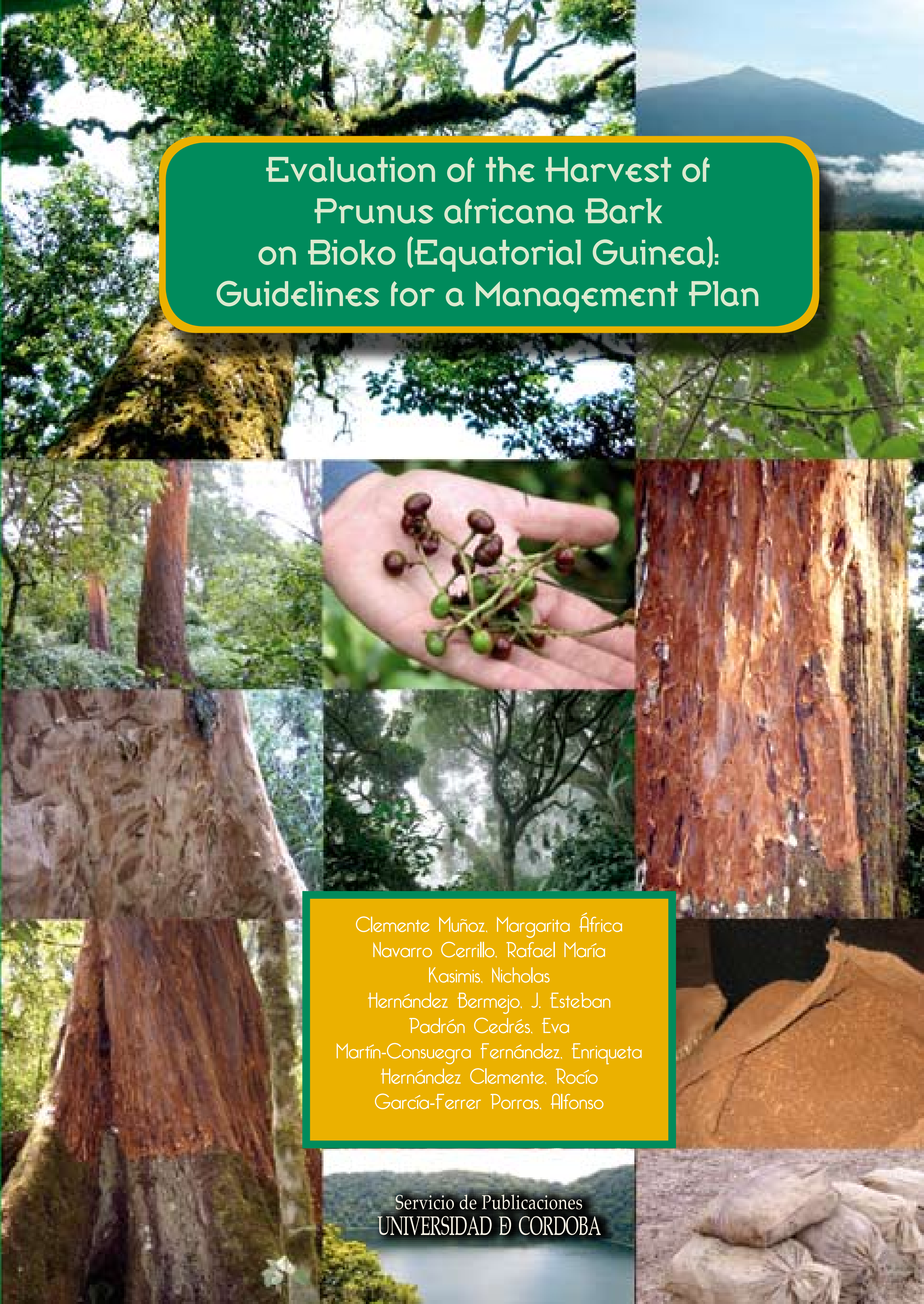

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- General Director of Fisheries and the Environment, Equatorial Guinea: Mr Santiago Engonga
- General Director of APRA in Equatorial Guinea: Mr Giovanni Bandini
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- Mayor of Moca: Mr Gabino Siloche
- Technical staff from the Ministries of Agriculture and Forestry and of Fisheries and the Environment: Mr José Luis Massoko Elonga, Mr Pelagio Mangué Mbomio, and Mr Ramón Willy Tomos

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ABBREVIATIONS USED

APRA: Aprovechamientos Agrícolas (Spanish company for agriculture and food products)

BA: Basal Area (m^2/ha): the average area of a cross-section of all trees per unit of terrain

CCF: Canopy Cover Fraction; fraction of ground area covered by crowns of trees, expressed in m^2, with respect to the total area (m^2)

CFA: Central African CFA franc (676 CFA = 1 €)

CITES: Convention on International Trade in Endangered Species of Wild Fauna and Flora

CoP: Conference of the Parties

CUREF: Project for Conservation and Rational Use of Equatorial Guinea's Forest Resources

D: Density (individuals/ha): average number of individuals per unit area

DBH: Diameter at Breast Height (cm)

ºdec: Decimal Degrees

EC: European Community

EPE: Estimated Position Error in determining the position (m) where 50% of the measurements received by the GPS can be found

ETM+: Enhanced Thematic Mapper Plus

EU: European Union

FAO: Food and Agriculture Organisation of the United Nations

GIS: Geographic Information System

GPS: Global Positioning System

ICRAF: International Centre for Research in Agroforestry

m.a.s.l.: metres above sea level

MIMAM: **Spanish Ministry of the Environment**

NATRA: **Consortium of Spanish companies to which APRA belongs**

NTFR: **Non-Timber Forestry Resources**

OJEC: **Official Journal of the European Communities**

ONADEF: **National Forestry Development Agency (Cameroon)**

SRG: **EU CITES Scientific Review Group**

PDOP: **Position Dilution of Precision**

UNEP-WCMC: **United Nations Environment Programme-World Conservation Monitoring Centre**

WGS 84: **World Geodetic System (1984)**

WWF: **World Wide Fund for Nature**

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1. Executive Summary

1. Executive Summary

The pilot project "Evaluation of the Harvest of *Prunus africana* Bark on Bioko (Equatorial Guinea): Guidelines for a Management Plan" surveys the current status of this species after recent years' harvest (1996-2004).

Products derived from the bark, with proven effectiveness in treatment of benign prostate hyperplasia, came under growing international demand in the early 1990s. It became evident that this situation could not continue without endangering survival of the species.

For this reason, international trade in *Prunus africana* has been regulated since 1995 under the Convention on International Trade in Endangered Species of Wild Fauna and Flora. By listing this species on Appendix II, the Convention aims to ensure its use is sustainable. This purpose is achieved through a system of permits that must be issued by the pertinent CITES Authorities, and which make it possible to establish the amounts of bark harvested on a yearly basis. These data are used to monitor the global level of exploitation of the species, falling under regular analysis by the CITES Plants Committee.

At its 12th meeting, in May 2002, the Committee decided to include the species in its Significant Trade Review and apply the provisions of the Resolution approved by the Parties to this effect [Conf. 12.8 (Rev. CoP13)]. In this Resolution, the Conference of the Parties directs the Plants Committee, in cooperation with the Secretariat and experts, and in consultation with range States, to review the biological, trade, and other relevant information on Appendix-II species subject to significant levels of trade, to identify problems and solutions concerning the implementation of Article IV, paragraphs 2 (a), 3 and 6 (a) of the Convention.

The demands and trends of the global market today are complex and challenging, and the debate over the need for sustainable use of forest resources is livelier than ever. In this context, the present pilot project offers complete methodology (new technologies and forest inventories adapted to the evaluation of Non-Timber Forest Resources, NTFR) that can be readily applied to establish guidelines for sustainable international trade in *Prunus africana*.

Given the historic ties between Spain and Equatorial Guinea and *Prunus africana* bark exports to Spain, the Spanish CITES Scientific Authority decided to carry out a pilot project confined to Equatorial Guinea and the bark-harvesting area on Bioko Island. The model for this survey, which could be applied to other countries and areas depending upon the availability of external funding, was promoted and funded by the Ministry of the Environment General Directorate for Biodiversity, CITES Scientific Authority of Spain, in June 2004.

A multidisciplinary team at the University of Córdoba developed the project under an agreement with the Córdoba Botanic Garden. The Spanish company NATRA S.A. provided logistical support.

A management model for NTFR formed the basis for working methodology, which was designed to prepare the necessary guidelines for implementation of a Management Plan for the species on Bioko. The guidelines provided are the culmination of a series of stages in work oriented towards evaluating the living forest resource: *Prunus africana* specimens and their current status following bark-harvesting activities. For this purpose, remote sensing techniques (a 2003 Landsat 7 ETM+ image) were used along with inventory of a representative area of Bioko *Prunus africana* forests and evaluation of the status of individual trees according to use patterns.

The main advantage of using remote sensing, combined with a specific forest inventory, following methodology defined for sustainable management of NTFR, is that it quickly and comprehensively covers the main objectives in developing a sustainable management plan for the harvest of *Prunus africana* bark. It provides specific proposals for each harvest area, while also being adaptable to other countries and regions.

The general goal of the project was to determine the potential and current range of *Prunus africana* on Bioko. Based on this range data, stocks could be assessed, bark harvest evaluated, and proposals made with necessary recommendations to consider in drawing up a management plan for sustainable use of the species.

The following specific objectives were established to achieve the general goal:

1. Survey of the distribution of dominant types of vegetation by means of a Landsat 7 ETM+ image
2. Characterisation of the forests where *Prunus africana* occurs in current and potential harvest areas, in terms of their structure, composition of the vegetation, wealth and diversity of tree species
3. Estimate of bark yield, and
4. Establishment of silvicultural criteria for sustainable use of *Prunus africana* forests

The results of this pilot project lead to the following general recommendations suppported by the CITES Plants Committee (16th meeting, Lima, Peru; July, 2006)

AT THE INTERNATIONAL LEVEL: Measures directed to international organisations, countries, and industries with a stake in imports, exports, and trade in products derived from *Prunus africana* bark.

1. Effectively foster implementation of management plans in range countries.
2. Coordinate promotion of thorough *Prunus africana* population surveys throughout its range.

3. Encourage international cooperation projects to advance use of *Prunus africana* in agro-forestry systems and plantations, including proper genetic diversity and optimising propagation and agro-forestry cultivation techniques.

4. Coordinate methods used on Bioko for evaluating *Prunus africana* production in natural ecosystems with other methodological proposals in CITES.

5. Ensure the quality of studies and follow-up of management plans for the species.

At the National Level: Measures directed to the Government of the Republic of Equatorial Guinea.

1. Define, initiate, and implement the *Prunus africana* Management Plan.

2. Promote use of *Prunus africana* in agro-forestry systems and plantations, including proper genetic diversity and optimising propagation and agro-forestry cultivation techniques, especially in the Moca area.

3. Establish *Prunus africana* plantations allowing an estimated 12-year period to reach the harvest phase. This would relieve the pressure on natural stands and maintain sustainable harvest of the species in the future.

4. Designate a skilled overseer, in coordination with harvest authorities, to ensure best practice.

5. Set the 2006 harvest quota at 197 t, with an 8-year return time.

6. This quota should be scientifically evaluated and revised annually.

7. Allow only one harvesting company to operate in the area.

At the Local Level: Measures directed to the local population in charge of harvesting the bark, which should be taken in conjunction with the export firm:

1. Workers should receive adequate prior training on bark harvesting techniques that do not damage the tree, and they should have the proper tools for the job.
2. Free at least one worker from debarking to take charge of supervising and reviewing best harvesting practice.
3. Encourage harvesters to work for the quality rather than the quantity of bark harvested.

The specific recommendations for sustainable management of *Prunus africana* on Bioko described in each section of the pilot project are summarised below:

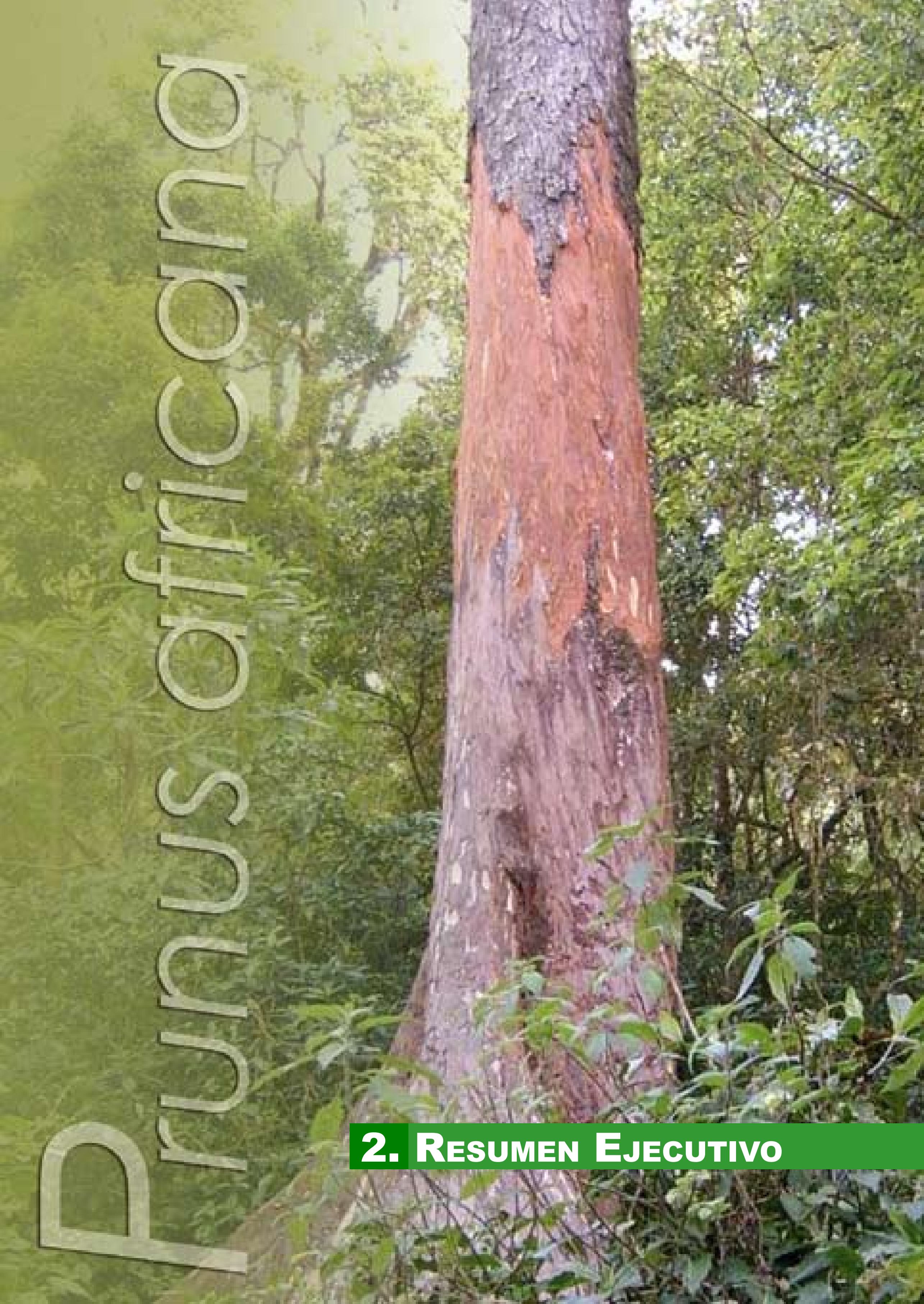
Summary of Recommendations for Sustainable Management of *Prunus africana* on Bioko

Recommendations	Remarks	Who is Responsible
INVENTORY		
Review inventory criteria cross-referencing existing information	See inventory models by group	Equatorial Guinean Ministries responsible for forestry management and CITES/APRA
Take inventory of the two new areas before beginning harvest	This would be highly advisable even before opening access routes, although it would be complicated	APRA
Mark inventory areas in the field to define basic production units	The basic production units will be those that produce an amount of bark within the annual quota	APRA
Label all trees during inventory with aluminium tags numbered at the base	Optimises inventory work and allows for proper control of the harvest, which is a basic requirement for any certification process	APRA

Recommendations	Remarks	Who is Responsible
PRODUCTION		
Calculate specific weight according to varying moisture content		APRA
Make more detailed study of real production per tree in the field	The very harvest activity itself may be used	APRA
Clearly establish the yield of the entire drying and grinding process up to shipment		APRA
Calculate potential production of new areas with data derived from inventory	No new work on bark parameters is necessary	Equatorial Guinean Ministries responsible for forestry management and CITES/APRA
Carry out precise zoning of harvest areas in accordance with the annual quota	Indiscriminate harvesting must be avoided	Equatorial Guinean Ministries responsible for forestry management and CITES/APRA
Select the location and layout of the campsite to meet the needs of the harvest areas	It is advisable to provide the necessary infrastructure for harvest at the outset (access route and campsite)	APRA
Correct signposting of harvest areas and producing trees	Harvest should follow certification standards	Equatorial Guinean Ministries responsible for forestry management and CITES/APRA
HARVEST PLAN		
Only allow harvest by one company committed to developing and complying with the Management Plan		Equatorial Guinean Ministries responsible for forestry management
Publish annual harvest quotas according to results of the present study. For 2006 this would be 197 t, considering new south and east Pico Basilé harvest areas		Equatorial Guinean Ministries responsible for forestry management
Give time for the north Pico de Basilé bark to regenerate	Harvesting is more intense in areas near the road, where second and third harvests have been recorded	Equatorial Guinean Ministries responsible for forestry management and CITES/APRA

Recommendations	Remarks	Who is Responsible
HARVEST PLAN		
Establish a strict protocol for bark harvesting	The protocol proposed in this survey is suggested as a starting point, to be validated during 2 years	Equatorial Guinean Ministries responsible for forestry management and CITES
Establish a control plot for harvest techniques		Equatorial Guinean Ministries responsible for forestry management and CITES
Clearly define the operational organisation for harvest activities	The proposal made in this survey is suggested as a starting point, to be validated during 2 years	Equatorial Guinean Ministries responsible for forestry management and CITES/APRA
Select and train a Guinean overseer for technical and operational supervision of work		Equatorial Guinean Ministries responsible for forestry management and CITES
Reconsider the current price of bark in order to establish an incentive system depending on quality of work		APRA
Halt harvest activities in Moca until an adequately trained team is available	Working groups have found problems with Moca residents, and incorrect harvesting in Biaó areas	APRA
Condition the opening of new areas on the availability of well-trained and organised teams		APRA
Set up an internal control system for harvest activities	Improve NATRA-APRA's internal control systems	APRA

Recommendations	Remarks	Who is Responsible
PLANTATIONS		
Promote study of genetic variation in the species and optimise propagation and cultivation techniques Study seed behaviour in germination and long-term storage Establish a seed bank for *Prunus africana*	Seek external institutional support	Equatorial Guinean Ministries responsible for forestry management and CITES in collaboration with Spanish Scientific and Management Authorities /APRA
Immediately establish a programme of plantations and agro-forestry systems		Equatorial Guinean Ministries responsible for forestry management and CITES/APRA
PARALLEL ACTIVITIES		
Foster institutional coordination		Equatorial Guinean Ministries responsible for forestry management and CITES in collaboration with Spanish Scientific and Management Authorities /APRA
Initiate a forestry certification process	Seek external institutional support from cooperation organisations	Equatorial Guinean Ministries responsible for forestry management and CITES in collaboration with Spanish Scientific and Management Authorities /APRA



2. Resumen Ejecutivo

2. Resumen ejecutivo

El proyecto piloto “Evaluación del aprovechamiento de la corteza de *Prunus africana* en Bioko (Guinea Ecuatorial): Directrices para un Plan de Gestión” aborda el estado actual de esta especie como consecuencia de la extracción a la que ha sido sometida en los últimos años (1996-2004).

A principios de los 90 debido a la creciente demanda internacional de productos derivados de la corteza, por su eficacia en los tratamientos de hiperplasia benigna de próstata, se puso de manifiesto que de seguir así la situación la supervivencia de la especie estaría en riesgo.

Por ello, el comercio internacional de *Prunus africana* está regulado desde 1995 por el Convenio sobre Comercio Internacional de Especies Amenazadas de Fauna y Flora Silvestres. El Convenio, con la inclusión de esta especie en su Apéndice II, trata de garantizar que el uso que de ella se hace es sostenible. Para ello se dispone de un sistema de permisos de exportación e importación que deben ser emitidos por las Autoridades CITES correspondientes y a través de los mismos es posible establecer anualmente las cantidades de corteza extraída. Con estos datos se realiza un seguimiento del nivel mundial de explotación de la especie que analiza regularmente el Comité de Flora de CITES.

En su 12 reunión, en mayo de 2002, el Comité decidió incluir la especie dentro del examen de comercio significativo y aplicar las disposiciones de la resolución correspondiente aprobada por las Partes [Conf. 12.8 (Rev. CoP13)]. En esta resolución la Conferencia de las Partes encarga al Comité de Flora que, en colaboración con la Secretaría y los especialistas competentes, y en consulta con los Estados del área de distribución, revisen la información biológica, comercial y de otro tipo sobre las especies del Apéndice II sujetas a niveles significativos de comercio, a fin de determinar los problemas y proponer soluciones respecto de la aplicación de los párrafos 2a), 3 y 6a) del Artículo IV del Convenio.

Las exigencias de las tendencias del mercado mundial son hoy en día complejas y desafiantes, y está más vivo que nunca el debate sobre la necesidad de un aprovechamiento sostenible de los recursos forestales. En este marco, el presente proyecto piloto plantea una metodología completa, de aplicación rápida y sencilla (nuevas tecnologías e inventarios forestales adaptados a la evaluación de Recursos Forestales No Maderables, RFNM) para el establecimiento de unas directrices que permitan el comercio internacional sostenible de *Prunus africana*.

Dados los lazos históricos existentes entre España y Guinea Ecuatorial y la exportación de corteza de *Prunus africana* hacia España, la Autoridad Científica CITES española se planteó la realización de un proyecto piloto circunscrito a Guinea Ecuatorial y a la zona de extracción de corteza: la isla de Bioko. El modelo de estudio, que podría ser aplicado a otros países y zonas en función de la disponibilidad de financiación externa, fue impulsado y financiado en junio de 2004 por la Dirección General para la Biodiversidad del Ministerio de Medio Ambiente, Autoridad Científica CITES de España.

El proyecto ha sido desarrollado por un equipo multidisplinar de la Universidad de Córdoba, a través del Convenio establecido con el Jardín Botánico de Córdoba y recibió apoyo logístico de la empresa española NATRA S.A.

Se ha aplicado una metodología de trabajo diseñada a partir de un modelo de gestión para RFNM con el fin de elaborar las directrices necesarias para la puesta en marcha de un Plan de Gestión de la especie en Bioko.

Los criterios y pautas que se proporcionan son la culminación de una serie de etapas de trabajo orientadas a la evaluación del recurso forestal vivo, esto es, los especímenes de *Prunus africana*, y su estado actual como consecuencia de las labores de extracción de corteza. Para ello se han utilizado técnicas de teledetección (una imagen Landsat 7 ETM+ de 2003) combinadas con un inventario forestal en campo representativo de los bosques de *Prunus africana* de Bioko, que también evalúa el estado de los individuos en función de su aprovechamiento.

La principal ventaja del uso de la teledetección, combinada con un inventario forestal específico dentro de una metodología definida para la gestión sostenible de RFNM, es que cubre los principales objetivos para el desarrollo de un plan de gestión sostenible para la extracción de corteza de *Prunus africana* de una manera integral, rápida y con propuestas específicas para cada área de extracción y que, por otro lado, es extensible a otros países y regiones.

El objetivo general del proyecto fue el estudio del área de distribución actual y potencial de *Prunus africana* en Bioko para determinar el aprovechamiento de corteza, la evaluación de sus existencias y proponer las recomendaciones necesarias que deberían tenerse en cuenta al elaborar un plan de gestión que permita un uso sostenible de la especie.

Para lograr este objetivo general se establecieron los siguientes objetivos específicos: Estudio de la distribución de los tipos de vegetación dominantes mediante el uso de una imagen Landsat 7 ETM+; Caracterización de los bosques con presencia de *Prunus africana* en las áreas actuales y potenciales de extracción en términos de su estructura, composición florística, riqueza y diversidad de especies arbóreas; Estimación de la producción de corteza y Establecimiento de los criterios selvícolas para el uso sostenible de los bosques de *Prunus africana*.

Los resultados obtenidos conducen a las siguientes recomendaciones generales, que fueron apoyadas por el Comité de Flora CITES (16ª reunión, Lima 2006).

A nivel internacional: Medidas dirigidas a organismos internacionales y países e industrias involucrados en la importación, exportación y comercio de productos derivados de la corteza de *Prunus africana*.

1. Impulsar de forma efectiva la puesta en marcha de planes de gestión en los países del área de distribución.
2. Promover de forma coordinada estudios completos sobre las poblaciones de *Prunus africana* a lo largo de todo su rango de distribución.
3. Impulsar proyectos de cooperación internacional que promuevan el uso de *Prunus africana* en sistemas agroforestales y plantaciones, utilizando la diversidad genética adecuada y optimizando las técnicas de propagación y cultivo agroforestal.
4. Coordinar la metodología de evaluación de producción de *Prunus africana* en ecosistemas naturales utilizada en Bioko con otras propuestas metodológicas utilizadas en CITES.
5. Velar por la calidad de los estudios y seguimiento de los planes de gestión de la especie.

A nivel nacional: Medidas dirigidas al Gobierno de República de Guinea Ecuatorial.

1. Definición, puesta en marcha y aplicación del Plan de Gestión de *Prunus africana.*
2. Impulsar el uso de *Prunus africana* en sistemas agroforestales y plantaciones, utilizando la diversidad genética adecuada y optimizando las técnicas de propagación y cultivo agroforestal, especialmente en la zona de Moka.
3. Establecimiento de plantaciones de *Prunus africana* con un período estimado de 12 años para alcanzar la fase de aprovechamiento, lo que permitiría en un futuro eliminar la presión de los bosques naturales y mantener el aprovechamiento sostenible de la especie.
4. Designación de un técnico que, en coordinación con los responsables de la extracción, vele por las buenas prácticas.

5. Debe implantarse una cuota anual de 197 t año^{-1} en 2006 y un turno de saca de 8 años.
6. Dicha cuota se debe evaluar científicamente, y revisarse cada año.
7. No se debe permitir que más de una empresa extractora opere en la zona.

A NIVEL LOCAL: Medidas dirigidas a la población local encargada de la extracción de corteza que deberían ser tomadas en acuerdo con la empresa exportadora:

1. Los extractores de corteza deberían recibir la formación adecuada previa en cuanto a las técnicas de extracción que no dañen al árbol y contar con las herramientas adecuadas para llevar a cabo sus trabajos.
2. Al menos un operario debe estar libre de la extracción de corteza y encargarse de la supervisión y revisión de las buenas prácticas de aprovechamiento.
3. Se debe fomentar que los operarios realicen la extracción en función de la calidad de ésta y no de la cantidad de corteza extraída.

Las recomendaciones específicas para una gestión sostenible de Prunus africana en Bioko descritas en cada uno de los apartados del proyecto piloto se resumen a continuación:

Resumen de las recomendaciones para una gestión sostenible de *Prunus africana* en Bioko.

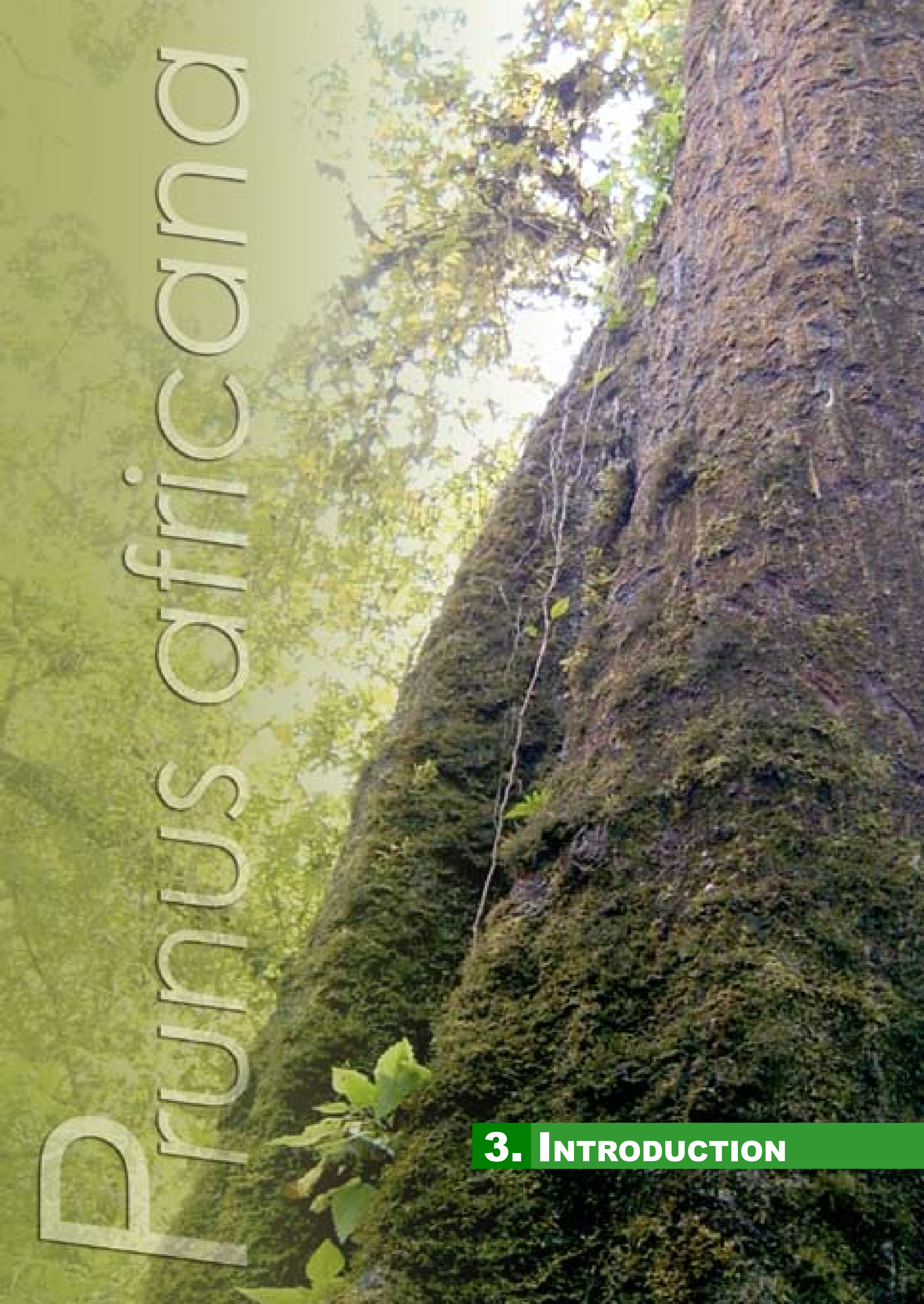
Recomendaciones	Observaciones	Organismo responsable
INVENTARIO		
Revisar los criterios de inventario mediante el cruce de la información existente	Ver modelos de inventario por grupo	Ministerios responsables en Guinea Ecuatorial de la gestión de bosques y de CITES/APRA

Recomendaciones	Observaciones	Organismo responsable
INVENTARIO		
Realizar los inventarios de las dos zonas nuevas antes de iniciar el aprovechamiento	Seria muy recomendable incluso antes de abrir las pistas, aunque resulta complicado	APRA
Marcar en campo las zonas de inventario para la definición de unidades básicas de producción	Las unidades básicas de producción serán aquellas que produzcan una cantidad de corteza correspondiente a la cuota anual	APRA
Etiquetar todos los árboles durante el inventario con chapas de aluminio numerado en la base	Optimiza el trabajo de inventario y permite el control adecuado de la extracción, lo cual es un requisito básico para cualquier proceso de certificación	APRA
PRODUCCIÓN		
Calcular el peso especifico en función de diferentes contenidos de humedad		APRA
Hacer un estudio más detallado de producción real por árbol en campo	Pueden utilizarse las propias labores de extracción	APRA
Establecer claramente el rendimiento de todo el proceso de secado y molido hasta su embarque		APRA
Calcular la producción potencial de las nuevas zonas con los datos derivados del inventario	No es necesario hacer nuevos trabajos de parámetros de corteza	Ministerios responsables en Guinea Ecuatorial de la gestión de bosques y de CITES/APRA
Realizar una zonificación exacta de las zonas de extracción de acuerdo a la cuota anual	Debe evitarse una extracción indiscriminada	Ministerios responsables en Guinea Ecuatorial de la gestión de bosques y de CITES/APRA

Recomendaciones	Observaciones	Organismo responsable
PRODUCCIÓN		
Seleccionar el trazado y localización del campamento de acuerdo a las zonas de extracción	Es recomendable dotar desde el comienzo de las infraestructuras adecuadas de extracción (pista y campamento)	APRA
Señalización correcta de zonas de extracción y árboles productores	La extracción debe adecuarse a los estándares de certificación	Ministerios responsables en Guinea Ecuatorial de la gestión de bosques y de CITES/APRA
PLAN DE APROVECHAMIENTO		
Permitir la extracción a una sola empresa y que ésta esté comprometida con el cumplimiento y desarrollo del Plan de Gestión		Ministerios responsables en Guinea Ecuatorial de la gestión de bosques
Publicar la cuota anual de extracción acorde con los resultados del presente estudio que para 2006 sería de 197 t, considerando las nuevas áreas de extracción de Pico Basilé sur y este		Ministerios responsables en Guinea Ecuatorial de la gestión de bosques
Dar periodo de reposición de corteza en Pico de Basilé norte	La extracción se intensifica en zonas cercanas a la carretera donde se han registrado segundas y terceras extracciones	Ministerios responsables en Guinea Ecuatorial de la gestión de bosques y de CITES /APRA
Establecer un protocolo estricto de extracción de la corteza	Se recomienda partir del protocolo propuesto en este trabajo y validarlo durante 2 años	Ministerios responsables en Guinea Ecuatorial de la gestión de bosques y de CITES
Establecer una parcela de control de técnicas de extracción		Ministerios responsables en Guinea Ecuatorial de la gestión de bosques y de CITES

Recomendaciones	Observaciones	Organismo responsable
PLAN DE APROVECHAMIENTO		
Definir claramente la organización operativa de las labores de extracción	Se recomienda partir de la propuesta realizada en este trabajo y validarlo durante 2 años	Ministerios responsables en Guinea Ecuatorial de la gestión de bosques y de CITES /APRA
Seleccionar y formar un técnico nacional para la supervisión técnica y operativa de los trabajos		Ministerios responsables en Guinea Ecuatorial de la gestión de bosques y de CITES
Reconsiderar el precio actual de la corteza con el fin de poder establecer un sistema de incentivos dependiendo de la calidad de las labores		APRA
Parar las labores de extracción en Moca hasta contar con un equipo adecuadamente formado	Se ha comprobado la existencia de problemas de los grupos de trabajo con los residentes en Moca, así como una incorrecta extracción en las zonas de Biaó	APRA
Supeditar la apertura de nuevas zonas a disponer de equipos bien formados y organizados		APRA
Establecer un sistema de control interno de la actividad	Mejorar los sistemas de control interno NATRA-APRA	APRA

Recomendaciones	Observaciones	Organismo responsable
PLANTACIONES		
Impulsar el estudio de la variación genética de la especie y optimizar las técnicas de propagación y cultivo Estudiar el comportamiento de las semillas en germinación y en su almacenamiento a largo plazo. Establecer un banco de germoplasma para *Prunus africana*	Buscar apoyo institucional externo	Ministerios responsables en Guinea Ecuatorial de la gestión de bosques y de CITES en colaboración con las Autoridades Científica y Administrativa españolas /APRA
Establecer un programa de forma inmediata de plantaciones y sistemas agroforestales		Ministerios responsables en Guinea Ecuatorial de la gestión de bosques y de CITES /APRA
ACTIVIDADES EN PARALELO		
Fomentar la coordinación institucional		Ministerios responsables en Guinea Ecuatorial de la gestión de bosques y de CITES en colaboración con las Autoridades Científica y Administrativa españolas /APRA
Iniciar un proceso de certificación forestal	Buscar apoyo institucional externo en organismos de cooperación	Ministerios responsables en Guinea Ecuatorial de la gestión de bosques y de CITES en colaboración con las Autoridades Científica y Administrativa españolas /APRA



3. Introduction

3. Introduction

International trade in *Prunus africana* (Hook. f.) Walkman (= *Pygeum africanum*) has been regulated by the Convention on International Trade in Endangered Species of Wild Fauna and Flora since February 16, 1995. This is a result of approval by the IX Conference of the Parties (CoP), in November 1994, of a proposal to list it on Appendix II (CITES, 1994).

Article II.2. of the Convention states that "*Appendix II shall include all species which although not necessarily now threatened with extinction may become so unless trade in specimens of such species is subject to strict regulation in order to avoid utilization incompatible with their survival.*" The purpose of including the species in CITES is to ensure its use in international trade is sustainable.

To achieve this goal, the Convention provides a system of export and import permits that must be issued by the pertinent CITES Authorities, through which it is possible to establish the amount traded internationally on a yearly basis. The level of exploitation of the species can be monitored with these data, which are analysed regularly by the CITES Plants Committee.

At its 12th meeting, in May 2002, the Committee decided to include *Prunus africana* in the Significant Trade Review process, applying the provisions of the Resolution approved by the Parties to this effect [Conf. 12.8 (Rev. CoP13)]. In this Resolution, the Conference of the Parties directs the Plants Committee, in cooperation with the Secretariat and experts, and in consultation with range States, to review the biological, trade and other relevant information on Appendix-II species subject to significant levels of trade, to identify problems and solutions concerning the implementation of Article IV, paragraphs 2 (a), 3 and 6 (a). Article IV of the Convention regulates trade in specimens of species included in Appendix II (Table 1).

Table 1 – Article IV of the Convention on International Trade in Endangered Species of Wild Fauna and Flora: Regulation of Trade in Specimens of Species Included in Appendix II

ARTICLE IV

Regulation of Trade in Specimens of Species Included in Appendix II

1. All trade in specimens of species included in Appendix II shall be in accordance with the provisions of this Article.
2. The export of any specimen of a species included in Appendix II shall require the prior grant and presentation of an export permit. An export permit shall only be granted when the following conditions have been met:
    a) a Scientific Authority of the State of export has advised that such export will not be detrimental to the survival of that species;
    b) a Management Authority of the State of export is satisfied that the specimen was not obtained in contravention of the laws of that State for the protection of fauna and flora; and
    c) a Management Authority of the State of export is satisfied that any living specimen will be so prepared and shipped as to minimise the risk of injury, damage to health or cruel treatment.
3. A Scientific Authority in each Party shall monitor both the export permits granted by that State for specimens of species included in Appendix I and the actual exports of such specimens. Whenever a Scientific Authority determines that the export of specimens of any such species should be limited in order to maintain that species throughout its range at a level consistent with its role in the ecosystems in which it occurs and well above the level at which that species might become eligible for inclusion in Appendix I, the Scientific Authority shall advise the appropriate Management Authority of suitable measures to be taken to limit the grant of export permits for specimens of that species.
4. The import of any specimen of a species included in Appendix II shall require the prior presentation of either an export permit or a re-export certificate.
5. The re-export of any specimen of a species included in Appendix II shall require the prior grant and presentation of a re-export certificate. A re-export certificate shall only be granted when the following conditions have been met:
    a) a Management Authority of the State of re-export is satisfied that the specimen was imported into that State in accordance with the provisions of the present Convention; and
    b) a Management Authority of the State of re-export is satisfied that any living specimen will be so prepared and shipped as to minimise the risk of injury, damage to health or cruel treatment.
6. The introduction from the sea of any specimen of a species included in Appendix II shall require the prior grant of a certificate from a Management Authority of the State of introduction. A certificate shall only be granted when the following conditions have been met:
    a) a Scientific Authority of the State of introduction advises that the introduction will not be detrimental to the survival of the species involved; and

b) a Management Authority of the State of introduction is satisfied that any living specimen will be so handled as to minimise the risk of injury, damage to health or cruel treatment.

7. Certificates referred to in paragraph 6 of this Article may be granted on the advice of a Scientific Authority, in consultation with other national scientific authorities or, when appropriate, international scientific authorities, in respect of periods not exceeding one year for total numbers of specimens to be introduced in such periods.

The CITES Secretariat commissioned an analysis of trade, which was submitted to range states for feedback on the data contained therein, setting November 2005 as the deadline for receiving such response. The Significant Trade Review process is still underway for *Prunus africana*, and the Plants Committee evaluated the status of the species throughout all its range countries in 2006.

The European Union has its own CITES Regulation, which is legally binding on the 25 Member States [Council Regulation (EC) No 338/97 of 9 December 1996 on the protection of species of wild fauna and flora by regulating trade therein (published on March 3, 1997, in Series L, No 61 of the OJEC)]. Under this Regulation, imports into the Union of *Prunus africana* – listed in Annex B – are covered by the provisions of Article 4. (Table 2)

Table 2 – Article 4 of Council Regulation (EC) No 338/97 of 9 December 1996 on the Protection of Species of Wild Fauna and Flora by Regulating Trade Therein

ARTICLE 4
The introduction into the Community of specimens of the species listed in Annex B shall be subject to completion of the necessary checks and the prior presentation, at the border customs office at the point of introduction, of an import permit issued by a management authority of the Member State of destination.
The import permit may be issued only in accordance with the restrictions established pursuant to paragraph 6 and when:
(a) the competent scientific authority, after examining available data and considering any opinion from the Scientific Review Group, is of the opinion that the introduction into the Community would not have a harmful effect on the conservation status of the species or on the extent of the territory occupied by the relevant population of the species, taking account of the current or anticipated level of trade. This opinion shall be valid for subsequent imports as long as the abovementioned aspects have not changed significantly…

Thus, the bark imported by the EU is assumed not to have a harmful effect on the conservation status of the species. This must be determined by the Scientific Authority of the importing member country upon examination of available data, and by the Scientific Review Group (SRG) made up of the scientific experts of the 25 member countries. Any such judgment requires checking population size and status, verifying that bark harvesting does not have a detrimental effect on the survival of specimens in the wild, seeing that the bark comes from areas under a sustainable management plan, and making sure the plan is being implemented and that it is feasible.

An increase in the number of applications for large imports of *Prunus africana* into the European Union was detected over 2003 and 2004. For this reason, the Scientific Authority of Spain began paying close attention to the available data, and this analysis led to the idea of carrying out a pilot project limited to a specific harvest area in Equatorial Guinea: the island of Bioko.

In July 2004, the SRG agreed to suspend trade with the Democratic Republic of Congo, on the understanding that unsuitable amounts of bark were being harvested, as the proposed quota affected some 800 trees, for an increase of 150% over the previous year. The Group also decided to request information from other range states – Equatorial Guinea, Tanzania, Cameroon, and Madagascar – on how they were managing the resource. Failure to provide these data could lead to suspension of trade with the EU. At this same meeting, the Scientific Authority of Spain informed of its intention to initiate the pilot project in Equatorial Guinea on harvest of *Prunus africana* bark on Bioko.

In December 2004, the SRG analysed the information received from Equatorial Guinea, Tanzania and the Democratic Republic of Congo, as well as an early report on Spain's pilot project in Equatorial Guinea. The Group agreed to allow imports from Equatorial Guinea and Tanzania, lift the trade ban on imports from the Democratic Republic of Congo, and to analyse any application from Cameroon, Madagascar, Kenya, or Uganda. Based on available information, the SRG later decided provisionally to allow imports from Cameroon and Madagascar, in March 2005. In June the Group agreed to request further data from Cameroon on how the quota they presented was calculated. Madagascar was advised to set a quota for 2006. In the case of Kenya, import permits would require analysis by the SRG, having received no information from that country.

In recent years, great effort has gone into proposals of management plans for sustainable use of *Prunus africana* in several range states. However, integral methodology must be established to evaluate the current situation, to know whether bark harvest is suitable or whether it is affecting the conservation status of the species, and propose corrective measures as needed to achieve sustainable use. The present study was devised in this context, to collaborate with Guinean authorities and with industry on management of the species. As a pilot project, covering a pre-selected area under 150,000 ha in Equatorial Guinea, it could give rise to a survey model and be applicable to other countries.

4. Background

4.1. *Prunus africana*

Numerous studies offer highly relevant information on the ecology of the species (Cunningham and Mbenkum, 1993; Acworth *et al.*, 1996; Dawson and Powell, 1999; Hall *et al.*(Eds), 2000; Page, 2003). Extensive work has been done on estimates of bark harvest and regeneration (Ndibi and Kay, 1997; Acworth *et al.*, 1998; Ewusi, 1998; Sunderland and Tako, 1999; CITES, 2001). Other authors have described the characteristics of the wood (Vales *et al.*, 1999) or propagation and planting techniques (Tchoundjeu *et al.*, 2002; Boffa, 2003; Negash, 2004; Sacande *et al.*, 2004).

4.1.1. Systematic Position and Description

Prunus africana belongs to the subfamily Prunoideae within the Rosaceae family. There are around 200 species in the genus *Prunus*, divided into two different subgenera: *Padus* (deciduous) and *Laurocerasus* (evergreen). The latter subgenus includes all the Asian and Eurasian tropical species, with *Prunus africana* as the only one found in Africa and Madagascar.

The tree reaches an average height of 25 m and diameters of 0.9-1 m, (branching at 20 m) although individuals up to 40 m high and over 1.5 m in diameter also occur. The trunk is straight and cylindrical, and often has four 8-10 cm-thick buttresses at the base, which may be concave or convex in shape, occasionally forming a V near the ground, separating as far out as 1 m from the tree, and rising up to 1 m in height. The bark is rough and blackish-brown. Leaves are alternate, simple, elliptic to oblong, sometimes slightly ovate, 3-6 cm wide and 5-15 cm long; 1-2 cm leaf stalks are reddish; the leaf blade is smooth, shiny dark green on the upper surface and paler on the lower surface, with finely dentate margins, acute apex and base. When the leaves are freshly broken, they give off a faint scent of bitter almonds. Flowers are small, white, fragrant, solitary or in 3-7 cm-long racemes, not far apart and located at the base of young branches; with small calyx and petals and 10 to 20 stamens. The fruit is a drupe, 10 mm in diameter, reddish-brown and very bitter.

4.1.2. Biology, Reproduction, Genetic Diversity

The flowering period occurs one or two months earlier or later, depending on the altitude, between October-November and from February to May. Pollination is by insects and perhaps by birds. The trees bear fruit 4 to 6 months after flowering from April to October in the tropics and somewhat later, from September to January, in southern regions.

Several authors have highlighted the interest in learning about pygeum propagation and optimising mechanisms to find an alternative to exploitation of the species by means of appropriate forestry management (Cunningham and Mbenkum, 1993; Cunningham *et al.*, 1997; Dawson and Powell, 1999; Cunningham *et al.*, 2002). Conservation and sustainable use of the afromontane forest should be improved, encouraging smallholders to grow forest species on their farms (Cunningham, 1993, 1997). Planting such copses would compensate deforestation and allow for a semi-domestic use of the species that is especially applicable to medium altitude sites (afromontane forests). Apparently, the model is adaptable to *Prunus africana*, and it began functioning in Cameroon (Cunningham *et al*, 1997). This practice should urgently be extended to other range countries, considering that the species takes over 15 years to bloom, bear fruit, and for the bark to attain an adequate thickness for harvesting (Simons, 1998).

Although *Prunus africana* seeds were initially thought to be recalcitrant (Sunderland and Nkefor, 1997), experience gathered more recently seems to indicate they would be semi-recalcitrant. Sacande *et al*

(2004) showed the need for further experience to guarantee that pygeum seeds could be kept – desiccated and at below zero temperatures – for long periods of time. These same authors offer good germination results after 10 days at a constant temperature of 25º following moist storage at 5ºC for 4 months. Various authors mention vegetative propagation taking cuttings from young plants, as reported in the monographic review by Hall *et al* (2000).

In the search for sustainable pygeum exploitation systems, Stewart (2003) stresses the importance of using *ex situ* techniques and adequate genetic diversity. She cites Cunningham *et al.* (2002) on the existence of three *P. africana* varieties detected by harvesters in Cameroon.

Evaluations of genetic diversity by means of molecular markers have begun recently. Dawson and Powell (1999), using RAPD, compared *Prunus africana* material from several populations in Cameroon, Kenya, Uganda, Ethiopia and Madagascar. Their results indicated outstanding variation among populations in Cameroon and in Madagascar, revealing a much higher level of heterogeneity than in other African tree species. The material from Uganda was genetically closer to that of Cameroon than to Kenyan or Ethiopian stock. The authors found the Mount Cameroon population to be clearly disjunct from other stands. In short, they not only insinuate that significant genetic diversity exists, but also that it follows geographical distribution patterns requiring further clarification.

Any management plan must first solve such aspects as: a) control of germination, b) medium- or long-term seed storage possibilities, c) the degree of genetic diversity of the material in cultivation and its natural range, and d) methods for sowing, planting, and growing the species.

4.1.3. Ecology and Geographic Distribution

Pygeum can boast of pan-African distribution, having been cited in 22 countries, mostly in the eastern part of the continent. Its altitude range falls between 600 and 3500 m, but elevations as low as 60 m have been reported. Inversely proportional to latitude, it occurs from 1000 to 3500 metres in regions near the equator, while in South Africa it can be found from 600-1000 m. It grows in forests where annual rainfall exceeds 900 mm , generally between 1100 and 1500 mm. (Hall *et al.*, 2000).

Prunus africana stands appear both in afromontane forests and in the transition between these and lowland forests, where they are less abundant (Hall *et al.*, 2000). It can even be the dominant species in some afromontane forest types, lending its name to plant communities, e.g., "Pygeum Moist Montane Forest" (White, 1983).

4.1.4. Use

Pygeum is a forest species of great importance in traditional African pharmacopoeia, as an effective treatment for stomach-ache, malaria, and fever. Exploitation began in the early 20th century in South Africa and Kenya, where it was a valuable timber species. In recent decades, the pharmacological features of this plant, used to treat prostate gland hypertrophy and benign prostatic hyperplasia, have received attention on a global scale. Since patenting of the bark extract for prostate remedy, (Cunningham and Mbenkum, 1993), it became commercially widespread. As men live longer and the world population increases, demand for the bark can only continue to grow in the upcoming years.

4.1.5. Harvest Control

In commercial operations, *Prunus africana* bark is removed from the tree, then dried and ground into the coarse granules that make up the final product, and chiefly exported in this form. Bark removal procedures are of key importance, but these have been uncontrolled, involving situations where the tree was felled to take the bark, or very aggressive debarking methods were used under no predefined criteria, causing irreparable damage and injuries to the trees. In the 1990s, Cameroon enacted legal guidelines for bark harvesting whereby only 50% of the available bark could be taken, leaving the other 50% on the tree for another 4-5 years (Tonye *et al.,* 2000). For trees with 30-50 cm DBH, opposite quarters were debarked, while in trees over 50 cm DBH, bark was removed in alternate one-eighth part sections (Figure 1).

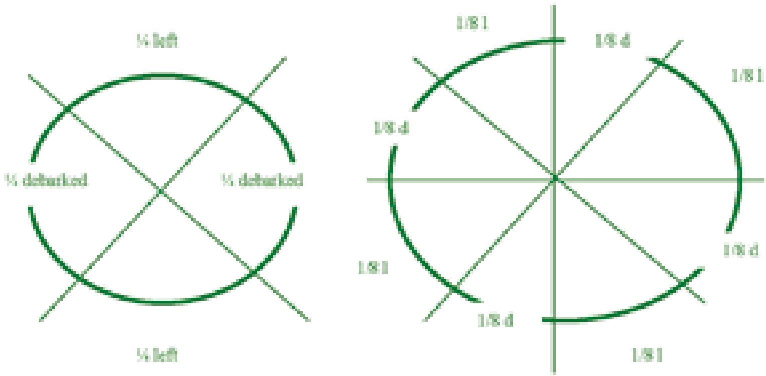


Figure 1 – Debarking alternate sections amounting to 50 percent of the tree's circumference (Nkuinkeu and Remi, 1998)

The procedure described in Ndam *et al* (2000) is summarised as follows:

- Bark should be removed using appropriate tools so as not to damage the cambium while separating bark panels from the tree. The cut should start about 1 m above the ground, and stop at the first main branch.
- Trees may not be debarked until they are ≥30 cm DBH.
- For trees ≤50 cm DBH, bark is to be removed by separating two panels on opposite sides of the trunk, taking care not to damage the cambium. The width of each panel must never exceed 25% of the perimeter.
- For trees ≥50 cm DBH, bark is to be removed by separating four panels, none of which may be broader than 12.5% of the tree's perimeter, taking care not to damage the cambium, and leaving the rest of the bark on the tree.

- All debarked trees must be marked.
- Trees must not be debarked again for a period of 4-5 years, when the bark will be taken from the sections not previously removed.
- Harvesting activities must be suspended during the rainy season.

In practice, these guidelines have scarcely been followed in any country. Studies contrasting the effects of their large-scale implementation do not exist.

4.2. Forest Ecosystem Mapping and Remote Sensing

In order to design a management plan there must be reliable field inventory data and accurate maps of the forest ecosystems in the range of the species under evaluation. Information on the evolution of the resource over time is also of interest.

At first, the cartography used in forestry management programmes was based on eyewitness, on-site reports contained in botanical surveys or studies of forest ecology (FAO, 1993; Figueiredo, 1994; Jones, 1994). Beginning in the 1990s, satellite data and imagery were used more often to study tropical forest ecosystems (McCracken *et al.*, 1999; Boyd and Duane, 2001; Cohen *et al.*, 2003; Foody *et al.*, 2003; Phua and Saito, 2003; Vieira *et al.*, 2003; Aplin, 2004, Thenkabail *et al.*, 2004). The basic advantage of satellite images is that they provide information on inaccessible sites. Nevertheless, forest inventories are still indispensable tools for defining the spectral characteristics of the images.

Sunderland and Tako (1999) signalled the need to quantify and define the spatial distribution of the resource in the case of Equatorial Guinea. It thus seemed appropriate to apply a combination of remote sensing and mapping techniques as the basis for evaluation of the status of *Prunus africana* on Bioko, and for planning future management of the species.

4.3. The Island of Bioko

4.3.1. Geographic Location

The Republic of Equatorial Guinea comprises three territories: Rio Muni (26,017 km^2), and the islands of Bioko (2,017 km^2) and Annobon (17 km^2). Bioko has a rectangular shape approximately 69 km long and 32 km wide (Figure 2), oriented from NE to SW, 32 km from the coasts of Cameroon, on the Cameroon line volcanic chain along with Mount Cameroon, Sao Tome, Principe, and Annobon. Three major volcanoes dominate Bioko: Pico de Basilé (3010 m) in the north, and Pico Biaó (2010 m) and Gran Caldera de Luba (2261 m) in the south.

4.3.2. Climate

Bioko's climate is typically oceanic and equatorial, with average temperatures of 25ºC in the lowlands and monsoon influence in its southern part. With rising elevations, the temperatures drop, reaching lows of 5ºC at the top of Pico Basilé. The island has two dry seasons: one from December to February – with under 100 mm average monthly rainfall – and a shorter one in July and August, when the monthly average is less than 500 mm (Juste and Fa, 1994). Average annual precipitation is over 11,000 mm in southern Bioko, and under 2000 mm in the northern part (Terán, 1962). Annual average relative humidity levels are around 90%, higher in the south and between altitudes of 1000 and 1500 m, as a consequence of dense cloud formations in montane areas (IUCN, 1991).

4.3.3. Geology and Soil

The small archipelago to which Bioko belongs sits on a fracture in the Earth's crust that stretches 2000 km out to sea, as far as the island of Saint Helena. This tectonic line continues well inland under Africa, separating two continental plates that have been unstable since late Precambrian times, when faults and upwellings gave rise to the granite basement rock of most of Cameroon's mountains (Bamenda, Rumpi, Mount Kupe, and Mount

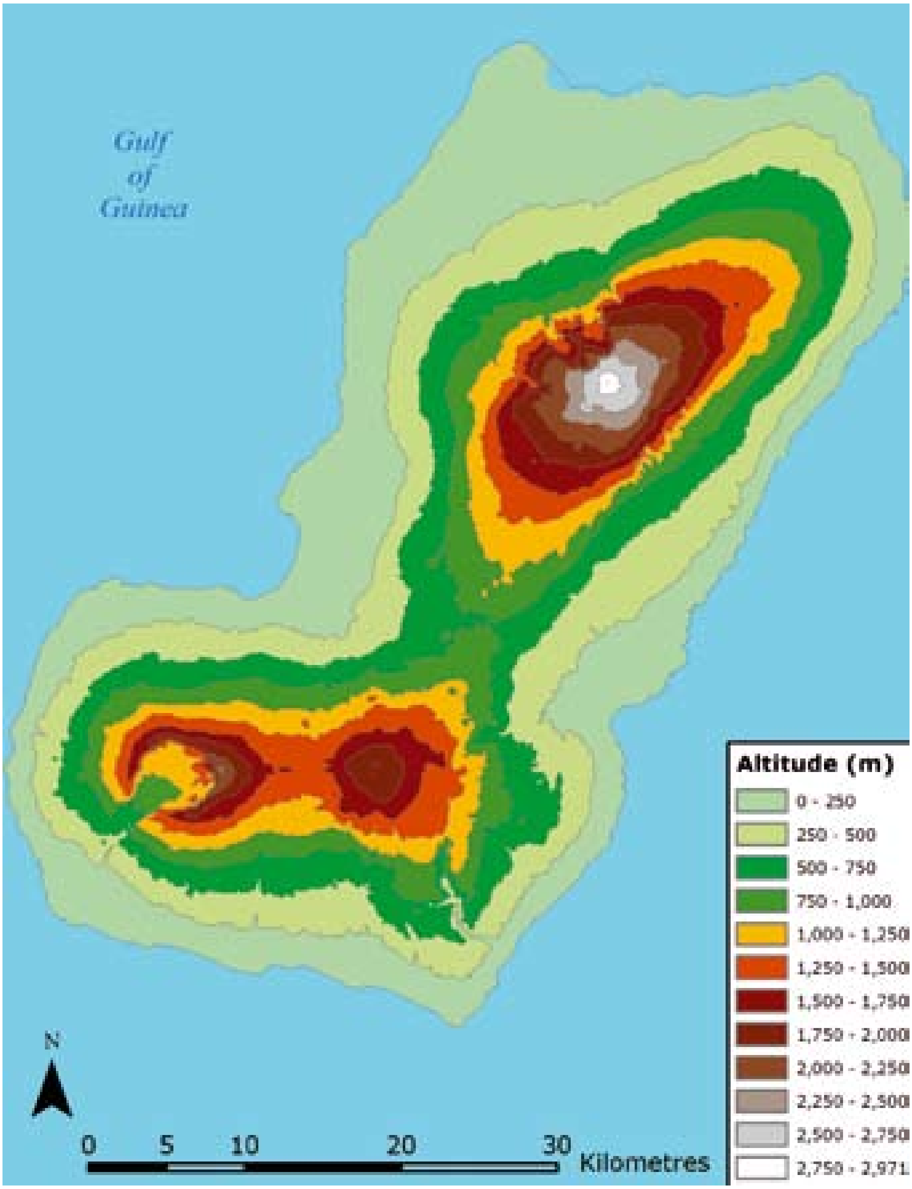


Figure 2 – Topographic map of Bioko (Equatorial Guinea)

Nlonako). Much later eruptive episodes modelled the original elevations, produced new ones on the continent (Mount Manenguba and Mount Cameroon), and also probably created the islands of Bioko, Principe, Sao

Tome and Annobon. No fossil sediments on Bioko indicate the date of the island's first eruptions. It was assumed to arise in the second half of the Tertiary period, probably towards the end of the Miocene epoch, some 10 million years ago, at the height of volcanic activity in the Gulf of Guinea. Bioko lower series basalts are analogous to, and presumably contemporary with those of Mount Cameroon. Therefore, the first eruptions would date back to the late Cretaceous period, some 100 million years ago, although most of the lava from both volcanoes belongs to the Quaternary period. Volcanic activity has continued intermittently throughout history, more intensely on Mount Cameroon where five eruptions were recorded in the past century alone, the latest of which was registered in 1982.

The existence of several carbon dioxide springs and a volcanic explosion near the village of Baho in 1897 are proof of some continuing activity even in modern times. Bioko was formed by a complex succession of lava and ash flows, mantle bedding, tuffs, and volcanic conglomerates, all predominantly basaltic in composition. The complexity arises out of major effusive eruption periods alternating with tremendously violent bursts of activity. An initial period characterised by fluid emissions deposited crystalline basalts, rich in olivine and augite. A second series of explosive, Strombolian, volcanic blasts produced thick blankets of ash and scoriaceous lapilli that would form the rims of the island's volcanoes (IUCN, 1991; Figueiredo, 1994; Larisoh *et al.*, 1999; Sunderland and Tako, 1999; Pérez del Val, 1999).

Bioko has three types of soils: lithosols, eutric nitosols, and ochric andosols (FAO, 2000). The lack of variety in soil types is due to the homogeneity of the base rock, made up of basaltic lava, but differences do exist in certain mechanical and chemical properties. There is greater contrast between lowland soils of alluvial origin and those resulting from erosion of the base rock at higher elevations (IUCN, 1991). Kubiena's 1965 classification shows Bioko soils to be relatively rich in iron hydroxide, reddish-brown in colour, poor in phosphorus, potassium and calcium, and rich in organic material. The pH never falls below 6, and the organic material content rises with altitude to proportions between 4 and 13%, although the average value does not surpass 2%.

4.3.4. Flora

Since the early 19th century, German, British and Spanish naturalists collected specimens on the island and deposited most of them with the Royal Botanic Gardens at Kew and Madrid. Boultbee began collecting before 1832, and Theodor Vogel, Charles Barter, and Gustav Mann continued later. Mann, in particular, found plants of great scientific interest that helped to describe several species.

In the 20th century, Günther Tessmann collected around 700 plant fact sheets from Bioko and Rio Muni. The German botanist Mildbraed published a complete catalogue of the island based on his own collections and on those of his most important predecessors. The first edition of Tropical West African Flora to include Bioko was published in 1927 by John McEwen Dalziel and John Hutchinson. *P. africana* appears in this text, citing Mildbraed's Central African expedition of 1910-1911 in the bibliography.

Expeditions of Spanish botanists began around the mid 20th century. Emilio Guinea collected over 3000 sheets, and the observations he made, his itineraries and collecting points during his fieldwork were later published (Guinea, 1949).

Manuel Fidalgo do Carvalho, with his 2498 specimens, created the main collection of plants from Bioko in the 1980s, over his five-year stay on the island (1986-91). In the last decade of the 20th century, Spanish botanists concentrated on documenting the complete flora of the island (Fernández Casas and Morales, 1995). Intense collaboration between the Royal Botanic Garden of Madrid and the Spanish Agency for International Cooperation during these years resulted in production of *Bases Documentales para la Flora de Guinea Ecuatorial* (Documentary Bases for the Flora of Equatorial Guinea), including the collections of all the botanists and naturalists who had previously worked on Bioko (Aedo *et. al.*, 1999).

The island of Bioko falls within the Guineo-Congolian floristic region, which covers a broad strip north and south of the equator and extends eastward from the Atlantic coast to the western foothills of the Kibu ridge (White, 1983). Because of its altitude, Bioko is a part of the Guineo-Congolian or afromontane regional centre of endemism.

Floristically, Bioko shows similarities with the mountains of Cameroon, where at least 129 of the same exclusive species appear. There is more diversity on Bioko compared to the other islands of the Gulf of Guinea, with over 1200 higher plant species, 185 fern and moss species (Pérez del Val, 1999), 605 genera and 124 families (Figueiredo, 1994). More than a hundred *Rubiaceae* species make this the best represented plant family, followed by the *Orchidaceae*, *Caesalpinaceae*, *Myristicaceae*, *Araliaceae*, and *Ericaceae* families. In spite of these data, it must be noted that Bioko has not received exhaustive floristic study, largely due to the difficulty of accessing much of the island.

Exell's surveys (1973 a, b) revealed that the flora on Bioko more closely resembled continental plant species than those of the other islands in the Gulf of Guinea. In spite of Bioko's greater floristic diversity, it had the lowest percentage of endemic plants: 42, as opposed to 95 on Sao Tome or 35 on Principe, with far less area. In floristic terms, Bioko loses its insular character and is treated as part of the continent (White, 1983; Figueiredo, 1994).

4.3.5. Synthesis of the Vegetation

A synthesised review (Table 3) of the island's potential vegetation was based on the work of Ocaña (1960) – who had himself compiled earlier vegetation studies (Nosti, 1947; Guinea, 1951; Adams, 1957) – and on data for the African continent as a whole (White, 1983). Descriptions in more recent studies were also taken into account

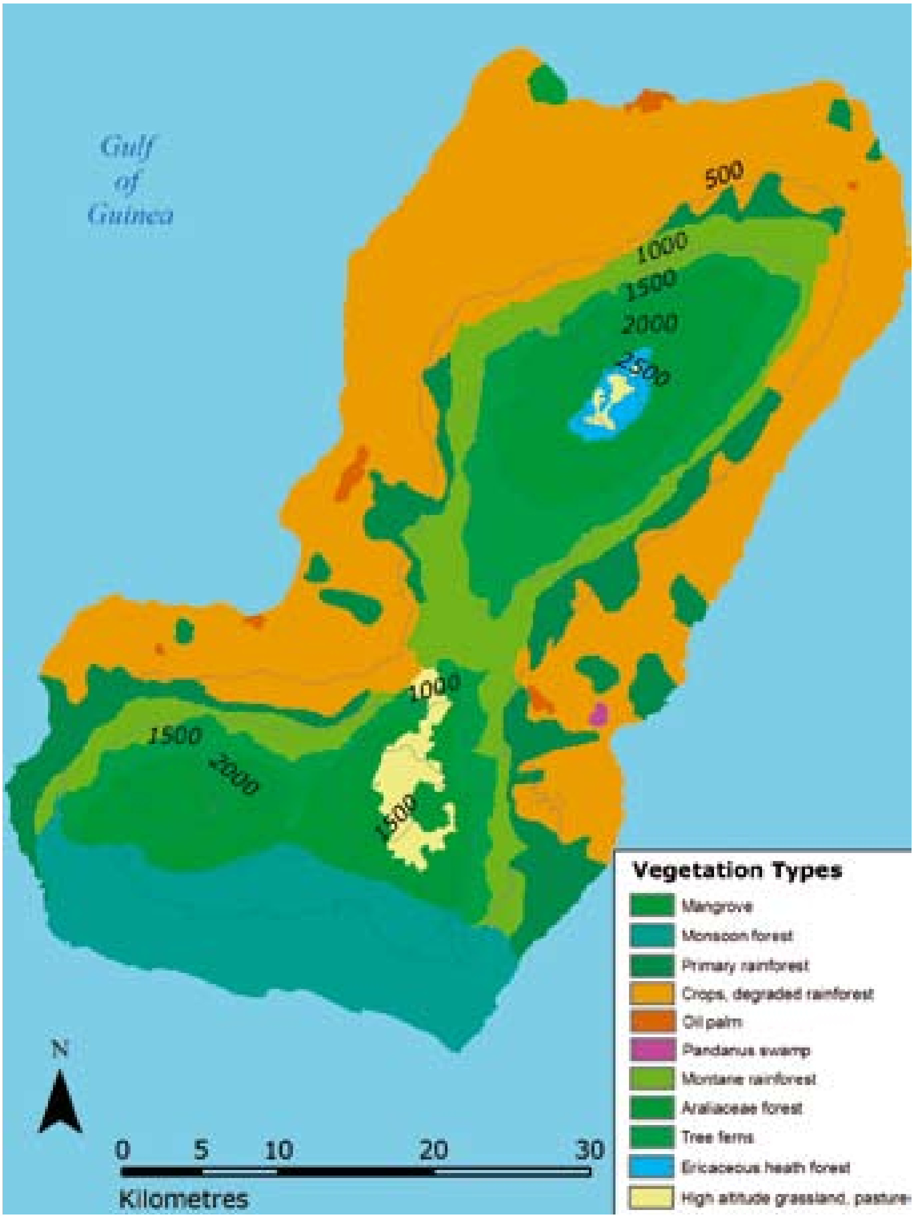


Figure 3 – Digitised map of the vegetation on Bioko (Ocaña, 1960)

(IUCN, 1991; Pérez del Val, 1999). Ocaña's vegetation map was digitised to facilitate calculation of the surface area occupied by each type of formation (Figure 3). Appendix I describes the different vegetation types, summarises all the references to previous authors, and provides a synthesis of the main species on each vegetation storey (Nosti, 1947; Ocaña, 1960; Terán, 1962; White, 1983).

Table 3 – Potential distribution of the main types of vegetation on Bioko by altitude ranges

Altitude range	Ocaña, 1960	White, 1983	Summary review of potential vegetation types
0-20 m	Coastal drapery of greenery; coconut palms; mangroves	Guineo-Congolian rainforest; mangroves	Coastal Guineo-Congolian rainforest; mangroves
20-(600) 800 m	Equatorial forest; crops; monsoon forest	Guineo-Congolian rainforest	Guineo-Congolian rainforest; crops; monsoon forest
(600) 800 (1000) / 1400-1500 m	Montane rainforest; monsoon forest	Afromontane forest	Lowland afromontane forest: monsoon forest
1400 / 1500-2500 m	Araliaceous forest		Highland afromontane forest (Araliaceae)
2500-2700 m	Ericaceous area	Afromontane shrub area	Afromontane heath forest (Ericaceae)
2700-3000 m	Highland herbaceous prairies	Afromontane herbaceous area	Afromontane herbaceous area

Ocaña (1960) describes Bioko vegetation between 1400 and 2500 m as a forest of *Araliaceae* dominated by the genus *Schefflera*. He makes no mention of *P. africana*, nor do other authors who refer directly to Bioko mountain forests (IUCN, 1991; Juste and Fa, 1994; Pérez del Val, 1999).

4.4. *Prunus africana* on Bioko

Pygeum occurs in relatively dispersed areas, more or less regularly distributed along an altitude band that runs between 1200 and 2500 m (Sunderland and Tako, 1999). In the 800 to 1800 m band, the insular forest is characterised by trees of medium height. Palm species disappear, and pure formations of tree ferns are frequent (*Alsophila camerooniana* and *A. manianna*) (Pérez del Val, 1999). Around 1400 m the floristic composition begins to change, from this height up to 2500 m, and a new vegetation storey appears on Pico de Basilé, with presence of *Polyscias fulva*, *Schefflera mannii* and *S. barteri,* in the family *Araliaceae* (Guinea, 1951). The main species providing shrub coverage is *Mimulopsis solmssii*, with *Pteridium* *aquilinum* and *Crassocephalum mannii* often occurring in clearings (Ocaña, 1960). Where fire devastated the vegetation, pyrophytes have proliferated (*Pteridium aquilinum* and *Rubus* sp) along with *Hypericum revolutum* bushes (Pérez del Val, 1999).

Bioko's two most important protected areas coincide with the range of *Prunus africana*: Pico de Basilé and Caldera de Luba-Lake Biaó (Figure 4), the latter ranking as a Scientific Reserve. Settlements are not allowed in these areas, and exploitation of forest resources is banned except for certain products of high value, when appropriate management plans are in place.

Harvest of pygeum bark is an important activity on Bioko, since it represents a source of employment in a rather depressed economy. Use of *Prunus africana* is governed by Equatorial Guinea's Forestry Law of 1995 (Regulation Implementing the Law on Forest Use and Management EQG/96/002), under an appendix of 1997 that regulates sustainable use of non-timber forest products and harvest of *Prunus africana* in particular (Article 62). In spite of legislative efforts, only limited regulation of bark exploitation is possible without adequate knowledge of the status of the forests, and in the absence of monitoring systems to control harvest procedures. In 1999, the Forestry Department of Equatorial Guinea set an annual export quota for *Prunus* bark of 500 tonnes per year, upon consultation with the CITES Authorities in Malabo (Sunderland and Tako, 1999).

Figure 4 – Location of Pico de Basilé and Caldera de Luba, Equatorial Guinea (WGS 84; Zone 32 N)

5. Objetives of the Project

5. Objectives of the Project

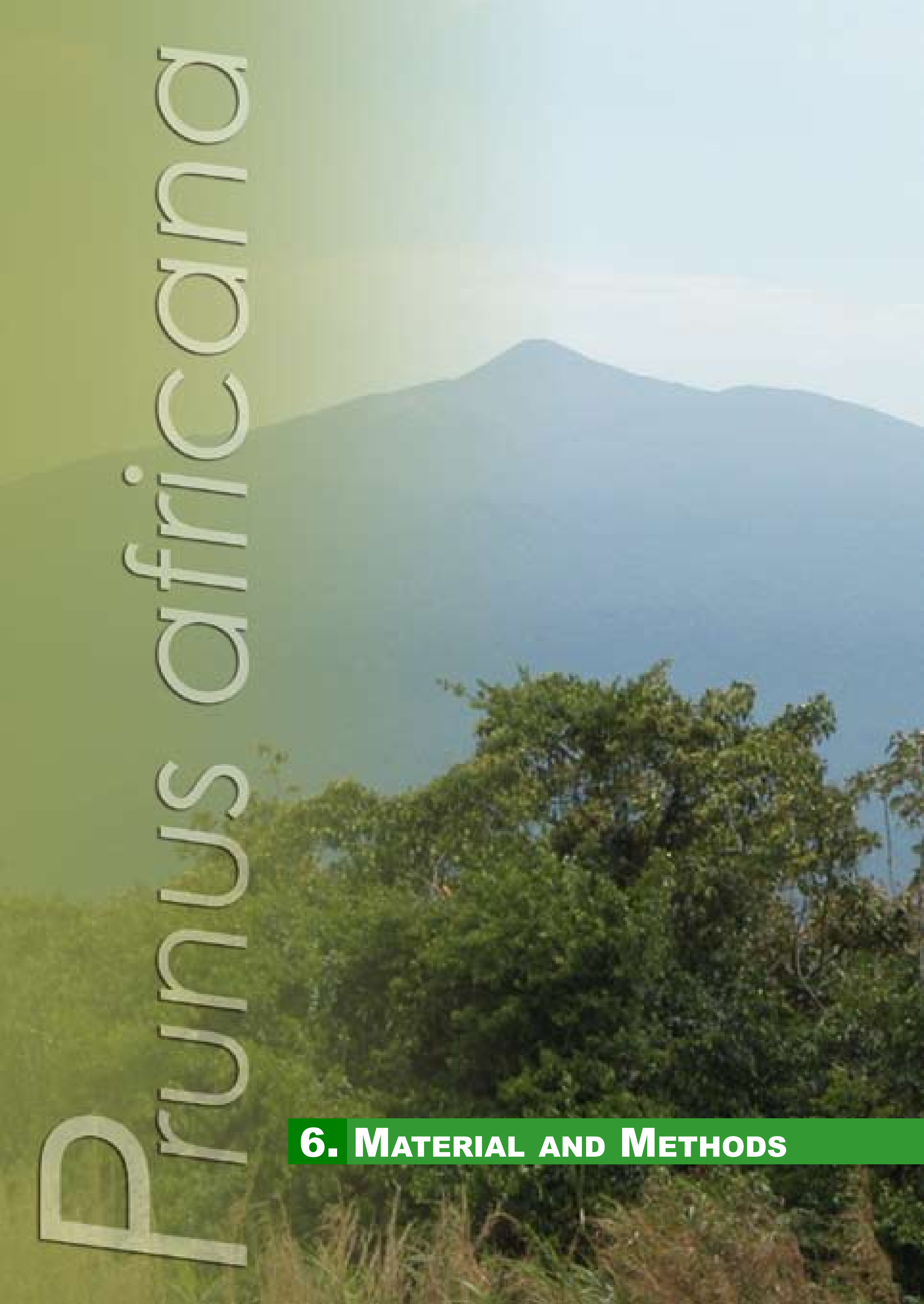
5.1. General Objective

The general objective of this project was to study the current range of *Prunus africana* on Bioko in order to determine present bark harvest, evaluate stocks, and propose the pertinent recommendations for consideration in designing a management plan to enable sustainable use of the species.

5.2. Specific Objectives

The following specific objectives were established to achieve the general objective:

- Survey of the distribution of the dominant vegetation types by means of a Landsat 7 ETM+ image
- Characterisation of forests where *Prunus africana* occurs in harvest areas and in areas where it could potentially be harvested (afromontane forest), in terms of their structure, floristic composition, wealth and diversity of tree species
- Estimate of bark yield from forests where *Prunus africana* occurs in harvest areas as well as non-harvest areas, depending on the characteristics of each site, stand structure, and theoretical quotas assigned
- Establishment of silvicultural criteria for sustainable use of *Prunus africana* forests



6. Material and Methods

6. Material and Methods

6.1. Study Area

The island in its entirety comprised the study area for purposes of determining the distribution of vegetation types by satellite imagery. The field study was conducted in the area where bark is actually being harvested, i.e., Pico de Basilé and Moca. The precise zone was defined using a digital terrain model with 90 m spatial resolution over the altitude range of *Prunus africana*, between 1200 m and 2500 m (Global Land Cover Facility Earth Science Data Interface website: http://glcfapp.umiacs.umd.edu:8080/esdi/index.jsp).

The theoretical area of potential *Prunus africana* distribution — in the interval from 1200 m to 2500 m — initially proposed by Sunderland and Tako (1999) was confined to an expanse of 31,969.3 ha (Figure 5). Of this terrain, 16,000 ha were located on Pico de Basilé, and the rest around Moca and the eastern region of Caldera de Luba.

6.2. Classification of Bioko Forest Ecosystem through Analysis of Landsat 7 ETM+ Imagery

6.2.1. Sensor and Pre-processing of the Image

A Landsat 7 ETM+ satellite image (30 x 30 metre resolution) of the study area taken in March 2003 (Figure 6) was used. The image did not need geometric correction, as it was already georeferenced.

Radiometric corrections were made to the three images by means of standard methods for converting digital data into spectral radiance values with Markham and Barker's formula (1986). Calibration for conversion to reflectance subsequently involved performing a series of equations factoring in variables such as the Earth-Sun distance, solar irradiance, and the sun elevation angle for the day and time when the image was taken.

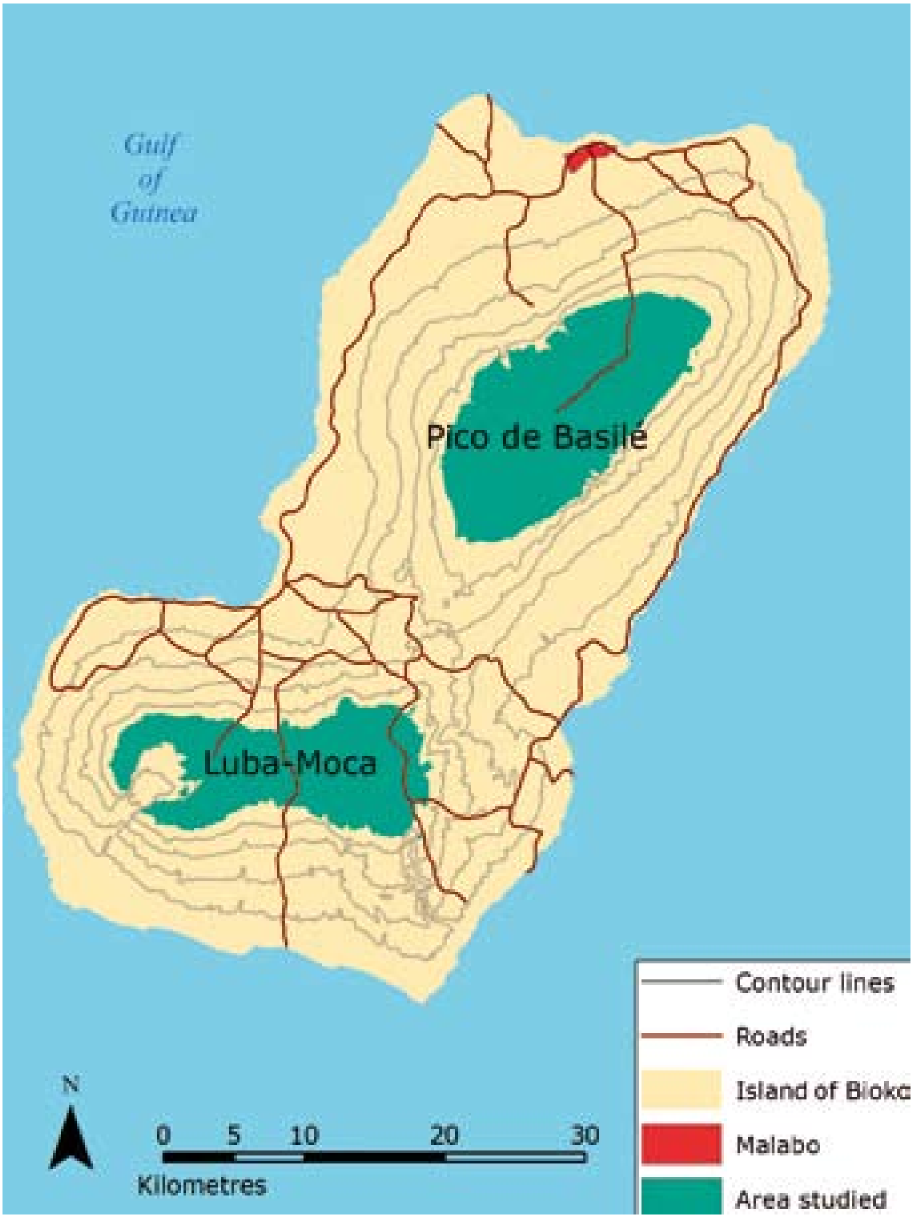


Figure 5 – Map of estimated *Prunus africana* distribution on Bioko (WGS 84; Zone 32 N)

The geometric and radiometric corrections were made using the header file coefficients for each of the bands from 1-5 and 7 of the Landsat images. Six of the eight bands were used to study the Bioko forests where *Prunus africana* occurs, disregarding the thermal and the panchromatic bands.

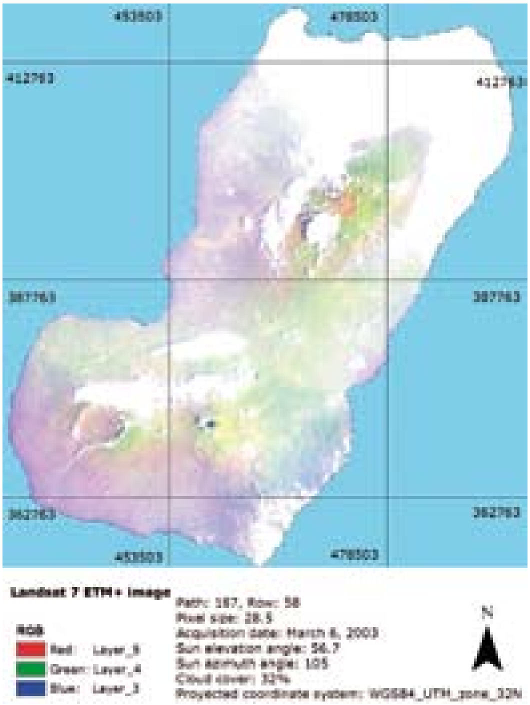


Figure 6 – Unclassified Landsat 7 ETM+ image of Bioko (WGS 84; Zone 32 N)

6.2.2. Unsupervised and Supervised Classification

First, an unsupervised classification was performed using the ISODATA module of the ERDAS 8.6 software, creating a cluster classification with 14 classes. Secondly, a supervised classification was made using the maximum likelihood classifier, including 14 vegetation classes. The validation was conducted using confusion matrices and Kappa indices.

6.3. Design of Sampling, Data Collection in the Field, and Data Analysis

In designing the forest inventory for the study area, other tropical African forest inventories were taken for reference (Acworth *et al.*, 1996; ONADEF, 1997). Such inventories for evaluating non-timber forest resources (NTFR) are instruments of considerable interest in a wide range of fields and disciplines. Review of the biometric quality of this type of survey, however, showed that statistical precision was often lacking (Wong, 2000). To avoid this problem, the present study follows the main recommendations proposed for NTFR inventories in similar works (Baker, 2001).

The design selected was a systematic inventory with a random starting point and data collection every 100 metres along existing harvest lanes. At the outset, the entire area of the forest was stratified into two altitude zones (Guinea, 1949). After the first few hands-on visits, the sampling sites were located where bark had been harvested. One was on the road to Pico de Basilé, between kms 14 and 20 (Figure 7). Another was near the village of Moca in an area connected to the road that had been harvested in the year 1998. The third site was found along a strip around Lake Biaó (Figure 8) where bark was being harvested in April 2005.

These three sites were felt to be representative of the study area, and the harvest lanes in use originated at these points. The plot distribution here had to adapt to existing lanes because opening new lanes was judged impossible. Estimates indicated that it would take an hour to clear 100 metres of pathway.

The inventory procedure was systematic in each transect (see Figure 9). Following the recommendations gathered by Hall (2000), a tree-by-tree inventory of *Prunus africana* covered each transect to account for a possible copse distribution. Forest mensuration data were collected for all the individuals along a 20 m strip on either side of the harvest lane (Figure 9).

Information on the proper sample size for tropical forest surveys – particularly NTFP evaluations – to reflect dynamic processes, is scarce. In mountain forests, with a simpler structure and just a few main species, as is the situation on Bioko, a minimum size of 1000 m^2 and a minimum total surface area of 5000 to 10,000 m^2 is considered a sufficient working sample (Cain and Oliveira, 1959; Bonham, 1989).

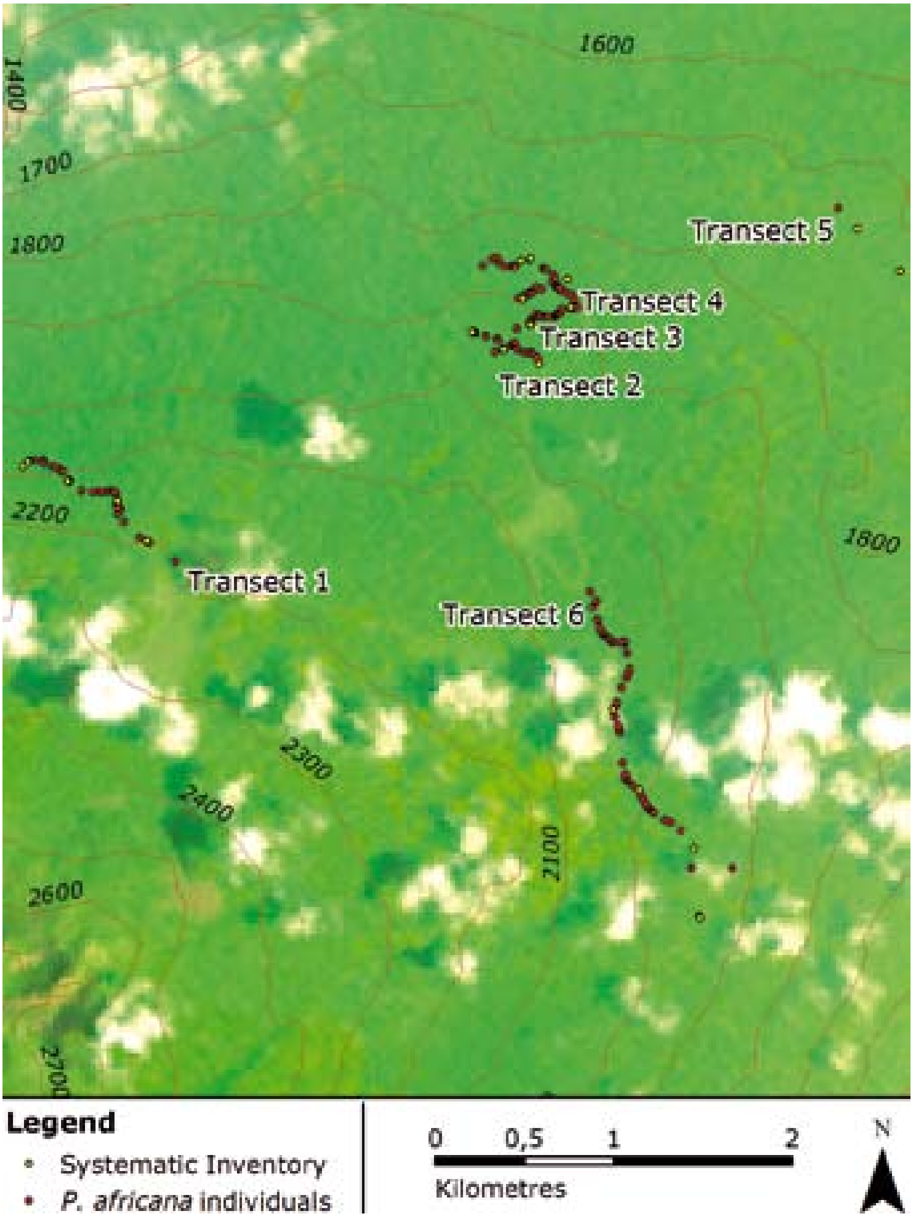


Figure 7 – Location of transects on Pico de Basilé: ***P. africana*** trees are marked with red dots and the systematic inventories are marked with yellow dots. (WGS 84; Zone 32 N)

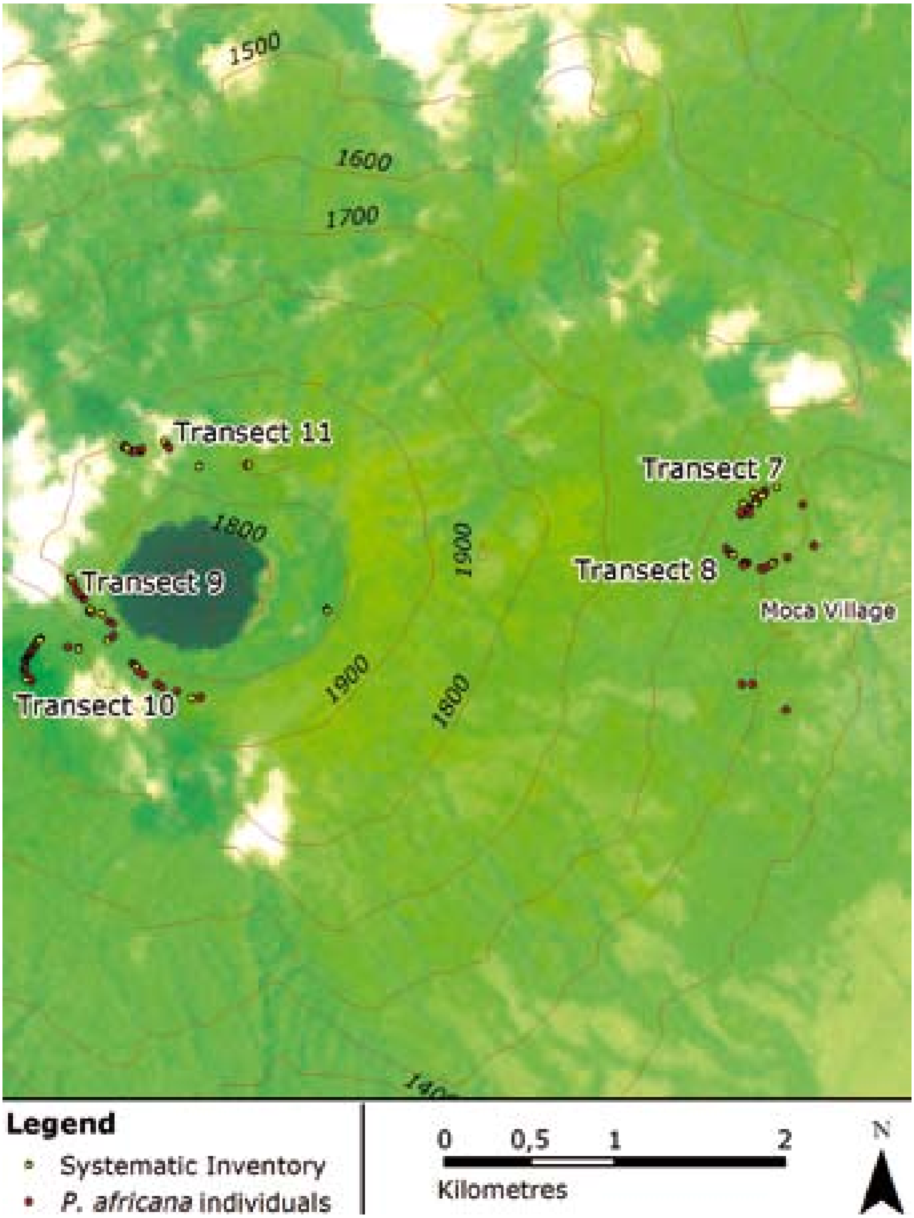


Figure 8 – Location of Moca and Lake Biaó transects: *P. africana* trees are marked with red dots and systematic inventories are marked with yellow dots. (WGS 84; Zone 32 N)

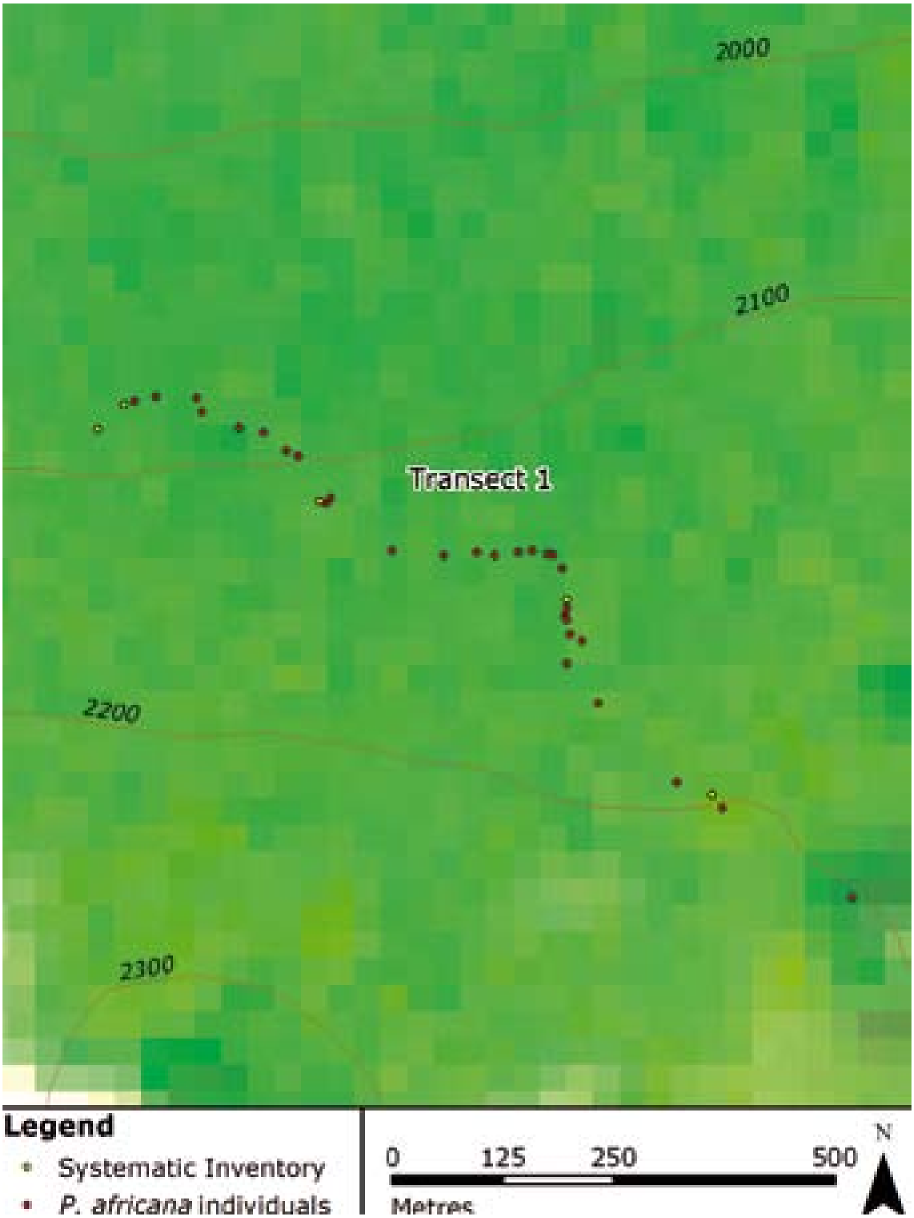


Figure 9 – Detail of distribution in Transect No 1 of the Pico de Basilé forest inventory (WGS 84; Zone 32 N)

A circular-shaped plot with a 20-metre radius and a surface area of 1,256.636 m^2 was defined for sampling. The next step was to locate plots of these dimensions all along the inroad, identifying the centre of the plot by GPS. 41 sample plots were laid out, 20 in the Pico de Basilé area (Figure 10), and 21 in the Moca area (Figure 11).

The procedure was as follows:

1) For the selection of transects:

- Selection of *Prunus africana* harvest lanes (6 on Pico Basilé and 5 on Moca) that were already open. These lanes varied in length from 500 to 2000 m.
- Systematic establishment of a plot every 100 m, first determining the centre and then marking off a circle with a 20 m radius around it [Magellan Meridian Color GPS navigator, average error (EPE) = 15 metres]
- Measurement of the slope of the terrain with a clinometer
- Inventory of all trees with diameter at breast height (DBH) over 10 cm
- GPS Georeferencing of all exploitable *Prunus africana* individuals (> 30 cm)

2) Parameters sampled (see field log in Appendix II):

- Forest mensuration and silvicultural data:
  - i. Abundance – existing tree species according to number of individuals
  - ii. Dimensions of each tree – estimated height (m), DBH (cm)
  - iii. Crown class of each tree and vertical stand structure
  - iv. Condition of *Prunus africana* trees in defoliation classes proposed by Sunderland and Tako (1999)

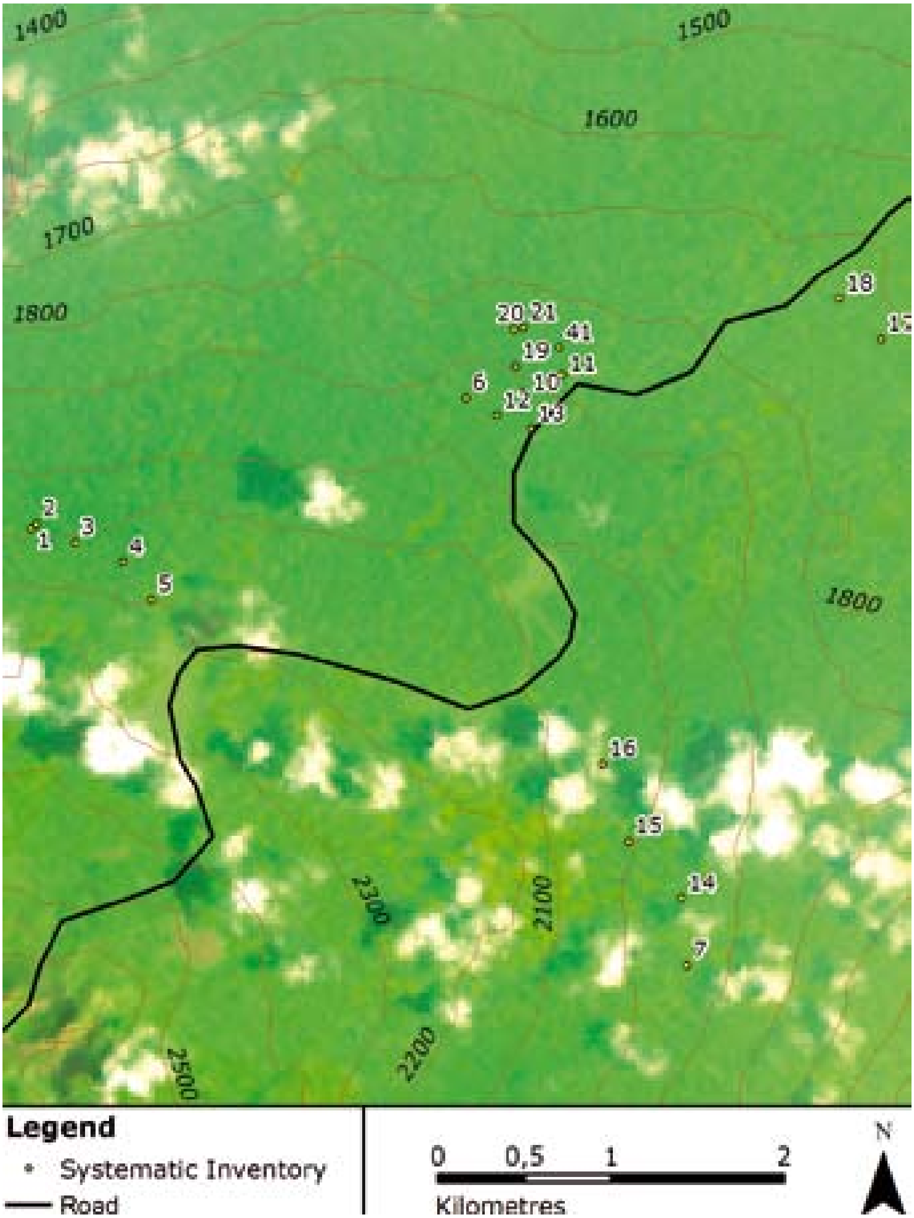


Figure 10 – Distribution of plots on Pico de Basilé (derived from GPS points) (WGS 84; Zone 32 N)

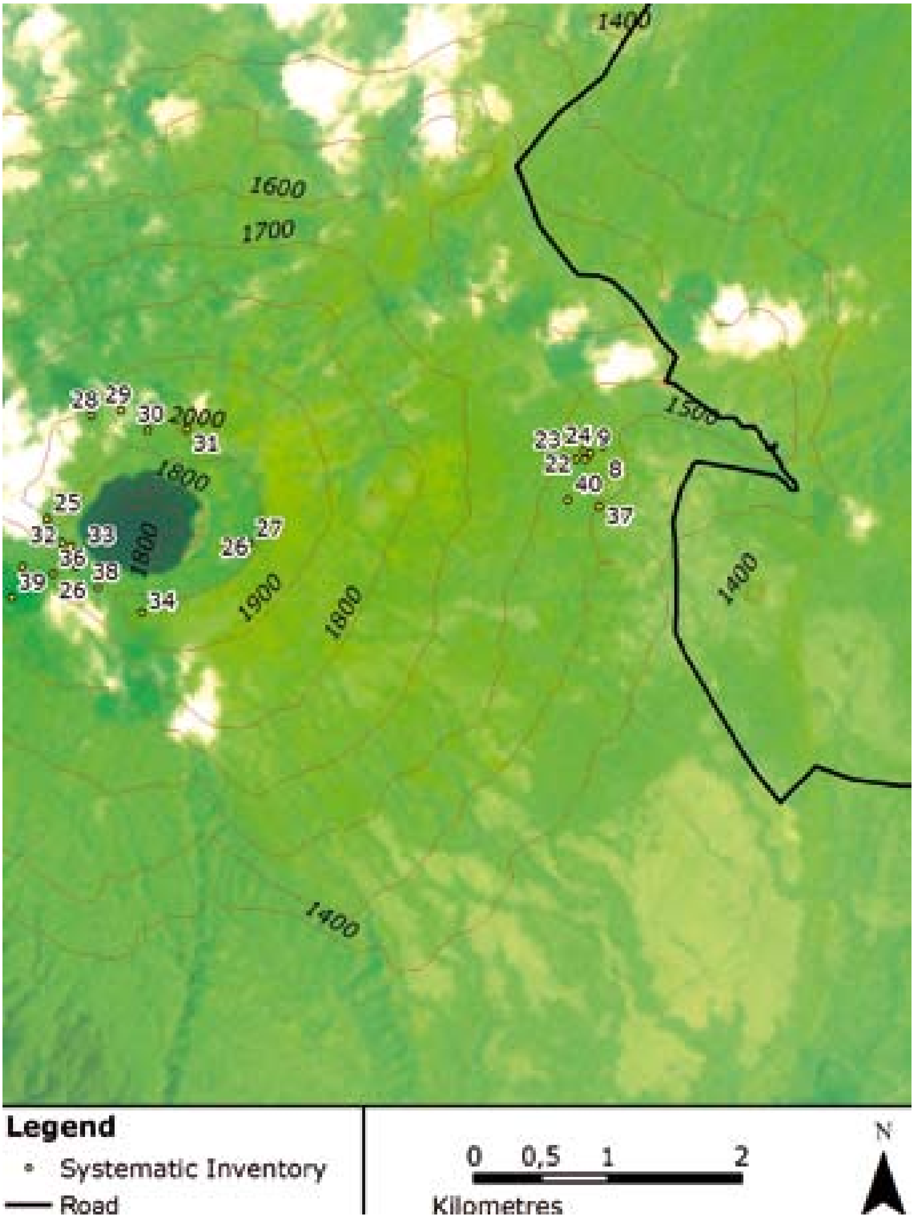


Figure 11 – Distribution of Moca plots (derived from GPS points) (WGS 84; Zone 32 N)

v. Year(s) bark is harvested – direct communication with harvesting team foremen (Isaías Enoko, Pico Basilé and Gabino Siloche, Moca)

vi. Bark thickness (cm) – measured with a Suunto bark gauge

vii. Extent of intervention in the forest – none, little, some, or much

3) Bark samples taken from 1 tree every 3 plots to measure thickness and specific weight

Table 4 outlines the position coordinates (longitude, latitude, and altitude) of the 41 plots sampled on Pico Basilé and Moca, from 1400-2200 m.a.s.l., in the fieldwork carried out over the last quarter of 2004 and the first quarter of 2005.

The vegetation structure on the plots was analysed by calculating values for relative and average basal area, and species density and frequency. In an attempt to find common structural patterns for the areas studied, species population structure was analysed on the sole basis of grouping individuals of the most significant species into diameter classes.

To determine specific weight, random 10 x 20 cm samples (N = 10) were gathered at a height of 0.80-1.30 m. Thickness of the living bark and surface area of the bark sample were the parameters analysed. Bark thickness was measured with a calliper (error: 0.1 mm), and the total surface area of the sample was determined in order to find the specific weight of the bark (g cm^{-3}).

For estimates of fresh bark yield and regeneration, field data on bark thickness (N = 264), DBH, and height up to where the bark had been removed were taken with a Suunto bark gauge, measuring regenerating bark on trees that had already been harvested (N = 192), and the bark on trees that were still intact (N = 72). In both cases, the measurements were made at a height of 1.20 m. Bark yield per tree and the evolution of bark

Table 4 – Position coordinates of the systematic sampling points

Plot No	Longitude (ºdec)	Latitude (ºdec)	Altitude (m)	Year	Location
1	3.619050	8.772092	2071	2004	Pico de Basilé
2	3.619300	8.772358	2086	2004	Pico de Basilé
3	3.618317	8.774350	2098	2004	Pico de Basilé
4	3.617317	8.776867	2158	2004	Pico de Basilé
5	3.615333	8.778342	2184	2004	Pico de Basilé
6	3.625833	8.794700	1957	2004	Pico de Basilé
7	3.596333	8.806183	1916	2004	Pico de Basilé
8	3.362733	8.656617	1507	2004	Moca
9	3.362283	8.655817	1556	2004	Moca
10	3.626183	8.797667	1906	2004	Pico de Basilé
11	3.627067	8.799700	1857	2004	Pico de Basilé
12	3.624950	8.796292	1937	2004	Pico de Basilé
13	3.624242	8.798092	1919	2004	Pico de Basilé
14	3.599817	8.805917	1958	2004	Pico de Basilé
15	3.602767	8.803167	1987	2004	Pico de Basilé
16	3.606792	8.801817	2025	2004	Pico de Basilé
17	3.628908	8.816300	1704	2004	Pico de Basilé
18	3.631025	8.814150	1713	2004	Pico de Basilé
19	3.627508	8.797275	1881	2004	Pico de Basilé
20	3.629417	8.797200	1857	2005	Pico de Basilé
21	3.629517	8.797683	1835	2005	Pico de Basilé
22	3.361883	8.655500	1532	2005	Moca
23	3.361867	8.654817	1584	2005	Moca
24	3.362417	8.655367	1533	2005	Moca
25	3.357883	8.619283	1933	2005	Moca
26	3.354617	8.621233	1829	2005	Moca
27	3.356200	8.632833	1944	2005	Moca
28	3.364800	8.622250	1920	2005	Moca
29	3.365183	8.624200	1939	2005	Moca
30	3.363850	8.626050	1982	2005	Moca
31	3.363900	8.628683	1997	2005	Moca
32	3.356267	8.620300	1836	2005	Moca
33	3.356050	8.620900	1833	2005	Moca
34	3.351567	8.625667	1953	2005	Moca
35	3.354650	8.617633	1723	2005	Moca
36	3.354167	8.619683	1792	2005	Moca
37	3.358683	8.656400	1429	2005	Moca
38	3.353250	8.622733	1876	2005	Moca
39	3.352567	8.616917	1758	2005	Moca
40	3.359133	8.654300	1507	2005	Moca
41	3.628467	8.799533	1838	2005	Pico de Basilé

thickness over time were surveyed by means of simple/multiple regression analysis between the bark thickness/age variables, or between fresh bark weight/debarking height and DBH.

Data analysis involved calculating and interpreting linear, potential, exponential, logarithmic, square, and cubic models. Statistical analysis was performed with the *SPSS 8.0* programme. In the process of selecting the best prediction model for bark regeneration, specifications for valid explanatory models resulted from analyses of the inventoried population sample. These analyses consisted of:

- Measuring goodness of fit, using the coefficients R for correlation, R^2 for determination, and SE to express standard estimating error
- Testing goodness of fit: analysing variance to contrast the statistical significance of R^2 by calculating the F ratio and the p value

Damage caused to *Prunus africana* trees through bark harvest was evaluated on a scale from 0 to 5, depending on the extent of defoliation the trees presented (Sunderland and Tako, 1999). A value of 0 was assigned in the absence of damage, and 5 meant the tree was dead (100% defoliation).

7. Results and Discussion

7.1. Unsupervised Classification

Figure 12 shows how the unsupervised classification distributed different vegetation types throughout the study area. Fourteen categories were classified.

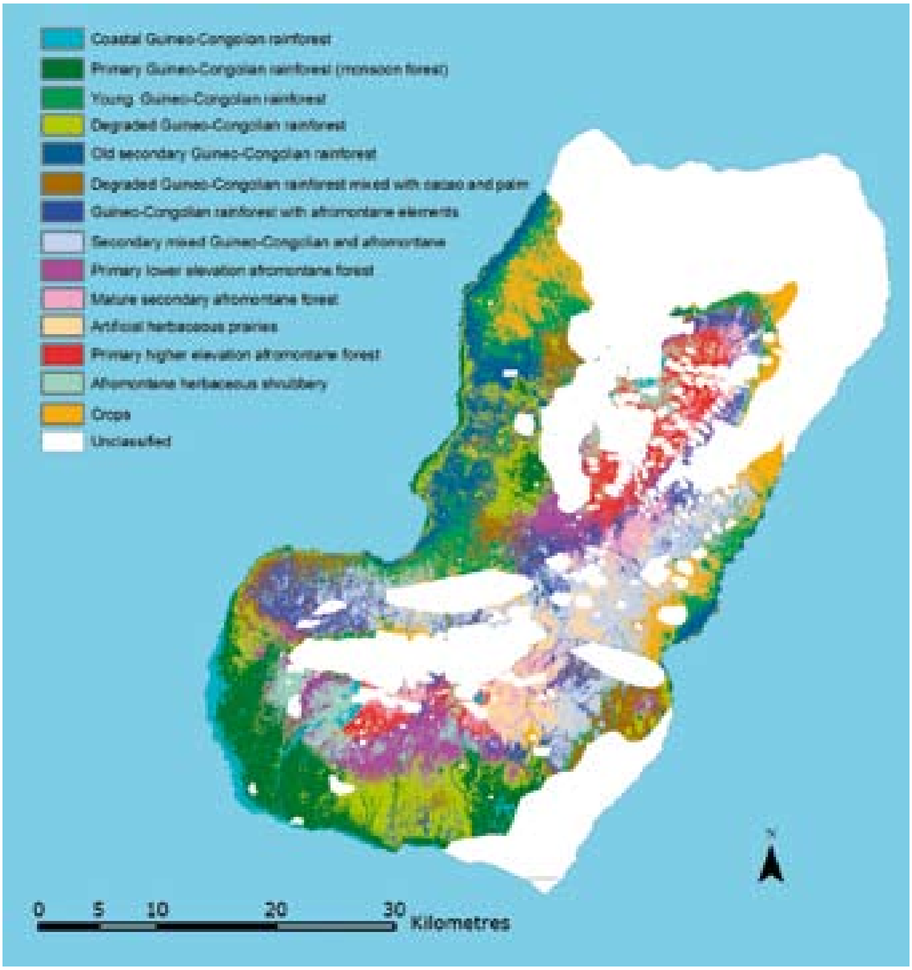


Figure 12 – Unsupervised classification on Bioko (WGS 84; Zone 32 N)

7.2. Supervised Classification

Figure 13 represents the Bioko vegetation map based on supervised classification. A overall accuracy of 72.01% was achieved with a Kappa coefficient of 0.69.

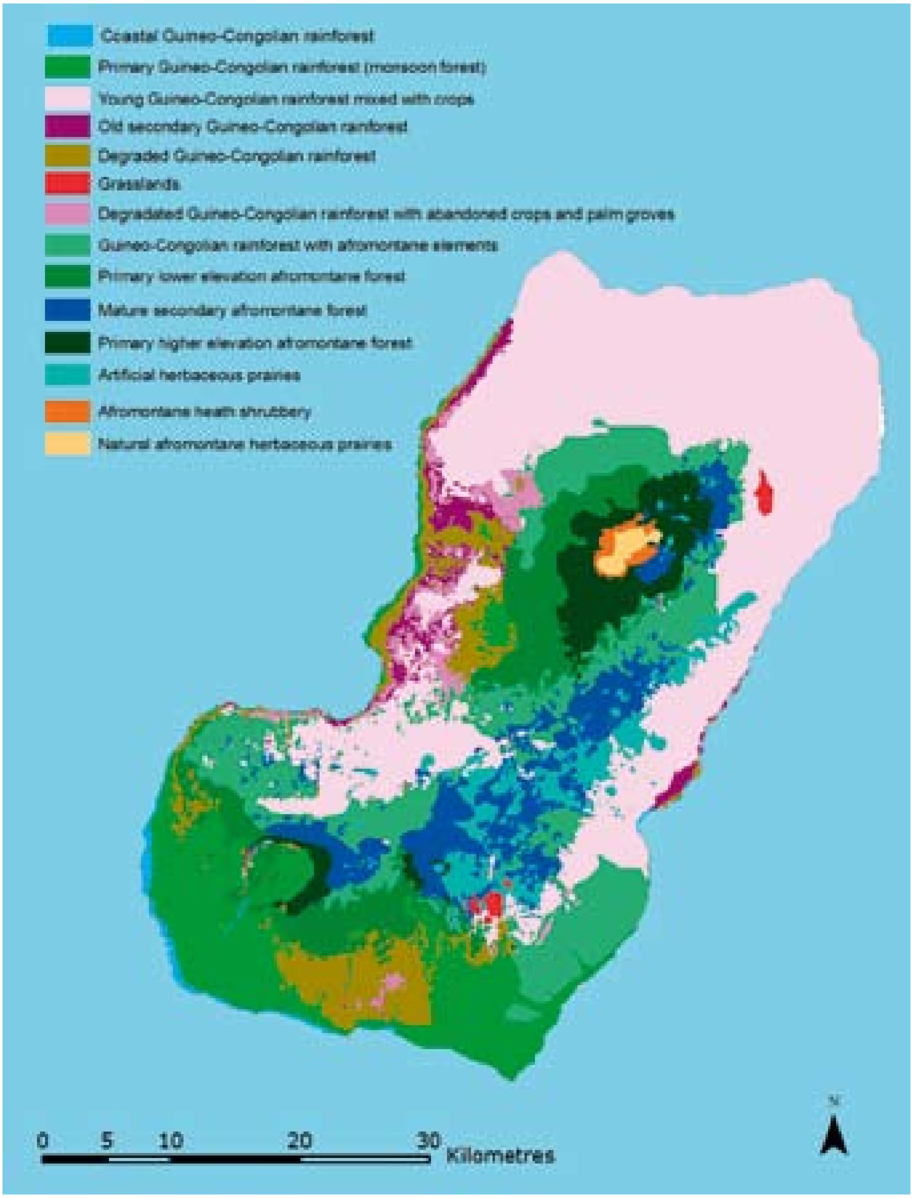


Figure 13 – Bioko vegetation map based on supervised classification (WGS 84; Zone 32 N)

7.3. Structure of *Prunus africana* Stands on Bioko

The forest types in which *Prunus africana* occurs are: lowland afromontane forest, highland afromontane forest (Araliaceae), transition areas between these and the Guineo-Congolian rainforest, and areas where the afromontane forest has undergone some kind of degradation (secondary afromontane forest). Figures 14 a and 14 b show how vegetation

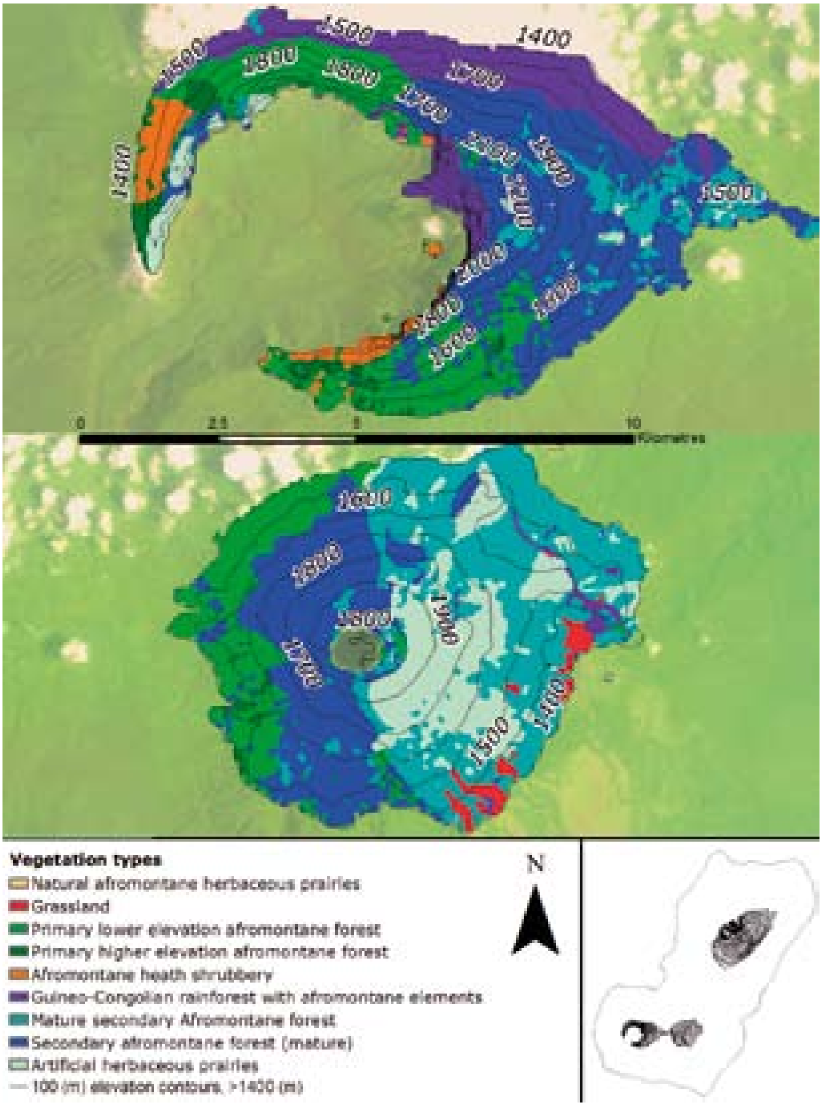


Figure 14 a – Distribution of vegetation types in Moca at altitudes above 1400 m according to supervised classification (WGS 84; Zone 32 N)

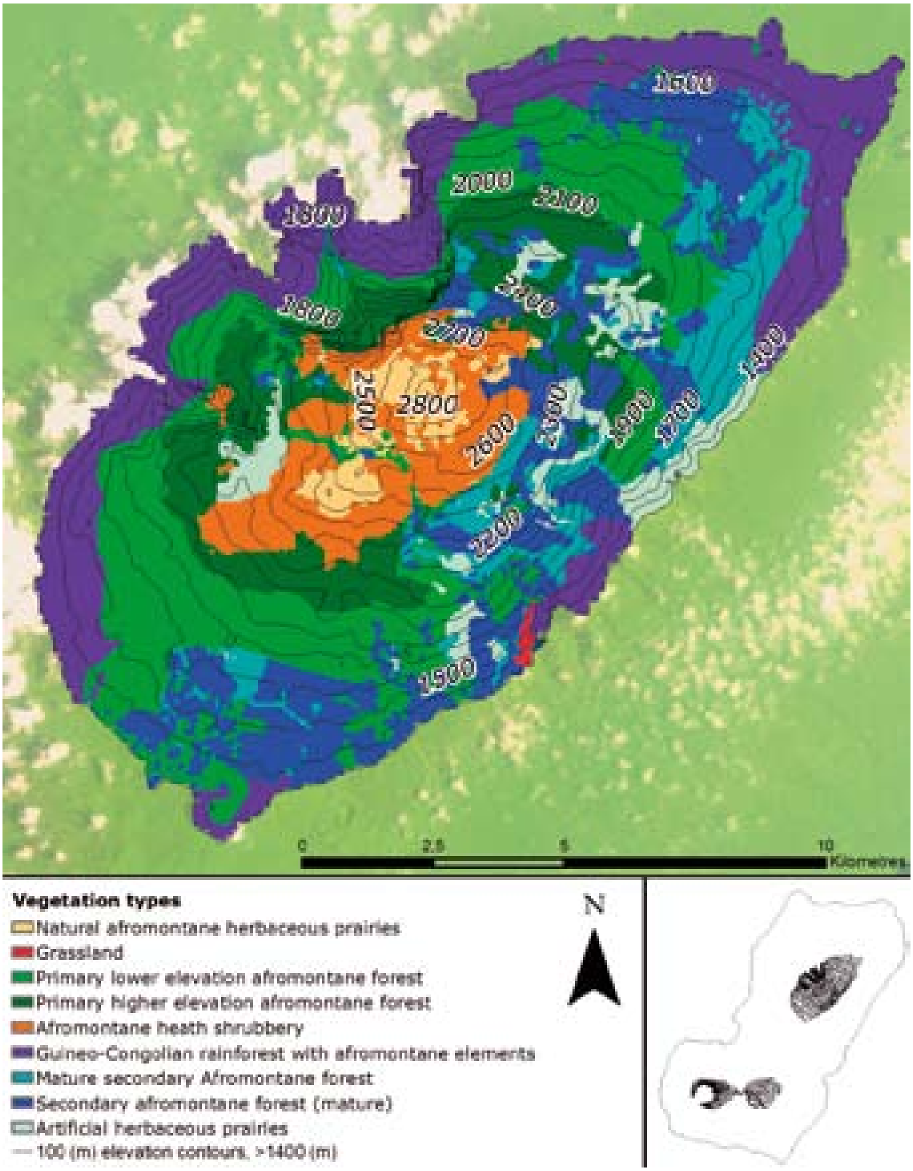


Figure 14 b – Distribution of vegetation types in Pico Basilé at altitudes above 1400 m according to supervised classification (WGS 84; Zone 32 N)

types above 1400 metres were distributed according to the supervised classification for Bioko (a overall accuracy of 79.65% was achieved with a Kappa coefficient of 0.81). This is the range of *Prunus africana*, around Pico de Basilé, Moca, and Caldera de Luba.

The range of *Prunus africana* was established from 1400 to 2500 m, occurring chiefly in connection with the araliaceous forest. While some authors (Sunderland and Tako, 1999) cite distribution of the species between 1200 and 2500 m on Bioko, the results of the present study partially coincide with Ocaña's findings (1960), associating the araliaceous forests with altitudes from 1400 to 2500 m, although Ocaña did not specifically mention *Prunus africana* in this forest. A closer study of Bioko's afromontane forests, in the context of the present pilot project, provides a more detailed description of the afromontane forest (>1400 m) (Kasimis, 2005).

Tables 5 and 6 compare hectare values for the estimated surface areas of each vegetation type according to the digitised version of Ocaña's map (see Figure 3), and the supervised classification with the 2003 Landsat 7 ETM+ image (see Figure 13). The total surface area of the main vegetation types nearly coincided, but the area covered by the araliaceous forest was noticeably smaller. Ocaña found this formation to occupy an area of 29,280 ha, while the supervised classification in the present study shows an expanse of 8841 ha.

Table 5 – Estimates of the area occupied by the main vegetation formations on Bioko, by Ocaña (1960)

Type of Vegetation	Ocaña, 1960 (ha)
Mangrove	476
Monsoon forest	23,267
Primary tropical rainforest	19,974
Crops; degraded tropical rainforest	75,791
Oil palm grove	936
Coconut palm grove	2333
Pandanus swamp	140
Montane rainforest	22,263
Araliaceous forest	29,280
Sub-zone of tree ferns	17,306
Heath forest (ericaceous shrubbery)	1390
Highland herbaceous prairies; grasslands	3321
Total	**196,477**

Table 6 – Estimates of the area occupied by the main vegetation formations on Bioko according to supervised classification

Type of Forest	Supervised Classification (Landsat 7 ETM+ 2003) (ha)
Coastal Guineo-Congolian rainforest	1255.68
Primary Guineo-Congolian rainforest (monsoon forest)	23,115.24
Young Guineo-Congolian rainforest with crops	69,937.20
Old secondary Guineo-Congolian rainforest	4360.32
Degraded Guineo-Congolian rainforest	12,311.64
Grasslands	809.64
Degraded Guineo-Congolian rainforest mixed with abandoned crops and palm groves	4022.28
Degraded Guineo-Congolian rainforest with afromontane elements	30,188.88
Primary lower elevation afromontane forest	15,435.36
Primary higher elevation afromontane forest (Araliaceae)	8841.24
Mature secondary afromontane forest	14,339.88
Artificial herbaceous prairies (degraded afromontane forest)	9162.00
Afromontane heath shrubbery (Ericaceae)	810.00
Natural afromontane herbaceous prairies	805.68
Total	195,395.04

The explanation for this difference is that the araliaceous forest estimated in the present supervised classification only included primary forest and parts of the natural range of this type of forest were seen to be degraded by fires or other disturbances. These parts, defined as herbaceous meadows or prairies – degraded afromontane forest – (9162 ha), had not yet acquired the category of secondary forest. A separate matter was the secondary afromontane forest (14,339 ha). It is important to point out that this latter type included the secondary araliaceous forest as well as the secondary lowland afromontane forest. Therefore, part of those 14,339 ha would not belong to the potential range of araliaceous forest, although *Prunus africana* could be found in this range. These data show that the afromontane forest distribution generally coincided with Ocaña's results in terms of altitude range, but the present supervised classification better detailed its area of distribution, while also distinguishing secondary formations and degraded parts.

The main difference within afromontane forest types between both vegetation distributions – the supervised classification in this study and Ocaña's findings – lies in what Ocaña denominated a subzone of tree ferns, but which did not appear defined as a vegetation type in the present supervised classification. This fact is justified by observations made in the field during the Pico de Basilé inventory, where tree ferns were not only found in the area described by Ocaña, but also in broader altitude ranges. For this reason, tree ferns were not felt to accurately characterise this forest type. Following White's proposal (1983), the subzone of tree ferns was redefined as lowland afromontane forest.

Some classes did not exist in Ocaña's classification, for example: Guineo-Congolian rainforest mixed with afromontane elements, old secondary Guineo-Congolian rainforest, and degraded Guineo-Congolian rainforest mixed with palm groves and abandoned crops. These aspects, however, are unrelated to *P. africana*'s range. Ocaña included most of the forests that had suffered some kind of degradation, along with croplands, under just one category, while the supervised classification considered transition zones between forest types and the extent of their degradation. It was also noted that Ocaña had not distinguished between herbaceous and ericaceous cover, defining an ericaceous expanse of over 1390 ha. In the supervised classification, these formations were established separately, as 810 ha (area of afromontane – ericaceous – shrubbery) and 840 ha (area of afromontane herbaceous plants) respectively.

Table 7 shows the results of supervised classification of the areas occupied by the main vegetation formations between 1400 and 2500 m, the elevation boundaries of *Prunus africana*'s range. The main non-degraded areas where *Prunus africana* occurs are located on Pico de Basilé: 7043 ha of araliaceous forest and 2030 ha of lowland afromontane forest.

Table 7 – Estimates of the area occupied by the main vegetation formations on Bioko (Pico de Basilé, Moca, and Gran Caldera de Luba) at altitudes above 1400 metres, according to supervised classification

Vegetation type	Supervised classification (Landsat 7 ETM+ 2003)	
	Pico de Basilé (ha)	Moca and Gran Caldera de Luba (ha)
Primary Guineo-Congolian rainforest	0.36	0
Young Guineo-Congolian rainforest mixed with crops	115	35
Old secondary Guineo-Congolian rainforest	0	0.5
Degraded Guineo-Congolian rainforest	1.5	14
Grasslands	17	76
Guineo-Congolian rainforest with afromontane elements	1568	390
Primary lower afromontane forest	2030	435
Primary higher afromontane forest (Araliaceae)	7043	1393
Mature secondary afromontane forest	1735	3443
Artificial herbaceous prairies (degraded afromontane forest)	175	1370
Afromontane heath shrubbery (Ericaceae)	1131.37	20.25
Natural afromontane herbaceous prairies	793	0.5
Total	**14,609.23**	**7177.25**

Nevertheless, a larger expanse of secondary afromontane forest – 3443 ha – did appear in the Moca area. These lands were formerly devoted to cattle raising, abandoned in the mid 20th century as the Spanish colonial period came to an end. *Prunus africana*, with its heliophilous temperament, has adapted easily and thrived here.

Recently abandoned areas where a South African company used to raise livestock were identified around the village of Moca (Gabino Siloche, personal communication). There has not been enough time for regeneration of *Prunus africana* or for establishment of any secondary woodland formation here. Therefore, these areas appear as herbaceous prairies in the supervised classification – 1370 ha of degraded afromontane forest – in locations where *Prunus africana* would naturally occur. In any case, the herbaceous prairies on Pico de Basilé (degraded afromontane forest) scarcely cover 175 ha, and these are chiefly the result of regeneration after forest fires.

Another point to bear in mind is that the elevation boundaries of the afromontane forest vary depending on the area and the orientation of the hillside. This is why a relatively large patch of Guineo-Congolian rainforest appears on the north side of Pico de Basilé, above the altitudinal limit of its range, in a mixture with afromontane elements. The reverse situation also takes place, when the altitudinal limit of the afromontane forest descends to the level of the Guineo-Congolian rainforest (e.g. on the south side of Basilé) and is equally defined in the supervised classification as Guineo-Congolian rainforest mixed with afromontane elements.

7.4. Species Composition of the Forests Sampled

Forest inventories accounted for a total of 355 individuals, belonging to 37 different tree species. Along with *Prunus africana*, the species found most often were *Schefflera mannii*, *S. barteri*, *Neboutonia macrocalix*, *Trichilia priureana*, *Bersama abysssinica*, *Maesa lanceolata*, *Xymalos monospora*, *Polyscias fulva*, *Oxyanthus* spp., and *Ficus clamydocarpa*. *Hypericum lanceolatum*, a characteristic species of the ericaceous upperstorey, appeared sporadically, chiefly in areas disturbed by fire, always accompanied by the aforementioned *Polyscias fulva*, which was even more abundant. The shrub stratum was made up of such species as *Uragoga manii*, *Oxyanthus tenuis*, and *Solanum* spp., with *Anchomanes diformis*, *Piper guineense*, and *Aframomun* sp., among many others, on the herbaceous stratum, but these strata were not inventoried in this project. The best-represented family of ligneous species was *Rubiaceae*, with a total of eight different species in the genera *Cephaelis*, *Psychotria*, *Oxyanthus*, and *Uragoga*. Other ligneous species besides those recorded in the forest inventories were also identified in the study area. Examples include *Ficus exasperata*, *Macaranga* spp., *Alangium begonifolium*, and *Dracaena* sp. The main families, genera, and species associated with *P. africana* observed and recognised in the course of fieldwork are summarised below:

Taxa associated with *Prunus africana*		Comments
Peridophytes		
CYATHEACEAE	***Cyathea mannii*** Hook.	
OSMUNDACEAE	***Lepicystis lanceolada*** (L.) Diels	
Magnoliophytes		
AGAVACEAE	***Dracaena fragans*** (L.) Ker Gawl.	
ALANGIACEAE	***Alangium begoniifolium*** (Roxb.) Baill.	found in Moca
ARACEAE	***Anchomanes difformis*** (Blume) Engl.	under *Prunus* forest
ARALIACEAE	***Polyscias fulva*** (Hiern) Harms	on the araliaceous storey, abundant, heliophyte but accompanies *Prunus* in the forest, seeming to behave as a secondary forest element
	Schefflera mannii (Hook.f.) Harms	
	Schefflera barteri (Seem.) Harms	
COMPOSITE	***Crassocephalum mannii*** (Hook.f) Milne-Rehd.	on the araliaceous storey, sometimes under *Prunus*, but preferably heliophilous in forest clearings
EUPHORBIACEAE	***Macaranga monandra*** Müll.Arg.	
	Macaranga occidentalis (Müll.Arg.) Müll.Arg.	
	Macaranga spinosa Müll.Arg.	
	Neboutonia macrocalyx Pax	from Moca up to Biaó
FLACOURTIACEAE	***Homalium*** sp.	
GUTTIFERAE	***Hypericum revolutum*** Vahl	on the ericaceous storey but also mixed in with *Prunus*
LOGANIACEAE	***Nuxia congesta*** R. BR.	
MELIACEAE	***Trichilia prieureana*** A. Juss.	appears in Pico de Basilé inventories; could be considered new location

Taxa associated with *Prunus africana*		Comments
MELIANTACEAE	***Bersama abyssinica*** Fresen.	
MYRICACEAE	***Myrica arborea*** Hutch	
MYRSINEACEAE	***Afrardisa oligantha*** Gilg & Schellenb.	
	Maesa lanceolata Forsk	
MONIMIACEAE	***Xymalos monospora*** (Harv) Baill.	
MORACEAE	***Ficus chlamydocarpa*** Mildbr. & Burret	
	Ficus exasperata Vahl	occurs in *Prunus* forest, in Moca lowlands, but did not appear in inventories
	Ficus sp.	
PIPERACEAE	***Piper guineense*** Schum. & Thonn.	in *Prunus* forest understorey; abundant
ROSACEAE	***Prunus africana*** (Hook. f.) Kalkm.	
		on the araliaceous storey, but its heliophilous nature prevents it from forming a part of the *Prunus* forest understorey; it thus remains on the fringe of the forest
RUBIACEAE	***Cephaelis densinervia*** (K. Krause) Hepper	
	Oxyanthus subpunctatus (Hiern) Keay	
	Oxyanthus sp.	
	Oxyanthus tenuis Stapt.	in *Prunus* forest understorey
	Psychotria sp.	Moca, in *Prunus* forest
	Psychotria peduncularis (Salisb.) Steyermark	
	Uragoga mannii (Hook f.) Hutch. & Dalziel	under *Prunus* forest
	Uragoga sp.	
RUTACEAE	***Zanthoxylum gilleti*** (De Willd.) Waterman	
SOLANACEAE	***Solanum torvum*** L.	
	Solanum indicum Sw.	

Taxa associated with *Prunus africana*		Comments
ULMACEAE	***Trema orientalis*** (L.) Blume	
URTICACEAE	***Elatostema*** sp.	under *Prunus* forest

During fieldwork, another series of taxa outside the *Prunus africana* range was also found. These taxa are listed below:

Taxa not associated with *Prunus africana*		Comments
Peridophytes		
SINOPTERIDACEAE	***Pteridium aquilinum*** (L.) Kuhn	on the ericaceous storey and lower mountainous areas, having suffered from forest fires
Magnoliophytes		
AGAVACEAE	***Dracaena arborea*** (Willd.) Link	
ALANGIACEAE	***Alangium chinense*** (Lour.) Harms	
AMARANTHACEAE	***Amaranthus spinosus*** L.	Asian neophyte
APOCYNACEAE	***Alstonia boonei*** De Wild.	
ARACEAE	***Calocasia esculenta*** (L.) Schott	cultivated
	Cyrtosperma senegalensis (Schott) Engl.	in wetlands near Luba
ARECACEAE	***Cocos nucifera*** L.	cultivated and grown wild
	Elaeis guineensis Jack.	wild and cultivated
BOMBACACEAE	***Ceiba pentandra*** (L.) Gaertn.	
BURSERACEAE	***Aucumea klaineana*** Pierre	
CARICACEAE	***Carica papaya*** L.	cultivated
CECROPIACEAE	***Musanga cecropiodes*** R.Br.	
COMBRETACEAE	***Terminalia catappa*** L.	
CONVOLVULACEAE	***Ipomoea*** sp.	
CUCURBITACEAE	***Telfairia occidentalis*** Hook. f.	cultivated

Taxa not associated with *Prunus africana*		Comments
ERICACEAE	***Aguaria salicifolia*** (Comm. ex Lam.) Hook. f.	on the ericaceous storey
	Philippia mannii (Hook. f .) Alm & T.C.E.Fr.	
EUPHORBIACEAE	***Alchornea cordifolia*** (Schum. & Thonn.) Müll.Arg.	
FABACEAE	***Adenocarpus mannii*** (Hook. f.) Hook. f.	on ericaceous storey
	Vigna sp.	wild near roads and crops
LAMIACEAE	***Pycnostachys volkensii*** Gürke	on ericaceous storey
LOBELIACEAE	***Lobelia columnaris*** Hook. f .	on ericaceous storey
LOGANIACEAE	***Anthocleista vogellii*** Gilg & Mildbr. Ex Huych. & Dalziel	coastal rainforest, near Luba
MYRISTICACEAE	***Pycnanthus angolensis*** (Welw.) Warb.	
MORACEAE	***Artocarpus altilis*** (Park.) Fosberg	cultivated
	Clorophora excelsa Benth. & Hook. f.	low areas on rainforest storey, perhaps reaching afromontane storey
	Ficus mucoso Ficalho	species probably grown in Malabo gardens
PITTOSPORACEAE	***Pittosporum mannii*** Hook. f.	on ericaceous storey
POACEAE	***Dactyloctenium aegyptium*** (L.) Willd.	meadows in the rainforest; neophyte
	Pennisetum purpureum Schumach.	
	Saccharum officinarum L.	cultivated

Taxa not associated with *Prunus africana*		Comments
ROSACEAE	***Rubus pinnatus*** Willd.	on the araliaceous storey, but its heliophilous nature prevents it from forming a part of the *Prunus* forest understorey; it thus remains on the fringe of the forest
STERCULIACEAE	***Theobroma cacao*** L.	cultivated
ULMACEAE	***Celtis*** sp.	
ZINGIBERACEAE	***Aframomum*** sp.	

Knowledge of the Flora of Equatorial Guinea is sketchy, in spite of the works published, the ambitious project undertaken since the decade of the 1980s by the Madrid Botanic Garden, and the valuable documentary collections kept in its herbarium (MA). Specimen collections of Equatorial Guinea's plant biodiversity are fragmentary. There is no Flora edited on this region of the world, and many of the local genera have only been partially studied. Nevertheless, the Flora of West Africa is always very helpful. Indigenous denominations, predominantly in Bubi, make up a large body of local terms that are conspicuously absent from bibliographies.

It must be underlined that the obstacles encountered in the course of forest inventory made it extremely difficult to identify species. The fieldwork was a huge task to be done in a limited time, conditioned on obtaining official permits and safe-conducts, which reduced mobility and ability, consequently affecting the quality of the herborisation. Collecting nearly always had to make do with plants in a vegetative state and there was often no choice but to resort to characters relating to the shape and arrangement of the leaves, or at best their nerve pattern, texture, or – usually non-existent – indumentum. Furthermore, cloud forest species frequently present heteromorphism depending on their age and the amount of insolation they receive. This produces morphological variations that can sometimes be more patent in individuals of the same species and different ages than between different species, increasing the complexity of making a correct identification.

All these difficulties notwithstanding, 29 out of the 37 taxa of trees mentioned in inventories were identified to the species level and 4 to the genus level. When it came to characterising *Prunus africana* forest communities, other accompanying species were identified but not included in the inventories because of their smaller size or herbaceous character. Figure 15 shows only those species of the tree canopy that were abundant enough to be considered representative, excluding those with densities under 1 stem ha^{-1}.

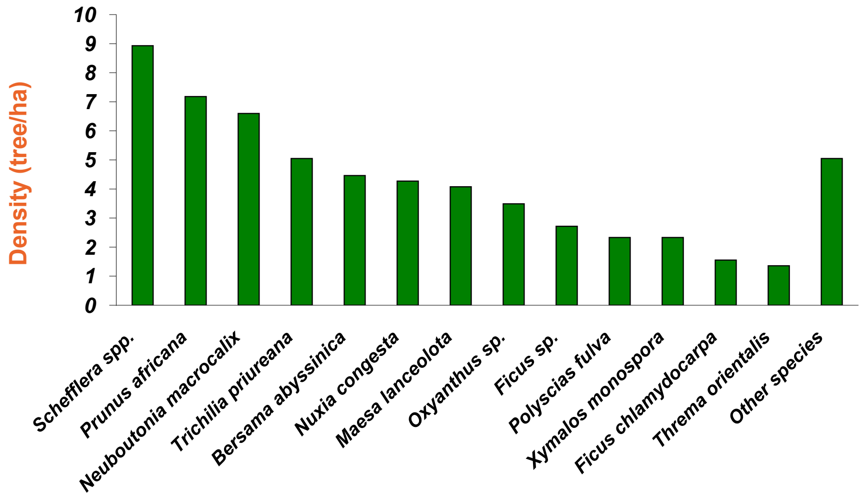


Figure 15 – Density of main tree species in sample area (Pico de Basilé and Moca)

7.5. Ecological Conditions of the Range of *Prunus africana*

The forest inventory found *Prunus africana* individuals from 1400 up to 2500 m on Bioko. The 41 plots inventoried in the potential range showed a theoretical distribution of the species at elevations between 1400 and 2500 m, with an average slope of 17%.

The potential surface areas obtained for the altitudinal range proposed here (1400-2500 m) were smaller than those that would have been obtained by considering an altitudinal range from 1200-2500 m (Sunderland and

Tako, 1999). In this case, the total theoretical surface area estimated for the island would be 31,969.3 ha, of which 16,000 ha would be located on Pico de Basilé and 15,969.3 ha in the Moca-Gran Caldera de Luba area.

Nevertheless, following the supervised classification and the altitude limits established (1400-2500 m), the total surface area of potential distribution would reach 21,620.12 ha, most of which would be located on Pico de Basilé (14,492.37 ha), and the remaining 7127.75 ha would be divided between Moca (3559 ha) and Caldera de Luba (3568 ha) (Figure 16). Furthermore, fieldwork gave a sense that actual distribution in Moca was probably lower as a result of deforestation for former livestock use in the area.

Table 8 summarises values for potential surface areas of *Prunus africana* distribution on Bioko (Pico de Basilé and Moca + Caldera de Luba), estimated according to supervised classification for altitude ranges of 1200-2500 m and 1400-2500 m.

Table 8 – Surface areas of potential *Prunus africana* distribution on Bioko (Pico de Basilé and Moca + Caldera de Luba) estimated according to supervised classification for altitude ranges of 1200-2500 m and 1400-2500 m

Site	Potential surface area (ha) (1200-2500 m)	Supervised classification (ha) (1400-2500 m)
Pico de Basilé	16,000	14,492.37
Moca + Caldera de Luba	15,969.3	7127.75
Total Bioko	**31,969.3**	**21,620.12**

As for the extent of intervention in the forest, the results indicated that most of the sampled plots had been subject to "little intervention" for some years. They are areas where *Prunus africana* bark had been harvested, but no other plant harvesting activity had taken place. The main reason for the degradation of the forest was fire, although these could not yet be labelled regenerated secondary forest areas (Table 9). The Monguibus (Moca) area was an exception, since it was used for livestock purposes in the early 20th century and then abandoned, becoming a secondary forest with *Prunus africana* as the principal species 60 years later.

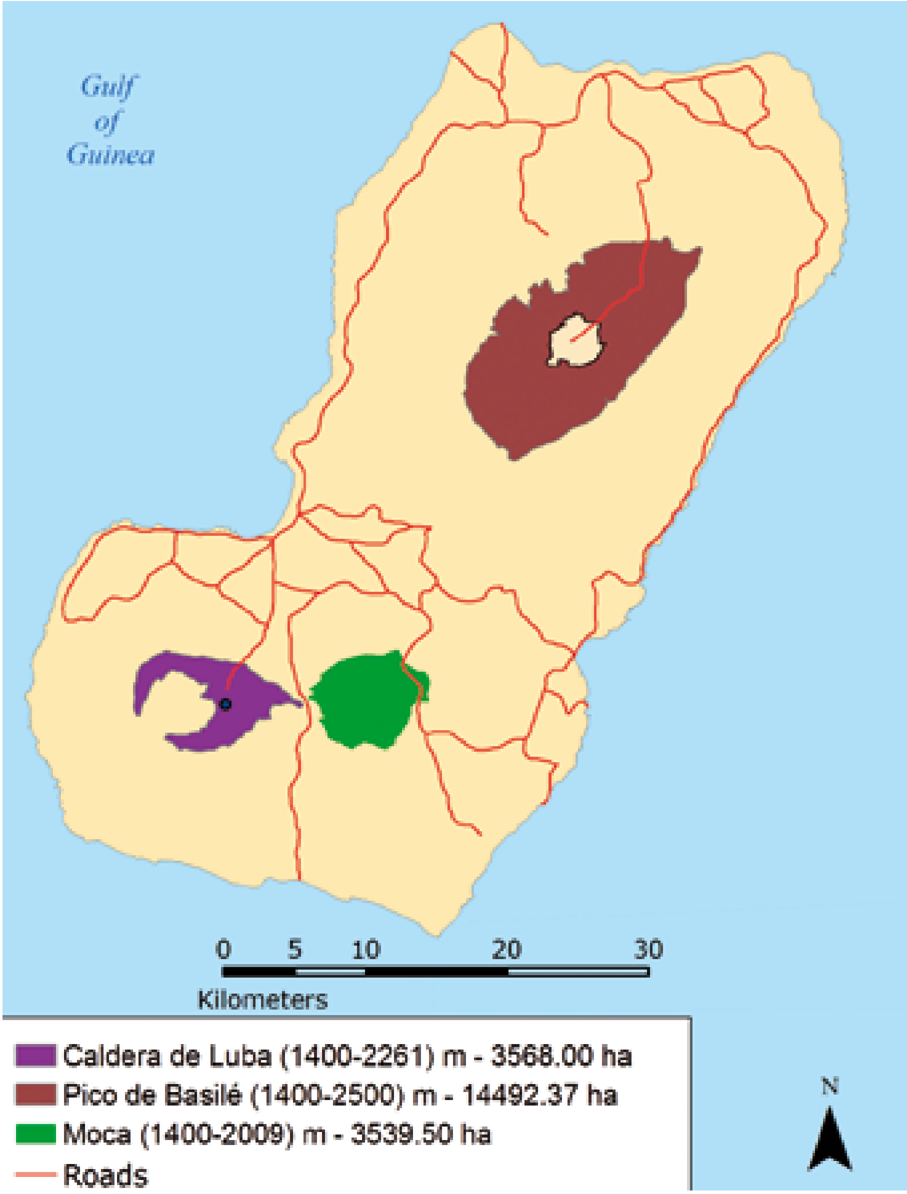


Figure 16 – Potential distribution of *Prunus africana* on Bioko according to forest inventory

Table 9 – Physiographic characteristics of forestlands inventoried

Area	Altitude range (m.a.s.l.)	Scrub coverage (%)	Average slope (%)	Longitude range (ºdec.)	Latitude range (ºdec.)	Ecosystem type
Bioko	1426-2184	89	17	3.351667-3.611025	8.616917-8.816300	Little intervention
Pico de Basilé	1704-2184	67	18	3.596333-3.611025	8.772091-8.816300	Little intervention
Moca	1429-1997	91	22	3.351667-3.365183	8.616917-8.656617	Some intervention

7.6. Structure of Forests where *Prunus africana* Occurs

Table 10 shows the average structural attributes obtained for forests with *Prunus africana* on Pico de Basilé and Moca. They are expressed as total tree density, density of *Prunus africana*, canopy cover fraction – both overall and specifically for *Prunus africana* – in units per hectare and average stand height in metres.

Table 10 – Structural attributes of the vegetation in the ecosystems where *Prunus africana* occurs on Pico de Basilé and Moca, showing absolute values for total density, density of *Prunus africana*, average stand height, and canopy cover fraction (CCF)

Site	Total tree density (trees ha^{-1})	*P. africana* density (trees ha^{-1})	Average stand height (m)	Total tree CCF (%)	*Prunus africana* CCF (%)
Pico de Basilé and Moca	69.29	7.18	24	77.16	14.7

Table 11 shows estimated densities of *Prunus africana* found in various previous works.

Table 11 – Average densities, basal area, and absolute frequency of *Prunus africana* in different parts of its range

Study area	Distribution area	Abundance (stems ha^{-1})	Source
Pico de Basilé	1400-2500 m	50	(Monforte, 2000)[1]
Mount Cameroon	1500-2500 m	5.5	(Eben Ebai *et al.*, 1992)[2]

Study area	Distribution area	Abundance (stems ha^{-1})	Source
Mount Cameroon	Dense humid forest with crops	0.87	(ONADEF, 1997)[3]
Mount Cameroon	Crops	1.03	(ONADEF, 1997)[3]
Mount Cameroon	Dense humid forest	1.17	(ONADEF, 1997)[3]
Ethiopia	afromontane rainforest	7.2	(Chaffey, 1980)[3]
Ethiopia	Non-differentiated afromontane forest	8	(Chaffey, 1980)[3]

[1] Report prepared for APRA
[2] Source mentioned in Cunningham and Mbenkum, 1993
[3] Source mentioned in Hall *et al.*, 2000 *in* Hall *et al.,* (Eds), 2000

Contrasting these values with the results obtained (Table 10), earlier estimates on Pico de Basilé (Monforte, 2000) gave much higher values for density per hectare than those found in the present forest inventory. There are also quantitative differences between the average results obtained for Pico de Basilé and Moca and the density values of other inventories carried out on Mount Cameroon. Abundance is low in most of the earlier studies, oscillating between 3 and 7 stems ha^{-1}. The only density similar to that found in the Bioko forests was observed in Ethiopia. These results, *a priori*, seem contradictory, as Bioko is floristically closer to the Cameroon afromontane forests. Other factors, which should be the subject of future studies, are thus likely to influence *Prunus africana* density.

Figure 17 shows diameter class distribution of *Prunus africana* on Bioko. Remarkably few individuals under 30 cm were found, which may be evidence that this tree is a light-demanding species that tends to grow rapidly in its early stages, reaching thick diameters and leaving few individuals in small diameter categories. These observations coincide with those of other studies on the species (Cunningham and Mbenkum, 1993; Sunderland and Tako, 1999). Such a pattern of age class distribution is not rare for long-lived species associated with forest borders and disturbances.

Further complications arise from irregularities in recruitment, owing to annual variability of seed production (Ndam *et al.*, 2000).

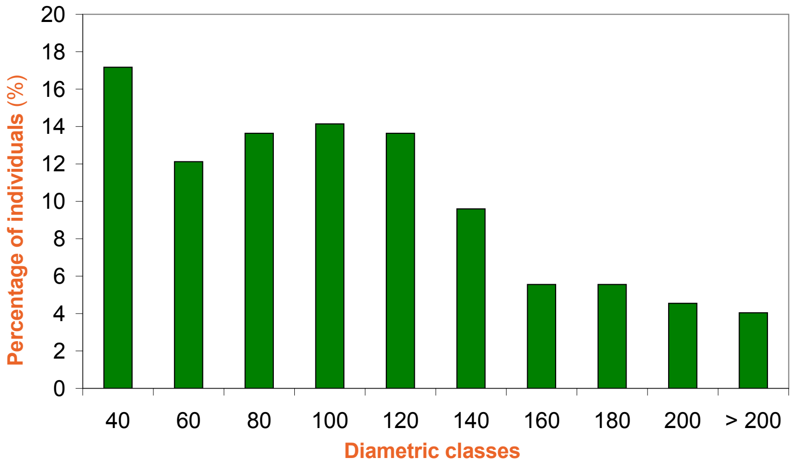


Figure 17 – Distribution of *Prunus africana* by diameter classes (N = 264) on Bioko

Table 12 shows the structural attributes obtained, expressed in values of absolute mean density and basal area (BA), for the main species that make up the vegetation in *Prunus africana* forests on Bioko.

Prunus africana and *Schefflera* spp. (*Schefflera mannii* and *Schefflera barteri*) were the species in this area (Pico de Basilé and Moca) with the highest representation, followed by *Neboutonia macrocalix*, *Trichilia prieureana, Nuxia congesta*, and *Ficus* sp; *Schefflera* and *Prunus africana* have similar densities but significant differences in their basal areas, those of the former being much larger. These taxa make up the dominant stratum of the Araliaceae forest, as expressed by their greater abundance (8.93 stems ha^{-1} and 7.18 stems ha^{-1}, respectively). Their high basal area is a major factor explaining their importance in the stand structure. Other species in a good structural position are *Trichilia prieureana* and *Neboutonia macrocalyx*, with relatively high densities (5.05 stems ha^{-1} and 6.60 stems ha^{-1}, respectively). The high density of *Prunus africana*, with the second highest value of all the species present, is largely responsible for its

Table 12 – Structural attributes of the vegetation in *Prunus africana* forests by species, showing absolute values for density and basal area (BA)

Taxa	Place	Density (trees ha^{-1})	BA (m^2 ha^{-1})
Bersama abyssinica	Moca	4.46	1.43
Crassocephalum mannii	Basilé and Moca	0.39	0.31
Ficus chlamydocarpa var. chlamydocarpa	Moca	1.55	0.46
Ficus sp.	Basilé and Moca	2.72	1.04
Ficus sp.	Basilé	0.39	0.31
Homalium sp.	Moca	0.58	0.26
Hypericum lanceolatum	Basilé and Moca	0.39	0.31
Macaranga spinosa	Basilé	0.58	0.26
Maesa lanceolata	Moca	4.08	1.21
Neboutonia macrocalix	Basilé	6.60	1.91
Nuxia congesta	Basilé and Moca	4.27	1.29
Oxyanthus spp.	Moca	3.49	1.94
Polyscias fulva	Basilé and Moca	2.33	0.51
Prunus africana	Basilé and Moca	7.18	0.94
Psycotria peduncularis	Moca	0.78	0.37
Psycotria sp.	Moca	0.19	0.16
Schefflera spp. (*S. barteri, S. mannii*)	Basilé and Moca	8.93	1.65
Trema orientalis.	Basilé and Moca	0.97	0.40
Trichilia prieureana	Basilé	5.05	1.62
Uragoga sp.	Basilé and Moca	0.39	0.22
Xymalos monospora	Moca	2.33	0.87
Zanthoxylun sp.	Moca	0.39	0.22
Other unidentified species (Bubi names)	Basilé and Moca	11.05	5.64
Total Figures		**69.29**	**23.51**

structural importance (see Appendix III). Furthermore, its relative basal area values were among the highest on all the plots.

As for the rest of the species, there is no clear pattern in the sequence of their relative structural significance. The structural differences among species accompanying *Schefflera* and *Prunus africana* in different areas are worth mentioning. For example, in Monguibus (Moca), there was a sorry show of accompanying species, because the secondary structure of the forest made for less species diversity.

Figure 18 shows the diameter class distribution (individuals per ha) of the two dominant species in the upper stratum: *Prunus africana* and *Schefflera* sp. The percentage of individuals is low in the first two classes (10-30 cm and 30-60 cm), increasing in the last class (> 60 cm). The inverted J-shape distribution curves for diameter classes are characteristic of pioneer species, as occurs with *Prunus africana*. This temperament allows the species to easily colonise degraded terrain and clearings that open up in forests as a result of natural or anthropic disturbances. The combination of robust character and longevity would justify this distribution of pygeum, in the form of large, isolated individuals within the forest communities where they are present, or appearing in copses or relatively pure groups, as other authors seem to suggest (Hall *et al.,* 2000). The results of the present study, however, do not offer clear evidence of *Prunus africana* forming copses on Bioko. Instead, it would seem to have a more or less homogenous distribution, varying with altitude.

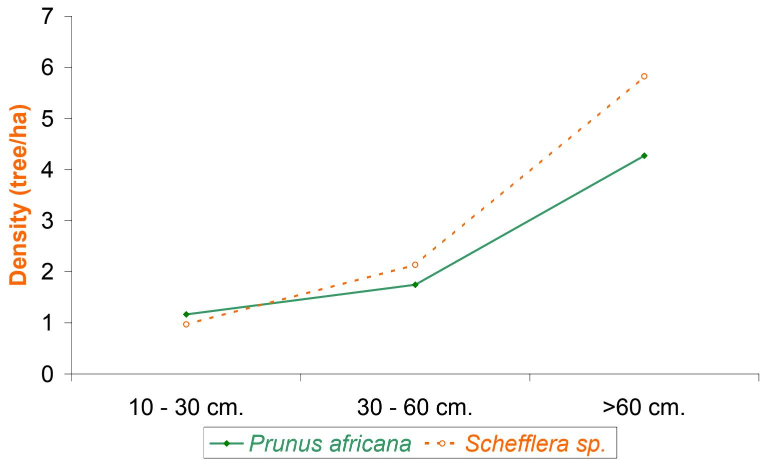


Figure 18 – Distribution of individuals of dominant species in the higher stratum of the forest where *Prunus africana* occurs, by diameter classes

Figure 19 shows diameter class distribution (individuals per ha) for two of the species in the intermediate stratum: *Neboutonia macrocalix* and *Nuxia congesta*. The presence of a high number of individuals in the smallest diameter classes that gradually diminishes over the middle range, down to a very low number in the largest class, would indicate good reproduction and continuous establishment of these species.

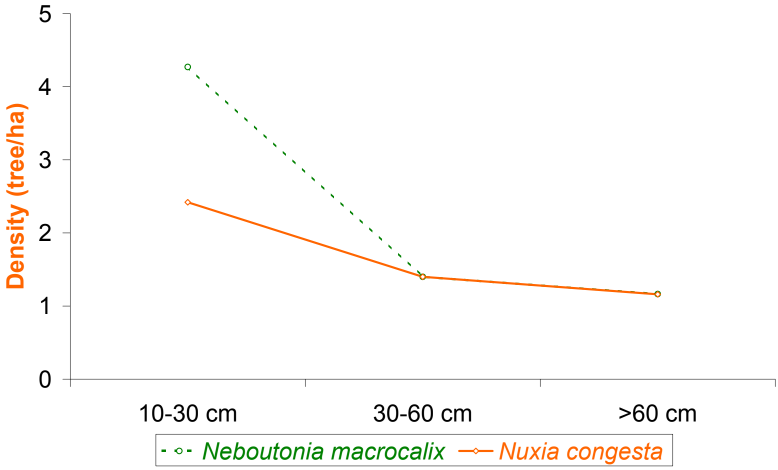


Figure 19 – Distribution of individuals of the main species in the intermediate stratum of the forest where *Prunus africana* occurs, by diameter classes

7.7. Classification of *Prunus africana* Stands According to Altitude and Population Criteria in Harvest Areas

Bark harvesting has chiefly focussed on the northern part, on the access road to the Pico de Basilé antenna, since the year 1996, except for the period from 1999 to 2002 and more recently, in 2005, when this focus shifted to the southern part, the Pico Biaó crater, and thereabouts. *Prunus africana* bark was also harvested near the village of Moca in 1998.

The harvest area estimated by Monforte (2000) was 3500 ha, on an expanse of approximately 7 x 5 km along the Basilé-Pico de Basilé road, and 270 ha in Moca, covering roughly 5 x 1 km around Lake Biaó. In any case, it must be noted that difficulty of access limits the chances

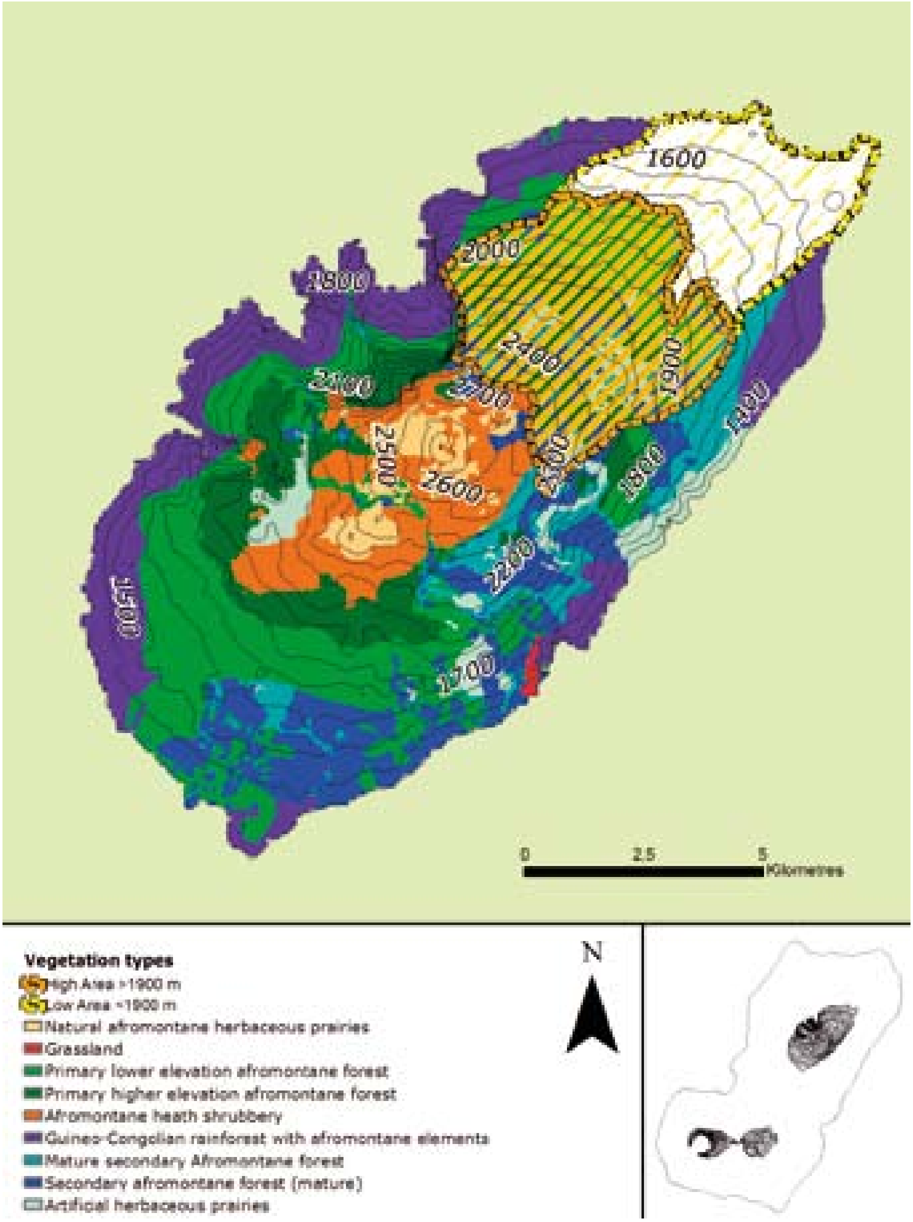


Figure 20 – *Prunus africana* harvest areas on Pico de Basilé by altitudinal distribution (WGS 84: Zone 32 N)

of harvesting in some areas. This limitation was taken into account in the study, and the final estimate of the actual harvest area considered accessibility on Pico de Basilé and Moca (see Figures 20 and 21).

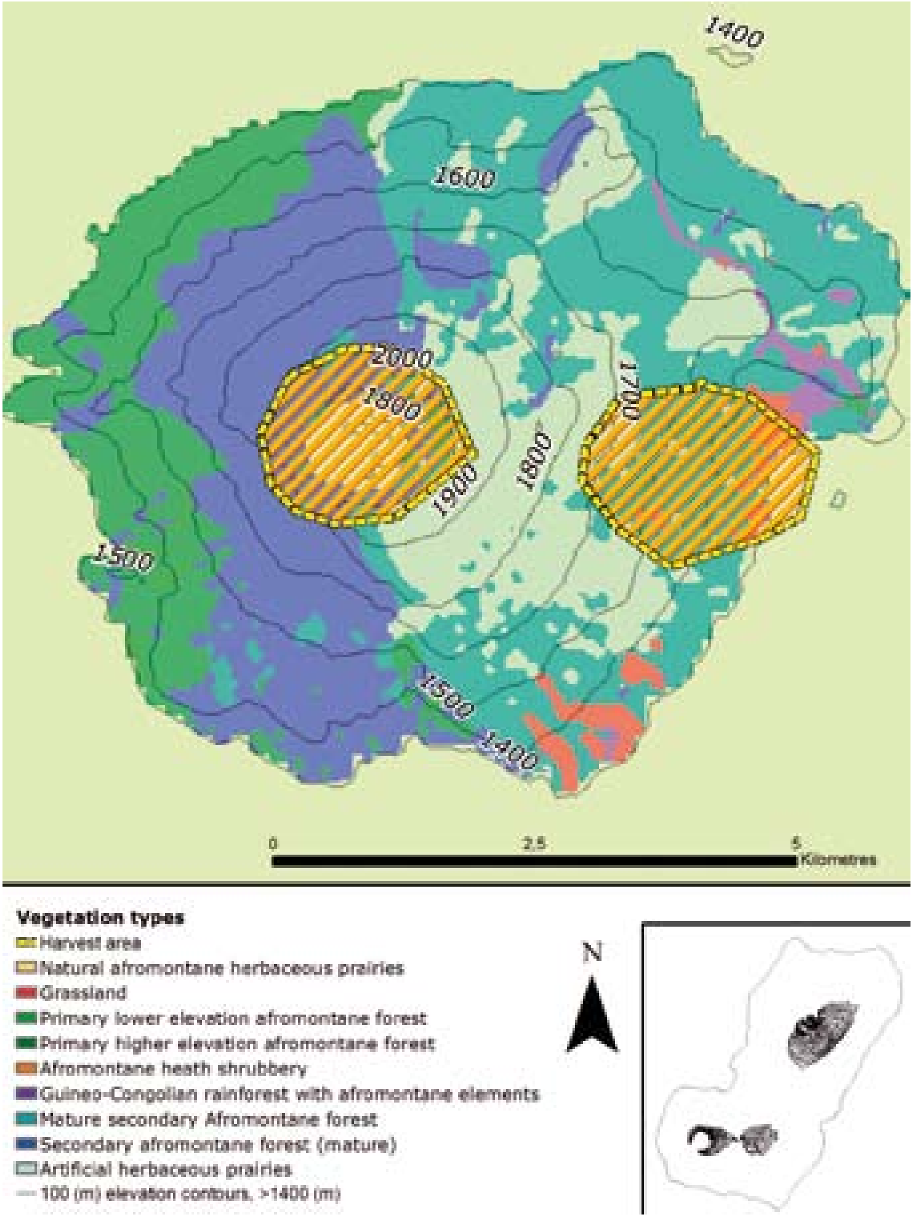


Figure 21 – *Prunus africana* harvest areas in Moca and Lake Biaó highlands, by vegetation types

7.7.1. *Prunus africana* Stands on Pico de Basilé

Calculation of the surface area of current harvesting activity was established considering the altitude range of *Prunus africana* distribution

(1400-2500 m) and the harvesters' access route, which occupied 1.5 km on both sides of the road (Figure 20). Using these criteria, and excluding the fire-razed parts (60 ha), an area of exploitation of 2741 ha was determined for Pico de Basilé.

Although earlier studies (Guinea, 1949) described a change in vegetation at 1800 m.a.s.l., the results of the present survey led to setting the limit at 1900 m.a.s.l. between the lowlands and the highlands on the north side of Pico de Basilé. The lowland area (1119 ha) was characterised by two ground cover types in the supervised classification: Guineo-Congolian rainforest mixed with afromontane elements, and secondary afromontane forest, while the highland area was araliaceous forest (1622 ha).

Table 13 shows the structural attributes (total tree density, density of *P. africana*, canopy cover fraction – overall and specifically for *P. africana* – and average stand height) of areas where *Prunus africana* occurs on Pico de Basilé, by altitude range (see Figure 10 for the distribution of the sample plots). *Prunus africana* density is greatest at elevations beyond 1900 m.a.s.l.

Table 13 – Structural attributes of the vegetation on Pico de Basilé in two altitude ranges, showing measurements of total density, density of *P. africana*, CCF – of all trees and of *P. africana* – and average stand height

Area	Altitude range (m.a.s.l.)	Total tree density (stems/ha)	*P. africana* density (trees/ha)	Total tree CCF (%)	*Prunus africana* CCF (%)	Average stand height (m)
Pico de Basilé	**1704-2184**	**61.67**	**7.56***	**67**	**18**	**26**
Low area	1704-1900	87.54	2.65	75.83	6.33	22
High area	1900-2184	61.54	15.38	64.07	31.64	29

*Note: average *P. africana* density for each area was obtained as the weighted value depending on the surface area of its distribution in each of the subzones.

7.7.2. *Prunus africana* Stands in Moca

Three sampling sites were established in the harvest area: 1) the Pico Biaó crater and thereabouts, 2) the south side of Pico Biaó, and 3) a site near the village, known as the lowland area (see sample plots in Figure 11). The second site was called Monguibus in the local Bubi language, meaning forest of monkeys. The name comes from the English "Monkey bush." This was where a secondary forest resulted from deforestation of the area in the early 20th century for livestock purposes. In the Moca area, as on Pico de Basilé, potential distribution of *Prunus africana* was encountered above 1400 m (see Figure 21).

Prunus africana stands exhibited greater heterogeneity due to disturbances caused by human activity, such as the presence of cattle on the hillsides of Pico Biaó and the specific characteristics of its crater, in terms of orientation and moisture, given its topographic configuration (2009 m.a.s.l.). This area has undergone human-induced alterations that have greatly reduced the actual forest distribution compared to original suppositions. Data from the fieldwork performed for this study and basic map identification (1: 50,000) were used to estimate current harvest areas: 72 ha (Lake Biaó), 103 ha (Monguibus) and 282 ha (lowland area near Moca).

Table 14 shows structural attributes (total density of trees, density of *P. africana*, canopy cover fraction – of trees in general and of *P. africana* in particular – and average stand height) for each area and for Moca as a whole.

Table 14 – Structural attributes of the vegetation in Moca by altitude range and type of forest, showing absolute values for total density, density of *Prunus africana*, and canopy cover fraction (CCF)

Area	Altitude range (m)	Total density (stems/ha)	*P. africana* density (stems/ha)	Total CCF (%)	*Prunus africana* CCF (%)	Average stand height (m)
Moca	**1429-1997**	**75.79**	**6.82***	**88**	**12**	**23**
Pico Biaó	1833-1997	54.91	6.37	78	13	23
Monguibus	1723-1829	103.45	5.68	96	8	24
Low area	1429-1556	79.58	9.95	100	19	21

*Note: average *P. africana* density for each area was obtained as the weighted value depending on the surface area of its distribution in each of the subzones.

7.8. Damage Caused to Trees as a Result of the Harvest Process

Around 91% of the *Prunus africana* trees on Pico de Basilé have been subject to some kind of harvest activity, and harvesters have lately resorted to taking regenerated bark from previously exploited trees. In the Moca area, harvest on Pico Biaó is recent, and there are sites in the Moca highlands that remain untapped in spite of being near the road, as Sunderland and Tako (1999) indicated. The percentage of unexploited individuals thus exceeds 50%. Figure 22 gives the percentages of individuals unharvested, harvested once, and harvested twice on Pico de Basilé (N=168) and Moca (N=96).

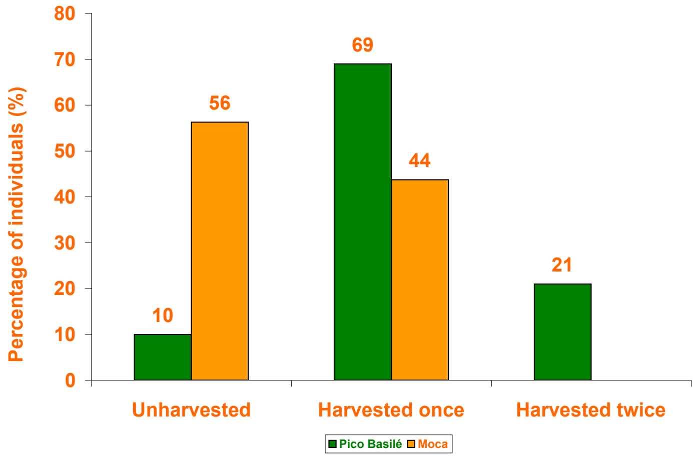


Figure 22 – Percentage of individuals found in the sample: unharvested, harvested once, and harvested twice (N = 168 on Pico de Basilé; N = 96 in Moca)

Evaluations performed on each individual included the extent of defoliation (indicating a weakened state of the tree after removal of its bark), mortality rate, and harvest technique used. The number of individuals and area of bark harvested were also assessed (Table 15).

In Figure 23, defoliation values are represented for all the *Prunus africana* trees that had been exploited (N = 181) in both harvest areas. Nearly 6 % of these trees were dead, another 3% belonged to the >80%

Table 15 – Characteristics of *Prunus africana* trees inventoried on Basilé and in Moca

Area	Nº of trees	Percentage of trees harvested (%)	Defoliation (%)	Mortality rate (%)	Harvest technique
Pico de Basilé	168	92.42	40	5.95	Total debarking
Moca	96	56.25	2	0	Total debarking

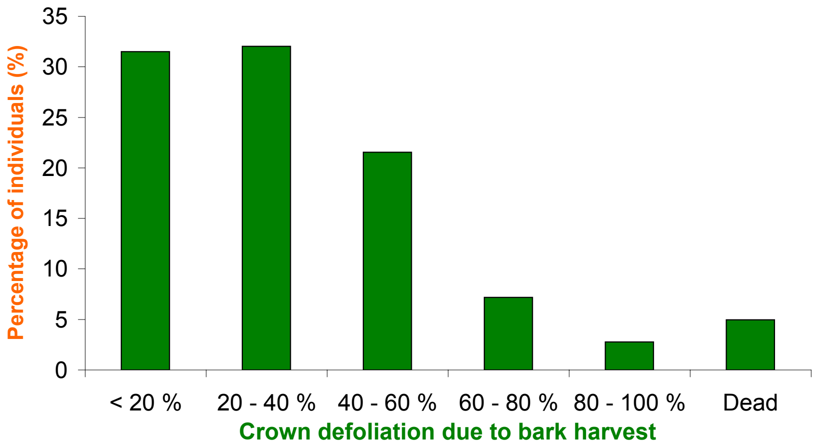


Figure 23 – Percentage of individuals according to crown defoliation categories of *Prunus africana* trees harvested once or twice on Pico de Basilé and Moca (N=181)

defoliation category, while approximately 63% showed little loss of vigour or moderate defoliation problems (0%-40% defoliation classes).

There were marked differences between the status of *Prunus africana* trees on Pico de Basilé (Figure 24) and that of Moca trees (Figure 25). Mortality was only detected on Pico de Basilé, and 6% of the individuals presented defoliation values >80%, compared with no mortality and insignificant defoliation among the Moca population. The explanation for these results may be that the Moca trees were only harvested once, in 1998, and most of those trees had since recovered.

The trees exploited in Moca during 2005 apparently had not yet suffered the stress of debarking at the time of fieldwork conducted for the present study, because this harvest had been so recent. The trees on Pico de Basilé, however, had undergone continued stress due to second harvests – and even occasional third harvests in some cases – with possible cumulative effects on the trees' vigour (Figure 24).

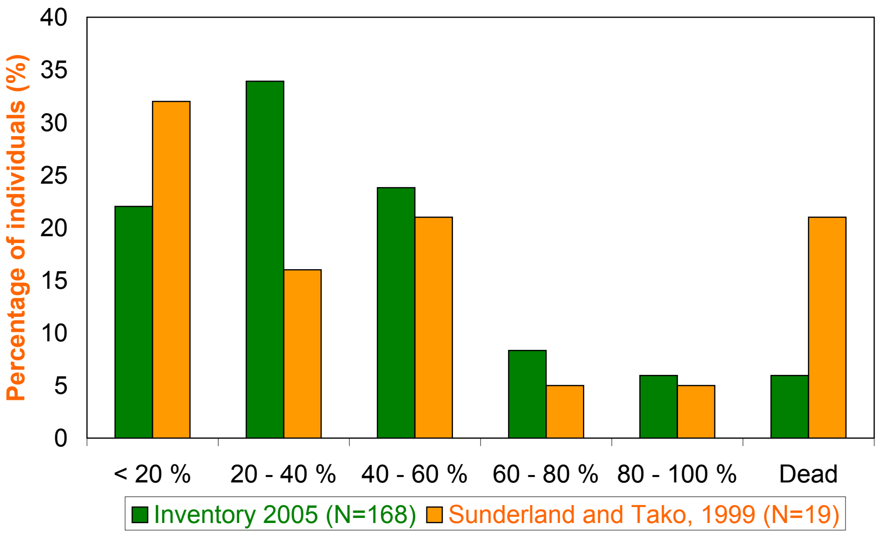


Figure 24 – Percentage of individuals according to crown defoliation categories of harvested and unharvested *Prunus africana* trees sampled on Pico de Basilé

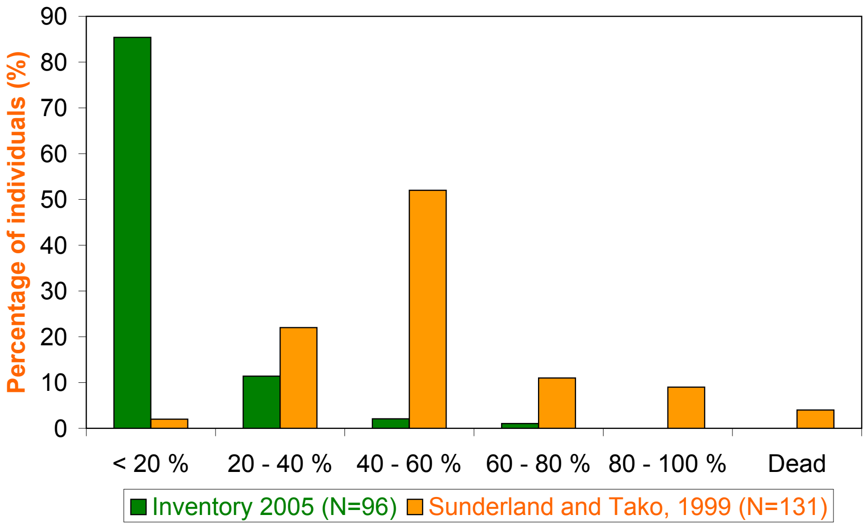


Figure 25 – Percentage of individuals according to crown defoliation categories of harvested and unharvested *Prunus africana* trees sampled in Moca

In general terms, judging by the results of the defoliation values found here, *Prunus africana* seems to show good recovery capacity following bark removal, as long as the proper techniques are used and the tree is left long enough for the bark to regenerate. Under these circumstances, the stress of harvest seems to cause a reversible loss of vigour, visible in partial defoliation of the crown, which later recovers as the bark regenerates. This would also explain the differences found in 2005 (Figure 25) compared to the results of defoliation percentages obtained in Moca by Sunderland and Tako (1999).

It must also be noted that the condition of the trees revealed differences in harvesters' skills. Experienced personnel worked on Pico de Basilé, while considerable damage to the cambium of recently harvested trees in Moca was detected because of failure to use the correct harmless techniques. This situation could generate a high level of stress in most of the individuals, eventually resulting in weakness and death. As for time to allow the bark to grow back, second harvests were underway in 2005 on Pico de Basilé (see Figure 22) without controlling rotation, which could bring about an increase of dead trees in subsequent years, particularly of those with over 40% defoliation.

7.9. Calculation of the Specific Weight of the Bark and Average Thickness by Diameter Class

Average weight of dry bark depending on diameter classes (see Figure 16) was calculated by taking the specific weight of *Prunus africana* bark, which was found to be 0.57 g cm^{-3}. Table 16 gives bark thickness values depending on DBH for trees that were still intact. As the table shows, the thickness figures in the present study are slightly lower than those found by Tonye *et al.* (2000). Nevertheless, bark thickness tends to increase noticeably with the diameter (age) of the tree, reaching 1.59 cm in diameter classes larger than 1 m.

Table 16 – *Prunus africana* bark thicknesses (average ± standard error) by DBH compared to those mentioned by Tonye *et al.* (2000)

DBH	N	Bark thickness (cm)	Bark thickness (cm) (Tonye *et al.*, 2000)
≤ 30	4	0.8 (0.05)	
30-40	11	0.96 (0.07)	1.1
40-50	14	1.06 (0.06)	1.2
50-60	9	1.08 (0.07)	1.3
60-70	5	1.22 (0.14)	1.4
70-80	6	1.29 (0.08)	1.5
80-90	—	—	1.5
90-100	3	1.39 (0.06)	1.5
≥ 100	20	1.59 (0.10)	1.5-1.7

7.10. Equations for Estimating Fresh Bark Yield

Prunus africana bark yield is proportionate to the diameter of the tree and the height at which the bark is removed. If the trunk is represented as a cylinder, the fresh bark harvested can be calculated by diameter class.

Table 17 shows the linear regression equation to relate the status variables DBH and harvest height (H) with fresh bark yield. The result is a high coefficient of correlation ($R^2 = 0.91$), validating the formula for a simple estimate of bark yield on the basis of inventory data. This calculation will give the kilos of dry bark produced by the average individual in each diameter class (Table 18), for unharvested trees.

Table 17 – Equation for linear estimate of *Prunus africana* bark yield (Q) by DBH and debarking height (H)

Equation	R	R^2	F	*P*
Q = -10.256 + 0.095 x DBH + 1.665 x H	0.95	0.91	789.43	<0.001

Table 18 gives the values obtained (kg tree^{-1}) on Bioko for bark weight – both fresh and dry – depending on diameter class, taking 0.57 g cm^{-3} as the specific weight of the bark, and an average thickness for each diameter class in accordance with Column 3 of Table 16. To calculate the average weight of dry, powdered bark, 50% loss was estimated to occur during the drying process (APRA, personal communication).

Table 18 – Estimated average (± standard error) weight of fresh and dry bark of *Prunus africana* individuals by DBH and average debarking height for each diameter class in an unharvested stand

DBH (cm)	Average debarking height (m)	Number of trees measured	Fresh weight (kg $tree^{-1}$)	Dry weight (kg $tree^{-1}$)
≤30	3.5	4	30.6 (4.0)	15.3 (2.0)
30-40	4.5	10	47.2 (8.4)	23.6 (4.2)
40-50	4	14	67 (4.6)	33.5 (2.3)
50-60	4.5	16	69.2 (5.0)	34.6 (2.5)
60-70	4.1	12	92.6 (8.1)	46.3 (4.1)
70-80	4.8	12	123 (16.0)	61.5 (8.0)
80-90	5.5	5	150.4 (22.6)	75.2 (11.3)
90-100	6.2	14	152.0 (14.0)	76.0 (7.0)
100-110	7.3	7	196 (26.0)	98.0 (13.0)
110-120	6	17	215.6 (18.2)	107.8 (9.1)
120-130	6.5	13	247.4 (28.0)	123.7 (14.0)
130-140	6.9	9	278.6 (46.2)	139.3 (23.1)
140-150	6.5	11	275.6 (41.8)	137.8 (21.4)
150-160	6.4	3	374.4 (98.6)	187.2 (49.3)
160-170	5.3	6	437.2 (19.2)	218.6 (9.6)
170-180	5.6	3	441.2 (48.6)	220.6 (24.3)
180-190	4.5	2	442.4 (56.2)	221.2 (28.1)
> 190	6.0	15	463.12 (46.2)	231.56 (23.1)

Diverse authors cite widely varying bark yield values, giving figures of 8, 27.8, 55, 85, and even above 200 kg (Ndam *et al.*, 2000). This extensive information is difficult to interpret, as it would be necessary to know whether the calculations considered the same variables in order to establish comparisons. The figures for Bioko differed greatly, as a function of the diameter class (15-231 kg $tree^{-1}$) and an average yield of dry bark per tree of 100.5 kg $tree^{-1}$. This value resulted from an estimated weighted average of the distribution of individuals by diameter classes and average yield by class, for a situation of complete harvest up to the mean heights shown in Table 18.

7.11. Equations for Estimating Bark Regeneration

Figure 26 shows a growth curve for *Prunus africana* bark (N = 27) depending on the number of years between harvests (return time). Results on bark thickness by DBH indicated that a thickness of 1 cm was attained at a DBH larger than 40 cm (see Table 16), and that the necessary return time would be from 8 to 10 years. Nevertheless, the central values of the sample are widely dispersed, which may mean that bark regeneration varies, and that it depends on other factors such as removal technique, genetic variability, and seasonal quality. Consequently, taking into account current harvest conditions among the trees studied, setting a return time of 8 to 10 years is recommended.

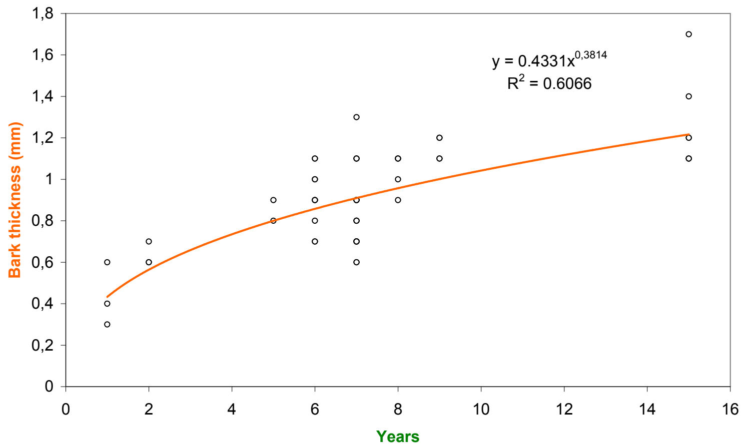


Figure 26 – Bark thickness by number of years since harvest on Pico de Basilé

7.12. Calculation of Potential *Prunus africana* Bark Yield in Harvest Areas

To calculate the average yield per ha, stem distribution was considered by diameter class. Taking this into account, average dry bark yield (kg ha^{-1}) was estimated for each harvest area (Table 19) according to the densities of each of the areas studied (see Tables 13 and 14) and the percentage distribution of individuals by diameter class (Figure 27).

Table 19 – Average yield of dry *Prunus africana* bark (kg ha^{-1}) by diameter class in the different harvest areas

Harvest area	Yield of the average tree (kg tree^{-1})	Density (stems ha^{-1})	Average dry bark yield by diameter class (kg ha^{-1})*
Pico de Basilé – high area	107.11	15.38	1647.35
Pico de Basilé – low area	115.92	2.65	307.19
Moca – low area	39.68	9.95	394.82
Moca – Monguibus	30.87	5.68	175.34
Moca – Biaó	35.04	6.37	223.21

* 50% fresh weight / dry weight yield

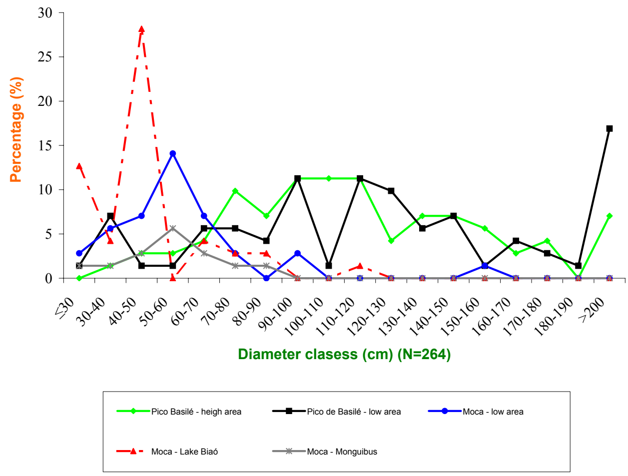


Figure 27 – Percentage distribution of *Prunus africana* individuals by diameter class in each of the harvest areas studied on Bioko

The harvest areas in the present study were figured as explained in Section 7.7; i.e., 2741 ha for Pico de Basilé and 457 ha for Moca, according to the following breakdown: Pico de Basilé high area (1622 ha), Pico de Basilé low area (1119 ha), Moca low area (282 ha), Moca-Monguibus (103 ha) and Moca-Biaó (72 ha). These results led to calculation of maximum potential dry bark yield for each harvest area (Table 20) based on the previously estimated total surface areas.

Table 20 – Maximum potential dry bark yield in harvest areas by total surface area, and average dry bark yield

Harvest area	Surface area (ha)	Average dry bark yield by diameter class * (kg ha^{-1})	Maximum potential dry bark yield (t)
Pico de Basilé – high area	1622	1647.35	2672.00
Pico de Basilé – low area	1119	307.19	343.75
Moca – low area	282	394.82	111.34
Moca – Monguibus	103	175.34	18.06
Moca – Biaó	72	223.21	16.07

* 50% Fresh Weight / Dry Weight Yield

A potential harvest quota was determined for the accessible sites using Ondigui's proposed equation (2001), assuming an unharvested stand:

$$Q = [A \times P \times RME \times Y \times V]\, F^{-1}$$

where:

Q = annual quota per management unit (kg of dry material)
A = harvest area (ha)
P = proportion of area exploited (%)
RME = minimum estimated density of *Prunus africana* in the harvest unit (trees ha^{-1})
Y = estimated yield per tree per harvest (kg of dry material per tree)
V = proportion of exploitable trees (%) (alive and not over-exploited)
F = return times (years)

Table 21 includes all the data that went into calculating the estimated annual potential yield per harvest area, for a theoretical situation of unharvested bark.

Factors considered in this calculation were the harvest area, the proportion of area under exploitation (P = 80%), *Prunus africana* density, the proportion of exploitable trees (P = 90%), estimated yield per tree, and two possible scenarios: a 10-year harvest cycle and an 8-year harvest cycle.

There are no records in the trade data of exports prior to 1995, when the species was listed on Appendix II. Monitoring of international trade began at that time. Table 22 shows trade in *Prunus africana* bark exported from Equatorial Guinea and imported by Spain, according to the UNEP-WCMC database.

Table 21 – Estimated potential annual dry bark yield for an unharvested stand, by surface area to be harvested, proportion of area exploited, *Prunus africana* density, estimated dry bark yield in current and new proposed harvest areas, proportion of trees exploited, and return times (F = 10 years and F = 8 years). Values for the new proposed harvest areas are shown in boldface type.

Working area	A Surface area harvested (ha)	P Proportion of area exploited (%)	RME *Prunus africana* density (stems ha^{-1})	Y Estimated yield per tree (kg $tree^{-1}$)	RME x Y Estimated dry bark yield[1] (kg ha^{-1})	V Proportion of exploitable trees (%)	Estimated potential bark yield[2] (t $year^{-1}$) in unharvested condition, depending on F (Nº of years between harvests)	
							F = 10 years	F = 8 years
Current areas							Current areas	Current areas
Pico de Basilé – high area	1622	80	15.38	107.11	1647.35	90	192.38	240.48
Pico de Basilé – low area	1119	80	2.65	115.92	307.19	90	24.74	30.93
Moca – low area	282	80	9.95	39.68	394.82	90	8.16	10.02
Moca – Monguibus	103	80	5.68	30.87	175.34	90	1.30	1.62
Moca – Lake Biaó	72	80	6.37	35.04	223.21	90	1.15	1.44
Total current areas[3]							227.73	284.49
New areas							**New areas**	**New areas**
Pico de Basilé – south area	1500 (estimated)	80	7.56 (estimated)	111.5 (estimated)	842.94 (estimated)	90	**91.03 (estimated)**	**113.79 (estimated)**
Pico de Basilé – east area	1000 (estimated)	80	7.56 (estimated)	111.5 (estimated)	842.94 (estimated)	90	**60.69 (estimated)**	**75.86 (estimated)**
Total with new areas[4]							**379.45**	**474.14**

[1] 50% estimated fresh bark-dry bark yield
[2] The average yield per hectare was calculated according to diameter class frequency in each harvest area.
[3] Values not including new potential harvest areas
[4] Values including new potential harvest areas

Table 22 – *Prunus africana* imports in the period 1995-2004. Source: UNEP-WCMC Database and the CITES Management Authority of Spain.

Year	Importing country	Country of origin	Unit	Quantity	Term
1996-1997	Spain	Equatorial Guinea	kg	569,200	powder
1998	Spain	Equatorial Guinea	kg	150,293 (719,493*)	powder
1999	Spain	Equatorial Guinea	kg	161,655	powder
2000	Spain	Equatorial Guinea	kg	224,659	powder
2001				0	
2002	Spain	Equatorial Guinea	kg	7521	powder
2003				0	
2004	Spain	Equatorial Guinea	kg	141,228	powder
TOTAL POWDER			kg	1,254,286	
TOTAL DRY BARK (90% dry bark / powder yield)			kg	1,393,651	

* Of this amount, 150,293 kg were real imports occurring in 1998 and 569,200 kg were traded under a retroactive permit covering the total amount of bark imported between the years 1994 and 1997. Source: CITES Management Authority of Spain.

The first record to appear is in 1998, for a total amount of 719,493 kg. The Spanish Management Authority reported that 150,293 kg out of that amount were actually imported in 1998, while the remaining 569,200 kg fell under a retroactive permit that covered the total amount of bark imported in the years 1996 and 1977. NATRA-APRA also reported on their records, which began in 1997. Both reports – by the company and by the Spanish Management Authority – register lower amounts than those recorded in the UNEP-WCMC database. A possible explanation for the difference in these figures may be that the amounts finally received in Spain were not as high as those shown on the permits. The estimate in Sunderland and Tako (1999) of 200 t exported annually could not be confirmed for the years 1992, 1993, and 1994. Perhaps the personal communication that gave rise to this estimate was referring to initial harvest of bark that would be exported in later years, and which was included in the retroactive permit issued by Spain covering imports between 1996 and 1997.

Along these lines, the company and the Spanish Management Authority confirmed that the merchandise actually imported in 2002 was powdered bark and not whole bark as shown on the UNEP-WCMC database. Only one company has existed in Equatorial Guinea with the concession to export bark, and it began trading under the permits mentioned above, registered in the UNEP-WCMC database for the period 1998-2004. From these data, total exports of ground dry bark were estimated to reach 1393 t, implying that average harvest was 199 t $year^{-1}$ over the 7 years of trade records.

Nearly all of this harvest took place on Pico de Basilé, although the low part of Moca was also harvested in 1998. In 2005, with a harvest area restricted by the road and by the inward distance (1.5 km), harvesting could be concluded to focus on trees that had already been debarked. This was visible in all the transects on Pico de Basilé, indicating that a second harvest (or even a third, on occasional trees) continued to be the practice in areas of easy access. Trees harvested for the first time were only a scattered few.

The main problem with this second harvest is that it occurred with no knowledge of the distribution of previous seasons' harvests, resorting to trees with scant bark regeneration, showing no regard for the years gone by since the first harvest. Under these circumstances, harvesters return to exploit trees in the field with only minimum bark regeneration (≤0.5 cm), at the consequent risk of causing damage that could potentially increase future mortality. Accordingly, it would be wise to provide these trees a rest period for the bark to regenerate properly.

In the case of Moca, the situation was different. Bark was removed during the year 1998, and exploitation resumed in 2005. In April 2005, harvest extended into new areas where the trees were still intact, specifically around Lake Biaó. Some stocks, albeit limited, will therefore be available for a second harvest.

The Monguibus location is the site of easiest access for the harvesters. The Moca lowland area is the one with the largest stocks, but many of the trees have already been exploited, meaning reduced potential yield and increased risk of mortality.

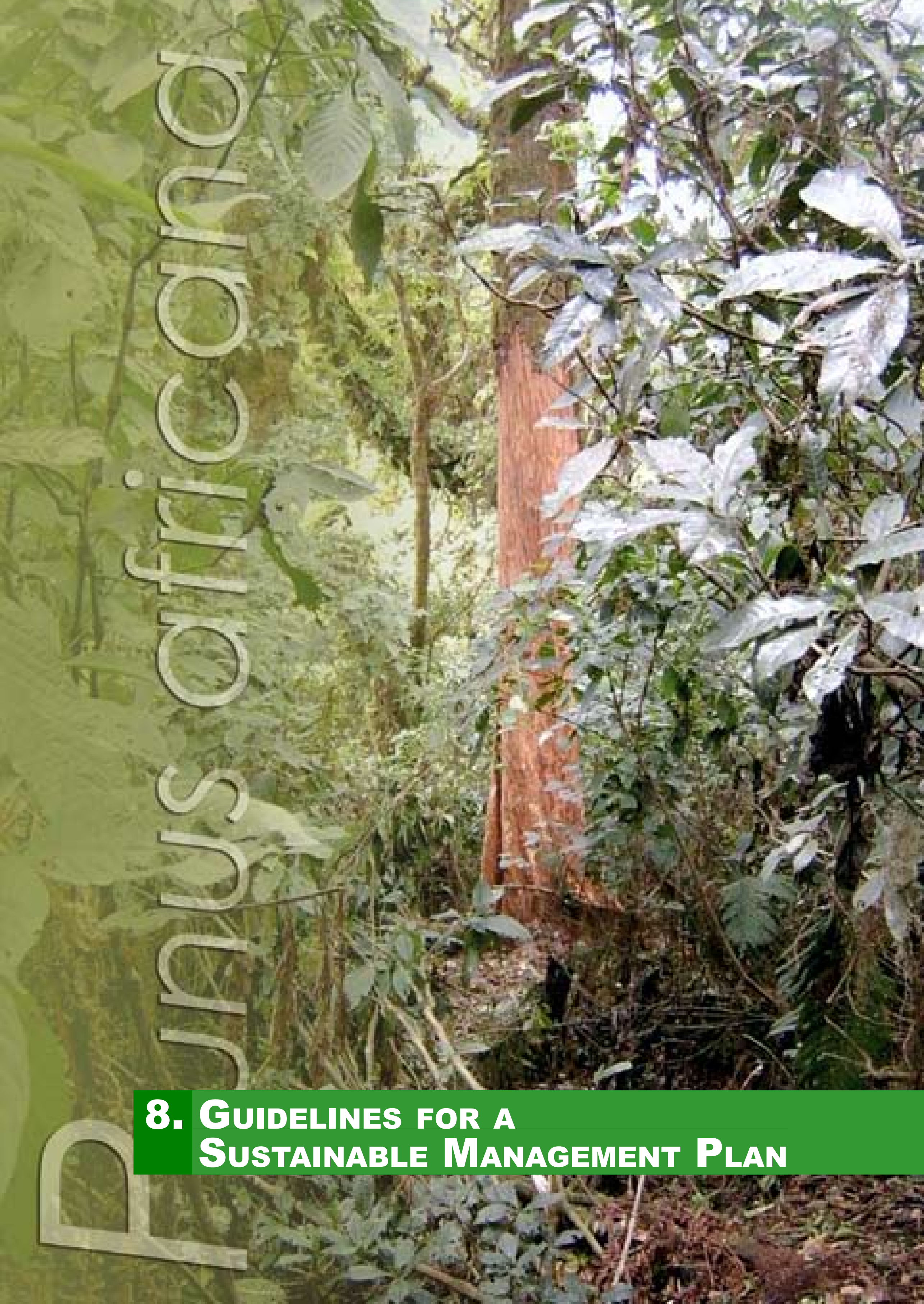
Finally, it must be indicated that two new harvest areas have been proposed (APRA personal communication) on southern and eastern Pico de Basilé. These sites have yet to be visited, and there are no previous surveys of their potential yield, but certain inferences could be drawn. These afromontane forests are arguably of comparable stand structure to those previously studied, where *Prunus africana* stem density is expected to be similar. Calculations in the present study were based on an estimated density of 7.58 stems ha^{-1} and a yield per tree of 111.5 kg, in light of the results obtained for the northern part of Pico de Basilé. Thus, a prediction of the new harvest areas may be offered. South Basilé would potentially bring a yield of 91.03 t $year^{-1}$ of dry bark with a 10-year return time, and 113.79 t $year^{-1}$ with an eight-year return time. East Basilé would produce 60.69 t $year^{-1}$ with a 10-year return time, and 75.86 t $year^{-1}$ leaving 8 years between harvests. It would be very important to perform the pertinent preliminary studies before beginning harvest activities, and to implement the precepts of a management plan from the very outset.

In short, for a theoretical situation of no previous exploitation and a return time of 10 years, the total potential yield of dry bark would be 227.73 t $year^{-1}$ in the current harvest areas, and 379.45 t $year^{-1}$ with the addition of the two new areas. Given an 8-year return time, it would be 284.49 t $year^{-1}$ in the current areas and 474.14 t $year^{-1}$ with the new ones. Under these circumstances, the recommended total annual quota for 2006 was designed to leave time for Pico de Basilé bark to regenerate, while counting on fewer stocks in the Moca and Lake Biaó lowland area that had already been harvested once. Table 23 compares estimated potential bark yield (t $year^{-1}$) in unharvested condition and the recommended quota for 2006 based on analysis of the status in current and new harvest areas, for return times of 10 and 8 years (see Table 21).

Table 23 – Estimated potential bark yield (t year^{-1}) in unharvested condition and recommended quota for 2006 following analysis of status in current and new harvest areas, considering 10-year and 8-year return times

Harvest area	Estimated potential bark yield (t yr^{-1}) in unharvested condition, depending on F (nº of yrs between harvests)		Recommended quota (t yr^{-1}) for 2006 following analysis of statusin current and new harvest areas	
	F = 10 yrs	F = 8 yrs	F = 10 yrs	F = 8 yrs
Current areas	Current areas	Current areas	Current areas	Current areas
Pico de Basilé highlands	192.38	240.48	0 (bark regeneration period)	0 (bark regeneration period)
Pico de Basilé lowlands	24.4	30.93	0 (bark regeneration period)	0 (bark regeneration period)
Moca lowlands	8.16	10.2	4.8 (2nd harvest)	5.1 (2nd harvest)
Moca Monguibus	1.30	1.62	1.30 (unharvested)	1.62 (unharvested)
Moca Lake Biaó	1.15	1.44	0.58 (2nd harvest)	0.72 (2nd harvest)
Total current areas	**227.73**	**284.49**	**5.96**	**7.35**
New areas	**New areas**	**New areas**	**New areas**	**New areas**
Pico de Basilé (south)	**91.03 (estimated)**	**113.79 (estimated)**	**91.03 (estimated)**	**113.79 (estimated)**
Pico de Basilé (east)	**60.69 (estimated)**	**75.86 (estimated)**	**60.69 (estimated)**	**75.86 (estimated)**
Total with new areas	**379.45**	**474.14**	**157.68**	**197**

The maximum annual dry bark quota recommended for 2006, with the addition of the new areas, would be 157.68 t year^{-1} considering a 10-year return time, and 197 t year^{-1} if the return time is set at 8 years. In the future, the areas already harvested should be monitored to see how their status evolves, and preliminary surveys conducted in the new areas. This would enable thorough harvest planning and establishment of subsequent annual quota proposals in the context of an overall management scheme.



8. Guidelines for a Sustainable Management Plan

8. Guidelines for a Sustainable Management Plan

Figure 28 summarises the stages of a management strategy (adapted from Wong, 2000) that can be adjusted periodically, as harvest of non-timber forest products is evaluated for sustainability. This outline is synoptic of the main results and conclusions of the present project, including analyses of the advantages and disadvantages of the current situation, to guide possible improvements and final recommendations for consideration in designing a Management Plan.

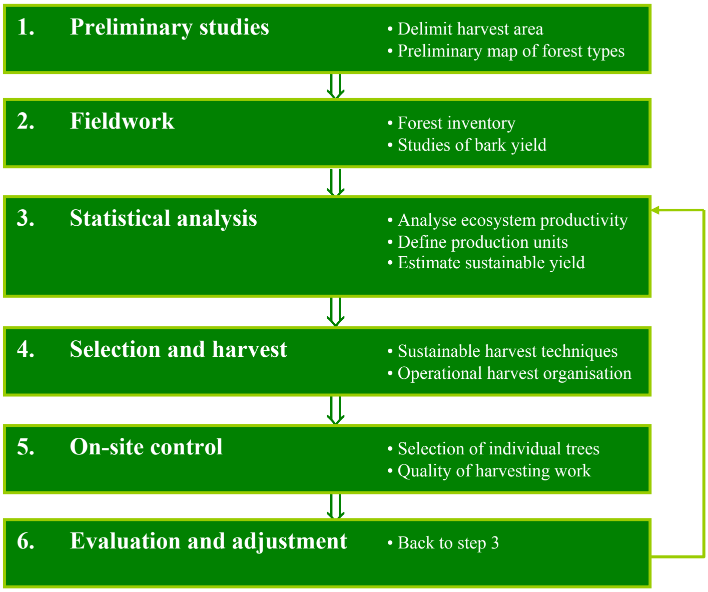


Figure 28 – Stages of a modular management strategy for sustainable harvest of non-timber forest products (adapted from Wong, 2000)

8.1. Definition and Preliminary Mapping of Harvest Areas

According to the supervised classification of Landsat-7 ETM image data and the established altitude range (1400-2500 m), the total surface area of potential distribution would be 21,620.12 ha, mostly located on Pico de Basilé (14,492.37 ha) with the remaining 7127.75 ha divided between Moca (3559 ha) and Caldera de Luba (3568 ha). This may seem a large area in theory, but it became obvious in the course of fieldwork that access to this area was severely limited due to problems of topography, legal authorisation, etc.

Bioko harvest areas include the two existing sites, Moca and Pico de Basilé, and two proposed new areas. The existing sites are the lowlands (where only a very small part has been exploited, for reasons of accessibility and probably also because of sacred connotations for the Bubi population) and the Monguibus area near Moca, and northern Pico de Basilé. The proposed new areas are the Moeri highlands and the Basacate highlands, both in the southern and eastern foothills of Pico de Basilé. Estimating accessibility, and considering maximum harvesting distances of 2-4 km to be economically feasible, it would appear difficult to reach more than 2500 ha in these two new sectors.

Considering the established altitude range containing the species (1400-2500 m) and the harvesters' access area, which amounted to 1.5 km on both sides of the road (see Figure 20), the size of the current harvest area could be calculated. Using these criteria and excluding the fire-razed parts (60 ha), this area was found to be 2741 ha for Pico de Basilé.

Although earlier studies (Guinea, 1949) described a change in vegetation at 1800 m.a.s.l., the results of the present study led to setting the limit at 1900 m.a.s.l. between the lowlands and the highlands of northern Pico de Basilé. The lowlands (1119 ha) encompassed two of the vegetation classes in the supervised classification: Guineo-Congolian rainforest mixed with afromontane elements and secondary afromontane forest, while the highlands (1622 ha) were characterised by araliaceous forest.

In the Moca area, as with Pico de Basilé, potential distribution of pygeum was encountered above 1400 m (see Figure 21). Stands exhibited greater heterogeneity due to disturbances of an anthropic nature, such as the presence of cattle on the hillsides of Pico Biaó, and specific characteristics of its crater; orientation and moisture, owing to its topographic configuration (2009 m.a.s.l.). This area has undergone human-induced alterations that have greatly reduced the actual forest distribution compared to original suppositions. Data from the fieldwork for this study and basic map identification (1: 50,000) were used to estimate current harvest areas: 72 ha (Lake Biaó), 103 ha (Monguibus) and 282 ha (lowland area near Moca).

Table 24 summarises the status of current and possible new harvest areas on Bioko. The map in Figure 29 puts these locations into perspective.

Table 24 – Current and potential *Prunus africana* bark harvest areas on Bioko

Harvest area	Surface area (ha)	Density (stems/ha^{-1})	Access	Current status
Pico de Basilé – high area	1622	15.38	road	Needs rest period
Pico de Basilé – low area	1119	2.65	road	Needs rest period
Moeri highlands (south area)	1500 (estimated)	7.56 (estimated)	no access	Unharvested
Bacake highlands (east area)	1000 (estimated)	7.56 (estimated)	no access	Unharvested
Moca – Biaó	72	6.37	lane	Second harvest planned
Moca – low area	282	9.95	road	Second harvest planned
Moca – Monguibus	103	5.68	lane	Unharvested

Figure 29 – Locations of current and potential *Prunus africana* bark harvest areas on Bioko

Having defined the harvest areas, a series of analyses and recommendations should be taken into account in designing a Management Plan. These are expressed in Tables 25 and 26.

Table 25 – Analysis of *Prunus africana* bark harvest areas on Bioko

Harvest area	Advantages	Disadvantages
Pico de Basilé – high area	Existing access passable year-round (currently under repair) Short distance to Malabo	Needs regeneration period; exhausted Need to extend harvesting distance from road (3-4 km)
Pico de Basilé – low area	Existing access passable year-round (currently under repair) Short distance to Malabo	Needs regeneration period Need to extend harvesting distance from road (3-4 km)
Pico de Basilé – south area	Unharvested resource Harvesting distance from road (0-2 km)	Access to new wild areas Access partially marked (it seems there is an access route) New lanes open for harvest Not passable year-round Greater distance to Malabo
Pico de Basilé – east area	Unharvested resource Harvesting distance from road (0-2 km)	Access to new wild areas Access not marked (there does not seem to be an access route) New lanes open for harvest Not passable year-round Greater distance to Malabo
Moca – low area	Existing access passable year-round (near town) Furthest point from Malabo (2-3 hours)	Second harvest, regeneration period therefore planned
Moca – Monguibus	Unharvested resource Harvesting distance from road (2-3 km) with lanes open Furthest point from Moca (1 hour by tractor)	Difficult topography Scant stocks; few young trees
Moca – Biaó	Harvesting distance from road (2-3 km) with lanes open Medium-sized stocks Furthest point from Moca (1 hour by tractor)	Difficult topography, particularly north of the Lake Partial harvest, limited stocks

Table 26 – Recommendations on harvest areas for sustainable use of *Prunus africana*

Recommendations	Remarks	Who is responsible
Make preliminary study of new harvest areas based on existing cartographic information to determine surface area for harvesting	This should be conditioned on knowledge of *Prunus africana* stocks, but the simplest way is to base it on the vegetation map	Responsible Ministries / NATRA-APRA
Plan layout of access routes to take best advantage of the entire potential area and minimise secondary environmental impacts	Opening new routes may have a very significant impact on wild populations, particularly of primates	Government of Equatorial Guinea / NATRA-APRA
Limit people's access to new routes	Casual access exists, largely of military personnel, and of residents for hunting activities to a lesser extent	Government of Equatorial Guinea
Do not use routes in the winter		NATRA-APRA

8.2. Forest Inventory

Inventories taken to determine the abundance of *Prunus africana* in the two areas where bark is currently harvested provide precise data on the stocks in each sector (Table 27).

Table 27 – *Prunus africana* density and distribution values (%) by diameter classes

Zone	*Prunus africana* (stems ha^{-1})	≤40 cm	40-60 cm	80-100 cm	100-120 cm	120-140 cm	140-160 cm	160-180 cm	180-200 cm	>200 cm
						%				
Pico Basilé	**7.56**									
Low area	2.65	1.41	5.63	14.08	18.31	22.54	11.27	12.68	7.04	7.04
High area	15.38	8.45	2.82	11.27	15.49	12.68	15.49	8.45	7.04	18.31
Moca	**6.82**									
Pico Biaó	6.37	16.90	28.17	7.04	2.82	1.41	0.00	0.00	0.00	0.00
Monguibus	5.68	2.82	8.45	4.23	1.41	0.00	0.00	0.00	0.00	0.00
Low area	9.95	8.45	21.13	9.86	2.82	0.00	0.00	1.41	0.00	0.00

Prunus africana stands showed great heterogeneity due to factors that are difficult to pinpoint, such as ecological variations, natural forest dynamics, or historic use patterns. This led to a selection of five different zones: two on Pico de Basilé and three in Moca. Abundance varied significantly; more on Basilé than in Moca. The average abundance per zone, however, remained relatively constant (7.5-6.8 stems ha^{-1}), which are very high values compared to other natural populations studied, meaning these forests can be considered rich in this species. It is important to highlight the imbalance found in the distribution of *Prunus africana* diameter classes, as other authors had indicated (Cunningham and Mbenkum, 1993; Sunderland and Tako, 1999). Those of harvest size are recorded in Table 27 (≥30 cm). The values derived from this inventory may need to be qualified somewhat, given the intrinsic difficulty of the work and the distribution of the species. In any case, the results are quite reliable, particularly by comparison with other available inventories taken on Bioko and in other parts of Africa.

Table 28 gives an analysis of the advantages and disadvantages associated with current stocks, and Table 29 offers the most important recommendations to ensure success of a Management Plan. Both tables are based on the data from the forest inventory conducted for this study.

Table 28 – Analysis of *Prunus africana* stand structure in present and future harvest areas

Harvest area	Advantages	Disadvantages
Pico de Basilé – high area	Very high abundance Trees with medium-high diameters	Lacking regeneration and young trees
Pico de Basilé – low area	Low density but may be harvested	Trees are widely dispersed, greatly lengthening harvesting distances
Pico de Basilé – south area	No data	No data
Pico de Basilé – east area	No data	No data
Moca – low area	Medium-high density	Medium-sized trees
Moca – Monguibus	Medium-high density	Small-medium-sized trees
Moca – Biaó	Medium-high density Trees with medium-high diameters	Lack of regeneration

Table 29 – Recommended fieldwork for sustainable use of *Prunus africana* bark

Recommendations	Remarks	Who is responsible
Review inventory criteria cross-referencing existing information	See inventory models by group	Responsible Ministries / NATRA-APRA
Take inventory of the two new areas before beginning harvest	This would be highly advisable even before opening access routes, although it would be complicated	NATRA-APRA
Mark inventory areas in the field to define basic production units	The basic production units will be those that produce an amount of bark within the annual quota	NATRA-APRA
Label all trees during inventory with aluminium tags numbered at the base	Optimises inventory work and allows for proper control of the harvest, which is a basic requirement for any certification process	NATRA-APRA

8.3. Bark Yield and Calculation of Estimated Yield by Zones

The inventory taken as a part of this project provided the basis for a thorough study of potential bark yield in the current harvest areas. The specific weight of the bark was established at 0.57 g cm^{-3} and used as a parameter in determining bark yield. Bark thickness varied from 0.8 to 1.5 cm depending on the diameter class, which was consistent with figures shown in the literature consulted, if slightly lower (Tonye *et al.*, 2000). These data made it possible to calculate dry bark yield by diameter class and debarking height, which oscillated between 15 kg $tree^{-1}$ (diameter ≤30 cm) and 231 kg $tree^{-1}$ (diameter ≥200 cm) (see Table 18). Estimation of average dry bark weight was based on a 50% weight loss in the drying process (APRA, personal communication). Average yield per ha was established considering stem distribution by diameter class (Table 30).

Table 30 – Average dry bark yield per ha for current and potential harvest areas according to distribution of diameter classes

Harvest area	Yield of the average tree (kg tree^{-1})	Density (stems ha^{-1})	Average dry bark yield (kg ha^{-1})
Pico de Basilé – high area	107.11	15.38	1647.35
Pico de Basilé – low area	115.92	2.65	307.19
Pico de Basilé – south area	111.5 (estimated)	7.56 (estimated)	842.94
Pico de Basilé – east area	111.5 (estimated)	7.56 (estimated)	842.94
Moca – low area	39.68	9.95	394.82
Moca – Monguibus	30.87	5.68	175.34
Moca – Biaó	35.04	6.37	223.21

The harvest areas in the present study were figured as explained in Section 7.7; i.e., 2741 ha for Pico de Basilé and 457 ha for Moca, according to the following breakdown: Pico de Basilé high area (1622 ha), Pico de Basilé low area (1119 ha), Moca low area (282 ha), Moca-Monguibus (103 ha) and Moca-Biaó (72 ha). The proposed new areas in the southern and eastern foothills of Pico de Basilé were estimated to reach 2500 ha, given maximum harvesting distances and accessibility. Maximum potential dry bark yield of each harvest site was determined on the basis of the previously estimated total surface areas (Table 31).

Table 31 – Maximum potential dry bark yield of harvest sites by total surface area and average dry bark yield

Harvest site	Surface area (ha)	Average dry bark yield by diameter classes * (kg ha^{-1})	Maximum potential dry bark yield (t)
Pico de Basilé – high area	1622	1647.35	2672.00
Pico de Basilé – low area	1119	307.19	343.75
Pico de Basilé – south area	1500 (estimated)	842.94 (estimated)	1264.41 (estimated)
Pico de Basilé – east area	1000 (estimated)	842.94 (estimated)	842.94 (estimated)
Moca – low area	282	394.82	111.34
Moca – Monguibus	103	175.34	18.06
Moca – Biaó	72	223.21	16.07

* 50 % fresh weight / dry weight yield

Growth of *Prunus africana* bark estimated by harvest seasons indicated that it would take the trees 8-10 years to regenerate the minimum bark thickness for a second harvest. Data on productivity enabled analysis of the advantages and disadvantages of the current situation (Table 32), and the most important recommendations to ensure success of a Management Plan (Table 33).

Table 32 – Analysis of the status of *Prunus africana* bark stocks on Bioko

Harvest area	Advantages	Disadvantages
Pico de Basilé – high area	Maximum potential yield	Needs regeneration period
Pico de Basilé – low area	Low yield	Needs regeneration period
Pico de Basilé – south area	High estimated yield values Not harvested	Harvesting should be done under different conditions from current ones
Pico de Basilé – east area	High estimated yield values Not harvested	Harvesting should be done under different conditions from current ones
Moca – low area	Medium-low yield	Last viable harvest before rest period Regulation should be established
Moca – Monguibus	Low yield	Harvesting should be done under different conditions from current ones
Moca – Biaó	Low yield	Partially harvested Harvesting should be done under different conditions from current ones

Table 33 – Recommended studies on *Prunus africana* bark yield to enhance current knowledge

Recommendations	Remarks	Who is responsible
Calculate specific weight with varying moisture content		NATRA-APRA
Make more detailed study of real production per tree in the field	The very harvest activity itself may be used	NATRA-APRA
Clearly establish the yield of the entire drying and grinding process up to shipment		NATRA-APRA

Recommendations	Remarks	Who is responsible
Calculate potential production of new areas with data derived from inventory	Improve and extend calculation of bark parameters	Responsible Ministries / NATRA-APRA

8.4. Definition of Production Units and Estimate of Harvest Quotas

The harvest areas in the present study were figured as explained in Section 7.7; i.e., 2741 ha for Pico de Basilé and 457 ha for Moca, according to the following breakdown: Pico de Basilé high area (1622 ha), Pico de Basilé low area (1119 ha), Moca low area (282 ha), Moca-Monguibus (103 ha) and Moca-Biaó (72 ha). The proposed new areas in the southern and eastern foothills of Pico de Basilé were estimated to reach 2500 ha, given maximum harvesting distances and accessibility.

Table 34 includes all the data that went into calculating the estimated annual potential yield per harvest area, for a theoretical situation of unharvested bark. Factors considered were the harvest area, the proportion of area under exploitation (P = 80%), *Prunus africana* density, the proportion of exploitable trees (P = 90%), estimated yield per tree, and two possible scenarios: a 10-year harvest cycle and an 8-year harvest cycle. A potential harvest quota was determined for the accessible sites using Ondigui's proposed equation (2001), assuming an unharvested stand.

The final proposal for a recommended quota took the following aspects of the current situation into account:

Exports reported in accordance with CITES regulations appeared in 1998 and ceased over the period 1999-2002. The authors of the present study, however, believe they had begun in 1996, and that average annual harvest was 199 t. Nearly all of this harvest took place on Pico de Basilé, although the low part of Moca was also harvested in 1998.

In 2005, with a harvest area restricted by the road and by the inward distance (1.5 km), harvesting could be concluded to focus on trees that

Table 34 – Estimated potential annual dry bark yield for an unharvested stand, by surface area to be harvested, proportion of area exploited, *Prunus africana* density, estimated dry bark yield in current and new proposed harvest areas, proportion of trees exploited, and return times (F = 10 years and F = 8 years). Values for the new proposed harvest areas are shown in boldface type.

Harvest area	A Surface area to be harvested (ha)	P Proportion of area exploited (%)	RME *Prunus africana* density (stems ha^{-1})	Y Estimated yield per tree (kg $tree^{-1}$)	RME x Y Estimated dry bark yield[1] (kg ha^{-1})	V Proportion of exploitable trees (%)	Estimated potential bark yield[2] (t $year^{-1}$) in unharvested condition, depending on F (nº of years between harvests) F = 10 years	F = 8 years
Current areas							Current areas	Current areas
Pico de Basilé high area	1622	80	15.38	107.11	1647.35	90	192.38	240.48
Pico de Basilé low area	1119	80	2.65	115.92	307.19	90	24.74	30.93
Moca low area	282	80	9.95	39.68	394.82	90	8.16	10.02
Moca Monguibus	103	80	5.68	30.87	175.34	90	1.30	1.62
Moca Lake Biaó	72	80	6.37	35.04	223.21	90	1.15	1.44
Total current areas[3]							227.73	284.49
New areas							**New areas**	**New areas**
Pico de Basilé – south area	1500 (estimated)	80	7.56 (estimated)	111.5 (estimated)	842.94 (estimated)	90	**91.03 (estimated)**	**113.79 (estimated)**
Pico de Basilé – east area	1000 (estimated)	80	7.56 (estimated)	111.5 (estimated)	842.94 (estimated)	90	**60.69 (estimated)**	**75,86 (estimated)**
Total with new areas[4]							**379.45**	**474.14**

[1] The estimated yield from fresh bark to dry bark was 50%.
[2] The average yield per hectare was calculated according to the frequency of diameter classes in each harvest area.
[3] Values not including new potential harvest areas
[4] Values including new potential harvest areas

had already been debarked. This was visible in all the transects on Pico de Basilé, indicating that a second harvest (or even a third, on occasional trees) continued to be the practice in areas of easy access. Trees harvested for the first time were only a scattered few.

The main problem with this second harvest is that it occurred with no knowledge of the distribution of previous seasons' harvests, resorting to trees with scant bark regeneration, showing no regard for the years gone by since the first harvest. Under these circumstances, harvesters return to exploit trees in the field with only minimum bark regeneration (≤0.5 cm), at the consequent risk of causing damage that could potentially increase future mortality. Accordingly, it would be wise to provide these trees a rest period for the bark to regenerate properly.

In April 2005, harvest extended into new areas where the trees were still intact, leaving some – albeit limited – stocks, particularly around Lake Biaó, for a second harvest. The Monguibus location is the site of easiest access for harvesters. The Moca lowland area holds the largest stocks, but many of these trees have already been exploited, meaning reduced potential yield and increased risk of mortality.

As for the two new harvest areas, although they have yet to be visited and there are no previous surveys of their potential yield, it could be inferred that these are similarly structured afromontane forests. Therefore, *Prunus africana* stem density should be comparable to that of stands in the areas studied. Estimates here were based on a density value of 7.58 stems ha^{-1} and a yield per tree of 111.5 kg, in light of the results obtained for the northern part of Pico de Basilé. Thus, predictions for the new harvest areas may be offered. South Basilé would potentially bring a yield of 91.03 t $year^{-1}$ of dry bark with a 10-year return time, and 113.79 t $year^{-1}$ with an eight-year return time. East Basilé would produce 60.69 t $year^{-1}$ with a 10-year return time, and 75.86 t $year^{-1}$ leaving 8 years between harvests. It would be very important to perform the pertinent preliminary studies before beginning harvest activities, and to implement the precepts of a management plan from the very outset.

In short, for a theoretical situation of no previous exploitation and a return time of 10 years, the total potential yield of dry bark would be 227.73 t year^{-1} in the current harvest areas, and 379.45 t year^{-1} with the addition of the two new areas. Given an 8-year return time, it would be 284.49 t year^{-1} in the current areas and 474.14 t year^{-1} with the new ones.

Under these circumstances, the recommended total annual quota for 2006 was determined considering that bark would require a rest period in order to regenerate on Pico de Basilé, while bearing in mind that one harvest in the Moca and Lake Biaó lowland area had already reduced available stocks. Table 35 compares estimated potential bark yield (t year^{-1}) in unharvested condition and the recommended quota for 2006 based on analysis of the status in current and new harvest areas, for return times of 10 and 8 years (see Table 34).

The maximum annual dry bark quota recommended for 2006, with the addition of the new areas, would be 157.68 t year^{-1} considering a 10-year return time, and 197 t year^{-1} if the return time is set at 8 years. In the future, the areas already harvested should be monitored to see how their status evolves, and preliminary surveys conducted in the new areas. This would enable thorough harvest planning and establishment of subsequent annual quota proposals in the context of an overall management scheme.

Production units were defined, estimating their capacity for sustainable harvest. This enabled analysis of the advantages and disadvantages of the current situation (Table 36), as well as the most important recommendations to ensure success of a Management Plan (Table 37).

8.5. Harvest Technique

Harvest technique is one of the most critical points, as the trees' vigour and survival into the future depends on it. Current debarking procedures continue to follow the traditional method of totally peeling the trunk. Bark is removed from a height of 1 m up to the highest point the workers can reach, which averages between 3 and 6 metres. The first metre is usually

Table 35 – Estimated potential bark yield (t year^{-1}) in unharvested condition and recommended quota for 2006 following analysis of status in current and new harvest areas, considering 10-year and 8-year return times

Harvest area	Estimated potential bark yield (t yr^{-1}) in unharvested condition depending on F (nº of yrs between harvests)		Recommended quota (t yr^{-1}) for 2006 following analysis of status in current and new harvest areas	
	F = 10 yrs	F = 8 yrs	F = 10 yrs	F = 8 yrs
Current areas	Current areas	Current areas	Current areas	Current areas
Pico de Basilé high area	192.38	240.48	0 (bark regeneration period)	0 (bark regeneration period)
Pico de Basilé low area	24.74	30.93	0 (bark regeneration period)	0 (bark regeneration period)
Moca low area	8.16	10.02	4.08 (2nd harvest)	5.01 (2nd harvest)
Moca Monguibus	1.30	1.62	1.30 (unharvested)	1.62 (unharvested)
Moca Lake Biaó	1.15	1.44	0.58 (2nd harvest)	0.72 (2nd harvest)
Total current areas	**227.73**	**284.49**	**5.96**	**7.5**
New areas	**New areas**	**New areas**	**New areas**	**New areas**
Pico de Basilé – south area	**91.03 (estimated)**	**113.79 (estimated)**	**91.03 (estimated)**	**113.79 (estimated)**
Pico de Basilé – east area	**60.69 (estimated)**	**75.86 (estimated)**	**60.69 (estimated)**	**75.86 (estimated)**
Total with new areas	**379.45**	**474.14**	**157.68**	**197**

left unharvested, although some trees had been completely stripped from the ground up. Harvest goes largely uncontrolled, technically, although it is more careful on Basilé than in the Moca area, which could cause a strong impact on these trees in upcoming years.

It was common practice to debark above a height of one metre from the base of the trunk. The bark closest to the ground was left intact on most of the trees studied in the Pico de Basilé area, although this was not

Table 36 – Analysis of present status of current and potential *Prunus africana* bark harvest areas on Bioko

Harvest area	Advantages	Disadvantages
Pico de Basilé – high area	—	Needs regeneration period
Pico de Basilé – low area	—	Needs regeneration period
Pico de Basilé – south area	High estimated yield values Not harvested	Harvesting should be done under different conditions from current ones Accessibility
Pico de Basilé – east area	High estimated yield values Not harvested	Harvesting should be done under different conditions from current ones Accessibility
Moca – low area	Medium-low yield Accessibility	Last viable harvest; needs rest period Regulations should be established
Moca – Biaó	Low yield Campsite installed	Partially harvested Harvesting should be done under different conditions from current ones
Moca – Monguibus	Low yield Campsite installed	Harvesting should be done under different conditions from current ones

always the case in the other areas. Machetes were the only tools seen to cut off the bark.

Harvest technique obviously must be considered most carefully. An excellent starting point can be found in the numerous proposals put forward for Cameroon, which seem to have improved harvesting conditions in that country, but observations made in the course of fieldwork on Bioko and data obtained in this study have led to reconsideration of some aspects contained in those proposals. The following suggestions are offered:

- Remove bark with machetes, since they seem to be the tools the workers handle best, giving them better control so as not

Table 37 – Recommendations on current and potential harvest areas with a view to a *Prunus africana* Management Plan for Bioko

Recommendations	Remarks	Who is responsible
Calculate potential production of new areas with data derived from inventory	New work on bark parameters is necessary	NATRA-APRA
Carry out precise zoning of harvest areas in accordance with the annual quota	Indiscriminate harvesting must be avoided	Responsible Ministries / NATRA-APRA
Select the location and layout of the campsite to meet the needs of the harvest areas	It is advisable to provide the necessary infrastructure for harvest at the outset (access route and campsite)	NATRA-APRA
Correct signposting of harvest areas and producing trees	Harvest should follow certification standards	Responsible Ministries / NATRA-APRA
Give time for bark to regenerate in current harvest areas on Pico de Basilé	Harvesting is more intense in areas near the road, where second and third harvests have been recorded	Responsible Ministries / NATRA-APRA

to damage the cambium. Use of any tool that is aggressive to the cambium should not be permitted.

- Begin cutting at a height of approximately 1 m above the ground, or just above the ridges (where present).
- Increase the minimum diameter for harvest to trees with ≥40 cm DBH.
- The technique of totally stripping the bark does not seem to cause massive tree mortality (<6%), as this species has shown a great capacity for bark regeneration. Therefore, the system of debarking by quarters or eighths does not seem very operational. An intermediate alternative would be to leave a section of about 20% of the perimeter intact.

- Another alternative that might be advisable is to remove 50 % of the bark with each "peeling," leaving a rotation period of 5 years between each harvest. In any case, this is a matter for discussion, relating to the effectiveness of the system.
- Mark trees, setting a recommended return time of 8 years.
- Condition any second harvest on the vigour of the stands. Trees with over 40% defoliation should not be harvested.
- Suspend harvesting activities during the rainy season, given the high risk of rotting, as well as practical considerations (accessibility, workers' welfare, etc.) that make work ill advised at this time.
- Leave some trees in the harvest areas for seed. One sole harvest of 1 tree in every 10 (≥60 cm) is recommended, not harvesting one tree in every 20 (≥60 cm).

Recommended harvest techniques are formulated in Table 38.

Table 38 – Recommendations on implementation of basic guidelines for a *Prunus africana* bark harvesting protocol on Bioko

Recommendations	Remarks	Who is responsible
Establish a strict protocol for bark harvest techniques	The recommendations proposed in this survey are suggested as a start, to validate results over 2 years	Government of Equatorial Guinea
Establish a control plot for harvest techniques		Government of Equatorial Guinea

8.6. Operational Harvest Organisation

There has been much insistence upon the importance of establishing an appropriate harvest protocol, but having this information is clearly insufficient without a good operational organisation in the field, since the workers are the ones who are ultimately responsible for harvest procedures. Surprisingly, earlier studies only discussed this aspect in very general terms, although it is a crucial element in any Management Plan.

True, socioeconomic conditions (property, social organisation, traditional uses, etc.) differ widely from one country to another, and it is impossible to propose an operational organisation that fits them all. Nevertheless, distinguishing the particularities of each situation, it is fundamental to consider this aspect, either through free harvest systems by communities, or in systems organised by a harvesting company, as in the case of Equatorial Guinea.

Focusing analysis on Bioko, the current operational organisation obviously needs improvement. Comments on this issue are summarised below:

- Selecting and training field workers. Harvesters who initially have an acceptable level of previous experience carry out field chores on Basilé, but Moca personnel are largely inexperienced in this type of work. In Pico Basilé these labourers are organised in a harvesting group with a foreman who is also a bark harvester. This person is usually elected on the basis of his experience and authority. Moca harvesters, by contrast, have no prior experience, and the supervisor's real authority over the group is negligible. Harvesters need to be trained, raising their awareness of the task they are going to perform and of the responsibility involved.
- Organising harvesting chores. Each labourer sets out to cover one of the harvest areas, identify the trees, and remove the bark. The debarking method is the sole responsibility of the harvester. Depending on his own criteria and any recommendations received, he will do the job one way or another. The group foreman also has his own harvesting duties. His capacity to control the others is therefore limited, and his influence over the rest of the group depends on his personal leadership skills. The distance the workers must travel varies, but the main route may be several kilometres long, and then they still have the 2-4 km harvest lane to go.

Once harvest is completed, the labourers fill sacks with the bark and carry them to the tractor access points. The sacks, weighing between 30 and 50 kg, are then piled up by the side of the access route where they are later collected. At times, topographic conditions and harvesting distances can understandably make it an arduous task to take the sacks to the collection points, which can greatly reduce harvest yield, not to mention the workers' benefits.

- Logistics of harvesting chores. Harvesting work revolves around a campsite where the workers stay throughout the entire harvest period (1-2 weeks of continuous work). The company supplies food and covers the workers' basic needs, attempting to provide appropriate conditions.
- Lines of responsibility and control. These are handed down from the local APRA authorities through an APRA staff worker, to a local agent, to one person responsible for the group or foreman, who is not an APRA staff worker, and finally to the harvesters. The foreman's and harvesters' earnings are directly proportionate to the amount of bark harvested. No official bodies control quality, nor does the company. In the course of fieldwork, the team was accompanied by several specialists from the pertinent Ministries, who in some cases were very familiar with the area from previous visits, but did not know about the current bark harvesting situation.
- Remuneration for the work. Considering harvesters alone, their salary depends on the amount of bark they bring to the collection points on the access route, at a price of 75 CFA/kg (676 CFA = 1 €).

This is not intended to describe the process in minute detail, but it helps to recommend changes that would be necessary to ensure sufficient operational capacity for a sustainable management plan to be successful. The most relevant recommendations (Tables 39 and 40) are enumerated as follows:

Table 39 – Analysis of operational organisation in current *Prunus africana* bark harvest areas on Bioko

Harvest area	Strengths	Weaknesses
Pico de Basilé – high and low areas	Experienced groups Group coordinator with leadership skills	Lack of training Piecework Limited supervision of workers Uneven work
Pico de Basilé – south area	—	—
Pico de Basilé – east area	—	—
Moca – low area	Direct control by Moca Mayor Good familiarity with harvest areas	Lack of training Piecework Second harvest
Moca – Monguibus	Campsite available	Lack of training Piecework Very difficult to supervise workers Very sensitive area
Moca – Biaó	Campsite available	Lack of training Piecework Very difficult to supervise workers Very sensitive area

- Labourers should be appropriately selected and receive preliminary training, possibly by experienced harvesters. The workers should be paid monetary incentives according to the quality of their harvesting work.
- The group supervisor should be a NATRA-APRA employee who should not have to perform harvesting chores. His main function would be to control harvest areas, debarked trees, and harvesting techniques, and provide support for the workers. He would not receive incentives for the quantity of bark harvested, but for the quality of the harvesting work.
- Workers should have marked itineraries and pre-marked trees to harvest. By no means should they have to make

Table 40 – Recommended operational organisation for sustainable harvest of *Prunus africana* bark on Bioko

Recommendations	Remarks	Who is responsible
Clearly define the operational organisation for harvest activities	The proposal made in this survey is suggested as a starting point, to be validated during 2 years	Government of Equatorial Guinea / NATRA-APRA
Select and train a Guinean overseer for technical and operational supervision of work		Government of Equatorial Guinea
Reconsider the current price of bark in order to establish an incentive system depending on quality of work		NATRA-APRA
Urgently train Moca harvesters	Harvesters have found problems with Moca residents, and very deficient harvesting in Biaó areas	NATRA-APRA
Condition opening new areas on availability of well-trained, organised teams		NATRA-APRA

harvesting decisions. The work – distances and amounts obtained – should be fairly distributed among labourers to avoid arbitrariness.

- The price currently paid to the workers should be reconsidered. In the last year, it was raised to adapt it to the price paid in Cameroon, although it is still lower. An interesting alternative would be to equal the Cameroon unit prices and condition an additional amount per kilo on the quality of harvest work.
- Coordination of working groups in each area should be the responsibility of an adequately trained specialist, who would give advice on tasks, supervise the quality of the work, along with the group supervisor, and coordinate logistics. This specialist would be expected to spend periods of 2-3 days straight in the harvest areas.

8.7. Control and Monitoring System

A sustainable Management Plan needs the best possible control system to guarantee compliance with the criteria established. A great advantage on Bioko was the concentration of all commercial activity in just one company, and this situation should by all means remain unchanged. The company is committed to the Management Plan, and consequently is willing to participate with the Guinean authorities in follow-up and control.

A control and monitoring system must provide for diverse aspects (Table 41):

- Definition of quality standards through a protocol for control and monitoring. The internal control standards for the harvest plan would be based on complying with the operational process described in the previous sections. Each stage includes a series of activities that must be programmed in time and monitored at different levels of responsibility. Control of these activities would fall to the company as a part of its regular working plan, and would contribute to ensuring the technical and economic viability of the operation.
- Uncontrolled exploitation, causing indiscriminate harvest of the most bark in the shortest time, should be avoided.
- Needless to say, the process will generate certain additional costs that must be financed from some source. Several alternatives are available: national or international aid from importing countries, payment by the industry receiving the resource for final processing, out of interest in keeping up the proper environmental image and guaranteeing future use, or finally joint action by all stakeholder institutions and companies. Of all these options, the most appropriate would be the second one, involving the industrial sector in the destination countries.

- With the company as the only direct participant, the system may be accused of lacking rigour and truthfulness. For this reason, a procedure for periodic external, independent evaluations should be established.
- Coordination with the competent national institutions on control and commercialisation of the bark. Equatorial Guinea has trained personnel to perform these coordinating duties, who should receive *ad hoc* support from international institutions in order to do their job.
- It would be highly advisable to initiate a certification process for *Prunus africana* bark, as one of the commitments under the management plan.

Table 41 – Recommendations for a control and monitoring system

Recommendations	Remarks	Who is responsible
Set up an internal control system for harvest activities, with periodic external evaluations	Improve NATRA-APRA's internal control systems	NATRA-APRA
Institutional Coordination		Spanish Ministry of the Environment / Government of Equatorial Guinea / NATRA-APRA
Initiate a forestry certification process	Seek external institutional support CITES – cooperation agencies	Government of Equatorial Guinea / NATRA-APRA
Begin planning and developing activities	Seek external institutional support	Government of Equatorial Guinea / NATRA-APRA

8.8. Establishment of Plantations and Agro-Forestry Systems

It is of crucial importance to take immediate action on a series of aspects with repercussions for the future projection of *Prunus africana* management. In this context, the following recommendations have been formulated:

- Establish *Prunus africana* plantations in Moca. The first plantation experience has now been dismantled, but it produced very promising results in its early years. Its failure was due to abandonment of maintenance duties in the absence of an agreement between the inhabitants of Moca/NATRA-APRA/responsible Ministries on payment for these tasks. A plantation is not very costly, and yet this type of experience would have a major impact on the company's image, nationally and internationally. Furthermore, preliminary work showed very encouraging results, obtaining individuals with diameters of 30 cm in 12 years (Ndam *et al*, 2000).
- Foster an agro-forestry project in the Moca area to promote use of *Prunus africana* in agricultural systems, similar to the one developed by ICRAF (Ekola *et al*, 2000). Implementation of such systems would allow for reduction of the pressure on natural stands within 10-15 years.
- Conduct studies on the genetic viability of *Prunus africana* populations, for future application in a process of domestication, selection, and improvement.
- Perform studies to discover a way of extracting the active principle from other tissues of the plant.

8.9. Summary of Recommendations

The results of this pilot project lead to the following general recommendations, supported by the CITES Plants Committee (16th meeting, Lima, Peru, July 2006):

At the International Level: Measures directed to international organisations, countries, and industries with a stake in imports, exports, and trade in products derived from *Prunus africana* bark.

1. Effectively foster implementation of management plans in range countries.

2. Coordinate promotion of thorough *Prunus africana* population surveys throughout its range.
3. Encourage international cooperation projects to advance use of *Prunus africana* in agro-forestry systems and plantations, including proper genetic diversity and optimising propagation and agro-forestry cultivation techniques.
4. Coordinate methods used on Bioko for evaluating *Prunus africana* production in natural ecosystems with other methodological proposals in CITES.
5. Ensure the quality of studies and follow-up of management plans for the species.

At the National Level: Measures directed to the Government of the Republic of Equatorial Guinea.

1. Define, initiate, and implement the *Prunus africana* Management Plan.
2. Promote use of *Prunus africana* in agro-forestry systems and plantations, including proper genetic diversity and optimising propagation and agro-forestry cultivation techniques, especially in the Moca area.
3. Establish *Prunus africana* plantations allowing an estimated 12-year period to reach the harvest phase. This would relieve the pressure on natural stands and maintain sustainable harvest of the species in the future.
4. Designate a skilled overseer, in coordination with harvest authorities, to ensure best practice.
5. Set the 2006 harvest quota at 197 t, with an 8-year return time.
6. This quota should be scientifically evaluated and revised annually.
7. Allow only one harvesting company to operate in the area.

AT THE LOCAL LEVEL: Measures directed to the local population in charge of harvesting the bark, which should be taken in conjunction with the export firm:

1. Workers should receive adequate prior training on bark harvesting techniques that do not damage the tree, and they should have the proper tools for the job.
2. Free at least one worker from debarking to take charge of supervising and reviewing best harvesting practice.
3. Encourage harvesters to work for the quality rather than the quantity of bark harvested.

The specific recommendations for sustainable management of *Prunus africana* on Bioko described in each section of the pilot project are summarised below:

Summary of Recommendations for Sustainable Management of *Prunus africana* on Bioko

Recommendations	Remarks	Who is Responsible
INVENTORY		
Review inventory criteria cross-referencing existing information	See inventory models by group	Equatorial Guinean Ministries responsible for forestry management and CITES/APRA
Take inventory of the two new areas before beginning harvest	This would be highly advisable even before opening access routes, although it would be complicated	APRA
Mark inventory areas in the field to define basic production units	The basic production units will be those that produce an amount of bark within the annual quota	APRA
Label all trees during inventory with aluminium tags numbered at the base	Optimises inventory work and allows for proper control of the harvest, which is a basic requirement for any certification process	APRA

Recommendations	Remarks	Who is Responsible
PRODUCTION		
Calculate specific weight according to varying moisture content		APRA
Make more detailed study of real production per tree in the field	The very harvest activity itself may be used	APRA
Clearly establish the yield of the entire drying and grinding process up to shipment		APRA
Calculate potential production of new areas with data derived from inventory	No new work on bark parameters is necessary	Equatorial Guinean Ministries responsible for forestry management and CITES/APRA
Carry out precise zoning of harvest areas in accordance with the annual quota	Indiscriminate harvesting must be avoided	Equatorial Guinean Ministries responsible for forestry management and CITES/APRA
Select the location and layout of the campsite to meet the needs of the harvest areas	It is advisable to provide the necessary infrastructure for harvest at the outset (access route and campsite)	APRA
Correct signposting of harvest areas and producing trees	Harvest should follow certification standards	Equatorial Guinean Ministries responsible for forestry management and CITES/APRA
HARVEST PLAN		
Only allow harvest by one company committed to developing and complying with the Management Plan		Equatorial Guinean Ministries responsible for forestry management
Publish annual harvest quotas according to results of the present study. For 2006 this would be 197 t, considering new south and east Pico Basilé harvest areas		Equatorial Guinean Ministries responsible for forestry management
Give time for the north Pico de Basilé bark to regenerate	Harvesting is more intense in areas near the road, where second and third harvests have been recorded	Equatorial Guinean Ministries responsible for forestry management and CITES/APRA

Recommendations	Remarks	Who is Responsible
HARVEST PLAN		
Establish a strict protocol for bark harvesting	The protocol proposed in this survey is suggested as a starting point, to be validated during 2 years	Equatorial Guinean Ministries responsible for forestry management and CITES
Establish a control plot for harvest techniques		Equatorial Guinean Ministries responsible for forestry management and CITES
Clearly define the operational organisation for harvest activities	The proposal made in this survey is suggested as a starting point, to be validated during 2 years	Equatorial Guinean Ministries responsible for forestry management and CITES/APRA
Select and train a Guinean overseer for technical and operational supervision of work		Equatorial Guinean Ministries responsible for forestry management and CITES
Reconsider the current price of bark in order to establish an incentive system depending on quality of work		APRA
Halt harvest activities in Moca until an adequately trained team is available	Working groups have found problems with Moca residents, and incorrect harvesting in Biaó areas	APRA
Condition the opening of new areas on the availability of well-trained and organised teams		APRA
Set up an internal control system for harvest activities	Improve NATRA-APRA's internal control systems	APRA

Recommendations	Remarks	Who is Responsible
PLANTATIONS		
Promote study of genetic variation in the species and optimise propagation and cultivation techniques Study seed behaviour in germination and long-term storage Establish a seed bank for *Prunus africana*	Seek external institutional support	Equatorial Guinean Ministries responsible for forestry management and CITES in collaboration with Spanish Scientific and Management Authorities /APRA
Immediately establish a programme of plantations and agro-forestry systems		Equatorial Guinean Ministries responsible for forestry management and CITES/APRA
PARALLEL ACTIVITIES		
Foster institutional coordination		Equatorial Guinean Ministries responsible for forestry management and CITES in collaboration with Spanish Scientific and Management Authorities /APRA
Initiate a forestry certification process	Seek external institutional support from cooperation organisations	Equatorial Guinean Ministries responsible for forestry management and CITES in collaboration with Spanish Scientific and Management Authorities /APRA

9. Bibliography

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10. Appendices

10.1. Appendix I – Description of Vegetation Types, Summary of References to Previous Authors, and Synthesis of the Main Species in the Different Vegetation Storeys

Coastal Guineo-Congolian rainforest and mangroves: comprising the coastal areas described by Ocaña (mangrove, pandanus swamp, littoral and hydrophilous vegetation), coastal Guineo-Congolian hydrophilous evergreen rainforests, riparian forests and Guineo-Congolian bog forests. Includes coconut palm (*Cocos nucifera*) groves and tropical almond (*Terminalia catappa*) stands, where some ferns occur (*Platycerium stemmaria*). There are only two mangrove areas on the island (one in the Bahía de Venus and another on the west coast) with *Laguncularia racemosa* and *Avicennia nitida*. In areas near the shore, closed groups of raffia palms (*Raphia* sp.) may be present, as in the Bahía de Riaba, near Baloeri or around the Bahía de Venus mangroves. Another coastal formation, typical of marshlands at river mouths, is the pandanus (*Pandanus* sp.) swamp. These appear in the Bioko bays, Bahía de Venus and Bahía de Riaba, and are scattered along the southwest coast.

Guineo-Congolian rainforest: comprising areas up to 800 m where precipitation varies from slightly less than 2000 mm to 3500 mm, and average monthly temperatures range from 19 to 31°C. This type of forest occurs in the eastern, northern, and western parts of Bioko. Rainfall in the south is more abundant, and another type of formation, known as monsoon forest, prevails there. The Guineo-Congolian rainforest on Bioko, because of its rainfall regime, belongs to the coastal evergreen hydrophilous type of Guineo-Congolian rainforest (White, 1983). It has a stratum of very tall trees, an irregular shrub stratum, and a herbaceous layer practically void of graminoids, with numerous sub-frutescent plants (Pérez del Val, 1999). The tree layer is characterised by tall individuals, and does not differ significantly from the neighbouring continental forest, although the absence of *Aucoumea klaineana* is noteworthy (Ocaña, 1960). Tree species include *Piptadenia africana, Sterculia oblonga, Chrysophyllum africanun, Chlorophora excelsa, Ricinodendron africanun, Crotogyne mannian,* etc. Guinea (1951) cites six *Ficus* species in this formation, and Mildbraed (Mildbraed in Ocaña, 1960) mentions *Allanblackia monticola* as a characteristic tree species. Palm groves are also present (*Elais guineensis* and *Cocos nucifera*). *Costus engleranus* is very common among the herbaceous vegetation, as are several species of the genera *Piper* sp. and *Peperomia* sp. in the pepper family, and two species of Commelinaceae, *Palisota hirsuta* and *Pollia condensata*. Within the confines of the lowland forest, Adams counted 80 fern species, including those found among coastal ground cover. *Cyclosorus afer* and *Nephrolepis biserrata* stand out as the most abundant ferns (Mildbraed in Ocaña, 1960).

The interior of Caldera de Luba has a special microclimate with much less precipitation than the outer hillsides. Vegetation here is consequently closer to the lowland forest than to the afromontane forest. There are no tree ferns or araliaceous plants, which are typical of the mountain storeys, but its cracks and crevices are home to small meadows of graminoids that appear in other areas of the island at elevations above 2000 m.

Primary Guineo-Congolian rainforest (monsoon forest): including the southern part of the island of Bioko, with higher rainfall, and the south-west of the Pico de Basilé foothills. This type of forest is present in the approximate range of the lowland rainforest, although it may climb up to meet the afromontane formations (1000 m.a.s.l.) in the south of the island, because of the abundant rainfall. Precipitation averages 11,000 mm in Ureka, but the absolute maximum, 14,451 mm (Terán, 1962), makes it one of the rainiest locations on the planet (Ocaña, 1960). This southern area, more difficult to access, is the least populous and the least studied. Therefore, no more than mere estimates of its size and floristic composition are available. Very few characteristic species of this monsoon rainforest have been recognised. Among these, *Mapania amplivaginata*, of the Cyperaceae family, covers the south side, along with *Costus* cf *dinkaglei* of the Costaceae family. African nutmeg or ilomba (*Pycnanthus angolensis*) is locally prevalent above Eori and in Ureka.

Tropical crops; cacao and coffee: grown for export since the mid 19th century in the Guineo-Congolian Rainforest range (up to 800-1000 m.a.s.l.) except in southern Bioko. These crops – chiefly cacao and, to a lesser extent, coffee – formerly covered a large expanse of the rainforest. They used to produce an annual yield of over 36,000 tonnes of cacao (IUCN, 1991), but this figure has decreased drastically in recent decades due to reasons of climate as well as commercial concerns associated with the international decline in the price of cacao and the beginnings of oil and gas exploitation. Interspersed among them or in the shade they provide, small, family-scale farms grow a variety of crops; mainly malangas (cocoyams), bananas, cassavas, pineapples, and yams.

In cacao plantations, several tall trees are often left to provide shade for the crop (20-25 stems per hectare). Common among these are some *Ficus* sp., iroko (*Chlorophora excelsa*), niove (*Staudtia* sp.), and the kapok tree (*Ceiba pentandra*). More exotic species also serve this purpose, such as *Erythrina* spp., and various members of the Mimosaceae family —*Acacia* sp., the naked albizia *Albizia carbonaria*, and *Pithecolombium saman*— (Pérez del Val, 1999). On some abandoned plantations, after 20 years it is difficult to distinguish the surviving cacao trees from the rest of the vegetation.

The landscape in the plantation area is the consequence of historically variable land use in the most populous part of Bioko. Nowadays, it is a complex mosaic of plots that may be cultivated, producing or abandoned, alongside natural forests that have suffered differing degrees of intervention. At altitudes below 800 m, a total of 90,670 ha, or 45 % of all the land on the island, has been subject to human intervention for one purpose or another. Of this land, 70,800 ha are cacao groves in varying states of neglect or production, where the forest was radically transformed. In 1989, producing cacao plantations were estimated to cover 44,440 ha, but reduction has been constant since then, due to gradually falling cacao prices and the socio-political situation in Equatorial Guinea. In 1993, yield was estimated around 2,000,000 kg, the lowest since 1906, which would have come from an area of approximately 4000-5000 ha, assuming an average-low yield of 400-500 kg ha^{-1}. Although the sector has recovered slightly, and there are projects to support attempts at revitalising production, all signs point to a scenario in which more than one major expanse – the most remote areas – will become abandoned cacao groves giving way to progressive forest regeneration in just a few years (Pérez del Val, 1999).

Lowland afromontane forest: where climatic conditions are not yet severe, between 800-1000 and 1400 m, precipitation increases to 3000-4000 mm annually, and the average temperature decreases to between 15º C and 23º C. Nearly permanent fog makes for high humidity and favours growth of epiphytic plants; largely mosses, ferns, orchids, and several species of *Begonia* sp. Canopy height is lower, the palm trees that thrive in the lowland forest disappear, and pure tree fern formations (*Alsophila camerooniana* and *A. manianna*) occur frequently. The understorey is relatively untangled, and often covered with Commelinaceae and Zingiberaceae (*Aframomum* sp.). The Pico Biaó hillsides, approximately 4230 ha of the area between 800 and 1800 m, are prairies where cattle used to graze, deforested since the early 20th century, but abandoned for the most part nowadays.

Highland afromontane forest (Araliaceae): included in the formation described by White as afromontane forest, which is divided into two types – lowland and highland. The latter is marked by the change in floristic composition as of 1400 m, and by the initial appearance of species in the Araliaceae family (*Polyscias fulva* and *Schefflera* spp.), along with *Prunus africana*. From here up to 2500 m, the dominant stratum of the canopy is made up of *Schefflera mannii, S. barteri,* and *Prunus africana*, accompanied by *Alangium begoniifolium*, *Polyscias fulva*, *Macaranga* sp., *Nuxia congesta*, and *Psycotria peduncularis*, among others. Tree ferns are also present (*Alsophila camerooniana* and *A. manianna*), although to a lesser extent than in the lowland afromontane forest. The predominant shrub coverage species in this formation are *Uragoga mannii*, *Oxyanthus tenuis* and *Crassocephalum mannii*, while *Anchomames diformis* and *Piper guineense* occur on the herbaceous layer.

The temperature range is even broader than in the mountain forest, with extremes estimated between 8º C and 30º C. The humidity decreases noticeably, as there is less rainfall and the fog is no longer so prevalent. Another factor at these altitudes is the high level of insolation, preventing the proliferation of mosses and epiphytic liverworts, which are replaced by hanging lichens (*Usnea* sp.) that resemble trimming on side branches most exposed to desiccation. On many hillsides, both on Pico Biaó and on Pico de Basilé, this forest has been deeply altered, mainly by fire on Pico de Basilé, and through the livestock activities that had taken place in the vicinity of Pico Biaó since the mid 19th century. In general, the altered areas have been colonised by pyrophyte species. Large patches are covered with *Pteridium aquilinum* fern communities reaching up to 2 metres in height on the north side of Pico Biaó, along with other species belonging to the ericaceous storey, such as *Rubus* sp., *Lobelia columnaris*, and *Hypericum lanceolatum*.

Afromontane heath forest (ericaceous shrubbery): by analogy with Mount Cameroon and the high East African mountains, where a true storey of ericoid vegetation exists. On Bioko, a similar formation can be found from 2500 m up to the summit. The Ericaceae *Aguaria salicifolia*, *Blaeria mannii*, Philippia *mannii*, as well as *Hypericum revolutum*, *Lobelia columnaris*, and *Crassocephalum mannii* are the most common species here. Other species that occur in the heath forest are *Adenocarpus manii*, *Pycnostachys volkensii*, and *Pittosporum manii*.

Afromontane herbaceous vegetation: above 2700 m, where the presence of ericoid types of species begins to decrease. At this elevation level, meadows of graminoids and cyperaceae begin to alternate with the ericoid vegetation groups. *Aguaria salicifolia* grows no higher (Pérez del Val, 1999).

Synthesis of the Main Species on Bioko by Vegetation Storeys (Nosti, 1947; Ocaña, 1960; Terán, 1962; White, 1983)

0-20 m.a.s.l. Coastal Guineo-Congolian rainforest. Mangroves, pandanus swamp, and coastal coconut palm groves. Coastal climate.

ARECACEAE	*Cocos nucifera*
COMBRETACEAE	*Laguncularia racemosa*
	Terminalia catappa
EUPHORBIACEAE	*Alchornea cordifolia*
	Ricinodendron africanum,
LEGUMINOSAE	*Vigna toningii, V. multiflora, V. oblonga*
MELASTOMATACEAE	*Tristemma littorale*
PANDANACEAE	*Pandanus candelabrum*
RIZOPHORACEAE	*Avicennia nitida*
	Rhizophora mangle
VITACEAE	*Cissus vogelli*

0-500; 0-600 (800/1000) m.a.s.l. Guineo-Congolian rainforest. Coastal climate.

AGAVACEAE	*Dracaena usambarensis*
ARECACEAE	*Cocos nucifera*
	Elaeis guineensis
	Raphia tandra
ASTERACEAE	*Vernonia conferta*
BIGNONIACEAE	*Kigelia pinnata*
	Spathodea campanulata
BOMBACACEAE	*Bombax flammeum*
	Ceiba pentandra
CECROPIACEAE	*Musanga smithii*
COMMELINACEAE	*Palisota hirsuta*
	Pollia condensata
STERCULIACEAE	*Cola filicifolia*
	Sarcocephalus sculentus
	Sterculia oblonga

EUPHORBIACEAE	*Crotonogyne manniana*
	Ricinodendron africanum
GUTTIFERAE	*Allanblackia monticola*
	Garcinia kola
LEGUMINOSAE	*Albizia fastigiata*
	Berlina bractosa
	Disthemonanthus benthamianu
	Entrada scadens
	Pentaclethra macrophila
	Piptadenia africana
LOGANIACEAE	*Anthocleista micrantha*
MYRISTICACEAE	*Picnanthus kombo*
	Staudtia gabonensis
MORACEAE	*Clorophora excelsa*
	Ficus clarecensis
	Ficus exasperata
SAPOTACEAE	*Chrysophyllum africanum*

600 (800/1000)-1400 m.a.s.l. Lowland afromontane forest. Highland climate.

ANNONACEAE	*Monodora brevipes*
	Uvaria fusca
APOCYNACEAE	*Conopharingia brachiantha*
	Funtumia africana
	Strophanthus bullenianus
ARACEAE	*Calocasia lanceolada, C. insulina*
ARISTOLOCHIACEAE	*Aristolochia goldicana*
ASTERACEAE	*Vernonia amigdalina*
BEGONIACEAE	*Begonia ampla, B. poculifera, B. furfuracea*
CYATHEACEAE	*Cyathea manniana, C. usambarensis*
CONNARACEAE	*Paxia zenkeri*
EUPHORBIACEAE	*Macaranga occidentalis*
FLACOURTIACEAE	*Calombosa welwitschii*
GUTTIFERAE	*Garcinia mannii*

LEGUMINOSAE	*Albizzia fastigiata*
	Bandeiraca termiflora
	Disthemonanthus benthamianus
LILIACEAE	*Dracaena fragans*
MYRISTICACEAE	*Coelocaryon prensil*
	Picnanthus microcephala,
	P. kombo
MORACEAE	*Clorophora regia*
	Dorstenia elliptica
STERCULIACEAE	*Sterculia oblonga, S. foetida*
ULMACEAE	*Trema guineensis*

1400-2500 m.a.s.l. Highland afromontane forest (Araliaceae). Mountain climate.

ACANTHACEAE	*Acanthus montanus*
	Brillantaisia lamina
ALANGIACEAE	*Alangium begoniifolium*
ARALIACEAE	*Scheffera barteri, S. mannii*
	Polyscias fulva
CARYOPHYLLACEAE	*Sagina obisinica*
CYPERACEAE	*Cyperus articulatus*
EUPHORBIACEAE	*Neboutonia macrocalyx*
MORACEAE	*Ficus chlamydocarpa*
	Ficus exasperata
	Ficus toningii
	Ficus ureolaris
ROSACEAE	*Prunus africana*
	Rubus pinnatus
VITACEAE	*Leea guincensis*

2500-2700 m.a.s.l. Afromontane heath forest (ericaceous shrubbery). Mountain climate.

ACANTHACEAE	*Acanthopale decendepedalis*
	Mimulopsis violacea
APOCYNACEAE	*Holalafia multiflora*
ASTERACEAE	*Crassocephalum mannii*
	Philippia mannii
ERICACEAE	*Aguaria salicifolia*
	Blaeria mannii
GUTTIFERAE	*Hypericum lanceolatum*
LAMIACEAE	*Pycnostackys volkensii*
LEGUMINOSAE	*Adenocarpus mannii*
LOBELIACEAE	*Lobelia columnaris*
MORACEAE	*Ficus clarecensis*
	Ficus camptoneuroides
PITTOSPORACEAE	*Pittosporum mannii*
SINOPTERIDACEAE	*Pteridium aquilinum*

2700-3011 m.a.s.l. Afromontane herbaceous plants. Mountain climate.

ASTERACEAE	*Helychrysum mannii, H. globosum, H. fruticosum*
	Senecio clarenciana
CYPERACEAE	*Bulbostylis erratica*
	Carex mannii
	Cyperus cimicinus
ERICACEAE	*Erica mannii*
LABIATAE	*Calamintha simensis*
PLANTAGINACEAE	*Plantago palmata*
POACEAE	*Agrostis mannii*
	Festuca giganta, F. schimperiana
	Helictotrichon manii
SCROPHULARIACEAE	*Veronica mannii*
UMBELLIFERAE	*Hydrocotile monticola, H. mannii*

10.2. Appendix II – Field Log

Point Nº	Collection Day	Group	Area	Population	PDOP
					Initial:
					Final:
Initial Longitude	**Initial Latitude**	**Final Longitude**	**Final Latitude**	**Total CCF (%)**	***Prunus* CCF (%)**
				Type of Point	**Harvest (Nº of Years)**
				1 2 3	
Average Tree Height (m)	**Slope (%)**	**Shrubbery Cover (%)**	**Ecosystem Type**	**Orientation**	**Level of Damage**
			1 2 3 4 5 6 7		1 2 3 4
Individuals					
DBH > 60 cm					
60-30 cm					
10-30 cm					
Regenerated					
Prunus africana					
DBH > 60 cm					
60-30 cm					
10-30 cm					
Regenerated					
Dead Individuals					
Use of Drill:	**YES/NO**	**Nº of Tree:**			
***Prunus* > 30 cm (Nº tree/DBH)**	**Longitude**	**Latitude**	***Prunus* > 30 cm (Nº Tree/DBH)**	**Longitude**	**Latitude**
Comments (type of harvest, soil, buildings, weather, etc.)					

10.3. Appendix III – Distribution of Highland Afromontane Forest Species (Araliaceae) by Diameter Classes

Name	Place	Densities (stems/ha)		
		> 60 cm	60-30 cm	30-10 cm
Bersama abyssinica	Moca	0.19	0.39	3.88
Crassocephalum mannii	Basilé and Moca	0.00	0.00	0.39
Ficus chlamydocarpa var. chlamydocarpa	Moca	0.39	0.39	0.00
Ficus sp.	Basilé and Moca	0.39	0.97	1.36
Ficus sp.	Basilé	0.19	0.19	0.00
Flaucurtia sp.	Moca	0.58	0.00	0.00
Hypericum lanceolatum	Basilé and Moca	0.00	0.00	0.39
Macaranga spinosa	Basilé	0.19	0.39	0.00
Maesa lanceolata	Moca	0.19	0.58	3.30
Neboutonia macrocalix	Basilé	0.78	1.16	4.66
Nuxia congesta	Basilé and Moca	0.78	1.16	2.33
Oxyanthus sp.	Moca	0.00	0.00	1.94
Oxyanthus sp.	Moca	0.00	0.00	1.55
Polyscias fulva	Basilé and Moca	0.19	1.75	0.39
Prunus africana	Basilé and Moca	4.27	1.75	1.16
Psycotria peduncularis	Moca	0.00	0.39	0.39
Psycotria sp.	Moca	0.00	0.00	0.19
Schefflera sp.	Basilé and Moca	5.82	2.14	0.97
Trema orientalis	Basilé and Moca	0.39	0.58	0.39
Trichilia prieureana	Basilé	1.94	1.75	1.36
Uragoga sp.	Basilé and Moca	0.39	0.00	0.39
Xymalos monospora	Moca	0.19	0.58	1.55
Zanthoxylun sp.	Moca	0.00	0.19	0.19
Booko	Moca	0.19	0.39	0.58
Bosoko (Bubi)	Moca	0.19	0.19	0.19
Cipoto-potó (Bubi)	Moca	0.39	0.19	0.00
Epepele (Bubi)	Moca	0.00	0.19	0.39
Mooté (Bubi)	Moca	0.19	0.58	1.55
Motoso (Bubi)	Basilé and Moca	0.19	0.19	0.00
Moya-baya (Bubi)	Moca	0.38	0.19	1.16
Pada (Bubi)	Moca	0.39	0.97	0.58
Sigoko (Bubi)	Moca	0.00	0.00	0.39
Unidentified	Moca	0.97	0.19	0.58
Yeke-yeke (Bubi)	Moca	0.39	0.00	0.19
Miscellaneous	Basilé and Moca	0.00	0.00	1.16

10.4. Appendix IV – Photographic Appendix

Types of vegetation studied

A. Highland afromontane forest (Araliaceae)
B. Degraded Guineo-Congolian rainforest with banana crops
C. Secondary afromontane forest
D. Secondary highland meadows (degraded afromontane forest)
E. Highland afromontane forests with understorey of tree ferns

General View of *Prunus africana*

A. Dry *Prunus africana* trees, Pico de Basilé
B. Panoramic view of Pico de Basilé
C. *Prunus africana* fruit in Moca
D. Trunk and crown of *Prunus africana,* Pico de Basilé
E. View of Lake Biaó (Moca) ecosystems with *Prunus africana*

Prunus africana Harvesting

A. Sacks of bark at APRA, Malabo
B. *Prunus africana* harvested above Lake Biaó, Moca
C. *Prunus africana* in sacks by the roadside, Pico de Basilé
D. APRA tractor for accessing, loading, and carrying bark and people, Moca
E. Drying hall for *Prunus africana* bark, Rebola

Proyecto *Evaluation* of the Harvest of *Prunus africana* Bark on Bioko (Equatorial Guinea): Guidelines for a Management Plan patrocinado

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