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Guidelines for the Sustainable Management of BioTrade Products: RESOURCE ASSESSMENT

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GUIDELINES FOR THE SUSTAINABLE MANAGEMENT OF BIOTRADE PRODUCTS: RESOURCE ASSESSMENT

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Note

For further information on UNCTAD's BioTrade Initiative please consult the following website:
http://www.unctad.org/biotrade, or contact: biotrade@unctad.org.

Acknowledgements

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Contents

I. INTRODUCTION

In 1997, the United Nations Conference on Trade and Development (UNCTAD) launched the BioTrade Initiative with the primary goal of promoting trade and investment in biological resources in support of sustainable development, in line with the three objectives of the Convention on Biological Diversity (CBD): conservation of biodiversity, sustainable use and equitable sharing of its benefits. To achieve its objective UNCTAD BioTrade Initiative has promoted the implementation of BioTrade Principles and Criteria through the establishment of programmes and projects to strengthen the capacity of organizations to enhance the production of value-added products and services derived from biodiversity for both domestic and international markets (UNCTAD 2007b).

BioTrade products are an extremely diverse group that includes medicinal plants, natural ingredients, fruit, oils, meat, honey, mushrooms, seafood, ecotourism and many others derived from different ecosystems (i.e. forests, mangroves, grasslands). These products are key assets in the livelihoods and health of hundreds of millions of people across the globe and have been used by human populations for subsistence use and trade over thousands of years (Vasquez and Gentry 1989, Ros-Tonen 2008).

Over the last decade, the market demand and the interest in managing forests and other ecosystems (i.e. alpine grasslands) for natural products has grown tremendously, which has generated concern for the ecological sustainability of the ecosystem resources from which they are produced (Arnold and Pérez 2001, Olsen 2005, Widayati *et al*. 2010). The growing commercial trade of natural products, in particular plant medicines and crafts, has resulted in the harvest of increasing volumes from wild plant populations and has therefore generated concern about overexploitation (Arnold and Pérez 2001). Consequently, the establishment of good practices to support sustainable management of wild-collected species becomes an increasing need together with the development of methodologies and tools to support management decisions. Special care should be given to those species that play key roles in ecosystem dynamics such as palm trees (Montúfar 2011).

Sustainable management is built on the principle that ecosystem management will meet current societal needs without prejudice to future generations, or the ecosystems' capabilities to maintain their own health (i.e. resilience). This concept embraces four fundamental standards:

- Ecosystem management is socially acceptable and equitable;
- The impact is ecologically benign;
- The economic impact to local communities is positive; and
- Increased commercial harvest of non-timber forest products (NTFPs) should add to the perceived value of natural ecosystems, thereby increasing the incentives to retain the habitat resource (Arnold and Pérez 2001).

However, underscoring these considerations, there lies a fundamental question: what are the ecological consequences of native species harvest? Although it is often assumed that harvest of wild species has little or no ecological impact, extraction may alter biological processes at many levels. For instance, harvest may affect the physiology and vital rates (i.e mortality and growth rates) of individuals, change demographic and genetic patterns of populations and alter community- and ecosystem-level processes (Balslev 2011, Liu *et al*. 2011, and Montúfar *et al*. 2011).

Management of a wild species or an ecosystem requires the implementation of *in-situ* or *ex-situ* actions based on scientific or empirical knowledge that promote their conservation either by strict protection or sustainable management alternatives (Primack 1994, Salafsky *et al*. 2001).

Sustainable exploitation of renewable resources depends on the existence of a reproductive surplus, which is determined by population attributes such as births, deaths and growth, which differ spatially and temporally as environmental conditions vary (Hilborn *et al*. 1995, and Robinson 1999). Therefore, understanding species biology and population dynamics is essential to determine sustainable yields either by direct experimentation, observation of natural systems or deduction from biological understanding (Hilborn *et al*. 1995).

With these considerations in mind, the purpose of this document is to develop a set of practical guidelines on conducting wild species resource assessments in compliance with BioTrade Principles and Criteria (UNCTAD 2007a). This document will therefore emphasize ecological concepts and methods to analyze species population dynamics as a basis for the definition of good collection practices, delineation of monitoring criteria and other management considerations. Further, modelling exercises are presented as a tool to assist BioTrade organizations in analyzing population dynamics as a way to establish a sustainable harvest rate and evaluate different good collection practices and management options. Additionally, the exercises presented help to evaluate the impacts of current or future management practices on the species populations and identify those underlying factors that drive population dynamics and can be conceptualized as determinant variables for the sustainable management of a species.

The present document complements the guidelines developed by UNCTAD (2009) for the development and implementation of management plans for wild-collected plant species used by organizations working with natural ingredients. The methodology for the development and implementation of management plans comprises five steps:

- Identification of collection areas and collectors;
- Assessment of managed resources;
- Definition of good practices to be implemented;
- Definition of follow-up and monitoring systems; and
- Implementation of documentation systems.

These guidelines will focus on the assessment of managed resources (second step) by providing additional detail, key ecological concepts and methodologies for completing a resource assessment, and guidance to incorporate findings into management plans and monitoring systems. Primary emphasis is given to guiding BioTrade organizations and other stakeholders involved in resources management activities on the analysis of species trade potential, comprehension of relevant population ecology concepts and identification of information gaps.

The guidelines will feature examples of applied resource assessments using specific case studies for three traded species based on two information sources: existing cases of UNCTAD BioTrade partners and examples from scientific publications or project reports. The population analysis and current harvest rates for each species were based on raw or processed field data plots. The case study species are *Caesalpinia spinosa*, *Mauritia flexuosa* and *Neopicrorhiza scrophulariiflora* (for further information on the case studies please visit: www.biotrade.org).

In the on-line web version these guidelines are organized into two main sections:

Section 1. Resource assessment guidelines which present the steps needed for developing a resource assessment on wild-traded species.
Section 2. Case studies, aimed at presenting the application of the guidelines to three selected species based on existing information (for further information on the case studies please visit: www.biotrade.org).

A. Key concepts

1. BioTrade: concepts and policy framework

The term BioTrade includes those activities of collection/production, transformation and commercialization of goods and services derived from native biodiversity (genes, species and ecosystems) under criteria of environmental, social and economic sustainability (UNCTAD 2007b). BioTrade activities imply the application of specific criteria to promote cost-effective activities by stakeholders involved in collection and trade of biodiversity-based products to assure the survival of managed species and the conservation of their habitats in the long term.

In establishing a business based on a wild-traded species it is important to consider the following:

- The design of a sustainable production system according to the ecological traits of the species;
- The definition of good practices and a monitoring programme based on an adaptive management concept; and
- An estimate of the investment required to design a management system that accomplishes BioTrade sustainability criteria.

These fundamental decisions need to be based on thorough biological knowledge about the species and its potential markets which allow the analysis of risks and of opportunities for commercial use.

BioTrade represents a innovative strategy to promote biodiversity conservation and sustainable use based on the following criteria:

1. The ecological impact of BioTrade products management is lower than conventional forest management;
2. Income generation by BioTrade organizations increases the perceived value of natural ecosystems, as well as local commitment to conserve the natural habitats of managed species; and
3. BioTrade has a positive impact on rural livelihoods income and promotes the preservation and valuation of traditional knowledge.

The main international framework that regulates the trade of BioTrade products is the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). It is an international agreement between governments, which aims to ensure that international trade in wild animals and plants does not threaten their survival. Another relevant international instrument for BioTrade organizations is the Convention on Biological Diversity (CBD) which is focused on three main objectives: conservation, sustainable use and equitable sharing of the benefits derived from the use of biodiversity. This international framework recognizes trade as a positive incentive measure and defines some approaches that encourage the implementation of good practices, which are applicable in the case of trade in BioTrade products.

In the CBD context, the Addis Ababa Principles and Guidelines (CBD 2004) provide a framework to assist governments, resource managers, indigenous and local communities, the private sector and other stakeholders, in ensuring that their use of the different components of biodiversity will not result in long-term decline of biological diversity (Becerra 2009). Nevertheless, up to now, there are limited case studies available that can provide guidance on the implementation of such principles (Perez and Byron 1999). However, parties recognize that implementation depends on many inter-related factors including the existence of incentive measures, availability of information and tools to implement sustainable management plans, and the capacity to put into practice appropriate monitoring systems.

Finally, it is important to take into consideration that other international environmental agreements may be relevant depending on the managed species, as well as other non-environmental regulations which also may have some influence in promoting the implementation of practices or measures that in some way or other affect the sustainable trade of BioTrade products. This is the case of conservation agreements such as the RAMSAR Convention on Wetlands that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources.

2. Resource assessment

A simple definition of a resource assessment is the process by which resource managers estimate the future production potential of a given product. For the purpose of these guidelines, a resource assessment are those activities needed to identify the sustainable production potential of a managed species by understanding the population dynamics and appropriate harvest rates and practices to assure sustainable management (Wong 2000, Hall and Bawa 1993). Resource assessment provides information for identifying information gaps that need to be filled as well as and population attributes that need to be monitored in the long term. This approach is focused on the managed-population possibilities and considers those attributes that directly affect the abundance of supply and the potential for sustainable use (Hall and Bawa 1993).

Other approaches are wider and seek to identify products and describe an ideal development process that in some cases starts with the selection of species and progresses through market research, resource inventory, participatory assessments, determination of sustainable harvest practices and intensities, management planning and monitoring (e.g. Peters 1994, 1996, and Stockdale 2005).

Whichever approach is taken in cases where sustainable yield or a harvest rate need to be defined, population dynamics knowledge of the species is a primary requisite. A simple inventory of the resource is not enough for making decisions. Managers need proper information of what is happening to the population and the activities they need to implement to ensure a sustainable management.

In cases where a BioTrade organization manages more than one species with several products in various areas, resource assessments need to be carried out for each species involved in each collection area. General information of species biology can be applicable, but productivity and demography vary according to environmental conditions and degree of disturbance.

3. Population ecology

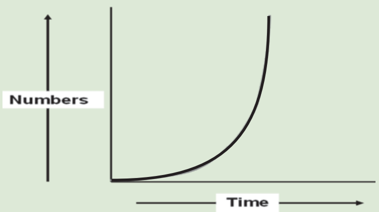
A population is a group of individuals of the same kind living in the same place at the same time. The size of a population in relation to the area it occupies is its density. Population and individuals are distributed in some kind of pattern over the landscape. Some are uniformly distributed, some are randomly distributed, but most are clumped in aggregations (Smith and Smith 2008).

Individuals making up the population may be divided into three ecological stages: pre-reproductive, reproductive and post-reproductive. The distribution of individuals within each group influences considerably the birth rate, mortality rate and population growth. A

Box 1. Exponential growth and carrying capacity concepts

Exponential growth

The population growth of a species in a newly colonized habitat will start exponentially. This is an example of positive feedback. The more individuals there are in a population the faster they will breed. The growth curve looks like this (often called the J-shaped curve):



The exponential growth curve can be modelled by the equation:

$$\frac{dN}{dT} = rN$$

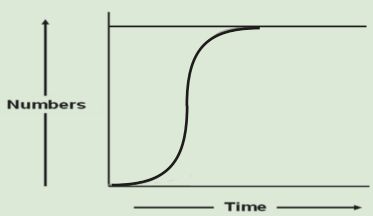
Where, r is the rate of increase of a species, dN the variation in the size of the population over the course of time (dT). Of course the higher N becomes the bigger the increase in the population becomes. This leads to exponential growth.

Real examples of exponential growth

Alien species, which often become pest species, show this growth pattern. Demographic explosion of feral goats (*Capra hircus*), rats (*Rattus spp*.) and feral cats (*Felis catus*) are well documented (Campbell *et al*. 2004). When a new species is introduced accidentally or deliberately into a new environment it has no natural predators or diseases to keep it under control. Another example of this is the bird Sturnus vulgaris, that was introduced into the United States at the end of the 19th century (160 of these birds were released in New York). By 1942 they had spread as far as California, with an estimated population of between 140 and 200 million, making it one of the commonest species of bird in the world.

The carrying capacity

One of Darwin's important observations was that a population never continues to grow exponentially forever. There is a resistance from the environment as the food supply or nesting sites decrease (i.e. competition increases) and the numbers of predators and pathogens increase. This resistance results from negative feedback. This leads to the classic s-shaped or sigmoid population curve (below):



The population dynamic in this case is controlled by a component that will slow down the population growth as it reaches a certain point, the carrying capacity of the environment (K). The equation is called the logistic equation:

$$\frac{dN}{dT} = rN\left[\frac{K - N}{N}\right]$$

Whilst N<K then r will be positive and the population will increase in size.
When N=K then r will be zero and the population growth will stop.
Should N>K then r will become negative and the population will decrease.

Source: Adapted from Smith and Smith (2008), Robinson and Bodmer (1999), Getz and Haight (1989), and Odum and Barrett (2005).

large number of young about to enter the reproductive stage suggests a potentially increasing population, whereas a high proportion in the post-reproductive age classes suggest a zero or declining population growth. Population tends toward a stable age distribution, in which the proportion of individuals in each age class remains the same, as long as growth continues at a constant rate. When deaths equal births and the proportion of individuals in the population remains constant, the population has arrived at a stationary age distribution (Odum and Barrett 2005).

Population size is influenced by the number of individuals added to the group by births and immigration and by the number leaving by death and emigration. The difference between the two determines the growth and mortality rates of populations. Mortality, concentrated in the young and the old, is often the greatest reducer of populations (Smith and Smith 2008).

In an unlimited environment, populations expand geometrically or exponentially, described by a J-shaped curve (Box 1). Such growth may occur when a population is introduced in an unfilled habitat. Nevertheless, because resources are limited, geometric growth cannot be sustained indefinitely. Population growth eventually slows and arrives at some point of equilibrium with the environment, called the carrying capacity. However, natural populations rarely maintain a stable level, but rather fluctuate about some mean (Smith and Smith 2008, Odum and Barrett 2005)

Mortality and its complement, survivorship, are two key parameters for comparing demographic trends within a population and among populations living under different environmental conditions, as well as for comparing survivorship among various species. In general, mortality rates, graphically portrayed as curves, assume a J shape, whereas survivorship curves fall into one of three major types: type I, in which the survival of young is low; type II, in which mortality and thus survivorship, is constant through all ages; and type III, in which individuals tend to live out their physiological lifespans. Survivorship curves follow similar patterns in both plants and animals.

The sustainable exploitation of renewable resources depends on the existence of a reproductive surplus, which is determined by the balance between births, deaths and somatic growth (Hilborn *et al*. 1995). In the case of wild-traded species, the definition of a sustainable yield (i.e. harvest rate) and collection practices guidelines must be based on an analysis of population dynamics.

The key to protecting and managing wild species is to have a good understanding of the ecology of the species, its distinctive characteristics (natural history), the status of its populations and the dynamic processes that affect population size and distribution (Primack 2004, Olmsted and Alvarez-Buylla 1995). Management decisions should try to answer as many questions as possible with respect of the aforementioned variables (Primack 2004).

Population dynamics helps resource managers to analyse the effect of harvest regimes on the state of a population through time, by means of contrasting the balance between births, deaths and other fundamental ecological aspects of the traded species. These analyses are essential to help formulate management practices and establish sustainable harvest regimes.

4. Adaptive management

Trade in wild species has an increasing relevance considering the diversity of species and the value that it represents to local economies of developing countries (Burgener and Walter 2007). Several authors highlight the fact that management criteria for natural resources are influenced by market pressures and demands, which often affect the sustainability of subsistence systems and promote overexploitation, local extinction of species and concentration on a few products with high market potential (Arnold and Pérez 2001, Bennett and Robinson 2000, Wilkie and Godoy 1996).

However, information regarding population dynamics and basic ecological data for the majority of traded wild species is incomplete or completely lacking, especially in the Tropics (Primack 1994). This reality constrains resource managers or BioTrade organizations in establishing a scientifically sound harvest rate, which in turns hampers the possibility of determining the sustainability of their activities without further investigation and monitoring.

Yet, management decisions may have to be made before relevant information is available or while it is being gathered (Primack 2004, Hilborn *et al*. 1995). In this scenario, the adaptive management framework allows designing production systems that involve monitoring practices and applied research activities that may provide resources managers with important information to adjust management activities and assure their sustainable use in the long term.

Therefore, an adaptive management approach represents a key strategy for sustainable management of

BioTrade species. According to Walters and Hilborn (1978), adaptive management refers to all situations where the best action for a certain system cannot be defined *a priori*. It allows for the establishment of sequential evaluations of the sustainability of the natural system and the subsequent modification of management actions to assure the desired changes in the state of the system.

In practice, adaptive management is based on the systematic analysis of information, applied to a specific context in order to improve natural resource management with a long-term perspective (Walters and Holling 1990, Wilhere 2002). In this framework, the use of experimental and quantitative models provides a tool to analyze the dynamic of production systems, as well as management risks and costs (Walters and Hilborn 1978, Hilborn *et al*. 1995, Schreiber *et al*. 2004).

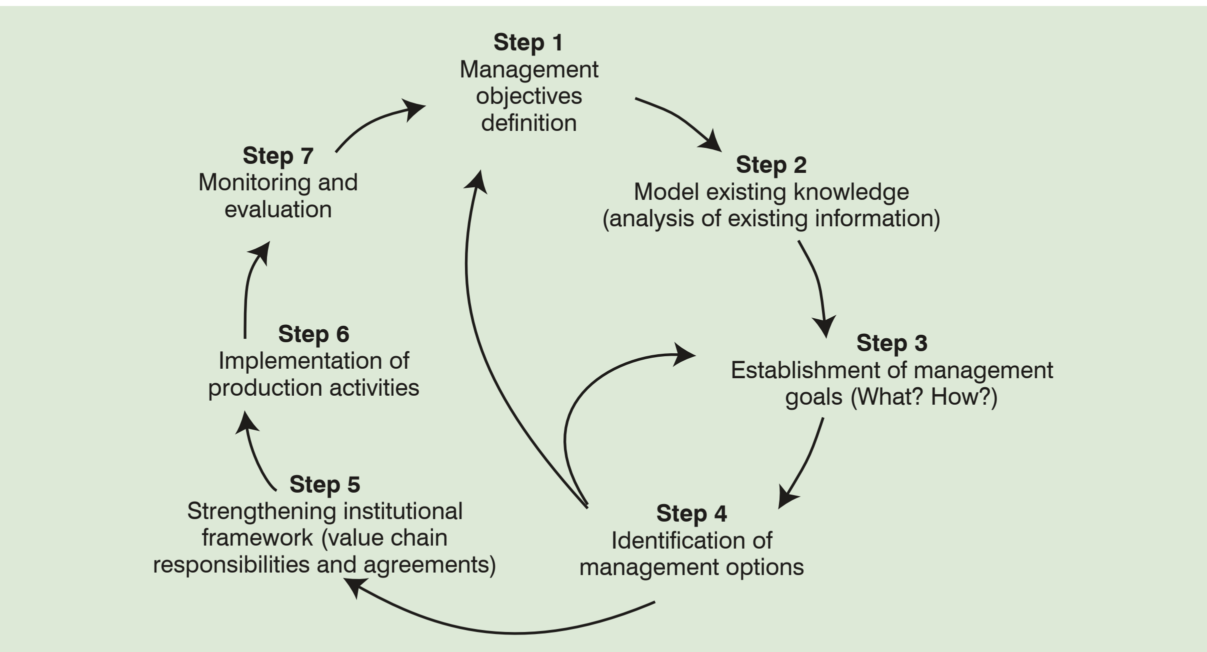
The adaptive management approach is based on the design and implementation of a management plan for each resource species that is continuously adapted to the outcomes of well designed "experiments" that allow stakeholders to collect data systematically and use those data to take decisions about best alternatives of management and conservation of the managed resources or areas (Blumstein 2007) .

According to Schreiber *et al*. (2004) the adaptive management framework structures management processes in a series of seven stages with the whole cycle being repeated through time (Figure 1). It is expected that BioTrade organizations could apply and adjust these stages in the development of their management plans, according to the methodology proposed by UNCTAD (2009) in the *Guidelines for the Development and Implementation of Management Plans for Wild-collected Plant Species used by Organizations Working with Natural Ingredients*.

In an adaptive management process, the resource assessment provides critical information to model alternative management options, and based on these outcomes, identify good practices to be implemented, information gaps and define key variables to be monitored to adjust management activities.

According to Schreiber *et al*. (2004), the process of identification and definition of management objectives is a fundamental element of adaptive management programmes. As presented in Figure 1, in the context of species sustainable management a resource assessment contributes directly to steps 2, 3 and 4 relating to information analysis, the definition of management goals (e.g. harvest rates, monitoring needs, good practices) and the identification of sustainable use options.

Figure 1. Adaptive management cycle applied to the sustainable management of BioTrade species



Source: Adapted from Schreiber *et al*. (2004).

II. GUIDELINES FOR DESIGN AND IMPLEMENTATION OF RESOURCE ASSESSMENTS FOR BIOTRADE WILD-COLLECTED SPECIES

1. Introduction

Prior to conducting a resource assessment and in accordance with adaptive management principles (see Figure 2), BioTrade organizations and resource managers should have previously identified management objectives for the selected species, collection areas and collectors that may be involved in the species management activities.

In this context the BioTrade organization should compile the following information:
- Spatial information of potential collection areas that helps to assess the landscape context and the ecosystems contained; the thematic resolution of the information is subject to the size of the collection areas. In many cases information from an area 30 by 30 metres should be enough;
- Analysis of the quality (i.e. landscape matrix) and conservation status (i.e. rapid ecological assessments) of the collection areas;
- Taxonomic identification of species. It is recommended to get professional advice from a herbarium;
- Local uses and harvest regimes. This should include the amount of the resource harvested (quantities and periodicity), techniques and practices applied for retrieving the product(s), the number and gender of collectors and the communities to which they belong, land tenure rights, incomes derived from species management, among others. This information can be collected using different participatory techniques such as participatory rural appraisal – PRA (Chambers 1994); and
- Local regulations applicable to the management of wild species (e.g. exclusion areas, temporal restrictions).

Preparation of a resource assessment should promote community participation, integration of local and scientific knowledge, local authorities' involvement and implementation of cost-efficient production systems.

The majority of natural products in the world are harvested by people from rural communities, of whom a significant proportion are indigenous people (Stockdale 2005). In a resource assessment, community participation has meanings at two levels. Local populations contribute with their experience and knowledge on resource management and participate in decision-making processes related to improvement of management practices and market access. Tasks such as the compilation of existing information about species biology, management practices, markets and other relevant issues can be done in close collaboration with local communities involved in the production system. The long-standing ties between natural products and communities mean that continued species use is often also linked to the maintenance of rural livelihoods (Stockdale 2005).

The relevance and applicability of a resource assessment depends on information quality and availability; for this reason a BioTrade organization should get expert advice from a qualified biologist, ecologist and/or biodiversity science specialist, in charge of supporting resource managers throughout the processes of producing the baseline information, which includes the generation of harvesting scenarios (i.e. dynamic populations models) and the design and implementation of an appropriate monitoring system.

The BioTrade organization, with the support of a specialist on species management, should guarantee a good data management system in order to provide accurate and scientifically verifiable results to improve knowledge about the species, evaluate the implementation of management activities and adjust them accordingly. The scientific expert should also directly engage with the local communities, local authorities and other relevant stakeholders during any participatory assessment exercises.

In compliance with applicable local or national regulations related to the management of resources, local authorities should be involved in the elaboration of a resource assessment. In this way, they are able to provide specific guidelines and recommendations for the elaboration of management plans as well as specific information required by national regulations.

Cost analysis is relevant before starting a resource assessment. Analysis should take into account the existing information on the species, previous experiences in wild collection activities and access to markets. Cost of a resource assessment preparation is closely related to the quantity and quality of information in place, access to the collection areas and involvement of relevant stakeholders. In this context costs should consider field trips, stakeholders' participation (e.g.

workshops, surveys, visits) and the development of specific field research to collect relevant information regarding local population, ecosystems status, or any other relevant aspects.

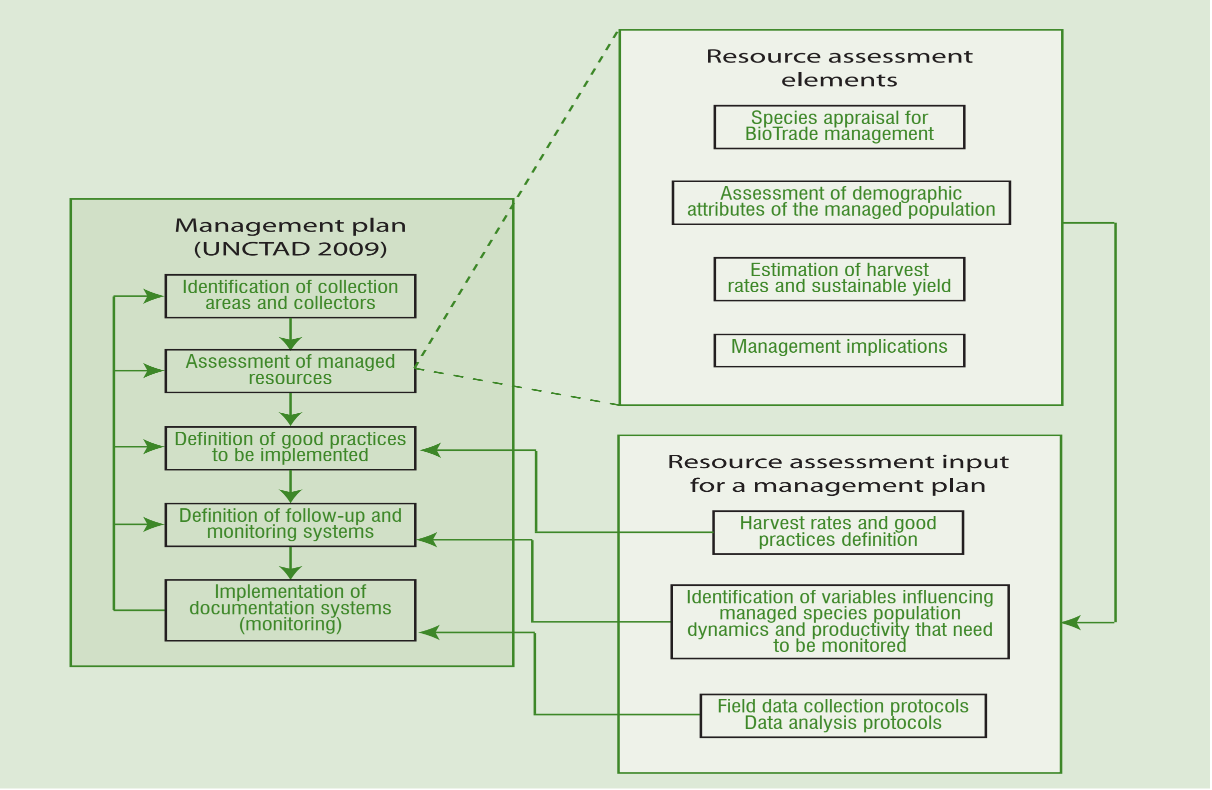
The elements of a resource assessment

A resource assessment entails the following stages:

1. **Species appraisal for BioTrade management**
   The first stage is the compilation and analysis of existing knowledge (including traditional and scientific information available) on the selected species and its population's ecological characteristics. Based on this information, a BioTrade organization will then be able to evaluate the species potential for BioTrade schemes under sustainable use and identify information gaps.
2. **Assessment of demographic attributes of the managed population**
   This stage involves the establishment of an ecological baseline for the harvested population. This assessment entails the estimation of the population size and other key population ecology variables such as population density, spatial distribution and age structure among others.
3. **Estimation of harvest rates and sustainable yield**
   The objectives of this stage are twofold. The first looks to analyze the species' population dynamics. The second aims to evaluate the implications of harvest regimes on the population dynamics as a way to identify a suitable harvest rate.
4. **Management implications**
   The final stage is to draw up conclusions and recommendations on good practices to be implemented in order to assure a trade system founded on a sustainable basis that is able to produce raw materials in the quantities and qualities needed.

Chapter II contains four stages that provide a detailed explanation of tools and analysis necessary to carry out all stages of a resource assessment.

Figure 2. Elements needed to carry out a resource assessment and identify the contribution of this process to the design of a management plan.



Source: UNCTAD (2009).

A. Stage 1. Species appraisal for BioTrade management

Objectives:
- Appraisal of the available information on the species to be managed.
- Evaluate opportunities and alternatives for sustainable management of the species.

Expected outcomes:
- Compilation of existing information on the biology of the species, habitats and current conditions.
- Information gaps identified.
- Assessment of the species potential for sustainable use.

Development:
Baseline establishment includes the collection of key relevant information on the BioTrade species, an assessment of their potential use and field data collection to develop the *in-situ* baseline.

A. Compilation of available biological and socio-economic information on the managed species.
B. Identification of information gaps and assessment of potential sustainable use.

Information to be gathered by BioTrade organizations
- Management conditions and socio-economic considerations
- Species biology
- Population demography
- Habitat information and ecosystem characteristics

Analysis of existing information allows BioTrade Organizations to understand the biological and ecological characteristics of the managed species, as well as to identify information gaps that need to be fulfilled through field data collection and monitoring schemes.

1. Compilation of available biological and socio-economic information on the managed species

The quality and relevance of the management decisions for any species, including the definition of a harvest rate, relies on the available information on the population ecology of the species in question. This type of information can be obtained from three major sources: scientific papers (i.e. peer-reviewed journals), published literature from research centers and non-governmental organizations (NGOs) available on the web, and grey literature (i.e. unpublished reports and fieldwork data sheets).

An important source of information comes from traditional knowledge and scientific experts. In this sense, it is recommended to BioTrade organizations to gather *in-situ* information (i.e. management regimes, productivity) by rural appraisal methodologies such as focus groups, interviews and questionnaires (Chambers 1994). At the same time, researchers at universities, botanical gardens or research centers could be also interviewed. A considerable amount of information can be gleaned from unpublished reports written by scientists, government agencies and conservation organizations (Primack 2004).

Information on the following parameters needs to be compiled in order to complete a resource assessment. This information will allow BioTrade organizations to understand the population dynamics and the impact of current management practices, as well as identify those aspects that determine management conditions.

a) Management conditions and socio-economic considerations

Before gathering specific information on the biology of the species, it is recommended to understand the current management practices and the social and economic conditions associated with the management of the species. It is important to involve local communities and collectors in order to have a good understanding of current practices, the quantities commercialized and the price of raw materials, and production costs, among other parameters that affect species management and production sustainability in the long term.

1. **Products derived from the use of the species and parts used**
   Management practices have a differential impact on the population, which is directly related to the living part of the individual that is collected (i.e. leaves, roots, bark). Some of these management practices require the extraction of the individual from the population generating a direct impact on the population. Others require the harvest of specific

parts from the individuals such as fruits or leaves. In these cases the management practices have a different effect on the population, altering other attributes such as the germination rate.

2. **Traditional use**
   Information on traditional practices, management regimes and current harvest rates is needed. This information is important in the experimental design and field protocols for establishing good management practices in order to control its potential effects on the population demography.

3. **Yield and harvest rate**
   Information on harvested quantities of specific products (e.g. flowers, fruits, barks, roots and seeds) and the capacity of production per individual allows quantifying the potential yield of a population, and thus, allows the establishment of a harvest rate needed to supply demand but under the maximum sustainable yield of the given species. In the case of species that have been harvested traditionally or commercially for a considerable period of time, it is important to carry out interviews to obtain additional information from the resources users in order to understand the possible impact of these practices.

4. **Relevant socio-economic issues affecting resource management**
   Where a formal supply system of raw materials is introduced, discussions with providers regarding the estimated production and supply capacities are recommended (UNCTAD 2009). Economic aspects include information on prices and current production costs including the investments needed to implement good management practices.

b) Species biology

Information on the ecological traits of the species allows BioTrade companies to identify physiological and ecological limitations to the population growth and consider the options of managing these to optimize production and resource management (Guillot and Becerra 2003). Reproduction strategies are important variables that control population dynamics. In this context it is recommended to gather information on the following aspects:

1. Natural propagation strategies: seed dispersal, pollination, sexual reproduction;
2. Reproductive biology: number and duration of reproduction events (annual, biannual, perennial). This is especially important when the collected parts are fruits, leaves or seeds as well as in the case of annual species that have a unique reproductive event;
3. Fecundity: offspring number and size in each reproductive event;
4. Male to female ratio in the case of bisexual or dioecious species;
5. Age of first reproduction and lifespan;
6. Information on species vulnerability and resilience to anthropic disturbance; and
7. Interspecific interactions (parasitism, herbivory, pollination).

c) Population demography

The main variables that describe the status and population dynamics are the following: population size, population density and population structure. For this reason it should be a priority to collect good quantitative data on these variables, either by published scientific studies or through specific field studies implemented as part of the baseline phase in the resource assessment process (Guillot and Becerra 2003)

1. **Density**
   Population size generally refers to the number of individuals present in the population. Density refers to the number of individuals in a given area. For ecologists density is usually a more useful measure. This is because density is standardized per unit area, and, therefore, can be correlated with environmental factors or used to compare different populations.

2. **Population structure**
   Distribution of various age/size groups in a population permits the analysis of how the population is growing, the reproductive capabilities and likelihood of the population in the mid- and long term. In this context it is important to have information on the distribution of the population according to their age classes (e.g. saplings/infants, juveniles, adults) and the characteristics of each such as:
   a. Longevity/life expectation;
   b. Growth time at each stage (transition time among age classes);
   c. Mortality rate; and
   d. Density at each population stage.

d) Habitat information and ecosystem characteristics

Habitat quality, ecosystems fragmentation and anthropic disturbance regimes such as timber extraction, fires, cattle grazing or hunting that might have considerable direct impacts on the target species and its populations, need to be collected. In order to identify those variables that could affect sustainable management it is recommended to get general information related to the following aspects:

1. Relevant habitat characteristics for the management of the species;
2. Climate variability (seasonal, successional);
3. Existing habitat management regimes (disturbance, conservation status, other uses); and
4. Status of fragmentation/connectivity of the landscape matrix.

2. Identification of information gaps and assessment of potential sustainable use

Screening of BioTrade species via a multi-criteria analysis helps to identify information gaps and assess species potential for harvest and trade on a sustainable basis considering the ecosystem/adaptive management scheme. To identify information gaps a

Table 1. Information gap analysis on collection areas and managed resources of *Caesalpinia spinosa*

Variable	Information availability	Source	Information gathering tools
Management practices			
Parts used and management practices at local level	Available	Field studies Ecobona Regional Programme	Participatory assessment (local knowledge)
Collection practices	Available	Field studies Ecobona Regional Programme	Participatory assessment
Current harvest rates	Available	Field studies Ecobona Regional Programme	Participatory assessment
Prices and trade flows	Available	Field studies Ecobona Regional Programme	Participatory methods, specific market studies
Selling seasons	Available	Field studies Ecobona Regional Programme	Participatory assessment
Land tenure rights	Available	Field studies Ecobona Regional Programme	Participatory assessment
Species biology and population demography			
Reproduction strategies	Incomplete	Secondary sources	Scientific research
Density	Available	Field studies Ecobona Regional Programme	Field studies (inventories)
Age classes and demography	Available	Field studies Ecobona Regional Programme	Field studies (inventories)
Germination/reproduction rates	Non-existent		Field studies (inventories)
Longevity/mortality rates	Incomplete	Secondary source	Field studies (inventories)
Seasonality	Incomplete	Secondary source	Secondary information and field studies
Habitats and ecosystems			
Ecosystems and habitats involved	Available	Field studies Ecobona Regional Programme	Participatory assessment
Climate characteristics	Available	Field studies Ecobona Regional Programme	Existing meteorological information and reports
Landscape matrix characteristics	Available	Field studies Ecobona Regional Programme	Mapping participatory assessment
Habitat characteristics and conservation status	Available	Field studies Ecobona Regional Programme	Field studies (habitat analysis)

Source: Adapted from Becerra (2009), data from Larrea (2011).

checklist can be prepared to summarize the information obtained and the tools used to get it (see Table 1). Once gaps have been identified the collection of key additional information can be prioritized. The relevance of this information for making management decisions can then be analysed (Becerra 2009).

Based on the information gathered the BioTrade organization can use a multi-criteria assessment to carry out a preliminary assessment to evaluate the feasibility of a species for harvest and trade under sustainable conditions (see Table 2). The assessment is based on a qualification index aimed at evaluating the potential sensitivity of the species to be collected and traded based on the life traits, the population attributes and the ecosystem characteristics of the species. When a species has a low or medium score, resource managers should include specific management practices to guarantee sustainable use.

Table 2 presents an example of the use of this multi-criteria assessment to evaluate the potential of sustainable use of *Caesalpinia spinosa*, *Mauritia flexuosa* and *Neopicrorhiza scrophulariiflora*. All three species are likely to be used for BioTrade purposes but with specific considerations and best management practices formulated for each. However, in the case of *Mauritia flexuosa*, which presents the lowest score in the life history attributes, this should suggest to a BioTrade organization that variables such as germination rate and dispersal mechanisms require special attention and could have a high influence in the population dynamics. On the other hand, the score of *Caesalpinia spinosa*, shows that a BioTrade organization should pay special consideration to ecosystem variables, as the existing information indicates it does not have the expected quality to assure sustainable production (for further information on the case studies please visit: www.biotrade.org).

The multi-criteria matrix is a very practical and useful tool for BioTrade organizations. The matrix helps to screen the potential use of a species under sustainable conditions. Further, the matrix identifies the key variables that need to be considered in the design of the production system. Where insufficient information is available to screen a species on the matrix, it is recommended to contact experts for further guidance.

Table 2. Multi-criteria matrix to assess potential sustainable use. Data relate to the four study cases discussed in these guidelines (for further information on the case studies please visit: www.biotrade.org)

a. Life history traits

Variable	Options	Scores	*Caesalpinia spinosa*	*Mauritia flexuosa*	*Neopicrorhiza scrophulariiflora*
Part of the plant harvested	Entire individuals, bark, shots, roots	2	4	2	2
	Latex, flowers, pollen, seeds	4			
	Leaves, fruits	6			
Dispersion system (spores, seeds)	Biotic specialist (frugivores: birds, mammals)	2	6	2	6
	Biotic generalist (small mammals)	4			
	Abiotic (ramets, wind cross-pollination)	6			
Seed germination rate	Low	2	6	4	2
	Medium	4			
	High	6			

b. Population attributes

Variable	Options	Scores	*Caesalpinia spinosa*	*Mauritia flexuosa*	*Neopicrorhiza scrophu-lariiflora*
Birth rate	High Medium Low	2 4 6	6	4	6
Juveniles mortality rate	High Medium Low	2 4 6	2	4	6
Age-size class of first reproduction	Late Mid Early	2 4 6	4	6	6
Ecological strategy	Mature habitats Secondary forest Colonizers	2 4 6	4	2	4
Population structure	Constrictive pyramid Stationary pyramid Expansive pyramid	2 4 6	2	2	4
Population density	Low Medium High	2 4 6	6	4	4
Population spatial distribution	Random Aggregated Homogeneous	2 4 6	6	4	4

c. Ecosystem attributes

Variable	Options	Scores	*Caesalpinia spinosa*	*Mauritia flexuosa*	*Neopicrorhiza scrophu-lariiflora*
Landscape context	Small isolated patches (highly fragmented) Long and connected patches (fragmented) Matrix (not fragmented)	2 4 6	2	6	4
Carrying capacity	Low Medium High	2 4 6	2	6	4
Habitat integrity	Highly disturbed Average disturbance Low disturbance	2 4 6	2	6	4

d. Total score

Variable	Options	Scores	*Caesalpinia spinosa*	*Mauritia flexuosa*	*Neopicrorhiza scrophu-lariiflora*
Score	Low (poor management aptitude) Medium (to be used under specific management considerations) High (High potential of *in-situ* sustainable use)	26–38 38–64 65–78	52	52	56

Source: Adapted from Becerra (2009).

B. Stage 2. Assessment of demographic attributes of the managed population

Objectives:
- To establish an ecological baseline for the harvested population by assessing the population size and its conservation status in the management area.
- Identify and fill in existing information gaps to establish a sustainable harvest rate.

Expected outcomes:
- Relevant biological and demographic information completed.
- Species demographic information that includes population density, age-size structure, transition time among classes, germination rate (fecundity) and seedlings mortality.

Development:
To start the analysis of population dynamics and arrive at a harvest rate it is important to improve the basic demographic information of the managed species available to the resource assessment.

A. Field inventories to collect data on key population parameters.
B. Data analysis and calculation of demographic parameters.

One of the most fundamental problems faced by community and population ecologists is that of measuring population sizes and distributions. They are necessary for impact assessments (measuring the effects of disturbance) and restoration ecology (restoring ecological systems) as well as to set harvest limits on commercial and game species (e.g. fish, deer).

The need to assess community structure has generated a number of quantitative field methods as well as an appreciation of which methodology works best in any given situation. These methods have been designed to generate reliable estimates of the abundance and distribution of each species within a community. This information makes it possible to compare species or groups of species within a community or to contrast species composition and abundance among communities.

Furthermore, measures of species abundances within a community taken at one point in time provide a baseline against which future measures of species abundances within that community can be compared. This type of information allows resource managers to evaluate population changes over time, as a response to specific management activities (e.g. BioTrade).

In most cases it is either difficult or simply not possible to census all of the individuals in the target area. The only way around this problem is to estimate population size using some form of sampling technique. There are numerous types of sampling techniques. Some are designed for specific types of organisms (e.g. plants *vs*. mobile animals). As well there are numerous ways of arriving at estimates from each sampling technique. All of these procedures have advantages and disadvantages. In general, the accuracy of an estimate depends on: the number of samples taken, the method of collecting the samples and the proportion of the total population sampled.

Cunningham (1994, 1996) proposed a method with the focus of being a protocol to collect available knowledge, local as well as scientific, about a resource species and which does not itself generate any new data. The compiled information is used to identify species, resources or sites that may be vulnerable to overexplotation. A standard summary sheet is prepared and the information collected evaluated according to a set of criteria of sustainability drawn from ecology, economics and social sciences. On the basis of the assessment, each species is classified into one of eight management categories. Appropiate management recommendations are given to each category. Yet this rapid vulnerability assessment does not includes any protocols for inventory as the method is intended to be a rapid first assessment of the species. However, the assessment is only as good as the information available, which is often lacking.

This section provides information on the main quantitative field methods best suited to study natural communities and how to apply them, in order to establish the baseline for the species of interest.

1. Field inventories to collect data on key population parameters

Once a BioTrade organization has identified the principal information gaps, those variables that need more attention and have to be collected through field inventories can be pinpointed. In order to begin field sampling, the BioTrade organization needs to select the area to be inventoried taking into account that all managed habitats are well represented and the field techniques to be applied are appropriated for the wild-collected species. The information collected for the baseline and completed through the field inventories will also provide key information for the population modelling exercise and the establishment of a preliminary harvest rate.

Field inventories are similar to experiments in the sense that they are carried out to test hypotheses, which are further used to take management actions. In case of management activities the hypotheses are related to the effectiveness or efficiency of implementation of management practices in order to reach a sustainable harvest rate.

a) Why sample?

Sampling methods are invaluable for numerous biological investigations. Such methods are used to determine the structure of a natural community. It would be extremely time consuming, for example, to count and measure every individual of each species within a community in order to determine the abundances and distributions of each species within the community. Sampling methods enable us to estimate reliable information by use of samples. However, it is critical that the samples be taken without bias and in sufficiently large number so that the resulting data can be summarized to give valid estimates of the desired

Box 2. Sampling methodologies

1. The area-sample method (quadrats or plots)

Area-sample methods are best suited for plant communities (e.g. mushrooms, herbs, forest trees) and sessile or sedentary animals (e.g. sponges).

Quadrats: When using quadrat samples it is important to determine the appropriate quadrat size to use on the basis of the size and density of the individuals within the population being sampled. Quadrats must be large enough to contain a number of individuals, but small enough that the individuals present can be separated, counted and measured. For example, quadrat sizes for herbaceous vegetation might be 1 m^2, while for shrubs 10–20 m^2 and 100 m^2 for forest trees.

Quadrat shape is also important as it affects the ease of establishing quadrats and the efficiency of sampling. For example, circular "quadrats" are more easily established than square quadrats; and elongated rectangular "quadrats" furnish more variety of species than an equal number of square quadrats of the same area. This latter relationship holds because a rectangle encompasses more environmental variety due to environmental gradients (e.g. slopes, soil-moisture variation) than a square of the same area. However, because rectangular quadrats have more perimeter than square quadrats of the same area, accuracy tends to decline as quadrats become more elongated due to the "edge effect" (Barbour *et al*. 1999). The best quadrat size and shape depends on the application, for this reason it is recommended to define this with the advice of a specialist.

Plots: Plots are use to sample count individuals and sample habitat characteristics. A subset of plots is used with the assumption that it is a representative area. Selecting the area and the best number or location of plots requires insight into patterns of distribution of the species across the landscape, the type of vegetation (forest, grassland) and the life form growth in the case of plants.

2. The distance-sample method

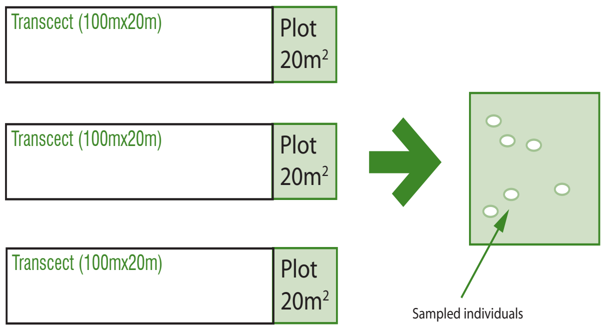
Distance-sample method (e.g. transects) are more frequently used to sample species or community variation along environmental gradients such as different types of ecosystems along an altitudinal gradient.

Transects: A transect is a straight line or series of straight-line segments laid out in the area to be sampled. Transects are used widely to obtain systematic samples of spatially distributed populations (e.g. plants, insects). In this cases plots placed along transects are the actual sample units. Each transect is treated as an independent observation. The estimation of the abundance of biological populations (such as terrestrial mammal species) can be achieved using a number of different types of transect methods, such as strip transects, line transects, belt transects, point transects and curved line transects. As in the case of the area-sample method, the size and number of transects to set up depends on the ecological and biological attributes of the species and the type of ecosystem where the collection area occurs.

Point sampling: A set of points is established throughout the population and measurements are taken from each point. Points are spaced widely enough to negate members of the population being sampled more than once. This method requires the use of mathematical formulas to estimate population size and is more frequently used for avian surveys.

Source: Adapted from Smith and Smith (2008), Robinson and Bodmer (1999), Getz and Haight (1989), Odum and Barrett (2005).

Figure 3. Example of a sampling design for *Caesalpinia spinosa* including three sample units (transect) and five subsample units (plots)



Source: Adapted from Primack (2004).

parameters, in this case population structure, density and other population parameters needed for the establishment of the sustainable harvest rate of the traded species.

b) Sampling methods

The specific sampling method used to assess community structure depends on the nature of the organisms, including the variables listed above, and the community to be sampled. In the context of these guidelines, the sampling techniques to be used in a resource assessment are defined according to the population attributes of the species of interest such as their spatial distribution and their life growth form in the case of plants. Furthermore, to analyse population dynamics it is recommended to identify a methodology that allows documenting species density and population structure as a standard basis.

With these considerations in mind, the application of two quantitative field methods best suited to study communities of sessile or sedentary animals and most types of vegetation are recommended:

- Area-sample method (quadrats or plots); and
- Distance-sample methods (e.g. transects).

Box 2 refers to the most common sampling techniques that can be applied to collect basic information to analyse managed population characteristics.

Survey design relies on the objectives of the field study, for example estimation of population size, recruitment, species composition, annual production of fruits, etc. Based on this information sample size is defined in order to have the best representation of the managed population.

Sample size refers to the number of independent sample units (e.g. quadrants). Definition of sample size is referred to as the number of replicates (e.g. 5 transects of 100 m) and subsamples as the number of observations in a sampling unit (e.g. 5 plots per transect) (Figure 3). The sample size should be big enough to have a high likelihood of detecting a true difference between two groups that is statistically significant.

Sampling size depends on the distribution of the managed species in the landscape. Some species are located in several habitats in the landscape, so it is advisable to set sampling plots in areas with similar characteristics. In the case of managed species, observations on non-managed areas (control areas) are especially important in the design of field studies. Observations from randomly selected control areas can be compared with observations associated with managed populations to identify effects derived from management practices. Table 3 contains an example of a survey design checklist.

2. Data analysis and calculation of demographic parameters

Information derived from sampling plots and collected information should be analysed and organized in a way that allows BioTrade organizations to evaluate and define the biological and ecological characteristics of the managed species.

a) Part of the plant harvested and collection practices

Information on the type of management and parts of the plants or animals being used allow organizations to consider management implications and collection practices (Figure 4).

Table 3. Survey design checklist for *Caesalpinia spinosa*

Question	Example
What is the survey objective?	Evaluate density and population parameters of *Caesalpinia spinosa*
To what population we want to make inferences?	Community of Perucho (Imbabura, Ecuador)
What is the best sampling method?	Transects
What will be the sampling unit?	Plots
What is the estimated area to be sampled?	50 hectares
What sample design is the best?	5 managed forest fragments, 2 control forest fragments 5 transects of 100 m x 20 m in each forest fragments 5 plots of 20 m^2 per transect
What are the variables to be measured?	Number of individuals (all individuals identified as *Caesalpinia spinosa*) Population size distribution for each individual based on diameter size at breast height Reproductive condition Evidence of mortality causes (diseases, seeds or fruit predation, herbivores, cattle grazing, etc.)
Frequency (specify sampling frequency in case information is needed for monitoring)	Every year before extraction season

Source: Adapted from Bookhout (1996), data from Larrea (2008).

Figure 4. Examples of part of the species harvested and collection practices of three species

Caesalpinia spinosa (seeds fruits and pods)	• Seed production occurs once a year in a asynchrony pattern lasting four to five months at the end of the rainy season (July till November). Pods (and seeds) are collected from the soil or directly from the tree avoiding the collection of non-mature pods. On each collection almost all pods are collected (Larrea 2011).
Neopicrorhiza scrophrulariiflora Rhizomes (ramets)	• In the national parks plants are harvested only for local use, the main users being specialists known as amchi trained in the Tibetan medical system. • In the buffer zone the species is collected for trade. The harvesting approach of commercial collectors is destructive.
Mauritia flexuosa (fruits)	• Because of the height of adult individuals, female palms are cut down to retrieve the fruits

b) Population density and structure (size-age classes)

To analyze population dynamics it is important to understand the composition of the population in terms of its age structure (i.e. number of individuals that comprise the population per each age/sex class) and its density (number of individuals per area unit). This will aid a BioTrade organization in evaluating whether the population has a good proportion of individuals from which the traded parts will be collected (fruits, seeds, barks, etc.), as well as whether the availability of saplings and young individuals will be capable of sustaining such production (harvest rate) in the future. Normally in a healthy population the proportion of seedling, saplings and young individuals is greater than that for adult individuals, however, this condition can vary depending on the species and the management conditions.

1. Total density calculation

Densities are calculated measuring the number of individuals of each plot per plot area (individuals/area). Average and standard deviation values of density from several plots provide an estimation of the total population density for that area (Table 4). In subtropical ecosystems, trees can be aged approximately by counting annual growth rings and then correlate the measures with standing individuals – their height and trunk diameter at breast height (DBH). In this way individuals from a managed area can be grouped in size-age classes. In tropical ecosystems without four seasons where tree rings do not work properly, individuals are classified using height and DBH measures as for the tree species used in the study cases (for further information on the case studies please visit: www.biotrade.org). Height measurements can be substituted in the case of herbaceous plants, small understorey palms or woody shrubs.

Densities can be monitored by sampling the same transects and plots each production season or annually. Systematic data collection allows resource managers to evaluate differences in production by season, habitat conditions that could affect population growth or analyse impact of collection practices or intervention activities.

2. Densities by age/sex classes

Populations may be divided into three ecological periods: pre-reproductive, reproductive and post-reproductive. It is important to revise species biology to check those characteristics that allow the identification of individuals at these stages. During the field study it is important to get support from local managers or a botanist to identify seeds, seedlings and young individuals that frequently are not easily identifiable.

This concept is important to adjust the size-age classes' classification of any given population by defining those characteristics that could be used as indicative of the age of the individuals (e.g. size, height, presence of flowers, other characteristics to distinguish young and adult individuals). In the case of plants this is particularly important taking in to account that individuals with no flower production during flowering season are either too young or too old.

Sex classes are defined in the case of animals and dioecious plants. Here it is important to get information on physical characteristics to distinguish females and

c) Reproduction biology

The dynamics of a natural population are highly determined by species reproduction strategies. As shown in the case studies, different strategies have different implications for the management of the populations (Table 6). (For further information on the case studies please visit: www.biotrade.org). In many cases this

Table 4: Example of a matrix of calculation of total density based on information derived from sampling units

	Number of sampled individuals		
	Transect 1	**Transect 2**	**Transect 3**
Plot 1	23	39	25
Plot 2	20	28	28
Plot 3	10	36	25
Plot 4	19	12	32
Plot 5	30	25	30
Individuals/20 m²	20.4	28	28
Individuals/20 m²		25.4	
		Total density = 1.27 individuals/m²	

Source: Adapted from Bookhout (1996), data from Larrea (2008).

Table 5. Average densities and age classes for *Caesalpinia spinosa* from two sites in the Ecuadorian Andes

Age class	Characteristics	No. individuals (average plots)	Population (%)
Seedlings	≤ 1 cm diameter at the base	151	76
Saplings	1–2 cm	13.5	6.82
Young adults	> 2–6 cm (from this size harvest starts)	11	5.56
Adults	> 6–20 cm	25	7.07
Elders	> 20 cm	9	4.55
Total density		**209**	**100**

Estimated total density: 0.36–0.63 trees per m^2 (mean = 0.5; standard deviation = 0.19)

Source: Adapted from Bookhout (1996), data from Larrea (2008).

type of information is obtained from secondary sources such as scientific reports or local knowledge.

1. Growth time

Life expectancy and growth time of individuals in each age-size class are important to analyse in population dynamics and determining the possibilities of sustainable production in the long term.

Growth time information could be derived from secondary information from scientific studies on the species biology or traditional local knowledge. In the case of rapid growth species, such as annual herbs, a field study could be carried out to monitor the individual's growth, measuring the size of individuals in sampling plots.

When information is not available for the managed species, it is recommended to take into account information on similar species and use some referential values that could be adjusted in the monitoring programme under the adaptive management framework. Table 7 presents examples of growth time information available for three species and helps to understand how age classes are defined. More details are found in the case studies (for further information on the case studies please visit: www.biotrade.org).

d) Germination, natality and mortality rates

This information can be gathered by scientific literature if available. If not, permanent plots should be established as part of a monitoring programme aimed at

Table 6. Information on the reproduction biology for Caesalpinia spinosa, Mauritia flexuosa and Neopicrorhiza scrophrulariiflora based on secondary sources

Species	Sexuality	Management implications
Caesalpinia spinosa	Perennial, produces flowers and seeds every year. Sexual reproduction occurs through cross-pollination by insects (i.e. wasps, honey bees).	In this case it is important to identify the insects that are responsible for the pollination of plants and assure that management practices do not affect pollination.
Mauritia flexuosa	Sexual reproduction system. Palm dioecious (male and female individuals are differentiated). Evidence of density dependence is reported.	Because of the dioecious condition and density dependence, management is strongly influenced by the females' dynamics (i.e. growth and reproduction characteristics) and the density of the population and the effects of this variable on germination rates.
Neopicrorhiza scrophrulariiflora	Vegetative growth (ramets) and sexual reproduction.	Reproduction by ramets makes it difficult to identify individuals and population analysis is frequently based on the rate of ramet production. Management practices should take into account this condition.

Source: Larrea (2008), Holm *et al*. (2008) and Ghimire *et al*. (2005)

Table 7. Transition time required of individuals from populations of the three case studies species from lower size-age class to higher size-age class

Caesalpinia spinosa (Larrea 2008)

Age class	Transition time (years)
Seedlings	1
Saplings	2
Young adults	4
Adults	15
Elders	30
Natural dead	10
Total life expectancy	**62**

Mauritia flexuosa (Holm *et al*. 2008)

Age class	Transition time (years)
Seedlings	1
Young juveniles	5
Juvenile 1	8
Juvenile 2	5
Old juvenile	10
Adult 1	17
Adult 2 (elders)	14
Total life expectancy	**60**

Neopicrorhiza scrophrulariiflora (Ghimire *et al*. 2005)

Age class	Transition time (years)
Saplings	1
Young	1.5
Adult 1	3
Adult 2	8
Total life expectancy	**13.5**

Sources: Larrea (2008), Holm *et al*. (2008) and Ghimire *et al*. (2005) .

filling information gaps not identified during the establishment of the baseline. This requires marking a statistically representative number of individuals from adults to seedlings and to monitor over time (Table 8).

e) Distribution/dispersion

Basically, there are three possible types of spatial distribution or dispersion of individuals (see Figure 5). In a random dispersion, the locations of all individuals are independent of each other. In a uniform dispersion, the occurrence of one individual reduces the likelihood of finding another individual nearby. In this case the individuals tend to be spread out as far from each other as possible. In a clumped dispersion, the occurrence of one individual increases the likelihood of finding another individual nearby. In this case, individuals tend to form groups (or clumps).

Ecologists are often interested in the spatial distribution of populations because it provides information about the social behaviour and/or ecological requirements of the species. For example, some plants occur in clumped distributions because they propagate by rhizomes (underground shoots) or because seed dispersal is limited. Clumped distributions in plants may also occur because of slight variations in soil chemistry or moisture content. Many animals exhibit rather uniform distributions because they are territorial (especially birds), expelling all intruders from their territories. Random distributions are also common, but their precise cause is more difficult to explain.

Unfortunately, it is often difficult to visually assess the precise spatial distribution of a population. Furthermore, it is often useful to obtain some number (quantitative measure) that describes spatial distribution in order to compare different populations. For this reason, there are a variety of statistical procedures that are used to describe spatial distributions.

1. How to measure distribution/dispersion: Generally two types of methods are used: quadrat methods and distance methods (transects). The quadrat method (variance/mean ratio method) is based on the Poisson probability distribution whereas the distance method (Clark-Evans method) relies on the distance to the nearest neighbour measure, which measures the probability that a circle of radius (r) is not empty.

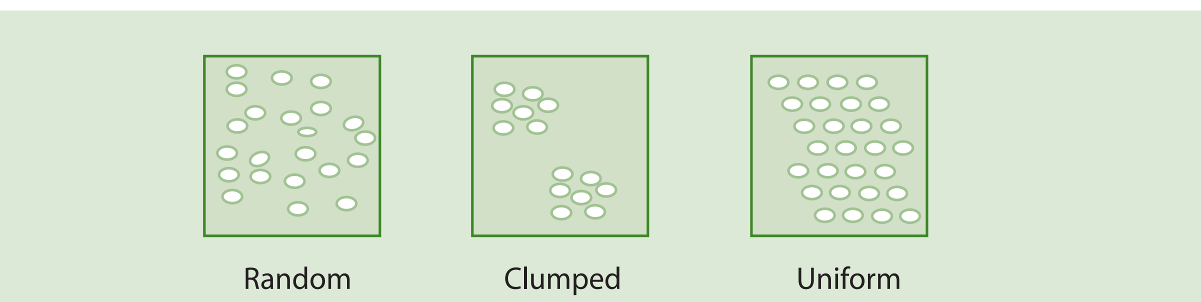
The variance/mean ratio method focuses mainly on determining whether a species fits a randomly spaced distribution, but can also be used as evidence for either an even or clumped distribution. In the variance/mean ratio method, data are collected from several random samples of a given population. In this analysis, it is imperative that data from at least 50 sample plots are considered. The number of individuals present in each sample is compared with the expected counts in the case of random distribution. The expected distribution can be found using Poisson distribution. If the variance/mean ratio is equal to 1, the population is found to be randomly distributed. If it is

Table 8. Considerations to identify key variables used to determine germination and mortality rates

<table>
<tr><th>Species</th><th>Germination rate</th><th colspan="2">Mortality rate</th></tr>
<tr><td rowspan="6">Caesalpinia spinosa</td><td rowspan="6">The dynamic population model was built under the assumption of a germination rate of 0.9 per cent of all seeds being produced annually.</td><td>Age class</td><td>Mortality</td></tr>
<tr><td>Seedlings</td><td>0.91</td></tr>
<tr><td>Saplings</td><td>0.19</td></tr>
<tr><td>Young adults</td><td>0.08</td></tr>
<tr><td>Adults</td><td>-0.27</td></tr>
<tr><td>Elders</td><td>0.36</td></tr>
<tr><td>Mauritia flexuosa</td><td>The effect of density means that populations with a higher number of individuals present a lower growth rate. Seedling survival and growth decreases as density of the entire palm population increases. Consequently, in this case, female population size and population growth are the key variables that determine the number of new individuals that become part of the population.</td><td colspan="2">Mortality rate was estimated based on the number of individuals contained in each size class that pass to the following size class at the next time interval. For example, if there were 260 saplings and 247 individuals became juveniles, it was assumed that 13 individuals died over one year (time a sapling takes to become juvenile). These figures give a mortality rate of 22 per cent (0.22).</td></tr>
<tr><td>Neopicrorhiza scrophrulariiflora</td><td>Based on the data provide by Ghimire et al. (2005), the dynamic population model was built on the assumption of a recruitment rate of 2.3 new individuals each year over the 1 m^2 surveyed.</td><td colspan="2">The assumption was made that immature individuals have a mortality rate of 11.4 per cent and other size-age classes 9 per cent. More specific information is needed.</td></tr>
</table>

Source: Larrea (2008), Holm *et al*. (2008) and Ghimire *et al*. (2005).

Figure 5. Examples of types of population's special distributions



Box 3. Species distribution models (SDMs) – an important tool to estimate population size and its distribution at the habitat level

Building ecological niche models to predict species ranges has been one of the main focuses over the last 20 years in landscape ecology and conservation biology. Special concern has been devoted to develop species ranges in poorly known regions where only presence points are available (Guisan and Thuiller 2005, Marmion *et al*. 2009, and Pearson *et al*. 2006). Several analytical approaches have been applied to these challenges, varying from simple sets of rules based on overlays of environmental and species occurrences data creating a so-called "environmental envelop" (Krabbe *et al*. 1998) to sophisticated multivariate analyses such as Mahalanobis distance (Cuesta *et al*. 2003) or logistic regression (Loiselle *et al*. 2003).

In the management of larger areas, where inventory plots would not be sufficient to analyse population densities and distribution, field data could provide information for species niche modelling. In the context of a resource assessment, habitat models improve substantially the ability to predict species occurrence and to locate new populations for initiation for management purposes under sustainable harvest regimes. For example, the odds of finding American ginseng in Shenandoah National Park, United States of America, based on the habitat model were 12.3 times greater than random searches, and this helped the Fish and Wildlife Service to evaluate population estimates of this traded species (Van Manen *et al*. 2005).

The increase in applications of species distribution models is based on the growth in the availability of remotely sensed data and development of geographical information systems (GIS) techniques integrated with novel statistical methods (Guisan and Zimmermann 2000). Carefully generated predictive models can effectively contribute to the insufficient field survey and museum data (Muñoz *et al*. 2005, Guisan *et al*. 2006, and Rodriguez *et al*. 2007) and occasionally even provide a more useful basis for biodiversity assessments than existing published range and national ecosystem maps (Bustamante and Seoane 2004).

In this context, different studies confirm that among the different modelling techniques, the maximum entropy algorithm of the Maxent platform (Phillips *et al*. 2006, Phillips and Dudík 2008) is one of the best suited for this type of exercises. The Maxent algorithm is a machine learning technique used to fit the geographical distribution of a species based on a set of presence-only data points, and a set of environmental descriptors (Elith *et al*. 2010, Phillips *et al*. 2006). Maxent has been tested extensively and has been found to outperform most of the "common" niche modelling techniques, such as Bioclim (Busby 1991), Domain (Carpenter *et al*. 1993), generalized additive and generalized linear models (Austin 2002), genetic algorithm for rule-set production (GARP) (Stockwell 1999), while performing similar to other novel approaches and machine learning-based techniques both under current and future conditions (Costa *et al*. 2010, Fitzpatrick and Hargrove 2009, Hijmans and Graham 2006, Loiselle *et al*. 2008, Phillips and Dudik 2008, VanDerWal *et al*. 2009, and Veloz 2009).

With these considerations in mind, for the purpose of these guidelines we propose the use of Maxent to define the habitat suitability for any given species of interest in the BioTrade programme, and based on the model outputs define on a more sound base the collection area and from there quantify the size of the population. The use of this tool could support national authorities and resources users in the analysis of potential management areas, as well as with the identification inventory methods to use according to information available and monitoring needs..

Sources: Guisan and Thuiller (2005), Marmion *et al*. (2009), Pearson *et al*. (2006), Krabbe *et al*. (1998), Cuesta *et al*. (2003), Loiselle *et al*. (2003), Van Manen *et al*. (2005), Guisan and Zimmermann (2000), Muñoz *et al*. (2005), Guisan *et al*. (2006), Rodriguez *et al*. (2007), Bustamante and Seoane (2004), Phillips and Dudík (2008), Elith *et al*. (2010), Phillips *et al*. (2006), Busby (1991), Carpenter *et al*. (1993), Austin (2002), Stockwell (1999), Costa *et al*. (2010), Fitzpatrick and Hargrove (2009), Hijmans and Graham (2006), Loiselle *et al*. (2008), VanDerWal *et al*. (2009), and Veloz (2009)

significantly greater than 1, the population is found to be a clumped distribution. Finally, if the ratio is significantly less than 1, the population is found to be evenly distributed. Typical statistical tests used to find the significance of the variance/mean ratio include the t-test and chi squared.

In the Clark-Evans nearest neighbour method, the distance of an individual to its nearest neighbor is recorded for each individual in the sample. For two individual that are each the other's nearest neighbor, the distance is recorded twice, once for each individual.

To receive accurate results, it is suggested that the number of distance measurements should be at least 50. The average distance between nearest neighbors is compared with the expected distance in the case of random distribution to give the ratio:

$$\frac{mean\ distance}{\frac{1}{2}\sqrt{density}}$$

If this ratio is equal to 1, then the population is randomly dispersed. If the ratio is significantly greater than 1, the population is evenly dispersed. Lastly, if the ratio is significantly less than 1, the population is clumped. Statistical tests (such as the t-test, chi squared, etc.) can then be used to determine whether the ratio is significantly different from 1.

However, many researchers believe that species distribution models based on statistical analysis, without including ecological models and theories, are too incomplete for prediction. Instead of conclusions based on presence or absence data, probabilities that convey the likelihood a species will occupy a given area are preferred because these models include an estimate of confidence in the likelihood of the species being present or absent. Additionally, they are also more valuable than data collected based on simple presence or absence because models based on probability allow the formation of spatial maps that indicate how likely a species is to be found in a particular area. Similar areas can then be compared to see how likely it is that a species will occur there also; this leads to a relationship between habitat suitability and species occurrence (see Box 3).

C. Stage 3. Estimation of harvest rates and sustainable yield

Objectives:

- Analyze population dynamics and harvest implications.
- Identify a suitable harvest rate according to species population dynamics.

Expected outcomes:

- Scenarios to analyze implications of harvest rates on managed population dynamics.
- Suitable harvest rates identified.

Development:

Harvest rate estimation is developed based on analysis of species and population data. Dynamic population models are used as a tool to analyse information and generate management scenarios.

A. Analysis of population dynamics without harvesting.

B. Analysis of the implications of harvesting scenarios.

The reproductive surplus differs spatially and temporally as environmental conditions vary, and even in the absence of exploitation, change is the rule and constancy is the exception (Hilborn *et al*. 1995). Sustainable yields may be estimated by direct experimentation, observation of natural systems or deduction from biological understanding (Hilborn *et al*. 1995, Daly 1990).

Information for estimating harvest rates could derive from harvesters or scientists. Harvesters have empirical data on resources availability (yield) and production trends to analyse whether a population is increasing or decreasing. Models are then used to calculate sustainable yields for the resource (Stockdale 2005).

Most of the models developed to define harvest rates depend either on secondary data or observations over only short time periods. Given the complexity of tropical ecosystems, such models are very much a "first look" at the problem and much research has to be done (Wong 2000). The development of methods for determining the optimal model on which to base harvesting decisions is very much something "science can contribute" to BioTrade organizations. There is therefore a need to evaluate both the theory and experience of wild-collected species harvesting in order to derive sound proposals for the analysis of sustainability which can be applied by Biotrade organizations, from national to local levels.

On the other hand, is important to consider that in many cases, BioTrade organizations lack sufficient specialized skills and access to modelling tools. Yet, based on local knowledge and on the information gathered during the baseline establishment, organizations are capable of setting up a preliminary differential harvest rate in different management areas. The sustainability of these thresholds will be evaluated with permanent plots under the monitoring programme that has to be set up as part of the management plan. Within the permanent plots marked trees can be evaluated as proposed by Peters (1994) in the periodic harvest adjustment methodology together with key population variables such as seedlings and sampling dynamics, age structure and density.

In this context, system dynamics is a tool that has been applied to natural resources in order to simulate population growth and the potential effects of disturbance, markets, economy and other variables. System dynamics is an approach to understand the behaviour of complex systems over time. It deals with internal feedback loops, stocks, flows and time delays that affect the behaviour of the entire system.

Simulation models help to visualize and understand the type of information required for a resource assessment, the applicability of population models for the design of a robust resource assessment, and highlight the information gaps and the limitations inherent in the majority of traded species due to fragmented or limited knowledge on the ecology of the species. Yet, model outputs and their ecological interpretation are extremely useful in the sense of providing a baseline to produce more refined and sophisticated population models when more information is available or produced by the monitoring programme associated with the management plan. Finally, the outputs of the models serve as a basis to test if the harvest rate proposed is sustainable over time and the definition of priority variables that have to be monitored on a long-term basis.

To guide decisions on harvest rates and management practices, a first step in defining harvest rates is to establish the current harvest regimes by local resource users. Such data relate to management conditions and socio-economic issues. Examples of the consid-

Box 4. Considerations to estimate harvest rates for each case study species

Caesalpinia spinosa

Locally people harvest almost 100 per cent of the total seed production (Larrea 2008). Yet, different harvest rates were used in order to create different scenarios and evaluate the influence harvest rate has on population viability of the species.

Mauritia flexuosa

Considering a harvest system oriented to extract adult females from the population, four harvesting scenarios were generated: 10, 25, 50 and 75 per cent of the adult female population (Holm *et al*. 2008). The scenarios consider a density dependence conditions, which translates into an increased growth rate (λ = 2.366) due to a lower resource competition a therefore a higher germination rate per each female palm.

Neopicrorhiza scrophrulariiflora

Based on information provided by Ghimire *et al*. (2005) the model was built considering different harvesting scenarios: 0, 25, 50, 75, and 100 per cent of adult population as a way to evaluate the influence harvest rate has on population viability of the species.

Sources: Adapted from Larrea (2008), Ghimire *et al*. (2005), and Holm *et al*. (2008).

erations to take into account for the three case studies are presented in the Box 4, and more information is presented in Section 2 (For further information on the case studies please visit: www.biotrade.org).

This guide provides an overview of the key ecological aspects to consider in defining specific harvest rates for the three case studies:

- *Caesalpinia spinosa*;
- *Mauritia flexuosa*; and
- *Neopicrorhiza scrophulariiflora*

1. Analysis of population dynamics without harvesting

Knowing about population dynamics is very important when estimating sustainable the harvesting limit, as a harvesting limit estimated at current population levels will be unsustainable if the population is in decline (Stockdale 2005).

Population dynamics analysis allows the identification of key variables that influence the population's density in the long term. For example in the case of *Caesalpinia spinosa* (Box 5) the seedling mortality rate was identified as a determinant variable. In this case, analyses were made using different values of seedling mortality rates to identify how this variable influences densities in the long term. As an important conclusion for management, the analyses allow the identification of practices to assure low seedling mortality rates to assure sustainable management.

Box 5. Population dynamics of *Caesalpinia spinosa*

A dynamic system model using Vensim (version 5.11) was built in order to model the population dynamics of *Caesalpinia spinosa* for a timespan of 100 years in a 400 m^2 plot. According to this model, the current population presents a continuous decline if all the environmental conditions remain the same. Yet, the population is quite sensitive to the parameter "seedling mortality rate". With high mortality rates (0.90 and 0.80) the populations grew in both cases during the first years reaching a maximum of 400 and 310 individuals during years 6 and 4 respectively. After that, populations decline for both scenarios reaching 7 and 13 individuals at the end of the 100-year period. On the contrary, if lower rates of seedling mortality are applied (0.75 and 0.70), then a different outcome is obtained. After 20 years, with a seedling mortality rate of 0.70, the population is 4 and 5 times bigger than the 0.90 and 0.80 scenarios. Further, when a mortality rate of 0.70 is applied, the population after 100 years is a bit smaller than at the start, reaching 161 individuals.

The behavior of the different segments of the population in these scenarios differs. The older trees increase their population size for all the scenarios during the first 30 years reaching a size 10 times bigger. On the other hand, the saplings show a dramatic decrease in all scenarios after an initial exponential growth during the first 3 years. After less than 10 years the number of saplings is below the starting value. After 50 years this segment of the population is extinct except in the 0.70 seedlings mortality rate scenario. This implies that the current population status is highly affected by past and present human impacts and important management actions are required such as working to decrease the mortality rate of seedlings.

2. Analysis of the implications of harvesting scenarios

In population ecology and economics maximum sustainable yield (MSY) is theoretically, the largest yield (or catch) that can be taken from the stock of a species over an indefinite period. This concept has been developed based on the principles that harvest rates should equal regeneration rates (Daly 1990). However, there is currently a need for a review of the definition and methodology of determining sustainable yield due to difficulties in its quantitative application. Taking into account these methodological difficulties, the use of simulations to analyse harvesting scenarios is a tool to understand the possible effects of harvesting on the population and define a harvest rate that could be adjusted by monitoring activities.

Once the current population dynamics are understood, population behaviour is simulated using different scenarios. Scenarios can be defined according harvest rates used and varying relevant population characteristics. For example, in the case of *Caesalpinia spinosa*, simulations were made based on different harvest rates (50, 75, 80 and 100 per cent) and variations in seedling mortality (90 and 70 per cent), taking into account that this was identified as a sensitive parameter. Box 6 presents the results of the scenarios for Caesalpinia spinosa.

In general, the first scenario set shows that under the current conditions of the remnant population of *Caesalpinia spinosa* in Ecuador, the total population will decline after 10 years. We can conclude that this species cannot be managed on sustainable basis without specific environmental good practices guidelines such as habitat enrichment, silviculture and monitoring of seedlings (Becerra 2009). Yet, if the remnant habitats are preserved and human activities are set aside, especially timber and cattle grazing, the species might recover and will present a better population structure and the high mortality rate of seedlings will decrease. As the second scenario set portrays, with a lower mortality rate of seedlings, the population is capable of resisting high fruits extraction regimes.

Box 6. Harvesting scenarios for *Caesalpinia spinosa*

Harvesting scenarios were generated: 100, 80, 75 and 50 per cent of the fruit (pods) production and considering seedling mortality rates of 0.90 and 0.70.

Scenario set 1: Simulations for the four harvest rates tested, using seedling mortality rate of 0.90, population show an exponential growth during the first 5 to 6 years; after this point, the species declines very fast and ending in a population of less than 12 individuals for all cases.

Scenario set 2: When a seedling mortality rate of 0.70 is applied, the modelled results are very different, showing a better response of the population to the harvested regimes even for the 100 per cent harvesting scenario in which the total population at the end of the simulation is 20 individuals of which all belong to the elder age class.

A regime with a harvest rate of 50 per cent and 0.70 seedling mortality rate shows a good response by the population at the end of the 100-year period with a total population of 325 individuals (195 elders, 56 adults, 33 young adults, 21 sapling and 20 seedlings), resembling a constrictive pyramid shape, suggesting that if the population is well managed and recovers from historical human impacts, it can be sustainably managed in its natural habitat.

According to these results resource managers should consider a harvest rate of 50 per cent and guarantee the implementation of practices to safeguard seedling survival. Densities and mortality at each age class need to be monitored as well as the effectiveness of the good practices implemented. Further details are presented in the Section 2. (For further information on the case studies please visit: www.biotrade.org).

D. Stage 4. Management implications

Objectives:

- Identify good management practices that should be included in the management plan.
- Recognize information gaps and variables that need to be included in the monitoring system of the management plan

Expected outcomes:

- Good practices identified and included in the management plan.
- Key variables to be monitored identified

Development:

Based on results from the population dynamics and harvest rate scenarios, BioTrade organizations identify key variables that influence the population's density in the long term, information gaps and variables that determine the species productivity. In this context, the resource assessment provides specific information to analyse best practices and propose a set of variables to be monitored in order to improve the population dynamics knowledge and, consequently, the productive system.

A. Identification of good practices.
B. Improving monitoring systems.

1. Identification of good practices

According to WHO (2003) good collection practices are those that maintain the basic conditions of managed populations and the quality of raw materials in the long term as well as the survival of wild populations and their corresponding habitat.

UNCTAD (2009) recommends that good collection practices should be implemented, taking into consideration three key factors:

- The direct management of species;
- Management of impact on habitat; and
- Interaction of actors managing the species along the value chain.

Based on the results of the population dynamics analyses, a BioTrade organization will be able to identify those good practices related to the direct species management of the species such as habitat improvement to assure juveniles survival, identify techniques to improve germination rates or improve collection practices to diminish the impact of collection on individual survival.

Good collection practices can be defined based on the identification of such variables that have a high effect on the population dynamics and the yield. For example, in the case of *Caesalpinia spinosa* cattle grazing affects directly the survival of seedlings and this has a direct impact on population growth. In this case, good practices should be oriented to implement specific practices such as reduction in cattle grazing, monitoring seedling mortality, proper extraction techniques that do not affect seedlings and agronomic practices to increase seedlings survival. Table 9 lists good management practices which consider the impact of harvest rates on population dynamics and the long-term sustainability of the *Caesalpinia spinosa* population.

2. Improving monitoring systems

Monitoring is an integral part of management; it is a process that commences with a baseline survey, ideally undertaken before any interventions take place

Table 9. Main facts affecting *Caesalpinia spinosa* production and good practices suggested (for further information on the case studies please visit: www.biotrade.org)

Main factors affecting population dynamics	Good practices suggested
Caesalpinia spinosa population presents high seedling mortality rate caused by cattle trampling and grazing. This affects the population growth in the future and therefore the production of seeds for trade. High regimes of seeds extraction represent the reduction of seeds available in natural habitats to generate new individuals affecting population growth and genetic diversity in the mid-term.	• Implement practices to reduce cattle grazing in *Caesalpinia spinosa* forest remnants. • Enrichment of natural habitats by planting seedlings and juvenile individuals if possible. • Regulate seed harvest rates and identify a percentage of seeds that should not be harvested in order to increase germination rates. • Create a seed bank to monitor germination rates and produce seedlings for habitat enrichment and keep a good representation of species genetic diversity.

and continuing at frequent intervals with the data used to revise management prescriptions as necessary. Without a quantitative and biometrically rigorous inventory it is not possible to say with any confidence that changes in the resource base are occurring (Wong 2000).

From an ecological standpoint, one of the most essential ingredients required to achieve a sustainable level of resource use is information, information about the density and distribution of resources within the forest, information about the population structure and productivity of the resources, and information about the ecological impact of differing harvest levels. These are the main themes a monitoring programme should focus on (Peters 1996).

According to Peters (1994), the impact of harvesting needs to be evaluated across the entire life cycle of an exploited species as long-term productivity depends on continued recruitment of new individuals, as well as the productivity of the adults. In this context, if an organization identifies those key variables that have a direct impact on the population density and the productivity, it could define a good monitoring system that would allow it to improve its management system progressively.

However, there is no specific methodology for resource monitoring and most of the techniques and methodology discussed above can be used within the context of a monitoring scheme for NTFP extraction. An important biometric issue in the design of monitoring activities is the consideration of the "power" of the design (Wong 2000). This is the programme's ability to distinguish trends from random errors in the estimates. Yet, getting sampling errors low requires large numbers of plots and is therefore costly. Cost is an important issue for routine monitoring and as a consequence there is much interest in the use of simple, easy and cheap indirect indicators of resource condition.

Indirect indicators of NTFP stocks (e.g. market surveys, harvest levels, basal area sweeps) will be an appropriate basis for making management decisions (Abbot and Guijt 1998, Cunningham 1996). For example, through market surveys Vasquez and Gentry (1989) were able to alert conservationists to the advent of destructive harvesting. Note that different stakeholders will have different perceptions of change and therefore will consider different indicators to be appropriate (Abbot and Guijt 1998).

The review of available literature suggests that there are two general approaches to monitoring natural products harvesting. These are monitoring the health of residual populations which is forest-based (e.g. methods proposed by Hall and Bawa 1993, Sheil and van Heist 2000, Pilz and Molina 1996) and monitoring the size and quality of the harvest (e.g. Wong 2000). Ideally both approaches should be used in tandem (such as for caiman, Velasco *et al*. 2003) and at the local scale to permit the development of an understanding of the interaction between resource availability, harvest intensity and market values.

In the context of the preparation of a resource assessment and applying the adaptive management approach, the impact of such harvest rates and practices need to be monitored in order to adjust the production system, either to increase productivity or reduce the impact on the managed populations. Results presented by UNCTAD (2009) suggest that monitoring systems should generate information at three levels:

- Impact on the managed resource;
- Biology of the species; and
- Yield.

This would establish whether or not production capacity (in terms of quality and quantity) meets sustainability criteria. Table10 presents examples of variables that need to be part of a monitoring system for *Caesalpinia spinosa* including a point (d.) related to relevant information gaps.

This example of *Caesalpinia spinosa* defines some variables related to the species biology and yield that could be applicable to other wild-collected species such as:

- Population growth (total density, adult individuals/area, young individuals/area);
- Germination rate;
- Natality and mortality rates (individuals/area); and
- Production (biomass/area - biomass/individual).

Other variables, related to the impact of management practices or fulfilment of information gaps, need to be identified case by case. For example in the case of *Caesalpinia spinosa* it is important to monitor cattle grazing taking into account that this activity has a specific impact on the young individuals and consequently on population growth.

a) Periodic harvest adjustment

Harvest rate is a variable that is not monitored as such taking into account that it depends on the decision of the resource managers and is adjusted according

Table 10. Suggested variables to be assessed under a monitoring programme for *Caesalpinia spinosa*

Current situation	Variables to be monitored
a. Impact on the managed resource	
Cattle grazing is having a negative impact on young individuals' survival. A consequence of this will be a reduction of total population density in the future, and therefore a reduction in production capacity. In this context good practices could be monitored to analyse the reduction of impact of cattle grazing on the population: • Practices to reduce cattle grazing; • Enrichment of natural habitat; • Regulation of seed harvest rates; and • Creation of a seed bank.	Seedling mortality by cattle grazing. Forest area affected by cattle grazing. Growth rate of seedling/juvenile individuals planted. Percentage of seeds not collected. Seedling density in natural habitats. Seed germination rate in seed banks.
b. Biology of the species	
Production capacity of *Caesalpinia spinosa* depends on the following aspects: • Current population density to assure the production of fruits; • Germination rate – collection practices need to assure a good quantity of seeds that could generate new individuals; and • Mortality of young individuals needs to be reduced.	Total density – number of individuals of each age class in sampling plots. Germination rate – number of viable seeds produced per kilogramme based on samples of different *Caesalpinia spinosa* forest remnants. Mortality rate of seedlings and young individuals that, according to the model, have a higher mortality rate.
c. Yield	
Fruits of *Caesalpinia spinosa* are collected for international markets.	Production of average of fruits per tree. Production of fruits per area.
d. Information gaps	
There is no information on germination rates. Variation in germination rates affects directly the population growth and the production capacity in the mid-term.	Number of viable seeds produced per kilogramme based on samples of different *Caesalpinia spinosa* forest remnants.

to the results of the monitoring system. When several collection areas are managed at the same time, it is advisable to define different harvest rates and monitor one or two areas without harvest. This condition would allow the BioTrade organization to compare the impact of different harvest rates on the managed population and adjust harvest rates applying an adaptive management approach.

A method has been developed by Peters (1994, 1996) that integrates harvesting impacts by monitoring the health of regeneration. This method is based on the establishment of a network of small permanent regeneration plots and visual appraisal of the conditions of adult trees.

1. Regeneration survey

In these plots a total number of seedlings and saplings from the selected species is recorded and classified into four size classes. These data represent the threshold values by which sustainability is measured. These plots are enumerated at five-year intervals. If at a subsequent enumeration seedling or sapling density drops below the threshold value the harvest intensity is reduced and *vice versa*.

2. Harvest assessment

This entails visual appraisals of the conditions of adult trees along with harvesting activities (Peters 1994). During harvest activities, the health, flower and seed abundance and harvesting impacts are recorded for marked trees in yield plots. If specific problems are identified, e.g. a drop in productivity, then adjustments in harvest regimes are needed.

A methodology for using successive approximations to arrive at a sustainable harvesting level would be to firstly determine the magnitude and patterns of year-to-year variability in productivity. This would require annual observations of fruit production over a number of consecutive years and complementary records of climate variable such as rainfall. These data could provide the basis for forecast models of fruit production (Wong 2000). Harvest levels could be set in relation to either long-term yields, to maintain the population into the future, or a fraction of the forecast annual yield etc. Perhaps more important than being able to set a harvesting level is the ability to forecast the current year's harvest so people can make considered choices as to whether to harvest and make the necessary preparations (Belonogova 1988).

(For further information on the case studies please visit: www.biotrade.org)

Glossary

BioTrade initiatives: Business ventures in different stages of development headed by economic actors (communities, community-based associations, small and medium-sized enterprises, among others) that meet the BioTrade principles and criteria (UNCTAD 2007a).

BioTrade products and services: BioTrade activities are generally oriented towards the production, transformation and commercialization of products derived from the sustainable use of biological resources, or to the provision of services derived from such resources. BioTrade products may include those coming from wild collection or from cultivation practices. The latter refers to products derived from cultivation of native species (domesticated and wild varieties) through activities such as agriculture or aquaculture. In this case, cultivation is considered as a strategy to assure the conservation of concerned species and their ecosystems. Products derived from wild collection include products such as fauna (e.g. ornamental fish), fauna derivates (e.g. crocodile leather or meat) and flora (e.g. medicinal plants) (UNCTAD 2007a). Services include, for example, carbon sequestration and ecotourism.

BioTrade: The term BioTrade refers to those activities of collection/production, transformation and commercialization of goods and services derived from native biodiversity (species and ecosystems), under criteria of environmental, social and economic sustainability.

Age distribution: The proportion of individuals in a population in age classes. Typically this is displayed in a modified bar chart called an age pyramid.

Age-specific fertility rate: The number of births per individual within a specific age interval during a specified time.

Age-specific mortality rate: The fraction of individuals in a population that die during a given age interval. For example, if the probability of dying between age 5 and 10 is 0.25 or 25 per cent, that would be the mortality rate for that age class.

Crude birth rate: The number of individuals, per thousand in the population, born during a time interval. For example, crude birth rates for the human are generally in the range from 10 per thousand per year to 40 per thousand per year.

Crude death rate: The number of individuals, per thousand in the population, dying during a time interval. For example, crude death rates for the human population generally range from 5 per thousand per year to 25 per thousand per year.

Density dependence: A form of population growth in which the birth rates and/or death rates per individual depend on the size or density of a population. This often results when individuals are competing for some limiting resource.

Dependency ratio: The fraction of a population that is "dependent" on the rest of the population. In the human population, this has generally been considered to be the fraction under 15 years plus the fraction over 65 years.

Doubling time: The time it would take a population to double, given no changes in age-specific mortality or fertility rates. Any change in the fertility or the mortality graphs changes the doubling time. Demography represents doubling times as negative if the population is decreasing.

Finite rate of increase (*lambda*): A measure of the rate of growth of a population. The amount that the population must be multiplied by to give the population size in the next time unit (assuming the population is in stable age distribution)

Generation time: The average age at which a female gives birth to offspring. This is equivalent to the time that it takes for a population to increase by a factor equal to the net reproductive rate.

Intrinsic rate of increase (r): A measure of the rate of growth of a population. This is the instantaneous rate of change (per individual per time interval), assuming the population is in stable age distribution. It is equal to the natural log (ln) of the finite rate of increase.

Mean life expectancy: How long an individual can be expected to live, on average. This is influenced only by the age-specific mortality graph.

Net reproductive rate (R_0): The average number of offspring an individual in a population will produce in his/her lifetime. Unlike the total fertility rate, R_0 depends on age specific mortality rates.

Population momentum: The tendency for a rapidly growing population to keep on growing, even after the implementation of policies designed to halt population growth.

Sex ratio: The fraction of the population that is female. Technically, this value is not a "ratio", but this has become a common way of representing the gender distribution of a population. The primary sex ratio is the proportion of births that are female.

Stable age distribution: The age distribution which the population will reach if allowed to progress until there is no longer a change in the distribution.

Survivorship: The probability that an individual survives from age zero to a given age.

Total fertility rate (TFR): The total number of offspring a female would have, on average, if she were to live to the maximum age. (Compare with net reproductive rate.)

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