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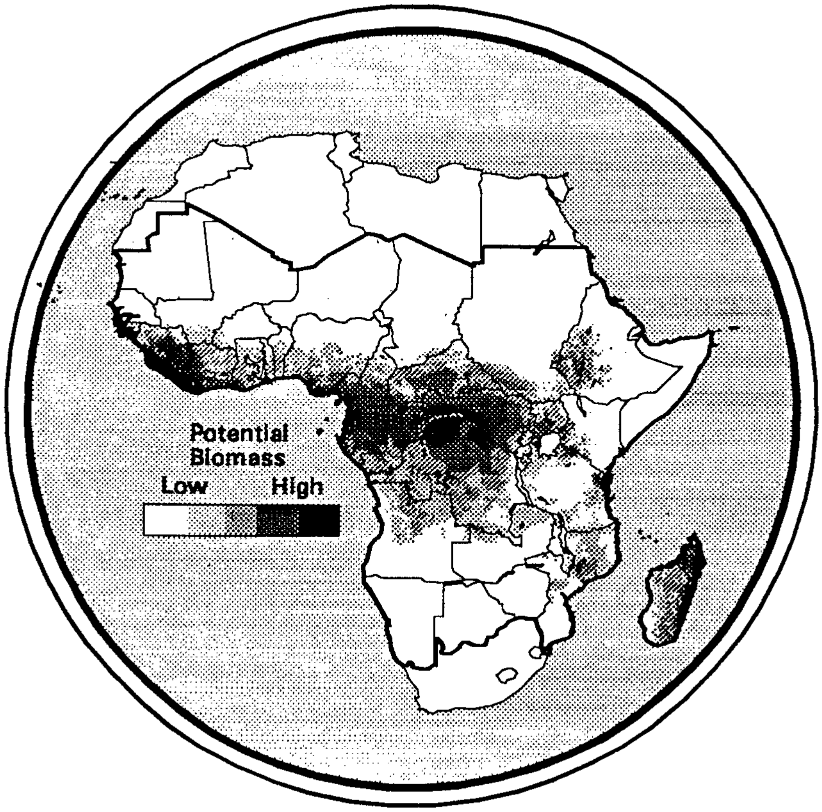
R. C. Daniels, editor



Carbon Dioxide Information Analysis Center
Oak Ridge National Laboratory

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TROPICAL AFRICA: LAND USE, BIOMASS, AND CARBON ESTIMATES FOR 1980

–WITH A METHOD FOR EXTENDING THE DATA TO 1990 AND BEYOND–

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Contents

Abstract

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This document describes the contents of a digital database containing maximum potential aboveground biomass, land use, and estimated biomass and carbon data for 1980 and describes a methodology that may be used to extend this data set to 1990 and beyond based on population and land cover data. The biomass data and carbon estimates are for woody vegetation in Tropical Africa. These data were collected to reduce the uncertainty associated with the possible magnitude of historical releases of carbon from land use change. Tropical Africa is defined here as encompassing 22.7×10^6 km^2 of the earth's land surface and includes those countries that for the most part are located in Tropical Africa. Countries bordering the Mediterranean Sea and in southern Africa (i.e., Egypt, Libya, Tunisia, Algeria, Morocco, South Africa, Lesotho, Swaziland, and Western Sahara) have maximum potential biomass and land cover information but do not have biomass or carbon estimate.

The database was developed using the GRID module in the ARC/INFO™ geographic information system. Source data were obtained from the Food and Agriculture Organization (FAO), the U.S. National Geophysical Data Center, and a limited number of biomass-carbon density case studies. These data were used to derive the maximum potential and actual (ca. 1980) aboveground biomass-carbon values at regional and country levels. The land-use data provided were derived from a vegetation map originally produced for the FAO by the International Institute of Vegetation Mapping, Toulouse, France.

Analyses conducted with this database found that 18% of Tropical Africa was in closed forest and 36% was in open forest in 1980. These forested lands contained over 138×10^9 Mg of aboveground live biomass, equivalent to 69×10^9 Mg of carbon. Closed forests and open forests had mean aboveground biomass values of 209 Mg/ha and 67 Mg/ha, respectively, in 1980. These values are down from maximum potential aboveground live biomass values of 296 Mg/ha for closed forest and 108 Mg/ha for open forest.

These data are available as a Numeric Data Package (NDP) from the Carbon Dioxide Information Analysis Center. The NDP consists of this document and a set of 26 digital files. The 26 files consist of seven ARC/INFO™ export files, eight flat ASCII data files, ten FORTRAN and SAS™ data retrieval files, and one descriptive file that explains the contents and format of each data file. The documentation contains information on the methods used in calculating each variable; detailed descriptions of file contents and formats; and a discussion of the sources, restrictions, and limitations of the data.

List of Figures

PART 1: INFORMATION ABOUT THE DATA PACKAGE

1. Name of the Numeric Data Package

TROPICAL AFRICA:
LAND USE, BIOMASS, AND CARBON ESTIMATES FOR 1980

2. Contributors

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3. Keywords

Carbon release, climate change, deforestation, forestry, population.

4. Background Information

Human-induced changes in the Earth's land cover may influence ecological and climatic systems. The potential for these changes to have regional or global implications makes the task of developing an all-inclusive general circulation model (GCM) with predictive capabilities essential. However, to accurately predict the effects of long-term increases in the number and concentration of greenhouse gases on climate, GCMs require information on the timing and magnitude of past releases of CO_2, methane, nitrous oxide, water vapor, and a host of other anthropogenic gases, and an understanding of all the major processes leading to the release (sources) and storage (sinks) of these gases over time.

The prediction of regional trends in climate will be problematic until a well-documented understanding of the past, present, and possible future usage of fossil fuels and land is obtained. Such an understanding is possible only with the concerted effort of many investigators from a diverse set of disciplines. The perspectives of ecologists, biologists, historians, geographers, foresters, mathematicians, physicists, and others are needed if a multifaceted examination of the causes and consequences of land-cover change and human population growth on the world's climate is to be obtained.

Reductions in the amount of carbon stored in terrestrial ecosystems are partially responsible for the increase in the concentration of atmospheric CO_2 that has occurred since 1850 (Houghton 1993). For example, live vegetation in terrestrial ecosystems is estimated to have contained over 900 Pg of carbon, with 90% of this being in forests, before any land clearing occurred on Earth (Olson et al. 1985, Dale et al. 1991). Houghton et al. (1985) estimated that in 1980 only 550 Pg/C remained in live vegetation.

Decline in the amount of carbon sequestered in vegetation has been associated with the rapid increase in human population that began during the industrial revolution. This population growth created demands for food and forest products that were fulfilled through the clearing and conversion of large tracts of forest to agriculture and other uses. This land-cover change has direct impacts on the concentration of atmospheric CO_2. For example, a 1% change in the total amount of carbon stored in living vegetation would release about 21 Pg of carbon to the atmosphere, almost four times the present annual emission from fossil fuels (Houghton 1993).

5. Contents, Funding Support, and Applications of the Database

This numeric data package (NDP) contains historical land-use and biomass data collected or derived by Sandra Brown and Greg Gaston for the U.S. Department of Energy's Global Change Research Program. The data set contains 1980 land use, maximum potential aboveground live biomass, and biomass and carbon estimates for woody vegetation in 1980 [a similar database has been collected for South and Southeast Asia and is described in Brown et al. (1993) and Iverson et al. (1994)]. The database includes information on human populations in each country and political sub-unit of Tropical Africa for the years 1960, 1970, 1980, and 1990 and biomass estimates for 1980 by country (see Appendix A). Methods, results, and conclusions drawn by researchers based on these data are described in detail in Brown et al. (1993), Iverson et al. (1994), and Brown and Gaston (1995). Brown and Gaston (1995) is reprinted in Appendix B of this report.

The database was developed by Sandra Brown, Louis Iverson, Ariel Lugo, Anantha Prasad, Greg Gaston, and others between 1990 and 1994. Development was supported by a series of contracts and grants from the U.S. Department of Energy, Global Carbon Cycle Program (presently under the direction of Roger C. Dahlman). All funding was part of a multiyear, multidisciplinary research initiative to examine the impacts of land-use change in tropical regions of the world on global atmospheric CO_2 concentrations. The primary contract that supported the collection of the data was the U.S. Department of Energy, Office of Health and Environmental Research, contract DEFG02-90ER61081. Additional support was obtained from the U.S. Environmental Protection Agency through its postdoctoral fellowship program, administered by the National Research Council.

These data were collected to reduce the uncertainty associated with the possible magnitude and time course of historical releases of carbon from land-cover change. Thus, these data may be used by demographers, historians, geographers, or other researchers interested in the relationship between land-cover change, land degradation, population growth, and climate.

6. Scope of the Data

For purposes of this NDP, Tropical Africa is defined as encompassing nearly 22.7 × 10^6 km^2 of land, of which nearly 12.2 × 10^6 km^2 was forested in 1980. Tropical Africa is composed of the following countries: Angola, Botswana, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Congo, Benin, Equatorial Guinea, Ethiopia, Djibouti, Gabon, Gambia, Ghana, Guinea, Ivory Coast, Kenya, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Namibia, Niger, Nigeria, Guinea-Bissau, Zimbabwe (Rhodesia), Rwanda, Senegal, Sierra Leone, Somalia, Sudan, Tanzania, Togo, Uganda, Burkina Faso (Upper Volta), Zaire, and Zambia. Africa is larger than Australia, China, India, and the continental United States combined (Figure 1). Thus, databases covering Africa are of critical importance to global carbon cycle studies. As defined here, Tropical Africa does not include countries in Mediterranean and southern Africa (i.e., Egypt, Libya, Tunisia, Algeria, Morocco, Western Sahara, South Africa, Lesotho, and Swaziland), even so, Tropical Africa is still nearly three times larger than the continental United States.

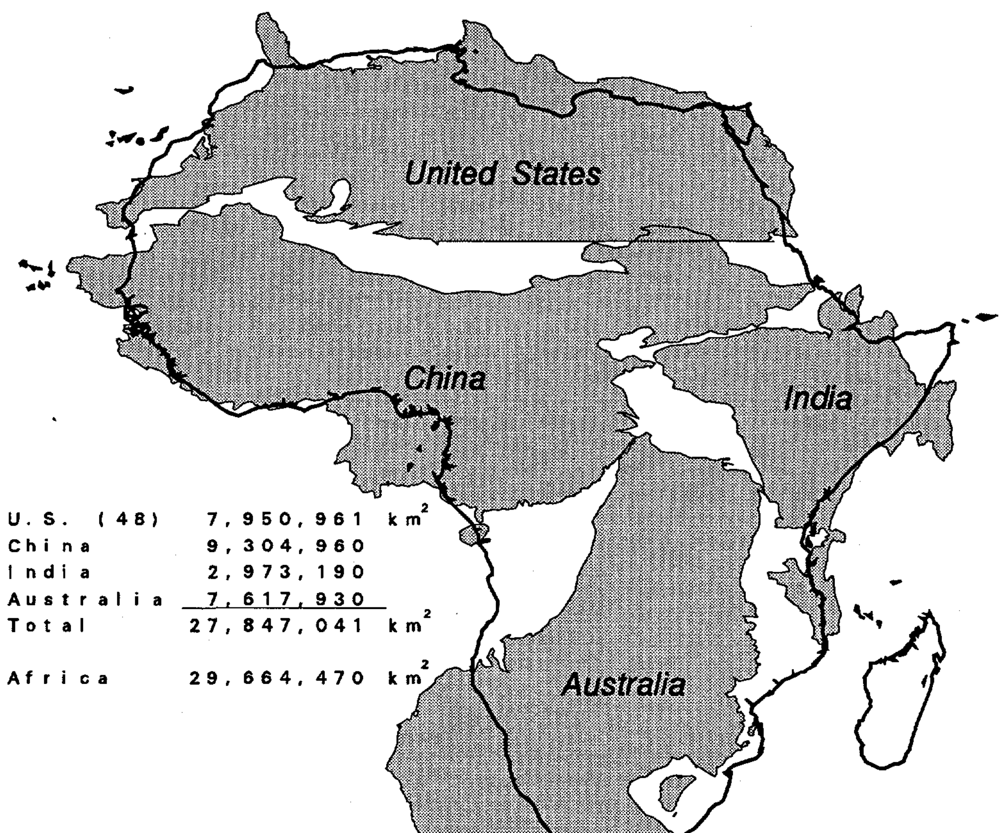

Figure 1. Map of Africa showing its size in relation to Australia, China, India, and the United States.

7. Description of the Study Area

Africa, like any large continent, has a wide variety of vegetation communities. The central portion of Africa contains large areas of moist tropical forest (e.g., in the Zaire river basin). These tropical forests are bounded by seasonal forests, woodlands, savanna, and desert –the Sahara to the north and Kalahari to the south. The distribution of these land-cover types was historically determined based on climate, topography, and soils. Since the industrial revolution, however, this distribution has changed significantly. These changes (e.g., replacement of seasonal forest by woodland/savanna) and land degradation (reduction in biomass within a given land-cover class) have been related to the density and intensity of human activity within an area (Iverson et al. 1994, Brown and Gaston 1995).

In the research that created this database, population density data for 501 political units were used to estimate the reduction in biomass from precolonial levels (1880s) for woody vegetation in Tropical Africa. The names and locations of these political units are listed in Table 1 and are shown in Figures 2a through 2f.

Table 1. **Listing of country names, country codes, political units, political unit codes, and political unit areas for Tropical Africa**

Country code	Political unit	Political code	Area (km^2)	Country code	Political unit	Political code	Area (km^2)
			ANGOLA				
7	ZAIRE	1	40,130	7	BENGUELA	9	31,788
7	UIGE	2	58,698	7	HUAMBO	10	34,274
7	KWANZA-NORTH	3	24,190	7	BIE	11	70,314
7	KWANZA-SOUTH	4	55,660	7	HUILA CUNENE	12	164,344
7	MOXICO	5	223,023	7	BENGO LUANDA	13	33,789
7	KUANDO-KUBANGO	6	199,049	7	CABINDA	14	7,270
7	MALANGE	7	97,602	7	NAMIBE	15	58,137
7	LUNDA-NORTH & LUNDA-SOUTH	8	148,432				
			BOTSWANA				
20	CENTRAL NORTH EAST	16	152,850	20	CHOBE	21	20,800
20	GHANZI	17	117,910	20	NGAMILAND	22	109,130
20	KGALAGADI	18	106,940	20	NGWAKETSE	23	27,370
20	KGATLENG	19	7,960	20	BAROLONG SOUTH EAST	24	2,880
20	KWENENG	20	35,890				
			BURUNDI				
29	BUBANZA	25	1,093	29	KIRUNDO	33	1,711
29	BUJUMBURA	26	1,334	29	MAKAMBA	34	1,972
29	BURURI	27	2,515	29	MURAMVYA	35	1,530
29	CANKUZO	28	1,940	29	MUYINGA	36	1,825
29	CIBITOKE	29	1,639	29	NGOZI	37	1,468
29	GITEGA	30	1,989	29	RUTANA	38	1,898
29	KARUZI	31	1,459	29	RUYIGI	39	2,365
29	KAYANZA	32	1,229				
			CAMEROON				
32	EXTREME	40	34,260	32	SOUTH	45	47,190
32	NORTH	41	67,798	32	LITTORAL	46	20,220
32	ADAMOUA	42	61,992	32	SOUTH	47	24,910
32	EAST	43	108,900	32	NORTH	48	17,300
32	CENTER	44	68,942	32	WEST	49	13,890
			CAPE VERDE				
35	BOAVISTA	50	620	35	SANTIAGO	55	991
35	BRAVA	51	67	35	SANTO ANTAO	56	779
35	FOGO	52	476	35	ST. NICOLAU	57	388
35	MAIO	53	269	35	ST. VINCENTE	58	227
35	SAL	54	216				
			CENTRAL AFRICAN REPUBLIC				
37	LOBAYE	59	19,235	37	BAMINGUI-BANGORAN	66	58,200
37	OMBELLA-MPOKO BANGUI	60	32,450	37	VAKAGA	67	46,500
				37	HAUTE-KOTTO	68	86,650
37	SANGHA-ECONOMIC HAUE-SANGHA	61	49,606	37	OUAKA	69	49,900
				37	BASSE-KOTTO	70	17,604
37	NANA-MAMBERE	62	26,600	37	M'BOMOU	71	61,150
37	OUHAM-PENDE	63	32,100	37	HAUT-M'BOMOU	72	55,530
37	OUHAM	64	50,250				
37	KEMO-GRIBINGUI GRIBINGUI ECON.	65	37,200				

Table 1. (continued)

Country code	Political unit	Political code	Area (km²)	Country code	Political unit	Political code	Area (km²)
			CHAD				
39	BATHA	73	88,800	39	LOGONE OCCIDENTAL	80	8,695
39	BET	74	600,350	39	LOGONE ORIENTAL	81	28,035
39	BILTINE	75	46,850	39	MAYO KEBBI	82	30,105
39	CHARI BAUIRMI	76	82,910	39	MOYEN CHARI	83	45,180
39	GUERA	77	58,950	39	OUADDAI	84	76,240
39	KANEM	78	114,520	39	SALAMAT	85	63,000
39	LAC	79	22,320	39	TANDJILE	86	18,045
			CONGO				
46	KOUILOU	87	13,694	46	PLATEAUX	92	38,400
46	NIARI	88	25,942	46	CUVETTE	93	74,850
46	LEKOUMOU	89	20,950	46	SANGHA	94	55,800
46	BOUENZA	90	12,265	46	LIKOUALA	95	66,044
46	POOL	91	34,055				
			BENIN				
53	ATACORA	96	31,200	53	MONO	99	3,800
53	ATLANTIQUE	97	3,222	53	OUEME	100	4,700
53	BORGOU	98	51,000	53	ZOU	101	18,700
			EQUATORIAL GUINEA				
61	INSULAR	102	2,034	61	CONTINENTAL	103	26,017
			ETHIOPIA				
62	ARSSI	104	23,675	62	ILLUBABOR	111	46,367
62	BALE	105	127,053	62	KEFFA	112	56,634
62	GAMO GOFFA	106	40,348	62	SHEWA	113	85,316
62	GOJJAM	107	61,224	62	SIDAMO	114	119,760
62	GONDER	108	79,579	62	TIGRAY	115	64,921
62	ERITREA ASSEB			62	WELLEGA	116	70,481
	ADMINISTRATION	109	121,143	62	WELLO	117	82,144
62	HARARGE	110	272,637				
			DJIBOUTI				
72	DJIBOUTI	118	23,200				
			GABON				
74	WOLEU-NTEM	119	38,465	74	OGOOUE-LOLO	124	25,380
74	ESTUARIE	120	20,740	74	HAUT-OGOOUE	125	36,547
74	OGOOUE-MARITIME	121	22,890	74	NGOUNIE	126	37,750
74	MOYEN-OGOOUE	122	18,535	74	NYANGA	127	21,285
74	OGOOUE-IVINDO	123	46,075				
			GAMBIA				
75	BRIKAMA	128	1,911	75	GEORGETOWN	131	2,901
75	MANSAKONKO	129	1,326	75	BASSE-SANTA SU	132	2,046
75	KEREWAN	130	2,163				
			GHANA				
81	WESTERN	501	23,921	81	ASHANTI	506	24,389
81	CENTRAL	502	9,826	81	BRONG AHAFO	507	39,557
81	GREATER ACCRA	503	3,245	81	NORTHERN	508	70,384
81	EASTERN	504	19,323	81	UPPER WEST	509	18,476
81	VOLTA	505	20,570	81	UPPER EAST	510	8,842

Table 1. (continued)

Country code	Political unit	Political code	Area (km²)	Country code	Political unit	Political code	Area (km²)
			GUINEA				
90	BOFFA	141	5,003	90	TOUGUE	156	6,200
90	BOKE	142	10,053	90	DABOLA	157	6,000
90	COYAH	143	5,576	90	DINGUIRAYE	158	11,000
90	FORECARIAH	144	4,265	90	FARANAH	159	12,400
90	CONAKRY	145	308	90	KANKAN MANDIANA	160	31,350
90	FRIA	146	2,175	90	KEROUANE	161	7,950
90	KINDIA	147	8,828	90	KOUROUSSA	162	12,035
90	TELIMELE	148	8,080	90	SIGUIRI	163	19,750
90	DALABA	149	3,400	90	BEYLA	164	17,452
90	GAOUAL	150	11,500	90	GUEKEDOU	165	4,157
90	KOUBIA LABE LELOUMA	151	6,150	90	KISSIDOUGOU	166	8,872
90	KOUNIDARA	152	5,500	90	LOLA N'ZEREKORE	167	8,000
90	MALI	153	8,800	90	MACENTA	168	8,710
90	MAMOU	154	6,160	90	YOMOU	169	2,183
90	PITA	155	4,000				
			IVORY COAST				
107	ABENGOUROU	170	6,865	107	SASSANDRA SOUBRE	183	26,350
107	ABIDJAN ABIDJAN VILLE	171	14,690	107	DALOA ISSIA	184	15,450
107	ABOISSO	172	6,295	107	GAGNOA OUME	185	6,940
107	ADZOPE	173	5,320	107	MANKONO SEGUELA	186	22,060
107	AGBOVILLE	174	3,850	107	BOUAFLE ZUENOULA	187	8,660
107	DIVO LAKOTA	175	10,760	107	BOUAKE	188	23,480
107	BONDOUKOU	176	16,840	107	BONGOUANOU DIMBOKRO	189	14,110
107	BOUNA	177	21,460	107	DABAKALA	190	9,770
107	BIANKOUMA	178	4,845	107	KATIOLA	191	9,450
107	DANANE	179	4,625	107	BOUNDIALI TINGRELLA	192	10,070
107	GUIGLO	180	14,630	107	FERKESSEDOUGOU	193	17,040
107	MAN	181	6,940	107	KORHOGO	194	12,245
107	TOUBA	182	8,615	107	ODIENNE	195	21,005
			KENYA				
114	NAIROBI	196	684	114	MERU	216	9,922
114	KIAMBU	197	2,448	114	BARINGO	217	10,627
114	KIRINYAGA	198	1,437	114	ELGEYO MARAKWET	218	2,722
114	MURANGA	199	2,476	114	KAJIADO	219	20,963
114	NYANDARUA	200	3,528	114	KERICHO	220	4,890
114	NYERI	201	3,284	114	LAIKIPIA	221	9,718
114	KILIFI	202	12,414	114	NAKURU	222	7,024
114	KWALE	203	8,257	114	NANDI	223	2,745
114	LAMU	204	6,506	114	NAROK	224	18,519
114	MOMBASA	205	210	114	SAMBURU	225	20,809
114	TAITA TAVETA	206	16,959	114	TRANS-NZOIA	226	2,468
114	TANA RIVER	207	38,694	114	TURKANA	227	61,769
114	GARISSA	208	43,931	114	UASIN GISHU	228	3,784
114	MANDERA	209	26,470	114	WEST POKOT	229	5,076
114	WAJIR	210	56,501	114	KISII	230	2,196
114	EMBU	211	2,714	114	KISUMU	231	2,093
114	ISIOLO	212	25,605	114	SIAYA	232	2,522
114	KITUI	213	29,388	114	SOUTH NYANZA	233	5,714
114	MACHAKOS	214	14,178	114	BUNGOMA	234	3,074
114	MARSABIT	215	73,952	114	BUSIA	235	1,629
				114	KAKAMEGA	236	3,520

Table 1. (continued)

Country code	Political unit	Political code	Area (km²)	Country code	Political unit	Political code	Area (km²)
			LIBERIA				
123	BONG COUNTY			123	MARYLAND COUNTY		
	GIBI TERRITORY	237	10,289		KRU COAST TERRITORY	242	4,338
123	GRAN BASSA COUNTY			123	MONTSERRADO COUNTY BOMI TERRITORY		
	RIVER CESS TERRITORY	238	13,144		MARSHALL TERRITORY	243	5,767
123	CAPE MOUNT COUNTY	239	5,827	123	NIMBA COUNTY	244	12,043
123	GRAN GEDEH COUNTY	240	17,028	123	SIMOE COUNTY		
123	LOFA COUNTY	241	19,359		SASSTOWN TERRITORY	245	11,266
			MADAGASCAR				
129	ANTSERANANA	495	43,046	129	FIANARANTSOA	498	102,373
129	MAHAJANGAA	496	150,023	129	TOLIARA	499	161,405
129	TOAMASINA	497	71,911	129	ANTANANARIVO	500	58,283
			MALAWI				
130	CHITIPA	247	3,504	130	DEDZA	258	3,624
130	KARONGA	248	2,955	130	NTCHEU	259	3,424
130	NKHATA BAY	249	4,090	130	MANGOCHI	260	6,272
130	RUMPHI	250	5,952	130	MACINGHA	261	5,964
130	MZIMBA	251	10,430	130	ZOMBA	262	2,580
130	KASUNGU	252	7,878	130	CHIRADZULU	263	767
130	NKHOTA-KHOTA			130	BLANTYRE	264	2,012
	SALIMA	253	6,455	130	MWANZA	265	2,295
130	NTCHISI	254	1,655	130	THYOLO	266	1,715
130	DOWA	255	3,041	130	MULANJE	267	3,450
130	LILONGWE	256	6,159	130	CHIKWAWA	268	4,755
130	MCHINJI	257	3,356	130	NSANJE	269	1,942
			MALI				
133	KAYES	270	197,760	133	MOPTI	274	88,752
133	KOULIKORO	271	90,100	133	TOMBOUCTOU	275	408,977
133	SIKASSO	272	76,480	133	GAO	276	321,996
133	SEGOU	273	56,127				
			MAURITANIA				
136	NOUAKCHOTT TRANZA	277	67,920	136	ADRAR	283	215,300
136	HODH CHARKI	278	182,700	136	NOUADHIBOU	284	17,800
136	HODH GHARBI	279	53,400	136	TAGANT	285	95,200
136	ASSABA	280	36,600	136	GUIDIMAKA	286	10,300
136	GORGOL	281	13,600	136	TIRIS ZEMOUR	287	252,900
136	BRAKNA	282	33,000	136	INCHIRI	288	46,800
			MOZAMBIQUE				
144	NIASSA	289	129,055	144	SOFALA	295	68,018
144	CABO DEL GADO	290	82,625	144	INHAMBANE	296	68,615
144	NAMPULA	291	81,606	144	GAZA	297	75,709
144	ZAMBESIA	292	105,008	144	CID MAPUTO MAPUTO PROV.		
144	TETE	293	100,724		L. MARQUES	298	26,358
144	MANICA	294	61,661				
			NAMIBIA				
147	NAMIBIA	299	823,144				
			NIGER				
158	NIAMEY	300	90,293	158	ZINDER	304	145,430
158	DOSSO	301	31,002	158	DIFFA	305	140,216
158	TAHOUA	302	106,677	158	AGADEZ	306	714,790
158	MARADI	303	38,581				

Table 1. (continued)

Country code	Political unit	Political code	Area (km²)	Country code	Political unit	Political code	Area (km²)
			NIGERIA				
159	BORNO	307	116,400	159	LAGOS	317	3,345
159	GONGOLA	308	91,390	159	OGUN	318	16,762
159	BAUCHI	309	64,605	159	OYO	319	37,705
159	KANO	310	43,285	159	ONDO	320	20,959
159	KADUNA	311	70,245	159	BENDEL	321	35,500
159	SOKOTO	312	102,535	159	RIVERS	322	21,850
159	KWARA	313	66,869	159	IMO	323	11,850
159	NIGER	314	65,037	159	ANAMBRA	324	17,575
159	PLATEAU	315	58,030	159	CROSS RIVER	325	27,237
159	BENUE	316	45,174				
			GUINEA-BISSAU				
175	BAFATA	326	5,981	175	CACHEU	330	5,175
175	BIOMBO/BISSAU	327	917	175	GABU	331	9,150
175	BOLAMA	328	2,624	175	OIO	332	5,403
175	QUINARA	329	3,138	175	TOMBALI	333	3,737
			ZIMBABWE (Rhodesia)				
181	MANICALAND	334	34,870	181	MATABELELAND NORTH	337	73,537
181	MASHONALAND WEST			181	MATABELELAND SUD	338	66,390
	CENTRAL	335	87,751	181	MIDLANDS	339	58,967
181	MASHONALAND EST	336	24,934	181	MASVINGO	340	44,310
			RWANDA				
184	BUTARE	341	1,844	184	GITARAMA	346	2,239
184	BYUMBA	342	4,978	184	KIBUNGO	347	4,135
184	CYANGUGU	343	2,239	184	KIBUYE	348	1,317
184	GIKONGORO	344	2,186	184	KIGALI	349	3,238
184	GISENYI	345	2,397	184	RUHENGERI	350	1,765
			SENEGAL				
195	CAPVERT	351	550	195	FLEUVE	355	44,127
195	CASAMANCE	352	28,350	195	SENEGAL ORIENTAL	356	59,602
195	DIOURBEL	353	4,359	195	SINE SALOUM	357	23,945
195	LOUGA	354	29,188	195	THIES	358	6,601
			SIERRA LEONE				
197	LOKO WESTERN	359	6,266	197	KAILAHUN	365	3,888
197	KOINADUGU	360	12,102	197	PUJEHUN	366	4,110
197	KAMBIA	361	3,000	197	BONTHE	367	3,464
197	BOMBALI	362	8,006	197	MOYAMBA	368	7,175
197	KONO	363	5,640	197	BO	369	5,214
197	KENEMA	364	6,025	197	TONKOLILI	370	6,980
			SOMALIA				
201	NORTH	371	45,000	201	MIDDLE	379	22,000
201	TOGDHER	372	41,000	201	BANAADIR	380	2,000
201	SANAG	373	54,000	201	LOWER	381	25,000
201	BARI	374	70,000	201	LOWER	382	61,000
201	NUGAL	375	50,000	201	MIDDLE	383	23,000
201	MUDUG	376	70,000	201	GEDO	384	32,000
201	GALGADUD	377	43,000	201	BAKOL	385	27,000
201	HIRAN	378	34,000	201	BAY	386	39,000
			SUDAN				
206	NORTH REGION	387	477,405	206	KARTHOUM	392	28,187
206	EAST REGION	388	334,331	206	EQUATORIAL REGION	393	198,122
206	CENTRAL REGION	389	139,124	206	BAHR AL GHAZAL	394	201,047
206	KORDOFAN	390	380,552	206	UPPER NILE	395	238,975
206	DARFUR	391	509,075				

Table 1. (continued)

Country code	Political unit	Political code	Area (km²)	Country code	Political unit	Political code	Area (km²)
			TANZANIA				
215	DODOMA	396	41,311	215	SINGIDA	407	49,340
215	ARUSCHA	397	82,098	215	TABORA	408	76,150
215	KILIMANGIARO	398	13,250	215	RUKWA	409	68,635
215	TANGA	399	26,677	215	KIGOMA	410	37,040
215	MOROGORO	400	70,624	215	SCHINJANGA	411	50,760
215	DARESSALAM	401	1,393	215	KAGERA	412	28,456
215	LINDI	402	66,040	215	MUANSA	413	19,683
215	MTWARA	403	16,710	215	MARA SANSIBAR	414	23,420
215	RUVUMA	404	63,669	215	PEMBA	415	984
215	IRINGA	405	56,850	215	PWANI	416	32,547
215	MBEYA	406	60,350				
			TOGO				
217	GOLFE	417	345	217	SOTOUBOUA	427	7,490
217	LACS	418	713	217	KOZAH	428	1,693
217	YOTO	419	1,250	217	BIMAH	429	465
217	VO	420	750	217	DOUFELGOU	430	1,120
217	ZIO	421	3,337	217	KERAN	431	1,085
217	OGOU	422	6,145	217	ASSOLI	432	938
217	KLOTO	423	2,790	217	BASSAR	433	6,330
217	AMOU-WAWA	424	4,383	217	OTI	434	4,840
217	HAHO	425	3,658	217	TONE	435	3,762
217	TCHAOUDJO-NYALA	426	5,693				
			UGANDA				
226	KAMPALA LUWERO MUKONO	436	23,678	226	IGANGA JINJA KAMULI	444	18,195
226	MASAKA RAKAI	437	21,300	226	KAPCHORWA	445	1,738
226	MPIGI	438	6,222	226	KUMI SOROTI	446	12,921
226	MUBENDE	439	10,310	226	MBALE	447	2,546
226	BUNDIYBUGYO KABAROLE KASESE	440	13,904	226	TORORO	448	4,553
226	BUSHENYI MBARARA	441	16,235	226	APAC LIRA	449	13,739
226	HOIMA MASINDI	442	19,536	226	ARUA NEBBI	450	10,721
226	KABALE RUKUNGIRI	443	5,242	226	GULU KITGUM	451	27,871
				226	KOTIDO MOROTO	452	27,321
				226	MOYO	453	5,006
			BAKINA FASO (Upper Volta)				
233	PONI	454	10,361	233	NAMETENGA	467	7,755
233	COMOE	455	18,393	233	KOURITENGA	468	1,627
233	KENEDOUGOU	456	8,307	233	BOULGOU	469	9,033
233	HOVET	457	16,672	233	NAHOURI	470	3,843
233	BOUGOURIBA	458	7,087	233	BOULKIEMDE SANGUIE SISSILI	471	23,039
233	KOUSSI	459	13,177	233	PASSORE ZOUNDWEOGO	472	7,531
233	SOUROU	460	9,487	233	BAM SANMATENGA	473	13,230
233	YATENGA	461	12,292	233	BAZEGA GANZOURGOU KADIOGO OUBRITENGA	474	15,262
233	SOUM	462	13,350	233	GOURMA	475	26,613
233	OUDALAN	463	10,046	233	MOUHOUN	476	10,442
233	SENO	464	13,473				
233	TAPOA	465	14,780				
233	GNAGNA	466	8,600				
			ZAIRE				
250	KINSHASA	477	9,965	250	KASAI-ORIENTAL	482	168,216
250	BAS-ZAIRE	478	53,920	250	KASAI-OCCIDENTAL	483	156,967
250	BANDUNDU	479	295,658	250	KIVU	484	256,662
250	EQUATEUR	480	403,293	250	SHABA	485	496,965
250	HAUT-ZAIRE	481	503,239				

Table 1. (continued)

Country code	Political unit	Political code	Area (km²)	Country code	Political unit	Political code	Area (km²)
			ZAMBIA				
251	CENTRAL	486	94,394	251	NORTHERN	491	147,826
251	COPPER BELT	487	31,320	251	NORTH WESTERN	492	125,826
251	EASTERN	488	69,106	251	SOUTHERN	493	85,283
251	LUAPULA	489	50,567	251	WESTERN	494	126,386
251	LUSAKA	490	21,896				

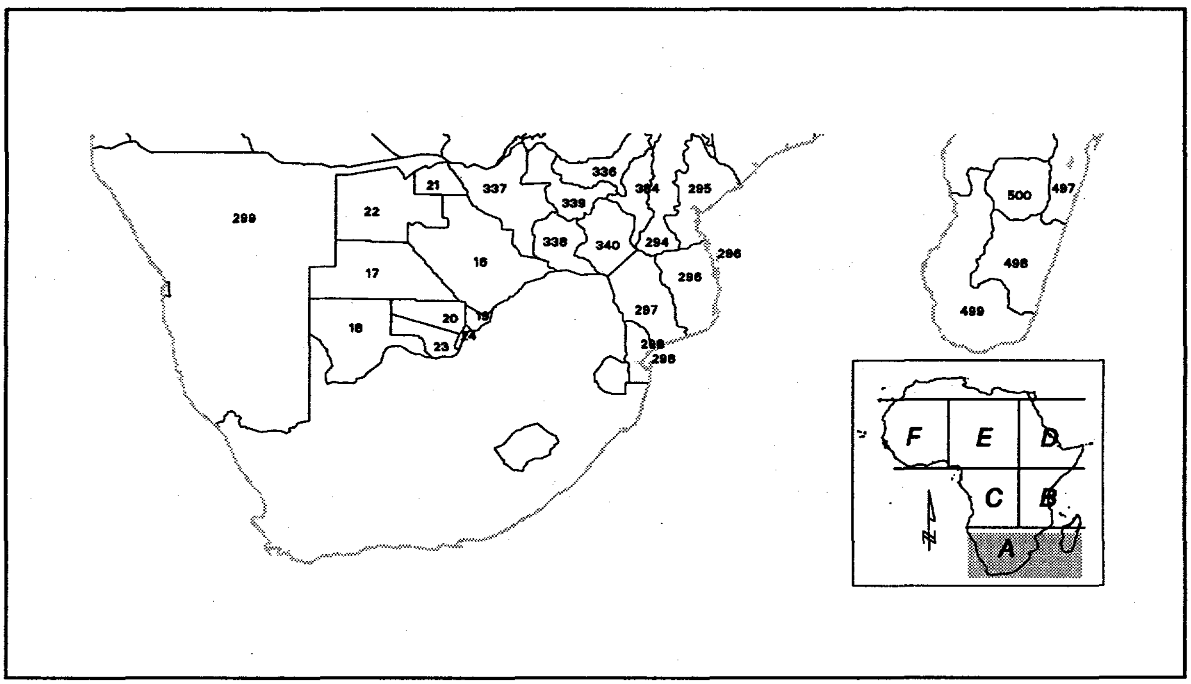

Figure 2a. Map of the political unit identification numbers in southern Africa.

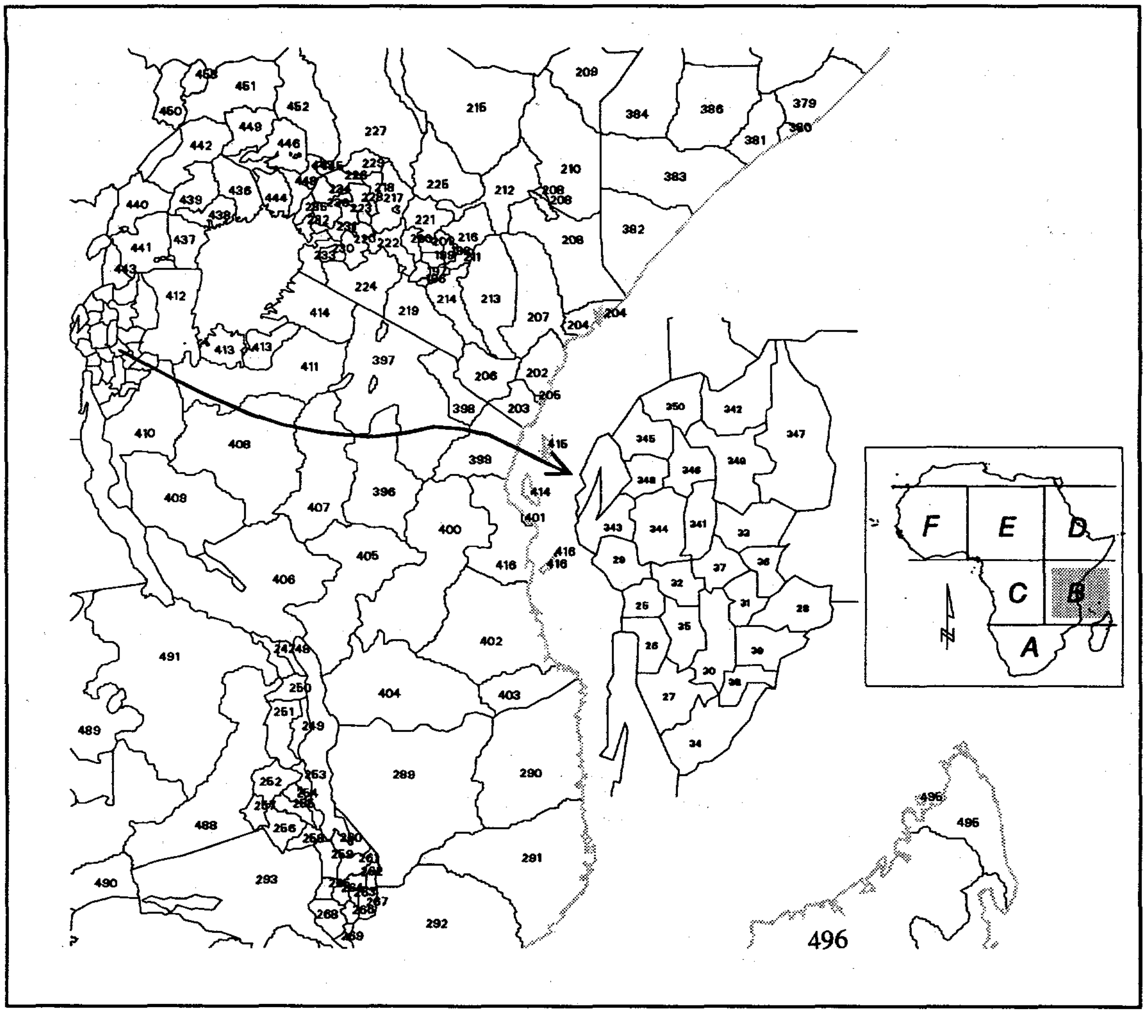

Figure 2b. Map of the political unit identification numbers in southeastern Africa.

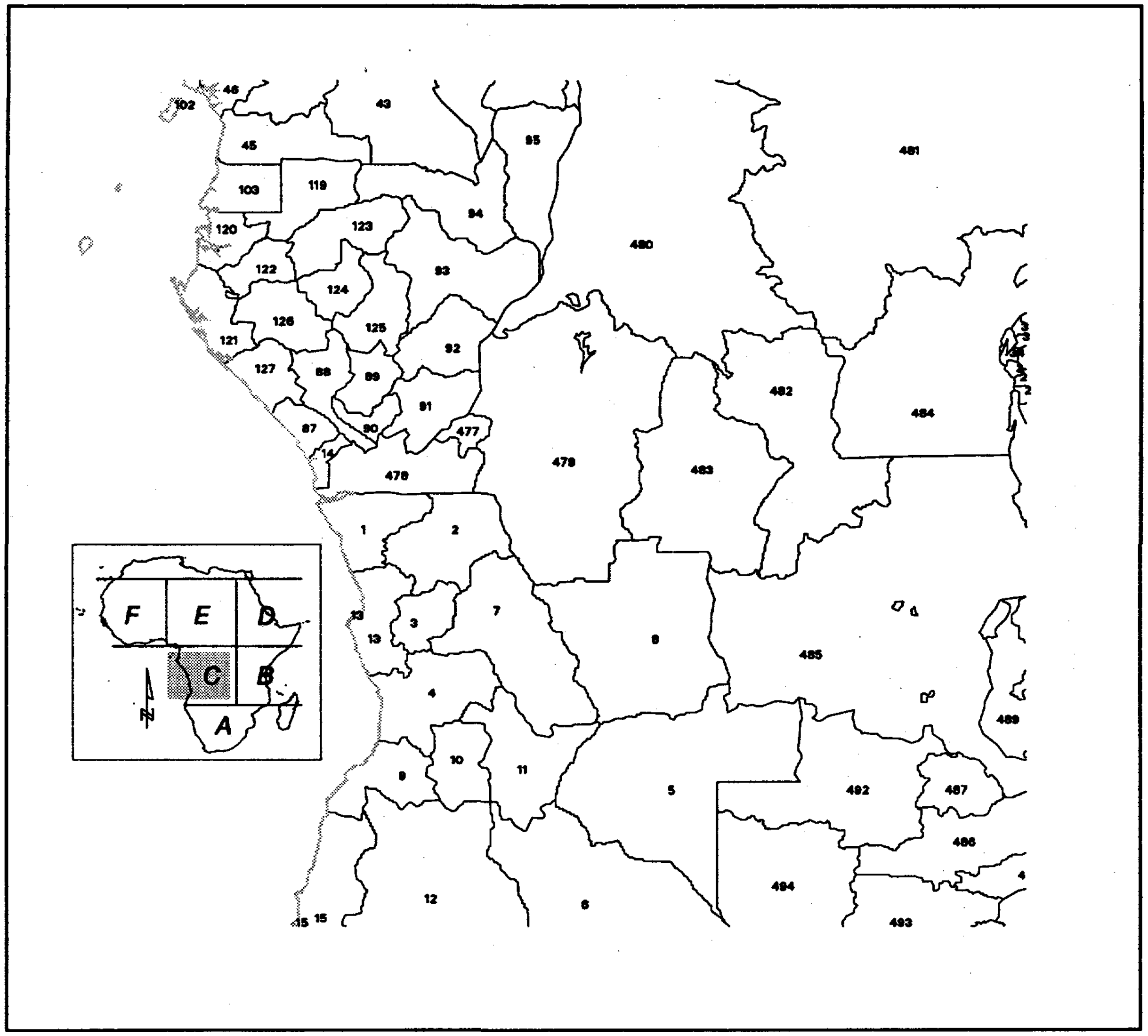

Figure 2c. **Map of the political unit identification numbers in southwestern Africa.**

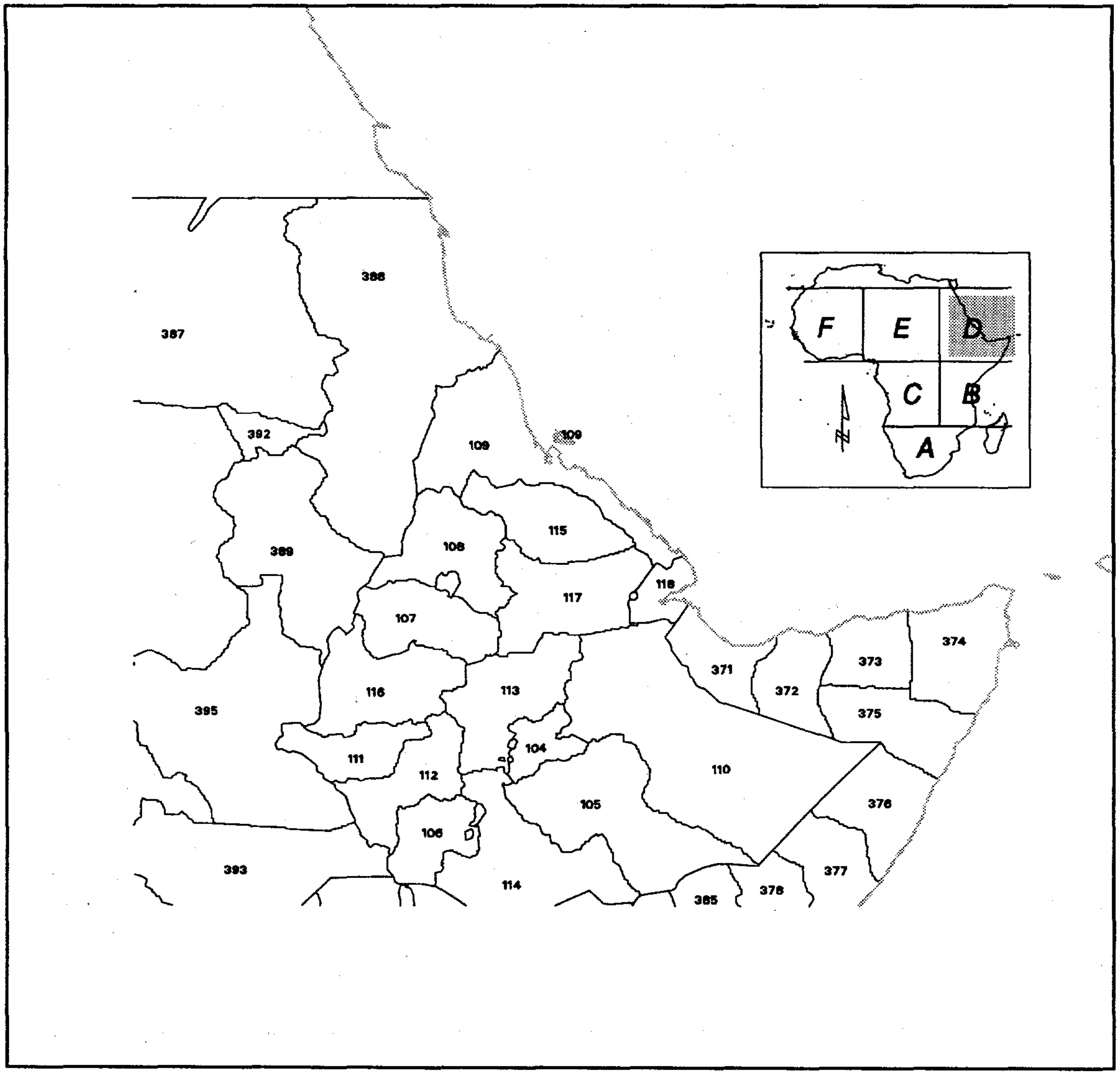

Figure 2d. Map of the political unit identification numbers in eastern Africa.

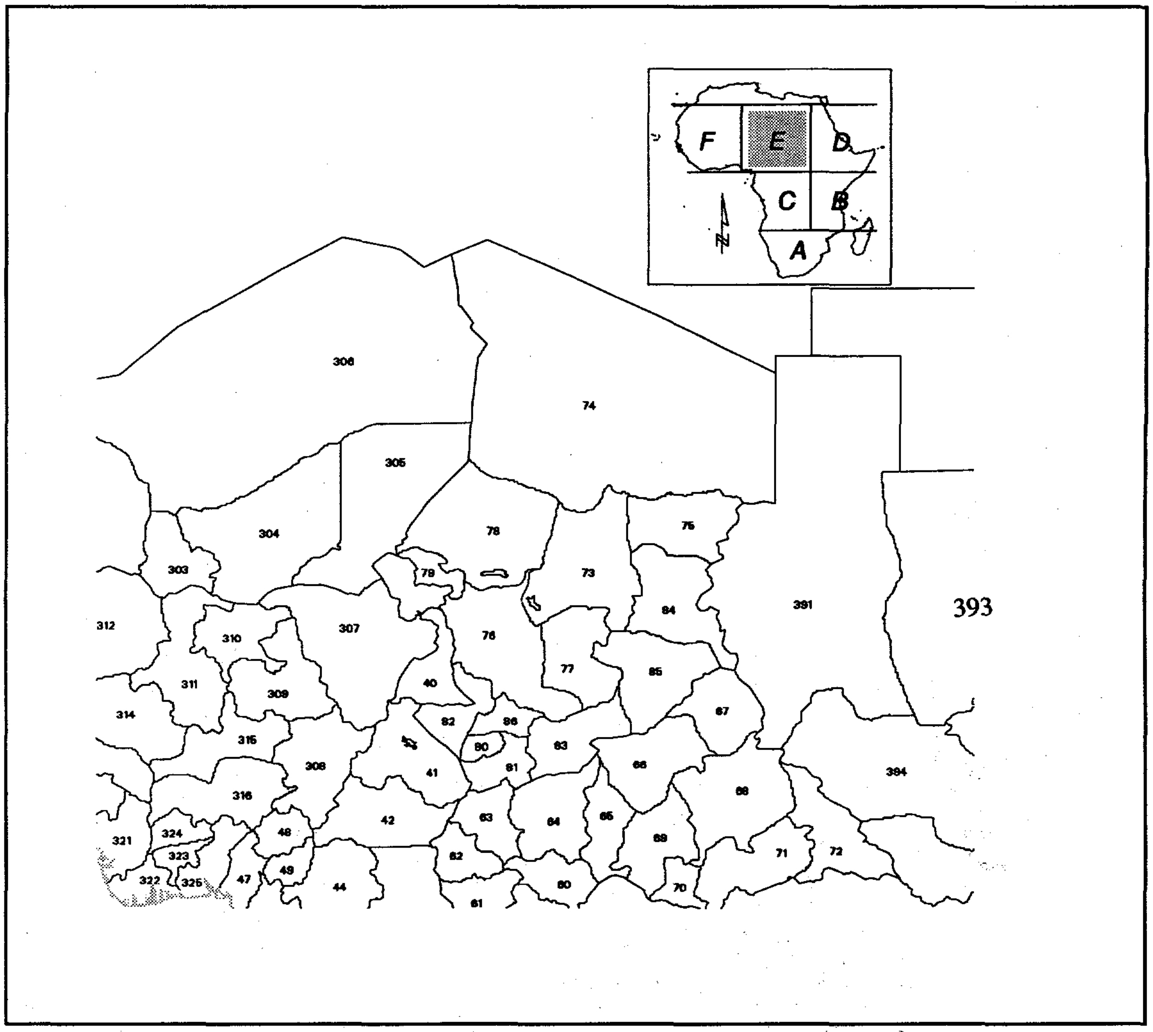

Figure 2e. Map of the political unit identification numbers in central Africa.

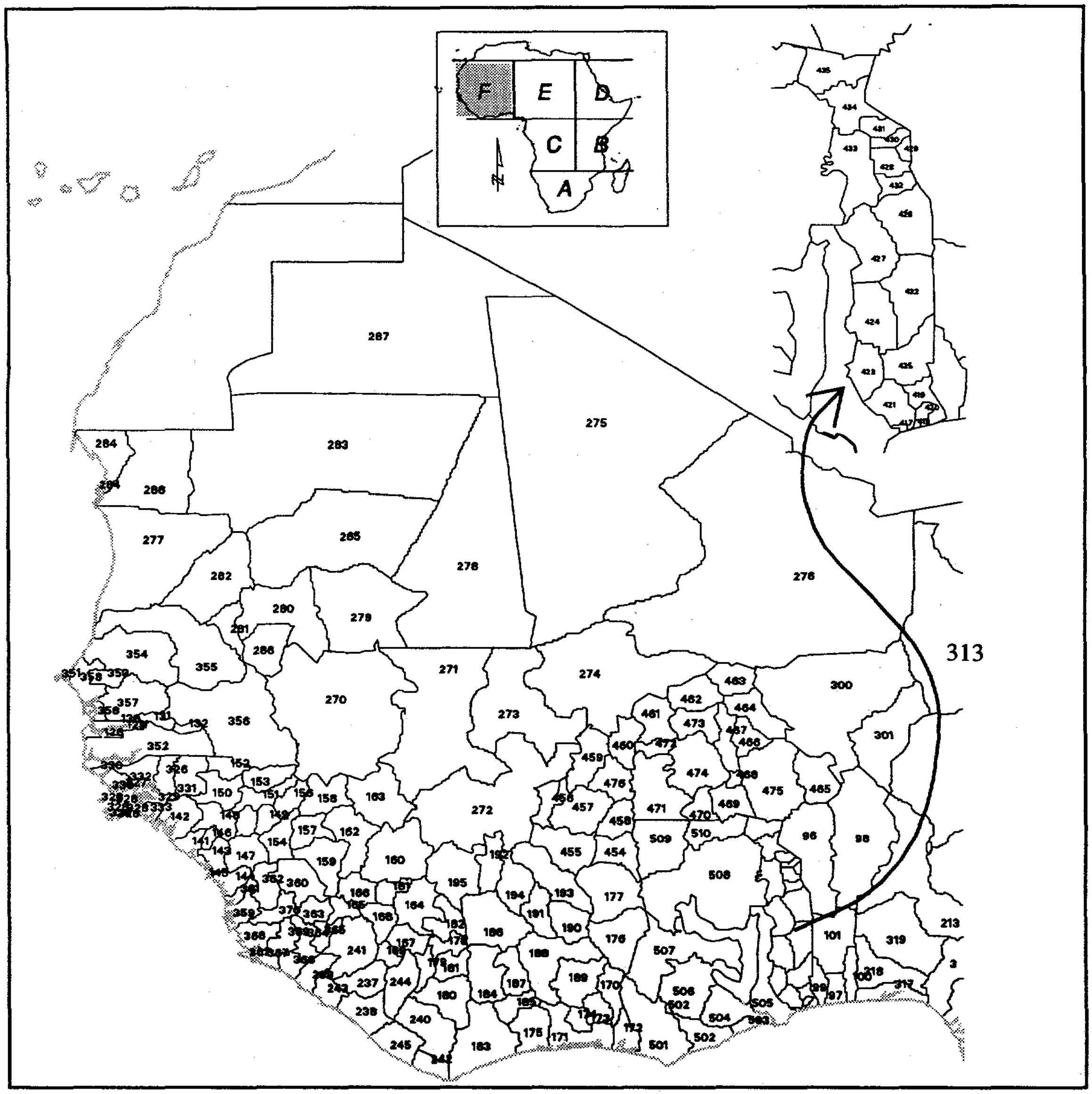

Figure 2f. Map of the political unit identification numbers in western Africa.

7.1 Data Sources

The major effort in the compilation of this database involved the acquisition and processing of the source data sets. Most of these data sets were acquired from the United Nations Environmental Program's (UNEP) Global Resources Information Database (Jaakkola 1990) or from the United Nation's Food and Agriculture Organization (FAO 1993). These data, in turn, were input, georeferenced, and converted into a raster format as needed using an ARC/INFO™ geographic information system (GIS). The spatial data sets used in the development of this NDP are as follows:

(1) National boundaries were derived from the U.S. Defense Mapping Agency's *Digital Chart of the World* at a scale of 1:1,000,000. Boundaries for subnational political units were derived from *The New International Atlas*, the *Encyclopedia of the Nations*, and the FAO's Tropical Forest Resources Assessment Program–1990 population data (Worldmark Press 1984, Rand McNally 1980). Boundaries for large water bodies (e.g., Lake Victoria) were copied from the *Digital Chart of the World*; moderate-size lakes (>20 km in length in any direction) were digitized from the Unesco *Vegetation Map of Africa*, scale 1:5,000,000 (UNESCO/AETFAT/UNSO 1981, White 1983).

(2) Population density data for 1960, 1970, 1980, and 1990 for national and subnational political units were provided by M. Lorenzini and K. D. Singh, FAO, Tropical Forest Resources Assessment Program–1990 (FAO 1993).

(3) Elevation data were derived from a global digital elevation database originally developed by the U.S. Defense Mapping Agency (ETOPO5). The elevation data were reclassified into 15-m increments, and all bathymetry data were set to zero.

(4) Soils data were derived from the FAO *Soils Map of the World* (FAO 1971–81). The soils data were reclassified into five soil texture classes, five slope classes, and two soil depth classes and were used in calculating the maximum potential biomass values included with this database. These soil data are not included with this NDP.

(5) Climatic data were obtained from the FAO agro-meteorology database and two maps were developed using the spatial coordinates for each station and the mean monthly precipitation, maximum temperature, minimum temperature, day-night temperature differential, evapotranspiration rate, and vapor pressure. The first map is a isopleth map of annual precipitation and the second is of an integrated climate index that provides a measure of the growing season length based on five climatic variables (Weck 1970).

(6) Vegetation data were obtained for approximately the year 1980 from the FAO *Vegetation Map of Africa* (Lavenu 1987).

7.2 Data Manipulation and Interpolation

The methodology described in Iverson et al. (1994) and Brown and Gaston (1995) (reprinted in Appendix B) were used to obtain degradation ratios. These degradation ratios were applied to a map of maximum potential aboveground biomass density to obtain a map of current (ca. 1980) aboveground biomass. Since the linear regression models used to estimate the degradation ratios were calibrated for woody vegetation only, this map was screened using a land cover map for 1980 with four land-use classes. All areas not in a forested or wooded class were deleted. This process resulted in a map showing the amount of aboveground biomass in woody vegetation for 1980. Comparison of this map on a region (or cell) basis with the maximum potential aboveground biomass density map allows for the change (emission) of carbon from land use change and land degradation from the 1880s to 1980 be estimated for closed forest (moist tropical and seasonal forests) and open forest (woodland/wooded savanna).

Two of the data sources used in calculating the maximum potential aboveground biomass values needed additional processing before their use in the biomass estimation model. First, the meteorology data were used to calculate a climatological index for each station based on a modified version of Weck's (1970) methodology. Second, these climatological indices (point data) were interpolated into a thematic map using a thin-plate spline technique (Iverson et al. 1994). Lastly, the FAO vegetation map used (Lavenu 1987) was reclassified from over 64 ecosystem types into a map showing closed forest, open forest, grassland savanna, and other nonforested lands. See Appendix C for a description of the reclassification scheme used.

The source data were then projected into a cylindrical equal-area projection using a central meridian of 15° East and a standard parallel of 0°. This equal-area version of the source data were then converted into 5 km × 5 km raster grids using the ARC/INFO™ POLYGRID command.

8. Modeling Biomass

The maximum potential biomass density of woody vegetation is assumed to be the product of a combination of the prevailing climatic and geomorphic conditions in an area. To estimate the maximum potential biomass for each grid cell, each input layer (i.e., mean annual precipitation, climate index, elevation and slope, and soil quality and texture) was recoded and given values from 1 to 25 based on the perceived importance of the layer in the growth of woody vegetation. A weighted overlay of the four layers (Figure 3) was then performed to obtain a biomass index with a minimum possible value of 4 and a maximum value of 100 (in Tropical Africa the values ranged from 40 to 100).

8.1 Estimation of Maximum Potential Biomass

The climate-related layers (mean annual precipitation and climate index) account for 50% of the possible index value. The soil layer accounts for 25% and the elevation and slope layer [formed by combining the elevation data (maximum value 13) with the slope data (maximum value 12)] accounts for the remaining 25%. The same weighting scheme as was used by Iverson et al. (1994) for Tropical Asia was used here. The scheme was found to give satisfactory results for Africa when compared to available literature sources for the region (Graham et al. 1990, Martin 1991, Lavenu 1987).

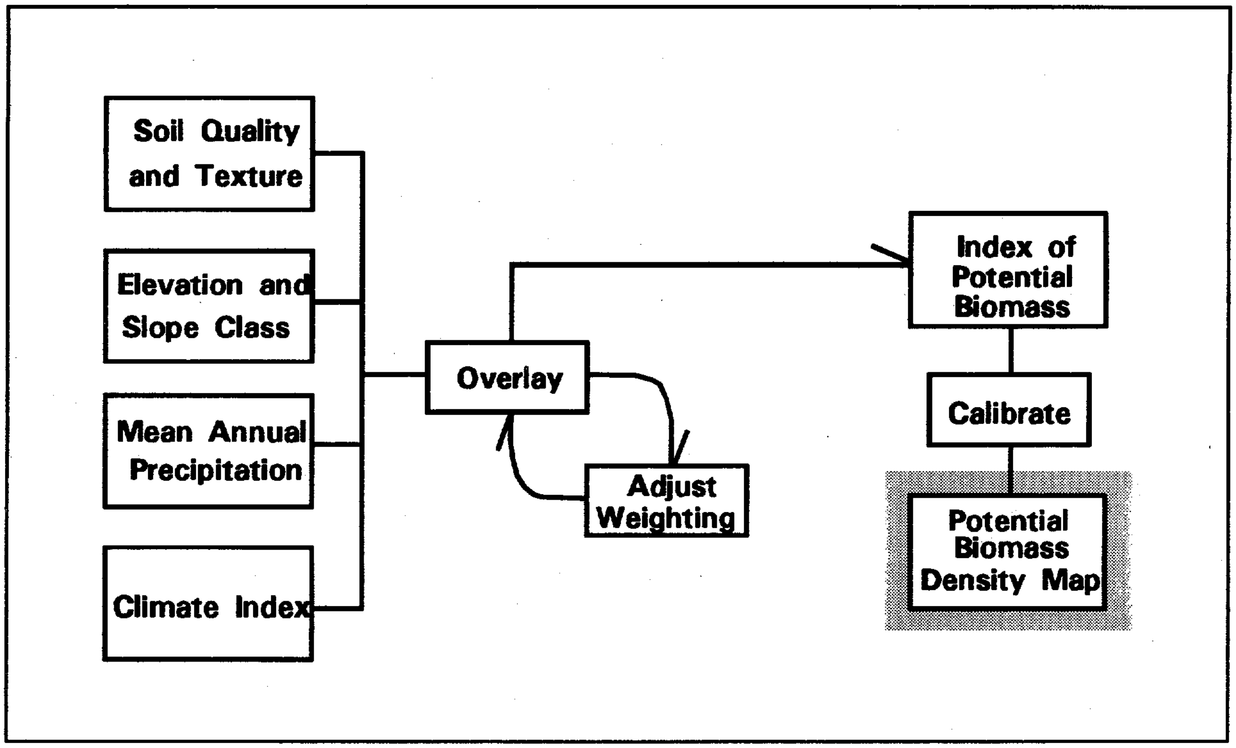

Figure 3. **Flow diagram of the processing steps taken to produce the maximum potential biomass density map.**

Potential biomass density (PBD) indices for forests, woodlands, and woody savannas were calibrated by assigning aboveground biomass density estimates obtained from the literature to the range of index values. This task posed a challenge because few measurements of mature forest biomass have been done in this region (Brown and Lugo 1982). The highest reported biomass densities were about 500 Mg/ha (Huttel and Bernhard-Reversat 1975, Huttel 1975) for tropical moist forests in western Africa, the location of the highest range of PBD indices (>96). A PBD index value of 51 was assumed to represent the lower limit for tree or shrub savannas and was assigned a biomass density of 15 Mg/ha based on data in Lamotte (1975), Lamotte and Bourliere (1983), and Menaut et al. (1991). It was then assumed that biomass density exhibited a logistic-shaped function between the PBD index and biomass. Biomass values (in Mg/ha) were assigned to the PBD values as shown in Table 2. The lower index value (i.e., ~40) and upper index value (i.e., 100) for Tropical Africa were equated with 1 Mg/ha and with 500 Mg/ha, respectively. Between these two bounds the potential biomass index was divided into twelve ranges. Intermediate values of biomass density were obtained or estimated from Greenland and Kowal (1960), Pierlot (1966), Freson et al. (1974), and Brown et al. (1994).

Table 2. Assignment of the biomass indices to potential biomass densities based on forest inventories

Potential biomass index	Potential biomass (Mg/ha)
41–45	1
46–50	7
51–55	15 (limit of open forest)
56–60	27
61–65	42
66–70	75
71–75	150
76–80	250
81–85	350
86–90	425
91–95	475
96–100	500

The remainder of this methodology is designed for woody vegetation only. Thus, the next step in determining the actual biomass in forests for 1980 was to remove nonwoody vegetation formations from the map of maximum potential biomass density that is distributed with this database. This was done by taking the reclassified FAO vegetation map for 1980 (Lavenu 1987) [i.e., with four classes –closed forest, open forest (woodland/wooded savanna), grassland savanna, and other] and setting those grid cells with closed forest or open forest to a value of 1. All other cells were set to NO–DATA. This temporary map was multiplied with the potential biomass density map. This process set or masked most grid cells without woody vegetation as of 1980 to NO–DATA. The resulting maximum potential biomass density map is of forested areas only. The only nonwooded areas remaining in this map are grid cells located within lakes.

8.2 The Degradation Ratio

To estimate the actual biomass remaining in live woody vegetation in 1980, researchers developed degradation ratios based on population data and applied them to the maximum potential biomass density map for forested lands. The degradation ratios were based on the assumption that the degree to which forests are reduced from their potential biomass is a function of the population density and forest type or ecofloristic zone. For example, high population densities will result in low degradation ratios (i.e., highly degraded forests), while dryer regions will be degraded more severely than moist regions because of the ability of moist forests to replace biomass faster (Brown and Lugo 1982).

Other socioeconomic factors such as the ratio of rural to urban population, the importance of subsistence versus export-oriented agriculture, and the state of industrialization affects the rate of biomass reduction. In fact, in developed countries a population density and stage of industrial development have been reached at which no further biomass loss occurs and other factors come into play, factors that may actually lead to increases in biomass (Flint and Richards 1994).

In most of Tropical Africa this threshold has not been reached, as exemplified by the fact that 90% of the population in Africa still uses wood for cooking. The average amount of wood used for cooking per family is equivalent to about 1.5 tons of fuel oil per year. It has been estimated that the annual addition to the fuelwood supply through the growth of biomass was less than consumption in 1980 and that the half-life of tree stocks (the time it would take for stocks to decline by 50%) averaged about 25 years in 1980. Furthermore, tree stocks are declining at accelerating rates because consumption is increasing exponentially with population growth (Anderson and Fishwick 1984).

Degradation equations have been estimated for two forest types (closed forest and woodland/wooded savanna) by comparing the potential biomass density in 1980 with biomass densities obtained from forest inventories for the same location. This process produced unitless factors that indicate the reduction from potential biomass to actual biomass as a function of population density. Eight reliable forest inventories for Tropical Africa were used in developing the degradation equations (Clement and Nouvellet 1978, Development and Resources Corporation 1967, Republique de Cote d'Ivoire 1975, United Nations 1972, FAO 1989). Due to the limited number of suitable forest inventories, 27 additional inventories from tropical South and Southeast Asia were also included in the analysis (Iverson et al. 1994).

The data for the closed forest zone of Tropical Africa were combined with the moist forest data from South and Southeast Asia, while data for the woodland/wooded savanna zone were combined with the dry forest data from South and Southeast Asia. A least-squares regression was conducted for each zone, and the following degradation equations were produced. The equations, sample sizes, and correlation results for closed forest are

PD > 12: **DR = 0.847 – 0.091 ln (PD), (n = 25, r^2 = 0.72),** **(1a)**

PD ≤ 12: **DR = 1 - 0.032 PD,** **(1b)**

where DR is the degradation ratio and PD is the population density in people per km^2. The equations, sample sizes, and correlation results for open forest (woodland/wooded savanna) are

PD > 7: **DR = 0.866 - 0.118 ln (PD), (n = 10, r^2 = 0.54),** **(2a)**

PD ≤ 7: **DR = 1 - 0.050 PD,** **(2b)**

where DR is the degradation ratio and PD is the population density in people per km^2.

Equation 1a and 2a for each forest type is based on the range of available data, and the minimum PD for which it is applicable. For PDs less than these minimums, simple linear equations (Eq. 1b and 2b) were developed between the DR at zero PD —assumed to be one, and the value of DR from equation 1a and 2a at the minimum PD. A linear function of PD was then calculated for each land cover class between these DR values.

Use of the natural logarithm in Eq. 1a and 2a allows negative DR values to occur for PDs greater than 11,022 for closed forest and 1,539 for the open forest (woodland/wooded savanna) land cover class. Though not a problem in most cases —since forests lands tend to have lower population densities than these, calculated DR values less than 0.1 were reset to 0.1.

8.3 Estimation of 1980 Biomass

The actual-biomass-density map for 1980 is the product of the potential-biomass-density map for woody vegetation, the population density map for 1980 stratified by land-cover type (closed forest and open forest), and the calculated degradation ratios. The map of actual biomass densities for 1980 was calculated on a cell-by-cell basis, with each cell within a political unit having the same population density value. The forest strata, however, may vary within a political unit causing the degradation equation used to vary. Thus, the map of actual biomass density for woody vegetation in 1980 reflects the predicted maximum potential biomass, the forest type stratification, and the population density in 1980.

Due to the coarse scale of the input data used in generating the potential biomass density map, some large water bodies within Africa were not represented. Boundaries for large water bodies (e.g., Lake Victoria) and moderate-size lakes (>20 km in length in any direction) were digitized and entered into a lake coverage (map). Following a process similar to that used for the land cover data, those grid cells within a lake (i.e., >50%) were given a value of NO–DATA, and the remainder were set to one. This coverage was multiplied with the grid cells in the map of actual biomass density for 1980 to set all "wet" grid cells to NO–DATA.

This final map of actual live aboveground biomass density contains only lands that were in closed forest (moist forest and seasonal forest) or open forest (woodland/wooded savanna) in 1980 (per Lavenu 1987). The final map contains 4,025,375 km^2 of closed forest land with a mean biomass density of 208.7 Mg/ha and 8,156,575 km^2 of open forest (woodland/wooded savanna) with a mean biomass density of 67.1 Mg/ha. As expected, the minimum biomass densities were located in lowland dry zones to the north and south, maximum values were located in the humid lowlands in southwest and south central Africa (i.e., Congo, Gabon, Zaire), and highland areas had slightly less biomass than their lowland counterparts. The presence of these known patterns increased our confidence that the methodology described here generated reasonable estimates of biomass density for Tropical Africa.

8.4 Carbon Estimates

The primary product of this GIS methodology is the actual biomass density information for woody vegetation in 1980. With the addition of a land-cover map and population data for year X (e.g., 1990) the actual biomass density in year X may be determined as described for 1980. The results may then be compared to determine the change in biomass (carbon) from woody vegetation in the intervening years. For an example of this process for 1990 see Appendix D.

The biomass for 1980 may also be compared to the maximum potential aboveground biomass for the region. The difference between the mean maximum potential biomass density for closed forest lands and the mean actual biomass density in 1980 is 86.9 Mg/ha (40.5 Mg/ha for open forest). On the basis of the average biomass to carbon conversion factor of 1 kg of wood to 0.5 kg of carbon (Smith 1991), and the assumption that the removed wood was eventually burned, the amount of CO_2, CO, CH_4, and other gases emitted from this per ha reduction in biomass may be estimated for closed forest and open forest. Table 3 shows the estimated emission of CO_2, CO, and CH_4 that would have occurred if 86.9 (40.5) Mg of dry biomass was burned using traditional West African stoves, based on emission factors calculated by Brocard et al. (1995). (If forest fire based emission factors were used the emission of CO_2 and CO would increase while the amount of CH_4 and carbon in the "other" category would decline.)

Table 3. Emission of CO_2, CO, and CH_4 that would have occurred if the measured reduction in dry biomass (from potential to actual in 1980) were burned as fuelwood

	Emissions from fuelwood burning	
	Closed forest	Open forest
Biomass reduction (kg/ha)	86,900	40,500
Carbon reduction (kg/ha)	43,450	20,250
Emissions (g of C/ha)		
$C[CO_2]$	34,760 ± 5,648	16,200 ± 2,633
C[CO]	2,607 ± 869	1,215 ± 405
$C[CH_4]$	130 ± 52	61 ± 24
C[other[1]]	5,953	2,774
Total area (ha)	402.5×10^6	815.6×10^6
Total Emissions (kg)		
$C[CO_2]$	14.00×10^{12}	13.21×10^{12}
C[CO]	1.05×10^{12}	0.99×10^{12}
$C[CH_4]$	0.05×10^{12}	0.05×10^{12}

[1]Predominantly charcoal.

Africa had an estimated total population of 100 million in 1650 (density of 0.03 people per km^2). Two hundred years later (1850) the population was still about 100 million (Udo 1982). Thus, it may be assumed that prior to the colonial period, which began in the mid to late 1800s, the amount of land in forests had remained relatively stable for over two hundred years. Since the land in the closed forest and open forest (woodland/wooded savanna) land-cover classes in 1980 were located in the interior of larger forests in 1880, it can be assumed that they were at or near their maximum potential biomass density in the beginning of the colonial period. If this was the case, the emission of CO_2 due to the degradation of these forested lands (i.e., reduction of biomass from the maximum potential to the "actual" biomass in 1980) would total 27.21×10^{12} kg/C. If this CO_2 had been emitted at a constant rate since 1880, 272.1×10^6 Mg C per year would have been released into the atmosphere. To put this figure into perspective, Houghton and Hackler (1995) calculated that the regional net flux of carbon in Tropical Africa from all land-use changes was 238.69×10^6 Mg C in 1980 and had increased to 341.5×10^6 Mg C by 1990.

9. Limitations and Restrictions of the Data

The following paragraphs list the limitations and caveats that should be considered when using this database. Failure to consider these limitations could result in erroneous interpretations of the data.

(1) All data coverages (maps) in this database have been resampled into 5 × 5 km grid cells. This cell size and the small scale of most of the input data used preclude the use of these data for site-specific studies.

(2) The soil texture, slope, and elevation data used in the development of the map of maximum potential aboveground biomass densities were based on small-scale data sources (1:1,000,000 to 1:5,000,000).

(3) The climate data were extrapolated into areas with little or no data. Consequently, effects of local topography on precipitation and temperature patterns are not considered in the map of maximum potential aboveground biomass.

(4) The population data used to calculate the degradation ratios are based on national internal political subdivisions as of 1980. The population data provided with this database (i.e., for 1960, 1970, 1980, and 1990) are keyed to these 1980 divisions.

(5) The limited number of forest inventories in Tropical Africa makes verification of the final map of actual biomass density for woody vegetation in 1980 difficult. However, average biomass densities were obtained for Guinea, Gambia, Mozambique, and Burkina Faso from national level forest inventories and compared to those calculated here. The values for Guinea, Gambia, Mozambique, and Burkina Faso were within 3%, 19%, 3%, and 38%, respectively, of the inventory values (Brown and Gaston 1995).

10. Data Checks Performed by CDIAC

An important part of the data-packaging process at the Carbon Dioxide Information Analysis Center (CDIAC) is the quality assurance (QA) of the data before its distribution. The QA process is an important component in the value-added concept of ensuring accurate, usable information. The complete QA of a data set can be a time-consuming process, since data received by CDIAC are rarely in condition for immediate distribution, regardless of source. The following summarizes the QA checks performed on the various data groups presented in this document.

(1) The map of maximum potential aboveground biomass density is derived from an index calculated from six climatic and geomorphic variables. The index values were associated with the known upper and lower limits of biomass density in Africa, and the range was divided into 12 density groupings (Table 2). The maximum potential aboveground biomass density map (5 × 5 km grid cells) was correlated with a 1 × 1 degree map of carbon in live vegetation (Olson et al. 1983). The analysis obtained an r^2 value of 0.4, n = 1195611, $\propto$ = 0.0001. Because of cell size differences, a higher correlation value should not be expected; however, the significance of the correlation (>99%) implies that the two independently derived data sources are measures of the same variable.

(2) The map of maximum potential aboveground biomass (5 × 5 km grid cells) and the Olson et al. (1983) 1 × 1 degree map of carbon in live vegetation were printed and visually compared to ensure that the location of low and high carbon/biomass densities matched.

(3) The land-use map for 1980 derived from Lavenu (1987) was printed and compared to a similar map prepared by the United Nations (White 1983).

(4) On the basis of QA steps 2 and 3, it was determined that neither the land cover nor potential-biomass-density map had accounted for internal water bodies in Tropical Africa. A new map was created for use with this database that contains all permanent (versus seasonal) lakes larger than 20 km in length in any direction.

(5) The population data for 1960, 1970, 1980, and 1990 were aggregated by country and compared to secondary data sources (e.g., WorldMark Press 1984, Udo 1982, and Goode 1992).

(6) The final actual-biomass-density map for 1980 was aggregated on a cell-by-cell basis to obtain the mean biomass density by country (see Appendix A). These mean values were compared with national level forest inventories available for Guinea, Gambia, Mozambique, and Burkina Faso to ensure that the calculated values were within accepted ranges for tropical regions of the world.

11. How to Obtain the Package

These data may be used with a vector or raster geographic information system (GIS) or non-GIS database systems. The computerized data are available on Exabyte 8-mm tapes, QIC ¼" tape cartridges, IBM DOS-compatible floppy diskettes (3.5" or 5.25" diskettes), and through an anonymous File Transfer Protocol (FTP) service from CDIAC. Requests for magnetic media should include any specific instructions required by the user and/or the user's local computer system. Requests for this data package should be addressed to:

Carbon Dioxide Information Analysis Center
Oak Ridge National Laboratory
Post Office Box 2008
Oak Ridge, Tennessee 37831-6335
U.S.A.

Telephone: (423) 574-3645 or (423) 241-4854
FAX: (423) 574-2232

FTP: cdiac.esd.ornl.gov
URL: http://cdiac.esd.ornl.gov/
INTERNET: CDIAC@ORNL.GOV

The data files may be acquired via INTERNET from CDIAC's anonymous FTP service as follows:

- FTP to CDIAC.ESD.ORNL.GOV (128.219.24.36).
- Enter "ftp" as the user id.
- Enter your electronic mail address as the password (e.g., BIRDT@ORNL.GOV).
- Change to the directory "cd pub/ndp055".
- Set ftp to get ASCII files by using the FTP "ascii" command.
- Retrieve the ASCII database documentation file by using the FTP "get ndp055.doc" command.
- Retrieve the ASCII data files by using the FTP "mget *.asc" command.
- Retrieve the ASCII FORTRAN files by using the FTP "mget *.for" command.
- Retrieve the ASCII SAS™ files by using the FTP "mget *.sas" command.
- Set FTP to get binary files by using the FTP "binary" command.
- Retrieve the binary ARC/INFO™ export files by using the FTP "mget *.e00" command.
- Exit the system by using the FTP "quit" command.
- Contact CDIAC by phone, FAX, or electronic mail to order a hard copy of this documentation.

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PART 2: INFORMATION ABOUT THE COMPUTERIZED DATA FILES

13. Contents of the Computerized Data Files

The following table lists the files on the magnetic media distributed by CDIAC along with this documentation. These files are also available through CDIAC's anonymous file transfer protocol service (at cdiac.esd.ornl.gov) via the INTERNET.

Table 4. List and description of the digital files

File number	Name, type, and description	Logical records	Record length	Block size	File size (bytes)
1.	NDP055.DOC General descriptive information file	663	80	800	53040
2.	BIOMAX.E00 Exported ARC/INFO GRID with the maximum potential biomass densities in Mg/ha	461,181	X	1024	32,741,000
3.	BIOMAX.ASC ASCII data file with the maximum potential biomass densities in Mg/ha	1,508	X	1024	13,826,047
4.	LAND.E00 Exported ARC/INFO GRID with land use information classified into four land use categories	461,170	X	1024	32,740,800
5.	LAND.ASC ASCII data file with land use information classified into four land use categories	1,508	X	1024	13,826,047
6.	PD80.E00 Exported ARC/INFO GRID with population-density data for 1980 in people/km^2	461,157	X	1024	32,740,206

Table 4. (continued)

File number	Name, type, and description	Logical records	Record length	Block size	File size (bytes)
7.	PD80.ASC ASCII data file with population-density data for 1980 in people/km^2	1,508	X	1024	20,738,254
8.	LAKES.E00 Exported ARC/INFO GRID with all nonseasonal lakes >20 km in any direction	461,166	X	1024	32,740,600
9.	LAKES.ASC ASCII data file with all nonseasonal lakes >20 km in any direction	1,508	X	1024	13,826,047
10.	BIO1980.E00 Exported ARC/INFO GRID with the calculated "actual" aboveground biomass in woody vegetation for 1980 in Mg/ha	461,135	X	1024	32,739,906
11.	BIO1980.ASC ASCII data file with the calculated "actual" aboveground biomass in woody vegetation for 1980 in Mg/ha	1,508	X	1024	20,738,254
12.	INTGRID.SAS SAS™ input/output code to read and print the cell- based ASCII data files containing integer values	34	80	800	2,720

Table 4. (continued)

File number	Name, type, and description	Logical records	Record length	Block size	File size (bytes)
13.	INTGRID.FOR FORTRAN retrieval code to read and print the cell-based ASCII data files containing integer values	51	80	800	4,080
14.	REALGRID.SAS SAS™ input/output code to read and print the cell-based ASCII data files containing real values	33	80	800	2,640
15.	REALGRID.FOR FORTRAN retrieval code to read and print the cell-based ASCII data files containing real values	52	80	800	4,160
16.	COUNTRY.E00 Exported ARC/INFO polygon coverage with national and internal subnational political boundaries and 1980 population data	30,066	X	1024	1,688,985
17.	COUNTRY.ASC ASCII data file with national and internal subnational political boundaries	59,204	40	800	2,368,160
18.	COUNTRY.SAS SAS™ input/output code to read and print the coordinates defining the national and internal political boundaries for Africa as of 1980	29	80	800	2,320

Table 4. (continued)

File number	Name, type, and description	Logical records	Record length	Block size	File size (bytes)
19.	COUNTRY.FOR FORTRAN retrieval code to read and print the coordinates defining the national and internal political boundaries for Africa as of 1980	44	80	800	3,520
20.	POPDEN.E00 Exported INFO database file with population-density data for 1960, 1970, 1980, and 1990	1,016	X	1024	43,600
21.	POPDEN.ASC ASCII data file with population-density data for 1960, 1970, 1980, and 1990	501	132	1320	66,132
22.	POPDEN.SAS SAS™ input/output code to read and print the population-density data for 1960, 1970, 1980, and 1990	11	80	800	880
23.	POPDEN.FOR FORTRAN retrieval code to read and print the population-density data for 1960, 1970, 1980, and 1990	35	80	800	2,800
24.	SUM1980.ASC ASCII data file with country totals for the amount of land and biomass in open and closed forests in 1980	39	132	1320	5,148

Table 4. (continued)

File number	Name, type, and description	Logical records	Record length	Block size	File size (bytes)
25.	SUM1980.SAS SAS™ input/output code to read and print the country totals for 1980	15	80	800	1,200
26.	SUM1980.FOR FORTRAN retrieval code to read and print the country totals for 1980	33	80	800	2,640
	Total Logical Records:	2,405,175		Total Size:	250,909,086

Notes:

1. "X" in the record length column indicates that the record length varies between 1 and 13,807 characters per logical record. ARC/INFO E00 files have record lengths between 1 and 80. Files PD80.ASC and BIO1980.ASC have maximum record lengths of 13,807. Files BIOMAX.ASC, LAND.ASC, and LAKES.ASC have maximum record lengths of 9,205.
2. ARC/INFO™ export files (Version 7) are coverages converted to flat ASCII files for data transfer purposes. The IMPORT command in ARC/INFO™ must be used to enter these files into your system. GRID is ARC/INFO's raster (cell-based) modelling subsystem. INFO is the proprietary database management system and format used by ARC/INFO™ to store attribute data. ARC/INFO™ is a registered trademark of the Environmental Systems Research Institute, Inc., Redlands, CA 92372.
3. SAS™ is a registered trademark of the SAS Institute, Inc., Cary, NC 27511-8000.

14. Descriptive File on the Magnetic Media

The following is a listing of the first file provided on the magnetic media distributed by CDIAC. This file provides variable descriptions, formats, units, and other pertinent information about each file associated with this database.

TITLE OF THE DATA BASE

TROPICAL AFRICA: LAND USE, BIOMASS, AND CARBON ESTIMATES FOR 1980

CONTRIBUTORS

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SCOPE OF THE DATA

This numeric data package (NDP-055) describes a land-use and biomass database for Tropical Africa that contains 1980 land cover, maximum potential aboveground biomass, and biomass estimates for woody vegetation in 1980. In addition, the database includes information on human populations in each nation and sub-national political unit in Tropical Africa for the years 1960, 1970, 1980, and 1990. These data were collected to reduce the uncertainty associated with the possible magnitude and time course of historical releases of carbon from land-cover change and may be used by demographers, historians, geographers, and other researchers interested in the relationship between land cover change, land degradation, climate, and anthropogenic activities.

For purposes of this NDP Tropical Africa is defined as encompassing nearly 22.7 $\times 10^6$ km^2 of the world's surface and includes the following countries: Angola, Botswana, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Congo, Benin, Equatorial Guinea, Ethiopia, Djibouti, Gabon, Gambia, Ghana, Guinea, Ivory Coast, Kenya, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Namibia, Niger, Nigeria, Guinea-Bissau, Zimbabwe (Rhodesia), Rwanda, Senegal, Sierra Leone, Somalia, Sudan, Tanzania, Togo, Uganda, Burkina Faso (Upper Volta), Zaire, and Zambia. As defined here Tropical Africa does not include countries in Mediterranean and southern

Africa (i.e., Egypt, Libya, Tunisia, Algeria, Morocco, Western Sahara, South Africa, Lesotho, and Swaziland).

The database was developed by Sandra Brown, Louis Iverson, Ariel Lugo, Anantha Prasad, Greg Gaston, and others between 1990 and 1994. Results and conclusions drawn by these researchers are described in detail in Brown et al. (1993), Iverson et al. (1994), and Brown and Gaston (1995). Development of the data was supported by a series of contracts and grants from the U.S. Department of Energy, Global Carbon Cycle Program (presently under the direction of Roger C. Dahlman). The primary contract that supported the collection of the data was the U.S. Department of Energy, Office of Health and Environmental Research, contract DEFG02-90ER61081. Additional support was obtained from the U.S. Environmental Protection Agency through its post doctoral fellowship program, administered by the National Research Council.

DATA FORMATS AND UNITS

The data distributed with this NDP were initially received as ARC/INFO™ GRIDs and the base map used was derived from the 1:1,000,000-scale *Digital Chart of the World* developed by the U.S. Defense Mapping Agency with additional information digitized from a 1:5,000,000 scale land use map of Africa (White 1983). The ARC/INFO™ GRID files have been exported using both the EXPORT and UNGENERATE commands in ARC/INFO™. Thus, the data contained in this NDP are available in flat ASCII files (data and base map) and in the ARC/INFO™ E00 export format.

The human population data provided are expressed in people per km^2. The biomass density values are expressed in Mg per ha (i.e., 2 Mg of dry biomass = 1 Mg/C or 1 metric ton of carbon).

FLAT ASCII DATA FILES:

Eight flat ASCII data files are provided with this data package. SAS™ and FORTRAN programs designed to read and print the contents of each ASCII data file are also provided. The information within these files will allow the user to ascertain population densities, the amount of land remaining in forests in 1980, the maximum potential aboveground biomass densities within Africa, and the biomass in aboveground woody vegetation in Tropical Africa in 1980. What follows is a description of the contents and formats (e.g., variable names, widths) of the eight flat ASCII data files distributed with this data package.

ARC/INFO™ is a registered trademark of the Environmental Systems Research Institute, Inc., Redlands, CA 92372.

SAS™ is a registered trademark of the SAS Institute, Inc., Cary, NC 27511-8000.

FILE: BIOMAX.ASC, LAND.ASC, and LAKES.ASC

The flat ASCII files BIOMAX.ASC (File 3), LAND.ASC (File 5), and LAKES.ASC (File 9) are formatted as shown in the following FORTRAN code and may be read using the input/output programs INTGRID.FOR or INTGRID.SAS. BIOMAX.ASC contains maximum potential biomass density data in Mg/ha; LAND.ASC contains land-use information classified into four land-use categories; and LAKES.ASC contains the location of all nonseasonal lakes >20 km in any direction in Tropical Africa.

Each file of these three files contains header information containing a set of key words followed by cell (i.e., data) values in row-major order.

```
          READ (5,100) NCOLS
          READ (5,100) NROWS
          READ (5,110) XLLCORNR
          READ (5,110) YLLCORNR
          READ (5,100) CSIZE
          READ (5,100) NODATA
          DO 10 ROWS = 1, NROWS
               READ (5,120)  (VALUE(ROWS,COLS), COLS=1, NCOLS)
 10       CONTINUE
C
 100      FORMAT(14X,I5)
 110      FORMAT(14X,F15.5)
 120      FORMAT(1534(1X,I5))
```

The data are in a normal (type 1) cylindrical equal-area projection with a central meridian of 15° longitude and a standard parallel of 0° latitude. Data are provided for 1,502 rows and 1,534 columns, with the first cell being located in the upper-left corner. Each data cell covers a 25 km^2 square area, 5,000 m per side. The area covered by the data is bounded by a box with the following coordinates: lower-left –3616156.500, –3644063.04465; upper-right 4053843.500, 3865936.955.

The variables in BIOMAX.ASC (File 3), LAND.ASC (File 5), and LAKES.ASC (File 9) are formatted as listed in Table 5 and are shown in the same order as they would appear in the files.

Table 5. Variable formats for BIOMAX.ASC, LAND.ASC, and LAKES.ASC.

Variable name	Variable type	Variable width	Start column	End column
NCOLS	Integer	5	15	19
NROWS	Integer	5	15	19
XLLCORNR	Real	15.5	15	29

Table 5. (continued)

Variable name	Variable type	Variable width	Start column	End column
YLLCORNR	Real	15.5	15	29
CSIZE	Integer	5	15	19
NODATA	Integer	5	15	19
	-------------- END OF HEADER --------------			
VALUE(1,1)	Integer	5	2	6
VALUE(1,2)	Integer	5	8	12
...				
VALUE(1,1533)	Integer	5	9,194	9,198
VALUE(1,1534)	Integer	5	9,200	9,204
	-------------- END OF ROW 1 --------------			
VALUE(2,1)	Integer	5	2	6
VALUE(2,2)	Integer	5	8	12
...				
VALUE(2,1533)	Integer	5	9,194	9,198
VALUE(2,1534)	Integer	5	9,200	9,204
	-------------- END OF ROW 2 --------------			
...				
VALUE(1502,1534)	Integer	5	9,200	9,204
	-------------- END OF FILE --------------			

Where:

NCOLS	is the number of columns in the data file (values per row),
NROWS	is the number of rows in the data file,
XLLCORNR	is the X coordinate of the lower-left corner of a box covering the data area,
YLLCORNR	is the Y coordinate of the lower-left corner of a box covering the data area,
CSIZE	is the size in meters of the square grid cells,
NODATA	is the value (i.e., –9999) used to represent areas with no-data.
VALUE (NROWS,NCOLS)	In BIOMAX.ASC "value" is a single cell of an integer array with 1,502 rows and 1,534 columns containing the maximum potential aboveground biomass in Mg/ha estimated using climatic, topographic, and geomorphic information.

In LAND.ASC "value" is a single cell of an integer array with 1,502 rows and 1,534 columns containing four land-use classes as follows:

Value	Land cover
1	Closed Forest (includes tropical and seasonal forests),
2	Open Forest (woodland/wooded savanna),
3	Grassland Savanna,
4	Other (includes agriculture),
–9999	No-Data.

In LAKES.ASC "value" is a single cell of an integer array with 1,502 rows and 1,534 columns showing the location of non-seasonal medium-to-large lakes in Africa. Cells may have a value of –9999 (no-data) or 1. A value of 1 indicates that 50% or more of the cells 25 km^2 area was underwater in 1980.

FILE: PD80.ASC and BIO1980.ASC

The flat ASCII files PD80.ASC (File 7) and BIO1980.ASC (File 11) are formatted as shown in the following FORTRAN code and may be read using the input/output programs REALGRID.FOR or REALGRID.SAS. PD80.ASC contains population-density data for 1980 in people/km^2 and BIO1980.ASC contains the calculated "actual" aboveground live biomass in open and closed forest for 1980 in Mg/ha.

Each of these two files contains header information with a set of key words followed by cell values in row-major order.

```
       READ (5,100) NCOLS
       READ (5,100) NROWS
       READ (5,110) XLLCORNR
       READ (5,110) YLLCORNR
       READ (5,100) CSIZE
       READ (5,120) NODATA
       DO 10 ROWS = 1, NROWS
            READ (5,130)  (VALUE(ROWS,COLS), COLS=1, NCOLS)
 10    CONTINUE
C
 100   FORMAT(14X,I5)
 110   FORMAT(14X,F15.5)
 120   FORMAT(14X,F8.2)
 130   FORMAT(1534(1X,F8.2))
```

The data are in a normal (type 1) cylindrical equal-area projection with a central meridian of 15° East longitude and a standard parallel of 0° latitude. Data are provided for 1,502 rows and 1,534 columns with the first cell located in the upper-left corner. Each data cell covers a square area, 5,000 m per side. The area covered by the data is bounded by a box with the following coordinates: lower-left –3616156.500, –3644063.04465;

upper-right 4053843.500, 3865936.955.

The variables in PD80.ASC (File 7) and BIO1980.ASC (File 11) are formatted as listed in Table 6 and are shown in the same order as they would appear in the files.

Table 6. Variable formats for PD80.ASC and BIO1980.ASC

Variable name	Variable type	Variable width	Start column	End column
NCOLS	Integer	5	15	19
NROWS	Integer	5	15	19
XLLCORNR	Real	15.5	15	29
YLLCORNR	Real	15.5	15	29
CSIZE	Integer	5	15	19
NODATA	Real	8.2	15	22
	-------------- END OF HEADER --------------			
VALUE(1,1)	Real	8.2	2	9
VALUE(1,2)	Real	8.2	11	18
...				
VALUE(1,1533)	Real	8.2	13,790	13,797
VALUE(1,1534)	Real	8.2	13,799	13,806
	-------------- END OF ROW 1 --------------			
VALUE(2,1)	Real	8.2	2	9
VALUE(2,2)	Real	8.2	11	18
...				
VALUE(2,1533)	Real	8.2	13,790	13,797
VALUE(2,1534)	Real	8.2	13,799	13,806
	-------------- END OF ROW 2 --------------			
...				
VALUE(1502,1534)	Real	8.2	13,799	13,806
	-------------- END OF FILE --------------			

Where:

NCOLS	is the number of columns in the data file (values per row),
NROWS	is the number of rows in the data file,
XLLCORNR	is the X coordinate of the lower-left corner of a box covering the data area,
YLLCORNR	is the Y coordinate of the lower-left corner of a box covering the

	data area,
CSIZE	is the size in meters of the square grid cells,
NODATA	is the value (i.e., −9999.00) used to represent no-data areas.
VALUE (NROWS,NCOLS)	In PD80.ASC "value" is a single cell of a real number array with 1,502 rows and 1,534 columns containing population densities in people per km^2 for sub-national political units in Tropical Africa. In BIO1980.ASC "value" is a single cell of a real number array with 1,502 rows and 1,534 columns containing an estimate of the aboveground biomass density of wooded vegetation in 1980 for Tropical Africa. Values are in Mg/ha and were estimated based on the maximum potential biomass data (BIOMAX.ASC), the land- use data (LAND.ASC and LAKES.ASC), and a degradation ratio derived from the population information in PD80.ASC.

The degradation ratio equations used in calculating BIO1980.ASC are described below. For a detailed description of these equations see Part 1, Section 8.2, of the documentation. (The documentation for NDP-055 is available free-of-charge from the Carbon Dioxide Information Analysis Center, Oak Ridge, Tennessee).

Degradation equations were estimated for two ecofloristic zones [closed forest and open forest (woodland/wooded savanna)] by comparing the potential biomass density with current biomass and population densities obtained for the same location. This process produced unitless factors that indicate the reduction from potential biomass to "current" biomass as a function of population density. A least-squares regression was then conducted for each zone and the following degradation equations were produced. The equations, sample size, and correlation coefficient for closed forest are

PD > 12: $\mathbf{DR = 0.847 - 0.091 \ln (PD), (n = 25, r^2 = 0.72),}$ **(1a)**
PD ≤ 12: $\mathbf{DR = 1 - 0.032\ PD\ .}$ **(1b)**

The equations, sample size, and correlation coefficient for open forest (woodland/wooded savanna) are

PD > 7: $\mathbf{DR = 0.866 - 0.118 \ln (PD), (n = 10, r^2 = 0.54),}$ **(2a)**
PD ≤ 7: $\mathbf{DR = 1 - 0.050\ PD\ .}$ **(2b)**

Where DR is the degradation ratio and PD is the population density in people per km^2.

FILE: COUNTRY.ASC

The flat ASCII file COUNTRY.ASC (File 17) contains digital coordinates for polygons that describe the national boundaries within Africa and subnational political boundaries for countries in Tropical Africa. The data are projected into the same cylindrical equal-area projection used by the cell based data and may be overlaid onto any of the data files previously discussed to provide locational information.

The file is formatted as shown in the following FORTRAN code and may be read using the input/output programs COUNTRY.FOR or COUNTRY.SAS. The variable "NAME" contains the political unit identification number of the given polygon; "NUM" is the number of X, Y pairs used to describe the polygon. "NAME" values greater than 1,000 are used to indicate polygons that are outside of Tropical Africa while values of –9999 indicate no-data areas (e.g. lakes). For the areas within Tropical Africa, the value of the "NAME" variable may be cross-referenced with the "ADMP" variable in the POPDEN.ASC (File 19) population file.

```
 10     READ (5,100,END=999) NAME,NUM
        DO 20 I = 1,NUM
           READ (5,110) X,Y
 20     CONTINUE
        GOTO 10
C
 100    FORMAT(A8,1X,I5)
 110    FORMAT(F16.6,2X,F16.6)
```

The coordinates for the national boundaries were derived from the U.S. Defense Mapping Agencies *Digital Chart of the World* at a scale of 1:1,000,000. Boundaries for subnational political units were derived from *The New International Atlas*, the *Encyclopedia of the Nations*, and the FAO, Tropical Forest Resources Assessment Program—1990 population data. Boundaries for large water bodies (e.g., Lake Victoria) were copied from the *Digital Chart of the World* while moderate size lakes (> 20 km in length in any direction) were digitized from the UNESCO *Vegetation Map of Africa*, scale 1:5,000,000.

FILE: POPDEN.ASC

The flat ASCII file POPDEN.ASC (File 21) contains population density data for 1960, 1970, 1980, and 1990 for the subnational political units shown in Table 1 of the documentation that accompanies this database. The data were provided by M. Lorenzini and K. D. Singh (FAO, Tropical Forest Resources Assessment Program–1990). The file is formatted as shown in the following FORTRAN code and may be read using the input/output programs POPDEN.FOR or POPDEN.SAS.

```
 10      READ (5,100,END=999) ADMP, LANDAREA, PD60, PD70,
     1                        PD80, PD90, CNTRYNUM, REGNAME
         GOTO 10
C
 100     FORMAT(I4,I10,4F8.3,I5,A40)
```

The variables in POPDEN.ASC (File 21) are formatted as listed in Table 7 and are shown in the same order as they appear in the file.

Table 7. Variable formats for POPDEN.ASC

Variable name	Variable type	Variable width	Start column	End column
ADMP	Integer	4	1	4
LANDAREA	Integer	10	5	14
PD60	Real	8.3	15	22
PD70	Real	8.3	23	30
PD80	Real	8.3	31	38
PD90	Real	8.3	39	46
CNTRYNUM	Integer	5	47	51
REGNAME	Character	40	52	91

Where:

ADMP — is a unique identification code for administrative divisions or metropolitan places in Tropical Africa,

LANDAREA — is the land area in km^2 of the given division, metropolitan place, or subnational political unit,

PD60	is the population density for 1960 in people/km^2,
PD70	is the population density for 1970 in people/km^2,
PD80	is the population density for 1980 in people/km^2,
PD90	is the population density for 1990 in people/km^2,
CNTRYNUM	is a unique identification code for each nation (a.k.a., CNTRY-NUMBER in the ARC/INFO™ coverages),
REGNAME	is the name of the given division, metropolitan place, or subnational political unit (a.k.a., REGION-NAME in the ARC/INFO™ coverages).

Values of –9999.00 for variables PD60, 70, 80, and 90 indicate that data were not available from the FAO for the given political subdivision.

FILE: SUM1980.ASC

The flat ASCII file SUM1980.ASC (File 24) contains the amount of land and biomass in open and closed forest by country for 1980 (this is the same information as is shown in Appendix A of the documentation). The file is formatted as shown in the following FORTRAN code and may be read by using the input/output programs SUM1980.FOR or SUM1980.SAS.

```
 10      READ (5,100,END=999) COUNTRY, CNTRYNUM, TOTCELL,
     1           TOTAREA, CFAREA, OFAREA, CFBIO, OFBIO,
     1           TOTBIO, FOREST
         GOTO 10
C
 100     FORMAT(A40,I4,I11,I10,2I9,2F13.1,F11.4,F9.1)
```

The variables in SUM1980.ASC (File 24) are formatted as listed in Table 8 and are shown in the same order as they appear in the file.

Table 8. Variable formats for SUM1980.ASC

Variable name	Variable type	Variable width	Start column	End column
COUNTRY	Character	40	1	39
CNTRYNUM	Integer	4	40	43
TOTCELL	Integer	11	44	54
TOTAREA	Integer	10	55	64
CFAREA	Integer	9	65	73
OFAREA	Integer	9	74	82
CFBIO	Real	13.1	83	95
OFBIO	Real	13.1	96	108
TOTBIO	Real	11.4	109	119
FOREST	Real	9.1	120	128

Where:

COUNTRY	is a country name,
CNTRYNUM	is a unique identification code for each nation (a.k.a., CNTRY-NUMBER in the ARC/INFO™ coverages),
TOTCELL	is the number of 5 × 5 km cells within a country,
TOTAREA	is the land area in km^2 of COUNTRY,
CFAREA	is the amount of land in closed forests (in km^2) for COUNTRY,
OFAREA	is the amount of land in open forests (in km^2) for COUNTRY,
CFBIO	is the mean biomass of closed forests (in Mg/ha) for COUNTRY,
OFBIO	is the mean biomass of open forests (in Mg/ha) for COUNTRY,
TOTBIO	is the total biomass of forests (in 10^6 Mg) in COUNTRY in 1980,
FOREST	is the percent of COUNTRY that is forested.

There are no NO-DATA flags in this file.

ARC/INFO™ (Version 7) EXPORT FILES

Seven ARC/INFO™ E00 export files are provided with this NDP. These files contain the same data as the first seven flat ASCII data files described previously. The ARC/INFO™ E00 export files were produced by using the EXPORT command with the NONE option in ARC/INFO™ Version 7. These files are in an uncompressed, fixed-block format that may be moved across computer systems. The coverages are in a normal (type

1) cylindrical equal-area projection with a central meridian of 15° East longitude and a standard parallel of 0° latitude. All unites are in meters and the spheroid is a sphere with a radius of 6,370,997 meters (vs. the Clark 1866 spheroid).

After these files are loaded onto your system and imported into ARC/INFO™, data from any of the coverages may be accessed directly (e.g., in GRID), or a RELATE may be created that links the coverages based on a common variable. It is recommended that the "relate item" used be either the unique identification code for administrative divisions or metropolitan places in Tropical Africa (variable ADMP) or the unique country code (variable CNTRY-NUMBER).

Five of the coverages (BIOMAX.E00, LAND.E00, PD80.E00, LAKES.E00 and BIO1980.E00) are in the GRID ARC/INFO™ format and have 1,502 rows and 1,534 columns, with each data cell covering a square area with 5,000 m per side. The remaining two files include a polygon coverage with regions (COUNTRY.E00) and a INFO file with population data (POPDEN.E00). The area covered by the data is bounded by a box with the following coordinates: lower-left –3616156.500, –3644063.04465; upper-right 4053843.500, 3865936.955. A listing of the variable names and data formats for these last two E00 files are shown in Tables 9, 10, and 11.

Table 9. Variable formats for COUNTRY.PAT in COUNTRY.E00 (File 16)

Start column	Item name	Data width	Display width	Data type*	Decimal places
1	AREA	4	12	F	3
5	PERIMETER	4	12	F	3
9	COUNTRY#	4	5	B	-
13	COUNTRY-ID	4	5	B	-
17	NAME	30	30	C	-
47	ADMP	4	4	I	-
51	PD80	8	12	N	3
59	INTPD80	10	10	N	-
69	CNTRY-NUMBER	5	6	I	-

*Data types are B-binary, C-character, F-float, I-integer, and N-numeric. F and N data types are real numbers with different precisions (precision is system dependent).

Where:

AREA is the area in m^2,

PERIMETER	is the perimeter in meters,
COUNTRY#	is the internal ARC/INFO™ polygon identification number,
COUNTRY-ID	is the external ARC/INFO™ polygon identification number,
NAME	is the country or nation name (also may be "Water"),
ADMP	is a unique identification code for administrative divisions or metropolitan places in Tropical Africa,
PD80	is the population density for 1980 in people/km^2,
INTPD80	is the population density for 1980 in people/km^2 multiplied by 1,000,
CNTRY-NUMBER	is a unique identification code for each nation (a.k.a., CNTRYNUM in the ASCII file POPDEN.ASC).

Zero values for variable ADMP indicates polygons that are outside of Tropical Africa or that have NO-DATA (e.g. lakes).

Table 10. Variable formats for COUNTRY.PATCOUNTRYBND (the region attribute file) in COUNTRY.E00 (File 16)

Start column	Item name	Data width	Display width	Data type*	Decimal places
1	AREA	4	12	F	3
5	PERIMETER	4	12	F	3
9	COUNTRYBND#	4	5	B	-
13	COUNTRYBND-ID	4	5	B	-
17	CNTRY-NUMBER	5	6	I	-

*Data types are B-binary, C-character, F-float, I-integer, and N-numeric. F and N data types are real numbers with different precisions (precision is system dependent).

Where:

AREA	is the area in m^2,
PERIMETER	is the perimeter in m,
COUNTRYBND#	is the internal ARC/INFO™ polygon identification number,
COUNTRYBND-ID	is the external ARC/INFO™ polygon identification number,
CNTRY-NUMBER	is a unique identification code for each nation (a.k.a., CNTRYNUM in the ASCII file POPDEN.ASC).

Table 11. Variable formats for POPDEN.DAT in POPDEN.E00 (File 19)

Start column	Item name	Data width	Display width	Data type*	Decimal places
1	ADMP	4	4	I	-
5	LANDAREA	10	10	I	-
15	PD60	8	12	N	3
23	PD70	8	12	N	3
31	PD80	8	12	N	3
39	PD90	8	12	N	3
47	CNTRY-NUMBER	5	6	I	-
52	REGION-NAME	40	42	C	-

*Data types are B-binary, C-character, F-float, I-integer, and N-numeric. F and N data types are real numbers with different precisions (precision is system dependent).

Where:

ADMP	is a unique identification code for administrative divisions or metropolitan places in Tropical Africa,
LANDAREA	is the land area in km^2 of the given division, metropolitan place, or sub-national political unit,
PD60	is the population density in 1960,
PD70	is the population density in 1970,
PD80	is the population density in 1980,
PD90	is the population density in 1990,
CNTRY-NUMBER	is a unique identification code for each nation (a.k.a., CNTRYNUM in the ASCII file POPDEN.ASC),
REGION-NAME	is the name of the given division, metropolitan place, or subnational political unit (a.k.a., REGNAME in the ASCII file POPDEN.ASC).

Values of −9999.00 for variables PD60, 70, 80, and 90 indicate that data were not available from the FAO for the given political subdivision.

15. Listing of the FORTRAN Data Retrieval Programs

This section lists the five FORTRAN data retrieval programs provided by CDIAC with this database. Each program is designed to read and write the contents of one or more of the eight flat ASCII data files.

The first FORTRAN program (File 13 on the magnetic media) is designed to read and print files BIOMAX.ASC, LAND.ASC, and LAKES.ASC with only slight modification (i.e., changing the input file name).

```
C*********************************************************
C*   FORTRAN PROGRAM TO READ AND PRINT FILE BIOMAX.ASC,  *
C*   LAND.ASC, AND LAKES.ASC                             *
C*********************************************************
        REAL*8  XLLCORNR, YLLCORNR
        INTEGER VALUE(1502,1534)
        INTEGER NCOLS, NROWS, COLS, ROWS, CSIZE, NODATA

C*********************************************************
C*   OPEN FILES FOR INPUT/OUTPUT                         *
C*********************************************************
        OPEN(UNIT=5,FILE='./biomax.asc')
        OPEN(UNIT=6,FORM='PRINT')

C*********************************************************
C*   PRINT CELL VALUES AS WELL AS ROW AND COLUMN NUMBER  *
C*********************************************************
        READ (5,100) NCOLS
        READ (5,100) NROWS
        READ (5,110) XLLCORNR
        READ (5,110) YLLCORNR
        READ (5,100) CSIZE
        READ (5,100) NODATA
        WRITE (6,200) NCOLS, NROWS, XLLCORNR, YLLCORNR,
     1              CSIZE, NODATA
        DO 10 ROWS = 1, NROWS
             READ (5,120)  (VALUE(ROWS,COLS), COLS=1, NCOLS)
 10     CONTINUE
        DO 30 ROWS = 1, NROWS
             DO 20 COLS = 1, NCOLS
             WRITE(6,210) ROWS, COLS, VALUE(ROWS,COLS)
 20     CONTINUE
 30     CONTINUE
C
 100    FORMAT(14X,I5)
 110    FORMAT(14X,F15.5)
 120    FORMAT(1534(1X,I5))
 200    FORMAT(1X,'ncols          ',I5,/,
     1         1X,'nrows          ',I5,/,
     1         1X,'xllcorner      ',F15.5,/,
     1         1X,'yllcorner      ',F15.5,/,
     1         1X,'cellsize       ',I5,/,
     1         1X,'NODATA_value   ',I5)
 210    FORMAT(1X,I6,',',I6,' = ',I6)
```

```
C***********************************************************
C*           CLOSE FILES AND EXIT GRACEFULLY               *
C***********************************************************
 999    CLOSE(UNIT=5)
        CLOSE(UNIT=6)
        STOP
        END
```

The second FORTRAN program (File 15 on the magnetic media) is designed to read and print files PD80.ASC and BIO1980.ASC with only slight modification (i.e., changing the input file name).

```
C***********************************************************
C*   FORTRAN PROGRAM TO READ AND PRINT FILE PD80.ASC AND   *
C*   BIO1980.ASC.                                          *
C***********************************************************
        REAL*8  XLLCORNR, YLLCORNR
        REAL VALUE(1502,1534), NODATA
        INTEGER NCOLS, NROWS, COLS, ROWS, CSIZE

C***********************************************************
C*   OPEN FILES FOR INPUT/OUTPUT                           *
C***********************************************************
        OPEN(UNIT=5,FILE='./pd80.asc')
        OPEN(UNIT=6,FORM='PRINT')

C***********************************************************
C*   PRINT CELL VALUES AS WELL AS ROW AND COLUMN NUMBER    *
C***********************************************************
        READ (5,100) NCOLS
        READ (5,100) NROWS
        READ (5,110) XLLCORNR
        READ (5,110) YLLCORNR
        READ (5,100) CSIZE
        READ (5,120) NODATA
        WRITE (6,200) NCOLS, NROWS, XLLCORNR, YLLCORNR,
     1                CSIZE, NODATA
        DO 10 ROWS = 1, NROWS
             READ (5,130)  (VALUE(ROWS,COLS), COLS=1, NCOLS)
 10     CONTINUE
        DO 30 ROWS = 1, NROWS
             DO 20 COLS = 1, NCOLS
             WRITE(6,210) ROWS, COLS, VALUE(ROWS,COLS)
 20     CONTINUE
 30     CONTINUE
C

 100    FORMAT(14X,I5)
 110    FORMAT(14X,F15.5)
 120    FORMAT(14X,F8.2)
 130    FORMAT(1534(1X,F8.2))
 200    FORMAT(1X,'ncols          ',I5,/,
     1          1X,'nrows          ',I5,/,
```

```
    1         1X,'xllcorner      ',F15.5,/,
    1         1X,'yllcorner      ',F15.5,/,
    1         1X,'cellsize       ',I5,/,
    1         1X,'NODATA_value   ',F8.2)
 210    FORMAT(1X,I6,',',I6,' = ',F8.2)
C**********************************************************
C*          CLOSE FILES AND EXIT GRACEFULLY              *
C**********************************************************
 999    CLOSE(UNIT=5)
        CLOSE(UNIT=6)
        STOP
        END
```

The third FORTRAN program (File 19 on the magnetic media) is designed to read and print file COUNTRY.ASC.

```
C**********************************************************
C* FORTRAN PROGRAM TO READ AND PRINT COUNTRY.ASC.         *
C**********************************************************
        CHARACTER NAME*8
        INTEGER I, NUM, NLIN
        REAL    X , Y

C**********************************************************
C*                OPEN FILES FOR INPUT/OUTPUT            *
C**********************************************************
        NLIN=0
        OPEN(UNIT=5,FILE='./country.asc')
        OPEN(UNIT=6,FORM='PRINT')

C**********************************************************
C* READ AND PRINT LINE NAME AND NUMBER OF POINTS IN LINE *
C**********************************************************
  10    READ (5,100,END=999) NAME,NUM
        WRITE(6,300)
        WRITE(6,200) NAME,NUM

C**********************************************************
C*      READ AND PRINT X,Y COORDINATES FOR THE POLYGON   *
C**********************************************************
        WRITE(6,310)
        DO 20 I = 1,NUM
           READ (5,110) X,Y
           WRITE(6,210) X,Y
  20    CONTINUE
        GOTO 10
C
 100    FORMAT(A8,1X,I5)
 110    FORMAT(F16.6,2X,F16.6)
 200    FORMAT(1X,A8,',',I5)
 210    FORMAT(1X,F16.6,', ',F16.6)
 300    FORMAT(1X,'NAME    ,NUMBER')
 310    FORMAT(1X,'X       ,Y ')
```

```
C***********************************************************
C*          CLOSE FILES AND EXIT GRACEFULLY                *
C***********************************************************
 999    CLOSE(UNIT=5)
        CLOSE(UNIT=6)
        STOP
        END
```

The fourth FORTRAN program (File 23 on the magnetic media) is designed to read and print the file POPDEN.ASC.

```
C***********************************************************
C*   FORTRAN PROGRAM TO READ AND PRINT FILE POPDEN.ASC.    *
C***********************************************************
        INTEGER ADMP, LANDAREA, CNTRYNUM
        REAL    PD60, PD70, PD80, PD90
        CHARACTER*40 REGNAME

C***********************************************************
C*   OPEN FILES FOR INPUT/OUTPUT                           *
C***********************************************************
        OPEN(UNIT=5,FILE='./popden.asc')
        OPEN(UNIT=6,FORM='PRINT')

C***********************************************************
C*   PRINT CELL VALUES AS WELL AS ROW AND COLUMN NUMBER    *
C***********************************************************
        WRITE(6,200)
 10     READ (5,100,END=999) ADMP, LANDAREA, PD60, PD70,
     1                       PD80, PD90, CNTRYNUM, REGNAME
        WRITE(6,210)  ADMP, LANDAREA, PD60, PD70,
     1                PD80, PD90, CNTRYNUM, REGNAME
 20     GOTO 10
C
 100    FORMAT(I4,I10,4F8.3,I5,A40)
 200    FORMAT(1X,'ADMP',1X,'  LANDAREA',1X,'     PD60',
     1  1X,'     PD70',1X,'     PD80',1X,'     PD90',
     1  1X,' CNTY',1X,'   REGION NAME')
 210    FORMAT(1X,I4,1X,I10,4(1X,F9.3),1X,I5,1X,A40)
C***********************************************************
C*          CLOSE FILES AND EXIT GRACEFULLY                *
C***********************************************************
 999    CLOSE(UNIT=5)
        CLOSE(UNIT=6)
        STOP
        END
```

The last FORTRAN program (File 26 on the magnetic media) is designed to read and print the file SUM1980.ASC.

```
C**********************************************************
C*   FORTRAN PROGRAM TO READ AND PRINT FILE SUM1980.ASC. *
C**********************************************************
        INTEGER CNTRYNUM, TOTCELL, TOTAREA, CFAREA, OFAREA
        REAL    CFBIO, OFBIO, TOTBIO, FOREST
        CHARACTER*40 COUNTRY

C**********************************************************
C*   OPEN FILES FOR INPUT/OUTPUT                          *
C**********************************************************
        OPEN(UNIT=5,FILE='./sum1980.asc')
        OPEN(UNIT=6,FORM='PRINT')

C**********************************************************
C*   PRINT CELL VALUES AS WELL AS ROW AND COLUMN NUMBER   *
C**********************************************************
 10     READ (5,100,END=999) COUNTRY, CNTRYNUM, TOTCELL,
     1        TOTAREA, CFAREA, OFAREA, CFBIO, OFBIO,
     1        TOTBIO, FOREST
        WRITE(6,210) COUNTRY, CNTRYNUM, TOTCELL,
     1        TOTAREA, CFAREA, OFAREA, CFBIO, OFBIO,

     1        TOTBIO, FOREST
 20     GOTO 10
C

 100    FORMAT(A40,I4,I11,I10,2I9,2F13.1,F11.4,F9.1)
 210    FORMAT(1X,A40,I4,I11,I10,2I9,2F13.1,F11.4,F9.1)
C**********************************************************
C*          CLOSE FILES AND EXIT GRACEFULLY               *
C**********************************************************
 999    CLOSE(UNIT=5)
        CLOSE(UNIT=6)
        STOP
        END
```

16. Listing of the SAS™ Data Retrieval Programs

The following pages list the five SAS™ data retrieval programs provided by CDIAC with this database. Each program is designed to read and write the contents of one or more of the eight flat ASCII data files.

The first SAS™ program (File 12 on the magnetic media) is designed to read and print files BIOMAX.ASC, LAND.ASC, and LAKES.ASC with only slight modification (i.e., changing the input file name).

```
/*
   Code to read and print a ASCII file with integer
   data produced by Arc/Info's GRIDASCII command.
   This program may be used to read and print the
   contents of BIOMAX.ASC, LAND.ASC, and
   LAKES.ASC.
*/
OPTIONS LINESIZE=78 PAGESIZE=60;
DATA IN;
INFILE './biomax.asc' LRECL=32767;
FILE './print.out';
INPUT TXT $14. NCOLS;
PUT TXT $14. NCOLS;
INPUT TXT $14. NROWS;
PUT TXT $14. NROWS;
INPUT TXT $14. XLL;
PUT TXT $14. XLL 15.6;
INPUT TXT $14. YLL;
PUT TXT $14. YLL 15.6;
INPUT TXT $14. CSIZE;
PUT TXT $14. CSIZE;
INPUT TXT $14. NDVALUE;
PUT TXT $14. NDVALUE;
DO ROWS=1 TO NROWS;
  DO COLS=1 TO NCOLS;
  INPUT VALUE @@;
  PUT ROWS ', ' COLS ' = ' VALUE;
  IF VALUE = -9999 THEN VALUE = .;
  OUTPUT;
  END;
INPUT;
END;
/* PROC MEANS */
RUN;
```

The second SAS™ program (File 14 on the magnetic media) is designed to read and print files PD80.ASC and BIO1980.ASC with only slight modification (i.e., changing the input file name).

```
/*
   Code to read and print a ASCII file with real
   data produced by Arc/Info's GRIDASCII command.
   This program may be used to read and print the
   contents of PD80.ASC and BIO1980.ASC.
*/
OPTIONS LINESIZE=78 PAGESIZE=60;
DATA IN;
INFILE './pd80.asc' LRECL=32767;
FILE './print.out';
INPUT TXT $14. NCOLS;
PUT TXT $14. NCOLS;
INPUT TXT $14. NROWS;
PUT TXT $14. NROWS;
INPUT TXT $14. XLL;
PUT TXT $14. XLL 15.6;
INPUT TXT $14. YLL;
PUT TXT $14. YLL 15.6;
INPUT TXT $14. CSIZE;
PUT TXT $14. CSIZE;
INPUT TXT $14. NDVALUE 8.2;
PUT TXT $14. NDVALUE 8.2;
DO ROWS=1 TO NROWS;
  DO COLS=1 TO NCOLS;
  INPUT VALUE 9.2  @@;
  PUT ROWS ', ' COLS ' = ' VALUE 9.2;
  IF VALUE = -9999 THEN VALUE = .;
  OUTPUT;
  END;
INPUT;
END;
/* PROC MEANS */
RUN;
```

The third SAS™ program (File 18 on the magnetic media) is designed to read and print file COUNTRY.ASC.

```
/*
   Code to read and print the ASCII file
   COUNTRY.ASC. The file contains the
   x, y coordinates of the political units
   used in this NDP for Tropical Africa.
   The values of the NAME variable match
   the political unit numbers shown in
   Table 1 of the documentation. Numbers
   greater than 1000 indicate polygons
   that are not in Tropical Africa
   but that were included to provide
   a full map of national boundaries
   for the continent.
*/
OPTIONS LINESIZE=78 PAGESIZE=60;
DATA IN;
INFILE './country.asc' DLM=',';
FILE './print.out';
INPUT NAME $ 1-8  NUM 10-14;
PUT 'NAME     ,NUMBER';
PUT NAME ',' NUM 5.;
ARRAY X{1000};
ARRAY Y{1000};
PUT 'X        ,Y';
DO I = 1 TO NUM;
   INPUT X{I} 1-16 Y{I} 18-33;
   PUT X{I} 16.6 ',' Y{I} 16.6;
   END;
RUN;
```

The fourth SAS™ program (File 22 on the magnetic media) is designed to read and print the file POPDEN.ASC.

```
/*
   Code to read and print the population density
   data file (POPDEN.ASC).
*/
OPTIONS LINESIZE=132 PAGESIZE=60;
DATA IN;
INFILE './popden.asc';
FILE './print.out';
INPUT ADMP 1-4 LANDAREA 5-14 PD60 8.3 PD70 8.3
      PD80 8.3 PD90 8.3 CNTRYNUM 5. REGNAME $40.;
PROC PRINT NOOBS;
RUN;
```

The last SAS™ program (File 25 on the magnetic media) is designed to read and print the file SUM1980.ASC.

```
/*
   Code to read and print the country summary file
   (SUM1980.ASC). SUM1980.ASC contains the total
   amount of biomass remaining in open and closed
   forests by country.
*/
OPTIONS LINESIZE=132 PAGESIZE=60;
DATA IN;
INFILE './sum1980.asc';
FILE './print.out';
INPUT COUNTRY $ 1-39 CNTRYNUM 40-43 TOTCELL 44-54
      TOTAREA 55-64 CFAREA 65-73 OFAREA 74-82
      CFBIO 83-95 OFBIO 96-108 TOTBIO 109-119
      FOREST 120-128;
PROC PRINT NOOBS;
RUN;
```

17. Partial Listings of the Flat ASCII Data Files

This section provides sample listing of the first seven lines in the eight flat ASCII data files provided with this database. Due to the format of these data the first seven lines of BIOMAX.ASC, LAND.ASC, and LAKES.ASC, as well as PD80.ASC and BIO1980.ASC, are identical.

Sample listing for BIOMAX.ASC, LAND.ASC, and LAKES.ASC:

```
ncols         1534
nrows         1502
xllcorner     -3616156.500000
yllcorner     -3644063.044650
cellsize      5000
NODATA_value  -9999
 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 ...
```

Sample listing for PD80.ASC and BIO1980.AS:

```
ncols         1534
nrows         1502
xllcorner     -3616156.500000
yllcorner     -3644063.044650
cellsize      5000
NODATA_value  -9999.00
-9999.00 -9999.00 -9999.00 -9999.00 -9999.00 -9999.00 -9999.00 ...
```

Sample listing for COUNTRY.ASC:

```
"  1001",  144
  -386164.281250,    3485339.000000
  -390109.093750,    3473156.000000
  -392456.687500,    3435107.250000
  -379916.187500,    3422273.500000
  -381676.937500,    3417712.500000
  -387328.937500,    3414635.500000
...
```

Sample listing for POPDEN.ASC.:

```
   1      40130    2.670    1.021    2.247    3.641      7ZAIRE
   2      58698    7.334    6.584    9.859   13.448      7UIGE
   3      24190    9.758   10.129   12.901   15.263      7KWANZA-NORTH
   4      55660    7.254    8.273   10.292   11.964      7KWANZA-SOUTH
   5     223023    1.215    0.859    1.116    1.288      7MOXICO
   6     199049    0.570    0.566    0.633    0.629      7KUANDO-KUBANGO
   7      97602    4.607    5.545    7.329    9.134      7MALANGE
...
```

Sample listing for SUM1980.ASC.:

```
Angola                                             7     50127   1253175    66750  1063775       109.4
 69.7     81.4476       90.2
Botswana                                          20     23195    579875        0   101800         0.0
 13.1      1.3336       17.6
Burundi                                           29      1021     25525     2575     6900        57.1
 40.3      0.4251       37.1
Cameroon                                          32     18529    463225   221750   182500       297.5
120.0     87.8706       87.3
Central African Republic                          37     24856    621400   105425   515850       262.9
185.7    123.5096      100.0
Chad                                              39     50635   1265875        0   316825         0.0
 38.0     12.0394       25.0
Congo                                             46     13841    346025   247675      375       344.9
 36.4     85.4368       71.7
...
```

18. Verification of Transport: Flat ASCII Data Files

After the flat ASCII data files have been loaded onto your system, the files should be checked against Table 12 to insure that they have not been corrupted during transport. To do this, some or all of the characteristics presented in the following table should be obtained by using operating system commands or a statistical analysis package (e.g., SAS™).

Table 12. File characteristics of the eight flat ASCII data files provided with this numeric data package

File name Variable name	N	Mean	Minimum	Maximum
BIOMAX.ASC				
VALUE	2,304,068	−4765.76	−9999.00	500.00
LAND.ASC				
VALUE	2,304,068	−4796.45	−9999.00	4.00
PD80.ASC				
VALUE	2,304,068	−4786.76	−9999.00	2195.51
LAKES.ASC				
VALUE	2,304,068	−9955.43	−9999.00	1.00
BIO1980.ASC				
VALUE	2,304,068	−7860.27	−9999.00	466.34
COUNTRY.ASC				
NUM	653	170.17	4.00	537.00
X	58,551	389,139.02	−4495708.50	4395933.50
Y	58,551	275,776.22	−3637384.25	3864114.50
POPDEN.ASC				
ADMP	501	257.42	1.00	510.00
LANDAREA	501	45,745.39	67.00	823,144.00
PD60	501	−5,769.83	−9999.00	844.55
PD70	501	−671.63	−9999.00	1,262.67
PD80	501	69.90	0.11	2,195.51
PD90	501	98.45	0.05	3,045.15
CNTRYNUM	501	130.45	7.00	251.00

Table 12. (continued)

File name Variable name	N	Mean	Minimum	Maximum
SUM1980.ASC				
CNTRYNUM	39	127.92	7.00	251.00
TOTCELL	39	23276.38	422.00	99743.00
TOTAREA	39	581909.62	10550.00	2493575.00
CFAREA	39	103214.74	0.00	1860300.00
OFAREA	39	209142.95	0.00	1063775.00
CFBIO	39	110.33	0.00	344.90
OFBIO	39	62.82	0.00	244.50
TOTBIO	39	3556.64	0.00	46122.15
FOREST	39	60.75	0.00	100.00

The statistics shown in Table 12 should be used to check to ensure that the ASCII data files have not been corrupted in transport. These statistics should not be construed as either a summary or an indicator of trends in the data.

19. Verification of Transport: ARC/INFO™ Export Files

The seven ARC/INFO™ export files provided with this NDP were created in ARC/INFO™, Version 7, through the use of the EXPORT command with the NONE option. Each export file contains an entire coverage and its associated INFO data files in a fixed-length, uncompressed format. Importation of the ARC/INFO™ E00 files into the user's ARC/INFO™ system is accomplished by using the IMPORT command with the GRID, COVER, or INFO option. The IMPORT command will automatically recognize that the export file is in an uncompressed format (files should be EXTERNALED after being imported [e.g., ARC> external BIOMAX]).

The data are in a normal (type 1) cylindrical equal-area projection with a central meridian of 15° East longitude and a standard parallel of 0° latitude. Five of the coverages are in the GRID ARC/INFO™ format and have 1,502 rows and 1,534 columns with each data cell covering a 25-km^2 with 5,000 m per side. The remaining two files consist of one polygon coverage with regions (COUNTRY.E00) and a INFO file with population data (POPDEN.E00). The area covered by the data is bounded by a box with the following coordinates: lower-left −3616156.500, −3644063.04465; upper-right 4053843.500, 3865936.955.

After loading these files onto a system the user should verify that the files have been correctly transported. To verify the integrity of the coverages after importing the data, the total number of features and feature classes should be obtained by using the DESCRIBE command in ARC/INFO™ and then compared with Table 13 (use INFO to find the number of records in the POPDEN population data file). If the number of features and feature classes do not match, the coverage may have been corrupted in transport.

Table 13. File characteristics of the ARC/INFO™ E00 export files provided with this numeric data package

File name Coverage type	Data type	Number of features (records or cells)	Attribute data (bytes)	Mean value
BIOMAX				
Grid	Integer	1502 × 1532	8	85.997
LAND				
Grid	Integer	1502 × 1532	28	2.851
PD80				
Grid	Floating	1502 × 1532	–	11.987
LAKES				
Grid	Integer	1502 × 1532	8	1.000
BIO1980				
Grid	Floating	1502 × 1532	–	113.940
COUNTRY				
Cover	Polygons	626	74	–
	Regions	41	22	–
POPDEN				
Info	Info file	501	–	–

The statistics shown in Table 13 are provided to allow the data user to ensure that the E00 files have not been corrupted in transport. These statistics should not be construed as either a summary or an indicator of trends in the data.

20. References

Brown, S. and G. Gaston. 1995. Use of forest inventories and geographic information systems to estimate biomass density of tropical forests: Application to Tropical Africa. *Environmental Monitoring* 38:157-168.

Brown, S., L. R. Iverson, A. Prasad, and D. Liu. 1993. Geographical distributions of carbon in biomass and soils of tropical Asian forests. *Geocarto International* 4:45-59.

Iverson, L. R., S. Brown, A. Prasad, H. Mitasova, A. J. R. Gillespie, and A. E. Lugo. 1994. Use of GIS for estimating potential and actual forest biomass for continental South and Southeast Asia, pp. 67-115. In *Effects of Land-Use Change on Atmospheric CO_2 Concentrations: South and Southeast Asia as a Case Study*, V. H. Dale (ed.). Springer-Verlag Inc., New York.

APPENDIX A: BREAKDOWN BY COUNTRY OF THE AMOUNT OF LAND AND BIOMASS IN OPEN AND CLOSED FOREST IN 1980

Country	Country number	Number of cells	Country area (km^2)	Closed forest (km^2)	Open forest (km^2)	Closed forest mean biomass (Mg/ha)	Open forest mean biomass (Mg/ha)	Total biomass (10^6 Mg)	Percent of country forested
Angola	7	50127	1253175	66750	1063775	109.4	69.7	8144.7567	90.2%
Botswana	20	23195	579875	0	101800	0.0	13.1	133.3580	17.6%
Burundi	29	1021	25525	2575	6900	57.1	40.3	42.5102	37.1%
Cameroon	32	18529	463225	221750	182500	297.5	120.0	8787.0625	87.3%
Central African Republic	37	24856	621400	105425	515850	262.9	185.7	12350.9577	100.0%
Chad	39	50635	1265875	0	316825	0.0	38.0	1203.9350	25.0%
Congo	46	13841	346025	247675	375	344.9	36.4	8543.6758	71.7%
Benin	53	4664	116600	4325	103675	75.6	56.4	617.4240	92.6%
Equatorial Guinea	61	1072	26800	24725	0	318.0	0.0	786.2550	92.3%
Ethiopia	62	49920	1248000	375450	325400	65.3	35.6	3610.1125	56.2%
Djibouti	72	854	21350	0	0	0.0	0.0	0.0000	0.0%
Gabon	74	10446	261150	228450	0	342.5	0.0	7824.4125	87.5%
Gambia	75	422	10550	5150	875	30.5	15.7	17.0813	57.1%
Ghana	81	8710	217750	74200	125725	121.5	68.3	1760.2317	91.8%
Guinea	90	9843	246075	26975	199450	170.7	132.7	3107.1647	92.0%
Ivory Coast	107	12876	321900	102250	164875	211.8	133.4	4365.0875	83.0%
Kenya	114	22774	569350	38000	315250	64.5	35.6	1367.2000	62.0%
Liberia	123	3861	96525	79825	6550	309.2	244.5	2628.3365	89.5%

Country	Country number	Number of cells	Country area (km^2)	Closed forest (km^2)	Open forest (km^2)	Closed forest mean biomass (Mg/ha)	Open forest mean biomass (Mg/ha)	Total biomass (10^6 Mg)	Percent of country forested
Madagascar	129	23759	593975	132975	49475	196.3	198.1	3590.3990	30.7%
Malawi	130	3827	95675	4650	83825	83.9	38.7	363.4162	92.5%
Mali	133	50194	1254850	0	138575	0.0	44.4	615.2730	11.0%
Mauritania	136	41602	1040050	0	125	0.0	5.6	0.0700	0.0%
Mozambique	144	31074	776850	97950	639650	46.6	58.6	4204.7960	94.9%
Namibia	147	32999	824975	0	141175	0.0	10.7	151.0572	17.1%
Niger	158	47273	1181825	0	48075	0.0	8.4	40.3830	4.1%
Nigeria	159	36085	902125	185900	490600	100.3	27.8	3227.5155	75.0%
Guinea-Bissau	175	1308	32700	11225	11750	98.2	70.2	192.7145	70.3%
Zimbabwe	181	15521	388025	5800	360375	37.5	13.3	501.0487	94.4%
Rwanda	184	994	24850	7300	1525	31.5	46.3	30.0557	35.5%
Senegal	195	7916	197900	13500	63975	52.8	25.8	236.3355	39.1%
Sierra Leone	197	2899	72475	30875	28400	220.6	174.9	1177.8185	81.8%
Somalia	201	25573	639325	350	165675	11.4	12.4	205.8360	26.0%
Sudan	206	99743	2493575	5425	737150	134.0	63.0	4716.7400	29.8%
Tanzania	215	35629	890725	5550	529800	73.5	48.6	2615.6205	60.1%
Togo	217	2297	57425	725	49575	40.9	71.7	358.4180	87.6%
Uganda	226	8204	205100	12075	131825	124.0	101.7	1490.3902	70.2%

Country	Country number	Number of cells	Country area (km^2)	Closed forest (km^2)	Open forest (km^2)	Closed forest mean biomass (Mg/ha)	Open forest mean biomass (Mg/ha)	Total biomass (10^6 Mg)	Percent of country forested
Burkina Faso	233	10957	273925	0	97375	0.0	34.0	331.0750	35.5%
Zaire	250	92433	2310825	1860300	378175	223.9	118.2	46122.1455	96.9%
Zambia	251	29846	746150	47250	579650	45.9	52.3	3248.4470	84.0%
		Total:	22694475	4025375	8156575		Total:	138709.1170	
		Total land in forest:		12181950	Average:	208.72	67.06		

Note: Biomass values have been rounded to the nearest 1/10th. Country areas were calculated from 5 × 5 km grid cells and are not authoritative. The closed and open forest average biomass values are weighted by area.

APPENDIX C: RECLASSIFICATION SCHEME USED TO OBTAIN THE FOUR LAND USE CATEGORIES USED IN THIS NUMERIC DATA PACKAGE

RECLASSIFICATION SCHEME USED TO OBTAIN THE FOUR LAND USE CATEGORIES USED IN THIS NUMERIC DATA PACKAGE

The 64 land cover classes in the original FAO land cover map (Lavenu 1987) were combined using the reclassification scheme shown here to obtain the 4 land use categories used in this numeric data package.

Land use category	FAO class number and land cover description
Closed Forest	
	Dense Forest
	1. Dense Forest (1a)
	2. Dense Forest–Dense Tree Thicket (1a-1b)
	3. Dense Forest–Dense Tree Thicket–Forest Fallow (1a-1b/6)
	4. Dense Forest–Miombo Woodland (1a-2a)
	5. Dense Forest–Miombo Woodland–Forest Fallow (1a-2a/6)
	6. Dense Forest–Discontinuous Tree/Shrub Thicket (1a-2b)
	7. Dense Forest–Discontinuous Tree/Shrub Thicket–Forest Fallow (1a-2b/6)
	8. Dense Forest–Discontinuous Tree/Shrub Thicket–Savanna Fallow (1a-2b/7)
	9. Dense Forest–Tree/Woodland Savanna (1a-2c)
	10. Dense Forest–Tree/Woodland Savanna–Cropland/Plantation (1a-2c/5)
	11. Dense Forest–Grass Savanna (1a-3a)
	13. Dense Forest–Forest Fallow (1a/6)
	14. Dense Forest–Forest Fallow–Miombo Woodland (1a/6-2a)
	15. Dense Forest–Forest Fallow–Tree/Woodland Savanna (1a/6-2c)
	Dense Tree Thicket
	16. Dense Tree Thicket (1b)
	17. Dense Tree Thicket–Discontinuous Tree/Shrub Thicket (1b-2b)
Open Forest	
	Woodland
	19. Miombo Woodland (2a)
	20. Miombo Woodland–Tree/Woodland Savanna (2a-2c)
	21. Miombo Woodland–Tree/Woodland Savanna–Forest Fallow (2a-2c/6)
	22. Miombo Woodland–Shrub Savanna/Steppe (2a-2d)
	23. Miombo Woodland–Grass Savanna (2a-3a)
	24. Miombo Woodland–Grass Steppe (2a-3b)
	26. Miombo Woodland–Forest Fallow (2a/6)

Land use category	FAO class number and land cover description

Open Forest (continued)

Discontinuous Trees

27. Discontinuous Tree/Shrub Thicket (2b)
28. Discontinuous Tree/Shrub Thicket Tree/Woodland Savanna (2b-2c)
29. Discontinuous Tree/Shrub Thicket Tree/Woodland Savanna Forest Fallow (2b-2c/6)
30. Discontinuous Tree/Shrub Thicket Tree/Woodland Savanna Savanna Fallow (2b-2c/7)
31. Discontinuous Tree/Shrub Thicket Shrub Savanna/Steppe (2b-2d)
32. Discontinuous Tree/Shrub Thicket Shrub Savanna/Steppe Savanna Fallow (2b-2d/7)
33. Discontinuous Tree/Shrub Thicket Grass Savanna (2b-3a)
34. Discontinuous Tree/Shrub Thicket Grass Steppe (2b-3b)
35. Discontinuous Tree/Shrub Thicket Cropland/Plantation (2b/5)
36. Discontinuous Tree/Shrub Thicket Forest Fallow (2b/6)

Woodland Savanna

37. Tree/Woodland Savanna (2c)
38. Tree/Woodland Savanna Discontinuous Tree/Shrub Thicket (2c-2b)
39. Tree/Woodland Savanna Shrub Savanna/Steppe (2c-2d)
40. Tree/Woodland Savanna Grass Savanna (2c-3a)
41. Tree/Woodland Savanna Grass Steppe (2c-3b)
42. Tree/Woodland Savanna Cropland/Plantation (2c/5)
43. Tree/Woodland Savanna Forest Fallow (2c/6)
44. Tree/Woodland Savanna Savanna Fallow (2c/7)

Shrub Savanna

45. Shrub Savanna/Steppe (2d)
46. Shrub Savanna/Steppe Grass Savanna (2d-3a)
47. Shrub Savanna/Steppe Grass Steppe (2d-3b)
48. Shrub Savanna/Steppe Pseudodesertic Steppe (2d-4a)
50. Shrub Savanna/Steppe Cropland/Plantation Grass Savanna (2d/5-3a)
51. Shrub Savanna/Steppe Savanna Fallow (2d/7)

Grassland Savanna

Grass Savanna

52. Grass Savanna (3a)
53. Grass Savanna Shrub Savanna/Steppe (3a-2d)
55. Grass Savanna Savanna Fallow (3a/7)

Grass Steppe

56. Grass Steppe (3b)
57. Grass Steppe Pseudodesertic Steppe (3b-4a)
58. Grass Steppe Cropland/Plantation (3b/5)

Land use category	FAO class number and land cover description
Grassland Savanna (continued)	
	Grass Steppe
	56. Grass Steppe (3b)
	57. Grass Steppe–Pseudodesertic Steppe (3b-4a)
	58. Grass Steppe–Cropland/Plantation (3b/5)
Other	
	Agriculture/Plantation
	12. Dense Forest–Cropland/Plantation (1a/5)
	18. Dense Tree Thicket–Forest Fallow (1b/6)
	25. Miombo Woodland–Cropland/Plantation (2a/5)
	49. Shrub Savanna/Steppe–Cropland/Plantation (2d/5)
	54. Grass Savanna–Cropland/Plantation (3a/5)
	62. Cropland/Plantation (5)
	63. Cropland/Plantation–Forest Fallow (5/6)
	64. Cropland/Plantation–Savanna Fallow (5/7)
	Desert
	59. Pseudodesertic Steppe (4a)
	60. Desert (4b)
	61. Halophytic Soil (4c)

Lavenu, F. 1987. *Vegetation Map of Africa 1:5,000,000.* Institute de la Carte Internationale de la Vegetation, Universitie Paul Sabatier, Toulouse, France. Distributed by FAO Forest Resources Assessment Project–1990, Rome, Italy.

APPENDIX D: A METHOD FOR EXTENDING THE DATA TO 1990 AND BEYOND

A METHOD FOR EXTENDING THE DATA TO 1990 AND BEYOND

The methodology used by Brown and Gaston (1995), and described in this numeric data package, for calculating the biomass data for 1980 is based on (1) a maximum potential biomass map, (2) a land use map for 1980, (3) population data for 1980, and (4) least-square regression equations for each land-cover type. This methodology lends itself extension into the future, as all that is needed to calculate biomass data for another year are a land cover map and population data for the year of interest.

The population data needed to extend this database are readily available from the United Nations or the World Bank. Accordingly, the remainder of this appendix describes a method for deriving new land-cover maps. In this example a new land-cover map will be derived for 1980 and 1990 based on currently available NOAA/NASA Pathfinder Advanced Very High Resolution Radiometer (AVHRR) satellite data (AVHRR data may be downloaded from http://daac.gsfc.nasa.gov/).

Data Selection

The data used in this analysis are 8 × 8 km resolution monthly composites of the Normalized Differential Vegetation Index (NDVI) for the months of April, August, and December. These months were chosen because April covers early spring in the North and fall in the South, August is late summer in the North and early spring in the South, and December is winter in the North and midsummer in the South. Thus the April and August data show the spring green-up in each hemisphere, while the December data, when used with the preceding two months of data, will identify those areas that have fairly constant (and high) NDVI values (i.e., evergreen forest).

The 1 × 1 km AVHRR data were not used here as this data includes many clouds and bad scan lines that were still visible in the 8-km composite data. However, the primary reason for not using the 1-km data was that the classified data obtained would have to be compared to the land use map for 1980 which was derived from an FAO map at a scale of 1:5,000,000. Thus, the classified 1-km data would have required degrading by averaging into the 5-km cells used in the 1980 land use map. This process would result in "islands" of 1 to 3 pixels. These pixels would not have been visible in the 1980 land use map and would have artificially lowered the calculated correlation coefficients between the AVHRR data and the original 1980 map. Thus, it was felt that the use of the 1-km AVHRR data was not justified.

Classification of the Data

In this example three monthly composite AVHRR NDVI data sets were obtained for August 1981, December 1981, and April 1982. The ocean portion of each band was masked, and an unsupervised classification was conducted by using the ERDAS™ Imagine software. Each band was run through the ERDAS™ noise filter, and the three bands were combined into one three-band image. An unsupervised classification was conducted with 10 iterations, convergence value of 98%, and 50 classes.

A more robust classification grouping could have been obtained if AVHRR data from more than one year had been used (e.g., August 1981, 1982, 1983, December 1981, 1982, 1983 and April 1982, 1983, 1984). The use of several years of data would act to overcome the effects of annual variability in precipitation distributions and the timing of the spring green-up. However, due to the computational intensive nature of analyzing large multilayer data sets, only one year's of data will be used in this demonstration.

The 50 classes were then grouped (Table D1) into the four land cover classes used in this study (i.e., closed forest, open forest/wooded savannah, grassland savannah, other). The grouping process was done to maximize the correlation between the classified 1981 AVHRR data and the 1980 land use map. The goal was to obtain a standard grouping scheme that could be used on other classified AVHRR data sets to obtain land-cover maps for other years (in this case 1990).

Table D1. Grouping scheme used for the classified 1981-1982 AVHRR data to obtain and a map comparable to the 1980 land use map.

Class	Group
0, 50	No-data (e.g., ocean, lakes)
23, 31-38	Closed forest
17-22, 27-30	Open forest (wooded savannah)
12-16, 24-26	Grassland savannah
1-11, 39-49	Other lands

A 3 × 3 pixel filter was then passed over the grouped AVHRR data to remove small islands from the data set, and the data were resampled to 5 × 5 km pixel size to match that used in the original 1980 land-use map, and a correlation analysis performed. The 3 × 3 filter was used as the original 1980 land use data were derived from a map with a scale of 1:5,000,000. Thus, land cover types of less than 1,000 km^2 would not have been represented in the 1980 land use map and their inclusion in the AVHRR land cover map would have served only to artificially reduce the calculated correlation coefficients.

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Comparison with the FAO 1980 Land Use Map

Correlation analysis was performed between the 1980 land-use map (Figure D1) and the grouped 1981-82 AVHRR data for all of Africa (Figure D2). This analysis was also done only for those cells within the study area (i.e., countries with population data for 1980). For all of Africa the Pearson correlation coefficient was 0.77, for areas within the study area it is was 0.74. An error matrix (Table D2) was then constructed to look at the distribution between the grouped AVHRR data and the original 1980 land-use map. Note that in the following we assume that the 1980 land use map is "correct" to the 5 km level -which it is not.

Table D2. The "error" matrix in percent (%) between the classified 1981-82 AVHRR image and the original 1980 land use map.

AVHRR 1981-82 → Land Use Map 1980↓	Closed forest	Open forest	Grassland savanna	Other
Closed forest	63.89 52.66	30.30 14.13	4.27 4.88	1.54 1.12
Open forest	21.76 36.22	64.68 60.92	12.69 29.29	0.87 1.29
Grassland savanna	8.90 5.97	42.27 16.05	36.08 33.56	12.76 7.59
Other	3.54 5.15	10.79 8.90	15.98 32.27	69.69 90.00

Note: These percentages only compare classified pixels that occur in both the land-use map and the classified 1981-82 AVHRR image.

Table D2 shows that 94% of those areas in the closed forest class per the FAO 1980 land use map were placed into the open or closed forest classes by the classified AVHRR image. The AVHRR image had 86% of those areas in open forest per the 1980 land use map in the open or closed forest classes. Of the cells in the AVHRR image that were in the "other" class, 98% were in the grassland savanna or "other" category per the 1980 land use map.

When compared on an area basis for Tropical Africa (as defined in this document) with the FAO 1980 land use map, the classified 1981-82 AVHRR image has 195,991, 346,008, 141,202, and 220,977 pixels in the closed forest, open forest, grassland savanna, and "other" categories. These values compare to values calculated using the 1980 FAO land-use map of 161,983, 326,834, 131,813, and 286,107 pixels in the closed forest, open forest, grassland savanna, and other categories. This translates to differences of +17%, +6%, +7%, and −29%.

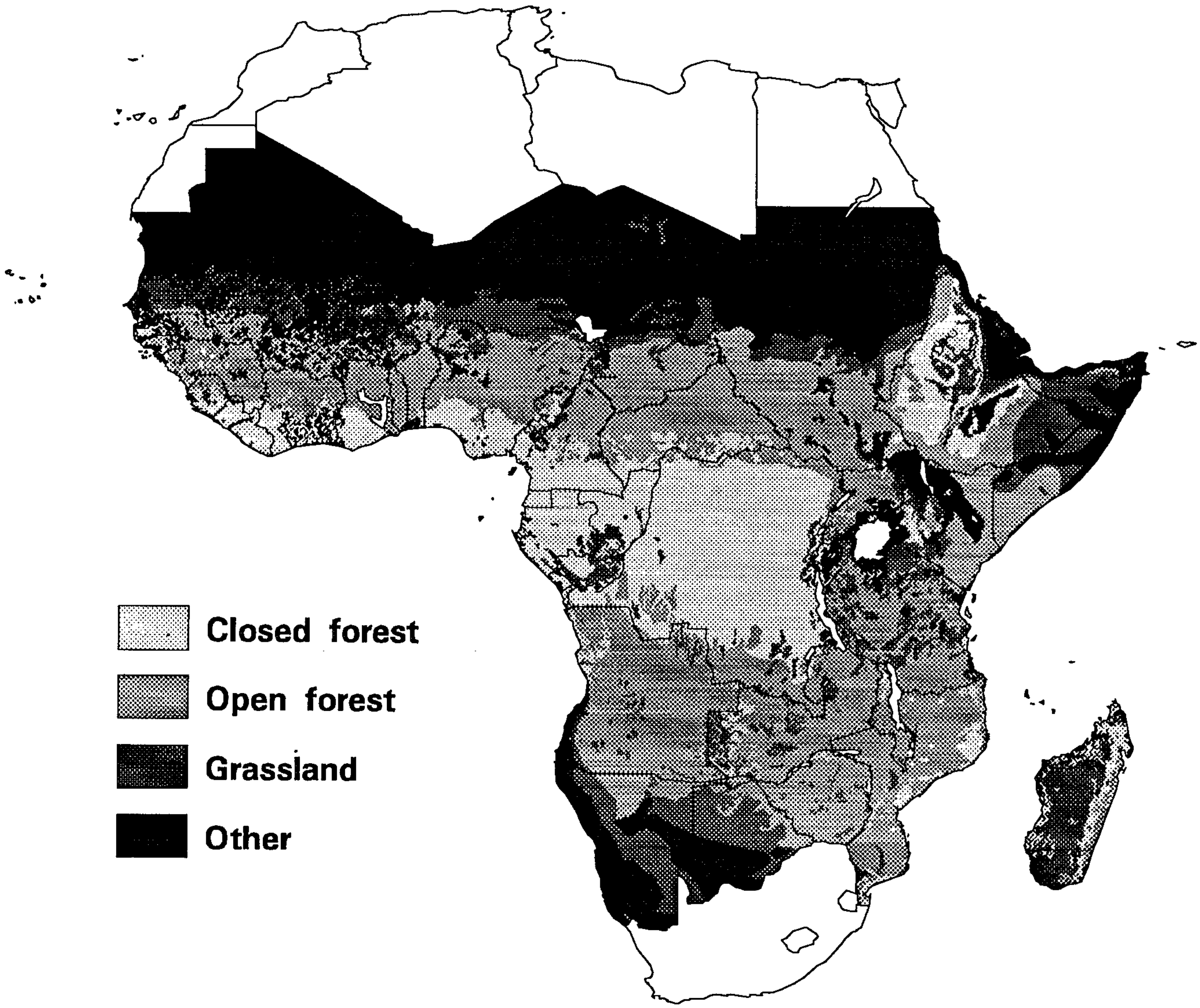

Figure D1. Map of Tropical Africa showing closed forest, open forest, grassland/savannah, and other (e.g., agriculture) land uses in 1980.

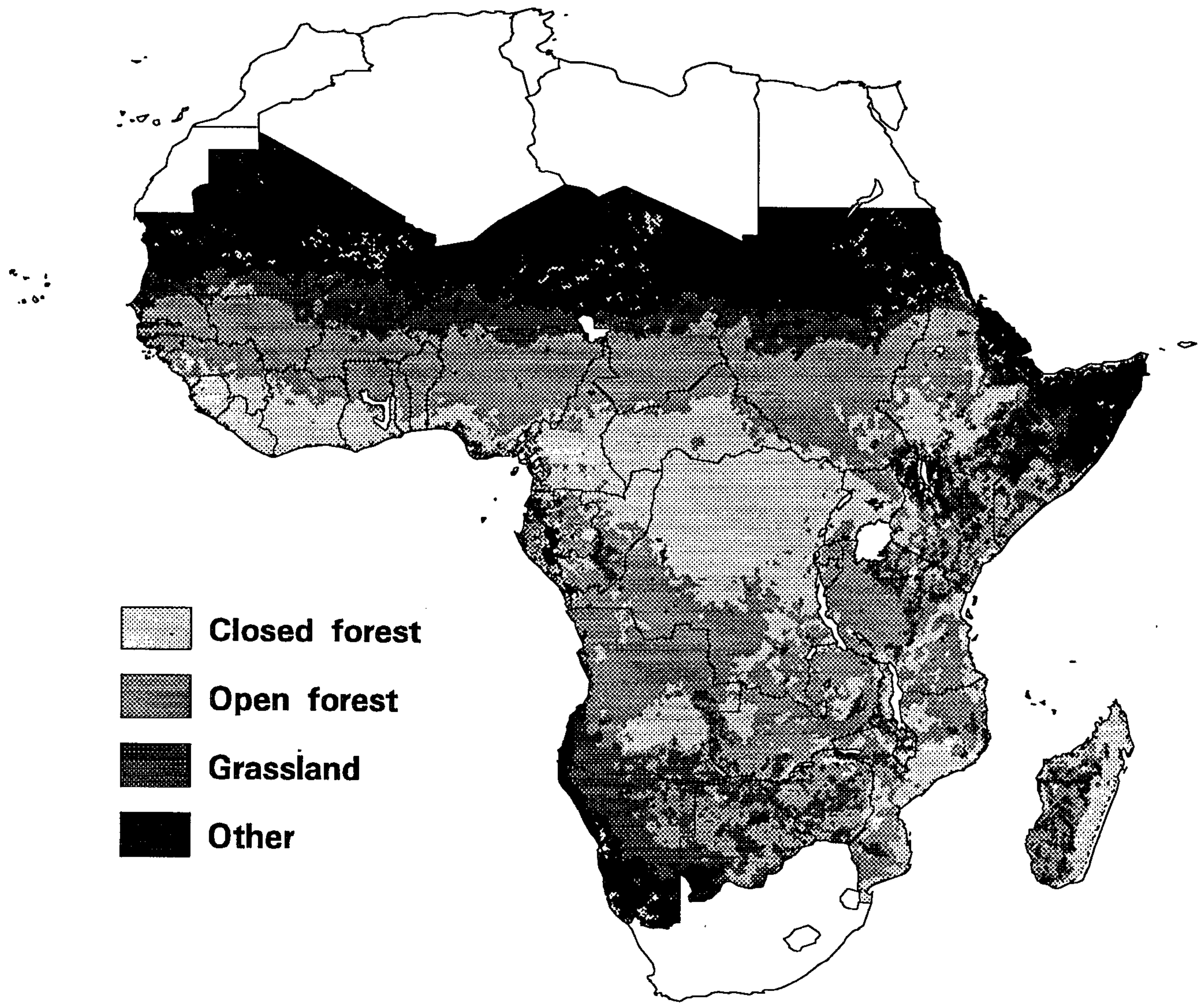

Figure D2. Land cover map of Tropical Africa derived from 1981-82 AVHRR data.

There are three primary causes for the transfer of land from the "other" land-cover category (which includes agriculture) to the closed forest, open forest, and grassland savannah land cover classes. First, the FAO 1980 land-use map does not include small tracts of open and closed forest that are located within regions that have been classified as being in the "other" land use category. Second, satellite signatures of pastures and many field crops are similar to grassland savannah. Lastly, tree plantations (e.g., palm oil, cocoa) were classified as agriculture. This last point is significant, as these plantations cover regions as large as 121,435 km^2 (4,857 pixels). The largest contiguous plantation regions are located around Lake Victoria, Lake Rudolf, and on the Ivory Coast. The amount of land in tree plantations in these three areas total 373,600 km^2 (14,944 pixels) alone. This accounts for 7% of the difference between the closed forest estimates provided by the FAO 1980 land use map and the classified 1981-82 AVHRR data.

Thus, the AVHRR classified image for 1980 has been shown to be equivalent to the FAO 1980 land use map for our purposes (with the proviso that tree plantations are managed forests and their biomass should be considered when determining the total amount of live aboveground biomass in Tropical Africa). Based on this conclusion the use of AVHRR data for the development of land-cover maps based on this methodology for other dates (1990 in this example) is justified.

Estimated Live Aboveground Biomass for 1990

Three monthly composite AVHRR NDVI data sets were obtained for August 1990, December 1990, and April 1990. The ocean portion of each band was masked, and an unsupervised classification was conducted as described in the 1980-81 AVHRR analysis. The 50 groups obtained by the unsupervised classifier were divided into four sets based on Table D1. Table D1 was modified slightly for use with the 1990 data (e.g., the definition for open forest was expanded from 17-22, 27-30 to 17-24, 28-30 and the definition of grassland savannah was shifted upwards from 12-16, 24-26 to 12-16, 25-27 and the group 23 --previously in closed forest, was moved to the open forest category). These modifications would have been minimized if multi-year sets of AVHRR data had been used in this demonstration (i.e., this would have accounted for interannual variations in precipitation and temperatures). The AVHRR land cover map for 1990 derived from this grouping process is shown in Figure D3.

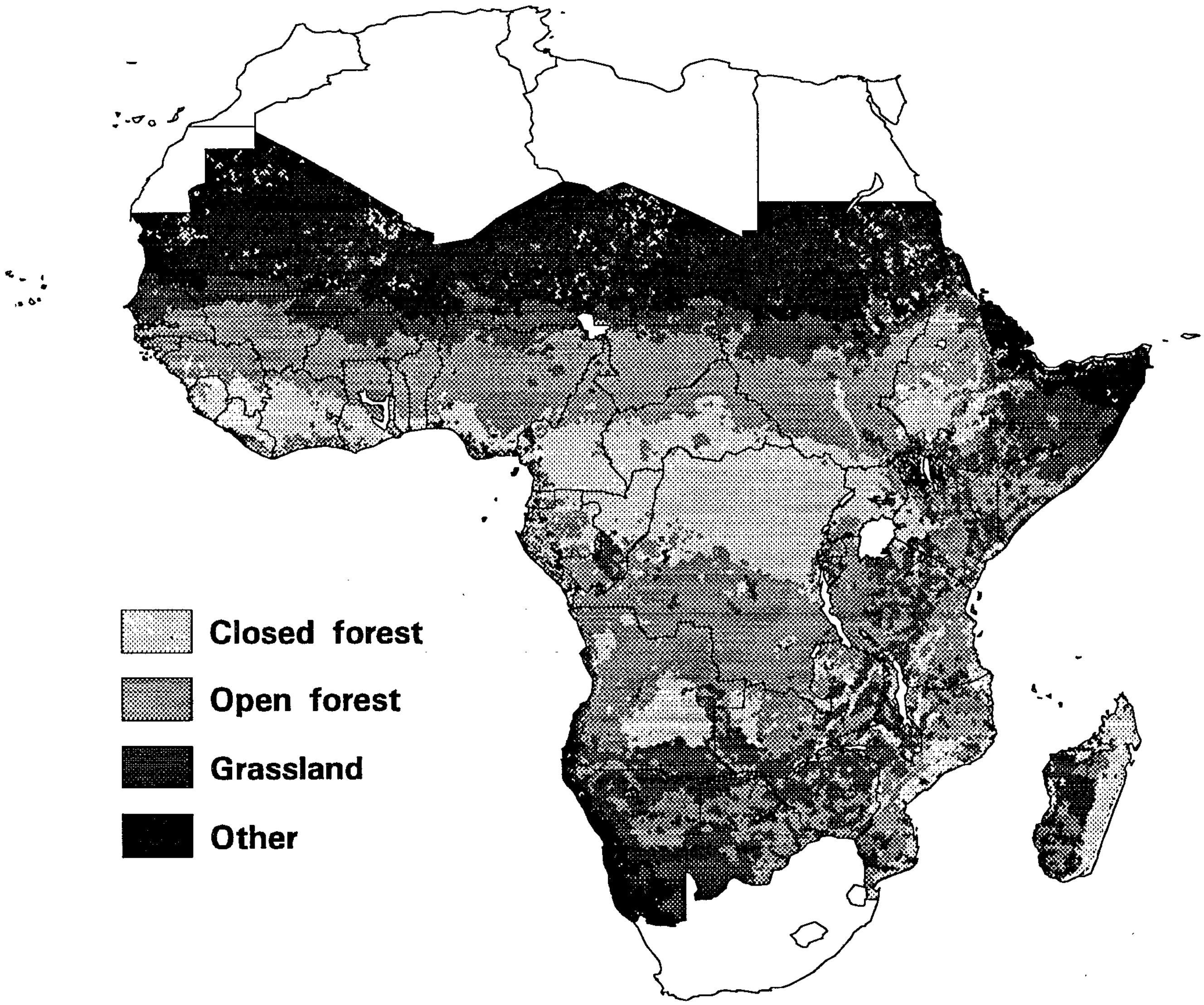

Figure D3. Land cover map of Tropical Africa derived from 1990 AVHRR data.

The area in each land-cover type in 1990, per the classified AVHRR images for 1981 and 1990, are compared in Table D3 to values calculated from the FAO 1980 land-use map. Table D4 contains estimates of the live aboveground biomass for 1980 and 1990 calculated on the basis of the AVHRR data and mean aboveground biomass values that were calculated for open and closed forest: these biomass values are based on Brown and Gaston (1995) and Appendix A.

Table D3. Area in each of the four land cover types per the FAO 1980 land use map and the classified AVHRR images for 1981-82 and 1990 (Values in 10^6 km^2).

	Closed forest	Open forest	Grassland savannah	Other (e.g., agriculture)
FAO 1980	4.049	8.170	3.295	7.153
AVHRR 1981-82	4.900	8.650	3.530	5.524
AVHRR 1990	4.050	7.865	4.939	5.750

Table D4. Estimated live aboveground biomass in open and closed forest, AVHRR estimates include tree plantations (values in 10^9 Mg). Estimates are based on mean 1980 biomass values for open forest and closed forest calculated from Appendix A.

	Closed forest	Open forest	Total
FAO 1980	84.51	54.78	139.3
AVHRR 1981-82	102.27	58.00	160.3
AVHRR 90	84.53	52.74	137.3

Note: Mean biomass values are 67.1 Mg/ha for open forest and 208.7 Mg/ha for closed forest.

The biomass values calculated for 1980 are based on the data distributed with this documentation, and differ from those obtained by using the AVHRR 1981-82 data by 13%. However, when the areas in large tree plantations (i.e., 373,600 km^2) near Lake Victoria, Lake Rudolf, and along the Ivory Coast are subtracted from the area in closed forest, and the AVHRR estimates for 1981-82 recalculated, total biomass in open and closed forest is 152.5 x 10^9 Mg. After correcting for these large plantations the 1981-82 AVHRR data are ~9% greater than those obtained using the FAO 1980 land use map. In light of the uncertainty in the mean biomass values used and the known limitations in the FAO 1980 land use map, these 1980 estimates can be considered equivalent.

Changes in Biomass from 1980 to 1990

Based on the assumption that the FAO 1980 and 1981-82 AVHRR estimates are equivalent, the change in biomass from 1980 to 1990 based on the AVHRR data may be estimated (in Table D4). In the ten years since ~1980 the total amount of live aboveground biomass in forests decreased by 23 × 10^9 Mg, a decreased of 14% from 1980 to 1990. The area in closed forest and open forest decreased by 850,000 km^2 and 785,000 km^2, respectively. The total forested area in Tropical Africa was reduced by 1,635,000 km^2, or 12%.

In contrast, recent work conducted at the subnational level by Greg Gaston and Sandra Brown (pers. comm.) based on FAO forest cover data for 1980 and 1990 derived an estimated decrease in forest biomass of only 6.6 × 10^9 Mg (one-fourth that derived from the AVHRR data). For there analysis, the FAO data gave an estimated net loss of forestland between 1980 and 1990 of 390,760 km^2.

The large discrepancy between these two analyses may be due to differences in the definition of forest used here and those of the FAO. For example, in 1980 the classified AVHRR data had 4.9 × 10^6 km^2 of closed forest and 8.65 × 10^6 km^2 of open forest. In contrast, the FAO data indicated that 5.39 × 10^6 km^2 of land were forested in 1980.

It appears that the area estimates differ for two reasons. Firstly, the FAO does not include most open forests in their forestland class (i.e., the FAO classifies land based on land use, not by land cover type). Secondly, the FAO does not consider the clearing of land for shifting cultivation as cause to reclassify a parcel of land from their forest class.

Conclusion

The biomass estimates discussed in this appendix are based on mean live aboveground biomass values that were derived for 1980. As a result, the 1990 estimates in Table D4 underestimate the total reduction in biomass from 1980 to 1990 (i.e., the degradation ratio described in Part 1 of this document was not used). This underestimation is due to the continued increase in population densities that have occurred over the last decade in Tropical Africa.

The 1990 biomass values calculated here are estimated based on 1980 mean forest biomass values and a land cover map for 1990 that was derived from only three composite AVHRR images. Because of this, the 1990 values shown here should be used with caution as they were derived here for demonstration purposes only.

However, the process described in this Appendix successfully derived two "new" land cover maps for Tropical Africa using readily available AVHRR data sets. These maps were then used to estimate the change in biomass over the last ten years. Thus, this appendix has demonstrating that land cover maps can be derived from readily available AVHRR data, or similar data sets, and may be used in conjunction with the methodology described in Part 1 of this document to obtain biomass estimates that are comparable to those presented here for 1980.

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