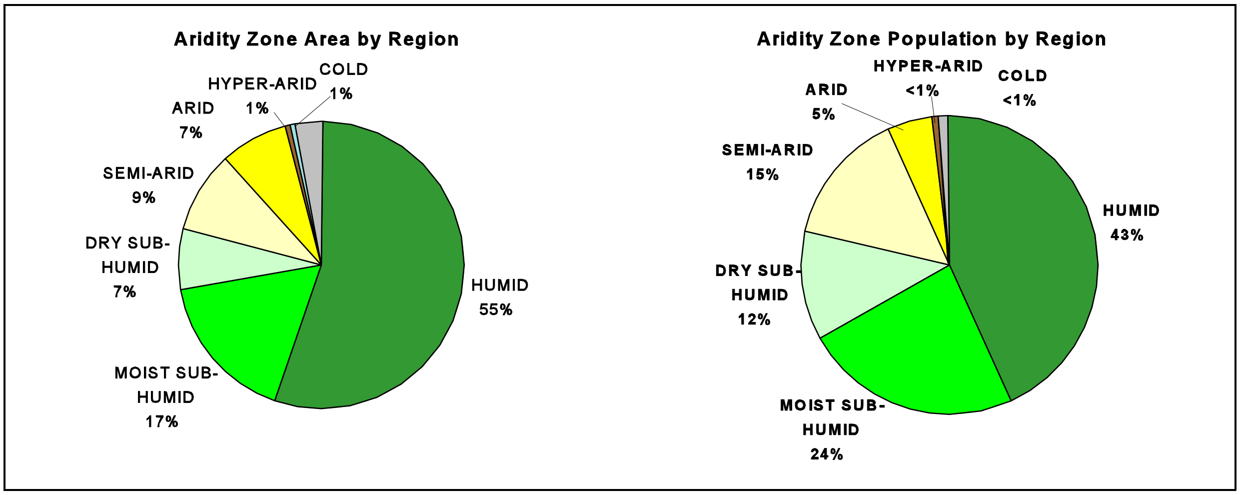


Table 6.1 provides the distribution of land area by aridity zone, while Table 6.3 provides a summary of the land area in drylands by country. Of the countries analyzed, India and Pakistan have the greatest dryland area. In Pakistan 74 percent of the area analyzed is dryland, followed by India with 46 percent and Myanmar with 10 percent dryland area.

A similar examination can be performed of population distribution in drylands areas. Table 6.2 provides a breakdown of a country's population by aridity zone, while Table 6.4 provides a summary for population on all drylands and all productive lands. Again, India, Pakistan, and Myanmar have the greatest number of people living in dryland areas, with 44 percent, 83 percent, and 23 percent of their respective populations in drylands.

Map 6.2 provides more detail on the distribution of the population within drylands in Asia. Average population density in drylands in India is 271 people per square kilometer, 200 per square kilometer in Pakistan and 164 per square kilometer in Myanmar.

Table 6.1 Land Area (Km²) per Aridity Zone

country	HUMID	MOIST SUB-HUMID	DRY SUB-HUMID	SEMI-ARID	ARID	HYPER-ARID	COLD	No Data	Total
Bangladesh	131,698	5,086							136,789
Bhutan	28,370	6,201	746	346			4,116		39,779
Brunei	5,901								5,901
Cambodia	110,697	71,367							182,091
India *	646,637	927,817	561,055	755,103	196,130		42,716	146,016	3,275,474
Indonesia	1,831,040	67,045	10,979	1,110					1,911,952
Laos	215,082	15,598							230,680
Malaysia	331,002								331,183
Myanmar	519,160	84,842	44,536	20,791					669,330
Nepal	114,388	24,534	1,742	648			5,950		147,262
Pakistan *	955	2,121	7,024	95,591	485,607	67,185		137,452	795,935
Papua New Guinea	455,589	8,388							464,422
Philippines	284,039	10,537	2,029	18					297,191
Singapore	597								597
Sri Lanka	48,198	18,423	178						66,816
Thailand	183,036	325,229	8,536						516,930
Vietnam	304,659	22,797	1,223						328,799
Aridity Zone Total:	5,211,047	1,589,986	638,050	873,606	681,738	67,185	52,781	283,468	9,401,130
% of Total Area:	**55.4%**	**16.9%**	**6.8%**	**9.3%**	**7.3%**	**0.7%**	**0.6%**	**3.0%**	

* Indicates data is missing for a portion of the country

Table 6.2 Population per Aridity Zone (numbers are in thousands)

	HUMID	MOIST SUB-HUMID	DRY SUB-HUMID	SEMI-ARID	ARID	HYPER-ARID	COLD	No Data	Total
Bangladesh	114,587	4,238	0	0	0	0	0		118,825
Bhutan	1,580	115	4	1	0	0	9		1,708
Brunei	292	0	0	0	0	0	0		292
Cambodia	3,584	6,342	0	0	0	0	0		9,926
India *	191,495	317,846	189,191	208,016	12,561	0	374	4,685	924,167
Indonesia	186,028	8,820	633	72	0	0	0		195,553
Laos	4,087	537	0	0	0	0	0		4,624
Malaysia	19,626	0	0	0	0	0	0		19,626
Myanmar	29,995	5,646	6,792	3,888	0	0	0		46,321
Nepal	18,656	3,447	41	5	0	0	20		22,169
Pakistan *	509	666	4,768	38,611	74,254	7,457	0	15,316	141,581
Papua New Guinea	3,822	480	0	0	0	0	0		4,302
Philippines	64,725	2,936	373	6	0	0	0		68,040
Singapore	2,848	0	0	0	0	0	0		2,848
Sri Lanka	15,287	2,843	12	0	0	0	0		18,142
Thailand	15,009	43,026	1,037	0	0	0	0		59,071
Vietnam	63,805	8,817	358	0	0	0	0		72,980
Total Population:	735,935	405,759	203,208	250,598	86,815	7,457	403	20,000	1,710,176
% of Total Population:	43.0%	**23.7%**	**11.9%**	**14.7%**	**5.1%**	**0.4%**	**0.0%**	**1.2%**	

* Indicates data is missing for a portion of the country

Table 6.3 Land Area Summaries Km² (numbers are in thousands)

	TOTAL AREA	PRODUCTIVE LAND	DRYLAND	PRODUCTIVE LAND / DRYLAND	PRODUCTIVE LAND / TOTAL AREA
Bangladesh	137	137	0	0%	0%
Bhutan	40	36	1	3%	3%
Brunei	6	6	0	0%	0%
Cambodia	182	182	0	0%	0%
India *	3,275	3,087	1,512	49%	46%
Indonesia	1,912	1,910	12	1%	1%
Laos	231	231	0	0%	0%
Malaysia	331	331	0	0%	0%
Myanmar	669	669	65	10%	10%
Nepal	147	141	2	2%	2%
Pakistan *	796	591	588	99%	74%
Papua New Guinea	464	464	0	0%	0%
Philippines	297	297	2	1%	1%
Singapore	1	1	0	0%	0%
Sri Lanka	67	67	0	0%	0%
Thailand	517	517	9	2%	2%
Vietnam	329	329	1	0%	0%
Total:	9,401	8,994	2,193		

* Indicates data is missing for a portion of the country

Table 6.4 Population Summaries (numbers are in thousands)

	TOTAL POP	PRODUCTIVE LANDS POP	DRYLANDS POP	DRY POP / PL POP	DRY POP / TOTAL POP
Pakistan *	142	119	118	99%	83%
India *	924	919	410	45%	44%
Myanmar	46	46	11	23%	23%
Thailand	59	59	1	2%	2%
Philippines	68	68	0	1%	1%
Vietnam	73	73	0	0%	0%
Indonesia	196	196	1	0%	0%
Bhutan	2	2	0	0%	0%
Nepal	22	22	0	0%	0%
Sri Lanka	18	18	0	0%	0%
Bangladesh	119	119	0	0%	0%
Brunei	0	0	0	0%	0%
Cambodia	10	10	0	0%	0%
Laos	5	5	0	0%	0%
Malaysia	20	20	0	0%	0%
Papua New Guinea	4	4	0	0%	0%
Singapore	3	3	0	0%	0%
Total:	1,710	1,682	541		

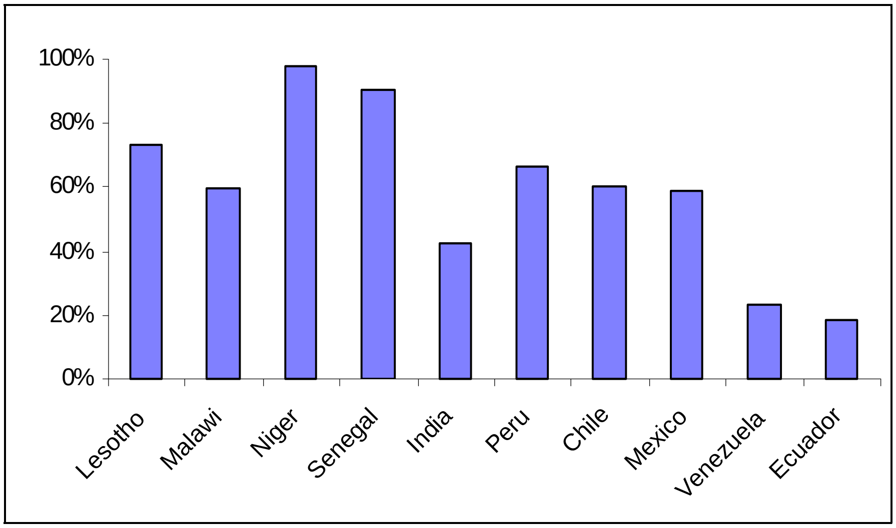
* Indicates data is missing for a portion of the country

7. Population as an Indicator of Pressure

Desertification, or land degradation in dry areas, is linked to both climate variation and unsustainable human activities such as overgrazing, deforestation, and poor agricultural management practices. Population within drylands is not a comprehensive measure of desertification risk, as it does not consider many of the stresses, economic activities and mitigating factors acting in dryland areas. It can, however, be interpreted as both an indicator of potential for degradation from human activity and an indicator of the magnitude of population that will be directly affected by degradation.

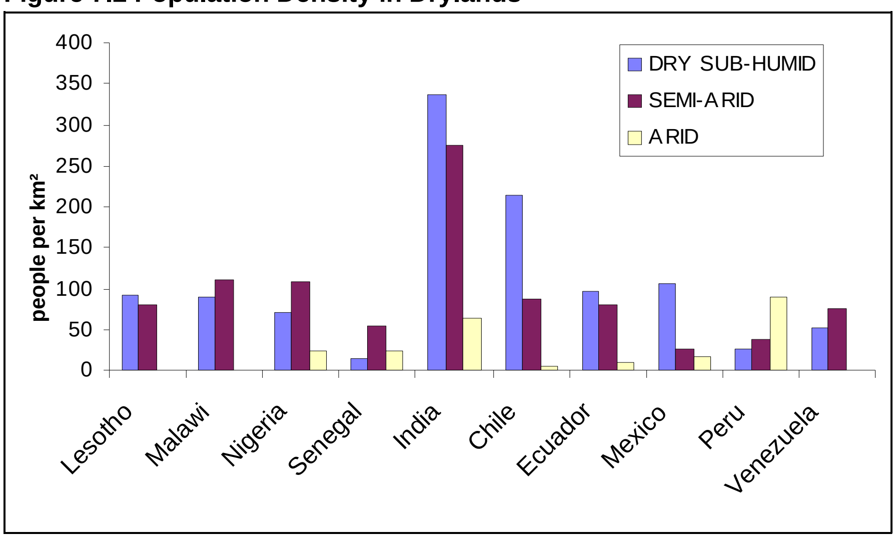
The indicator is calculated for each country by dividing the population within drylands by the total population. Presented in this way, the indicator highlights the extent to which countries are dependent on the resources of drylands. Figure 7.1 shows the population pressure indicator for selected countries in each region. The length of the bar indicates the degree of dependence on dryland resources within the country.

Figure 7.1 Dryland Population as a Percent of Total Population



The data could also be presented as population density in drylands. Figure 7.2 shows the population density within each arid zone for selected countries in each region. Population density and growth are often linked to land degradation. However, there are case studies which show this is not a direct linear relationship. In a study of two arid sites in Northern Nigeria, land conservation and improvement were found to be significantly more advanced in a high-density area (more than 350 people per km²) than a low-density (approximately 100 people per km²) area, where land degradation was occurring (Mortimore, 1993). As these cases suggest, humans can adapt to a changing environment, and human intervention can significantly impact the outcome.

Figure 7.2 Population Density in Drylands



8. Data Issues

As stated in the Introduction, this follow-up analysis was conducted using the same methodology as the World Atlas of Desertification, with improved climate and population data for Africa, Latin America and part of Asia. Improvements in all three regional climate datasets include a greater density of data points and an advanced algorithm used to interpolate the climate surfaces with greater accuracy (summarized in Figure 9.1) The population data used are part of a second generation of surfaces developed using a greater number of administrative units and, for Africa and Asia, an algorithm that incorporates additional information on cities and towns, roads and other features affecting the distribution of population. These improvements in spatial resolution and accuracy of the input data made it possible to summarize results at the country level. Although the datasets used in this analysis were compiled by different institutions, a serious effort was made to ensure that comparable methods were used in processing the data.

Figure 8.1 Progression of Dryland Assessments

	Map of the World Distribution of Aridity Zones (UNESCO, 1977)	World Atlas of Desertification Aridity Zone Map (UNEP / GEMS / GRID, 1992)	Drylands Population Assessment I (UNSO / WRI, 1997)	Drylands Population Assessment II (UNSO / WRI, 1998)
climate data parameters	time: "timeless" lor: res: unspecified def: AI = P/PET	time: 1951-1980 lor: 20 yr. continuous res: 30 min (50 km) def: AI = P/PET	time: 1951-1980 lor: 20 yr. continuous res: 30 min (50 km) def: AI = P/PET	Africa time: 1920 - 1990 lor: 5 yr. continuous res: 3 min (5 km) def: AI = P/PET Latin America time: 1920 - 1990 lor: 5 yr. continuous res: 5 min (9 km) def: AI = P/PET Asia time: 1961-1990 lor: all records res: 2.5 min (4.5 km) def: AI = P/PET

time = the period to which data refer
lor = the length of record criteria for inclusion of weather station records
res = the spatial resolution of the dataset
def AI = definition of aridity zones used

Although improvements have clearly been made in the data available for looking at drylands, there are some limitations associated with the current set of data. Despite the effort made to ensure consistency in the production of datasets, there remain some differences (see technical annex for detail). The data does not cover a significant portion of the world's dryland areas and should be extended, using a consistent methodology, to include the rest of Asia and North America. Also, in the current analysis, as in the WAD, drylands are defined by a simple aridity index which is the ratio of mean annual precipitation to mean annual potential evapotranspiration. This method does not take into account the timing of precipitation and the length of the growing season. These characteristics could be used to stratify within drylands based on vulnerability to drought or desertification. Areas that may receive a significant amount of rainfall during a short rainy season may still suffer water shortages in the dry part of the year and be constrained in the types of crops that can be grown. Also, this method ignores inter-annual climate variability which may be particularly high in dry areas, where total rainfall is minimal.

Finally, the standardization of data in developing indicators is important because it allows for comparison between different spatial units (countries, regions, districts), and different points in time. However, this must be balanced with the need to develop new and better techniques for looking at the data. It should also be recognized that the climate and population data used in these assessments represent dynamic phenonmena. There will continue to be improvements in the available data and changes in the underlying data themselves. For example, this study does not look at the degradation of drylands, which is of major concern to the Convention. A comprehensive, predictive model of desertification would incorporate all of the major factors contributing to the process, as well as the interaction of factors. There are many datasets currently available, such as information on land use, climate variability, soil type and susceptibility of the land to different activities, market forces, governance, and trends such as climate change and population growth rates, which could contribute to a more meaningful profile of indicators at the country level. Some of these are discussed in the following section.

9. Future Indicator Development

Indicators will likely play a major role in the implementation of the Convention to Combat Drought and Desertification. The Convention specifically calls for the development of “integrated sets of physical, biological, social and economic indicators” (Article 16c). Within each of these areas, we have identified simple indicators which could be derived at the regional or country level using a GIS methodology similar to that described for the population pressure indicator.

The physical factors affecting desertification include climate, soils, and topography. One global assessment of vulnerability to desertification, based on global soil and climate GIS databases has been completed by the USDA Natural Resources Conservation Service World Soil Resources Office (Eswaran, 1998). This assessment uses climate variability, soil depth, resilience, and other properties associated with the soil classification scheme to determine four classes of vulnerability to desertification in arid areas (low, medium, high, and very high). The final map is at a scale of 1:30 million. This map does not predict desertification, but combined with population data it would be a useful indicator of the potential for land degradation.

Although desertification is described in physical terms, socioeconomic and political factors can be influential drivers of the process. Factors such as market incentives, land tenure systems, political stability, and technology dissemination have a great impact on whether land is managed sustainably. Socioeconomic factors, particularly measures of wealth and well-being, can also be used to highlight the vulnerability of the human population to desertification. One such measure is the UNDP’s Human Development Index, an aggregated index composed of the following factors: life expectancy, adult literacy, school enrollment, per capita GDP. This index, which is calculated for every country, captures, to some extent, the level of resources available to mitigate the effects of desertification, if only temporarily. A combination of sub-national or national HDI values with population within drylands would help identify populations most at risk. The reverse side of this is the impact of human activity on the environment. This is fairly well-documented in the global map of human-induced soil degradation (GLASOD), but is not available at a scale suitable for country-level analyses. However, there remains a significant gap in available spatial data on agricultural practices and level of technological input.

A third area of indicators proposed in the Convention includes biological factors such as vegetative cover and plant and animal species. Some global maps of species, as well as habitat distribution do exist. The endemic bird areas map produced by BirdLife International, and the map of Ramsar sites (wetlands of international importance) could be used to identify drylands of particularly high biological value. In addition to these maps, there are several remote sensing based datasets which might be useful. A global landcover database developed at the USGS Eros Data Center could be used to evaluate the type of vegetative cover within drylands. The Rain Use Efficiency index, developed by researchers at the University of Maryland, may be useful as a tool for monitoring condition of vulnerable drylands.

A fourth, cross-cutting theme in indicator development should include the measurement of trends which may have an impact on future vulnerability to desertification. Population growth rates and climate change are two areas where global data are available. Urban and rural growth rates are available for most countries and the UN Urban Agglomerations database includes individual growth rates for 432 large cities. A global climate change map was developed as part of the World Atlas of Desertification in 1992. This map indicates the change in aridity index (increase, decrease, no change) between two time periods (1930-1959 and 1960-1989). Additionally, more recent estimates of potential climate change are available from global climate models used in support of the Intergovernmental Panel on Climate Change.

10. Conclusion

This paper presents land area and population by aridity zone for countries in Africa, South and Southeast Asia, and Latin America. This was achieved through the use of a new generation of high-resolution climate and population databases for each continent. The limitations of these datasets and the resulting indicator of population on drylands are clearly stated and areas for future indicator development are identified.

It is clear that more can be done with existing data to develop macro-indicators (global, regional, national) to support the Convention. These indicators are suitable for refining our understanding of where desertification may occur and identifying populations that may be affected. Standardization of indicators is of primary importance at this level. Development of indicators to support regional, national, and local level action plans and monitoring efforts require more research, data collection, and collaboration with local institutions in order to identify the immediate causes of desertification.

Annex: Technical Notes

1. Data Issues and Limitations

Climate

For climate data, high resolution raster databases including mean monthly precipitation, temperature and potential evapotranspiration were used. The data for Africa were developed by Corbett and O'Brien and published on the CD-ROM Spatial Characterization Tool for Africa by Texas A&M University (1997). The data for Latin America were from a preliminary set of climate surfaces developed by Corbett in 1994 at Texas A&M University System. The data for Asia were developed by Peter Jones at the International Center for Tropical Agriculture (CIAT), and converted to grid format at the International Center for Improvement of Corn and Wheat (CIMMYT), (1998).

Improvements in all three regional climate datasets include a greater density of data points and an advanced algorithm used to interpolate the climate surfaces. However, the data were not created as part of a single effort, but by different institutions with slightly different objectives, and it was difficult to ensure some level of input climate data and processing techniques Another set of surfaces developed by Utah State University Climate Center which includes all of Asia, was not used in this analysis because of significant differences in the processing of the climate data. Some of the defining characteristics of the regional datasets are summarized in the table and described in more detail below.

	Time period	Length of record	Interpolation technique	Timing of interpolation	Output resolution
Africa	1920-1990	5 years continuous	Thin plate spline function with variable lapse rate	Monthly means calculated, then interpolated	3 minutes
South & SE Asia	not defined	10 years (with exceptions)	inverse distance weighted with variable lapse rate	Monthly means calculated, then interpolated	2.5 minutes
Latin America	1920-1990	5 years continuous	Thin plate spline function with variable lapse rate	Monthly means calculated, then interpolated	5 minutes

<u>Time period</u>
Most of the weather data for Africa and Latin America were collected between 1920 and 1990. All available records were used for Asia, with error checking.

<u>Length of record</u>
Records from a greater number of weather stations were used because the criteria for inclusion was reduced from 20 years continuous record for the WAD to a minimum of 5 years continuous record for the Africa and Latin America climate surfaces, and a goal of 10 years, with exceptions in Asia. The incorporation of more data points increases the spatial accuracy, but introduces an element of variation related to the length of record. A 30-year cycle is generally considered representative of the long term

climate, whereas records of only five years or less might represent extremes in temperature or rainfall. This is particularly true for dryland areas, where interannual variability is high (WAD 2nd Edition). (Note that in the interpolation of precipitation surfaces for Africa and Latin America, data points were weighted according to length of record.)

<u>Interpolation technique</u>
Interpolation is necessary to create a continuous surface from the input data points. There are a number of different methods which can be used to fit the surface to the data points. A simple, inverse distance-weighted algorithm, was used for Asia. This technique is basically a connect-the dots approach, where the interpolated surface passes through data points. This technique is robust in areas of sparse data, and the impact of errors is highly localized.

The thin plate spline is a statistical method which attempts to model the spatial distribution of a variable as a function of observations distributed across a region, without knowledge of underlying causes. It tends to be more robust than other methods in areas of sparse data. The mathematical process is an iterative process which finds the optimum trade-off between goodness-of-fit and surface smoothness (Hutchinson et al., 1996). The spline function used for Africa and Latin America fits the surface by minimizing the error in a generalised cross validation (GCV). The GCV is a method which estimates the interpolation error obtained by removing each data point in turn and fitting a surface to the remaining data to see how well each omitted point can be predicted (Hutchinson et al., 1996). The interpolated surface takes into account all data points, but may not actually pass through any point.

In all regions, elevation is incorporated in the interpolation of temperature as a third, empirically derived variable lapse rate (coefficient of elevation covariate). The incorporation of a continuous, spatially varying dependence on elevation is a critical factor in the accuracy of these data.

<u>Timing of interpolation</u>
The timing of the interpolation of surfaces has a major impact on the output, and is the main reason the USU surfaces for Asia were not used in this analysis. For the climate datasets that were used in this analysis, monthly means were calculated for data points and then used to interpolate the surface.

<u>Output resolution</u>
The spatial resolution of the climate surfaces varies: 3 minutes (about 5 km) for Africa, 5 minutes (9 km) for Latin America, and 2.25 minutes (4.5 km) for Asia. Although the output resolution should be indirectly related to data point density, the actual cell dimensions are somewhat arbitrary.

<u>PET</u>
For all three regions, the Thornthwaite method was used to calculate potential evapotranspiration. This method requires minimal inputs (temperature and number of daylight hours).

Population

For all three regions, population data was compiled from the latest available census data - resulting in reference years ranging from 1970-1993 for Africa, 1981-1995 for Asia, and 1988-1996 for Latin America. For most countries in Asia and Africa, a district-specific growth rate was calculated for each administrative unit using the last two available census figures. A simple trend forecast was used to predict the 1995 population. The 1995 estimates were compared to the UN figures (World Population Prospects: The 1994 Revision, UNPOP/DESIDA, New York, 1994), and in a few cases adjustments were made to the growth rates to bring the 1995 estimates closer to UN figures. For Latin America, national level growth rates provided by the Center for Tropical Agriculture (CIAT) were applied to standardize all population counts to 1995, which means that subnational variation in population growth was not taken into account. No attempt was made to adjust for differences in the 1995 estimates and UN figures, except in the case of French Guyana, Suriname and Belize. For these countries, UN country estimates were used because the difference between UN estimates and 1995 projections based on available census data were extreme. For all regions, theaccuracy of the 1995 estimates varies, with reliability decreasing as the numbers of years since the latest census increases. The following table lists parameters of population datasets used for each continent.

	Time	Data format	Resolution
Africa	1995 estimate, using sub-national growth rates	Modeled grid	4.5 km
Asia	1995 estimate, using sub-national growth rates	Modeled grid	4.5 km
Latin America	1995 estimate, using national growth rates	Polygon	Administrative unit

For Africa and Asia, gridded population datasets were developed that more accurately represent the spatial distribution of people (Deichmann, 1996). Often, population compiled at the administrative district level is used with the assumption that the population is uniformly distributed within the district. This is obviously not the case in reality. Patterns of human settlement indicate that people are more likely to be located near roads, rivers and towns, where the relative opportunites for human interaction and contact are higher. The population datasets used in this analysis attempt to approximate reality by redistributing the total population within each district using a model that takes into account the location of existing infrastructure, as well as lakes, protected areas, and other sparsely populated areas.

The result of the model is a raster surface in which the population totals within each administrative district are preserved, but which more accurately depict the likely location of the population within the unit. The raster surfaces developed for Asia and Africa have a spatial resolution of 2.25 minutes (about 4.5 km). Although the modeled raster format is assumed to more accurately represent the distribution of population, precision is limited by cell size. Along country borders, the population within a single cell must be allocated to one country or the other, and occasionally a cell may be misallocated when the data is summarized by country or climate zones within countries. The magnitude of the resulting error can be quite significant (in Asia there are single cells with population greater than 1 million).

The population data for Latin America were developed at CIAT (1997). The data were not modeled, and so do not have the same level of spatial accuracy as the raster datasets. However, the lack of modeling is offset by the fact that data were compiled at a smaller administrative unit, the *municipio*, than for the other regions.

It is difficult to compare the quality, in terms of spatial accuracy, of the regional population databases used in the analysis because of the difference in file formats. It is possible, however, to compare the Latin America databases with the Asia and Africa databases prior to the implementation of the accessibility model. The figures listed in the table below give some measure of data resolution and available detail.

	Mean population per unit	Mean unit area (km^2)	Percent of units smaller than 500 km^2	Mean linear resolution
Asia	626,012	5,700	21%	75 km
Africa	130,322	6,100	21%	78 km
Latin America	41,370	1,900	54%	44 km*

*Note that mean resolution is the square root of the mean area, or the mean length of a side of an administrative units if all units were square.

2. GIS Analysis

The data processing and analysis was done using ArcView 3.1 with Spatial Analyst Extension and Arc/Info GIS software.

An aridity index (AI) was calculated by dividing mean annual precipitation (PPT) by mean annual evapotranspiration (PET). Aridity zones were derived by reclassifying the index into the six aridity zones identified in the 1977 UNESCO Map of the World Distribution of Aridity Zones. The ranges of AI for each aridity zone are listed in the table below. Note that the boundary between arid and hyper-arid was changed from 0.03 to 0.05 as defined under the terms of the CCD. This change is consistent with aridity zones used in the World Atlas of Desertification (1991) and in the previous dryland indicators report.

AZ	AI	LGP (days)	Typical Crops
Hyper-arid	< 0.05	0	No crops, no pasture
Arid	0.05 - 0.20	1 - 59	No crops, marginal pasture
Semi-Arid	0.20 - 0.50	60 - 119	Bulrush millet, sorghum, sesame
Dry sub-humid	0.50 - 0.65	120 - 179	Maize, bean, groundnut, peas, barley, wheat, teff
Moist sub-humid	0.65 - 1	180 - 269	Maize, cotton, sweet potato, finger millet
Humid	> 1	> 270	Cassava, coffee, banana, enset, tea, sugar cane

As in the WAD, a cold zone was included, which covers areas where more than six months have an average temperature less than 0°C, and not more than three months have an average temperature exceeding 6°C.

For Asia and Africa, the geometric intersection of aridity zones and countries was computed, creating an output file of country-climate zones in which each country is divided into the aridity zones which intersect it. Each feature in the output file has a unique identifier made up of a two or three-letter country abbreviation and a numeric code for the aridity zone. For Latin America, the geometric intersection of aridity zones and census unit was computed. The output from this processing step is the basic unit used to summarize the population data and an effort was made to ensure that this data matched the spatial extent of the population data (particularly along the coast where areas of high population density are often located). For some island nations (Cape Verde, Mauritius), climate data were not available so the WAD zones were used. Country boundaries used in this analysis were from the population datasets. It should be noted that these country boundaries differ from boundaries used to produce national statistics in the previous drylands population analysis, which results in slight differences in area and population estimates.

In the final step of the analysis, statistics on population were extracted by spatial query, overlaying the country-climate zones on population data and summing the values of the cells (which represent population counts) which fall within the zone. For Latin America, the original population counts were converted to density values which were used to re-calculate population counts for the new climate-population units. Area was calculated in a Lambert Equal Area projection optimized for each region.

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WWW SITES

Data and documentation were downloaded from the following WWW site:

UNEP GRID - Sioux Falls
http://grid2.cr.usgs.gov