1990—2000 Forest Cover and Change in Eastern Arc Mountains and Coastal Forests

25 0 25 50 75
kilometers
scale: 1/1,000,000
projection: Lamberts Equal Area Azimuthal
38° east longitude 7° south latitude
source image resolution: 28.5 meters

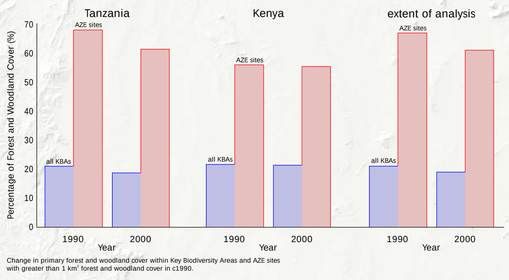
land cover
- forest lost by 2000
- woodland lost by 2000
- mangrove lost by 2000
- forest *both dates*
- woodland *both dates*
- forest and woodland 1990s *cloud 2000*
- mangroves
- nonforest *both dates*
- cloud 1990s *nonforest 2000*
- cloud *both dates*
- water
- sea (*outside of analysis*)

- Alliance for Zero Extinction (AZE) site
- Key Biodiversity Area *(extent, geographic extent unavailable)*
- CEPF funding area
- international political border
- district border
- town (national capitals underlined) *(extent, location only)*
- wetland

The Eastern Arc Mountains and Coastal Forests of Tanzania and Kenya has among the highest density of endemic species of any biodiversity hotspot in the world. The combination of extraordinary species endemism and an extremely high degree of threat led to the designation of this region as a biodiversity hotspot. This is one of the regions of the world that is likely to witness significant species extinctions in the coming decades. In 2004, a refinement of the original hotspots analysis resulted in this region being included as important parts of two larger, separate hotspots: the Eastern Afromontane – the montane regions of eastern and north-eastern Africa, and the Coastal Forests of Eastern Africa – which include a lowland forest mosaic along the coast of East Africa. However, this area still covers over 30,000 km^2, thus further prioritization is required to direct investment towards conservation sites on the ground. The Critical Ecosystem Partnership Fund (CEPF) investment in the region is focused on conserving the region's 333 globally threatened species, which are primarily found within 133 Key Biodiversity Areas (KBAs), which are sites of global significance for biodiversity conservation. The highest priority KBAs are called Alliance for Zero Extinction (AZE) sites; these sites contain one or more highly threatened species found nowhere else on Earth, thus, if an AZE site is lost one or more species will be extinct. CEPF's strategy in the region is to select sites for conservation intervention that deliver maximum conservation impact in terms of preventing extinctions, restore and increase connectivity among fragmented forest patches, increase protected area coverage, and assist communities to develop alternative livelihoods that prevent further forest destruction. Mapping the baseline of forest cover is key to carrying out this strategy. Finally, monitoring KBAs and AZE sites provides an important measure of both overall threat to biodiversity and success of current conservation efforts.

Change in primary forest and woodland cover from 1990 to 2000 within Key Biodiversity Areas (KBAs) and Alliance for Zero Extinction (AZE) sites

Habitat loss is the primary factor threatening species with extinction. Thus, the single most effective means of conserving biodiversity worldwide is by protecting Key Biodiversity Areas—sites where threatened and restricted-range species occur. Remote sensing data helps us understand the human and natural modifications to habitats that support important biodiversity. Fine-resolution, low-cost satellite data can be analyzed to track changes over time in habitat cover. In this case we mapped change in primary forest and woodland cover within KBAs between 1990 and 2000. In East Africa, primary forest and woodland are important habitats for many globally threatened and range-restricted species, with the forests being of particular importance.



Change in primary forest and woodland cover within Key Biodiversity Areas and AZE sites with greater than 1 km^2 forest and woodland cover in c1990.

The chart above shows change in the proportion of natural habitat cover for all KBAs and AZE sites. Findings across the extent of analysis show that overall habitat extent is greater for AZE sites compared to all KBAs. However, a higher rate of habitat decline is seen within AZE sites compared with all KBAs during the 10-year period. Similar overall habitat extent and rate of loss is seen for Tanzanian KBAs and AZE sites. For Kenya however, results show a lower rate of habitat loss in KBAs and AZE sites.

Conclusion

There is a great need to continue directing conservation investments within KBAs; in particular AZE sites where habitat loss threatens species more susceptible to extinction. Such conservation efforts need to be based upon sound science and address the needs of the communities reliant on the products and services provided by the forests.

Monitoring and reporting of biodiversity status, pressures and conservation responses must also continue over the long-term. In a world of limited resources and increased accountability, it is essential that such biodiversity monitoring efforts serve as a central means for guiding government policy and conservation planning and investment in East Africa. By systematically monitoring national and regional biodiversity status and trends we can support both reporting obligations and natural resource decision-making processes; specifically where, how and why future biodiversity conservation investment and strategies should be dedicated.

Primary Forest and Woodland Cover Change 1990—2000

by KBA

	Kenya KBA	c1990 (sq km)	c2000 (sq km)	loss (percent)
1	Arabuko-Sokoke Forest	325.60	325.26	0.10
5	Boni Forest	224.10	224.10	0
6	Buda FR	4.01	4.00	0.12
12	Dakatcha Woodland	37.61	32.94	12.42
15	Dodori	20.57	20.57	0
17	Dzombo Hill Forest	1.29	1.29	0
20	Gongoni FR	4.48	4.48	0
26	Kaya Dzombo	2.20	2.20	0.26
29	Kaya Gonja	1.07	1.07	0
64	Lunghi	125.97	125.95	0.02
68	Mangea Hill	8.80	6.70	23.89
69	Marafa	3.72	3.38	9.24
70	Marenji Forest	12.29	12.29	0
78	Mount Kasigau	2.15	2.14	0.42
79	Mrima Hill Forest	2.75	2.75	0
† 107	Shimba Hills	124.42	124.36	0.05
108	Shimoni Forests	7.09	7.04	0.60
† 110	Taita Hills Forests	4.13	3.15	23.73
111	Tana River Delta	10.55	10.54	0.12
112	Tana River Forests	52.42	49.82	4.96
129	Witu FR	26.26	26.26	0

	Tanzania KBA	c1990 (sq km)	c2000 (sq km)	loss (percent)
3	Bagamoyo (Kikoka FR)	7.87	7.84	0.37
4	Bagamoyo District CF	113.42	106.30	6.28
† 18	East Usambara Mountains	268.41	259.94	3.16
21	Handeni District CF	47.30	44.19	6.57
47	Kilombero Valley	448.35	167.91	62.55
48	Kilwa District CF	994.61	990.53	0.41
49	Kisarawe District CF	202.90	201.70	0.59
59	Lindi (Nyangao River)	22.89	22.25	2.77
62	Lindi Creek	4.03	3.99	1.01
63	Lindi District CF	311.40	304.88	2.09
66	Magombera FR	3.60	0.92	74.54
67	Mahenge Mountains	23.01	21.85	5.00
74	Mikindani (Mnima)	7.09	7.09	0
75	Mikumi National Park	306.61	289.52	5.57
77	Mnazi Bay	42.33	39.30	7.17
81	Muheza District CF	15.16	14.51	4.28
83	Newala (Kitama)	19.25	18.68	2.95
86	Newala District CF	35.18	29.53	16.04
87	Nguru Mountains	280.39	265.02	5.48
88	Nguu Mountains	226.38	189.24	16.40
89	North Pare Mountains	10.91	10.42	4.48
92	Pande GR and Dondwe CF	8.91	7.41	16.88
97	Pangani District CF	20.92	20.67	1.17
† 102	Rubeho Mountains	303.48	277.39	8.60
103	Rufiji Delta	79.69	77.38	2.90
104	Rufiji District CF	74.76	74.10	0.87
106	Selous GR	4276.10	4015.32	6.10
109	South Pare Mountains	143.08	126.00	11.94
† 122	Udzungwa Mountains	2419.55	2012.48	16.82
† 123	Ukaguru Mountains	151.93	143.56	5.51
† 124	Uluguru Mountains	308.06	280.47	8.96
125	Uvidunda Mountains	89.99	26.62	70.42
† 128	West Usambara Mountains	243.45	224.47	7.80

Primary forest and woodland loss statistics in Key Biodiversity Areas with greater than 1 km^2 primary forest and woodland cover in c1990 in extent of analysis
† Denotes Alliance for Zero Extinction (AZE) site
CF = Coastal Forests FR = Forest Reserve GR = Game Reserve

by district

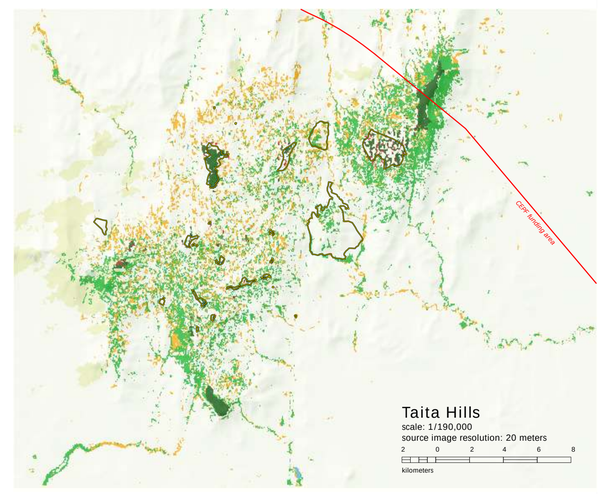
Kenya District	total area (sq km)	c1990 (sq km)	c2000 (sq km)	loss (percent)
Garissa	18,486	1,215	1,211	0.35
Kilifi	4,646	243	232	4.64
Kwale	8,460	232	228	1.65
Lamu	6,140	963	962	0.16
Malindi	7,748	659	620	5.90
Mombasa	213	less than 1	less than 1	5.54
Tana River	21,270	357	348	2.32

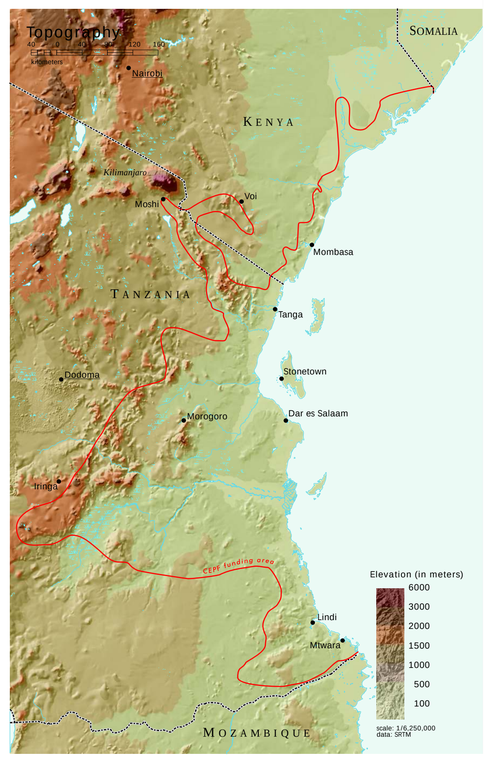
Tanzania District	total area (sq km)	c1990 (sq km)	c2000 (sq km)	loss (percent)
Bagamoyo	8,535	1,421	1,240	12.75
Handeni	8,045	2,810	1,676	40.34
Ilala	335	13	11	10.32
Iringa Urban	147	0	0	0
Kibaha	1,836	438	414	5.56
Kilindi	8,983	2,282	1,812	20.61
Kilolo	13,054	1,683	883	47.53
Kilombero	13,033	1,255	864	31.18
Kilosa	11,754	4,738	4,641	2.04
Kilwa	547	35	27	23.53
Kinondoni	4,856	1,771	1,720	2.92
Kisarawe	1,894	9	4	54.05
Kiteto	6,294	966	604	37.46
Korogwe	3,137	296	235	20.47
Lindi Rural	6,315	3,474	3,378	2.77
Lindi Urban	240	48	46	3.36
Liwale	20,382	4,640	4,540	2.17
Lushoto	4,081	577	386	33.15
Masasi	1,005	188	183	2.28
Mkuranga	2,722	952	888	6.76
Morogoro Rural	12,977	1,403	1,146	18.29
Morogoro Urban	535	29	22	21.82
Mpwapwa	4,928	160	122	23.96
Mtwara Rural	3,860	2,142	1,947	9.11
Mtwara Urban	195	70	64	7.67
Mufindi	6,761	537	360	32.85
Muheza	4,209	524	495	5.42
Mvomero	6,240	606	463	23.59
Mwanga	1,750	36	31	14.76
Newala	1,459	353	334	5.46
Njombe	4,163	155	70	55.17
Pangani	1,785	263	237	10.02
Ruangwa	1,382	633	628	0.77
Rufiji	13,177	3,767	3,665	2.71
Same	6,338	235	172	26.88
Songea Rural	501	26	3	89.32
Tandahimba	1,882	771	691	10.43
Tanga	594	6	4	20.11
Temeke	749	33	32	3.69
Ulanga	17,066	2,102	1,377	34.50

Primary forest and woodland loss statistics by district within extent of analysis

Roster of Key Biodiversity Areas
† Denotes Alliance for Zero Extinction (AZE) site

1 Arabuko-Sokoke Forest
2 Bagamoyo
3 Bagamoyo (Kikoka Forest Reserve)
4 Bagamoyo District Coastal Forests
5 Boni Forest
6 Buda Forest Reserve
7 Bungu
8 Cha Shimba
9 Chale Island
10 Chivara
11 Chuna Forest
12 Dakatcha Woodland
13 Dar es Salaam Coast
14 Diani Forest
15 Dodori
16 Dzitzoni
17 Dzombo Hill Forest
† 18 East Usambara Mountains
19 Gede Ruins National Monument
20 Gongoni Forest Reserve
21 Handeni District Coastal Forests
22 Jozani National Park, Zanzibar
23 Kambe Rocks
24 Kaya Bombo
25 Kaya Chonyi
26 Kaya Dzombo
27 Kaya Fungo
28 Kaya Gandini
29 Kaya Gonja
30 Kaya Jibana
31 Kaya Kambe
32 Kaya Kauma
33 Kaya Kinondo
34 Kaya Lunguma
35 Kaya Msambweni
36 Kaya Mtswakara
37 Kaya Muhaka
38 Kaya Mwarakaya
39 Kaya Puma
40 Kaya Rabai
41 Kaya Ribe
42 Kaya Sega
43 Kaya Teleza
44 Kaya Tiwi
45 Kaya Ukunda
46 Kaya Waa
47 Kilombero Valley
48 Kilwa District Coastal Forests
49 Kisarawe District Coastal Forests
50 Kisiju
51 Kisimani wa Ngoa
52 Kisite Island
53 Kiunga Marine National Reserve
54 Korogwe (Kwashemshi Sisal Estate)
55 Latham Island
56 Lindi
57 Lindi (Mkindani)
58 Lindi (Ngongo)
59 Lindi (Nyangao River)
60 Lindi (Ras Rungi)
61 Lindi (Tendaguru)
62 Lindi Creek
63 Lindi District Coastal Forests
64 Lunghi
65 Mafia Island
66 Magombera Forest Reserve
67 Mahenge Mountains
68 Mangea Hill
69 Marafa
70 Marenji Forest
71 Masasi
72 Masasi (Nyengedi)
73 Mida Creek, Whale Island and the Malindi-Watamu Coast
74 Mikindani (Mnima)
75 Mikumi National Park
76 Mkomazi Game Reserve
77 Mnazi Bay
78 Mount Kasigau
79 Mrima Hill Forest
80 Mtwara District Coastal Forests
81 Muheza District Coastal Forests
82 Mwache Forest Reserve
83 Newala (Kitama)
84 Newala (Kitangari)
85 Newala (Mahuta)
86 Newala District Coastal Forests
87 Nguru Mountains
88 Nguu Mountains
89 North Pare Mountains
90 Nyumba ya Mungu Reservoir
91 Nzovuni River
92 Pande Game Reserve and Dondwe Coastal Forests
93 Pangani
94 Pangani (Bushiri)
95 Pangani (Mwera)
96 Pangani Dam
97 Pangani District Coastal Forests
98 Pangani River (Hale-Makinjumbe)
99 Pangani River (Mauri)
100 Pemba Island
101 Ras Kituani
† 102 Rubeho Mountains
103 Rufiji Delta
104 Rufiji District Coastal Forests
105 Sabaki River Mouth
106 Selous Game Reserve
† 107 Shimba Hills
108 Shimoni Forests
109 South Pare Mountains
† 110 Taita Hills Forests
111 Tana River Delta
112 Tana River Forests
113 Tanga (Duga)
114 Tanga (Gombero Forest Reserve)
115 Tanga (Morongo)
116 Tanga (Nyamaku)
117 Tanga (Pangani)
118 Tanga North - Kibo Saltpans
119 Tanga South
120 Tsavo West National Park
121 Tumbatu Island
† 122 Udzungwa Mountains
† 123 Ukaguru Mountains
† 124 Uluguru Mountains
125 Uvidunda Mountains
126 Uzaramo (Dar to Morogoro)
127 Uzaramo (Msua)
† 128 West Usambara Mountains
129 Witu Forest Reserve
130 Zanzibar (Kiuani)
131 Zanzibar (Muyuni)
132 Zanzibar Island-East Coast
133 Zanzibar Island-South Coast





Forest Analysis Data

Coastal Forests

Baseline forest cover analysis for the Coastal Forests of Tanzania and Kenya was performed as part of a CEPF-funded BirdLife International project, "Instituting a standardized, sustainable biodiversity monitoring system in the Eastern Arc Mountains and Coastal Forests Hotspot."

Analysis conducted by:
B.P. Mbilinyi and J. Kashaigili
Sokoine University of Agriculture. Morogoro, TZ
K. Tabor and M. Steininger
Center for Applied Biodiversity Science. Arlington, VA USA
Acknowledgment: Neil Burges, John Watkin

Eastern Arc Mountains

The forest area baseline for the Eastern Arc Mountains was commissioned by the Forestry and Beekeeping Division (FBD) of the Ministry of Natural Resources and Tourism in Tanzania, through the project Conservation and Management of Eastern Arc Mountain Forests (CMEAMF) financed by the Global Environment Facility (GEF) through the United Nations Development Programme (UNDP).

Analysis conducted by:
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Sokoine University of Agriculture. Morogoro, TZ
Acknowledgment: Neil Burges, Felician Kilahama, and Ministry of Natural Resources and Tourism

Taita Hills

Forest cover analysis of the Taita Hills carried out as part of the TAITA project funded by the Academy of Finland.[1]

Analysis conducted by:
B.J.F. Clark and P.K.E. Pellikka
University of Helsinki. Helsinki, FI

1. B.J.F. Clark and P.K.E. Pellikka, 2008. Landscape analysis using multiscale segmentation and object orientated classification. In: Aplin, P. (ed.) *Recent Advances in Remote Sensing and Geoinformation Processing for Land Degradation Assesment.* Taylor & Francis.

Methodology

Eastern Arc Mountains and Coastal Forests

Forest cover and change was mapped by analyzing Landsat satellite imagery from circa 1990 and circa 2000. Most of the images were obtained for free from NASA's Geocover project, which stores data at the University of Maryland's Global Land Cover Facility (www.landcover.org). Additional images for cloudy areas were purchased from USGS and SPOT to have more complete coverage.

The analysis was conducted at a spatial resolution of 28.5 meters. The Landsat images from circa 1990 and circa 2000 were combined into one file, and the classification of forest cover and change was conducted in a single process with the multi-temporal data. The classification algorithm applied was a supervised maximum likelihood classifier. In this process, analysts delineate training sites for each land cover or change class, based on visual interpretation, and referring to ground reference data and high-resolution QuickBird imagery available on Google Earth. The entire Landsat images are classified based on the statistics of the image data in each class. The final classification was filtered to remove patches of less than 2 hectares. This method follows that reported in Harper et al.[2]

The Eastern Arc forest and woodland cover and change analysis incorporated ground truthing data from the following mountain blocks: Uluguru, Ukaguru, Rubeho, Mahenge, Image and Udzungwa. Twenty-meter SPOT imagery was also used to assist image interpretation for the East Usambara, Nguru, Nguu, Ukaguru, Rubeho, and Uluguru mountain blocks.

Accuracy of the land cover classification of the Coastal Forest region was estimated using high-resolution QuickBird imagery acquired between 2000 and 2001. Over 3,000 randomly-selected points from available high-resolution images were used in the accuracy assessment. These points were visually interpreted and labeled according to their true class, and then intersected with the final map to determine areas of agreement and disagreement. The overall map accuracy is 88% for forest cover in circa 2000.

2. Harper, G., Steininger, M.K., Tucker, C.J., Juhn, D. and Hawkins, F. 2007. Fifty Years of Deforestation and Forest Fragmentation in Madagascar. *Environmental Conservation* 34:1-9.

Taita Hills

A multi-scale segmentation/object relationship modeling (MSS/ORM) approach was applied to map land cover at a landscape level in the Taita Hills. The software tool used was eCognition. Various segmented image object spectral, contextual and hierarchical properties were utilized in the classification process. The output map was subject to final visual inspection and manual editing of any noted errors, relative to the SPOT imagery. Overall map accuracy of 89% was calculated using ground reference test data collected during field visits to the Taita Hills in January 2005 and 2006 and from 0.5m resolution true-color digital aerial photography flown in January 2004 (3 months after the SPOT acquisition date).

Landsat imagery used in Eastern Arc and Coastal Forest analyses

Path	Row	Date c1990	Date c2000	Analysis
165	61	09/01/1995	01/03/2005	Coastal Forest
165	62	18/03/1988	22/03/2001	Coastal Forest
165	66	12/03/1993	22/05/2000	Coastal Forest
165	67	07/06/1991	22/05/2000	Coastal Forest
166	61	26/01/1987	19/07/2001	Coastal Forest
166	62	25/06/1992	22/01/2000	Coastal Forest
166	63	16/06/1986	30/01/2003	Coastal Forest
166	64	26/01/1987	30/01/2003	Coastal Forest
166	65	09/06/1995	30/06/2000	Coastal Forest
166	66	08/06/1989	30/06/2000	Coastal Forest
167	63	01/01/1987	25/10/1999	Eastern Arc
167	64	02/07/1995	17/08/2003	Eastern Arc
167	65	05/06/1991	07/07/2000	Eastern Arc
167	66	05/06/1991	25/10/1999	Eastern Arc
168	65	11/07/1990	01/11/1999	Eastern Arc
168	66	11/07/1990	01/11/1999	Eastern Arc

SPOT imagery used in Taita Hills analysis

Date	Path	Row	Sensor
1990	143	143	SPOT 2
2000	357	357	SPOT 4

The Critical Ecosystem Partnership Fund is a joint initiative of l'Agence Française de Développement, Conservation International, the Global Environment Facility, the Government of Japan, the John D. and Catherine T. MacArthur Foundation, and the World Bank. A fundamental goal is to engage nongovernmental organizations, community groups, and other sectors of civil society in conserving Earth's biodiversity hotspots.

The political and geographic designations shown on this map do not imply the expression of any opinion on the part of Conservation International or any of its partners concerning the legal status or delineation of the frontiers of any country, territory or area.

data:
BirdLife International
Center for Applied Biodiversity Science at Conservation International, Arlington, VA USA
Forestry and Beekeeping Division Ministry of Natural Resources and Tourism, Tanzania
Global Shoreline Database, January 2001, Veridian (GDAIS)
Institute of Resource Assessment at the University of Dar es Salaam
International Livestock Research Institute
Kenya Forest Service
Nature Kenya
VMap0, National Geospatial-Intelligence Agency
Wildlife Conservation Society of Tanzania
World Wildlife Fund - Tanzania
World Wildlife Fund - United States

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Photo courtesy of Kerith Frank / Elizabeth B. Harper