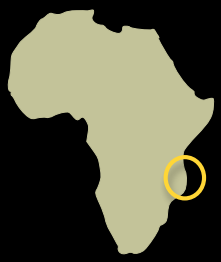
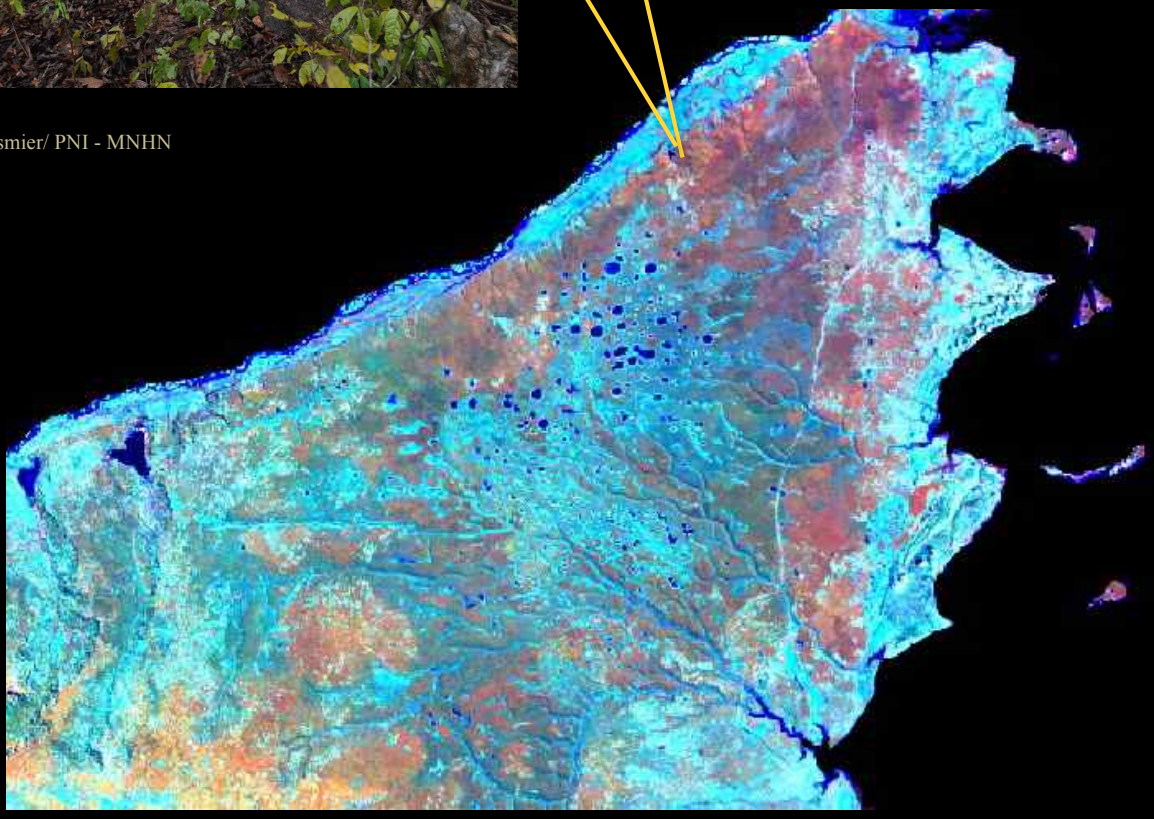
Mozambique 2008–2009





Observations on the Vegetation and Ecology of Palma and Nangade Districts, Cabo Delgado Province, Mozambique

G. Philip Clarke

March 2011

Citation: Clarke, G.P. (2011). *Observations on the Vegetation and Ecology of Palma and Nangade Districts, Cabo Delgado Province, Mozambique.* 130pp. Downloaded from http://coastalforests.org/

This report can also be downloaded from the Tanzania Forest Conservation Group website:

http://cf.tfcg.org/mozambique.html or http://coastalforests.tfcg.org/mozambique.html

Throughout this report the Mozambican spelling of Rovuma is used for the Ruvuma River.

This report is intended to be viewed in double page format.

Photos by the author unless otherwise stated.

Cover photos:
Emergent baobab *Adansonia digitata* and *Euphorbia* sp. over dense woodland near the village of Nhica do Rovuma (top).
Multi-stemmed emergent *Milicia excelsa* in scrub forest east of Lake Nhica do Rovuma at 10°42'10"S, 40°13'21"E (bottom).
Satellite photo derived from LandSat 7 images from 2000 analysed by Erik Prins of Prins Engineering, www.prinsengineering.com

This report acknowledges the tremendous contribution by the Prince Albert II Foundation of Monaco, the Total Foundation and the Stavros Niarchos foundation in funding the 'Our Planet Reviewed' expeditions to Cabo Delgado Province of northern Mozambique, an area that was largely unexplored by biologists and considered to be of little biodiversity interest.

Through the generous funding from the above institutions, Pro-Natura International and the French Museum of Natural History, in partnership with the Instituto de Investigação Agrãria de Moçambique, have been able to identify and visit potential key sites in Cabo Delgado through a systematic methodology of first analysing satellite images, followed by a low-level aerial survey to verify findings, and finally by extensive ground visits to collect specimens.

The majority of biological exploration and research today is focussed on areas that are already known to be rich in endemism and diversity. The above institutions therefore took a considerable financial risk by funding research in an area that was almost blank on the scientific map, but which, as a consequence of these expeditions, is now known to be of global biodiversity importance.

Without the support of the Prince Albert II foundation, the Total Foundation and the Stavros Niarchos foundation, it is unlikely that such a detailed investigation of the forests of Palma District and the southern rim of the Rovuma River would have been made for many years, by which time they would have become severely degraded and some of the ecological insights gained during these expeditions would have been impossible.

It is hoped that the results of these expeditions will place the Palma and Nangade District forests on the global biodiversity map, and encourage further research and conservation effort here.

Author's note

This report is a personal tribute to the unique heavily wooded landscape of Palma District in Mozambique. It attempts to document a series of observations made on its forests and their ecology, in the awareness that this task may become more difficult in the future as the area will change beyond recognition over the coming years. Numerous geo-referenced photos of the different vegetation types are included to provide baseline photo documentation, and to facilitate the analysis of satellite data for vegetation mapping.

The forests and dense woodlands of Palma District are extensive, and together provide the highest wooded cover of the entire eastern African coast. Yet despite their considerable extent, the forests are generally in poor condition and almost every site visited showed clear signs of having regenerated from relatively recent clearance/cultivation (within the last 60 years). The apparently huge scale of forest regeneration that has taken place here is unparalleled in eastern Africa in recent times (but may also have taken place in SE Tanzania).

Interpreting and classifying this complex vegetation mosaic involves a degree of uncertainty because so little is known about its former extent and condition. Furthermore, few data are available on the dynamics of forest regeneration in the eastern African (Swahilian) Coastal Forests, which are elsewhere being degraded or cleared rather than regenerating/expanding.

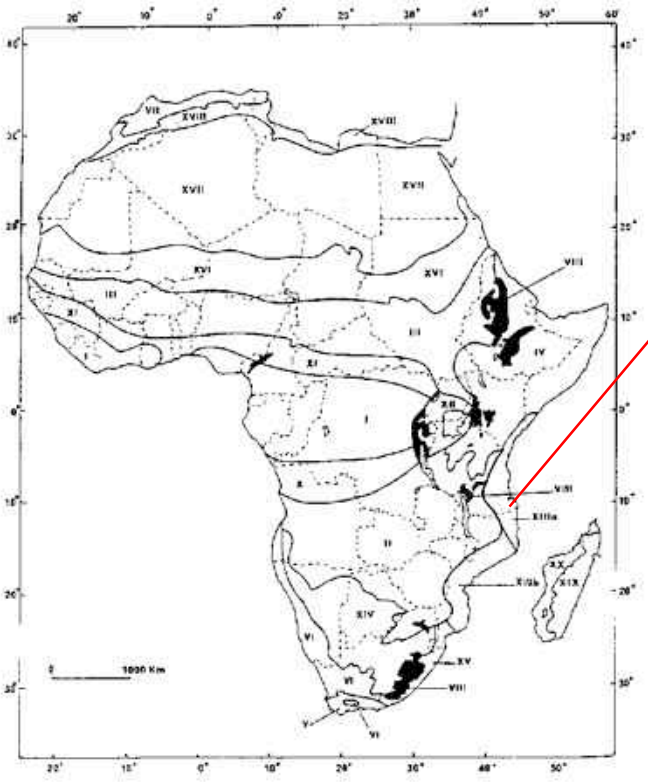
The interpretation of the vegetation of Palma and Nangade Districts therefore differs slightly from that by Timberlake *et al.* (2010) in their recent report on the dry forests of Cabo Delgado Province in Mozambique. They exclude much of the regenerating scrub forest from their enumeration of the extent of Coastal Forest, as these areas are species-poor and therefore of lower concern for biodiversity conservation. A wider approach is taken in this report, as depauperate scrub forest has other conservation values that include a refuge for game animals, a natural source of hardwood timber, a store of carbon and an important motor for the ongoing sequestration of carbon from the atmosphere. Furthermore it is believed that scrub forest could eventually recover to forest, as the most species-rich Coastal Forest in eastern Africa – the nearby Rondo Forest in SE Tanzania – has itself regenerated from severe disturbance over 100 years ago (Clarke 1995, p. 32 & 36) and rare birds have been observed in areas of plantation forest that were established even more recently. The regenerating scrub forests of Palma and Nangade might then develop into impressive forests if they are given the century of protection that the Coastal Forests in neighbouring Tanzania have already enjoyed.

It can also be difficult to draw a distinct line between dry forest and dense woodland; Timberlake *et al.* exclude all habitats that contain *Brachystegia spiciformis*, as this common miombo woodland tree may be indicative of poor-quality habitat, which they consider to at best reach dense woodland rather than dry forest. An alternative view is taken in this report, in line with the typology that has been used elsewhere in Tanzania and Kenya, where *Brachystegia* 'transition forest' is considered a variant of true Coastal Forest as it has a forest structure and a fire-excluded forest ecology. While *Brachystegia spiciformis* is predominantly found in woodland, its presence in dry forest is not considered unusual given that a number of species of *Brachystegia* are dominant in the moister Guineo-Congolian forests.

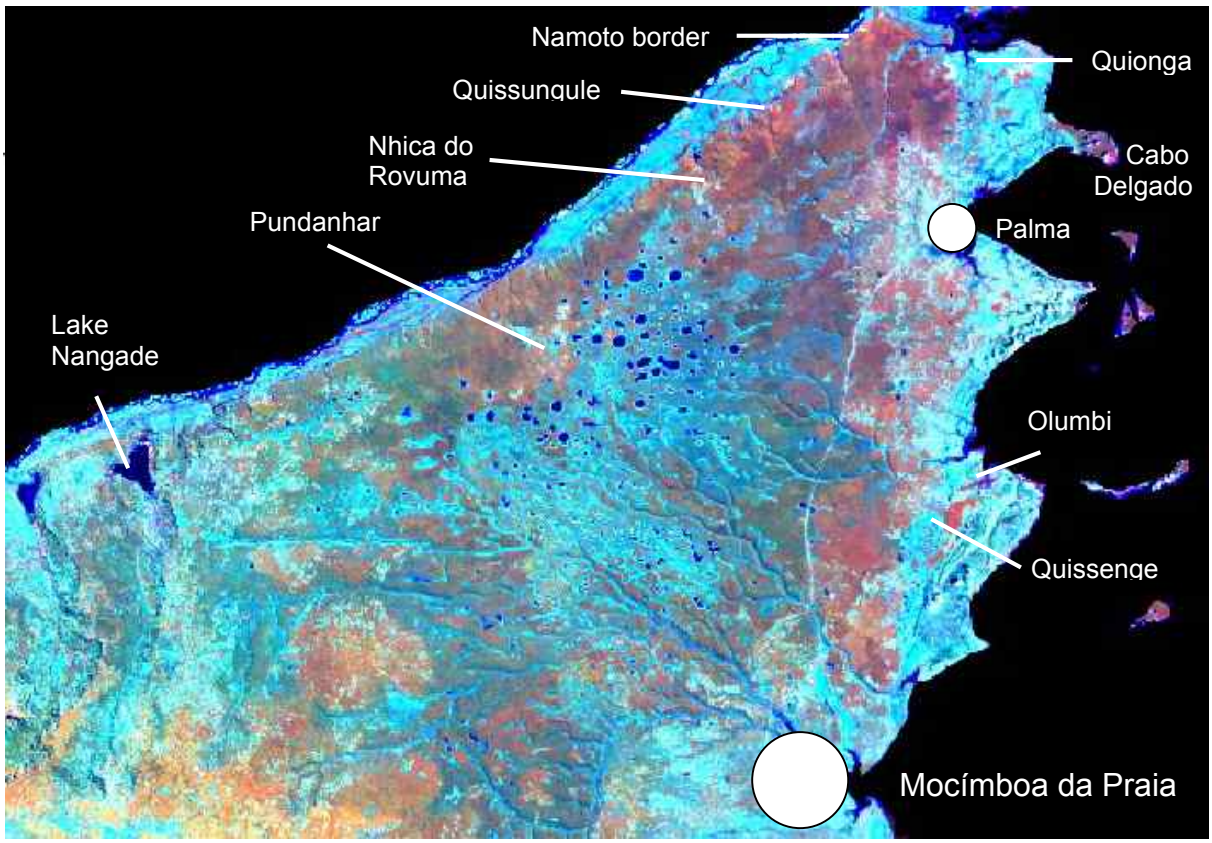
A copy of this report was sent to all participants on the botanical module of the 2008–2009 Pro-Natura Mozambique expedition for comment, but nonetheless remains the personal viewpoint of the author. Please refer to Timberlake *et al.* (2010) for the official expedition report and conservation recommendations.

Content

A large *Milicia excelsa* ('Mvule') tree on the thickly forested slopes to the east of Lake Nhica do Rovuma at 10°42'27"S, 40°12'40"E. The minimal disturbance to the forests in this area is demonstrated by the existence of this tree with 8 stems, each with an 80 cm diameter, just a few km from the border with Tanzania where few individuals of Mvule now survive beyond a 25 cm diameter (A. Ahrends, pers. comm.). This prized hardwood timber tree appears to have coppice regenerated from a stump cut perhaps during the 1950s.



The Swahilian regional centre of endemism was identified by Clarke (1998), and recognised for the first time the special importance of northern Mozambique within the Eastern African Coastal Forest biodiversity hotspot (*sensu* Myers *et al.* 2000), based on the results of historical botanical collections. The Pro-Natura International 2008–2009 expeditions have conducted the first major survey of the forests of Palma and Nangade Districts in northern Mozambique, and have confirmed their importance as part of the Swahilian regional centre of endemism/Eastern African Coastal Forests hotspot.



False-colour satellite map of the area inland of Palma in northern Mozambique, broadly covering Palma and Nangade Districts, with key towns marked. Reddish tone approximates to dry forest or regenerating scrub forest, red/green to *Brachystegia* forest, mid-blue to woodland (including *Brachystegia* woodland), pale blue to grassland and cultivation, and lilac to scrub forest over coral rag on the Cabo Delgado peninsula and on the islands. Dark blue spots and lines are water-filled pans and rivers. The orange tone vegetation to the southwest of the image was not investigated. LandSat 7 photo from 2000, analysed by Prins Engineering.

1. Key Findings

Palma District of Cabo Delgado Province, Mozambique stands out as by far the most heavily wooded area along the entire eastern African coast. Vast quantities of carbon biomass are stored in its forests and woodlands.

Nowhere else along the eastern African coast is so much near-pristine vegetation still visible on a landscape scale. This offers tantalising clues about the original nature of the vegetation both here and elsewhere along the eastern African coast, prior to the massive disturbance caused by humanity over the last many thousand years.

Of particular importance are the dry forests, which form part of the 'Coastal Forests of Eastern Africa' biodiversity hotspot. Most of the rare species found in this area are limited to this vegetation type.

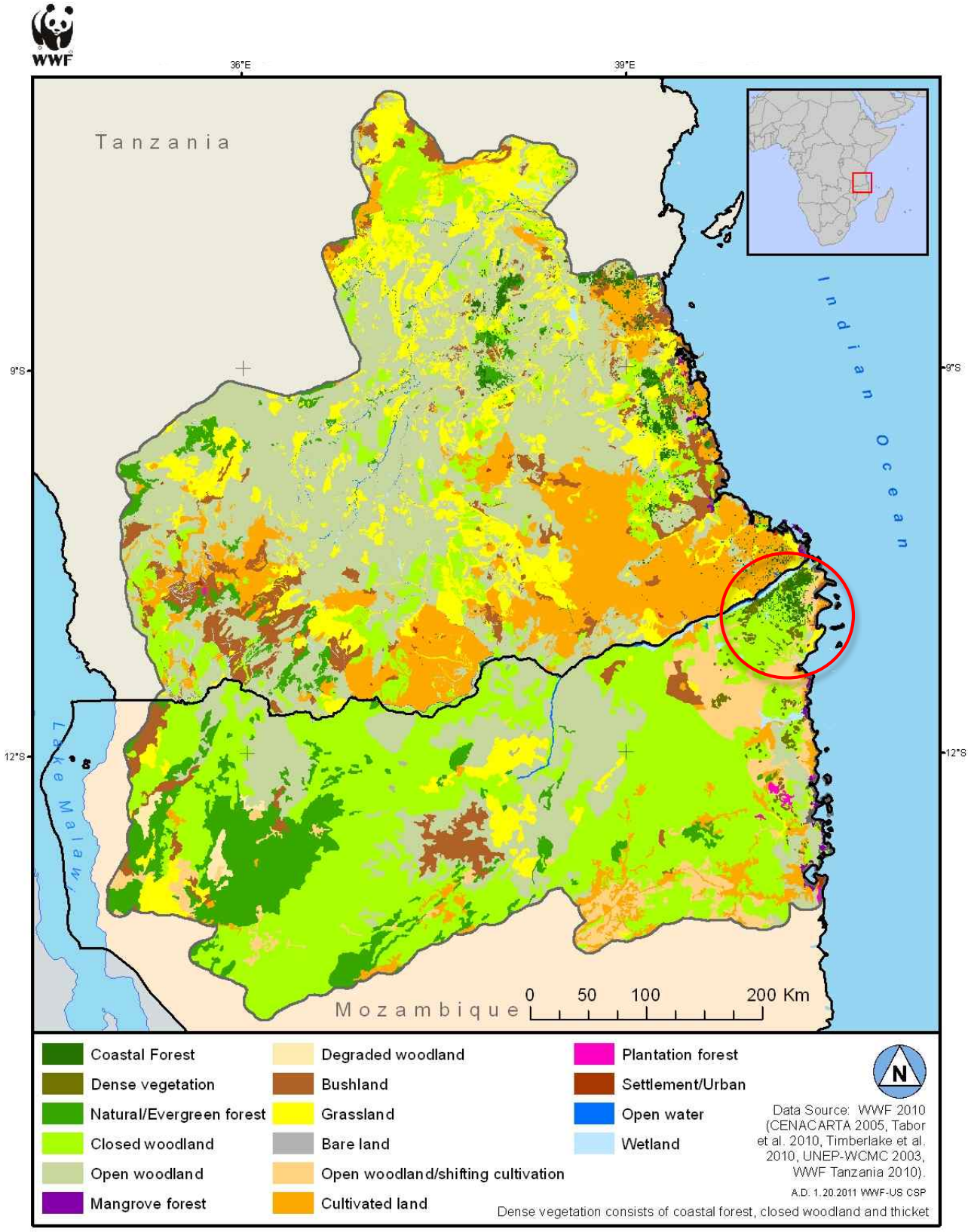
Most of the dry forest in Palma District appears to have regenerated over the last 50 years from an earlier period of heavy disturbance. This may explain the relatively poor diversity in forest types encountered, as well as the absence of certain indicator species.

Rapid resettlement of Palma District following the end of Mozambique's civil war is leading to a massive increase of deforestation at an unsustainable rate, particularly in forested areas. This threat is enhanced by the traditional practice of 'bush-fallow' shifting agriculture, as well as by uncontrolled bush fires.

Urgent conservation action is required to preserve this last remaining heavily-wooded landscape in lowland eastern Africa, that contains at least 11 endemic plants.

This action should focus on the Rovuma rim and include the forests along the lower reaches of the Macanga River as well as the nearby pan landscape.

Documentation of this unique vegetation landscape is provided in this report.



Land cover map of southern Tanzania / northern Mozambique, showing the relative size and isolation of the Palma and Nangade forest block (circled). Note the large expanses that are now under cultivation on the north side of the Rovuma River in Tanzania compared to the near absence on the south side, due in part to the mass migration of refugees from northern Mozambique to southern Tanzania during the independence and civil wars of 1964–1992, many of whom have not yet returned. Map © World Wide Fund for Nature Conservation.

2. Conservation Focus

The extensive forests of Palma and Nangade Districts of northern Mozambique include the following conservation values:

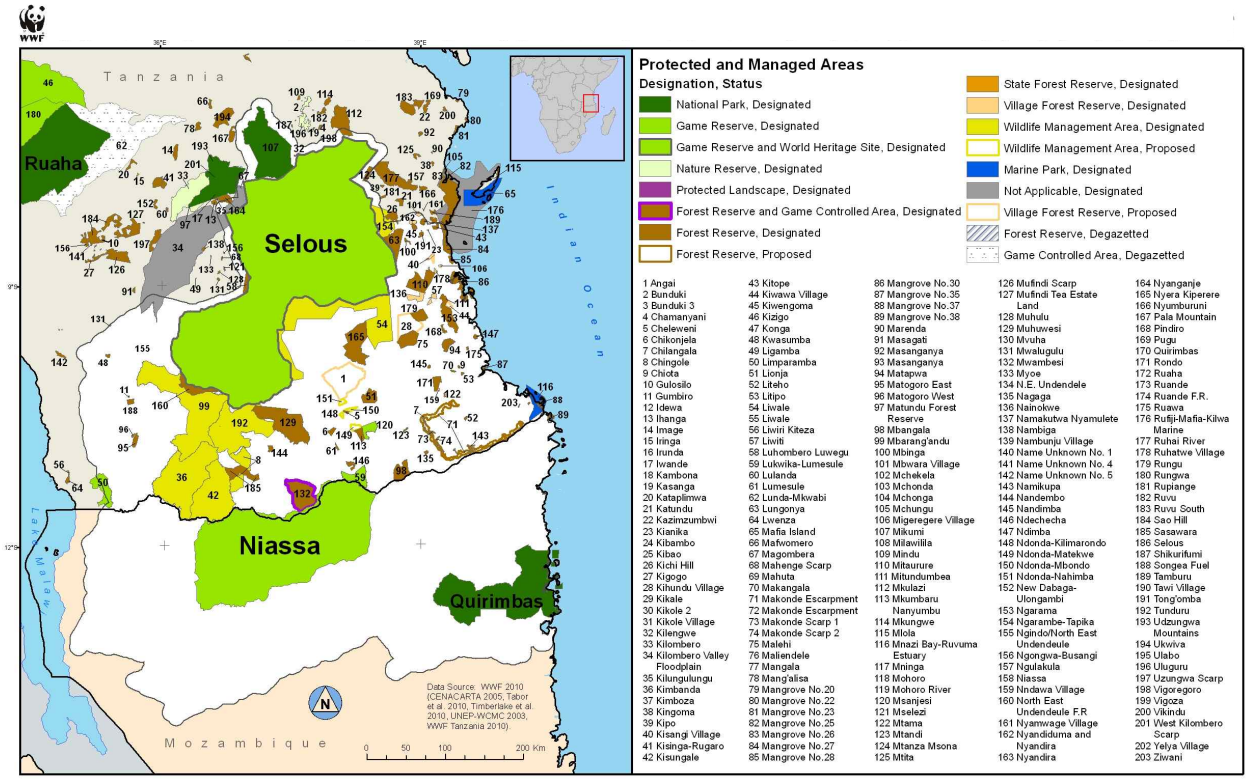
(a) The largest extent of Swahilian Coastal Forest in eastern Africa, containing a huge store of carbon and providing a motor for ongoing carbon sequestration.

(b) Contain at least 11 endemic and many rare plant species, and are likely to host numerous endemic invertebrates.

(c) Include areas with some of the best-developed forest structure of any Coastal Forest in eastern Africa, containing many large hardwood timber trees.

(d) Forests located along the Rovuma River provide a dry season refuge for game animals, and are a key component of a wider wildlife ecosystem.

(e) Forests are present in a wide range of near-pristine habitats including dense woodland, seasonal pans and the floodplain wetland of the Rovuma River.



Map of southern Tanzania / northern Mozambique, showing areas that are currently under some form of conservation protection. The very north-eastern corner of Mozambique where the Palma and Nangade forests are located is a totally blank area on this map, so all of its forests could be lost if nothing is done to give them legal protection. By contrast many of the protected areas in Tanzania have been gazetted for almost a century. Map © World Wide Fund for Nature Conservation (WWF).

Recommended areas for

None of the habitats in Palma and Nangade Districts are currently under any form of legal protection. They are particularly threatened by agricultural encroachment, so conservation priority should be given to the larger, richer and best tracts of forest before they become eroded and fragmented. Representative areas of dense woodland, pans and the Rovuma floodplain should also be protected for their wildlife, landscape and habitat values.

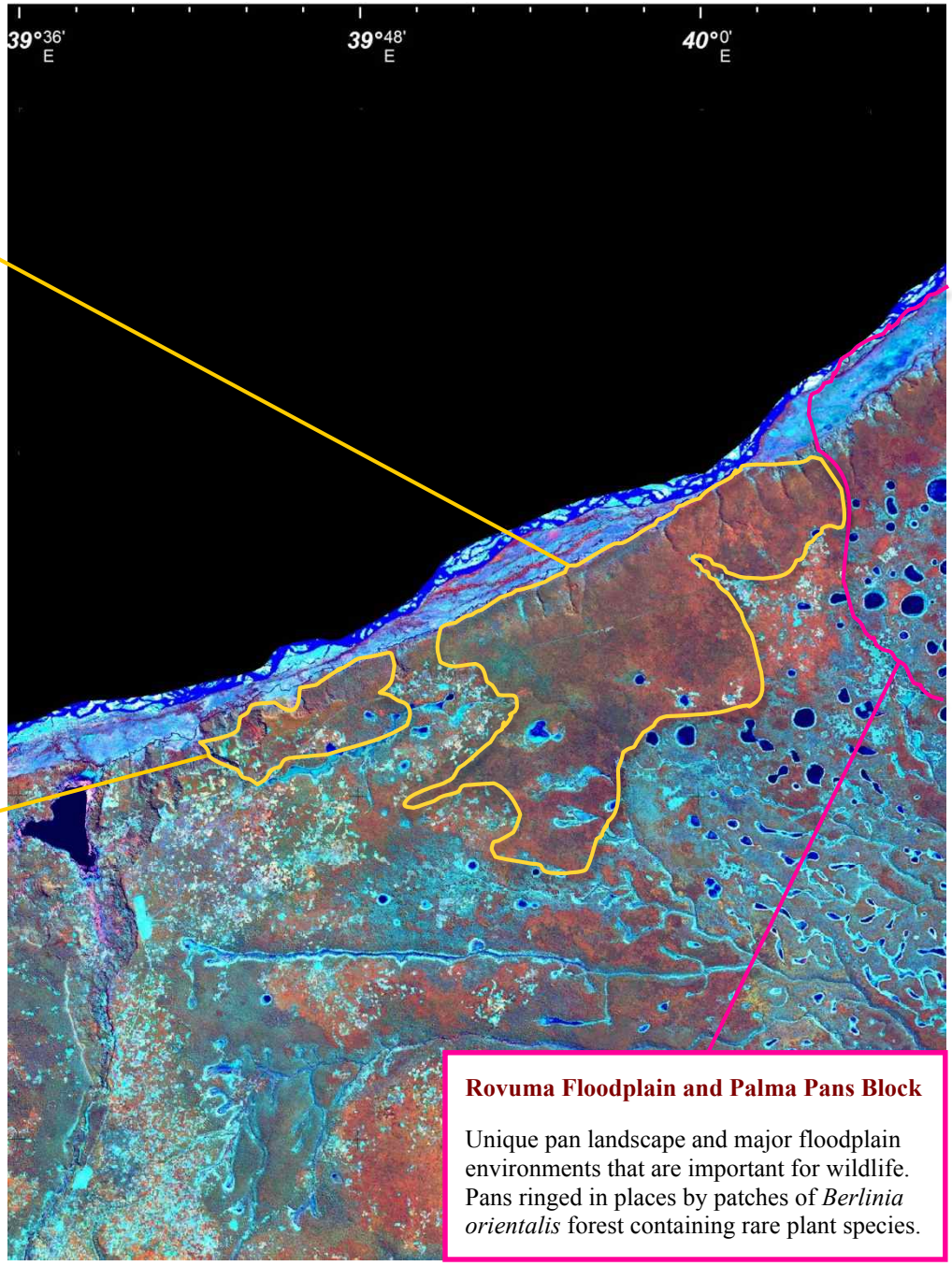
Five key forest blocks (one of which contains two important cores) are presented here, together with their main values. All of these blocks, with the exception of the Olumbi block, are also included in the recommendations presented by Timberlake *et al.* (2010).

Pundanhar Block

Mosaic of woodland and ca. 120 km^2 of forest, some of which contains the rare forest-dependant tree species *Scorodophloeus fischeri* and *Guibourtia schliebenii*, which indicate old-growth forest. The largest individuals of *Scorodophloeus fischerii* south of the East Usambara mountains in northern Tanzania are found here, even though this is the driest part of the eastern African coast.

Nangade Block

The vegetation to the immediate east of Lake Nangade is now reduced to a patchwork mosaic of just 5 km^2 of near pristine forest dominated by *Scorodophloeus fischeri* and *Guibourtia schliebenii*, interspersed with recent cultivation. Further investigation is needed of the values and quality of the forests in this area, which are threatened with total clearance for cultivation in the near future. Conservation of a representative sample of these forests is an extremely high priority.



Rovuma Floodplain and Palma Pans Block

Unique pan landscape and major floodplain environments that are important for wildlife. Pans ringed in places by patches of *Berlinia orientalis* forest containing rare plant species.

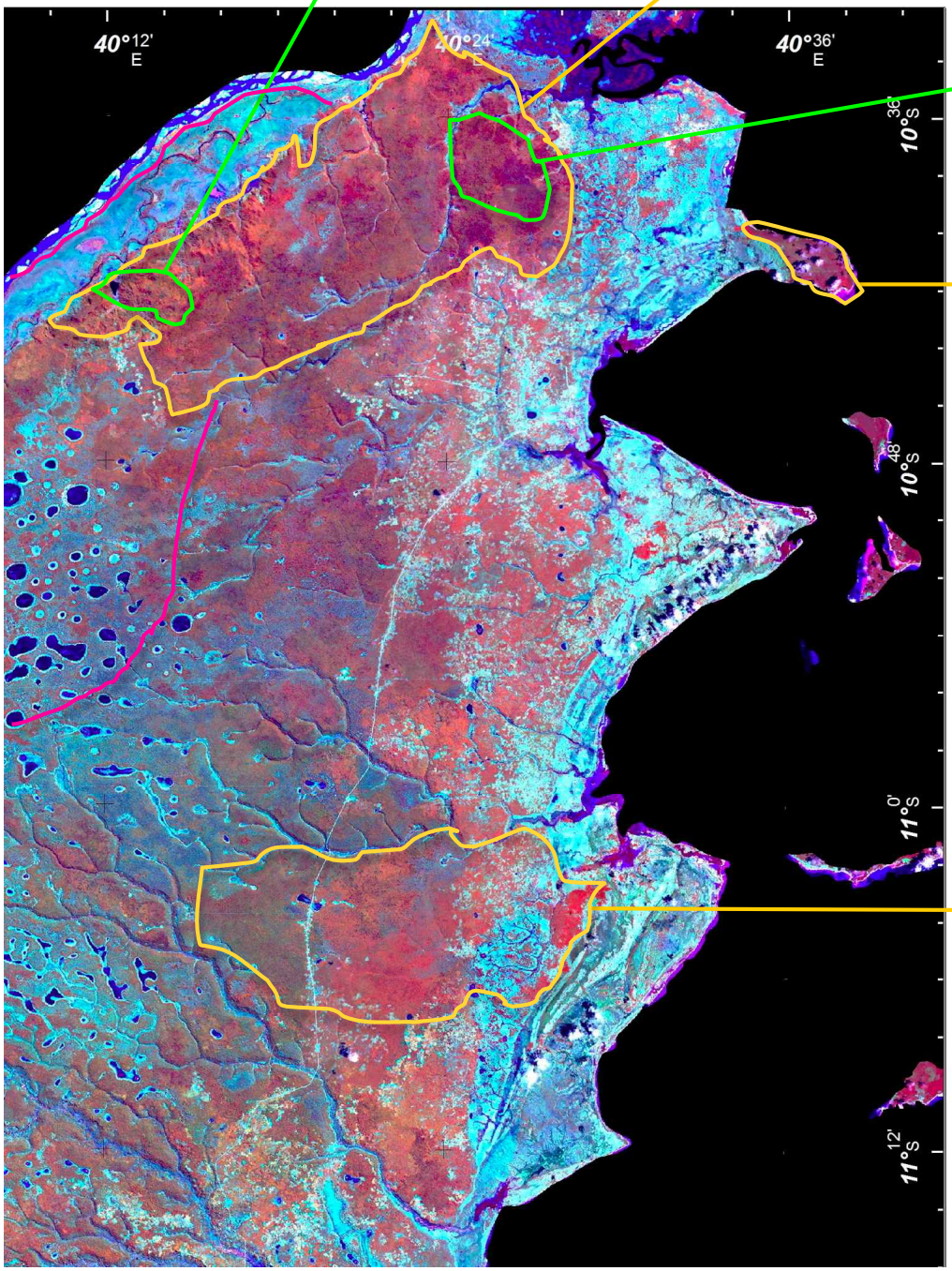
Conservation Protection

Nhica do Rovuma Conservation Core

Some of the best-developed Swahilian Coastal Forest in all of eastern Africa is present here, despite evidence of past logging. This contains enormous hardwood timber trees of a size now rarely seen elsewhere in eastern Africa, and is the most diverse forest encountered in the Palma area.
The forested hills surrounding Lake Nhica do Rovuma have a landscape value and present a future eco-tourism potential.
Dry season wildlife refuge linked to the nearby pan ecosystem.

Nhica do Rovuma – Macanga River Block

Covering some 280–300 km^2, one of the largest contiguous blocks of Coastal Forest in eastern Africa – a vast and important store of carbon.
Contains stands with some of the largest canopy trees seen for any Coastal Forest in eastern Africa.
Almost unique eastern African lowland landscape with forest developed over the entire catena.
Rare occurrence of forest so close to the coast.



Macanga Core

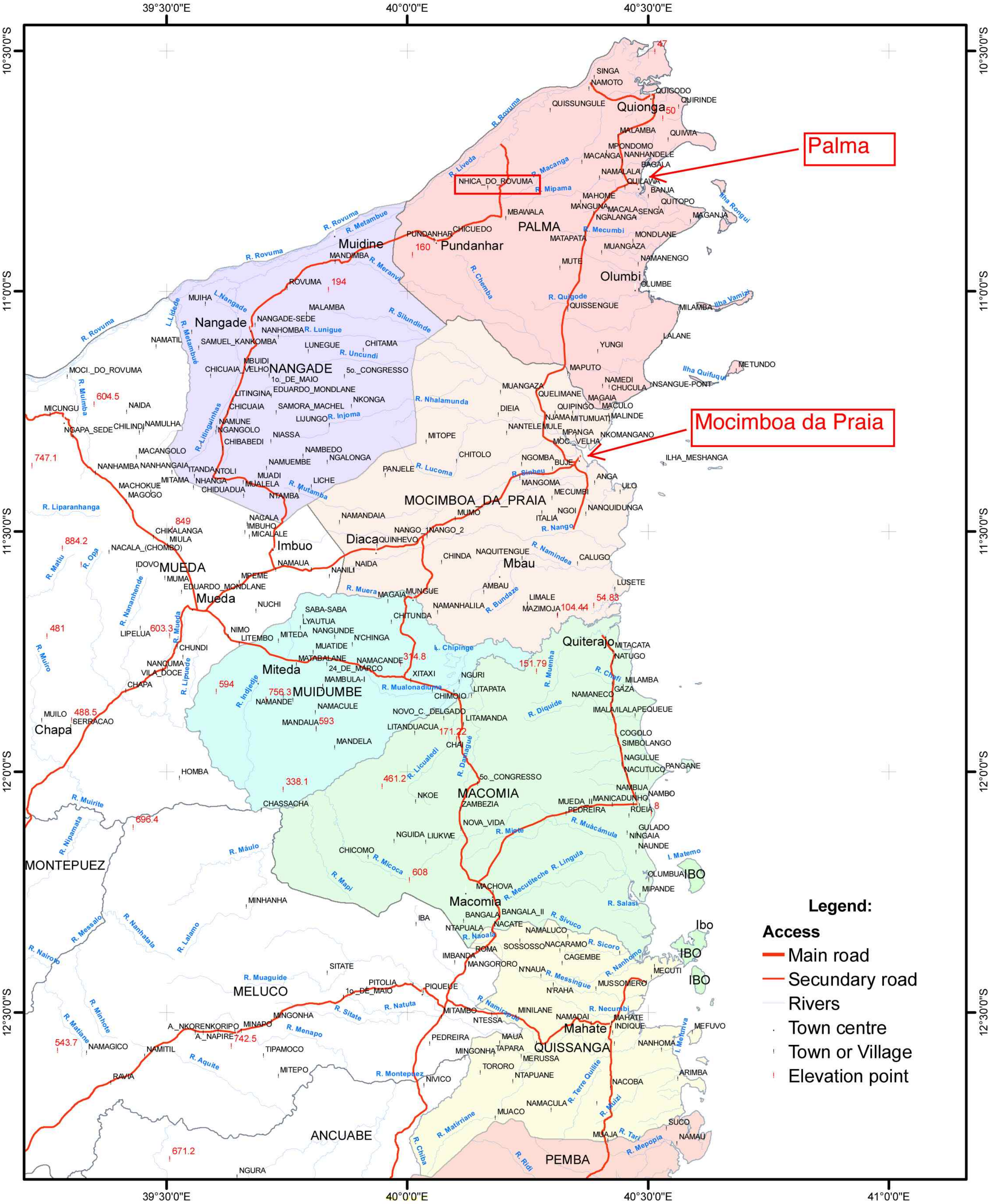
Large area of forest with exceptionally big trees.

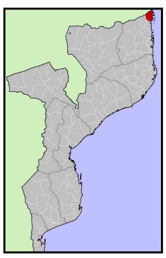
Cabo Delgado Block

Large area of maritime scrub forest on coral rag – the only such coral rag forest on the coast between Mucujo and the Tanzanian border.
Unique Mango forest with 40 m high trees at western tip – a potential tourist attraction in the long term.
Lighthouse at the tip of the peninsula with views from top and nearby sandy beaches are further tourist incentives.

Olumbi Block

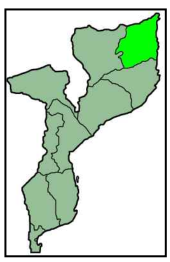
An opportunity still exists to demarcate a cross section of the coastal ecotone in the area to the immediate south of Olumbi. This ca. 160 km^2 block includes *Ochna-Manilkara* forest, *Brachystegia* forest, an unusual patch of forest dominated by the stilt-rooted *Uapaca zanzibarica*, as well as *Berlinia* forest on a rise of the coastal plain.





Administrative map of the northern part of Cabo Delgado Province in Mozambique (above), showing the main roads, towns and district boundaries, including Palma and Nangade Districts which are the subject of this report.

Palma District is the most extreme north-eastern district in Mozambique (left), and falls under the administration of Cabo Delgado province (right) which contained 1.6 million inhabitants in 2007, out of the total of 20.2 million inhabitants for Mozambique (source: Instituto Nacional de Estatistica Moçambique website (2007). Maps left and right from www.wikimedia.org.

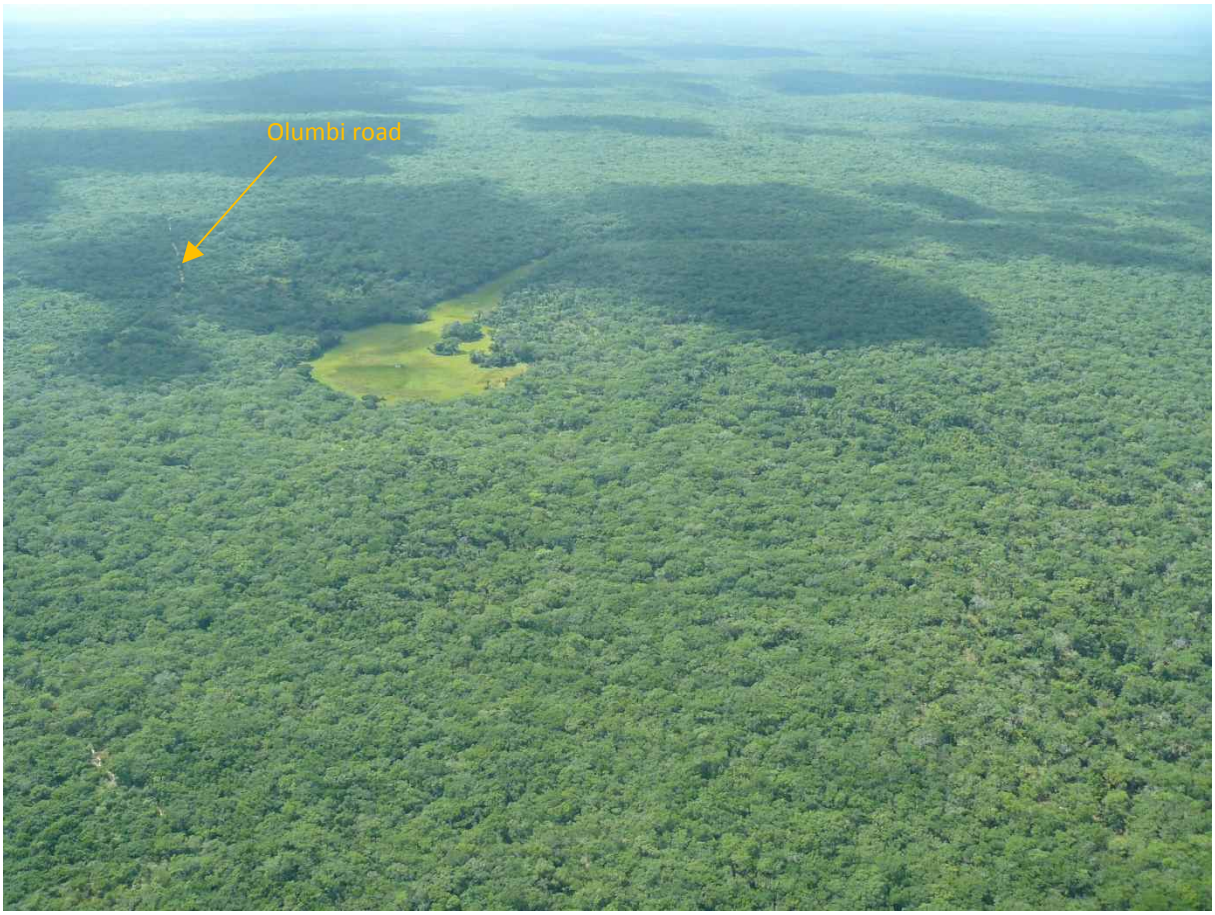


3. Background

Palma District of Cabo Delgado Province in northern Mozambique contains the most extensive area of Eastern African (Swahilian) Coastal Forest and woodlands remaining along the eastern African coast. This area was partially depopulated during wars that raged from 1964 until 1992, which has in turn led to a massively reduced human pressure on the vegetation. Landmines laid during these wars have further discouraged human interference (until they were cleared in 2007), while poor infrastructure and underdevelopment as a consequence of the wars have also slowed the return of refugees who had fled to Tanzania. The vegetation of Cabo Delgado has therefore experienced over 40 years of comparatively low interference, allowing it to regenerate in many areas.

Fire and cultivation, together with their absence, interact with underlying soils to produce the complex mosaic of vegetation types that are seen in Palma District today. These include Coastal Forest and woodland in various conditions and stages of regeneration (mostly from abandoned fields and orchards), areas that have been recently cleared for new cultivation, and areas that are intermediate between these nodes. Small areas of natural wetland are present along drainage lines and in the circular depressions that are characteristic of inland areas.

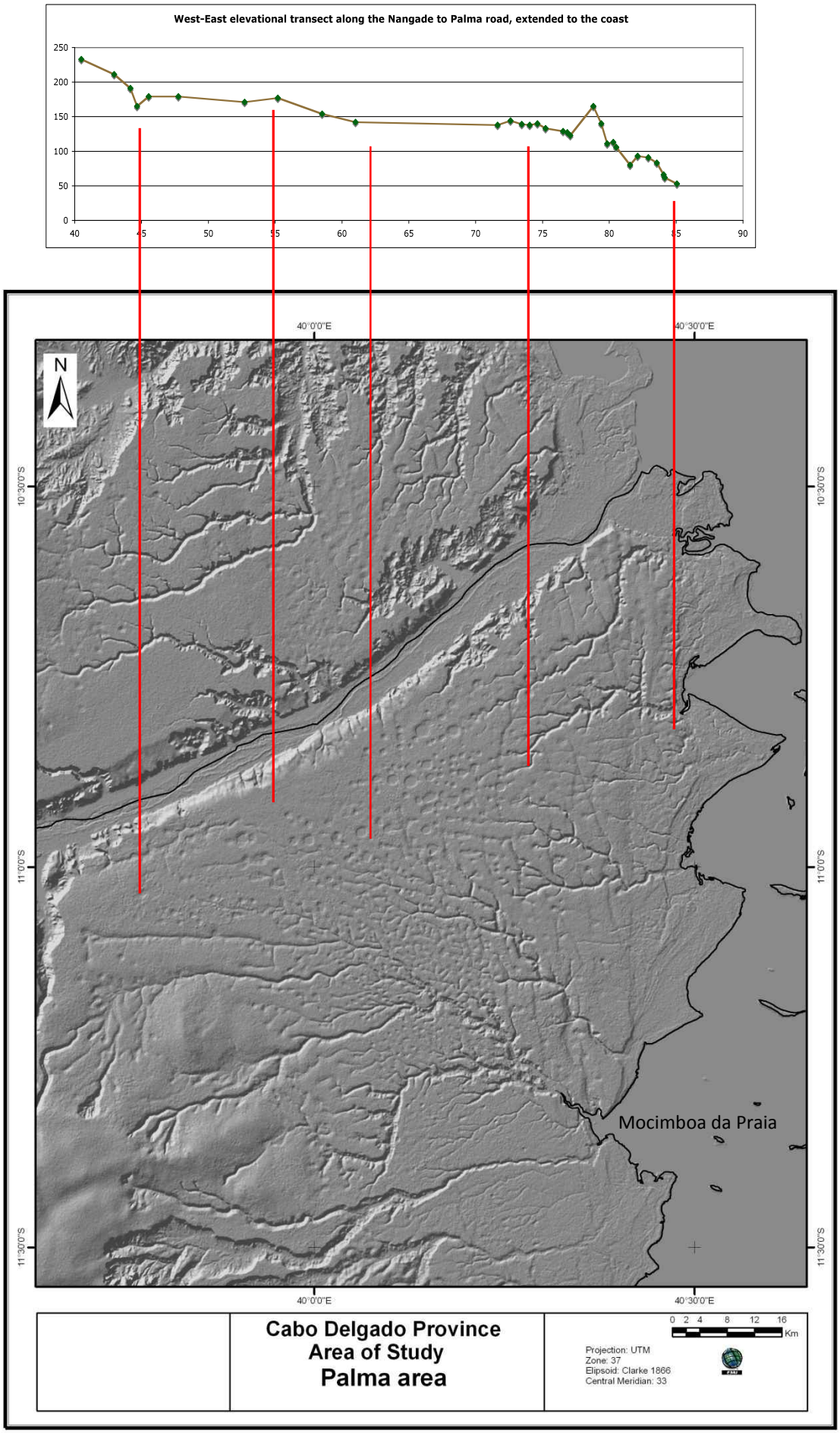
Old Portuguese army military road from Palma to Nhica do Rovuma, 10°45'10"S, 40°23'33"E looking west, 30th April 2008, demonstrating the patchwork pattern of natural vegetation, cultivation and fallow which is regenerating back to bush. This photo is taken at the end of the rains when all vegetation types are intensely green; by the end of the dry season most of the leaves will have dropped and the landscape will be dominated by the exposed silver white trunks of the trees. Note how extensive an area is being impacted by an extremely low population practising shifting cultivation. This method of 'bush fallowing' was described in detail by Gillman (1945) for the neighbouring Makonde Plateau in Tanzania, but is no longer practised there on the same scale due to the massively reduced extent of forest in SE Tanzania since 1945. Photo © Jonathan Timberlake.



Natural pan with exiting drainage line surrounded by dense woodland and forest, 11°00'14"S, 40°21'37"E, 30th April 2008, looking east towards the sea. The road to Olumbi is faintly visible through the canopy to the left. Note the almost continuous cover of dense woodland/forest as far as the eye can see – a sight that in coastal eastern Africa is unique to parts of Palma District. Photo © Jonathan Timberlake.

Open woodland descending to a drainage line, 30th April 2008. Photo © Olivier Pascal.

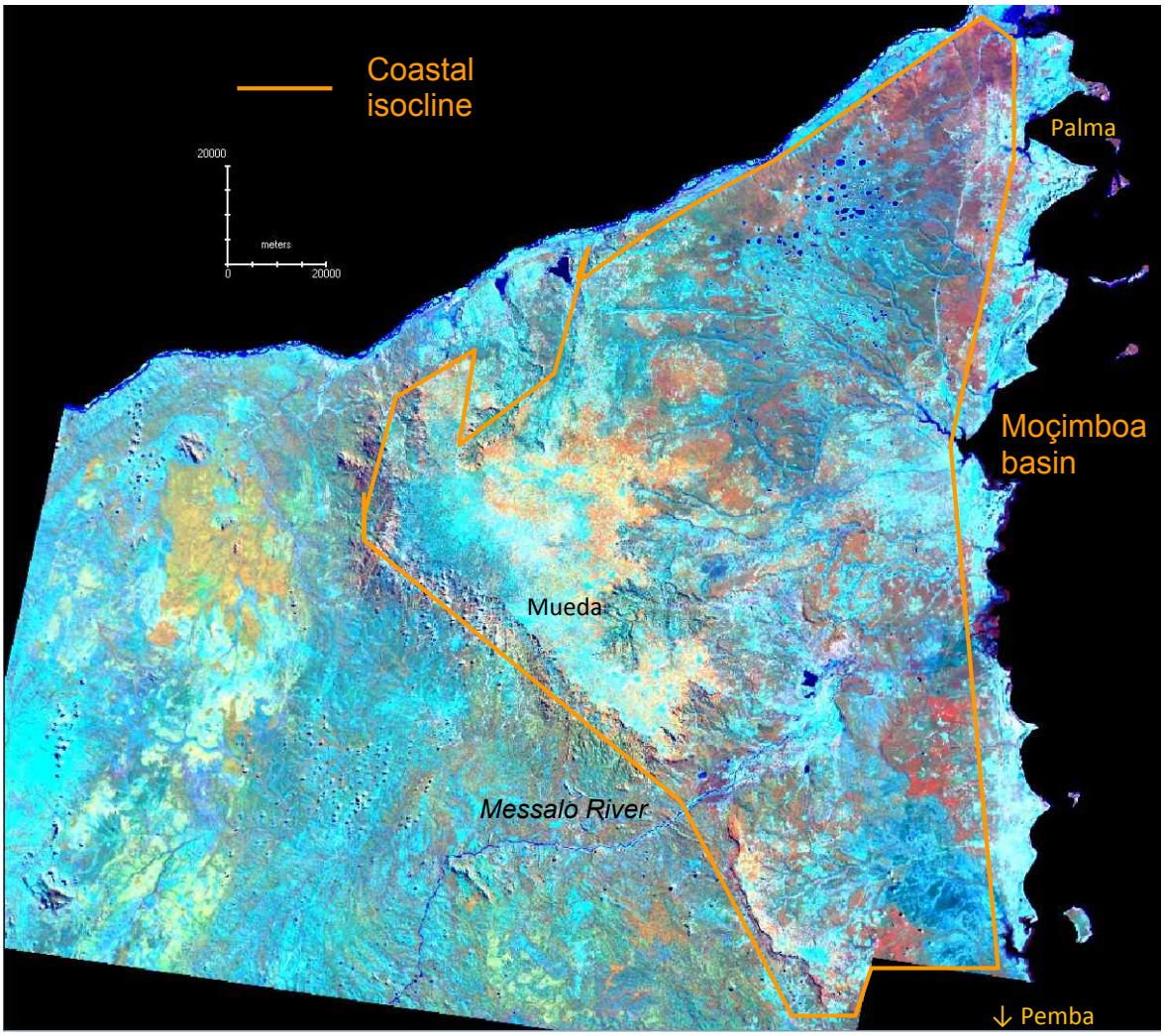
Rovuma River valley and associated floodplain looking WSW from above Kitaya in Tanzania (right bank), 10°39’33”S, 40°10’04”E, May 2008. The near pristine floodplain on the Mozambican side (left bank) is an important wetland for game animals.


West-East elevational transect along the Nangade to Palma road, extended to the coast
250
200
150
100
50
0
40
45
50
55
60
65
70
75
80
85
90
40°0'0"E
40°30'0"E
10°30'0"S
11°0'0"S
11°30'0"S
N
Mocimboa da Praia
Cabo Delgado Province
Area of Study
Palma area
0 2 4 8 12 16
Km
Projection: UTM
Zone: 37
Elipsoid: Clarke 1866
Central Meridian: 33

4. Topography

The Palma area is mostly contained within a large sedimentary isocline that slopes upwards and westwards to Mueda, whereupon the terrain falls steeply to the wide Lugenda River floodplain. This same isocline also ends abruptly along its northwestern edge where it drops dramatically to the Rovuma River, but is otherwise characterised in the Palma area by a general slope southeast to the Mocímboa basin. The isocline is part of a much larger isocline that extends from Pemba in the south to Lindi in southern Tanzania, but is now divided by the Messalo River (see below) and by the Rovuma River which has cut a narrow channel (see topographical image on previous page opposite).

The relatively even slope of the isocline is interrupted by deep river valleys along the coast. Uplifted coastal sands form low-lying plains between the river mouths.

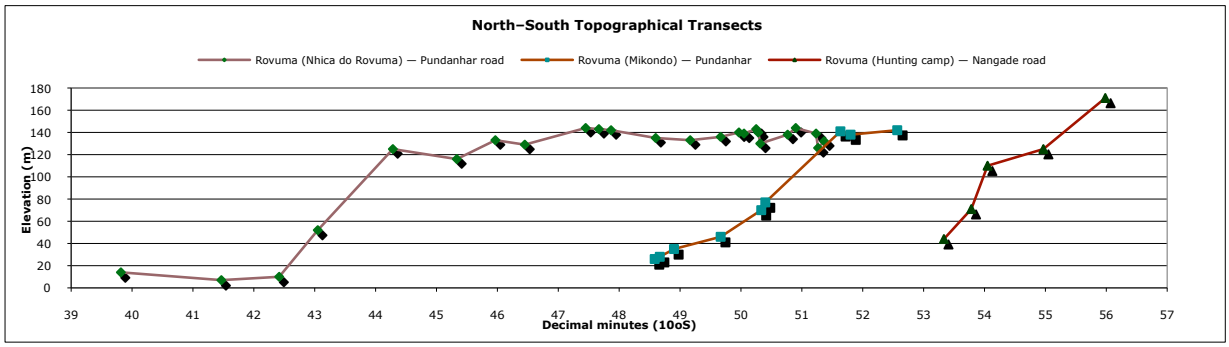


Satellite photo LandSat 7 from 2000, image analysis © Erik Prins, Prins Engineering, Denmark.

Certain areas of the isocline are sufficiently flat on a local scale for drainage to be impeded. Seasonal pans have developed where clays have collected in the shallow depressions. The pans prevent the development of a tree cover due to the standing water that remains until it evaporates away during the dry season. This pan landscape in the Palma area and to a smaller extent on the neighbouring Makonde Plateau in SE Tanzania is unique in eastern Africa, and lakes are otherwise almost totally absent along the eastern African coast, with the exception of Lake Lutamba and Lake Tandangogoro in SE Tanzania.

The unusual pan landscape may have been created by the tectonic warping of the landscape, effectively levelling areas that had formerly been sloping, and creating new drainage lines. The topographical image of the Palma area indicates the presence of ancient rivers that used to flow towards Mocímboa da Praia, but have been superseded by rivers that now flow directly to the coast.

No distinct pattern could be observed between the topographical position of forest and woodland in the landscape — both forest and woodland may be found throughout the catena.

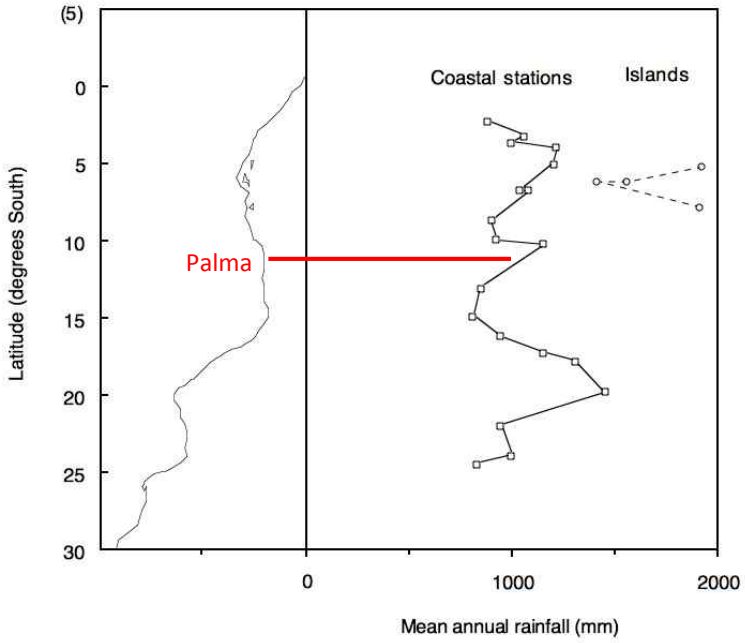


Approximate north-south transects of the Palma-Mueda-Pemba isocline taken along three tracks descending off the isocline/plateau at Nhica do Rovuma, Pundanhar and at a hunting camp between Pundanhar and Nangade. At this scale the topography along the north-south axis is that of a plateau, compared to the gentle slope towards the sea along the east-west axis (see image on top of page 16).

Southern edge of the Rovuma River floodplain looking south, showing the sudden rise in landscape up to the Palma–Mueda–Pemba isocline, near 10°38'56"S, 40°16'14"E, 30th April 2008. Note the presence of fire-climax woodland on the lower escarpment slope with fire-intolerant forest on the plateau beyond. The distribution of woodland on the hillsides overlooking the Rovuma River may be due to the frequent bush fires which are set by humans in the grasslands of the Rovuma floodplain, and which sweep up the surrounding slopes every year. Photo © Olivier Pascal.

5. Climate and soils

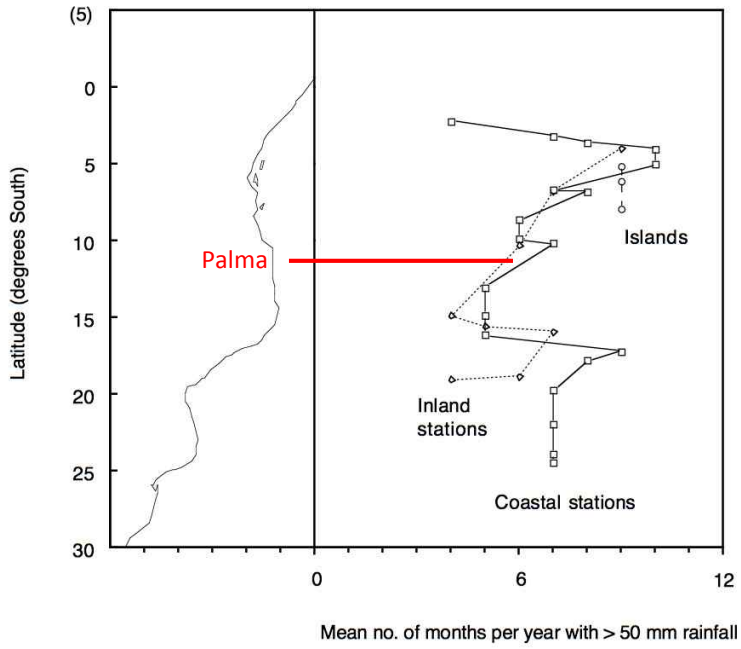
Palma District receives a humid tropical monsoon climate that is influenced by movements in the Inter-Tropical Convergence Zone (ITCZ). There are two seasons per year, a cool and dry season (May to October) and a hot and humid season (November to April). This area has one of the driest climates recorded along the eastern African coast, with mean annual rainfall of about 1000 mm.



Rainfall averages for coastal and island weather stations, (from Clarke 2000).

Mozambican climate data averaged over 30 years for 1919–1951 from Serviço Meteorological Nacional (1951).

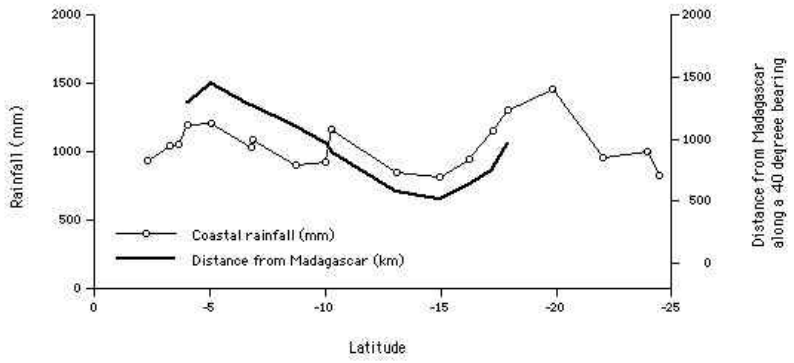
The greater proportion of rain (between 85-90%) is concentrated to a 5 to 6 month block of the year, generally between the months of December and April, inducing a severe water stress for plants over the rest of the year – and one of the severest dry seasons experienced along the eastern African coast.



Average number of months receiving more than 50 mm rainfall for coastal and island weather stations (from Clarke 2000).

Mozambican climate data averaged over 30 years for 1919–1951 from Serviço Meteorological Nacional (1951).

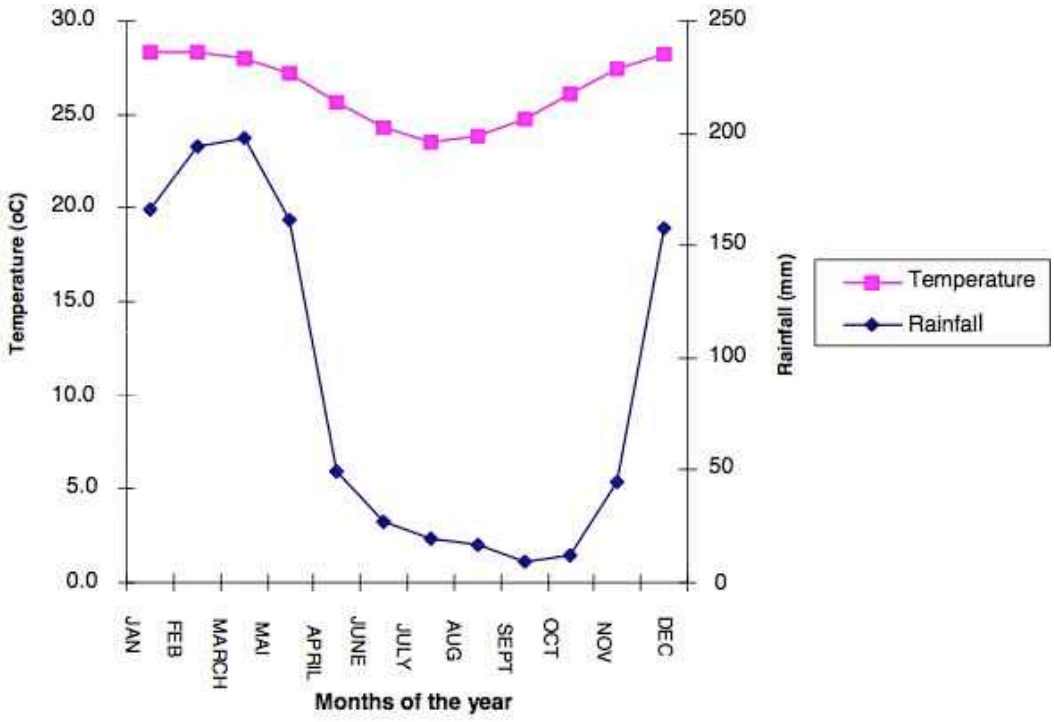
The exceptionally dry climate of Palma District (and Cabo Delgado Province) of northern Mozambique may be due to its position in the rainshadow of Madagascar. This can be demonstrated in the following correlation between rainfall along the eastern African coast, and the distance to Madagascar in the direction of the prevailing SE winds.



Rainfall averages for coastal weather stations, against distance from Madagascar (from Clarke 2000).

Mozambican climate data averaged over 30 years for 1919–1951 from Serviço Meteorological Nacional (1951).

The mean annual temperature in Palma District is 26°C (Clarke 2000). At Mocímboa da Praia, the minimum monthly average temperature reaches 18°C, between the months of July and August, and a maximum of 32° in March. Relative air humidity is high all year long, varying on average between 67.6 % in September to 82.2% in February along the coast (Garnier 2003).



10-year mean annual temperature and rainfall recorded at Mocímboa da Praia (INAM, 2006). Graph copied from Impacto (2007).

The vegetation of the Palma area has adapted to the severe water stress; most herbs die back and most trees lose their leaves by the end of the dry season. This increases the vulnerability of the area to bush fires, which readily burn the dry leaf litter and desiccated plant matter at the end of the dry season. The severely dry climate and consequent vulnerability to intense bush fires should make Palma District the least wooded part of coastal eastern Africa. Instead it is the most wooded, due to the opposing factor of having the lowest human population density in coastal eastern Africa, with a population of between 2–29 inhabitants per km^2.

District	**Administrative Post**	**1997**	**2007** (projected)	**2010** (projected)
Palma	Palma	20,526	24,608	27,092
	Quionga	5,712	6,848	7,539
	Olumbi	13,455	16,131	17,759
	Pundanhar	2,489	2,984	3,285
Mocímboa da Praia	Área Municipal	25,506	47,305	n/d >50,000
	Mocímboa da Praia	22,546	24,423	24,934
	Diaca	15,703	17,011	17,367
	M'Bau	11,246	12,182	12,437
Nangande	Nangade	24,667	30,509	33,819
	M'Tamba	25,816	31,930	33,819

Human population statistics in NE Mozambique from Impacto (2007), based on actual projections by the INE.

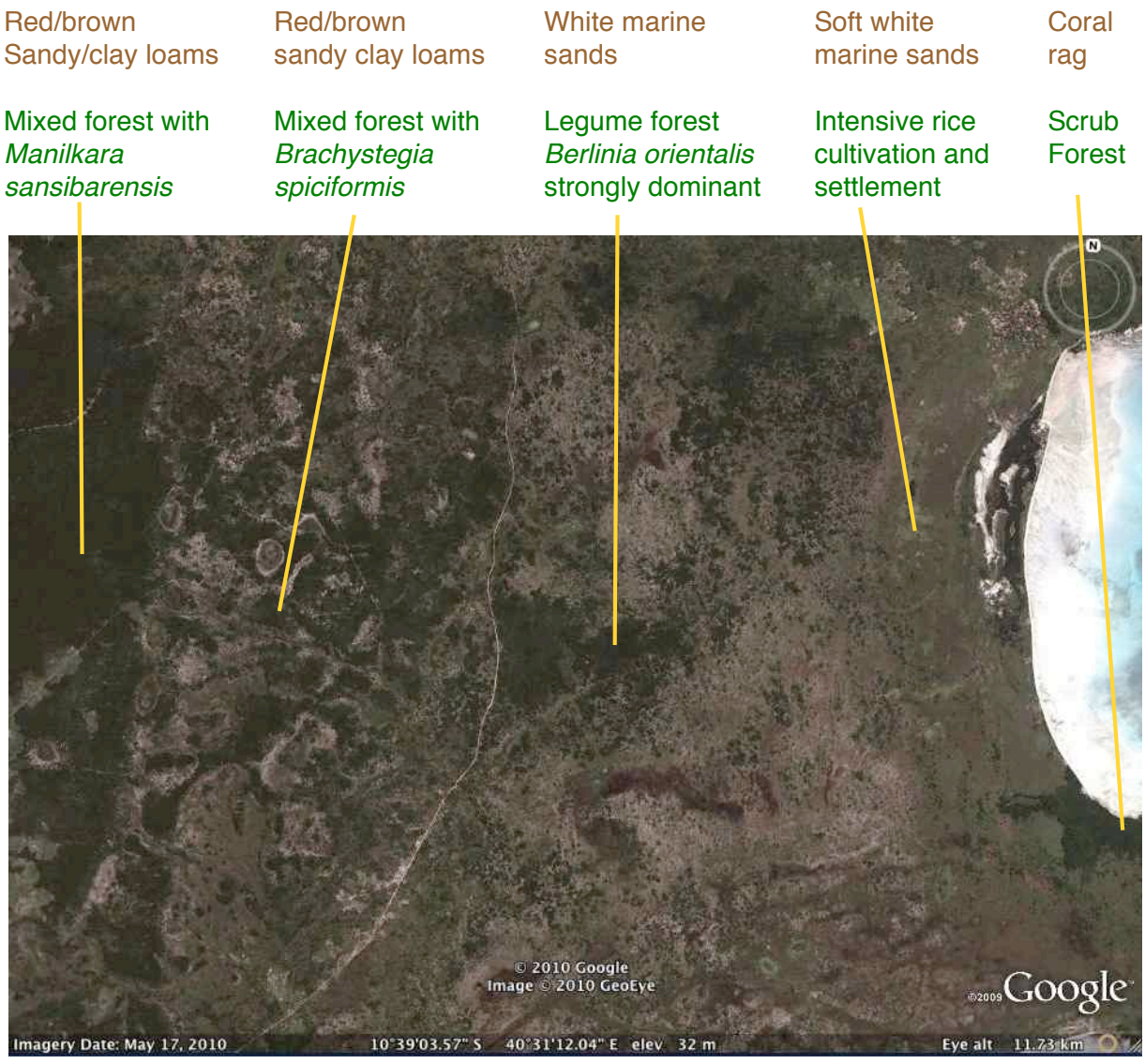
Partial view of the village of Nhica do Rovuma on the escarpment edge looking north to the Rovuma valley, November 2009. This is one of the larger settlements inland of Palma. Photo © Xavier Desmier / PNI-MNHN.

Soils

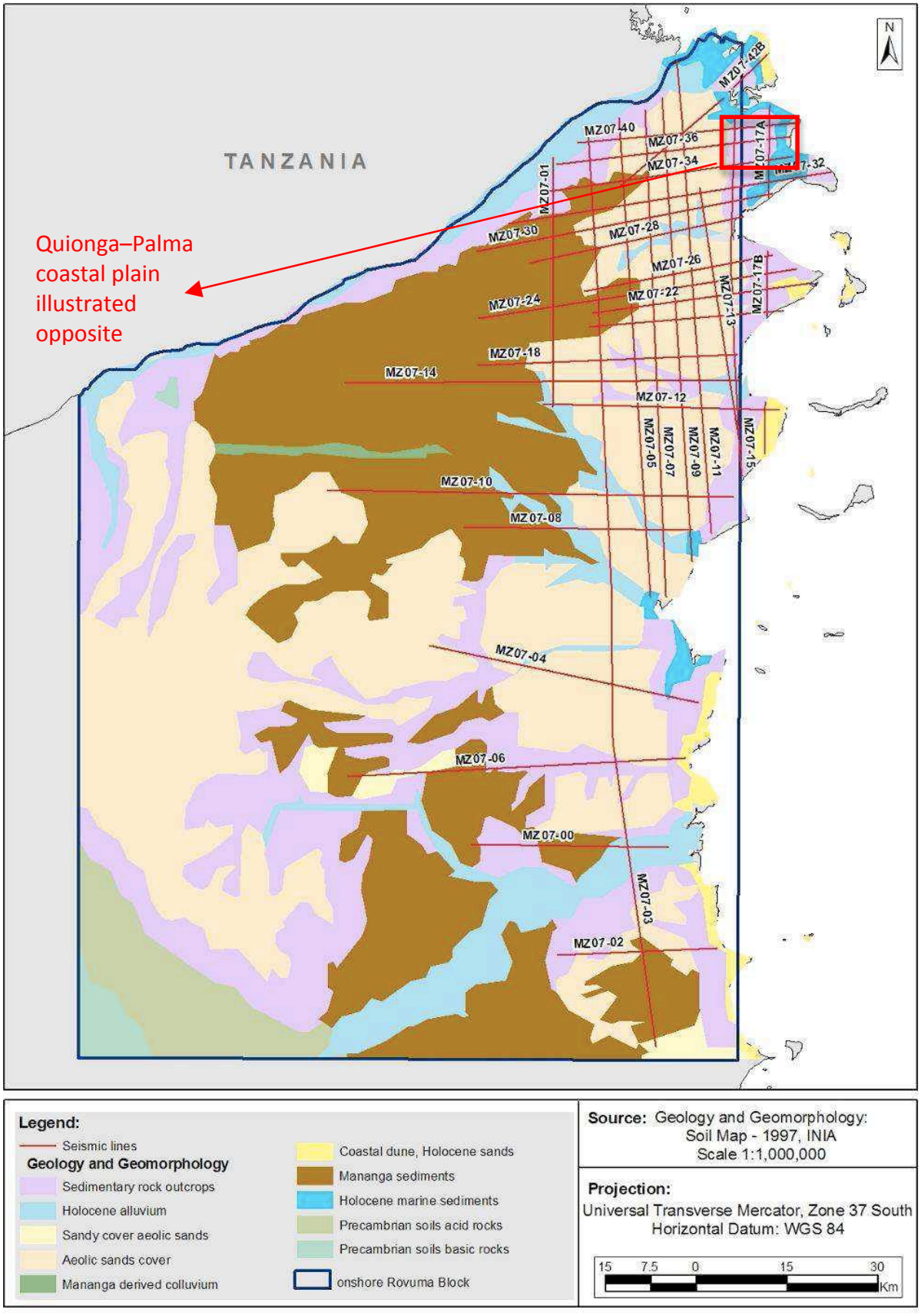
The substrate of Palma District comprises predominantly sedimentary rocks of the tertiary and quaternary eras (Impacto 2007). Rock outcrops are few, and are only seen when exposed on steep drainage lines. Uplifted calcareous coral formations of the Pleistocene era outcrop under a very thin soil layer at the Cabo Delgado peninsula.

The very saline fluvial and marine soils of the immediate coastal area are poorly drained. Further inland, reddish sandy clay loams predominate. These soils have very low fertility and low water retaining capacities. More fertile fluvial soils are concentrated along water courses. These deep, well drained soils are interspersed with poorly drained soils of low lying areas, which form seasonal pans. In the latter, grey and saturated soils dominate for most of the year, covered by grasses tolerant to seasonal and/or permanent saturation.

Forest is still present on most soil types, except for the soft white sands at the extreme coastal margin, possibly due to a long history of intensive cultivation and fire burning in this zone.



Coastal plain between Quionga and Palma, showing the remaining patches of forest over different soil substrates. Image spans from 10°36'25" to 10°41'29"S and 40°27'22" to 40°34'88" E. Image width 13 km.



Map showing basic soil types present in the NE corner of Mozambique. Source: Impacto (2007).

Muddy water at 2 m depth in a human-created water hole in Lake Mikulumu pan, 10°40’43”S, 40°25’05”E, at the start of the rains. Many such holes are found on the edges of pans near human settlements, but these are usually dry by the end of the dry season. Photo © Russell Scott.

6. Water and human settlement

Permanent standing/flowing water is rare in inland areas of Palma District, due in part to the strong dry season as well as to the gentle topography and well-drained sandy soils of the Palma–Mueda–Pemba isocline. These soils act as a sponge during the rains, but the absence of sudden topographical changes over most of the isocline does not allow for natural springs to occur in this area, where there is a notable absence of the tree species that are usually associated with riverine forests elsewhere in Africa. Only along the Rovuma River, which is the only permanent watercourse in the district, do such species occur.

Numerous pans and watercourses are present over the northern part of the isocline, containing a clay substrate formed by the collection of heavier particles in the depressions. This prevents the free drainage of water as well as reducing the possibility for plants to take up moisture from the soil. Such areas are characterised by standing water in the middle of the pans for many months of the year, and by the absence of trees. This is the case along most drainage lines (where this feature may be exacerbated by human-induced fire). By the end of the dry season all the pans are dry and water may only be available many metres below the surface.

Outside of the pans the water table is very far below the surface – a borehole sunk at Nhica do Rovuma village in December 2008 reached water at 150 m below the surface, but this dried up after a week, despite the rainy season having already started!

A rare all-year well on the escarpment slope below Nhica do Rovuma, where a subterranean stream is exposed at 3 m depth near 10°43’04”S, 40°12’16”E. This well is the main source of water for the entire village during the dry season, but is located about half an hour’s walk from people’s homes. Villagers explained that there is no permanent settlement near the well due to the large number of elephants that frequent this area.

Dugouts at a fishing settlement on the western shore of Lake Nhica do Rovuma, 10°42'00"S, 40°12'09"E. Despite the plentiful availability of fresh water here, there is no permanent human settlement, as little suitable flat land is available between the lake and the steep hillsides that plunge down to the lake shore, while flat land to the north and south of the lake is prone to seasonal flooding. The adjacent hillsides are very steep, and therefore unsuitable as village sites due to the risk of soil erosion over bare earth. Photo © Russell Scott.

The absence of standing/flowing and underground water at the end of the dry season in the northern part of Palma and Nangade Districts has a major influence on the movement of game animals. To cope with the seasonal water shortage, game animals migrate to the Rovuma River by the end of the dry season, where they find refuge in the forests and dense woodlands along the escarpment edge. With the onset of the rains, the animals disperse southwards over the area of the pans. A similar seasonal pattern of local migration can be observed in the Niassa Game Reserve, where game animals concentrate along the Lugenda and Rovuma Rivers during the dry season, but spread out throughout the reserve during the rains (Derek Littleton, pers. comm.).

This pattern of seasonal migration is probably reflected in historical human population settlement patterns in the area. Before the arrival of the bicycle, which has massively increased the mobility of the local people, small communities may have trekked from dry season camps located near the Rovuma River to areas beside the pans where they could plant their crops and obtain water from wells dug in the pans. A similar pattern of transhumance between dry season floodplain grazing and wet season cultivation is still practised in Southern Sudan today (see Prins 2010).

The arrival of the bicycle and the aspiration to live in permanent settlements may have altered this hypothetical transhumance lifestyle. Many people are now able to settle permanently in areas that are too far to walk to permanent water sources, but which can be supplied by buckets carried on a bicycle. Others live near permanent water sources, but commute by bicycle to remoter fields, and are then able to farm new areas without having to move home.

Abandoned village site at the foot of the escarpment below Nhica do Rovuma, at 10°42’44”S, 40°12’19”E on a small flat area immediately above the Rovuma floodplain where water is available throughout the dry season. The large tree to the left is *Mangifera indica*, one of about twenty large mango trees at this locality, whose almost 1 m diameter indicates that these date back to the 1950s. This village was forcibly relocated to the escarpment rim higher up the slope during the 1960s, as part of counter-insurgency measures to control the population at the end of the Portuguese era.

A very unusual natural water catchment at the base of a tree trunk beside the bicycle track between lake Mikulumu and the Rovuma River, near 10°39’17”S, 40°23’45”E.

Mixed dry forest on the slope to the east of Lake Nhica do Rovuma, taken from a stretch of cleared understorey along oil cutline 34, 10°42'26"S, 40°12'40"E, 16th November 2009. The tall trees are *Terminalia sambesiaca*, which are just coming into leaf, and are locally dominant here over an evergreen understorey of *Diospyros consolatae*. The massive difference in canopy height between the deciduous *Terminalia* and the understorey was only observed in this small area of a large block of forest. Local dominance by *Terminalia sambesiaca* was also not encountered elsewhere in Palma and Nangade districts, but was observed on Lupangua Hill near Quissanga.

7. Forest

Large areas of forest – ca. 800 km^2 – were still present in Palma and Nangade Districts in 2009. Much of this forest falls comfortably within the criteria set out by AETFAT – the association of taxonomists studying the flora of Africa – which defined forest as being a vegetation type where fire is rare to absent, with a canopy more than 10 m high, interlocking tree crowns, and a distinct leaf-litter layer (White 1983). The species composition of these forests identifies them as Eastern African / Swahilian Coastal Forest (*sensu* Clarke 1998).

A detailed breakdown for the amount of forest cover in the eastern part of Palma District is available from the grid of oil cut-lines constructed by oil company Artumas in 2008, for which the different vegetation types encountered along each cut-line have been classified. This has provided 560 km of systematic ground-truthed vegetation transect data, which gives the following estimates for the eastern half of Palma District (and excludes woodland):

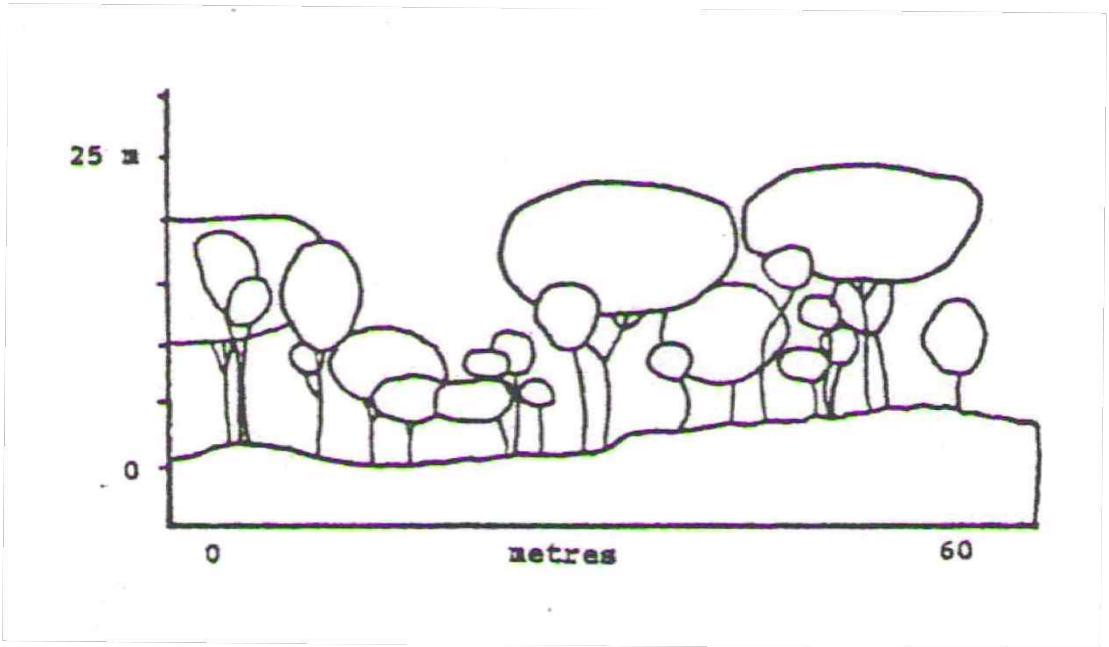
Forest type	%age cover	Area (eastern Palma District = 2000 km^2)
Prime (good) forest	7%	140 km^2
Other (degraded) forest	13%	260 km^2
Brachystegia forest	4%	80 km^2
Scrub forest	6%	120 km^2
Total Forest cover	**30%**	**600 km^2**

Interlocking tree crowns of the forest on the slope to the east of Lake Nhica do Rovuma, taken from a stretch of cleared understorey along oil cutline 34, 10°42'26"S, 40°12'40"E, 16th November 2009. The main tree species is *Terminalia sambesiaca*, which is just coming into leaf. Much of the uppermost canopy of the remaining areas of forest in Palma District is deciduous or semi-deciduous, presenting bare whitened branches when viewed from above at the end of the dry season.

Almost all areas of forest visited in Palma District showed signs of having been cleared in the past, as indicated by the largest trees having multiple trunks, while younger trees are usually single-stemmed. This suggests that the oldest trees have coppice regenerated through new stems sprouting from the edges of cut stumps, while younger trees have grown up during a period free from disturbance. The only exceptions are the trees *Bombax rhodognaphalon*, *Sterculia appendiculata* and the palms *Borassus* and *Hyphaene*, which all have tall single stems that emerge through the canopy. These species are usually left standing when vegetation is cleared for cultivation.

The canopy height of the forests of Palma District varies from 8 to 20 m (emergents to 40 m), with a tendency to a taller canopy at the base of inclines and a lower canopy on the tops of hills and plateaux. The canopy height in some areas may be an artefact of earlier clearance for cultivation, as many trees were observed with wide spreading crowns mounted on very low trunks, suggesting that these trees had been able to develop their crowns unimpeded by competition at this height – while elsewhere the same species was observed to develop a similar-sized crown at twice the trunk height. The squat trees often had multiple stems, reinforcing the evidence that these had regenerated in an open environment.

Some areas of forest comprise a mature overstorey of enormous canopy emergents, which are no longer seen in any quantity elsewhere in coastal eastern Africa, but whose existence is alluded to in old forestry records, e.g. on the Rondo Plateau in SE Tanzania (Clarke 1995). The canopy emergents are usually widespread deciduous species such as *Afzelia quanzensis, Brachystegia spiciformis, Hymenaea verrucosa, Pteleopsis myrtifolia, Milicia excelsa* but also include Swahilian endemics such as *Dialium holtzii* and *Berlinia orientalis*. The large trees are able to cope with the severe dry season by dropping their leaves, while the smaller canopy species that comprise a higher proportion of Swahilian endemics are more usually evergreen or semi-evergreen. It is this layer that maintains the forest microclimate during the critical dry season months and therefore forms the true forest canopy. Such a main canopy and emergent structure indicates mature forest that has been free from disturbance for a very long time.



Transect diagram from Gendagenda Forest Reserve in NE Tanzania, showing a similar canopy structure to that observed in the more pristine forests in Palma District, with a 25 m tall layer of overstorey emergents over a 12–15 m tall canopy. Note that in some areas in Palma District these overstorey emergents reach crown diameters of 25–30 m — twice that recorded at Gendagenda in the diagram above from Lowe & Clarke (2000).

Google Earth GeoEye 50 cm resolution satellite image of forest to the west of the Macanga River valley NNE of Palma, taken on the 17th May 2010. The image spans from 10°39’31” to 10°39’52”S and 40°23’26” to 40°24’05” E. Image width 1.2 km. Note the relatively even canopy texture compared to the image below, as few tree crowns are more than 15 m in diameter, except in the SW corner of the image. The bicycle track between Lake Mikulumu and the Rovuma River runs through this area of forest, which may have been cleared a long time ago, although no traces of old field boundaries are visible on the satellite photo.

Google Earth GeoEye 50 cm resolution satellite image of forest to the east of the Macanga River valley NNE of Palma, taken on the 17th May 2010. The image spans from 10°38’06” to 10°38’28”S and 40°24’00” to 40°24’41” E. Image width 1.2 km. Note the more uneven composition of the canopy compared to the image above, due to the presence of frequent overstorey emergents of 25–30 and sometimes up to 40 m in diameter. The importance of this area has only become apparent with the availability of this high-resolution satellite photo, and it was not visited by the Pro-Natura 2008–2009 expeditions, although an area a few km to the east on oil cutline 11 was visited which had a more scattered concentration of overstorey emergents.

Some of the various types of Swahilian/Eastern African Coastal Forest identified by Clarke & Robertson (2000) for Kenya and Tanzania are present in Palma District as follows:

(a) Swahilian legume-dominated dry forest

Five distinct nodes were observed:

(i) *Berlinia orientalis* forest occurs on the coastal plain, e.g. between Palma and Quionga at 10°39'29"S, 40°30'55"E and at 10°36'44"S, 40°31'10"E, on the coastal plain near Quissenga at 11°03'46"S, 40°28'34"E, at the edge of the Rovuma floodplain between Quissungule and the Namoto border at 10°35'00"S, 40°21'18"E, near the shores of Lake Nhica do Rovuma at 10°42'27S 40°12'29"E, and on the 'Church Road' north of Palma at 10°40'49"S, 40°26'09"E. Other canopy trees include *Albizia adianthifolia, Manilkara sansibarensis* and *Cassipourea mossambicensis* with *Warneckea sousae, Margaritaria discoidea* and *Diospyros mafiensis* in the small tree layer. Introduced orchard species such as mangoes *Mangifera indica* and cashews *Anacardium occidentale* are sometimes present in this forest type near human settlements – these may have been dispersed by elephants, or indicate forest regrowth in abandoned orchards. Canopy height ranges from 8–12 m. Emergents are rare but can include *Erythrina sacleuxii* and *Sterculia appendiculata* at inland locations.

Away from the coastal plain *Berlinia orientalis* becomes slightly less dominant and is partially displaced by a variety of other species, e.g. SE of Nhica do Rovuma village along a drainage line feeding into the main Macanga River valley at 10°45'01"S, 40°14'27"E, and on the edge of a pan beside the Palma–Pundanhar road at 10°50'49" S, 40°12'43" E. *Afzelia quanzensis, Balanites maughamii, Brackenridgea zanguebarica* and *Manilkara sansibarensis* are present in the canopy together with occasional *Brachystegia spiciformis, Hugonia castaneifolia, Pteleopsis myrtifolia, Uapaca nitida, Parinari curatellifolia, Pseudolachnostylis maprouneifolia* and *Garcinia livingstonei*. *Diospyros mafiensis* and *Baphia macrocalyx* are common small trees to about 5 m.

All of the above sites are associated with higher groundwater moisture availability, i.e. around pans or on the coastal plain where the water table is higher than further inland. A stand of almost pure *Berlinia orientalis* forest also exists in the Litipo forest Reserve in SE Tanzania (Clarke 1995), also located in an area of higher groundwater between two lakes.

(ii) *Berlinia orientalis – Brachystegia spiciformis* forest is found inland, in areas a little further away from the edges of pans and a little higher up the slopes of drainage lines, e.g. south of the Palma–Pundanhar road at 10°51'14"S, 40°13'09"E, north of the Palma–Pundanhar road at 10°50'05"S, 40°12'44"E, on the track to Muangaza at 10°55'35"S, 40°22'36"E, and east of the Mocímboa–Palma road at 10°55'40"S, 40°25'25"E. Other canopy species include *Afzelia quanzensis*, *Millettia stuhlmannii, Manilkara sansibarensis* with *Baphia macrocalyx*, *Diospyros shimbaensis*, *D. verrucosa, Brackenridgea zanguebarica, Hugonia castaneifolia*, *Olax dissitifolia, Pseudobersama mossambicensis* and *Bosqueopsis gilletii* as small trees. Canopy height 10–12m.

Berlinia orientalis – Brachystegia spiciformis is also present at Quiterajo south of Mocímboa da Praia along the edges of drainage lines, e.g. at 11°49'39"S, 40°20'34"E.

(iii) *Scorodophloeus fischeri – Guibourtia schliebenii* forest is present in Nangade District. Neither species are found in Palma District, despite both being found right beside the sea a few km to the north in SE Tanzania (Brenan 1967) and *Guibourtia schliebenii* dominated forest being present near the coast at Quiterajo, south of Mocímboa da Praia. This forest type is located on the escarpment edge overlooking the Rovuma valley north and north-east of Nangade at 10°57'40"S, 39°46'36"E, on the slope leading up from the Rovuma floodplain at 10°53'08"S, 39°53'16"E, on level terrain south of the Pundanhar–Nangade road at 10°56'26"S, 39°54'22"E. Canopy height 8–16 m.

Scorodophloeus fischeri and/or *Guibourtia schliebenii* are present as overstorey emergents up to 30 m (exceptionally 36 m) in this forest type, sometimes also with *Hymenaea verrucosa* and *Bombax rhodognaphalon*. *Scorodophloeus fischeri* and/or *Guibourtia schliebenii* likewise strongly dominate the main canopy, in association with *Commiphora serrata*, *Balanites maughamii*, *Afzelia quanzensis* (which can be common), *Hexalobus mossambicensis*, *Euphorbia ingens*, *Euphorbia lividiflora*, *Manilkara discolo*r, *Hugonia orientalis, Rourea orientalis, Tamarindus indica, Pteleopsis myrtifolia, Sterculia schliebenii, Oldfieldia somalensis, Millettia stuhlmannii, Maerua bussei, Cola* sp., *Fernandoa* sp. and *Zanthoxylum holtzii*.

(iv) *Guibourtia schliebenii – Hymenaea verrucosa* forest is present in Nangade District at the edge of the Rovuma River floodplain near the Hunter's Camp on the border between Nangade and Palma Districts at 10°54'16"S, 39°51'22"E. Main canopy 10 m high, with overstorey emergents to 30 m.

Guibourtia schliebenii and *Hymenaea verrucosa* are present as overstorey emergents as well as in the main canopy with *Pteleopsis myrtifolia* and *Millettia stuhlmannii* as well as *Fernandoa* sp.

(v) *Hymenaea verrucosa – Brachystegia spiciformis* forest is present beside the road to Olumbi at the base of a drainage line at 11°00'02"S, 40°21'58"E. Canopy height 15 m without an emergent overstorey layer.

Hymenaea verrucosa is the most common tree together with *Brachystegia spiciformis*. *Baphia macrocalyx* is common as a small tree with *Pseudobersama mossambicensis*, *Manilkara sansibarensis* and lots of *Hymenaea* saplings, as well as *Bosqueiopsis gilletii* and *Hugonia castaneifolia*.

The now disappeared 'Sachsenwald' forest near Dar es Salaam in Tanzania included areas of *Hymenaea verrucosa – Brachystegia spiciformis* forest.

Cynometra dominated forest appears to be totally absent from Palma and Nangade Districts, despite the presence of perhaps 3 species of *Cynometra* on the Makonde plateau to the immediate north in SE Tanzania – perhaps due to a long history of cultivation and fire here.

(b) Swahilian mixed dry forest

Mixed forest by definition includes diverse assemblages of tree species, making it difficult to recognise clear nodes in what is essentially a continuum of different tree communities.

Mixed forest with common *Manilkara sansibarensis*, *Ochna mossambicensis* and *Pteleopsis myrtifolia* is present in many areas in Palma District, e.g. on the Palma–Pundanhar road at 10°49'12"S, 40°20'31"E, and east of the Mocímboa–Palma road at 10°55'24"S, 40°23'35"E. Other canopy trees include *Brackenridgea zanguebarica, Berlinia orientalis, Strychnos myrtoides, Baphia macrocalyx, Grewia* sp., *Cassipourea mossambicensis* and *Manilkara discolor,* while the additional presence of *Pseudobersama mossambicensis, Cleistanthus schlecteri* and *Baphia* sp. nov are indicative of forest in good condition. Small trees include *Diospyros abyssinica, Memecylon natalensis, Oxyanthus* sp. A of FZ, *Bosqueopsis gilletii, Warneckea sousae* and *Tricalysia schliebenii*. Canopy height is about 12 m. Most of the larger trees are multi-stemmed, while large overstorey emergents are not always present in this forest type, suggesting that it may be seral.

The same assemblage of tree species occurs on ridge tops, where *Manilkara discolor* becomes the most common tree (about 10% of individuals), displacing *Manilkara sansibarensis*, which is then only occasionally present. Additional canopy trees include *Ochna polyneura, Pancovia holtzii, Hymenaea verrucosa* and *Strychnos myrtoides*. Examples of this forest type are found on the Palma–Quissungule road at 10°41'23"S, 40°19'32"E, and a few km further east at 10°41'28"S, 40°19'03"E and further west at 10°42'07"S, 40°14'21"E. Canopy height 5–6 m with 10–12 m emergents of *Pteleopsis myrtifolia*, *Manilkara discolor* and *Balanites maughamii*. This assemblage was one of the few seen in Palma District with all trees having a single straight trunk.

Brachystegia spiciformis is absent from both of the above types of mixed dry forest, but is the most common tree in what may be a seral/depauperate version of the latter forest type located beside the Lake Mikulumu–Rovuma River bicycle track on a plateau top at 10°39'04"S, 40°22'38"E. Other canopy trees here include *Ochna polyneura, Pseudobersama mossambicensis, Manilkara sansibarensis, Manilkara discolor, Berlinia orientalis, Strychnos myrtoides, Baphia* sp. nov. with *Bosqueopsis gilletii, Oxyanthus* sp. A of FZ, *Diospyros mafiensis, Rourea orientalis, Mostuea brunonis, Craibia brevicaudata* and *Pteleopsis myrtifolia* as small trees.

Some of the best developed forest in Palma District is characterised by the frequent presence of evergreen *Diospyros verrucosa* and/or *Diospyros kabuyeana* in the small tree layer and main canopy, e.g. on a flat plateau top north of Lake Mikulumu at 10°40'01"S 40°25'13"E, and on the upper slopes and plateau above Lake Nhica do Rovuma at 10°42'27"S, 40°12'40"E. *Diospyros verrucosa* appears to require the partial shade afforded by the huge deciduous canopy emergents of *Brachystegia spiciformis*, *Hymenaea verrucosa*, *Pteleopsis myrtifolia, Dialium holtzii, Berlinia orientalis, Afzelia quanzensis* that can reach 25m in height and form 30 m wide crowns. Additional canopy emergents are present on sloping terrain near Lake Nhica do Rovuma and include *Terminalia sambesiaca, Milicia excelsa, Adansonia digitata, Tamarindus indica* and *Cleistanthus schlecteri* over the12 m semi-evergreen canopy of *Diospyros verrucosa*, *Ochna mossambicensis, Manilkara sansibarensis, Warneckea sousae* and *Vitex* sp. *Baphia macrocalyx* is common as a smaller tree to 8 m. Many trees are multi-stemmed, including most the large canopy emergents and the clusters of *Diospyros verrucosa*, which appears to be preferentially cut for poles. Basal diameter of large canopy emergents up to 4 m, with individual trunks up to 1 m.

Evergreen to semi-evergreen mixed forest with frequent *Warneckea sousae* is present on a flat plateau top south of the Palma–Namoto road at 10°36'52"S, 40°25'04"E and at 10°37'28" S, 40°25'10" E. Single-stemmed and small-crowned evergreen *Warneckea sousae* can be locally very dominant. Other canopy species include *Diospyros verrucosa*, *Baphia macrocalyx* and *Baphia kirkii*. Canopy height 9 m with only a few small emergents (occasional *Afzelia quanzenis* and *Dialium holtzii* to 14 m). *Baphia* sp. nov is also present here, indicating an absence of human disturbance for many years.

Euphorbia trees were surprisingly infrequently encountered, probably because flat or very gently sloping terrain predominates in Palma District. These trees were only found on well-drained termitaria in the pans, as well as on steeper slopes such as on the side of a river valley east of Lake Nhica do Rovuma at 10°42'32"S, 40°13'16"E, and on the escarpment edge leading down to the Rovuma River floodplain between Quissungule and the Namoto border post at 10°36'13"S, 40°21'12"E. At both these locations *Euphorbia* sp. produced dense stands comprising some 50% of canopy trees.

(c) Swahilian groundwater forest

A small patch of moist forest on flat and seasonally waterlogged ground is present on the coastal plain near Quissenge at 11°03'44"S 40°26'51"E, dominated by *Uapaca sansibarica* with a 20 m wide spreading crown, together with *Berlinia orientalis* and *Brachystegia spiciformis* over a sparse shrub layer. Other trees in the canopy include *Parinari curatellifolia* as well as a single individual of *Uapaca nitida,* which is common in the wooded grassland outside the forest. Small trees include *Pseudolachnostylis maprouneifolia, Hymenaea verrucosa, Drypetes natalensis, Garcinia livingstonei, Diospyros verrucosa* and *Baphia macrocalyx. Phoenix reclinata* was present as a shrub growing out of termite mounds. Most of the trees – including the large trees – are single stemmed. Canopy height 15–16 m without overstorey emergents

(d) Swahilian swamp forest

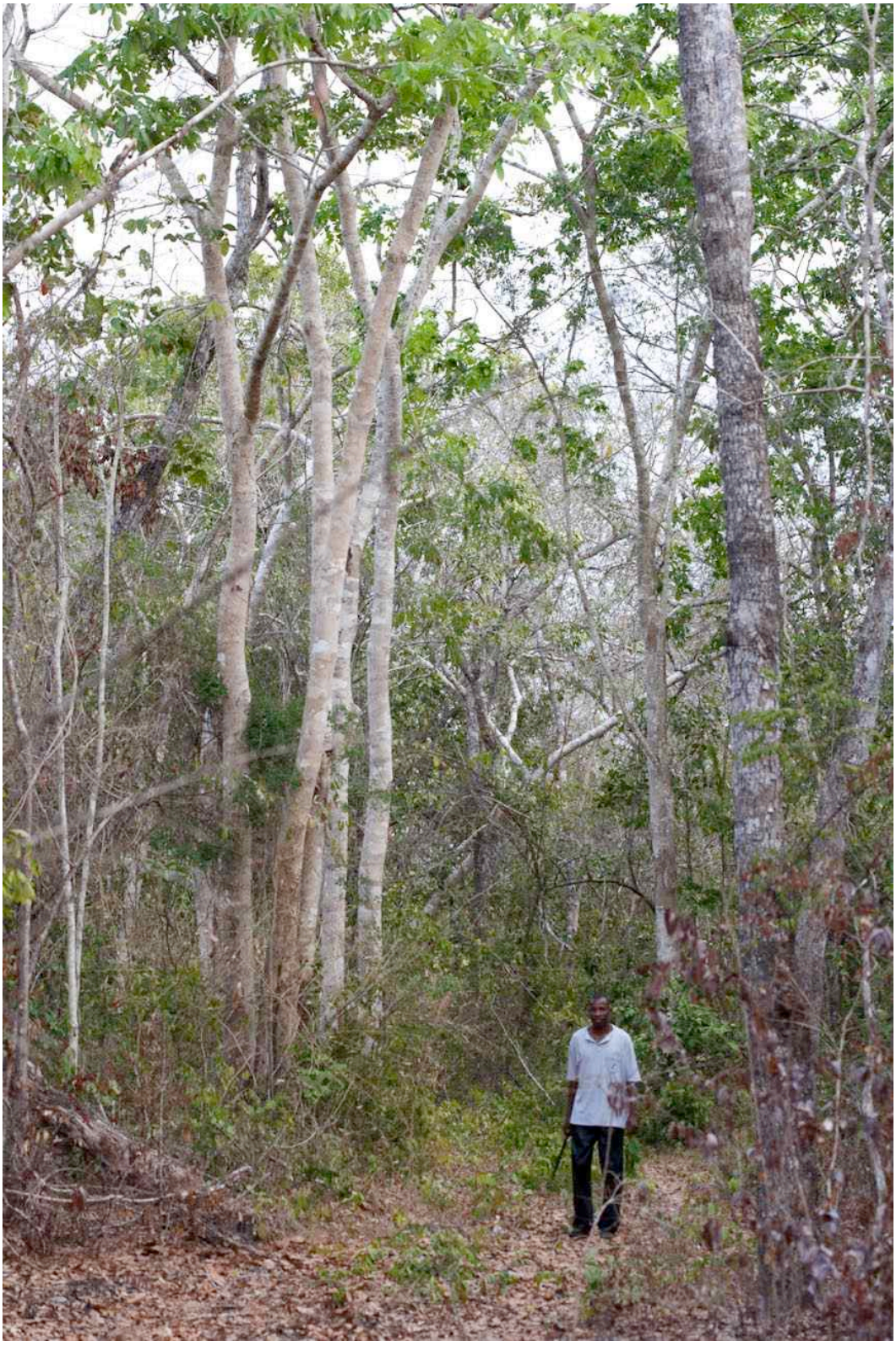
A small area of *Barringtonia racemosa* swamp forest is present on the southeast edge of Lake Nhica do Rovuma at 10°42'03"S, 40°12'25"E.

(e) Mixed scrub forest and maritime scrub forest

Treated separately in Section 8 of this report.

(f) Swahilian *Brachystegia* forest

Treated separately in Section 9 of this report. Not to be confused with *Brachystegia* woodland, which is also widely present in Palma District and treated in Section 10 of this report.



Dry legume-dominated *Brachystegia spiciformis — Berlinia orientalis* forest south of the Palma–Pundanhar road, 10°51'14"S, 40°13'09"E, 6th November 2009 (immediately before the rains). The large multi-stemmed trees to the left of botanist Hermegildo Matimele are *Berlinia orientalis* that have regenerated from stumps, probably following the creation of the road during the Portuguese era (this track appears on maps based on old aerial photos pre 1975). The tree with the grey striated bark in the foreground right is *Brachystegia spiciformis*. Photo taken at the end of the dry season, demonstrating that the 15 m high canopy is about 40% evergreen. Photo © Russell Scott. See overleaf for another photo of the same patch of forest taken one month later.

Dry legume-dominated *Brachystegia spiciformis — Berlinia orientalis* forest south of the Palma–Pundanhar road, 10°51'15"S, 40°13'10"E, 10th December 2008. This is the same patch of forest as on the previous page, but taken one month later in the season when the rains have started and all species have come into leaf. Other trees present here include *Manilkara sansibarensis*, *Pseudobersama mossambicensis* (an indicator of undisturbed forest), *Brackenridgea zanguebarica*, *Bosqueopsis gillettii*, *Diospyros verrucosa* and *Diospyros shimbaensis*. The rare tree *Vangueria randii* was collected here as a 15 m canopy tree. *Baphia macrocalyx* is common as an understorey tree.

Well-developed mixed dry forest on a hilltop, at the intersection between oil cut-line 34 and the Palma–Quissungule road, 10°41’23”S, 40°19’32”E. Most trees in this area are single-stemmed, but very large trees are absent. Canopy height is about 6-8 m.

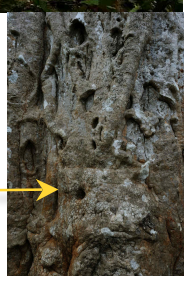
Well-developed mixed dry forest at the extreme western end of oil cut-line 34. All of the largest trees here are multi-stemmed, indicating coppice regowth following agricultural clearance dating perhaps as far back as the 1950s. The large tree cluster in the foreground is *Cleistanthus schlecteri*, with a large multi-stemmed *Milicia excelsa* behind and slightly to the right. Canopy height about 15 m with the large trees emerging to 25 m.

Single-stemmed trees in forest developed in an area of impeded drainage, beside an oil cutline near Quissenge airfield, 11°03'44"S, 40°26'51"E, 9th December 2008. Stilt-rooted *Uapaca sansibarensis* is the most common tree in this patch of forest (but not visible here). Other canopy tree species include *Brachystegia spicifomis Berlinia orientalis*, *Pseudolachnostylis maprouneifolia, Parinari curatellifolia* and *Hymenea verrucosa*. *Baphia macrocalyx, Dracaena manii, Drypetes natalensis* and *Diospyros* sp. are present as small trees. The palm *Phoenix reclinata* is visible in the background, growing out of a termite mound – a number of such individuals were seen in this forest patch, although none of these had progressed beyond the size seen here.

Well developed mixed dry forest on oil cutline 11, 10°40'01"S, 40°25'13"E, 7th December 2008. The large trees in the foreground are *Pteleopsis myrtifolia*, reaching 25 m high above the 12 m high canopy. The forest in this area contained a regular scattering of large canopy emergents of *Pteleopsis myrtifolia, Brachystegia spiciformis, Hymenaea verrucosa, Afzelia quanzensis*, all of which are deciduous (although Afzelia is only briefly deciduous), over a semi evergreen canopy of smaller trees that include *Diospyros verrucosa, Ptaeroxylon, Ochna mossambicensis* and *Diospyros* sp. All of the large canopy emergents were multi-stemmed, indicating that even in this area the forest may have been cleared many years ago.

Well-developed mixed dry forest with a very diverse species assemblage beside the 'church road' at 10°39'02"S, 40°29'11"E, 9th November 2009. This particular area of forest had an almost entirely evergreen subcanopy at the end of the dry season, just before the onset of the first rains. Small trees in the 7 m high canopy include *Hymenaea verrucosa, Baphia macrocalyx, Diospyros consolatae, D. mafiensis, Brackenridgea zanguebarica, Strychnos madagascariensis, Xylotheca tettensis, Craibia zimmermannii* and *Diplorynchus condylocarpus* with deciduous emergents of *Pteleopsis myrtifolia* and *Brachystegia spiciformis* to 14 m.

An unusual stand of Euphorbias in the forest on a ridge to the southeast of Lake Nhica do Rovuma, near 10°42’32”S, 40°13’16”E. *Tamarindus indica* was also common here. Photo © Russell Scott.



Two baobabs (*Adansonia digitata*) from a stand of about 10 trees on oil cutline 34 near Lake Nhica do Rovuma. Baobabs were not encountered elsewhere in forest in Palma District, and this stand may represent the relicts of an ancient human occupation site (see Clarke & Karoma 2000 for discussion), strategically located on a ridge above Lake Nhica at a sufficient distance to limit disturbance by wild animals. One of the baobabs bears a rectangular scar (right), which may be from the removal of bark for cloth. Photos © Xavier Desmier / PNI-MNHN.

Legume-dominated *Berlinia orientalis* — *Brachystegia spiciformis* forest on the bicycle track between lake Mikulumu and the Rovuma River, towards the bottom of a slight drainage line, ca. 10°40'05"S, 40°24'04"E, 15th November 2009.

Thick legume-dominated *Berlinia orientalis* — *Brachystegia spiciformis* forest beside the track to Muangaza village, towards the bottom of a slight drainage line, ca. 10°55'35"S, 40°22'36"E, 5th December 2008. Note the characteristic black crocodile bark of *Brachystegia spiciformis* on the tree trunk in the foreground, with the pale trunk of *Berlinia orientalis* in the background to the immediate left of this tree. Photo © Frances Crawford.

Legume-dominated *Berlinia orientalis* forest east of the Palma–Quionga road, 10°39'29"S, 40°30'55"E, 9th November 2009. *Berlinia orientalis* is strongly dominant here as in other forest patches on the low-lying coastal plain, sometimes occurring together with old mango and cashew nut trees. Almost all large individuals of *Berlinia orientalis* here are multi-stemmed, suggesting coppice regeneration from cut stumps or perhaps as a consequence of fire encroachment (see photo on page 85).

Dry evergreen mixed forest dominated by the rare *Warneckea sousae* at the northern end of oil cut-line 11, 10°36'52"S, 40°25'04"E, 6th December 2008, immediately before the onset of the rains. The canopy height here is about 10 m with only occasional overstorey emergents. All trees here are single-stemmed, suggesting that this patch of forest has remained undisturbed for a very long time. Photo © Olivier Dubuquoy.

Dry mixed forest on a plateau on the bicycle track between Lake Mikulumu and the Rovuma River, ca. 10°39'05"S, 40°22'48"E, 15th November 2009. The canopy here is dominated by *Brachystegia spiciformis*, *Pteleopsis myrtifolia* and *Afzelia quanzensis* with more occasional *Manilkara discolor* in the big tree layer. The largest trees are multi-stemmed, but medium-sized trees such as this individual of *Brachystegia spiciformis* have produced a single straight trunk, as would be normal when growing in forest conditions.

Dry mixed forest on a small rise to the immediate west of Lake Mikulumu, 10°40’42”S, 40°24’13”E, 23rd November 2008. High-resolution GeoEye satellite images reveal a patchwork of old cultivation in this area due to its proximity to the lake, and nowhere is the canopy more than 12 m tall. The tree to the right is *Baphia macrocalyx*, a common and vigorous species that regenerates readily from cut stumps. The scrubby – and impenetratable – nature of this forest is typical of much of the forests of Palma District.

An exceptional area of single-stemmed trees in mixed dry forest on the top of a plateau, beside the junctions of oil cutlines 34 and 7, 10°41'28"S, 40°19'03"E, 23rd November 2008. The dark-stemmed tree is *Manilkara discolor*, which is a common component of the forests in this area, together with *Manilkara sansibarensis*.

Single-stemmed trees in forest developed in an area of impeded drainage, beside an oil cutline near Quissenge airfield, 11°03'44"S, 40°26'51"E, 9th December 2008. Stilt-rooted *Uapaca sansibarensis* is the most common tree here. Other canopy tree species include *Brachystegia spicifomis Berlinia orientalis*, *Pseudolachnostylis maprouneifolia, Parinari curatellifolia* and *Hymenea verrucosa*.

A large single-stemmed individual of *Manilkara discolor* in dry mixed forest at the junction between oil cut-line 34 and the Palma to Quissungule road, 10°41’23”S, 40°19’32”E. This tree with a diameter of 40 cm is one of the largest in this type of forest, which is found on hilltops with well-drained sandy soils.

Manilkara discolor is evergreen and its dense foliage provides good shade – large individuals are sometimes selected by elephants for sleeping sites, as observed in the Palma forests and also in the Quiterajo forests south of the Messalo River.

Contrasting growth forms in the medium-value commercial timber tree *Afzelia quanzensis*. The tree avove (a) has coppice regenerated twice in its lifetime, producing a squat tree 10 m high with a wide crown and multiple stems, while the tree on the right (b) has managed to escape logging and has produced a single stem some 10 m to the first branch and a total height of about 30 m. The tree below (c) is intermediate between the two, having first produced a comparatively low multi-stemmed crown, followed later by a new shoot (grey, foreground) which is rising a full 10 m above the old crown.

Photo (a, above left) Quissungule to Namoto border road in an area of regenerating scrub, 24th November 2008. Photo (b, above) deep in mature forest at the intersection of oil cutline 34 and a drainage line, ca. 10°41'42"S, 40°17'20"E, 23rd November 2008. Photo (c, left) on the bicycle track between lake Mikulumu and the Rovuma River, on a plateau, ca. 10°39'11"S, 40°23'05"E, 15th November 2009.

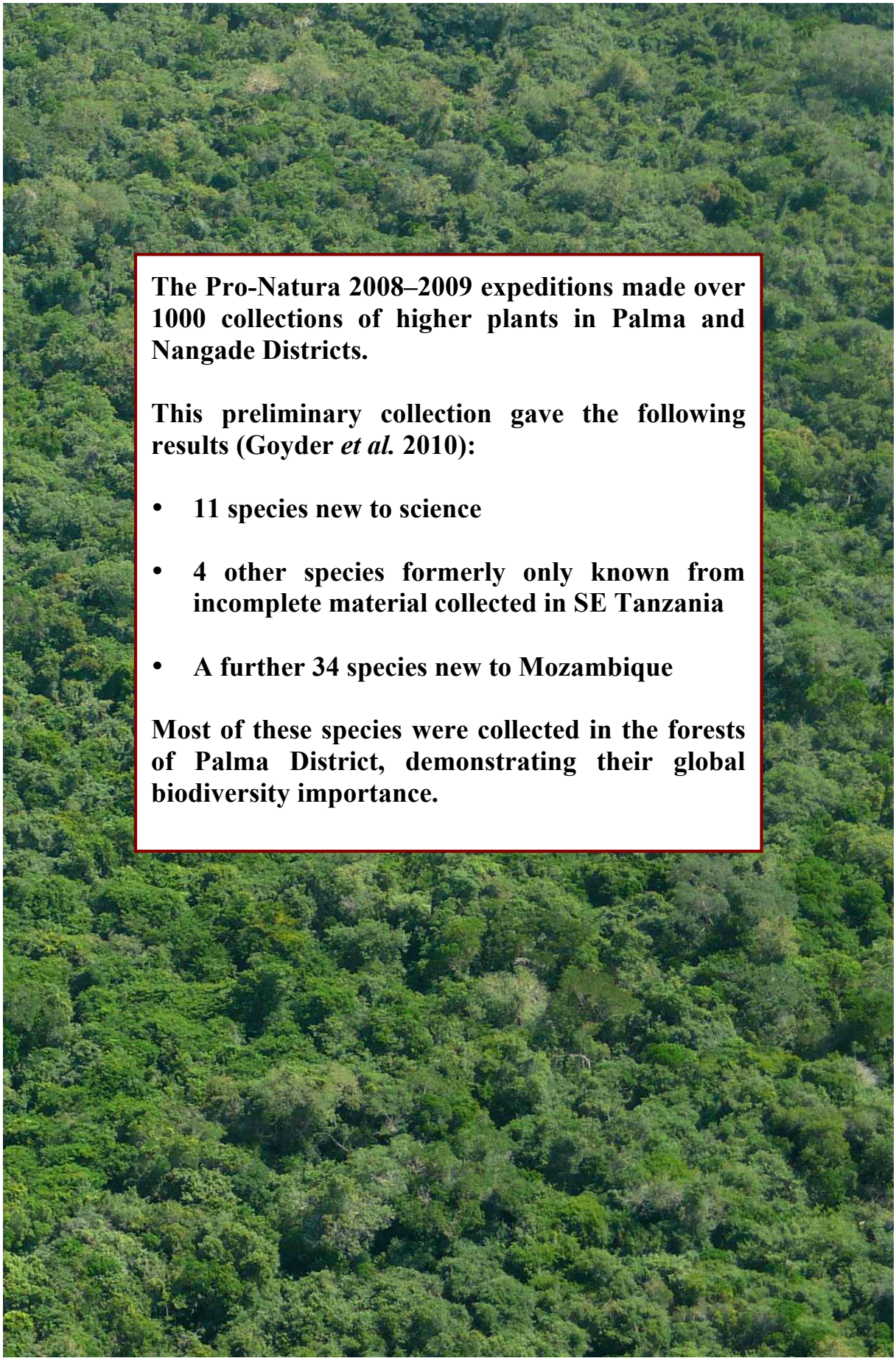
Stilt-rooted *Uapaca sansibarensis* (below), 11°03'44"S, 40°26'51"E, 9th December 2008.

Pteleopsis myrtifolia, single-stemmed tree branching at just 3 m above ground, west of Lake Mikulumu, near 10°41'07"S, 40°24'29"E, 14th November 2009.

Dialium holtzii. Multi-stemmed tree with a 20 m wide crown to the east of Lake Nhica, 10°41'43"S, 40°12'36"E, 13th November 2009.

Brachystegia spiciformis with a wide multi-stemmed crown branching at ground level, in thick forest on the bicycle track between Lake Mikulumu and the Rovuma River, ca. 10°39'05"S, 40°22'50"E, 15th November 2009. *Brachystegia spiciformis* is usually associated with miombo woodland, but is frequently encountered in mixed dry forest and also in *Brachystegia* forest in Palma District. It may be a relict of areas that were formerly under cultivation, although recruitment of younger, single-stemmed individuals was observed.

Hymenaea verrucosa. 20 m tall, multi-stemmed tree to the east of Lake Nhica, near 10°42'26"S, 40°12'40"E.



The Pro-Natura 2008–2009 expeditions made over 1000 collections of higher plants in Palma and Nangade Districts.

This preliminary collection gave the following results (Goyder *et al.* 2010):

- **11 species new to science**
- **4 other species formerly only known from incomplete material collected in SE Tanzania**
- **A further 34 species new to Mozambique**

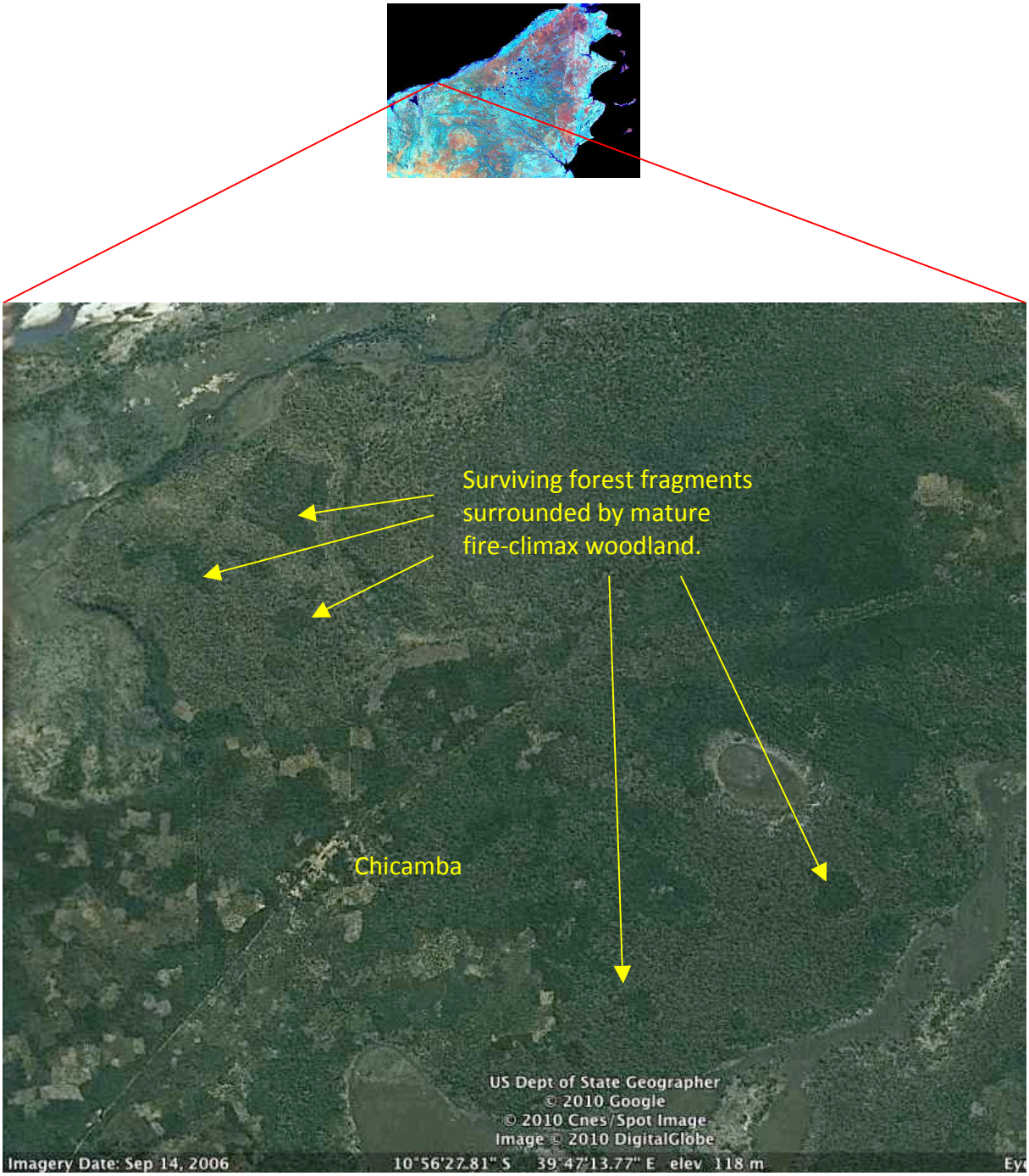
Most of these species were collected in the forests of Palma District, demonstrating their global biodiversity importance.

Beyond Palma – the Nangade forests

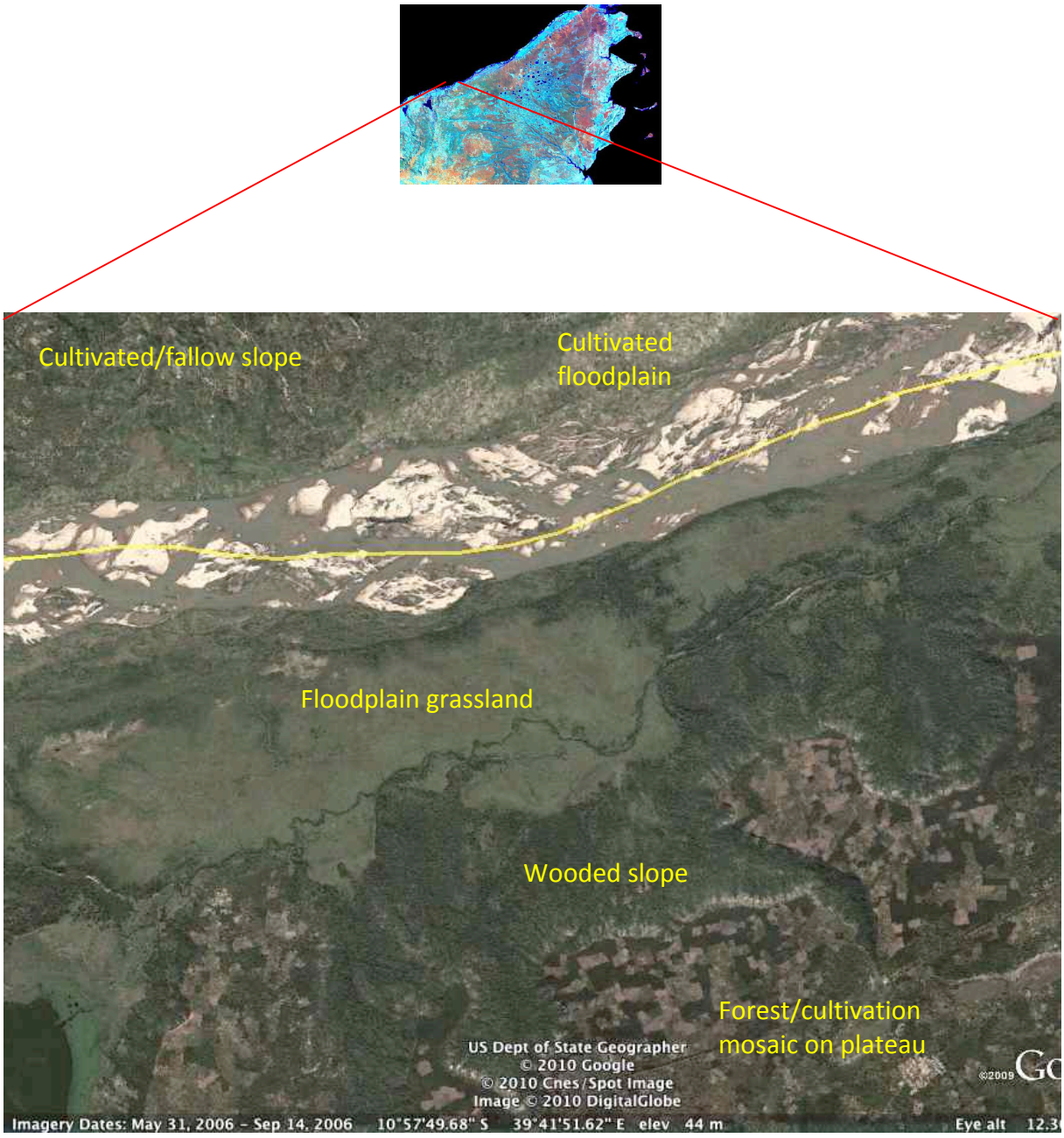
Further Swahilian Coastal Forest is found to the immediate west of Palma District in neighbouring Nangade District. Although only briefly visited, these forests comprise a totally different canopy tree species composition to those found in Palma District, being strongly dominated by *Scorodophloeus fischeri* and *Guibourtia schliebenii*, neither of which are found in Palma District. This block of forest is already heavily fragmented and is being rapidly cleared for cultivation.

Scorodophloeus fischeri and *Guibourtia schliebenii* dominated dry forest in the process of being cut at the edge of Chicamba village, 10°57'30"S, 39°46'44"E, March 2009. Photo © John and Sandie Burrows. Note the single straight trunks, the even canopy layer and absence of canopy emergents.

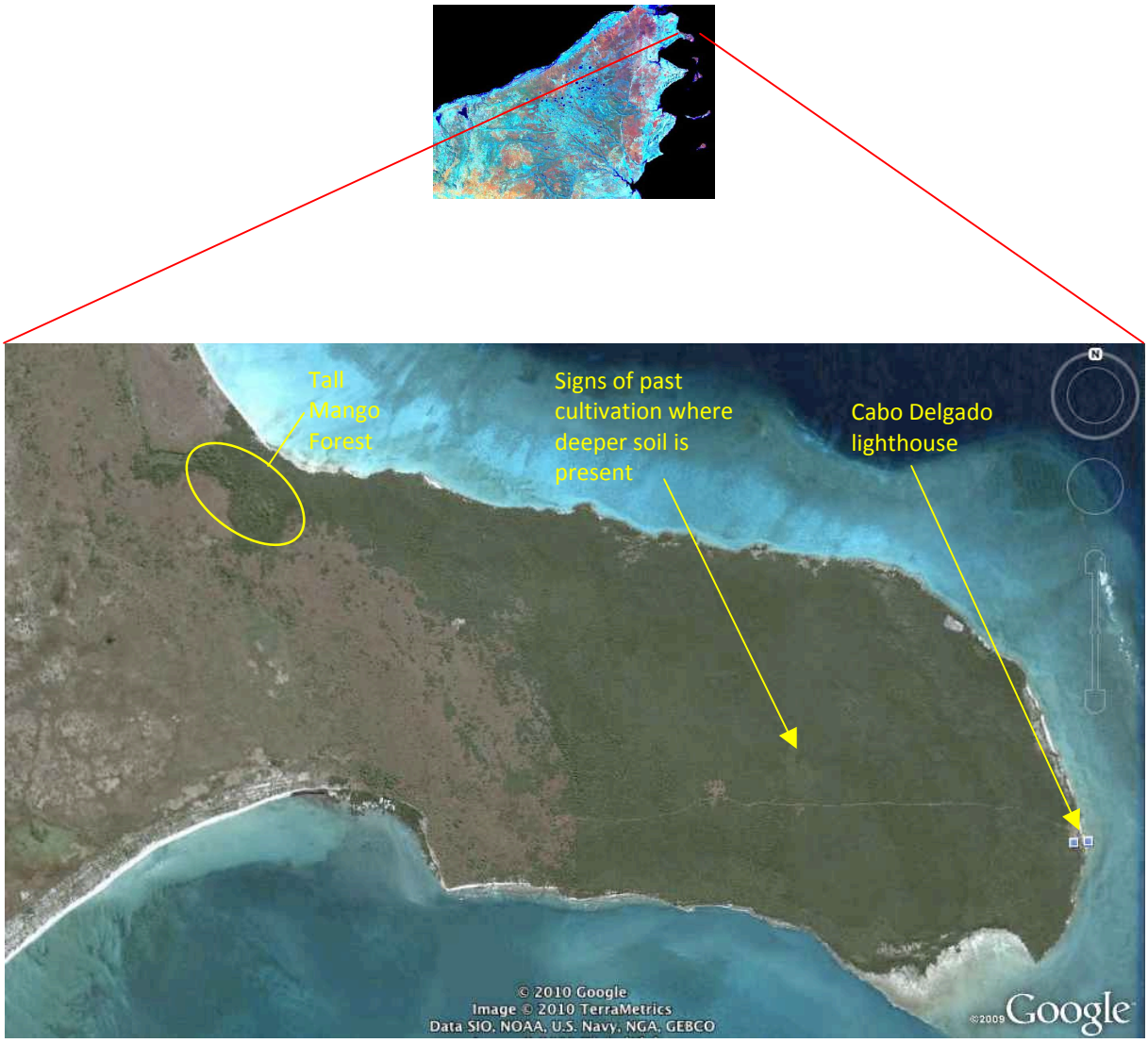
The distinctive 3-leaflet pinnae of *Scorodophloeus fischeri* together with a seed pod. *Scorodophloeus fisheri* is recognised as an indicator species for Swahilian Coastal Forest, being present in almost all the better developed patches of Coastal Forest in Tanzania and Kenya where it is often locally dominant (Clarke & Robertson 2000). Surprisingly it only just reaches south of the Rovuma River into Mozambique in the Nangade and Pundanhar forests, where it is again dominant. Photo © John and Sandie Burrows.



Chicamba village and surroundings from Google Earth Cnes/Spot image taken on the 14th September 2006, spanning from 10°55'05" to 10°59'08"S and 40°12'86" to 40°13'18" E. Image width 9 km. The Rovuma River is just visible in the top left corner of the photo. This photo suggests that the *Scorodophloeus fischeri – Guibourtia schliebenii* forests were contiguous in the lower left-hand side of the image until relatively recent times, but are now heavily fragmented by cultivation. Isolated patches of forest with a distinct edge surrounded by mature fire-climax woodland suggests that the *Scorodophloeus fischeri – Guibourtia schliebenii* forests extended further onto the plateau in former times.



Google Earth Cnes/Spot image taken between the 31st May and the 14th September 2006, spanning from 10°55'08" to 11°00'31"S and 39°38'00" to 39°45'27" E. Image width 14 km. The Rovuma River crosses the upper part of the image, and part of Lake Nangade is just visible in the lower left corner of the photo as a dark block. Note the near-natural vegetation ecotone from the Rovuma River with its many channels and exposed sandbanks to the wide grassland floodplain followed by the wooded escarpment edge and then the fragmented mosaic of *Scorodophloeus fischeri – Guibourtia schliebenii* forest on the plateau top. Note also the exposed white exposed sandy soils of the steep escarpment edges, where the near vertical slopes and sudden change in topography may be protecting the forests on the plateau top from the frequent fires that sweep through the Rovuma valley.



Google Earth satellite photo of the Cabo Delgado peninsula, showing the abrupt transition from the open coastal plain (brown) to dense closed canopy maritime scrub forest on the uplifted coral rag shelf (dark green). The very thin layer of soil over the coral rag makes it unsuitable for cultivation, and this may have protected the scrub forest from anthropogenic destruction. By comparison, the original forest on the coastal plain was probably cleared for farmland during a long and ancient process of shifting cultivation, and the forest subsequently prevented from regenerating by frequent bush fires.

A very rare shrub, *Xylopia* sp. A of FTEA – formerly only known from a now cleared forest patch on the coastal plain in SE Tanzania – was found in one of the few remaining forest patches near the Cabo Delgado peninsula. This find demonstrates the biodiversity importance of these remaining fragments of forest on the coastal plain. Extremely little forest now remains on the coastal plain anywhere along the eastern African coast, due to the long historical influence of humans in this zone. Paradoxically there is now very little agricultural activity on the coastal plain near Palma, due to the poor productivity of the leached white sandy soils that have lost their fertility following the loss of the humus layer associated with forest.

The small remaining pockets of forest on the coastal plain between Palma and Quionga are often associated with orchard trees such as mangoes *Mangifera indica* and cashews *Anarcardium occidentale* that may have been spread by elephants which are common in this area. One such patch of mango forest located at the extreme western end of the Cabo Delgado peninsula contains 40 m high mango trees – possibly among the tallest trees in Cabo Delgado province.

8. Scrub Forest

Non-seral scrub forest is only present in Palma District on the Cabo Delgado peninsula, where maritime scrub forest (*sensu* Clarke & Robertson 2000) has developed on the thin soils that overlay the uplifted coral rag that forms the cape. An intermittent soil cover and rocky substrate have protected this vegetation from being cleared for cultivation, though there are signs that this has taken place to a limited extent on the peninsula (see notes opposite).

Elsewhere in Palma District there are large areas of closed canopy vegetation that fall under the AETFAT definition of scrub-forest (White 1983), but which appear to be seral, i.e. forest in the process of regeneration where the canopy has not yet reached the required 10 m lower cut-off to be properly classified as forest (*sensu* White 1983). These scrub forests are primarily composed of most of the same tree and shrub species that are seen in adjacent woodland areas, but with an increasing number of additional tree species where scrub forest tends towards true forest. Woodland areas are effectively a depauperate version of this regenerating scrub forest, where the same tree species are present at a much lower density and are supplemented by a few widespread woodland species such as *Uapaca nitida*, *Parinari curatellifolia* and *Annona senegalensis,* which are not found in scrub forest. By contrast the additional non-woodland species found in scrub forest – such as *Pseudobersama mossambicensis* and *Baphia* sp. nov – are mostly restricted to the Swahilian regional centre of endemism/the eastern African Coastal Forest hotspot.

An interpretation for this phenomenon is that the long history of forest clearance associated with bush fallow cultivation in Palma District has over time positively selected for forest species that are able to coppice regenerate from stumps and also tolerate fire. Clearance for cultivation followed by frequent bush fires will then open up this vegetation to produce a woodland physiognomy, while an absence of fire and the cessation of further human disturbance will allow cleared areas to regenerate back to scrub forest and ultimately to forest given sufficient time, during which some restricted range non fire-tolerant forest species are able to recolonise the regenerating forest. This process appears to be taking place over much of Palma District at the moment.

A striking feature of almost all the forest areas visited in Palma District is the relative scarcity of restricted range Swahilian/eastern African Coastal Forest trees beyond those already present in scrub forest. This observation reinforces the hypothesis that almost all of the original forest cover of Palma District has at one time or another been cleared.

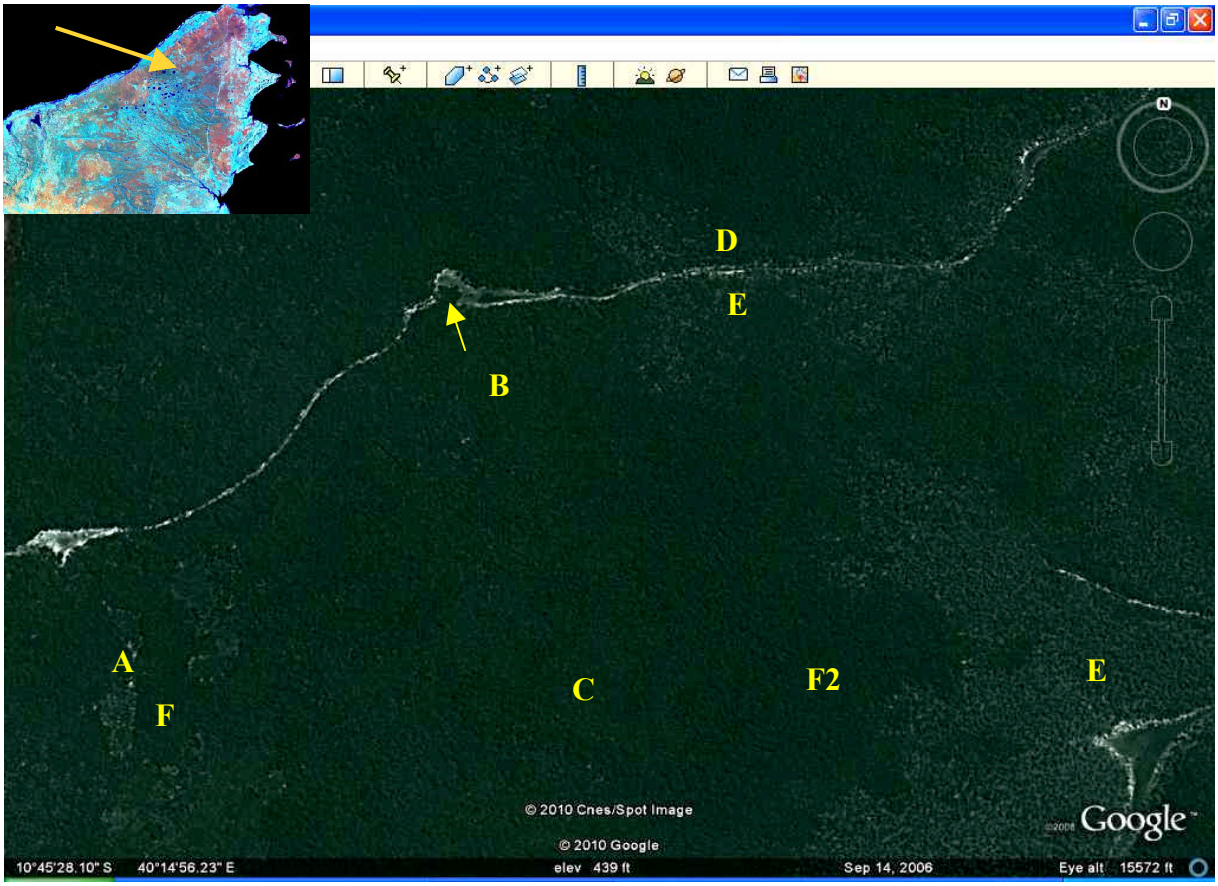
Fire occasionally penetrates into scrub forest, but as scrub forest tends towards forest, grasses become scarcer and invasive bush fires burn less hot and cause less destruction, thereby allowing regeneration to continue. Too frequent fires may cause the process to go in reverse, with an opening up of the scrub forest that can ultimately lead to a thicker grass layer, hotter fires and a shift towards the formation of woodland.

Typical seral scrub forest species in Palma District include *Brachystegia spiciformis* and *Berlinia orientalis* as the more common 'emergents' to about 10 m (scrub forest has no real canopy but a single shrub/small tree layer with occasional large trees), together with *Manilkara sansibarensis* and *Balanites maughamii*. Shrubs and small trees to about 6 m include common *Baphia macrocalyx* with *Strychnos myrtoides, Diospyros abyssinica, D. mafiensis, D. verrucosa, Rourea orientalis, Rinorea elliptica* and *Hugonia castaneifolia*. A representative example is located near Nhica do Rovuma at 10°44'50"S, 40°15'13"E.

Impenetratable scrub forest on a small hilltop at the western end of oil cutline 34 near Nhica do Rovuma, early November 2009. The rains have yet to arrive, and most trees and larger shrubs have yet to produce leaf.

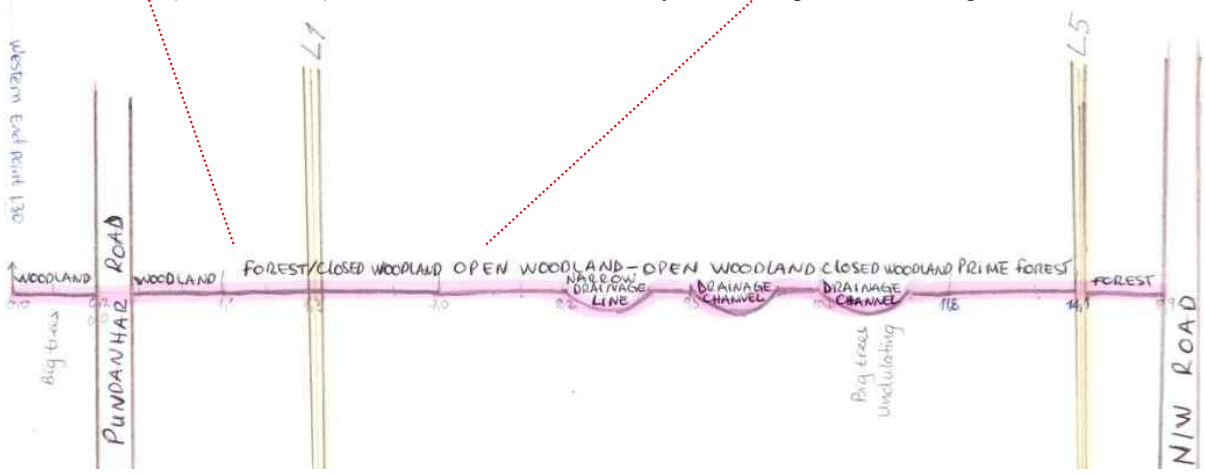
Impenetratable scrub forest on a small hilltop at the western end of oil cutline 34, end November 2009, a few weeks after the onset of the rainy season. Note the striking difference between this view and that of the previous photo, taken just a few weeks apart at almost the same location.

The canopy height of scrub forest in Palma District is highly uneven, possibly due to the different states of regeneration of this forest sub-type.



Vegetation mosaic to the SE of Nhica da Rovuma, from Google Earth Cnes/Spot image, 10°45'30" to 10°46'24"S and 40°13'27" to 40°16'20" E, September 2006. Image width 5 km. Note that the colour balance on this image is not correct, and is far too green given that this represents the middle of the dry season in September.

A. Abandoned cultivation and settlement beside forest with rare trees such as *Pseudobersama mossambicensis* to the immediate east.
B. *Berlinia orientalis*-dominated forest in bend of the drainage line where a higher water table is present.
C. Forest (not visited). The Spot satellite images of this area has a rather patchy tonality, suggesting that this are may have been cultivated a very long time ago. Might includes areas of scrub forest.
D. Scrub forest.
E. Woodland (not visited). Note the relative hard edge between this area and the forest to the west.
F. Forest (F2 not visited) with darker, more even tonality from the Spot satellite image.



Artumas oil cutline vegetation transect from a little south of the Google Earth image, showing similar vegetation.

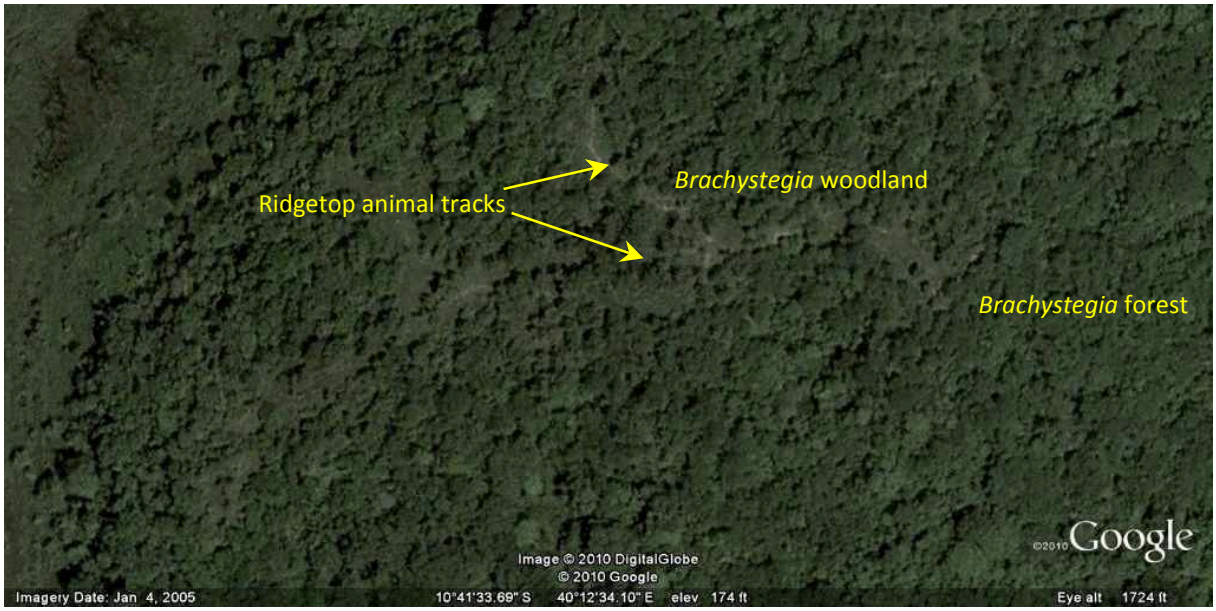
Well-developed *Brachystegia spiciformis* forest to the northeast of Lake Nhica, on the southern slope of the first ridge to the immediate south of the Rovuma River floodplain, 10°41'35"S, 40°12'41"E, 13th November 2009. A few metres to the north, the vegetation changes suddenly to open and depauperate *Brachystegia spiciformis* woodland, probably because the northern slope of this ridge is exposed to regular bush fires sweeping up from the Rovuma River floodplain.

9. *Brachystegia* Forest

White (1983, p. 188) recognised the presence of a 'transition woodland' vegetation sub-type in his Zanzibar-Inhambane regional mosaic, which he considered to be transitional because of its mix of Zanzibar-Inhambane (now Swahilian) forest species with *Brachystegia* spp. that are characteristic of Zambesian miombo woodlands. The local name 'miombo' for *Brachystegia boehmii* has become synonymous with this woodland type (Rodgers 1996), to the extent that the genus *Brachystegia* is sometimes exclusively associated with woodland. This genus of 28 species is primarily found in the Zambesian woodlands, where 17 species are found (Timberlake *et al.* 2007), many of which are the dominant or co-dominant trees.

Brachystegia dominated forests are however known from the Guineo-Congolian forests of West and Central Africa (White 1983, p. 77) – and also from the Swahilian regional centre of endemism/eastern African Coastal Forest hotspot. White's 'transition woodland' is now recognised to be a *Brachystegia* dominated forest (Clarke 2000). This classification is supported by observations in Palma District, where there is a clear difference between *Brachystegia* woodland and *Brachystegia* forest, even where they occur side by side (see images below and on previous page). Fire-climax *Brachystegia* woodland is species poor, whereas fire-excluded *Brachystegia* forest contains rare forest-dependent species.

Open and depauperate *Brachystegia spiciformis* woodland to the northeast of Lake Nhica, on the northern slope of the first ridge to the immediate south of the Rovuma River floodplain, 10°41'34"S, 40°12'36"E, 13th November 2009. A few metres to the south, the vegetation changes suddenly from fire-climax woodland to dense *Brachystegia spiciformis* forest, probably because the southern slope of this ridge is shielded from the regular bush fires that sweep up from the Rovuma River floodplain.



Google Earth satellite image showing the very subtle difference between the *Brachystegia* woodland and *Brachystegia* forest sites shown on the previous pages, when viewed from above with a 20 m Cnes/Spot image.

It is not known whether *Brachystegia* forest is a climax vegetation sub-type in Palma District, or whether it is an advanced stage in a succession sequence from *Brachystegia* woodland to forest. Almost all areas of *Brachystegia* forest in Palma District are located on relatively flat ground and dominated by *Brachystegia spiciformis*, while *Brachystegia* forest a few km to the north in SE Tanzania is associated with steep escarpment edges and is dominated by *Brachystegia tamarindoides* subsp. *microphylla*. *Brachystegia tamarindoides* subsp. *microphylla* was not observed in Palma District, and only two individuals were encountered in neighbouring Nangade District. These may have been planted as they were located beside a road near Aldea Rovuma village.

In Palma District *Brachystegia spiciformis* was observed to span a wide ecological amplitude – from a vigorous coloniser of formerly cleared areas, where it was found to be the most common seedling present in one vegetation plot in an abandoned cashew nut orchard, to a massive 25 m high and 30 m wide crown diameter canopy emergent in mature forest. It can be the dominant tree species in both woodland and *Brachystegia* forest, and was often found to be co-dominant with *Berlinia orientalis* on the edge of drainage lines. Only in mature *Manilkara discolor* forest on well-drained ridge tops and in mature *Manilkara sansibarensis – Ochna mossambicensis* forest on red sands was it found to be uncommon to absent in Palma District. It is absent from the climax *Scorodophloeus–Guibourtia* forest in Nangade District.

Because of the close association of *Brachystegia spiciformis* with miombo woodland, and its presence in dense vegetation that appears to have regenerated from disturbance, Timberlake *et al.* (2010) have excluded *Brachystegia* forest, and any forest that contains *Brachystegia*, from their enumeration of the extent of Coastal Forest in Cabo Delgado province in Mozambique.

Brachystegia spiciformis is only occasionally found in the Coastal Forests of Tanzania. It is however the major component of the *Brachystegia* forest at the Arabuko-Sokoke forest in Kenya, in association with the forest dependent and restricted range *Julbernardia magnistipulata*.

The much stronger presence of *Brachystegia spiciformis* in forest in Palma District compared to Lindi and Mtwara Districts in neighbouring Tanzania is puzzling, and may be linked to the observation that most of the forest in Palma District of Mozambique has been cleared in the relatively recent past. The ability of *Brachystegia spiciformis* to colonise cleared areas, and its absence to near absence from some types of mature climax forest suggest that its presence in forest can be correlated with areas that were formerly cultivated. The tree is able to reach an enormous size and therefore age, and its presence can then persist in forest for many years.

Brachystegia forest was encountered on flat terrain west of the Mocímboa–Palma road at 10°03'48"S, 40°15'24"E with frequent *Baphia macrocalyx* in the small tree and shrub layer, and on a slope east of Lake Nhica do Rovuma at 10°41'35"S, 40°12'41"E. At the latter site *Brachystegia spiciformis* was strongly dominant, producing a 14–16 m canopy over occasional *Cremasporum* sp. and *Sorindeia madagascariensis* as up to 4 m high small trees together with *Oxyanthus* sp. A of FZ, *Ochna polyneura*, *Grewia conocarpum, Xylotheca tettensis, Diospyros abyssinica* and *Cassipourea mossambicensis*. All trees were single-stemmed, demonstrating that this area had not been cultivated for a very long time.

Google Earth satellite image of *Brachystegia* forest / *Brachystegia* woodland mosaic along an old oil cut-line west of the Mocímboa–Palma road at 11°03'48"S, 40°15'24"E. Image width 2.5 km.

Dense *Uapaca nitida – Brachystegia spiciformis* woodland south of the Palma-Pundanhar road near 10°52’54”S, 40°12’29”E, 7th November 2009. Tree crowns almost touch but trees and shrubs are comparatively widely spaced compared to Coastal Forest. Photo © Russell Scott.

10. Woodland

Large areas of Palma District are covered by dense woodland, with a near continuous canopy that can be difficult to distinguish from forest when examining coarser satellite images (such as Landsat 7 with a 15m thermal band resolution), or when viewing the tree crowns obliquely from the air. High resolution satellite images (SPOT or finer) and ground surveys are required to clearly distinguish these areas of dense woodland from forest and scrub forest.

The Palma District woodlands are characterised by a fire-adapted understory of grasses with scattered shrubs. Tree crowns almost touch in some areas, but can be more widely spaced. These characteristics conform to the AETFAT[1] definition for woodland (White 1983).

Woodland is ecologically distinguished from forest by the agency of fire. Bushfires occur during the dry season, and almost all fires are started by people. Sometimes this happens accidentally during the clearing of fields when fires stray out of control, or originate from discarded cigarettes. Bushfires are also deliberately set by local people as a tool to manage the environment. They sweep through the woodland understory, consuming dried out grasses, fallen leaves and any dead wood. This opens up the habitat, giving a greater sense of security to the local population (Ferro 2007), who face a real risk of lethal encounters with wildlife (some 30 people were killed by lions in Palma District during late 2007/early 2008), while also killing snakes and other potential pests. A further incentive for creating bushfires is to attract antelopes by removing dead grass so that they can more easily graze on the following season's new shoots, which also makes it easier to see and therefore hunt these game animals.

Parinari curatellifolia woodland south of the Palma–Pundanhar road, grading into a seasonally inundated pan, 10°50'55"S, 40°12'29"E, 7th November 2009 (immediately before the rains). Note the fire-blackened lower portions of the tree trunks, and areas of bare ground – all evidence of a recent fire. Photo © Russell Scott.

[1] French acronym for the Association for the Taxonomic Study of the African Flora.

Mature woodland trees are tolerant of fire, while younger trees and shrubs of the same species may be killed or severely damaged if burned. In such cases the surviving shrubs and small trees/saplings may be forced to restart their growth again at ground level from their rootstocks during the following rainy season (see section on fire dynamics). Frequent burning thereby prevents small trees from becoming large enough to be able to escape the ravages of fire, which in turn hampers the recruitment of new trees into the woodland 'canopy'. This can cause the tree layer in woodland to thin over time.

The dense nature of the woodlands in Palma District may therefore be an artefact of the wars that ravaged Mozambique from 1964–1992. Many people fled from the rural areas of Palma District during this time, and the reduced human population would have meant fewer bushfires. This would in turn have meant that the shrubs and small trees in the woodlands would have been less frequently burned, thereby allowing more of them to grow high enough to escape the reach of fire and eventually develop into mature trees. Recent increases in the frequency of bushfires may now reduce the potential for small trees to mature, and that this will ultimately cause the woodlands to become less dense over time.

There is still some disagreement between vegetation ecologists about whether or not fire-climax woodland is a natural or an anthropogenic fire-induced vegetation climax. However, an ecologist who spent many years in the largely miombo woodlands of the nearby Selous Game Reserve in SE Tanzania reached the conclusion that these woodlands are seral 'fire dis-climax communities' (Rodgers 1996, p. 208). Furthermore, rare and endemic plant species are predominantly found in forest rather than woodland, suggesting that the latter is a more recent vegetation type. Woodland is however an important habitat for big game animals.

The following nodes in the woodlands of Palma District were identified, which are probably part of a wider continuum that includes other nodes/woodland types:

(a) *Brachystegia spiciformis* dominated woodland

Strongly dominated by *Brachystegia spiciformis* with only a scattering of other species such as *Ochna polyneura*. Present on heavily-leached slopes south of the Rovuma River, e.g. at 10°41'34"S, 40°12'36"E.

(b) Mixed *Brachystegia spiciformis* woodland

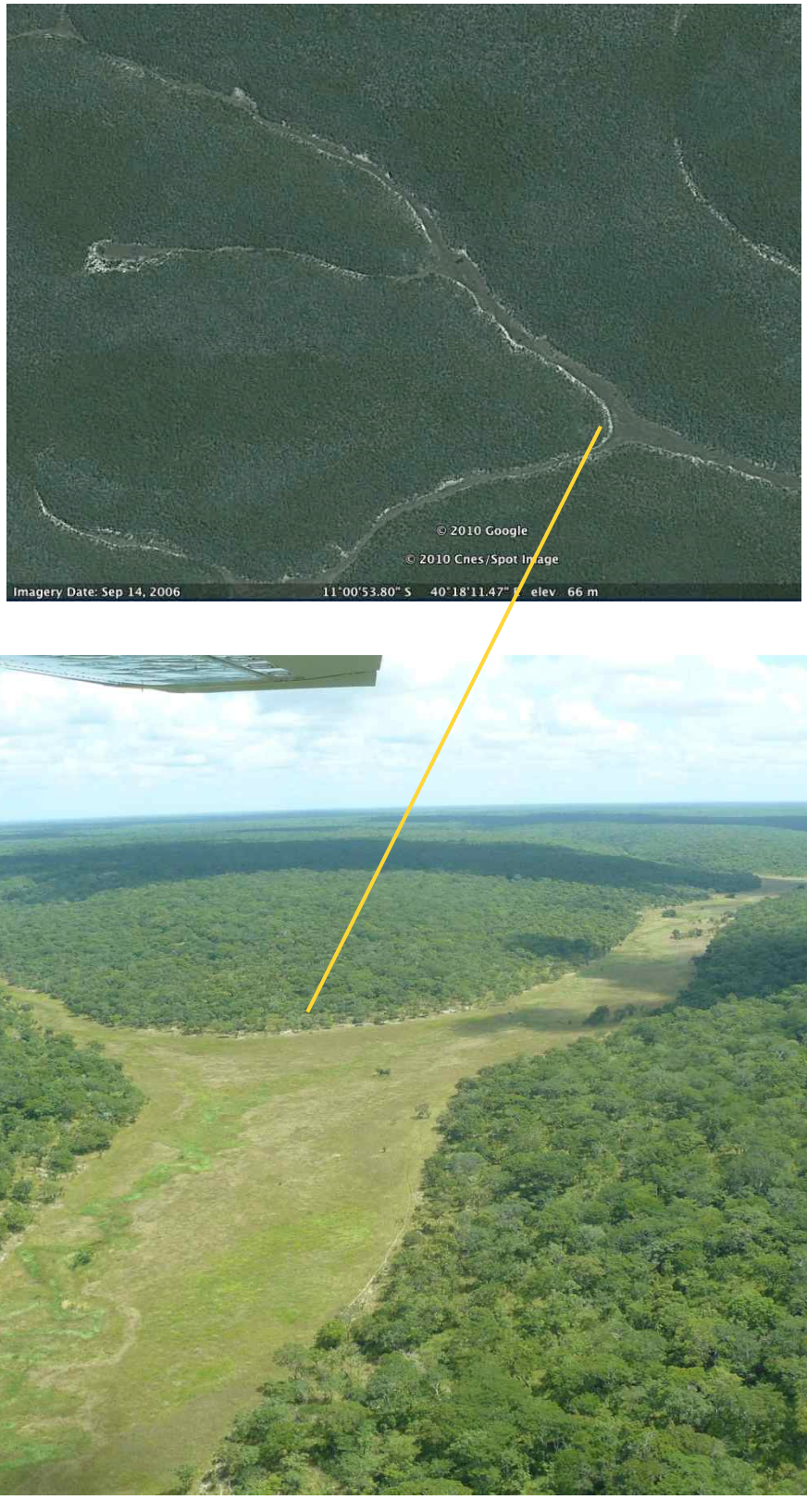
Up to 50% *Brachystegia spiciformis,* sometimes with *Parinari curatellifolia* as a common component. Other trees include occasional *Combretum collinum, Ximenia caffra, Strychnos madagascariensis, Kigelia africana, Pterocarpus angolensis, Hugonia orientalis, Sclerocarya caffra, Berlinia orientalis, Ochna polyneura, Swartzia madagascariensis* and *Diospyros* spp. Present on the slopes leading down to the Rovuma valley, e.g. at 10°51'22"S, 40°13'11"E.

(c) Mixed *Uapaca nitida – Brachystegia spiciformis* woodland

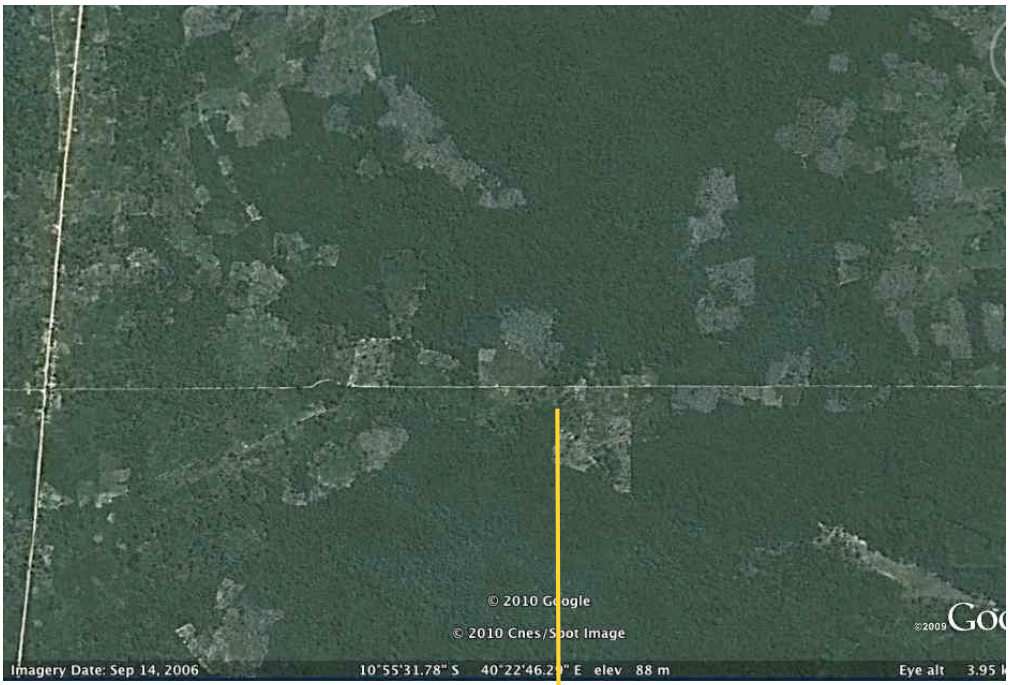
Uapaca nitida and *Brachystegia spiciformis* are the most frequent trees, with *Phyllocosmus lemaireanus, Parinari curatellifolia, Baphia macrocalyx, Margaritaria discoidea, Strychnos madagascariensis, Pterocarpus angolensis, Balanites maughamii, Berlinia orientalis, Diospyros verrucosa, Afzelia quanzensis, Brackenridgea zanguebarica, Hugonia orientalis* and *Annona senegalensis*. Extensively present around the pans between Palma and Pundanhar, such as at 10°51'22"S, 40°13'11"E, and at 10°44'58"S, 40°15'10"E.

Mixed *Brachystegia spiciformis* woodland on the road south of Nhica do Rovuma, near 10°47’27”S, 40°11’32”E, end November 2009. The understorey here has been opened up by an early fire during the preceding dry season, so much of the grass layer has been removed.

Mixed *Brachystegia spiciformis* woodland on the road south of Nhica do Rovuma, near 10°47’52”S, 40°11’27”E, end November 2009. The understorey in this patch of woodland has escaped fire during the preceding dry season. Many small shrubs have produced fresh growth that can be seen between the previous year’s dried out growth of grasses.



Drainage line of the Rio Quigode to the immediate west of the Mocímboa–Palma road taken from the air on the 30th April 2008 (top) and from a Google Earth Cnes/Spot image on the 14th September 2006 (above), image width 6 km spanning from 10°59'52" to 11°01'54"S and 40°16'30" to 40°19'53" E. Woodland is present here on the slopes leading down to the drainage lines, and grades gently into scrub forest or forest over the ridge tops. From satellite images it is possible to see a vague pattern of forest descending all the way down to drainage lines on slopes that are in the lee of the prevailing dry season north easterly winds, suggesting that the distribution of forest and woodland in Palma District is partly determined by the combined dynamics of fire, wind and water.



Regenerating woodland beside the track to Muangaza, 10°55'23"S, 40°23'38"E, 6th December 2008 (above). The wall of trees in the background marks the sudden transition to mixed forest; the abrupt woodland/forest ecotone here is the result of former cultivation beside the track, that has since been abandoned and has reverted to woodland because of the frequent intrusion of fire. The Google Earth Cnes/Spot satellite image (top) illustrates how forest is being eaten away by cultivation in this area, and only in certain fire-protected areas is able to revert to forest. Photo below © Frances Crawford. Google Earth satellite image above taken on the 14th September 2006, spanning from 10°54'47" to 11°56'15"S and 40°23'49" to 40°19'53" E. Image width 4.1 km.

Borassus aethiopum palm woodland in the Rovuma floodplain. The monodominant stands can appear like a forest to the observer from the ground, but trees are actually quite widely spaced apart. Top image ca. 10°45'00"S, 40°07'29"E, 30th April 2008, © Jonathan Timberlake. Lower image 10°54'19"S, 39°50'37"E, 3rd May 2008, © Camilla da Souza.

Depauperate *Brachystegia spiciformis* woodland on a ridgetop to the immediate south of the Rovuma River floodplain, 10°41'34"S, 40°12'36"E, 13th November 2009. Almost all trees here are of *Brachystegia spiciformis*, with few other tree or even shrub species, possibly due to the heavily leached and eroded soils.

Pans near Nhica do Rovuma (above) and on the coastal plain near Mocímboa da Praia (below), taken at the end of the rains when all trees are in leaf and standing water is present in the middle of some of the pans.

11. Drainage lines and pans

The landscape between Palma and Pundanhar contains numerous near-circular pans (*pantanos*) and drainage lines. The pans fill with water during the rains, while the drainage lines only briefly contain flowing water. Almost all pans dry out by the end of the dry season.

The Rovuma River is the only permanent river in Palma District, and is an important water source for wildlife during the dry season, which hides in the nearby forests during the day. Protecting the forests of the southern Rovuma rim would then conserve a key ecosystem component for big game animals. Much of the vegetation along the Rovuma is influenced by the annual dynamics of flooding, drying out and burning. Fire-tolerant woodland is therefore found on most of the raised levies, and forest is only able to develop on high banks where the Rovuma or its tributaries reach the southern limit of the floodplain.

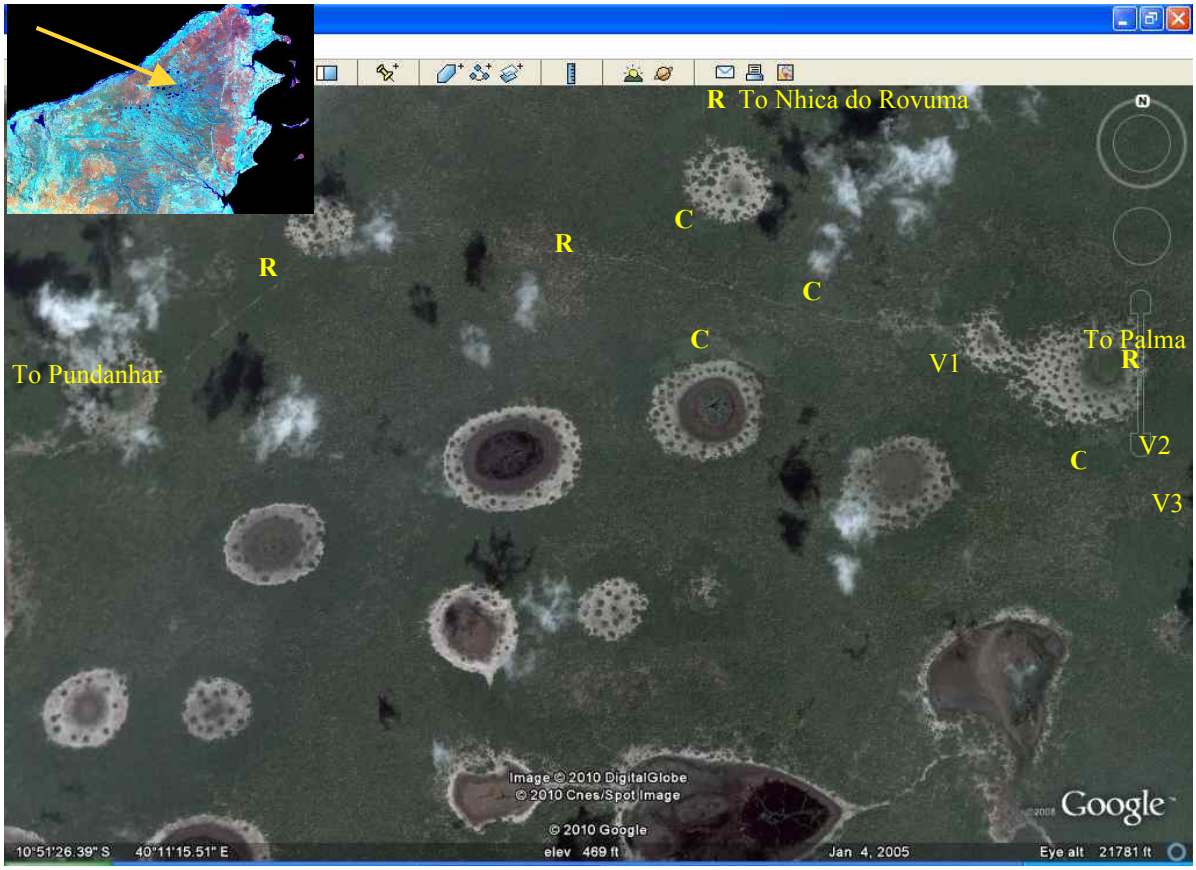
All the drainage lines and pans that were visited had been recently burned. Fire probably opens up this habitat more than would otherwise be the case for areas that are just temporarily flooded, as suggested by some sites where forest is able to develop across a drainage line. Such areas sometimes contain tree species that are typical of riverine/groundwater forests, such as *Sterculia appendiculata* at 10°42'42"S, 40°13'05"E. These species are otherwise absent from the edges of most pans and drainage lines in Palma District.

Drainage line southeast of the village of Nhica do Rovuma, feeding into the Rio Macanga, 10°44'56"S, 40°15'10"E. The trail to the right is a game trail, and had been used by a waterbuck, Sable Antelope, hyaena and elephants. The trees growing towards the centre of the line are predominantly *Parinari curatellifolia*, while *Brachystegia spiciformis* and *Berlinia orientalis* take over along the woodland edge. 11th November 2009.

Recently cleared woodland on the Rovuma floodplain to the north of Nhica do Rovuma, 10°41'26"S, 40°11'38"E, 13th November 2009. *Borassus* palms and *Sterculia appendiculata* (centre) have been left standing, because these have a spongy wood that does not burn easily and would therefore take a long time to remove if their trunks were to be left on the ground, thereby impeding cultivation. The positive selection for these species may partly explain the occurrence of large monospecific *Borassus aethiopium* stands on the Rovuma floodplain as well as on the Messalo River floodplain further south.

Charred log at the intersection of oil cutline 34 with the Macanga River valley, 10°40'48"S, 40°23'29"E, 23rd November 2008. This log provides evidence of a recent fire in this remote forest-enclosed location, and suggest that seasonal drainage lines such as this create fire corridors into the forest.

Pan located on the coastal plain between Quionga and Palma, situated among remnants of dry forest. Note how the pan has been partitioned into separate agricultural plots with associated guard/shelter towers at the edge of the pan, possibly built on former termite mounds (compare with images on the following pages). This image demonstrates the importance of pans as sources of prime agricultural land, with no disturbance to the surrounding vegetation here. It is not known why a number of the pans inland between Palma and Pundanhar are not under some form of cultivation, but this may be due to forced displacement into guarded villages during the independence war, as there is evidence that these were formerly cultivated. Google Earth GeoEye image taken on the 17th May 2010, spanning from 10°38’33” to 10°38’48”S and 40°29’04” to 40°29’19” E. Image width 0.5 km.



Vegetation mosaic dominated by seasonal pans '*pantanos*' south of the Palma to Pundanhar road, adjacent to the turn off to Nhica do Rovuma, from a Google Earth Cnes/Spot images taken on the 4th January 2005. The grid reference on image refers to the approximate centre of the photo, which spans from 10°50'03" to 10°52'42"S and 40°09'11" to 40°13'20" E. This image may be easier viewed upside down as the sun is coming from bottom right.

R. Road.

C. Evidence of relatively recent cultivation (within last 20 years). Note that cultivation in this low population-density and predominantly woodland habitat is focussed on the edges of pans and beside roads, demonstrating that agricultural development is strongly influenced by the needs for water and access/security.

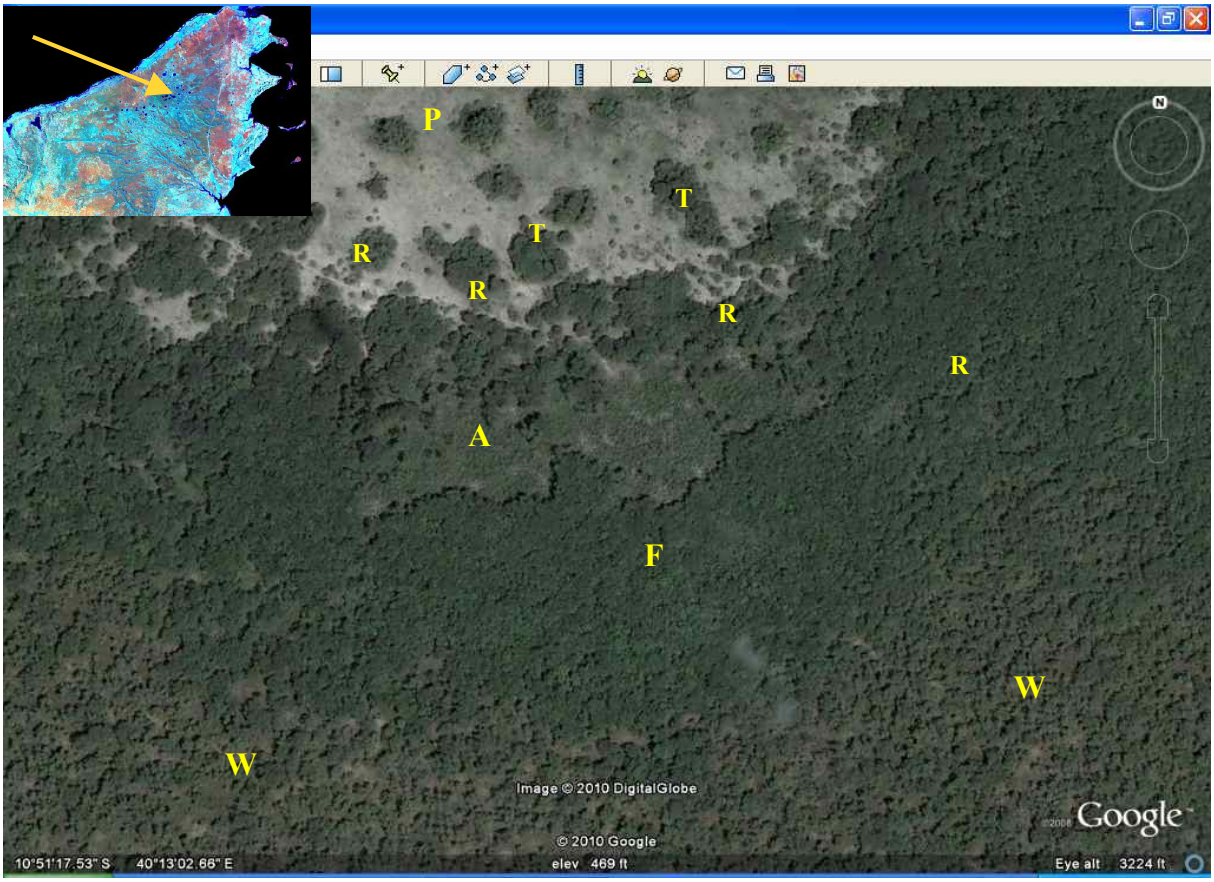
V1. Vegetation plot 1. Abandoned cashew nut orchard. *Brachystegia spiciformis* is the most common tree, with a few *Berlinia orientalis* and old moribund individuals of *Anarcardium occidentale*. Other trees include *Annona senegalensis, Margaritaria discoidea Phyllocosmus lemaireanus, Vangueria infausta, Brackenridgea zanguebarica* and very common *Baphia macrocalyx* in the shrub and small tree layer.

V2. Vegetation plot 2. *Berlinia orientalis – Brachystegia spiciformis* forest on a slope descending to the pan edge. See photos on pages 36 & 37 of this report.

V3. Vegetation plot 3. *Uapaca nitida – Brachystegia spiciformis* woodland. See photo on page 80 (top) of this report.

This area is dominated by little-disturbed woodland, and the satellite image demonstrates that the vegetation here generally becomes thicker towards the pans, where there may be additional moisture from groundwater drainage.

Note here the unusual pattern of forested anthills, which appear to occur in almost concentric circles around the smaller pans, particularly those that have a wide sandy margin between the standing water limit and the tree line. In general the shallower the pan depression, the more likely there are to be termitaria around the edge.



Detail of the vegetation mosaic around the edge of a pan south of the Palma to Pundanhar road, east of the turn off to Nhica do Rovuma, from a Google Earth Cnes/Spot images taken on the 4th January 2005. The grid reference on the image refers to the approximate centre of the photo, which spans from 10°51'18" to 10°51'28"S and 40°12'86" to 40°13'18" E. Elevation decreases from the lower part of the picture towards the top. This image may be easier viewed upside down as the sun is coming from bottom right.

A. Abandoned cultivation at the edge of the pan, eating into forest. The location of this little 'farm' was probably influenced by the presence of the track that ran through the band of forest at this point.

F. *Berlinia orientalis – Brachystegia spiciformis* forest. See photos on pages 36 & 37 of this report.

P. Pan edge with clumps of forest trees on termitaria. See photos on page 125 (bottom) of this report.

R. Old road/track dating from at least the Portuguese Era (visible on 1974 1:250,000 map). This track was rehabilitated by oil exploration company Artumas in 2008, subsequent to this image.

T. Termitaria. A nearby termite mound forest is detailed on pages 82–83 of this report.

W. *Uapaca nitida – Brachystegia spiciformis* woodland. Note the still predominantly brown grass around the trees. The rains may have been late in 2004 as fresh green shoots for the new growth are only just beginning to appear. See photo on page 80 (top) of this report.

Note how woodland grades into forest towards the moister base of the slope, before reaching the pan where edaphic conditions prevent the development of trees outside of termite mounds.

Termites crawling up a tree in the forest near Nhica do Rovuma. Termites are the major agent of decomposition in the bimodal climate of Palma District – as elsewhere along the eastern African coast – and play a significant influence on both woodland and forest ecology. Photo © Xavier Desmier / PNI – MNHN.

12. Fire and termitaria

Humans have burned the landscape of southern Africa for at least 100,000 years. It is estimated that 99% of all bushfires are started by man, and these have an enormous impact on the landscape and vegetation of areas that are regularly burned. Species that are unable to withstand fire are burned out, while even fire tolerant species may be prevented from growing to maturity by frequent (annual) fires. Many fire-tolerant species require a few years of fire-free conditions to grow high enough and with a thick enough bark to be able to withstand future fires and thereby be able to continue their upward growth. Fire dynamics therefore influence the ecology of woodland as well as forest – frequent fires will cause a gradual erosion of the forest edge, pushing forest back from areas where it was formerly present, while at the same time limiting the recruitment of trees into the woodland canopy, and thereby over a long time will open up woodland areas.

The large tracts of both forest and dense closed-canopy woodland in Palma District point to a history with a reduced incidence of fire in the area, almost certainly because of the 1964–1992 independence and civil wars, when the human population was massively reduced.

Baphia macrocalyx regenerating in an abandoned cashew nut orchard on the Palma–Pundanhar road, 10°50'54"S, 40°12'27"E, 7th November 2009 (immediately before the rains). Photo © Russell Scott.

The three individuals in the picture to the left (foreground) have produced a new shoot from the base of the 60 m high charred and dead stalk from the previous years growth. This stalk has died and will probably burn up completely during the next bush fire.

The tree in the image to the right is an estimated three to four years old, and the recent fire has here burned all the leaves up to about 1.6 m, but has not killed the tree, allowing it to produce new leaves from the burned parts of the stem. This tree will therefore be able to capitalise on previous years growth and continue to grow further beyond the reach of fires, while its neighbours in the picture to the left will have to start over again from ground level.

Fire burned *Uapaca nitida – Brachystegia spiciformis* mixed woodland, south of the Palma–Pundanhar road, 10°51'22"S, 40°13'11"E, 7th November 2009 (immediately before the rains). Vast tracts of woodland burn every year, and fires can spread many kilometres. Probably all of these fires are started by humans, both deliberately to drive game and to remove vegetation from pathways (Ferro 2007), and also unintentionally from abandoned cigarettes and from the cleaning of fields where the fire spreads out of control. Photo © Russell Scott.

Fire does not normally reach into forest, where soil and leaf litter moisture is kept higher by the closed canopy, and where there is an absence of a combustible grass layer. At the end of the dry season – when the leaf litter dries out completely – fires may penetrate into forest, such as here in the *Berlinia orientalis* dominated forest to the east of the Palma–Namoto road where the shrubs in the centre of the view have died from the fire at their bases. 10°39'29"S, 40°30'55"E, photo taken 9th November 2009.

Termites and termitaria

The presence of termites is evident throughout Palma District through the frequent large termite mounds that can be seen in all vegetation types – forest, woodland and in the grasslands of drainage pans. The latter are often covered by forest, as the termites aerate soils and build their mounds above the level of the wet season water table, thereby allowing plants that are intolerant of waterlogged soils to grow on them. Termite mounds (termitaria) in woodland areas are not usually covered by forest.

The tree species found in the forested islands that are present on the termitaria in the pans between Palma and Pundanhar are locally common and comprise a mixture of typical forest and woodland species, such as *Berlinia orientalis*, *Pseudobersama mossambicensis*, *Manilkara sansibarensis*, *Afzelia quanzensis*, *Uapaca nitida*, *Erythroxlon emarginatum*, *Garcinia livingstonei*, *Diospyros* sp., *Euclea natalensis*, *Euphorbia* sp., *Cleistanthus schlecteri*, *Oxyanthus* sp. together with species associated with floodplains edges such as *Hyphaene coriacea* and *Parinari curatellifolia*.

Heat scorched leaves on a spared individual of the high-value timber tree *Milicia excelsa* on the Rovuma floodplain north of Nhica do Rovuma, 10°41'26"S, 40°11'38"E, 13th November 2009. The hot fire from burning the cleared woodland has singed leaves in the canopy some 8 m from the ground, while those higher up are unaffected and are still green. Valuable timber trees such as *Milicia excelsa* and *Afzelia quanzensis* are often left standing during bush clearance for cultivation, to be cut and sold by the farmer at a later date when convenient.

Fire burned eastern slope of an island of forest on a termite mound at the edge of a pan beside the Palma–Pundanhar road, 10°50’55”S, 40°12’32”E, 7th November 2009 (immediately before the rains). The other side of the mound was unburned, suggesting that fire (and prevailing wind) influence the presence of forest development on termitaria. Photos © Russell Scott.

Unburned western (lee) slope of the same termitaria at the edge of a pan beside the Palma–Pundanhar road, 10°50’55”S, 40°12’32”E, 7th November 2009 (immediately before the rains). Note the absolute predominance of evergreen species. Photos © Russell Scott.

View of the same termitaria as shown on the previous pages on the Palma–Pundanhar road, near 10°50’55”S, 40°12’29”E, 6th November 2009 (immediately before the rains). Photo © Russell Scott.

Another termitaria (to the left) with a ‘tail’ of forest continuing along the wind shadow of its leeward side (to the right) – the prevailing wind direction is indicated by the plastic bag windsock. This tail of forest extends beyond the base of the termite mound and onto the pan itself, demonstrating that fire and its absence influence the potential development of forest. Areas in the lee of termitaria are burned less frequently, allowing thicker vegetation to develop which shades out the grasses which are otherwise found on the pans. These grasses are highly combustible when they die and dry out during the dry season, so areas without these grasses will burn less hot, and so experience less damage to regenerating trees and shrubs. Photo taken south of the Palma-Pundanhar road, near 10°50’55”S, 40°12’29”E, 7th November 2009 (immediately before the rains). Photo © Russell Scott.

Pockets of forest dominated by *Berlinia orientalis* on termite mounds in a pan on the track to Nhica do Rovuma at 10°50'19"S, 40°11'43"E, late November 2009 (top). *Berlinia* spreads through the explosive dehiscence of its seed pods, and this spread appears to be contained by hot fires from the dried out pan grasses that 'knock back' young Berlinia seedlings (above). Note how the shape of the multi-stemmed seedling resembles that of many adult tree crowns, suggesting that fire – in addition to past clearance – may be responsible for the multi-stemmed shape of many trees in Palma District.

Burned hillside on the escarpment slope to the north of Nhica do Rovuma near 10°43’03”S, 40°12’16”E. This area has probably been cultivated in the past, as suggested by the trees in the background, which are almost all multi-stemmed.

13. Clearance and cultivation

Most of the farmers in the Palma area practise a traditional 'bush fallowing' system of agriculture that was described in detail for the neighbouring Makonde Plateau in southern Tanzania by Gillman (1945). This involves clearing an area of forest, woodland or thicket, cultivating the land for a few years and then moving on to a new area when crop productivity falls due to the soils becoming depleted, or when weeds become too much effort to clear.

Forest in Palma District appears to be preferentially cleared over woodland. One reason may be due to more fertile soils (Timberlake *et al.* 2010) but this may also be due to forest being easier to clear, as only forest contains the required density of saplings and shrubs to produce enough combustible material (below right) for a fire that will be sufficiently hot to kill the tall canopy trees and remove their leaves. Clearing woodland would require physically chopping down the largest trees, which would require much more effort than clearing the shrub and small tree layer in a forest (above right).

Seavoy (1987) notes the overriding need to limit labour input in subsistence agriculture in East Africa, and clearing forest rather than woodland may then provide the twin benefits of a higher nutrient ash input and less effort to open the canopy and fully expose the ground to sunlight. Seavoy also notes that clearing a new area of forest requires less effort than weeding an established field, so farmers will preferentially clear forest rather than retain their existing fields if suitable areas of forest are available.

The first stage of field clearance involves cutting the bush and then leaving the dead branches and saplings in the ground to dry (top), sometimes for a year (as above, where coppice regeneration is already taking place from the cut stumps). Larger trees – which require more effort to cut – are usually left untouched at this stage. The piled up branches, twigs and dead leaves burn very hot due to the combination of the large amount of combustible material surrounded by oxygen/air, so the ensuing fire is hotter than most bushfires that feed predominantly on dead grass. The flames can then reach high into the canopy and will then kill many of the trees that have been left standing.

Top picture from the Mocímboa–Palma road, May 2008 © Jonathan Timberlake.

Bottom picture from the junction of the Pundanhar road with the Mocímboa—Palma road, 5th November 2009.

Stage 1. Mature Coastal Forest beside the Palma to Pundanhar road, near 10°49’12”S, 40°20’31”E, early November 2009. 360^{o} panorama taken from up a tree whose 3 main branches splay out in this view. Photo © Russell Scott.

Stage 2. Understorey cleared and burned alongside the Palma to Pundanhar road near 10°49’12”S, 40°20’31”E. The hot fire has killed the canopy trees, and a first crop of cassava will be planted here. 360^{o} panorama photo © Russell Scott.

Stage 3. Repeated burning and cultivation leaves the landscape denuded. Coppice regrowth threatens to choke the planted cassava. 10°48’56”S, 40°22’07”E, November 2009. 360^{o} panorama photo © Russell Scott.

Stage 4: recently abandoned field. Shrubs start to coppice. 10°48’13”S, 40°24’04”E. 360° panorama photo © Russell Scott.

Stage 5: Widespread coppice regrowth near the edge of a pan. 360° panorama photo © Russell Scott.

Stage 6: Development towards scrub forest, 10°48’07”S, 40°24’09”E. 360° panorama photo © Russell Scott.

Recently cleared forest in the process of being burned beside the Palma–Pundanhar road. Locations beside roads and tracks are frequently selected for cultivation due to the ease of access to such sites by bicycle, allowing farmers to 'commute' on a daily basis to their new fields while these are being cleared, and later providing better opportunities for transporting crops to market. 14th November 2009. Photo © Russell Scott.

Freshly burned forest/cleared field on the Palma–Pundanhar road, 14th November 2009. Photo © Russell Scott.

Fire resistant trees with a high crown that were not affected by the first burn are removed by ring-barking the trunks and then building a fire around these, thereby avoiding the laborious task of cutting the trees down by axe or machete. In this way even the largest trees can be felled and removed. Furthermore, the considerable biomass stored in these trees provides a significant input of fertile ash for the second cultivation season. The fire resistant trees in this view are predominantly *Berlinia orientalis*. Photo © Frances Crawford, ca. 10°55'34"S, 40°22'35"E, 5th December 2008.

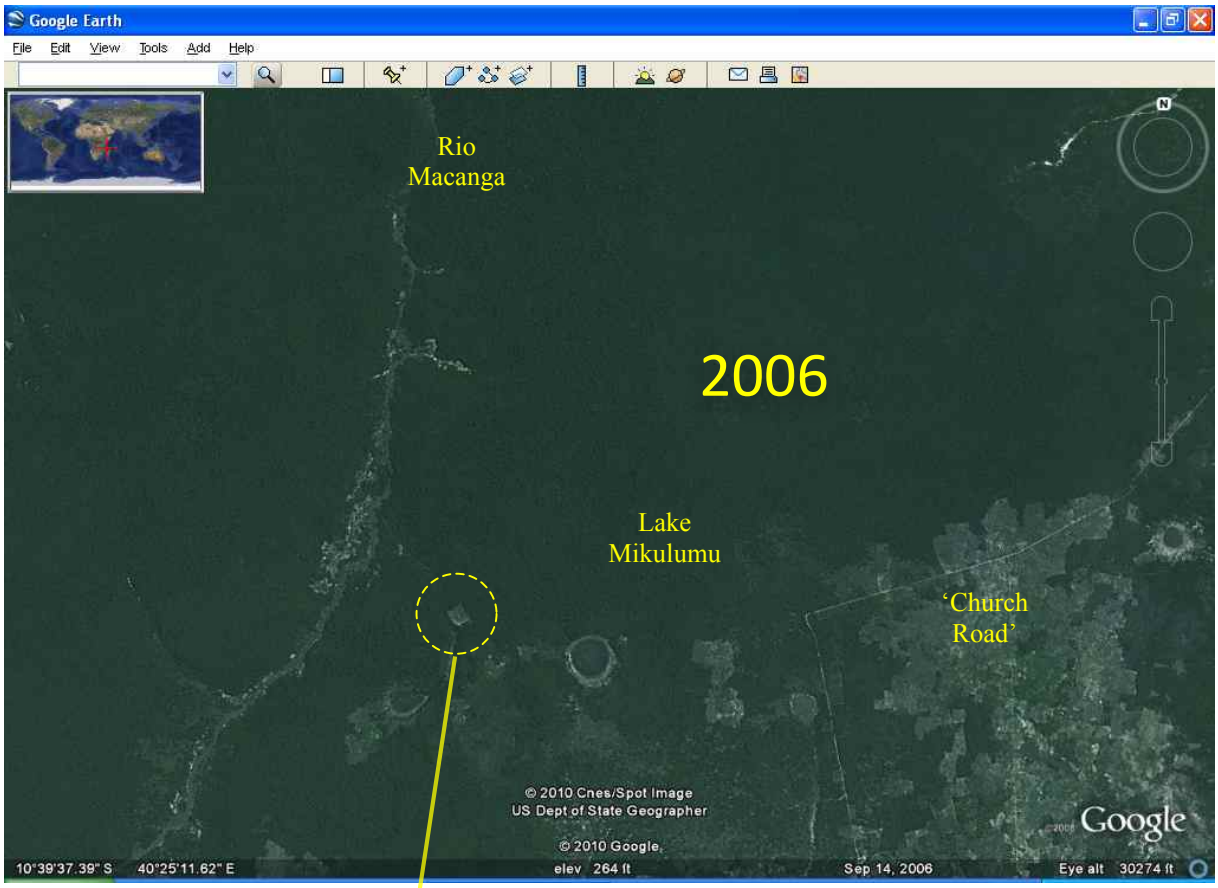
Tree in the process of being burn felled. Dried sticks have been piled around the ring-barked base, and a fire lit to kill the tree and burn through the trunk so that it falls over. Photo taken on the edge of Mbamba village in the Niassa Game Reserve, to the west of Palma and Nangade Districts, 26th November 2009.

The end result: cassava cultivated among burned stumps and charred logs. This field is probably a few years old, as all large standing trees have now disappeared. Note the vigorous coppice regeneration around the cassava plants; unless this area is continuously cleared and burned it will rapidly revert to bush. 10°48'56"S, 40°22'06"E, 14th November 2009. Photo © Russell Scott.

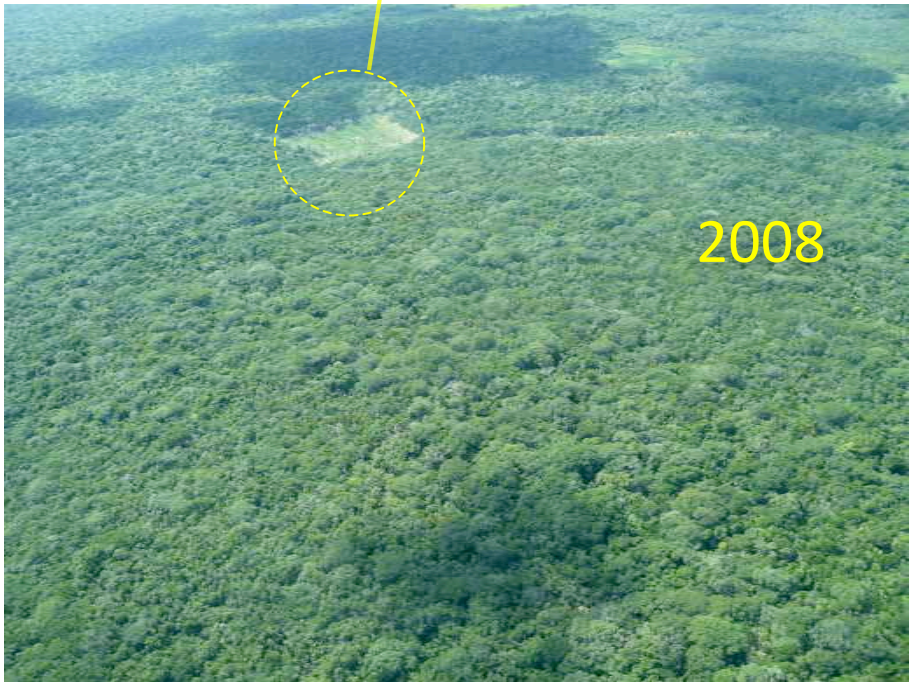
Although forest appears to be the preferred habitat that is cleared for agriculture, woodland areas are also cleared, such as here on the slope leading off the escarpment edge to the north of Nhica do Rovuma. Photo taken November 2009.

A bean field, recently tilled and burned on the edge of Lake Mikulumu, 10°40’35”S, 40°25’06”E, 14th November 2009.

Fallow cultivation ridges on the edge of Lake Mikulumu, 14th November 2009. The earth has been built up into long mounds to allow it to drain and permit cultivation in otherwise seasonally waterlogged soils.



Satellite image of the area to the NNE of Palma, from a Google Earth Cnes/Spot image taken on the 14th September 2006, showing the large and contiguous area of forest interrupted only by encroaching cultivation from the southeast. The grid reference on the image refers to the approximate centre of the photo, which spans from 10°37'50" to 10°41'36"S and 40°22'17" to 40°28'00" E. An aerial photo of the same patch of forest looking east to the square clearing on the 30th April 2008, is shown below. Photo © Jonathan Timberlake.



Satellite image of the area to the NNE of Palma, from a Google Earth GeoEye 50 cm resolution image taken on the 17th May 2010, showing the expanding cultivation along the rehabilitated 'Church Road' as well as along the bicycle track from Lake Mikulumu towards the Macanga River valley. The image spans from 10°37'50" to 10°41'36"S and 40°22'17" to 40°28'00" E. Image width 10 km. Note the fire scar near the top of the image. A close examination using Google Earth reveals that this scar occurs beside the intersection of two Artumas oil cut-lines from 2008, with one cut-line having stopped the spread of the fire in one axis. The fire may therefore have been inadvertently caused by an abandoned cigarette, and demonstrates the vulnerability of even the most pristine forests to fire.

The biodiversity-rich Swahilian Coastal Forests of Palma and Nangade Districts contain at least 11 endemic plant species[1], and are threatened by agricultural encroachment and fire, which will lead to their fragmentation and eventually elimination unless determined efforts are made to conserve this unique natural heritage.

[1]Goyder et al. (2010)

Cultivation in forest and regenerating scrub forest near Pundanhar, 30th April 2008. Photo © Jonathan Timberlake.

Open area of hard baked earth with the termite-eaten remains of a building in the foreground and old cashew nut trees in the background, some 4 km southwest of Nhica do Rovuma village, 10°45'58"S, 40°13'44"E, 12th November 2009. Many people were forcibly relocated from small settlements near border areas during the 1964-1975 independence war, including perhaps this one.

14. Fallow and regeneration

Large areas of Palma District are fallow farmland, and are readily reverting to forest, bush (scrub forest) or woodland due to the vigorous recolonisation by trees and shrubs that are able to regenerate through coppice regrowth. Only a few areas were observed which remain denuded of vegetation due to the formation of a laterite/hard pan surface. Some of these are due to massive soil erosion around culverts beside roads on steep hillsides, while others indicate former human occupation sites where the soil surface has been repeatedly stamped down and swept over many years, thereby slowing its recolonisation by vegetation (see photo on previous page opposite).

Saplings of *Berlinia orientalis* regenerating on a formerly cultivated field, 10°47'29"S, 40°25'55"E, 5th November 2009. Although restricted in distribution to a small area between Lindi in Tanzania and Macomia in Mozambique, this species is extraordinarily vigorous in Palma District and is one of the most common tree species encountered, due to its readiness to regenerate by coppice regrowth.

There are signs that suggest that most of the forest in the Palma area has regenerated from cultivation during the recent past, including: (a) larger trees in almost all of the areas visited have multiple main stems, suggesting that these have coppice-regenerated from cut stumps, and (b) lumps of charcoal are present in the soil horizon in areas of well-developed forest.

Lumps of charcoal (circled), 30 cm deep in the soil horizon within forest to the east of Nhica do Rovuma, 10°42'15"S, 40°13'22"E, 8th November 2009.

Abandoned cashewnut orchard on the Palma–Pundanhar road, 10°50'54"S, 40°12'27"E, 7th November 2009 (immediately before the rains). Photo © Russell Scott.

Old fields reverting to bush on the Palma–Pundanhar road. Photo © Russell Scott.

Mature bush/regenerating scrub forest with a highly uneven canopy on the track to Muangaza, 5th December 2008. The tall 'emergents' are probably relicts of the former pre-cultivation vegetation that were left standing when the rest of the land was cleared. Sites beside tracks and roads are favoured for cultivation due to their easy access, especially by bicycle. Photo © Frances Crawford.

Unfinished pitfall trap west of Lake Mikulumu on the edge of forest at 10°41’07”S, 40°24’28”E, 14th November 2009. This trap may have been intended to catch buffalo and antelopes. Photo © Russell Scott.

15. Human–wildlife interactions

A low human population density, together with an extensive wooded cover and the all-year availability of drinking water along the Rovuma River have meant that wildlife and big game animals are still relatively plentiful in Palma District. Many people in Palma District therefore regularly encounter wild animals.

Some of these game animals – particularly elephants and lions – pose a danger to humans, especially to the people who live at low densities in isolated locations. Permanent dwellings in remote areas where forest has recently been cleared are sometimes surrounded by a lion-proof stockade fence, to protect their inhabitants from attack by prowling lions at night. More frequently seen were raised shelters to enable farmers to reach safety from crop raiding elephants. These are usually associated with outlying fields that are some distance from people's houses e.g. along the 'Church road' and on the slopes below Nhica do Rovuma, but were sometimes also seen beside isolated permanent homes.

Most game animals usually avoid getting too close to larger villages; only Olumbi is surrounded by a fence, to protect it from intrusion by elephants.

Lion-proof fence around a dwelling place at 10°49'16"S, 40°19'51"E, 110m altitude, 14th November 2009, with its owner, who is a modern day pioneer – he was born in Tanzania to Mozambican parents who had fled from Palma District as refugees during the independence war. He worked on sisal estates in Tanzania as well as in Dar es Salaam before deciding to return to Mozambique with his mother, where he cleared a patch of remote forest along a stretch of the Palma–Pundanhar road that was only rehabilitated the previous year by oil company Artumas, and that had been abandoned due to the landmines that had been planted on it during the war.

Lions sometime prowl around this stockade at night, despite its location in thick forest where lions would not normally be encountered. Cabo Delgado Province suffers the highest number of humans killed by lions in Mozambique – with some 35 people killed in some years (Chardonnet *et al*. 2009, p. 37).

Abandoned tower shelter overlooking fallow fields near Nhica do Rovuma, November 2009. These towers provide a refuge from wild animals for farmers cultivating fields in remote locations. Photo © Russell Scott.

Inside of a dwelling place surrounded by a lion-proof fence at 10°49’16”S, 40°19’51”E, 110m altitude, 14th November 2009. Entrance on the right, where loose poles are inserted into the fence. Photo © Russell Scott.

Homestead in newly cleared forest near the Palma–Quissungule road, November 2009. Note the unusual two-storey building to provide shelter against wild animals. Photo: © Xavier Desmier / PNI-MNHN.

Dwelling place surrounded by a strong lion-proof fence near the Palma–Quissungule road, November 2009. Huts enclosed in high palisading to protect against lion attack were described a century earlier by Maugham (1910) from the south bank of the Zambesi. Photo © Xavier Desmier / PNI – MNHN.

Given the relative abundance of game, the local people inevitably set traps to provide extra meat for their diet. A few such traps were observed in the Palma area, and these were almost always situated on established animal tracks at the edge of forest or at the edge of pans.

Elephant trap near Lago Mikulumu pan, 10°40'33"S, 40°25'31"E, prior to completion in November 2008 (left) and after completion in November 2009 (right). The final depth of the trap reached 4m with a charred stake in the middle (see below left, stake fallen out of centre to the right). The flimsy cover would have easily collapsed under the weight of a small child. It is not known why the last section of the trap was left uncovered. Another pitfall trap was also observed (below right, take highlighted by arrow) west of Lake Mikulumu on the edge of forest at 10°41'07"S, 40°24'28"E, 14th November 2009. This trap was about 2 m across, probably to catch buffalo or antelopes.

Elephant fence surrounding the village of Olumbi, 5th December 2008. Although not strong enough to prevent elephants pushing through, this fence is a sufficient deterrent to prevent them from entering the village. Photo © Frances Crawford.

Dead elephant caught in a pit trap outside Olumbi village, May 2008. Frequent raids by elephants on crops cultivated around the village have led the local people to dig a series of pit traps. Photo © Artumas.

Sable antelope (*Hippotragus niger*) at the edge of a dried out watercourse near Pundanhar, mid 2008. Photo © Artumas.

Herd of Roan antelopes (*Hippotragus equinus*) grazing in a pan near Pundanhar, mid 2008. Photo © Artumas.

African Wild Dog (*Lycaon pictus*) in the pan landscape near oil cutline 26 between Palma and Pundanhar, mid 2008. Photo © Artumas.

Hippo (*Hippopotamus amphibius*) near the edge of Lake Nhica do Rovuma, November 2009. Photo © Xavier Desmier / PNI – MNHN.

Guinea-fowl or elephant-shrew live trap, beside a watercourse draining from the Pantanos do Quidolalo, 11th November 2009, near 10°45'24"S, 40°13'04"E. Releasing the trigger mechanism causes the inverted box to fall under the weight of the logs attached to the top of it.

Wire loop trap set across an elephant/game trail, in forest near the eastern shore of Lake Nhica, ca. 10°41'52"S, 40°12'31"E, 13th November 2009. This trap succeeded to partially trap a human! This was the only wire trap seen in the Palma area, possibly due to the expense of acquiring the thick wire needed.

Lassoo snare near the edge of a pan south of the Palma–Pundanhar road, 7th November 2009. A small hole is dug around a springy root that is cut and pushed down under another root to act as the trigger for the snare. The hole is covered with thin sheets of wood or bark, followed by dead leaves, as shown above. An animal that sets its foot on the trap disturbs the trigger, thereby releasing the snare which causes a bent sapling to spring back and close the lassoo around the animal's leg. Attempting to get away only causes the noose to tighten even more (below).

Baby hippo reportedly killed by adult hippos or disease at Lake Nhica do Rovuma, November 2009. Local people are issued licenses to kill a limited number of hippos each year, but humans are sometimes themselves killed by hippos and other wild animals (see table below). Photo © Xavier Desmier / PNI-MNHN.

Date	Animal	Description of conflict
March/April	Lion	Reports of locals killed around Mondlane
May	Elephant	Elephant found in trap near Olumbi
May	Lion	Report of local killed
14th July	Lion	Report of lion attack in Quiwia – appears to be a rumour but not confirmed.
Mid July	Elephant	Groups of elephant (up to 12) seen and 1 injured by snare on line 36
July 22	Lion	Killed lady 3 km north of Palma Camp
July 30th	Lion	Reported to have entered a hut in Nanhandele. Family fled to upper level and were safe.
July 30th	Lion	Lady killed in dip in between Palma village and Palma Camp. The lion was chased away (approx 9 am)
August 2nd	Lion	Lady killed 3 km north of Mondlane village
August 7th	Elephants	Pushed over tree on line 5, 5 km north of NW road
August 8th	Elephant	L40 - west of line 11. Closed line by pushing trees across the line
August 14th	Lions	Lion(s) killed a man near Mondlane village
August 20th	Elephant	L28 west - 3 elephant walked through the clearing team
August 22nd	Lion	Lion shot and wounded by Game Specialist near the village of Magaya in the Quelimane area - apparently died 5 days later
August 30th	Lion	Lion shot and killed at more the or less the same place by Game Specialists
End of August	Hippo	Local fisherman killed near tieline. Details unknown

Details of human–wildlife conflicts in the eastern part of Palma District between March and early September 2008 recorded by the environmental monitoring team of oil exploration company Artumas.

Tree brought down by an elephant across oil cut-line 34, 23rd November 2008. Elephant-felled trees were encountered at three different places along this cutline on that day, and had been recorded a few months earlier nearby on cutline 40 (see table opposite). These trees seem to have been deliberately pushed over to hinder human movement, possibly out of irritation over the recent intrusion of the cut-lines into the forest. A similar situation has been observed in Coastal Forest at Mwalungaje in Kenya and at Quiterajo south of Mocímboa da Praia in Mozambique, where many trees have been pushed over, again as a possible response to human pressure.

Cut *Afzelia quanzensis* trunk, ca. 1 m diameter on the Pundanhar to Nangade road, 11°02’32”S, 39°40’30”E, 6th November 2009. This tree was probably cut by illegal timber operators crossing the border from Tanzania where very few large timber trees now exist. It has not been possible to interpret either the Swahili or Arabic inscriptions on this log.

16. Logging

The main trees harvested in coastal areas of Mozambique at the start of the 21st century were *Khaya nyasica*, *Milicia excelsa* and *Dalbergia melanoxylon* for high value timber, together with *Afzelia quanzensis*, *Millettia stuhlmannii* and *Pterocarpus angolensis* for medium-value timber. Of these, *Khaya nyasica* was not seen in Palma District, while *Dalbergia melanoxylon* is only occasionally found in woodland areas. *Afzelia quanzensis* is very common throughout Palma District, and is a frequent component of the forest canopy, while *Pterocarpus angolensis* was often seen in woodland areas. Individuals of *Milicia excelsa* were only seen along the edge of the Rovuma escarpment — many of the larger of these around Lake Nhica had coppice regenerated from cut stumps, probably during the 1950s when there was a high demand for the tree in Europe to produce furniture.

Between Palma and Nhica do Rovuma, most of the larger individuals of the medium value *Afzelia quanzensis* had coppice regenerated from stumps, suggesting that this species had been systematically logged in the past, possibly during the Portuguese era. From Pundanhar to Nangade most of the larger *Afzelia quanzensis* along the roadside were single-stemmed, with specimens up to 1.2 m diameter.

Despite reports of illegal logging by a Chinese contractor in 2003 in the forests to the northwest of Pundanhar, there was otherwise little sign of any recent logging in the forests of the Rovuma rim. A single cut individual was however observed off the road to Nangade, and on the Palma to Quissungule road.

Large single-stemmed *Afzelia quanzensis*, Pundanhar–Nangade road, 6th November 2009. 11°01'01"S, 39°42'56"E. Individuals of *Afzelia quanzensis* of a metre in diameter are regularly encountered on this road.

An infrequently encountered *Milicia excelsa* with a single straight trunk of about 70 cm diameter, that would normally at this size have been harvested for its high value timber in neighbouring Tanzania. The repeated old slash marks demonstrate that the identity of this tree is clearly known to many of the local people. Forest edge to the east of Lake Nhica, 10°41'43"S, 40°12'34"E, 13th November 2009.

Unlike the individual in the picture above, this high-value *Milicia excelsa* tree — like many others in the forests around Lake Nhica — is multi-stemmed, as a result of having been logged. Each of its 8 stems are about 80 cm in diameter, which means that it was probably cut during the Portuguese era, perhaps during the 1950s when there was a strong market for *Milicia* in Europe. The stem pattern of the tree would also suggest that it may have been cut once before, perhaps around 1900. 10°42'27"S, 40°12'40"E, 16th November 2009.

17. Firewood and charcoal

Given the huge number of trees still present in Palma District, firewood is unsurprisingly the main source of fuel used by the local population for household cooking. Most of this firewood is collected for own-use, as it is readily available near people's homes. Only in Palma is there a small trade in firewood.

According to a wood merchant who makes a living from bringing firewood to Palma to sell to the urban population, a family in Palma needs 30-40 Kg of firewood per week. This equates to a single load of firewood that he was able to carry on his bicycle.

Charcoal-burning was only encountered at a single location on the old Palma to Nhica road, probably for supplying the market in Palma, although it was not seen for sale there. Charcoal is a comparatively low value commodity that it rather labour-intensive to produce, and so is usually only carried out within easy reach of a market. A recent study of charcoal production in coastal Tanzania has demonstrated that its production is focussed close to major urban centres, and expands outwards in concentric circles as wood supplies are totally exhausted closer to the urban centre (Ahrends *et. al.* 2010). Charcoal production is not therefore a threat to the Palma forests for the foreseeable future – except perhaps to supply Mtwara in Tanzania.

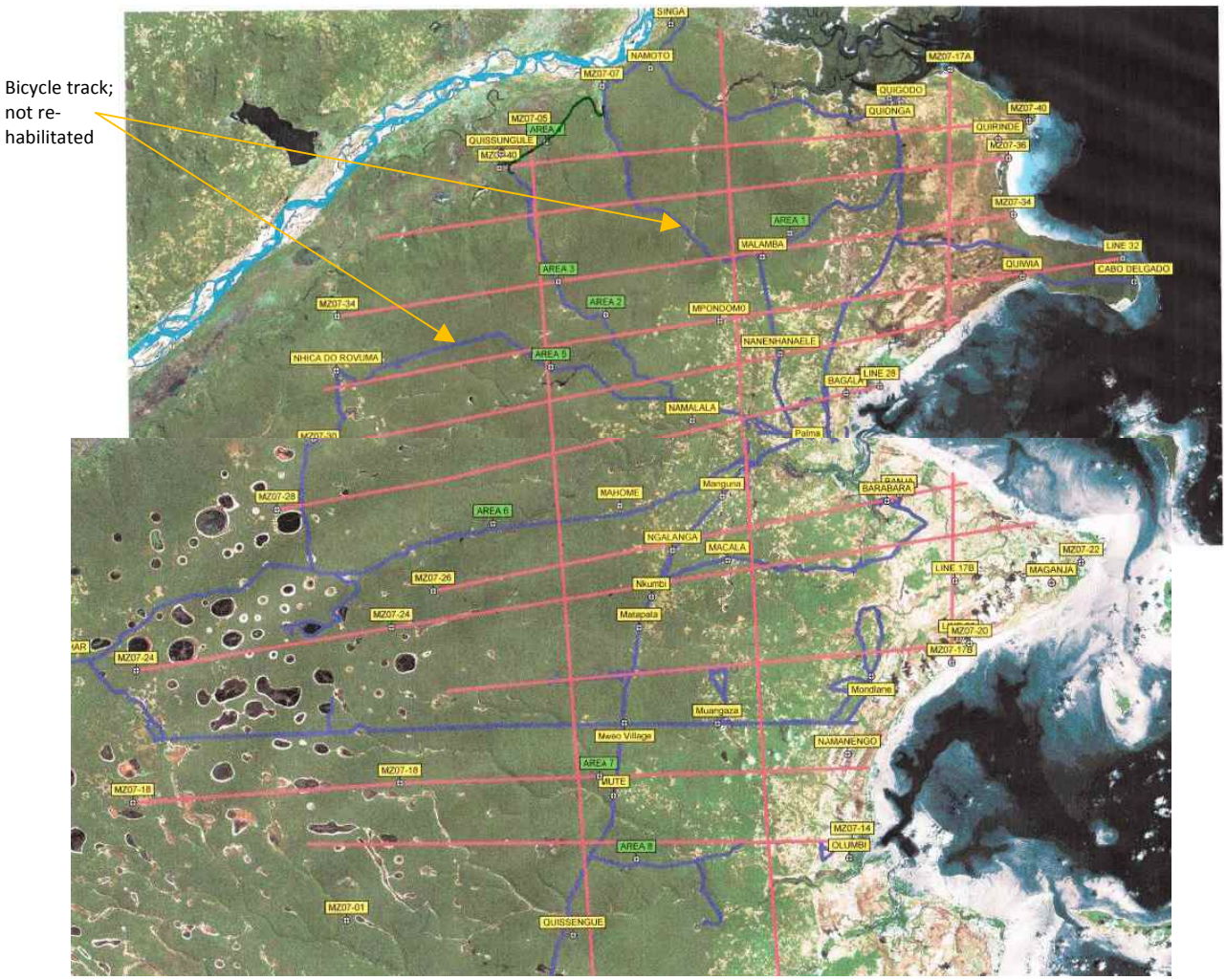
Firewood merchant and friend on the 'Church Road' north of Palma, 10°40'40"S, 40°26'10"E, 14th November 2009. All the wood seen stacked beside the road here is *Berlinia orientalis*, which is selected because it is plentiful here and has no other use due to its poor quality and propensity for being attacked by wood-boring insects, even when still alive. The journey from this point to Palma takes about an hour by heavy-laden bicycle, and a single load of wood is sold in the market for 10 meticais.
The firewood merchant estimated that *Berlinia orientalis* grows at about 1 m per year. Its vigorous ability to regenerate and coppice from cut stumps suggests that it would make an ideal woodlot tree to supply the domestic demand for fuelwood in Cabo Delgado region.

Oil cutline 34 traversing dry forest to the immediate northwest of Lake Mikulumu, 23rd November 2008, the day before this line was finally closed. The chopped branches that are visible along the sides of the road were then dragged across the road to present a continuous obstacle and impediment to movement, while an embankment and ditch were dug wherever the line intersected a road to prevent vehicles (particularly logging lorries) from being able to use the cutline in the future.

18. Oil Cutlines

Oil exploration was first conducted around the Mocímboa basin during the early 1980s, when a series of seismic lines were constructed between Pemba and the Rovuma River. The vegetation was cleared by bulldozer to form tracks that were initially 12 m wide. The bulldozers compacted the soils, slowing regeneration, so many of these cutlines are still visible on satellite photos, and some have been adopted as roads.

During the middle of 2008 oil exploration company Artumas created a further series of cutlines between Mocímboa da Praia and the Rovuma River. Environmental manager Martin Guard and Technical Adviser Rosalind Salter recognised the sensitivity of the Palma landscape and the risk posed by opening new access roads into previously undisturbed areas of Coastal Forest. They therefore persuaded Artumas to create narrower 3–4 m wide tracks that would be cut by hand to avoid compacting the soil with heavy machinery. Detours were made around trees larger than 20 cm diameter, and instead of being uprooted, the cut stumps were softened with a milling machine to prevent them puncturing car tyres. Martin Guard hoped this technique would allow the cut stumps to regenerate and quickly fill the open swathes created by the cutlines, thereby preventing these from becoming access routes.



Map of oil cutlines (pink) north of Quissengue on the Mocímboa – Palma road, together with old roads improved by oil exploration company Artumas (blue). The road east and west of Mweo village is an old cutline from the early 1980s that subsequently became the main access route to Pundanhar and Nhica do Rovuma due to the presence of landmines between Palma and the turning to Nhica do Rovuma.

The cutlines were closed at the end of November 2008 by digging trenches and constructing earth berms across the access points, and by dragging the cut timber back across the lines themselves. A year later, at the end of 2009, there was no evidence that any of the cutlines had been used as new access roads or footpaths, as progress over the logs and branches that were strewn across the lines could be very slow – in the worst cases just 1.5 km per hour. Furthermore, there was good coppice regeneration from many of the cut stumps, with some saplings having reached almost 2 m high a year after the cutlines had been closed.

The technique of hand-cutting cutlines employed some 5000 local people as labourers to cut the lines, thereby ensuring that some of the money used for the oil exploration was able to trickle down to a very large number of people in the community.

The Artumas environmental team used the cutlines to record over 550 km of vegetation transects, which have provided useful baseline data on the relative proportion of forest and woodland cover in the eastern part of Palma District – and to help identify target areas for biodiversity research. The oil cutlines also proved to be very useful for the Pro-Natura Mozambique expeditions, as they provided a secure means of access into large expanses of forest and woodland, where the lack of topography combined with dense vegetation would otherwise have made it easy to become disorientated and lost.

Artumas also rehabilitated the roads around Palma, including a few routes that had become overgrown from a lack of use during the civil war or because of the fear of landmines (although all of these roads were still used as footpaths and bicycle tracks). A decision was however made not to rehabilitate the last section of the old Palma to Nhica do Rovuma military road, or the bicycle track from Lake Mikulumu to the Rovuma River, to limit opening up road access into the heart of large forested areas.

Access to oil cut-line 30 blocked by two freshly-dug trenches and earth berms beside the Palma–Quissungule road, 3rd December 2008. Photo © Frances Crawford.

19. Landmines

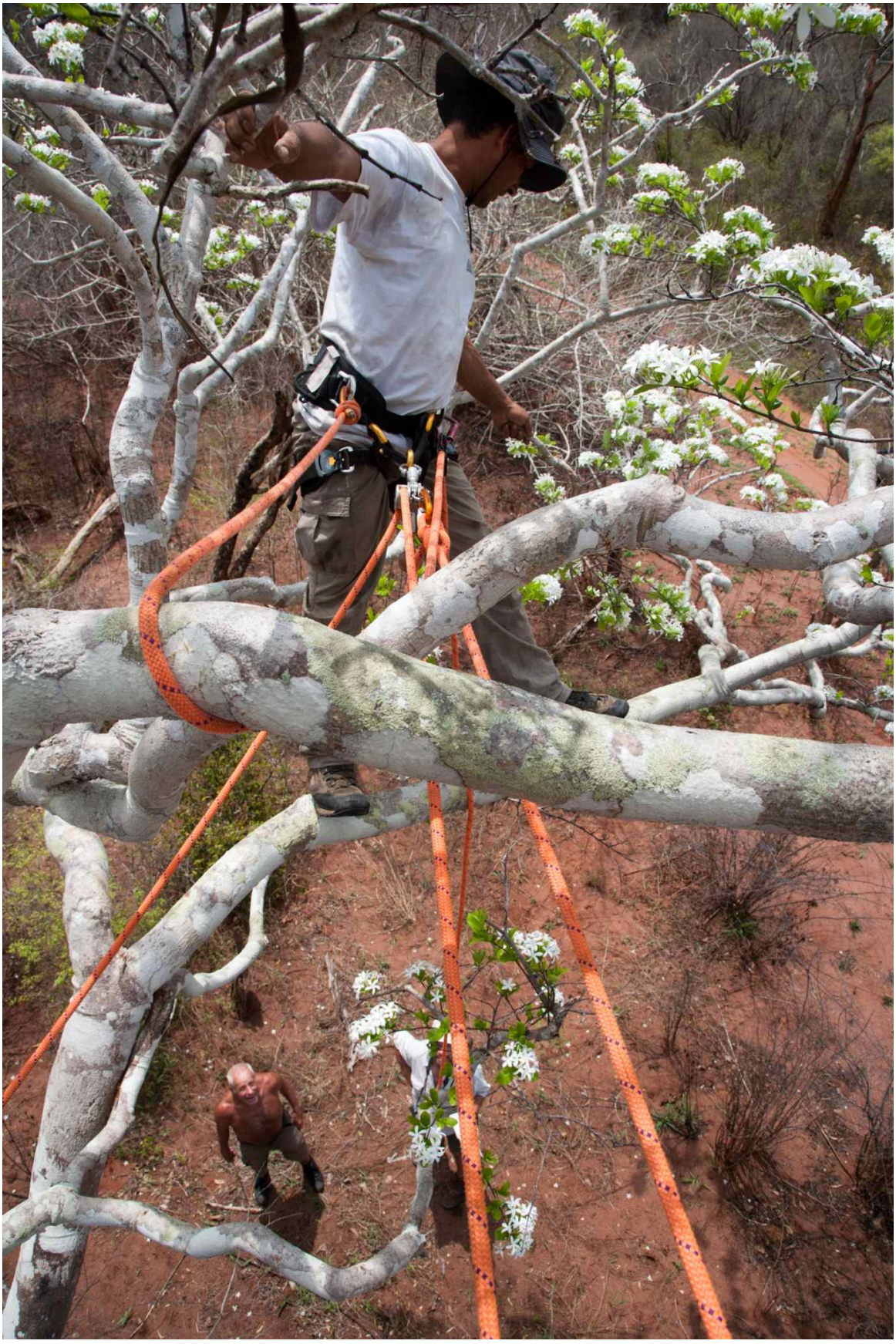
A considerable number of landmines were planted in Palma District during the 1964–1992 independence and civil wars, particularly along the Rovuma River frontier to prevent infiltration from armed groups based across the border in Tanzania.

Local people using a cleared lane through the minefields on the northern border, prior to the complete clearance of the minefield. Photo © Halo Trust.

The UK-based NGO Halo Trust started to demine the four northern provinces of Mozambique in 1993. In October 2007 Halo Trust was able to declare the northern half of Mozambique to be effectively mine-free, after having removed 100,843 landmines from all known 552 minefields. Every single village in northern Mozambique has declared that it is free from landmines (information from www.halotrust.org accessed October 2010).

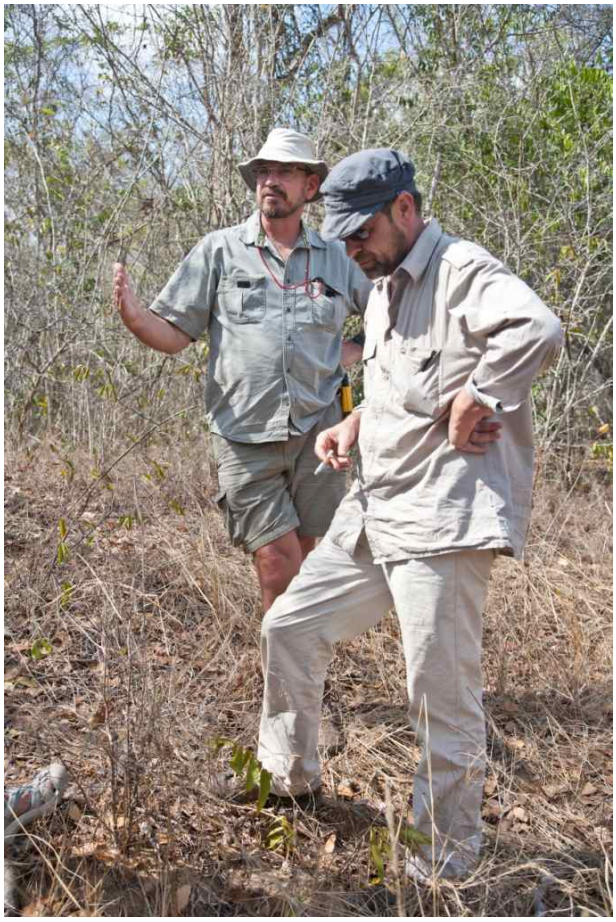
One of the most heavily mined areas was along the road going through the forest to the immediate west of Pundanhar, which was mined up to 25m from the road edge on its northern side. A former deminer described how each member of the Halo Trust team cleared 30–50 mines per day for many weeks in this area during 2006. Yet surprisingly the forest here is not in noticeably better condition than other areas in Palma District, even though it would have been free from all human intrusion for 40 years.

Recently cleared minefield to the immediate west of Pundanhar, on the road to Nangade. A very large number of mines were cleared from this area by the Halo trust ca. 2005-2006. Photo © Xavier Desmier / PNI-MNHN.



Tree-surgeon Frédéric Mathias collecting flowering material for botanist Tom Müller (on the ground). Photo © Russell Scott.

20. Acknowledgments



Jonathan Timberlake & Olivier Pascal © Russell Scott

The great Tom Müller © Russell Scott

Thanks to Olivier Pascal for organising the 2008–2009 Pro-Natura expeditions; to Jonathan Timberlake for organising the botanical component of the expedition; to botanists Tom Müller, Hermenegildo Matimela, Camilla de Sousa, Francis Crawford, Aurelio Banza, Alice Massingue David Goyder, Quentin Luke, Tereza Alves, John and Sandie Burrows for help with identifying plant specimens; and to Frédéric Mathias and Noui Baiben for climbing trees to get specimens.

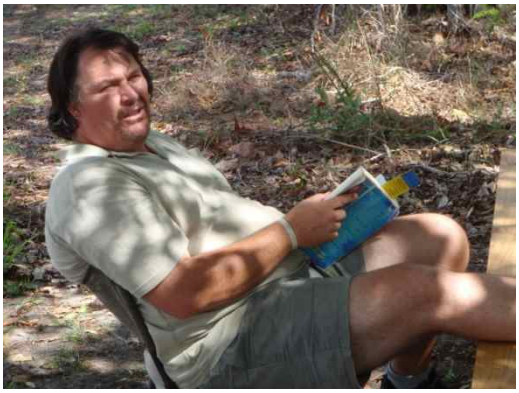
Hermenegildo Matimele

Camilla de Sousa, Phil Clarke & Frances Crawford © Russell Scott

Alice Masingue & David Goyder © Russell Scott

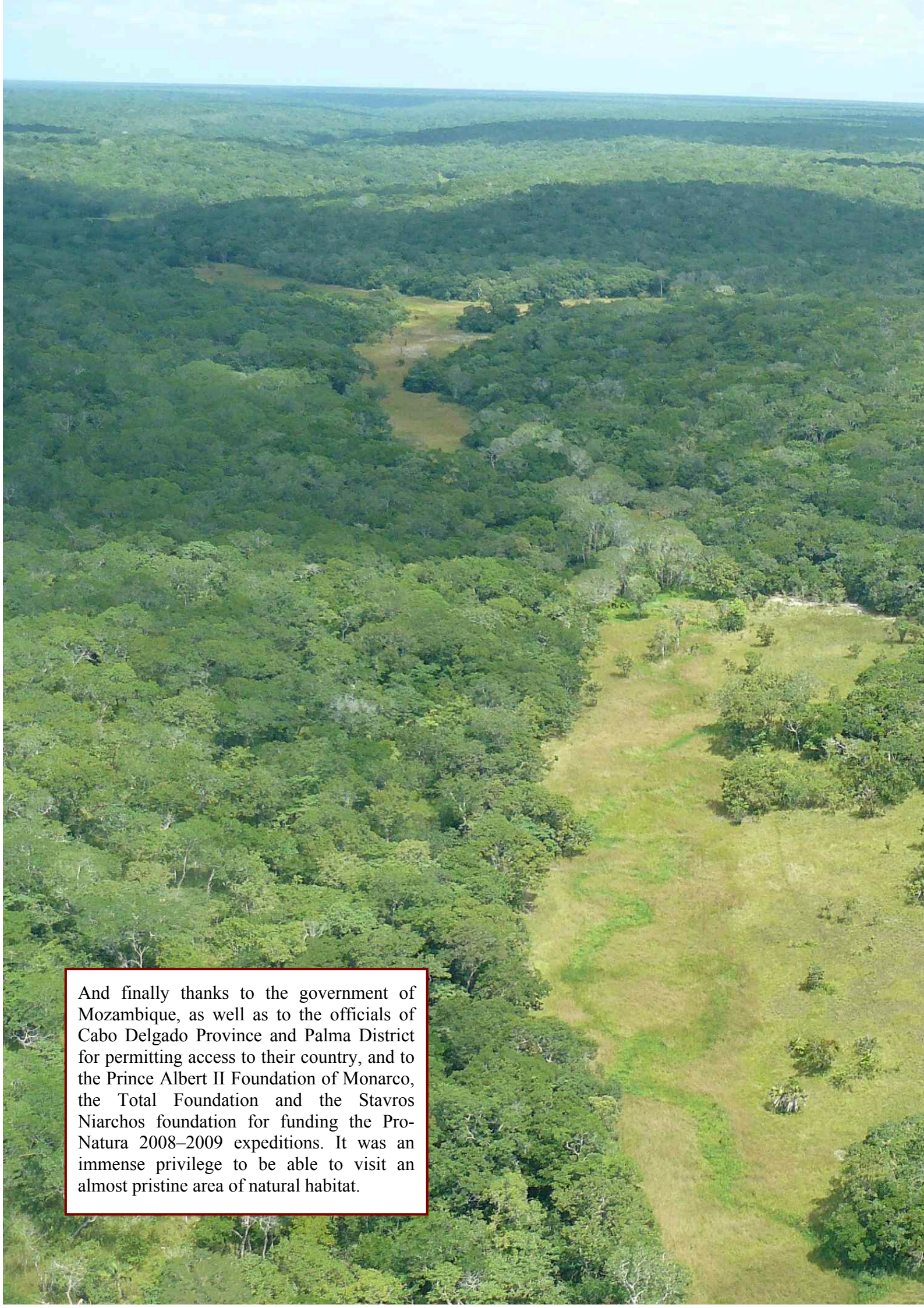
Photographers Russell Scott (below left), Olivier Dubuquoy and Xavier Desmier (below right with chameleon), generously allowed their photos to be used in this report.

Thanks to Markus Isselbacher (below left) and Adrian Nel, together with Russell Scott for driving, to Andy Trevella for guiding, and to Mike Scott and his team for logistics.



Olivier Pascal briefing the team at the Nhica do Rovuma camp. November 2009. Left to right: Mike Scott (in charge of logistics), Alice Masingue, Frances Crawford, Camila de Sousa, Hermegildo Matimela, David Goyder, Phil Clarke, Tereza Alves, Jonathan Timberlake, Dany Cleyet-Marrel, Pierre. Photo © Russell Scott.

Hermegildo Matimela, Phil Clarke & Frances Crawford pressing specimens on the tailgate of a Landcruiser in a pan south of the Palma–Pundanhar road, 7th November 2009. Photo © Russell Scott.



And finally thanks to the government of Mozambique, as well as to the officials of Cabo Delgado Province and Palma District for permitting access to their country, and to the Prince Albert II Foundation of Monarco, the Total Foundation and the Stavros Niarchos foundation for funding the Pro-Natura 2008–2009 expeditions. It was an immense privilege to be able to visit an almost pristine area of natural habitat.

References

Ahrends, A., Burgess, N. D., Milledge, S. A. H., Bulling, M. T., Fisher, B., Smart, J. C. R., Clarke, G. P., Mhoro, B. E., Lewis, S. L., (2010). Predictable waves of sequential forest degradation and biodiversity loss spreading from an African city. *Proceedings of the National Academy of Science* **107**, 14556–14561.

Brenan, J.P.M. (1967). Leguminosae Subfamily Caesalpinioideae. In Milne-Redhead, E. & Polhill, R.M. (eds.) *Flora of Tropical East Africa.* London: Crown Agents for Oversea Governments and Administrations. 230pp.

Chardonnet, P., Mésochina, P., Renaud, P.-C., Bento, C., Conjo, D., Fusari, A., Begg, C., Foloma, M. & Pariela, F. (2009). *Conservation status of the lion (Panthera leo Linnaeus, 1758) in Mozambique.* Maputo: IUCN.

Clarke, G.P. (1995). Status Reports for 6 Coastal Forests in Lindi Region, Tanzania. Frontier-Tanzania Technical Report No. 18. London & Dar es Salaam: The Society for Environmental Exploration/The University of Dar es Salaam. 63 pp.

Clarke, G. P. (1998). A new regional centre of endemism in Africa. In: *Chorology, Taxonomy and Ecology of the Floras of Africa and Madagascar*. Huxley, C. R., Lock, J. M., and Cutler, D. F. (Eds.) (1998). Royal Botanic Gardens, Kew, UK.

Clarke, G. P. (2000). Climate and climatic history. In: *Coastal Forests of Eastern Africa*. Burgess, N. D. and Clarke, G. P. (Eds.) (2000). IUCN Publications Services Unit, Cambridge, UK.

Clarke, G. P. (2000a). Defining the eastern African Coastal Forests. In: *Coastal Forests of Eastern Africa*. Burgess, N. D. and Clarke, G. P. (Eds.) (2000). IUCN Publications Services Unit, Cambridge, UK.

Clarke, G.P. & Karoma, J.A. (2000). History of anthropic disturbance. Chapter 5.1 in Burgess, N.D. & Clarke, G.P. (eds.). *Coastal Forests of Eastern Africa*. IUCN Forest Conservation Series. 434pp. Cambridge & Gland: IUCN.

Clarke, G. P. and Robertson, S. A. (2000). Vegetation communities. In: *Coastal Forests of Eastern Africa* (*2000*). Burgess, N. D. and Clarke, G. P. (Eds). (2000). IUCN Publications Unit, Cambridge, U.K.

Clarke, G. P., Vollesen, K. and Mwasumbi, L. B. (2000). Vascular Plants. In: *Coastal Forests of Eastern Africa*. Burgess, N. D. and Clarke, G. P. (Eds.) (2000). IUCN Publications Services Unit, Cambridge, UK.

Ferro, P. (2007). *Occasional and seasonal movement in the National Reserve of Niassa, Mozambique, 2006*. Maputo: Sociedade para a Gestão e Desenvolvimento da Reserva do Niassa, Moçambique.

Garnier, J. (2006). Human / Elephant Conflict in the Messalo Wilderness Area. The Zoological Society of London, Conservation Programmes Regent's Park. London. 38pp

Gillman, H. (1945). Bush fallowing on the Makonde plateau. *Tanganyika Notes and Records* **19**: 34–44.

Goyder, D., Banze, A., Crawford, F., Matimele, H. & Timberlake, J. (2010). Cabo Delgado Plant Records. Unpublished typescript. Kew: Royal Botanic Gardens.

Impacto (2007). *Hydrocarbons Exploration Project in the Onshore Block of the Rovuma Basin - EIA*. Maputo: Impacto Lda.

Lowe, A.J. & Clarke, G.P. (2000). Vegetation structure. Chapter 3.3 in Burgess, N.D. & Clarke, G.P. (eds.). *Coastal Forests of Eastern Africa*. IUCN Forest Conservation Series. 434pp. Cambridge & Gland: IUCN.

Maugham, R.C.F. (1910). *Portuguese East Africa and Zambesia*. London: H.N. Murray.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B. & Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature* **403**: 853-858.

Prins, E. (2010). *Satellite Mapping of Land Cover and Use in relation to Oil Exploitation in Concession Block 5A in Southern Sudan 1987–2006*. Utrecht: European Coalition on Oil in Sudan.

Rodgers, W.A. (1996). The Miombo Woodlands. Chapter 12, pp. 299–325 in McClanahan, T.R. & Young, T.P. (eds.). *East African Ecosystems and Their Conservation*. New York & Oxford: Oxford University Press.

Seavoy, R.E. (1988). Hoe shifting cultivation in East African subsistence culture. *Singapore Journal of Tropical Geography* **8**: 60-71.

Serviço Meteorological Naçional (1919–1951). *Anais Meteorologicos das Colonias. Volume V – XXXII – Ano de 1918–1945*. Coimbra and Lisbon: Direção dos servicos diplomaticos geograficos e de marinha / Direcção tecnica do fomento (Repartição do estudos geograficos) / Comissão de cartografia.

Timberlake, J.R., Pope, G.V., Polhill, R.M. & Martins, E.S. (2007). *Flora Zambesiaca.* Volume Three: Part Two. 218pp. London: Royal Botanic Gardens, Kew.

Timberlake, J.R., Goyder, D.J., Crawford, F.M. & Pascal, O. (2010). *Coastal dry forests in Cabo Delgado: Botany/Vegetation.* Unpublished report. London & Paris: Royal Botanic Gardens & Pro-Natura International.

White, F. (1983). *The vegetation of Africa. A descriptive memoir to accompany the Unesco/AETFAT/UNSO vegetation map of Africa.* UNESCO, Paris, France.

Cabo Delgado lighthouse, showing the exposed coral rag substrate of the peninsula. November 2009. Photo © Russell Scott.

Summary

During 2008–2009 a reconnaissance survey and two botanical expeditions were mounted to Palma and Nangade Districts of Cabo Delgado province in northern Mozambique, by Pro-Natura International, in cooperation with the Instituto de Investigação Agrãria de Moçambique, the Royal Botanic Gardens at Kew and the Paris Museum of Natural History.

Palma and Nangade Districts were hardly known by biologists, and the expeditions, together with satellite analysis and an aerial survey have documented the presence of some 800 km^2 of closed canopy dry forest belonging to the Eastern African Coastal Forest hotspot / Swahilian regional centre of endemism. This is the largest extent of such forest anywhere along the eastern African coast – representing a huge store of carbon and an important sanctuary for many rare plants and animals. The expeditions have also documented a unique landscape of seasonal lakes/pans and a near-pristine floodplain wetland along the Rovuma River, which together with the forests provide important wet and dry season habitats/sanctuaries for big game.

Preliminary botanical collections have recorded 11 plant species that are new to science, an additional 4 that were previously only known from fragmentary material collected in SE Tanzania, and a further 34 species that are new to Mozambique.

A description of some of the vegetation types present in Palma and Nangade Districts, together with the environmental and human factors that affect them, are presented here to document a unique ecosystem that is about to be changed beyond recognition by agricultural clearance. None of the forests are under any form of legal protection, and recommendations are given for the best sites and areas that should be conserved.

Author contact: phil (at) clarke (dot) dk

This report can be downloaded from http://coastalforests.org

Also the Tanzania Forest Conservation Group website http://cf.tfcg.org/mozambique.html