Handbook of Agricultural Biodiversity

Chapter 4. Wild plant and animal genetic resources

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[a]Introduction

Wild plant and animal resources are commonly defined as those which exist in a natural state, are not tamed, cultivated or domesticated, nor are in the care of people. A natural system (as opposed to an agricultural or human-managed system) is generally characterised by complex spatial arrangements in which different species co-exist, are genetically diverse, and consist of plants and animals of different ages and developmental stages, with offspring and seeds produced by a population in one year being the source of future generations (Alexander, 2010). Genetic resources can be defined as the heritable materials maintained within and among species that are of actual or potential economic, environmental, scientific or societal value. Genes are not consciously used, but people have taken advantage of genetic variation, by selecting plants and animals with preferred characteristics. Plant and animal genetic resources are the total genetic diversity of cultivated and domesticated species and their wild relatives, much of which may be valuable to breeders (Jackson and Ford-Lloyd, 1990).

Wild genetic resources differ from their domesticated counterparts as they reproduce independently of human control (Prescott-Allen and Prescott-Allen, 1983), as do the habitats in which they are found. The extent to which genetic resources can be considered to be wild can also be determined by their natural range, although wild populations can also result from benign introductions or deliberate reintroduction (Hemp, 2006). This wild versus cultivated dichotomy is however simplistic. In practice the distinction is blurred, with resources harvested from a continuum ranging from entirely natural systems to resource enriched, reconstructed and managed systems that often appear 'wild' (Wiersum et al, 2013).

This chapter provides an introduction to the range of resources gathered from the wild and their uses, with a focus on plant and animal resources at species level, with some examples of wild tree genetic resources presented.

Covering 30% of the globe (FAO, 2015), forests represent the predominant land cover (FAO, 2014) and are a major source of wild genetic resources (FAO, 2015). For this reason, examples of wild plant and animal resources from forested landscapes predominate in this chapter. Forest products provide a significant contribution to the shelter of at least 18% of the world's population and billions of people use forest products to meet their needs for food, energy and shelter. Wood energy is often the only energy source in rural areas of less developed countries, particularly by poor people, accounting for between 5 to 27% of energy supply regionally (FAO, 2015).

Characteristics distinguishing wild resources from cultivated ones are then discussed. These include the fact that many wild species are governed as public goods or common property, raising questions about if and how they are managed, and by whom; how access to, and benefits from, these resources are arranged; and how these governance factors affect sustainable use of species and genetic diversity. The chapter illustrates how knowledge of these aspects helps to underpin the development of sustainable measures for the use and conservation of wild plant and animal resources.

[a]Use and dependency on wild plant and animal genetic resources

Wild resources from ecosystems around the globe have been used for millennia to meet people's basic needs for food, fuel, medicines, tools and materials, and for spiritual and cultural uses (Cunningham, 2001). As well as being the source of most crops and domesticated animals (Diamond, 2002; Zohary et al, 2012), many wild species are still used for subsistence purposes and are the source of traded commodities (Newton, 2008).

In many developing countries, subsistence farmers and rural inhabitants depend to a higher, but highly context-specific extent, on wild resources from forests, mangroves, rivers and other wildlands, for both cash and subsistence (Wunder et al, 2014). Non-timber forest products (NTFPs), which include whole and parts of plants and animals that originate from natural, modified and managed forested landscapes, particularly provide an important contribution to the livelihood of communities living inside or near forests (FAO, 2015; Vira et al, 2015). NTFPs are used for food (e.g. berries, mushrooms, nuts, seeds, edible plants and exudates), medicinal and aromatic plants, fodder, ornamental plants, energy, materials and products e.g. for cultural use.

Wild plant and animal resources in tropical and temperate climates, including both developed and developing countries, have however received sporadic attention in terms of quantification, valuation and mapping, due to different perceptions of their importance (Ingram, 2014; Schulp et al, 2014; see also Boshier et al, Chapter 3 of this volume). Many assessments focus on their direct economic value for humankind (such as economic, nutritional or functional), but miss critical supporting, regulating and cultural ecosystem services.

A global study of rural households showed that income from natural resources is higher for the poorest households; and even higher when subsistence uses are considered (Angelsen et al, 2014). The study's findings challenge common thinking, as households in the highest income quintile had the highest environmental and forest incomes, indicating that wealthier people create higher pressure on natural resources, and not necessarily the poorest. Environmental income is however widely neglected by policymakers in poverty reduction strategies (Oksanen and Mersmann, 2003).

Along the same lines, an analysis of 8000 households in 24 developing countries showed that 28% of income came from environmental sources, 77% of which came from natural forests (Angelsen et al, 2014). A study in Thailand (Delang, 2015) complements this global data, showing how those collecting NTFPs used less cash than people depending only on markets. The study also showed how wild food plants remain a preferred alternative to commercial food crops, being a more efficient use of time. Knowledge of species and the environment is associated with the benefits that local communities derive from wild-harvested forest products (Sheil and Salim, 2012). All too often however, data on the source of environmental incomes and its impact on wild species, do not reach policy makers.

Wild-harvested products are also sometimes preferred to cultivated products. People's perceptions of availability, preferences and consumption of forest foods in relation to other, cultivated and exotic food species can be complex, for example *Balanites aegyptiaca, Ziziphus spina-christi* and *Tamarindus indica* in Tanzania (Msuya et al, 2010) and *Gnetum* spp. in Cameroon (Ingram, 2014).

Assumptions concerning the dependency of rural communities on NTFPs contend that NTFPs can help to reduce poverty, promote development, buffer shocks and mitigate seasonal shortfalls in income and products used for subsistence. Only in rare cases have NTFPs been shown to create a path out of poverty, however (Kusters et al, 2006).

In many developing countries a diversity of wild species (fish, plants, bushmeat, insects and fungi) underpin dietary diversity and good nutrition, and make an important contribution towards food security, especially in traditional 'hungry seasons' when crops are not yet ready for harvest (WHO, CBD, UNEP, 2015). For example, many wild foods are sold in Cameroonian cities, including bushmeat, fruits, vegetables, spices and insects, with an average of 25% of a household's food budget spent on wild foods (Sneyd, 2013). However, social and economic access to a diverse diet of often more nutritious foods are often priced out by imported, low cost, non-traditional staples, such as rice, alongside increasing trends towards urbanisation and associated access to processed foodstuffs. Scarcity, due to seasonal availability and over-exploitation also affects prices and dietary diversity (Sneyd, 2013). Nutritional diversity and food security are strengthened when wild foods are integrated into agro-ecological production systems managed to provide multiple benefits, combining biodiversity concerns with food production. The nutritional and livelihood benefits of diverse wild and agricultural production systems can help achieve food security, as well as being more resilient to climate induced events and other shocks (Sunderland, 2011). Wild species contribute to the agricultural biodiversity associated with dietary diversity (Johns et al, 2013; Powell et al, 2015).

Wild animal and plant genetic resources are also an important source of variation for breeding crops and livestock. They can confer characteristics of interest to domesticated species, including disease and pest resistance, higher yields, vigor and environmental adaptability. The latter is of increasing importance in relation to climate change.

[b] Wild plant and fungi resources

In the developed world, wild plant resources generally enhance, rather than form the basis of subsistence use, although some species are the foundation for trade, such as berries and truffles. For example, at least 27 species of mushrooms and 81 species of vascular plants are known to be collected and consumed in countries throughout Europe (Schulp et al, 2014). Income, age, gender, access and cultural factors explain the current variations found in gathering wild plants in Europe. While the economic and nutritional values of wild food comprise a tiny proportion of GDP and total food consumption, over 100 million EU citizens consume wild food sourced from plants and animals. Collecting is also an appreciated recreational activity, often creating a sense of place (Schulp et al, 2014).

The use of native European medicinal and aromatic plants has a long history. International trade data from the mid-1990s indicates that at least 2,000 species are used on a commercial basis, some 1,200-1,300 of which are native to Europe. Of these, 90% are still wild collected, totaling around 20,000 to 30,000 tons per year (Lange, 1998). Wild collection is particularly prominent in Albania, Turkey, Hungary and Spain. In the European Union, medicinal and aromatic plants are cultivated on an estimated 70,000 hectares, mainly in France, Hungary and Spain. Europe imports about a quarter of annual global market imports (440,000 tons valued at $1.3 billion in 1996), with Germany, France, Italy, Spain and the UK among the 12 leading countries of import and Germany, Bulgaria and Poland are among the 12 leading exporters

(Lange, 1998). In developing countries, the historical and current medicinal and aromatic use of an estimated 50,000 species of wild plants is known, but is less well documented (Schippmann et al, 2002). Approximately 2,500 of these species are also traded. Wild species can contain unique pharmaceutical properties not easily reproduced artificially. An example are the compounds extracted from *Prunus africana* bark, which act synergistically in traditional medicine, in a way not completely understood, to cure benign prostate hyperplasia (Kadu et al, 2012). In other cases, synthetic chemicals used as an alternative to the products harvested from wild tree populations may cause additional pathologies and cannot replace natural phytochemical compounds, such as the tree *Pterocarpus erinaceus*, a West and Central African leguminose whose bark is traditionally used for its strong anti-inflammatory, analgesic and antioxidant properties (Noufou et al, 2012).

[b]Wild animal resources

The range of animal species gathered from the wild and their uses, with a focus on forested landscapes, is illustrated in this section.

One of the most significant and traditional uses of natural resources is that of wild animals for food. In some countries, such as Australia, hunting for subsistence use and small scale, legal trade in wild animals, mainly for food (kangaroos, wallabies, brushtail possums, short-tailed shearwaters, crocodiles and emus), co-exist. Species with large populations, such as kangaroos, wallabies, wild boars, wild goats, rabbits and foxes, are the mainstay of trade (Ramsay, 1994). Impediments to the development of this wild animal trade include public perception, parochial attitudes, administrative and legislative structures, the variable operating environment, low product values, the novelty of products, lack of information of species and markets, animal welfare issues, and pest control activities that conflict with commercial harvesting. In the European Union, 38 game species are harvested and consumed, generally as part of recreational and cultural activities (Schulp et al, 2014).

In contrast, particularly in developing countries, bushmeat forms a major contribution to daily dietary needs (Nasi et al, 2008). Poor households especially can suffer from nutritional deficiencies when wildlife is removed from their diet because of their reliance on bushmeat (Golden et al, 2011). Since bushmeat is often the main source of meat available in some regions of developing countries, the loss of bushmeat species means decreases in protein, fats, and important micronutrients, such as iron, in diets. The nutritional importance of bushmeat is due in part to its fat content, as fat has considerably higher energy content per unit of mass than protein and carbohydrates (Siren and Machoa, 2008). However, bushmeat trade can also spread pathogens, increase exposure to and the transmission of zoonoses, such as from African apes to humans, and vice versa, which are linked to diseases such as HIV and Ebola (Leroy et al, 2004; Smith et al, 2012). In the Amazon and Congo Basin, a wide variety of taxa are hunted for food. In Gabon, 114 species have been recorded in hunter catches, household consumption and markets (Abernethy, 2009). In Latin America over 200 species of mammals, around 750 bird species (including over 530 species for the pet trade), more than 60 species of reptiles and at least five amphibian species are harvested for household use and trade (Ojasti 2000). Mammals make up the bulk of the catches both in number and biomass terms, with ungulates and rodents representing more than two thirds of the carcasses sold in urban markets or recorded from hunter off takes in both the Congo and Amazon Basins (Nasi et al, 2011), with mediumsized species between 2 and 50 kg being the most frequently hunted and the majority of mammal species hunted not listed as threatened on the IUCN Red List of Threatened Species. Generally, hunting reduces prey populations and, continued heavy hunting pressure can cause population or species extinction (Milner-Gulland & Bennett, 2003). However, understanding how hunting affects animal population dynamics is essential (Weinhaum et al,2013).

Another major use of wild animals (mostly parts of or whole) in many cultures is in traditional medicine. The Chinese, for example, have a long history of using animals to treat a variety of ailments (and pseudo-ailments) while the illegal trade in African elephant and rhino horn is largely targeted towards medicinal use in Asia (Biggs et al, 2013; Roberts, 2015). Less known and studied, though just as varied and rich, is the tradition of wild animal-based remedies in Africa and Latin America. At least 584 animal species are used in traditional medicine in Latin America (Alves and Alves, 2011). A single illness can be treated by using various animal species (e.g. in Latin America, 215 animal species are used to treat asthma and 95 for rheumatism), while many species can also be used to treat multiple illnesses, such the tegu (*Tupinambis teguixin*) and boa constrictor, used to treat 29 and 30 conditions respectively (Alves and Alves, 2011). In all cases however there is a fine line between exploitation and conservation with many parts of the trade driven by militias and cartels, so ensuring sustainable use remains a priority.

The high nutritional values of wild insects have long been known empirically around the world, and are increasingly being confirmed scientifically. For example, in Central Africa high consumption levels of many edible insect species play an important role in diets, pharmacopeia and agriculture, at all levels of society and as a standard ingredient, particularly in children's diets (Vantomme et al, 2004; Seignonbos et al, 1996). Similarly, in southern Africa, insects such as the mopane worm – the caterpillar of the emperor moth, *Imbrasia belin*a – are widely consumed by rural and urban households alike due to their high nutritional value. As a result, harvesting is increasingly changing from subsistence to commercial (Thomas, 2013). The role played by wild insects as pollinators, is also a critical to both wild and cultivated productive systems as about one in three mouthfuls of food comes from insect-pollinated crops (Aizen et al, 2008). Recent declines in bee populations and threats to other insect pollinators are cause for concern in this context (UNEP, 2010); see .

[a]Issues in the governance and sustainable use of wild plant and animal resources

Two particularities distinguishing wild resources from cultivated ones are discussed: their governance and the sustainability of their exploitation, and the consequences for genetic diversity.

[b]Governance

Many wild species are governed as public goods or common property, raising questions about if and how they are managed, and by whom; and how access to, and benefits from, these resources is arranged. The sustainability of exploitation of wild resources thus depends also on their governance.

Access and rights to forests and their products have been called the elephant in the 'land rights' room (Bauer, 2015). It is essential to make sure that land rights are looked at in the context of wildlife legislation, accompanied with greatly improved support to improve access and sustainability of these resources. While wildlife conservation programs now increasingly attempt to include forest-dependent communities in their wildlife protection programs (Rodrıguez-Izquierdo et al, 2010; Shackleton et al, 2010), weaknesses in hunting legislation may be an important barrier to their success (e.g. Gill et al, 2009; Shackleton et al, 2010). Among the main weaknesses are the unclear rights given to local communities. Whether recognized by statutory laws or not, rural communities often consider themselves to be the traditional owners of resources which fall within their respective domains (Alden Wily 2011; Laird et al 2010). For example, in Africa, colonial administrations adapted written laws to gradually replace customary laws to promote the development of virgin lands by the government. When central African countries started to gain independence in the early 1960s, the postcolonial land-tenure system incorporated customary land, which was considered to be vacant and unoccupied, into state land (Oyono, 2005). Customary ownership or tenure rights were replaced with user rights granted to farmers and local communities. In practice, given the scarcity of governmental resources, government laws are rarely enforced and people are left with an ambiguity between the need to comply with legal frameworks and with what remains of their customary practices (Laird et al, 2010). While some measures have been adopted in central African countries to devolve user rights, for example community and communal forests, such formalization and decentralization have also increased the rigidity of once relatively fluid customarily managed domains (Alden Wily, 2011). On a global level, measures to better govern wild resources exist, summarized in **Box 4.1**, but also often conflict with customary or local approaches adopted on the ground.

[!box!]**Box 4.1** *Global governance of wild species*

Global schemes to govern wild genetic resources intend to control or influence global processes and negotiate responses to problems affecting more than one state or region. Examples of such international agreements and conventions and voluntary, certification schemes are:

1 The 1975 **Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)** is a voluntary, international agreement between governments which aims to ensure that international trade in wild animals and plants does not threaten their survival and contribute to cause species extinction. CITES accords varying degrees of protection to over 30,000 animal and plant species. Appendix I lists the most endangered species threatened with extinction, for which international trade is prohibited except for non-commercial reasons. Appendix II lists species not necessarily now threatened with extinction but that may become so unless trade is closely controlled though agreeing annual quotas. Legally binding on its Parties, it does not replace national laws but provides a framework for implementing CITES within national legislation.

2 The 1993 **Convention on Biological Diversity (CBD)** aims to conserve biological diversity and the fair and equitable sharing of the benefits arising from the utilisation of genetic resources, ensuring the rights of countries and communities over their biological resources are respected. Also that access to traditional knowledge occurs with the approval of such knowledge holders, who should participate equitably in the resulting benefits should this be commercialised, establishing a system for access and benefit sharing (ABS). It recognises that access to these resources must be subject to the prior informed consent of the provider country and based on mutually agreed terms. The convention requires National Biodiversity Strategy and Action Plans

to be developed by member states, which would include approaches for species used for subsistence or commercial purposes.

3 The 2014 **Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization** to the **Convention on Biological Diversity** aims at sharing the benefits arising from the utilization of genetic resources in a fair and equitable way. The Access and Benefit-sharing (ABS) Clearing-House is a platform for exchanging information on access and benefit-sharing established by Article 14 of the Protocol. It aims to enhance legal certainty and transparency on procedures for access and benefit-sharing, and monitoring the utilization of genetic resources along the value chain, including through an internationally recognized certificate of compliance. The ABS Clearing-House aims to connect users and providers of genetic resources and associated traditional knowledge.

4 The **IUCN Red List of Threatened Species** aims to guide and evaluate the status of plant and animal species worldwide. Since 1994 species conservation status has been determined using a baseline and subsequent monitoring of changes. If data is available, the level of threat is categorized, ranging from ‘extinct’ to ‘critically endangered’, ‘endangered’, ‘vulnerable’, ‘near threatened’ and ‘least concern’. A red listing can trigger conservation actions from NGOs, governments and researchers.

5 The voluntary **FairWild Standard** assesses and certifies the sustainable harvest and trade of wild plants against various ecological, social and economic requirements. It aims to support efforts to ensure plants are managed, harvested and traded in a way that maintains populations in the wild and benefits rural producers. The FairWild Standard also supports the implementation of existing regulatory frameworks provided by national resource management

systems and international conventions the CBD and the non-detriment findings process of CITES.

6 The **International Federation of Organic Agricultural Movements** (IFOAM) sets internationally accepted basic standards for organic agriculture. **Organic wild collection** is a certification scheme with criteria to ensure the protection of the genetic diversity - for example in wild coffee populations - and the conservation of ecosystem, such as forests, authenticity. This certification scheme is applicable to wild coffee collected from unmanaged forests.

7 **Forest Stewardship Council (FSC)** certification ensures that products come from well managed forests that provide environmental, social and economic benefits. FSC certification is a way that forest owners and managers can demonstrate they are managing their forests responsibly and in the supply chain, FSC certification can provide benefits such as access to new markets. The "Expanding FSC certification to Ecosystem Services'' (ForCES) project is a multi-partner pilot for the certification of ecosystem services which addresses biodiversity.

8 A **geographic Indication** is a name or sign used on certain products which corresponds to a specific geographical location or origin. It can be used as a certification that the product possesses certain qualities, is made according to traditional methods, or has a certain reputation, due to its geographical origin. The inherent conservation approach can safeguard species biodiversity in this geographic area (Bérard et al, 2006)

9 The (IUCN and WWF) **TRAFFIC programme** aims to ensure that trade in wild plants and animals is not a threat to the conservation of nature. The long running programme includes a wildlife trade monitoring programme, networks with monitoring and enforcement agencies worldwide, and has projects to support the implementation of the CDB and CITES.[!box ends!]

The sustainable governance of wild genetic resources can also be complicated if there are competing claims to wild resources in a specific area. This can occur if timber extraction competes with the harvesting of NTFPs and wildlife, or if timber and NTFPs are harvested from the same species. For example, the impact of selective logging on NTFPs in three tropical cases had largely negative effects on NTFP availability (Rist et al, 2012). Positive impacts were limited to light-demanding tree species which respond well to canopy opening, and constitute a small proportion of species with livelihood value. Occasionally however multiple harvesting can be complementary (Shanley and Luz, 2003). Multiple-use landscape and forest management, taking into account timber and non-timber forest products and environmental services, is hence gaining attention as a promising approach for tropical forest conservation. Examples include the development of the ForCES certification scheme – see **Box 4.1** – and multi-objective, cross-sectoral initiatives on landscape level (see Milder et al, 2014) which address genetic diversity. Governing wild resources to provide for multiple goods and services is challenging however, by necessity taking into account different stakeholders views. Focusing on Brazil nuts (*Bertholletia excelsa*), a study on multipurpose management indicated that obstacles may include: policy barriers, a lack of enforcement, high management costs associated with small financial benefits; damage from logging to Brazil nut stands; and the reinvestment of forestry-derived income into livestock (Duchelle et al, 2012).

Different approaches to govern wild resources have had mixed success. Community forestry has potential to reduce overexploitation of wild resources (Porter-Bolland et al, 2012), with community-managed forests often more resilient, and experiencing lower and less variable annual deforestation than protected forests. Under specific circumstances, when external economic pressures or major environmental threats are not in place, participatory monitoring by local communities has been a successful measure in avoiding over-exploitation of NTFPs (Boissière et al, 2013). Other approaches rely on well-enforced customary rules, collective action along the value chains of wild forest products, voluntary standards and/or legislation, for example in the case of honey, woodfuel, eru (*Gnetum* spp.), bush mango (*Irvingia* spp.) and *Prunus africana* in Cameroon and Congo (Wiersum et al, 2013). Legislation has long been an approach to govern the harvest and trade of wild species. For example, in the 1990s about 150 species of medicinal and aromatic plants in Europe were reported as threatened in at least one European country as a result of over-collection from the wild (Lange, 1998). However, alongside regulatory revisions to reflect the dynamic nature of trade, conservation requires trade monitoring; improved law enforcement; *in situ* and *ex situ* protection; improved management programmers; public awareness initiatives; enhancement of cultivation; and research into trade; and the certification of plant material from sustainable sources. Voluntary schemes, such as certification standards, can play a role in promoting innovations in sustainable trade – see **Box 4.1** – for example in maintaining wild coffee diversity in Ethiopia (Schmitt and Grote, 2006) and biodiversity in forests managed under certification schemes (van Kuijk et al, 2009) .

[b]Drivers of change in wild plant and animal genetic resource availability

Wild resources worldwide are affected by a variety of factors which influence their availability and the sustainability of their extractive use. Knowledge on how different pressures affect the resource base is key to identifying management and policy measures that could help reduce negative impacts. Some important species may not be at risk of extinction as a consequence of unsustainable exploitation but specific populations, with distinct traits and valuable properties, genetically different from other populations of the same species, may be irreversibly lost. The relative contribution of hunting wild animals and gathering wild plants, compared to other drivers such as climate change, habitat alteration (i.e. land-use changes, destruction, fragmentation), and impact of invasive species (Wilkie et al, 2011), make it difficult to attribute causation to hunting or wild harvest alone. Globally, commercial and subsistence agriculture, logging, fuelwood collection, and livestock grazing are major causes of degradation and deforestation (Kissinger et al, 2012), affecting the availability of forest resources.

Scholte (2011) described factors driving changes in wildlife populations. Underlying drivers may not themselves cause change, but indirectly act to contribute to change. Identifying drivers and, where possible, quantifying their impact, facilitates the formulation of appropriate management guidelines for extractive use of wild resources. The main drivers of change are summarised as follows:

[c]Habitat loss and degradation

Hunter (2002) defines three forms of habitat destruction (viz. degradation, fragmentation and outright loss). Habitat loss has emerged in the 21st century as the most severe threat to biodiversity worldwide, threatening some 85% of all species classified as ‘threatened’ on the IUCN Red List of Threatened Species (Baillie et al, 2004).

[c]Large scale extractive and production projects

Many countries worldwide have allocated a large part of their territories to oil, mining, agriculture and extensive timber use (Walsh et al, 2003). For example, in Central Africa selective logging is the most extensive extractive industry, with logging concessions occupying 30–45% of all tropical forests and over 70% of forests in some countries (Laporte et al, 2007). In many countries, the mineral boom has contributed to the emergence of 'growth corridors' where infrastructure upgrades will improve the competitiveness of agriculture and other economic activities (Delgado et al, 1998) which impact wildlife habitats and disturb wildlife populations (noise, pollution, etc).

[c]Conflict and war

Wars have multiple impacts on biodiversity and protected areas, and livelihoods of local people dependent on natural resources. Impacts can be highly variable, and may be positive in some areas and negative in others (McNeely, 1998). Very often, war has significant negative effects directly or indirectly on threated wildlife and their habitats (Plumptre et al, 1997; de Merode et al, 2004)

[c]Human population growth

The impacts of human population growth on wild resources are the subject of much debate. While neo-Malthusian theories place population growth in the context of a vicious circle of destruction, others suggest that such theories oversimplify environmental degradation (Sunderlin and Resosudarno, 1999; Leach and Fairhead, 2000). According to neo-Malthusian theory, population growth causes intensified pressures on natural habitats and resources to satisfy growing demand for space, housing, food and water for drinking and sanitation. However, Boserup (1996) contends that people adapt to increased population density through innovative technologies that reduce pressure on natural resources.

[c]Wildlife and plant diseases

Ecological disturbances can also influence the emergence and proliferation of plant and wildlife diseases. Each environmental change, whether occurring as a natural phenomenon or through human intervention (deforestation, changes in land use, human settlement, commercial development, road construction, water control systems, introduction of cultivated species), changes the ecological balance and context within which disease hosts or vectors and parasites breed, develop, and transmit disease. The trade in wildlife provides disease transmission mechanisms (Smith et al, 2012) that can cause human and livestock disease outbreaks. Wildlife diseases can also have ecological impacts on native wildlife populations and affect the health of ecosystems. They can also severely affect local and international trade and rural livelihoods. The majority of recently emerging infectious diseases are associated with wildlife (WHO et al. 2015). Recent highly publicised examples include the ebola virus outbreak in West Africa and the avian influenza HN51 virus outbreaks in the Middle East and Asia. Such diseases also threaten their wild species hosts. Wildlife monitoring can aid early detection and prevention of human infections (WHO et al. 2015). Infection-related wild species population declines may also compromise the ecosystem services that wildlife provide. For example, White Nose Syndrome in North American bats and chytrid in amphibians may affect the pest control functions provided by these animals (WHO et al 2015). Wild plants too can act as bridges between geographically separated crops and for seasonally active infections, allowing the transmission of pathogens and contribute to the spread of plant epidemics (Dinoor, 1974). Host-pathogen interactions in wild plants and animals provide important insights concerning disease resistance and the genetic factors behind resistance.

[c]Invasive species

About 10% of invasive or 'alien' plants change the character, condition, form, or nature of ecosystems over substantial areas, and can be termed 'transformers', whilst around 50 to 80% of invaders have harmful effects can be termed 'pests' and 'weeds' (Richardson et al, 2000). Human activities, especially international travel and trade, have circumvented natural barriers and oceans which have regulated the distribution of the world's biota for millions of years, leading to species invading new continents at an increasing rate (Liebhold et al, 1995). Over 120,000 non-native species of plants, animals and microbes have invaded the United States, United Kingdom, Australia, South Africa, India, and Brazil. Many have led to significant economic losses in agriculture and forestry and negatively impacted ecosystem integrity, estimated to cost over US$ 314 billion per year (Pimentel et al, 2001). Whilst some introduced species, like corn (*Zea mays*), wheat (*Triticum* spp.), rice (*Oryza sativa*), plantation forests, chicken (*Gallus* spp.) and cattle (*Bos taurus*), are largely seen beneficial transformers, providing more than 98% of the world's food supply, some species have negative invasive impacts. For example cats (*Felis cattus*), pigs (*Sus scrofa*), nile perch (*Lates niloticus*), water hyacinth (*Eichhornia crassipes*) and miconia (*Miconia calvescens*) have been held responsible for the extinction of numerous wild species and lowering wild biodiversity (Lowe et al, 2000). Precise economic costs of the most ecologically damaging invasive species are generally not available (Pimentel et al, 2001).

[c]Climate change

Climate change may have diverse indirect effects on wildlife depending on the characteristics of the species (Foden et al, 2013). Similar predictions occur for wild flora. For example, forest ecosystems with low phenotypic plasticity and low genetic diversity at population level, where trees are at their adaptive limit and edge of distribution, are predicted to be more sensitive to climate changes (Loo et al, 2011). Expected impacts include mortality due to extreme climatic events and regeneration failure, increasing pest and disease attacks, changing fecundity, asynchronous timing between flowering and the availability of pollinators, increased fires, new species invasions, altered gene flow and species and population hybridization (Loo et al, 2011). Wild species with generalised and unspecialised habitat requirements are likely to be able to tolerate a greater level of climatic and ecosystem change than specialised species. However, many species rely on environmental triggers or cues for migration, breeding, egg laying, seed germination, hibernation, spring emergence and a range of other essential processes. Species dependent on interactions that are susceptible to disruption by climate change are at risk of extinction, particularly where they have high degree of specialization for the particular resource species and are unlikely to be able to switch to or substitute other species.

[b]Sustainable use of wild plant and animal genetic resources

How wild resources (and the ecosystems which provide them) are governed affects their sustainable exploitation. Sustainability is affected by supply and demand, determining how much of a wild resource is harvested, how, why and by whom. Interactions between supply and demand can determine population densities and the suitability of habitats for (different) wild and cultivated species (Green et al, 2005). Sustainability is also affected by factors such as: (1) the abundance of the species from which a product originates; (2) direct anthropogenic factors such as forest degradation, as well as semi-natural ones such as climate change threats; (3)

inherent species vulnerability which depends on the part(s) of the organism used; and (4) a species' tolerance to harvesting.

Worldwide, trade in timber threatens around 1,000 tree species (Rivalan et al, 2007). Regarding wood production from natural forests, there appears to be a decline in natural forest wood extraction in many nations, following a peak (around 1989) (Shearman et al, 2012; Warman, 2014). The trends observed resemble those found in non-renewable resources, as a result of many factors, primarily the limited length of the standard cutting cycles (30-40 years) that does not allow the wood volume to regenerate. Thus an increasing move to deliberate tree cultivation in response to local or national wood shortages has been observed (Warman, 2014).

Challenges for sustainable wild collection of tree resources include: determining sustainable harvest level and practices, definition of access and tenure rights, definition of a legislative and policy framework. Many wild species are governed as public goods or common property, raising questions about how (and if!) they are managed, and by whom; and how access to, and benefits from, these resources is arranged. Tenure has a crucial role in securing sustainable use of natural resources. With regard to forests, and particularly collective forests and resources, the term 'tenure rights' is used to refer to a bundle of rights ranging from access and use rights to management, exclusion and alienation (Schlager and Ostrom, 1992). A review of more than 100 empirical cases of forest outcomes in relation to specific land tenure conditions concluded that land tenure security is associated with less deforestation, regardless of the form of tenure. In addition, state-owned protected forests tend to be associated with more positive forest outcomes than private, communal or public land (Robinson et al, 2011).

Wildlife trade threatens around a third of birds and animals and 75% of fisheries (Rivalan, 2007). 'Defaunation' is often cited as the main impact of hunting, resulting in the so-called 'empty forest' syndrome (Redford, 1992) and the 'empty savannah' syndrome (Lindsey et al, 2013). Defaunation can be defined as the local or regional population decline or species extirpation of arthropods, fish, reptile, bird, or mammal species (Dirzo, 2001). Because defaunation is solely driven by human activities, it is also referred to as 'anthropocene defaunation' (Dirzo et al, 2014). Defaunation may also generate trophic cascades that alter ecological processes, leading to long-term changes in community composition and diversity loss (Dirzo et al, 2014; Muller-Landau, 2007). In many ecosystems, the larger vertebrate fauna, especially frugivorous birds, primates, ungulates, and mammalian carnivores, have been extirpated or severely reduced in number. As these large animals vanish, so do their myriad, often non-redundant, ecological interactions and the processes they generate, foremost trampling, ecosystem engineering, herbivory, seed predation, and dispersal (Dirzo et al, 2007). Therefore activities such as hunting have the potential to impact not only targeted species but the ecosystem more broadly. Examples of defaunation are numerous across the world, yet hunting does not always necessarily lead to defaunation. Species are impacted by hunting pressure to different extents. How populations respond to harvest can vary greatly depending on their social structure, reproductive strategies, dispersal patterns and intactness of habitats. Small species are typically more resilient to hunting than larger species, due to their higher reproductive rates (Cowlishaw et al, 2005). Dispersal, in particular, can have significant ramifications (both stabilizing and destabilizing) on population dynamics. Density-dependent dispersal may stabilize populations as immigration and emigration counterbalance between hunted (sink) and non-hunted (source). Junker et al. (2015) suggest that projects providing bushmeat protein alternatives and education may complement strategies to conserve chimpanzees in Liberia and possibly other countries in tropical Africa.

Many plant based NTFPs have higher levels of exploitation than the natural carrying capacity (Kusters et al, 2006). Such exploitation has led to concerns biodiversity loss and subsequent need for conservation (Cunningham, 1991; Abensperg-Traun, 2009). The extraction of wild harvested NTFPs tends to lead to overexploitation and degradation of the resources with negative externalities. Although NTFPs were seen as a potentially secure and stable source of cash income, with local communities actively involved in preventing the forest degradation in the past, there is growing evidence regarding the impacts of commercializing NTFPs on exploitation and biological degradation (Peters, 1996; Ingram, 2014). This is similar to other open access wild resources, such as fisheries (Bjørndal et al, 2004).

[b]Measures to increase the sustainable use of wild plant and animal genetic resources

Five major approaches, sometimes applied jointly, have led to variable degrees of success in encouraging a more sustainable governance of wild genetic resources:

1 Domestication and cultivation in farms and plantations have been the most commonly adopted approaches to fulfil multiple objectives, such as a) subtracting species from unsustainable harvesting pressures in the wild, b) enhancing expression of desirable traits through breeding, c) facilitating access to the resource thanks to the proximity of planting sites. Examples of species now widely cultivated, whose genetic diversity provides a unique selling point critical to their trade and is actively promoted, include cocoa (*Theobroma cacao*) and

coffee (*Coffea* spp.). However, currently, there is little evidence that cultivation has been successful in reducing pressure from wild harvested plant resources, as reviewed in Dawson et al, (2013). Furthermore, domestication determines shifts including potential losses of intraspecific diversity in the tree populations affected (Dawson et al, 2009). However these changes depend on what methods are used, with some domestication practices leading to the maintenance of higher genetic diversity (Cornelius et al, 2006) In addition, farming can also negatively affect wild species and it is seen, for example, as the greatest extinction threat to birds (Green et al, 2005).

2 Solutions that make trade offs between agriculture or wild nature, include environmentally-friendly farming, ecological intensification, land sparing and proactive management of trade and species, which can include initially counter-intuitive practices such ranching and trophy hunting which can conserve specific populations (Rivalan et al, 2007; Ingram et al, 2009). The success of such approaches is often highly dependent upon local conditions (Oosterveer and Sonnenfeld, 2012, Packer et al, 2013).

3 Market-based approaches such as voluntary standards and certification aim to sustainably govern access and use of wild resources and their markets (Schmitt and Grote, 2006; Shanley et al, 2008; FairWild Foundation, 2010). Successes have been highly variable and context specific, depending on factors such as the costs of adoption and adherence, strictness of the standards, degree of supply and demand, and consumer uptake (Potts et al, 2014).

4 Conservation in the form of customary and legal, national and international agreements that prohibit either access to areas which contain threatened wild resources, their use and/or trade

has resulted in both notable successes and failures (Fonseca et al, 2004; Porter-Bolland et al, 2012).

5 Conservation of genetic resources in the form of *in situ*, *circa situ* and *ex situ* approaches based on the characterization of intraspecific diversity and its spatial distribution. Both approaches pose some challenges. For *in situ* genetic conservation strategies to be effective, several conditions need to be in place, such as, for example, favourable policy and legislation frameworks, an appropriate characterization of the resource base through research, the establishment of genetic conservation reserves (FAO, 2014a). *Ex situ* crop collections are a way to conserve crop plant varieties and their wild varieties, and ensure genetic diversity is not lost, though this is not a viable option for all species. Several tropical tree species have recalcitrant seed, unable to survive drying and freezing. However, research has led to considerable innovation in seed storage recently, and increased tree seed longevity under drying conditions and improved storage technologies (Pritchard et al, 2014).

[a] The genetic consequences of exploiting wild plant resources

The wide range of goods and services provided by trees and forests is a result of, and evidence for, the genetic variability that supports their supply. Like wild species, 'wild genes' are threatened by the same pressures that drive changes in wild resources.

However, the impact of these threats is more difficult to identify and assess in wild genetic resources. Valuable genepools of widespread species may disappear undetected, because the intra-specific diversity of these species has not been yet characterized, or because the species per se is not under threat of extinction while some populations with important, distinct characteristics may be lost. These losses can eventually lead to species extinction.

Many tree species have very large within-species diversity (Hamrick et al, 1992) but just over 1% of tree species have been subject to genetic studies and a limited number of non-planted tree species have been characterized using molecular markers (FAOa, 2014). Most of the species characterized have commercial value or significant livelihood significance. Although the number of tropical wild-harvested tree species being genetically characterized is growing, the inclusion of genetic considerations into forest management has been relatively limited. There are also major gaps in the geographic distribution of studies, with a focus on neotropical species (Jalonen et al, 2014).

[!box!]**Box 4.2***The genetic diversity of wild forest species*

Sal (*Shorea robusta* Gaertn.) is a tropical tree of high economic value and classed as endangered in Nepal due to forest clearance and range fragmentation (Pandey and Geburek, 2009). Peripheral populations have been found to be genetically less variable than central ones, although they appear to have a distinct genetic profile that makes them suited to extreme conditions (Pandey and Geburek, 2009), highlighting the value of marginal populations of tropical plants.

Actions to conserve wild fruit trees and *in situ* management of African woody species in semi-arid areas are seen as critical (Bouvet et al, 2004; Diallo et al, 2007). An example is *Sclerocarya birrea*, a multipurpose plant in the Sahel-Sudanian savanna threatened by human pressure and climate change. An assessment of genetic diversity and spatial organization in Burkina Faso revealed a high within-species diversity and enabled the implementation of conservation initiatives (Kando et al, 2012).

The Brazil nut, *Bertholletia excelsa,* a key forest product in Brazil, Bolivia and Peru is traded for food and cosmetic use. Differences in the timing of fruiting and yields, mainly between the western and eastern Amazon led to an investigation of the genetic structure of this species across the Amazon (Sujii et al, 2015).

Prunus africana (Hook.f.) Kalkman is an evergreen tree found in Afromontane forests. For forty years the bark extract has been used as the basis for treating benign prostatic hyperplasia. The international trade and overexploitation of natural populations generated a study of the trees phylogeography, characterizing species genetic diversity in nine African countries. Insights into colonization dynamics and vegetation history enabled the identification of high priority regions for genetic diversity conservation, taking account of threats due to climatic change (Kadu et al, 2011).

To improve the understanding of the relationship between diversity in cultivated vs wild cacao (*Theobroma cacao*), a wide geographic sample of trees was genetically characterized (Motamayor et al, 2008). Ten genetic clusters were identified, as opposed to the two genetic groups traditionally recognized. The results provide new understanding on the diversification of Amazonian species generally, and particularly of traditional cacao cultivars.[!box ends!]

Long-term harvesting of wild plants and other kinds of disturbance at the individual and population levels can affect the genetic diversity of a species by altering individual fitness and genetic contribution. These effects can be detected through variations in genetic parameters.

Knowledge about the relationships between disturbance and genetic diversity within and among populations enables us to assess the adaptive capability of plant species.

Selective logging regimes are commonly applied in tropical forest management. These practices lead to a systematic removal of the largest individuals, which often contribute to regeneration, leaving behind only residual phenotypes with less desirable qualities to contribute to regeneration (Ledig, 1992). Changes in the genetic structure of logged tree populations, have been documented in a limited number of cases (with disputed results) in terms of changes in production volumes, timber quality and economic value (Cornelius et al, 2005), while studies on the genetic impact of harvesting NTFPs are very few in the scientific literature. Also the duration of the application of a specific management system is a factor of high relevance (Wickneswari et al, 2014).

For NTFPs, factors such the part of a plant harvested, the breeding system and the effective population size of the plant involved need be taken into account. Destructive harvesting before maturity is generally the most severe threat. The review of Dawson et al. (2014) concludes that if the part exploited is the seed or the fruit, the effects of intensive exploitation are highest.

[a]Conclusions

The socio-economic benefits to humankind of such resources for the multitude of functions they provide – food, energy, medicines, materials etc. are increasingly recognised, as is their role in ecosystem resilience. Debates on whether wild species, particularly those threatened with extinction, should be used, particularly commercially, and how to conserve them, have taken place over the last two decades (Garrison, 1994; Freese, 1998). There is a growing body of evidence supporting the need to critically examine why, when, how and where wild genetic resources are used, and by whom, in order to improve governance. Sustainable use and trade in wild genetic resources across the globe is critically important to meet a number of the Sustainable Development Goals. However, sustainable use is undermined by the continued poor and unsystematic nature of inventories of species used, of their abundance and the dependence by different peoples on their products, for both subsistence use and trade (Ingram, 2014; Schulp et al, 2014).

Five main approaches have led to variable degrees of success in encouraging a more sustainable governance of wild genetic resources: domestication and cultivation; trade offs between agriculture and wild nature; voluntary standards and certification; customary and legal, national and international agreements prohibiting access to threatened wild resources, their use and trade; and conservation through *in situ*, *circa situ* and *ex situ* approaches. Despite some successes, the increasing number of wild species extinctions and continued habitat loss indicate that generally we are inadequately counteracting the multitude of anthropogenic threats to our valuable wild genetic resources. The picture of how many species are in danger of becoming extinct, or have become extinct without our knowing is largely incomplete. Therefore, scaling-up and further implementing the initiatives mentioned above, taking account of specific ecological, economic, social-cultural contexts is imperative. Additionally, more systematic inventorying of local, traditional knowledge is needed, and improving *ex situ* collections of wild varieties and species of crops and livestock to ensure genetic diversity is not lost - guided by their risk status. Adopting new technologies such as open access, peer-checked, web-based Wikipedia style databases could help further. It is also important to address knowledge gaps, shown in **Box 4.3**.

[!box!]**Box 4.3** *Knowledge gaps on wild plant and animal genetic resources*

1 The extent to which environmental incomes depend on wild-harvested resources is not clearly documented, particularly with regard to those species that are threatened or endangered, and upon which people have a high dependence for their livelihood.

2 Indicators to specifically monitor changes in genetic diversity of wild-harvested plant and animal species are currently absent from comprehensive bio-monitoring schemes. Indicators for monitoring forest genetic diversity and dynamics based on ecological and demographic surrogates of adaptive diversity and genetic markers could be adopted to identify genetic erosion processes and assess gene flow (see Graudal et al, 2014).

3 Traditional and scientific knowledge of genetic diversity of the most threatened and endangered wild species is inadequate to support conservation actions.

4 The geographical representativeness of *in situ* genetic conservation areas compared to the distribution range is unknown for most wild species.

5 For most plant wild species,the capacity to adapt to climate change is unknown, particularly their phenotypic plasticity; the genetic adaptation; the location of areas of high adaptive potential and high conservation value (i.e. genetic diversity hotspots); the extent of standing genetic variation; the geographic distribution of future suitable habitats and dispersal rates; the current landscape fragmentation effects on their migration (see Loo et al, 2012).[!box ends!]

[a]References

Abensperg-Traun, M. (2009) ‘CITES, sustainable use of wild species and incentive-driven conservation in developing countries, with an emphasis on southern Africa’, *Biological Conservation*, vol 142, pp948-963

Abernethy, K. and A. M. N. Obiang (2009). Bushmeat in Gabon: 93.

Aizen, M. A., Garibaldi L. A., Cunningham S. A. and Klein A. M. (2008) ‘Long-term global trends in crop yield and production reveal no current pollination shortage but increasing pollinator dependency’ *Current Biology,* vol 18, pp1572-1575.

Alden Wily, L. (2011). Whose land is it? The status of customary land tenure in Cameroon. Moreton in Marsh/Yaoundé, Centre for Environment and Development / FERN / The Rainforest Foundation UK.

Alexander, H. M. (2010) ‘Disease in natural plant populations, communities, and ecosystems: insights into ecological and evolutionary processes’, *Plant Disease,* vol 94, pp492-503

Alves, R. R. and Alves, H. N. (2011) ‘The faunal drugstore: animal-based remedies used in traditional medicines in Latin America’, *Journal of Ethnobiology and Ethnomedicine*, vol 7, pp1-43

Angelsen, A., Jagger, P., Babigumira, R., Belcher, B., Hogarth, N., Bauch, S., Börner J, Smith-Hall C. and Wunder S. (2014) ‘Environmental income and rural livelihoods: a global-comparative analysis’, *World Development*, vol 64, pp12-28

Baillie, J., Hilton-Taylor, C. and Stuart, S.N., (2004). 2004 IUCN red list of threatened species: A global species assessment. IUCN.

Baldauf, C., Ciampi-Guillardi, M., dos Santos, F. A. M., de Souza, A. P. and Sebbenn, A. M. (2013) 'Tapping latex and alleles? The impacts of latex and bark harvesting on the genetic diversity of *Himatanthus drasticus* (Apocynaceae)', *Forest Ecology and Management*, vol 310, pp434–441

Bauer, J. (2015). Modern Adverse Trends Which Affect Wildlife Management Efforts. Tropical Forestry Handbook. pp 1-12

Beck, H., Snodgrass, J. W. and Thebpanya, P. (2013) 'Long-term exclosure of large terrestrial vertebrates: implications of defaunation for seedling demographics in the Amazon rainforest', *Biological Conservation*, vol 163, pp115-121

Bérard, L. and Marchenay P. (2006) 'Local products and geographical indications: taking account of local knowledge and biodiversity', *International Social Science Journal,* vol 58, pp109-116

Biggs, D., Courchamp, F., Martin, R. and Possingham, H. P. (2013) 'Legal trade of Africa's rhino horns', *Science*, vol 339, pp1038-1039

Bjørndal, T., D. E. Lane and A. Weintraub (2004). 'Operational research models and the management of fisheries and aquaculture: a review'. European Journal of Operational Research 156(3): 533-540.

Boissière, M., Bastide, F., Basuki, I., Pfund, J. L. and Boucard, A. (2013) 'Can we make participatory NTFP monitoring work? Lessons learnt from the development of a multi-stakeholder system in Northern Laos', *Biodiversity and Conservation*, vol 23, pp149–170

Boserup, E. (1996) 'Development theory: An analytical framework and selected application', *Population and Development Review,* vol 22, pp505-515

Bouvet, J. M., Fontaine, C., Sanou, H. and Cardi, C. (2004) 'An analysis of the pattern of genetic variation in *Vitellaria paradoxa* using RAPD markers', *Agroforestry Systems*, vol 60, pp61-69

Cornelius, J. P., Clement, C. R., & Weber, J. C., Sotelo-Montes, C., Van Leeuwen, J., Ugarte-Guerra, L. J., Ricse-Tembladera, A. and Arevalo-Lopez, L. (2006) 'The trade off between genetic gain and conservation in a participatory improvement programme: the case of peach palm (*Bactris gasipaes* Kunth)', *Forests, Trees and Livelihoods,* vol 16, pp17–34

Cornelius, J. P., Navarro, C. M., Wightman, K. E. and Ward, S. E. (2005) 'Is mahogany dysgenically selected?', *Environmental Conservation*, vol 32, pp129–139

Cowlishaw, G., S. Mendelson and J. Rowcliffe (2005).'Evidence for post-depletion sustainability in a mature bushmeat market'. *Journal of Applied Ecology* 42(3): 460-468.

Cunningham, A. B. (1991) 'The herbal medicinal trade: resource depletion and environmental management for a 'hidden economy'', in E. Preston-Whyte and C. Rogerson (eds), *South Africa's Informal Economy'* , Oxford University Press , Cape Town, South Africa

Cunningham, A. B. (2001) *Applied Ethnobotany: People, Wild Plant Use and Conservation,* Routledge, London, UK

Dawson, I. K., Leakey, R., Clement, C. R., Weber, J. C., Cornelius, J. P., Roshetko, J. M., Vinceti, B., Kalinganire, A., Tchoundjeu, Z., Masters, E. and Jamnadass, R. (2014) 'The management of tree genetic resources and the livelihoods of rural communities in the tropics: non-timber forest products, smallholder agroforestry practices and tree commodity crops', *Forest Ecology and Management*, vol 33, pp9–21

Dawson, I. K., Guariguata, M. R., Loo, J., Weber, J. C., Lengkeek, A., Bush, D., Cornelius, J., Guarino, L., Kindt, R., Orwa, C, Russell, J. and Jamnadass, R. (2013) ‘What is the relevance of smallholders’ agroforestry systems for conserving tropical tree species and genetic diversity in *circa situm*, *in situ* and *ex situ* settings? A review’, *Biodiversity and Conservation*, vol 22, pp301–324

Dawson, I. K., Lengkeek, A., Weber J. C. and Jamnadass, R. (2009) ‘Managing genetic variation in tropical trees: linking knowledge with action in agroforestry ecosystems for improved conservation and enhanced livelihoods’, *Biodiversity and Conservation*, vol 18, pp969–986

Delang, C. O. (2005) ‘Not just minor forest products: the economic rationale for the consumption of wild food plants by subsistence farmers’, *Ecological Economics,* vol 59, pp64-73

Delgado, C. L. (1998). ‘Africa's changing agricultural development strategies: past and present paradigms as a guide to the future’. *Brown Journal of World Affairs.* vol 5: 175.

Diallo, O. B., Joly, H. I., McKey, D., Hossaert-McKey, M. and Chevallier, M. H. (2007) ‘Genetic diversity of *Tamarindus indica* population: any clues on the origin from its current distribution?’, *African Journal of Biotechnology*, vol 6, pp853-860

Diamond, J. (2002) ‘Evolution, consequences and future of plant and animal domestication’, *Nature*, vol 418, pp700-707

Dinoor, A. (1974) ‘Role of wild and cultivated plants in the epidemiology of plant diseases in Israel’, *Annual Review of Phytopathology*, vol 12, pp413-436

Dirzo, R. and Mendoza, O. P. (2007) ‘Size-related differential seed predation in a heavily defaunated neotropical rain forest’, *Biotropica*, vol 39, pp355-362

Dirzo, R., Young, H. S., Galetti, M., Ceballos, G., Isaac, N. J. B. and Collen, B. (2014) 'Defaunation in the anthropocene', *Science*, vol 345, pp401-406

Duchelle, A. E., Guariguata, M. R., Less, G., Antonio, M. and Chavez, A. (2012) 'Evaluating the opportunities and limitations to multiple use of Brazil nuts and timber in Western Amazonia', *Forest Ecology and Management*, vol 268, pp39–48

FairWild Foundation (2010) 'FairWild Standard: Version 2.0', Weinfelden, Switzerland, FairWild Foundation: 12

FAO (2015a) *Global Forest Resources Assessment 2015. How are the world's forests changing?* FAO, Rome, Italy

FAO (2015b) *State of the World's Forests 2014*, FAO, Rome, Italy

FAO (2014a) *The State of the World's Forest Genetic Resources*, FAO, Rome, Italy

FAO (2014b) *Global land cover network*, Retrieved 25 September 2015, from http://www.glcn.org/databases/lc_glcshare_results_en.jsp

Foden, W. B., S. H. Butchart, S. N. Stuart, J.-C. Vié, H. R. Akçakaya, A. Angulo, L. M. DeVantier, A. Gutsche, E. Turak and L. Cao (2013). 'Identifying the world's most climate change vulnerable species: a systematic trait-based assessment of all birds, amphibians and corals'. *PLoS One* 8(6): e65427.

Fonseca, K. J. Gaston and M. Hoffmann (2004). 'Effectiveness of the global protected area network in representing species diversity.' *Nature* vol 428(6983): 640-643.

Freese, C. (1998) *Wild Species as Commodities: Managing Markets and Ecosystems for Sustainability*, Island Press, Washington, D.C. and Covelo CA, USA

Garrison, J. L. (1994) ‘Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and the debate over sustainable use’, *Pace Environmental Law Review*, vol 12:12

Gill, R. B. (2009). To save a mountain lion: evolving philosophy of nature and cougars. Cougar: ecology and conservation. University of Chicago Press, Chicago, Illinois, USA: 5-16.

Golden, C. D., Fernald, L. C., Brashares, J. S., Rasolofoniaina, B. R., & Kremen, C. (2011). ‘Benefits of wildlife consumption to child nutrition in a biodiversity hotspot’. *Proceedings of the National Academy of Sciences*, vol 108(49), 19653-19656.

Graudal, L., F. Aravanopoulos, Z. Bennadji, S. Changtragoon, B. Fady, E. D. Kjær, J. Loo, L. Ramamonjisoa and G. G. Vendramin (2014). "Global to local genetic diversity indicators of evolutionary potential in tree species within and outside forests." Forest Ecology and Management 333: 35-51.

Green, R. E., Cornell, S. J., Scharlemann, J. P. and Balmford A. (2005) ‘Farming and the fate of wild nature’, *Science*, vol 307, pp550-555

Hamrick, J. L., Godt, M. J. W. and Sherman-Broyles, S. L. (1992) ‘Factors influencing levels of genetic diversity in woody plant species’, *New Forests*, vol 6,pp95–124

Hemp, A. (2006) ‘Vegetation of Kilimanjaro: hidden endemics and missing bamboo’, *African Journal of Ecology*, vol 44, pp305–328

Hunter, M.D., 2002. ‘Landscape structure, habitat fragmentation, and the ecology of insects’. *Agricultural and Forest Entomology*, vol 4(3), pp.159-166.

Ingram, V. (2014) ‘Win-wins in forest product value chains? How governance impacts the sustainability of livelihoods based on non-timber forest products from Cameroon’, PhD Thesis, University of Amsterdam, the Netherlands

Ingram, V., Awono, A., Schure, J. and Ndam, N. (2009) ‘Guidance for a national *Prunus africana* management plan, Cameroon’, Project GCP/RAF/408/EC «Mobilisation et Renforcement des Capacités des Petites et Moyennes Entreprises impliquées dans les Filières des Produits Forestiers Non Ligneux en Afrique Centrale ». CIFOR. Yaoundé, Cameroun, FAO-CIFOR-SNV-World Agroforestry Center-COMIFAC-GTZ: 156

Jackson, M. T. and Ford-Lloyd, B. V. (1990) ‘Plant genetic resources – a perspective’, in M. T. Jackson, B. V. Ford-Lloyd and M. L. Parry (eds), *Climatic Change and Plant Genetic Resources*, Belhaven Press, London, UK, pp1–17

Jalonen, R., Hong, L. T., Lee, S. L., Loo, J. and Snook, L. (2014) ‘Integrating genetic factors into management of tropical Asian production forests: a review of current knowledge’, *Forest Ecology and Management*, vol 315, pp191–201

Johns, T., Powell B., Maundu P. and Eyzaguirre P. B. (2013). ‘Agricultural biodiversity as a link between traditional food systems and contemporary development, social integrity and ecological health’, *Journal of the Science of Food and Agriculture*, vol 93, pp3433-3442

Junker, J., Boesch C., Mundry R., Stephens C., Lormie M., Tweh C. and Kühl H. S. (2015). ‘Education and access to fish but not economic development predict chimpanzee and mammal occurrence in West Africa’ *Biological Conservation,* vol 182, pp27-35

Kadu, C. A. C., Parich, A., Schueler, S., Konrad, H., Muluvi, G. M., Eyog-Matig, O., Muchugi, A., Williams, V. L., Ramamonjisoa, L., Kapinga, C., Foahom, B., Katsvanga, C., Hafashimana, D., Cr, B. V. and Rainer Schumacher, T. G. (2012) 'Bioactive constituents in *Prunus africana*: Geographical variation throughout Africa and associations with environmental and genetic parameters', *Phytochemistry*, vol 83, pp70-78

Kadu, C. A. C., Schueler, S., Konrad, H., Muluvi, G. M., Eyog-Matig, O., Muchugi, A., Williams, V.L., Ramamonjisoa, L., Kapinga, C., Foahom, B., Katsvanga, C., Hafashimana, D., Obama, C. and Geburek, T. (2011) 'Phylogeography of the Afromontane *Prunus africana* reveals a former migration corridor between East and West African highlands', *Molecular Ecology*, vol 20, pp165–178

Kando, P. B., Bisseye, C., Nanema, R. K., Traore, E. R., Ye, H., Diallo, B. O. and Zongo, D. (2011) 'Genetic diversity of *Sclerocarya birrea* subspecies *birrea* populations in Burkina Faso detected by RAPDs', *African Journal of Biotechnology*, vol 11, pp99–108

Keesing, F. and Young, T. P. (2014) 'Cascading consequences of the loss of large mammals in an African savanna', *Bioscience*, vol 64, pp487-495

Kissinger, G., Herold, M. and De Sy, V. (2012) 'Drivers of deforestation and forest degradation: a synthesis report for REDD+ policymakers', Lexeme Consulting, Vancouver, Canada

van Kuijk, M., Putz, F. and Zaag, R. (2009) *Effects of forest certification on biodiversity,* Tropenbos International, Wageningen, the Netherlands

Kusters, K., Achdiawan, R., Belcher, B. and Ruiz Pérez, M. (2006) 'Balancing development and conservation? An assessment of livelihood and environmental outcomes of non-timber forest product trade in Asia, Africa, and Latin America', *Ecology and Society*, vol 11, p2

Laird, S. A., R. McLain and R. P. Wynberg, Eds. (2010). Wild Product Governance: Finding Policies that Work for Non-Timber Forest Products. People and Plants International Conservation Series. London, People and Plants International

Lange, D. (1998) 'Europe's medicinal and aromatic plants: their use, trade and conservation', Traffic Network Report, Traffic International, Cambridge, UK

Laporte, N. T., J. A. Stabach, R. Grosch, T. S. Lin and S. J. Goetz (2007). 'Expansion of industrial logging in Central Africa.' *Science* 316(5830): 1451-1451.

Leach, M. and J. Fairhead (2000). 'Challenging neo-Malthusian deforestation analyses in West Africa's dynamic forest landscapes'. *Population and Development Review* 26(1): 17-43.

Ledig, F. T. (1992) 'Human impacts on genetic diversity in forest ecosystems', *Oikos*, vol 63, pp87−109

Leroy EM, Rouquet P, Formenty P, Souquière S, Kilbourne A, Froment JM, Bermejo M, Smit S, Karesh W, Swanepoel R. (2004) 'Multiple Ebola virus transmission events and rapid decline of central African wildlife'. *Science*. Vol 303:387-390.

Liebhold, A. M., MacDonald, W. L., Bergdahl, D. and Mastro, V. C. (1995) 'Invasion by exotic forest pests: a threat to forest ecosystems', *Forest Science*, vol 41, ppa0001-z0001

Lindsey, P. A., G. Balme, M. Becker, C. Begg, C. Bento, C. Bocchino, A. Dickman, R. W. Diggle, H. Eves and P. Henschel (2013). 'The bushmeat trade in African savannas: Impacts, drivers, and possible solutions'. *Biological Conservation* 160: 80-96.

Loo, J., Fady, B., Dawson, I., Vinceti, B. and Baldinelli, G. (2011) 'Climate change and forest genetic resources: state of knowledge, risks and opportunities', Background study paper(56), Bioversity International, Maccarese, Italy

Lowe, S., Browne, M., Boudjelas, S. and De Poorter, M. (2000) ‘100 of the world's worst invasive alien species: a selection from the global invasive species database’, Invasive Species Specialist Group, Auckland, New Zealand

McNeely, J. A. (1998). Major Conservation Issues of the 1990s: Results of the World Conservation Congress Workshops, Montreal, Canada, 13-23 October 1996, IUCN.

de Merode, E., K. Homewood and G. Cowlishaw (2004). ‘The value of bushmeat and other wild foods to rural households living in extreme poverty in Democratic Republic of Congo’. *Biological Conservation* 118(5): 573-581.

Milder J. C., Hart A. K., Dobie P., Minai J. and Zaleski C. (2014) ‘Integrated landscape initiatives for african agriculture, development and conservation: a region-wide assessment,’ *World Development*, vol 54, pp68-80

Millennium Ecosystem Assessment (2005) ‘*Ecosystems and Human Well-Being: Opportunities and Challenges For Business and Industry’*, Island Press, Washington D.C., USA

Motamayor, J. C., Lachenaud, P., da Silva e Mota, J. W., Loor, R., Kuhn, D. , Brown J. S. and Schnell R. J. (2008) ‘Geographic and genetic population differentiation of the Amazonian chocolate tree (*Theobroma cacao* L.)’, *PLoS ONE*, vol 3:e3311

Msuya, T. S., Kideghesho, J. R. and Mosha, T. C. E. (2010) ‘Availability, preference, and consumption of indigenous forest foods in the Eastern Arc Mountains, Tanzania’, *Ecology of Food and Nutrition*, vol 49, pp208–27

Muller-Landau, H. C. (2007) ‘Predicting the long-term effects of hunting on plant species composition and diversity in tropical forests’, *Biotropica*, vol 39, pp372-384

Nasi, R., Brown, D., Wilkie, D., Bennett, E., Tutin, C., van Tol, G. and Christophersen, T. (2008) 'Conservation and use of wildlife-based resources: the bushmeat crisis', Technical Series no.33. Montreal and Bogor, Secretariat of the Convention on Biological Diversity and Center for International Forestry Research (CIFOR): 50

Newton, A. C. (2008) 'Conservation of tree species through sustainable use: how can it be achieved in practice?', *Oryx*, vol 42, pp195–205

Noufou, O., Wamtinga, S. R., André, T., Christine, B., Marius, L., Emmanuelle, H. A. and Pierre, G. I. (2012) 'Pharmacological properties and related constituents of stem bark of *Pterocarpus erinaceus* Poir. (Fabaceae)', *Asian Pacific Journal of Tropical Medicine*, vol 5, pp46–51

Oksanen, T. and C. Mersmann (2003). Forests in poverty reduction strategies-An assessment of PRSP processes in Sub-Saharan Africa. Forests in Poverty Reduction Strategies: Capturing the Potential. EFI Proceedings.

Oosterveer, P. and D. A. Sonnenfeld (2012). Food, globalization and sustainability. Routledge.

Oyono, P. R., C. Kouna and W. Mala (2005). Benefits of forests in Cameroon. Global structure, issues involving access and decision-making hiccoughs. *Forest Policy and Economics* 7(3): 357-368.

Packer, C., A. Loveridge, S. Canney, T. Caro, S. Garnett, M. Pfeifer, K. Zander, A. Swanson, D. Macnulty and G. Balme (2013). 'Conserving large carnivores: dollars and fence'. *Ecology Letters* vol 16(5): 635-641.

Pandey, M. and Geburek, T. (2009) 'Genetic differences between continuous and disjunct populations: some insights from sal (*Shorea robusta* Roxb.) in Nepal', *Conservation Genetics*, vol 11, pp977–984

Peters, C. M. (1996) 'The ecology and management of non-timber-forest resources', Technical papers, World Bank, Washington D.C., USA

Pimentel, D., McNair, S., Janecka, J., Wightman, J., Simmonds, C., O'Connell, C., Wong, E., Russel, L., Zern, J., Aquino, T. and Tsomondo, T. (2001) 'Economic and environmental threats of alien plant, animal, and microbe invasions', *Agriculture, Ecosystems & Environment*, vol 84, pp1-20

Plumptre, A. J., J. B. Bizumuremyi, F. Uwimana and J. D. Ndaruhebeye (1997). 'The effects of the Rwandan civil war on poaching of ungulates in the Parc National des Volcans'. *Oryx* vol 31(4): 265-273.

Porter-Bolland, L., Ellis, E. A., Guariguata, M. R., Ruiz-Mallén, I., Negrete-Yankelevich, S. and Reyes-García, V. (2012) 'Community managed forests and forest protected areas: An assessment of their conservation effectiveness across the tropics', *Forest Ecology and Management*, vol 268, pp6–17

Potts, J., M. Lynch, A. Wilkings, G. Huppe, M. Cunningham and V. Voora (2014). 'The State of Sustainability Initiatives Review 2014: Standards and the Green Economy.' International Institute for Sustainable Development and the International Institute for Environment and Development. London.

Powell, B., Thilsted S. H., Ickowitz A., Termote C., Sunderland T. and Herforth A. (2015) 'Improving diets with wild and cultivated biodiversity from across the landscape' *Food Security,* vol 7, pp535-554

Prescott-Allen, R. and Prescott-Allen, C. (1983) *Genes from the Wild*: *Using Wild Genetic Resources for Food and Raw Materials*, Earthscan, London, UK

Pritchard, H. W., Moat, J. F., Ferraz, J. B. S., Marks, T. R., Camargo, J. L. C., Nadarajan, J., & Ferraz, I. D. K. (2014) 'Innovative approaches to the preservation of forest trees', *Forest Ecology and Management*, vol 333, pp88–98

Ramsay, B. J. (1994). Commercial use of wild animals in Australia, Bureau of Resource Sciences (BRS), Department of Primary Industries and Energy.

Redford, K. H. (1992). 'The empty forest'. *BioScience* vol 42(6): 412-422.

Richardson, D. M., Pyšek, P., Rejmánek, M., Barbour, M. G., Panetta F. D. and West, C. J. (2000) 'Naturalization and invasion of alien plants: concepts and definitions', *Diversity and Distributions*, vol 6, pp93-107

Rijkers, T., Ogbazghi, W., Wessel, M. and Bongers, F. (2006) 'The effect of tapping for frankincense on sexual reproduction in *Boswellia papyrifera*', *Journal of Applied Ecology*, vol 43, pp1188–1195

Rist, L., Shanley, P., Sunderland, T., Sheil, D., Ndoye, O., Liswanti, N. and Tieguhong, J. (2012) 'The impacts of selective logging on non-timber forest products of livelihood importance', *Forest Ecology and Management*, vol 268, pp57-69

Rivalan, P., Delmas, V., Angulo, E., Bull, L. S., Hall, R. J., Courchamp, F., Rosser A. M. and Leader-Williams, N. (2007) 'Can bans stimulate wildlife trade?' *Nature*, vol 447, pp529-530

Roberts, A. M. (2015) 'Detailed look at the ivory trade and the poaching of elephants', *Quinnipiac Law Review*, vol 33, no 567

Robinson, B. B., Holland, M. B., and Naughton-Treves, L. (2011) 'Does secure land tenure save forests? A review of the relationship between land tenure and tropical deforestation', *Agriculture*, vol 10, Working Paper no 7, CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), Copenhagen, Denmark

Rodriguez-Izquierdo, E., M. C. Gavin and M. O. Macedo-Bravo (2010). Barriers and triggers to community participation across different stages of conservation management. *Environmental Conservation* 37(03): 239-249

Sanou, H., Lovett, P. and Bouvet, J. M. (2005) 'Comparison of quantitative and molecular variation in agroforestry populations of the shea tree (*Vitellria paradoxa* C. F Gertn) in Mali', *Molecular Ecology*, vol 14, pp2601-2610

Schlager, E. and E. Ostrom (1992). 'Property-rights regimes and natural resources: a conceptual analysis.' *Land Economics* vol 68: 3 pp 249-262.

Schippmann, U., Leaman, D. J. and Cunningham, A. (2002) 'Impact of cultivation and gathering of medicinal plants on biodiversity: global trends and issues', Biodiversity and the Ecosystem Approach in Agriculture, Forestry and Fisheries. Satellite event on the occasion of the Ninth Regular Session of the Commission on Genetic Resources for Food and Agriculture, Rome, 12-13 October 2002. Inter-Departmental Working Group on Biological Diversity for Food and Agriculture. FAO, Rome, Italy

Schmitt, C. and U. Grote (2006) 'Wild coffee production in Ethiopia: the role of coffee certification for forest conservation', Report project 'Conservation and use of wild populations of *Coffea arabica* in the montane rainforest of Ethiopia', Biodiversity and the ecosystem approach in agriculture, forestry and fisheries, Bonn, Germany

Scholte, P. (2011) 'Towards understanding large mammal population declines in Africa's protected areas: a west-central African perspective', *Tropical Conservation Science*, vol 4, pp1-11

Schulp, C. J., Thuiller, W. and Verburg, P. (2014) 'Wild food in Europe: A synthesis of knowledge and data of terrestrial wild food as an ecosystem service', *Ecological Economics*, vol 105, pp292-305

Seignonbos, T. I. C., Degune J-P. and Aberlenc H-P. (1996) 'Les mofu et leurs insects', *Joumale d'Agriculture Traditionale et de Bota Applique,* vol 358, pp125-187

Shackleton, S., M. Cocks, T. Dold, S. Kaschula, K. Mbata, G. Mickels-Kokwe and G. von Maltitz (2010). Non-wood forest products: description, use and management. The Dry Forests and Woodlands of Africa. E.Nn Chidumayo and D.J. Gumbo, eds: pp 93-130.

Shanley, P., Pierce, A., Laird, S. and Robinson, D. (2008) '*Beyond Timber: Certification and Management of Non-Timber Forest Products*', Center for International Forestry Research (CIFOR), Bogor, Indonesia

Shanley, P. and Luz, L. (2003) 'The impacts of forest degradation on medicinal plant use and implications for health care in eastern Amazonia', *Bioscience*, vol 53, pp573–584

Shearman, P., Bryan, J. and Laurance, W. F. (2012) 'Are we approaching "peak timber" in the tropics?' *Biological Conservation*, vol 15, pp17-21

Sheil, D. and Salim, A. (2012) 'Diversity of locally useful tropical forest wild-plants as a function of species richness and informant culture', *Biodiversity & Conservation*, vol 21, pp687–699.

Smith, K. M., Anthony, S. J., Switzer, W. M., Epstein, J. H., Seimon, T., Jia, H., Sanchez, M. D., Huynh, T. T., Galland, G. G., Shapiro, S. E., Sleeman, J. M., McAloose, D., Stuchin, M., Amato, G., Kolokotronis, S. O., Lipkin, W. I., Karesh, W. B., Daszak, P. and Marano, N. (2012) 'Zoonotic viruses associated with illegally imported wildlife products', *PLoS ONE*, vol 7:e229505

Sneyd, L. Q. (2013) 'Wild food, prices, diets and development: sustainability and food security in urban Cameroon', *Sustainability*, vol 5, pp4728-4759

Stoner, K. E., Vulinec, K., Wright, S. J. and Peres, C. A. (2007) 'Hunting and plant community dynamics in tropical forests: A synthesis and future directions', *Biotropica*, vol 39, pp385-392

Sujii, P. S., Martins, K., Wadt, L. H. D. O., Azevedo, V. C. R. and Solferini, V. N. (2015) 'Genetic structure of *Bertholletia excelsa* populations from the Amazon at different spatial scales', *Conservation Genetics*, vol16, pp955–964

Sunderland T. C. H. (2011) 'Food security: why is biodiversity important?', *International Forestry Review,* vol 13, pp265-274

Sunderlin, W. and I. A. P. Resosudarmo (1999). 'The effect of population and migration on forest cover in Indonesia'. *The Journal of Environment & Dev*elopment 8(2): 152-169.

Thomas, B. (2013). 'Sustainable harvesting and trading of mopane worms (*Imbrasia belina*) in Northern Namibia: an experience from the Uukwaluudhi area'. *International Journal of Environmental Studies* 70(4): 494-502.

UNEP (2010) *Global Honey Bee Colony Disorders and Other Threats to Insect Pollinators*, United Nations Environment Programme, Nairobi, Kenya

Vantomme, P., D. Göhler and F. N'Deckere-Ziangba (2004) 'Contribution of forest insects to food security and forest conservation: the example of caterpillars in Central Africa', Wildlife Policy Briefing Number 3, ODI:4

Vira, B., Wildburger, C. and Mansourian, S. (eds) (2015) '*Forests, Trees and Landscapes for Food Security and Nutrition. A Global Assessment Report*', IUFRO World Series – Forests, Trees and Landscapes for Food Security and Nutrition, Collaborative Partnership on Forests

Walsh, S. J., L. Zonn and J. P. Messina (2004). Deforestation of the Ecuadorian Amazon: characterizing patterns and associated drivers of change. WorldMinds: Geographical Perspectives on 100 Problems, Springer: 299-304.

Warman, R. D. (2014) 'Global wood production from natural forests has peaked', *Biodiversity and Conservation*, vol 28, pp1063–1078

Wickneswari, R. W., Rajora, O. P., Finkeldey, R., Aravanopoulos, F., Bouvet, J-M., Vaillancourt, R. E., Kanashiro, M., Fady, B., Tomita, M. and Vinson, C. (2014) 'Genetic effects of forest management practices: Global synthesis and perspectives', *Forest Ecology and Management*, vol 333, pp52-65

WHO, CBD and UNEP (2015). *Connecting Global Priorities: Biodiversity and Human Health A State of Knowledge Review*. Geneva: World Health Organization and the Secretariat of the Convention on Biological Diversity.

Wiersum, K. F., Ingram, V. J. and Ros-Tonen, M. A. F. (2014) 'Governing access to resources and markets in non-timber forest product chains', *Forest, Trees and Livelihoods*, vol 23, pp6-18

Wilkie, D. S., E. L. Bennett, C. A. Peres and A. A. Cunningham (2011). 'The empty forest revisited'. *Annals of the New York Academy of Sciences* 1223(1): 120-128.

Wunder, S. (2014) 'Forests, livelihoods, and conservation: broadening the empirical base', *World Development*, vol 64, pp1-11

Zohary, D., Hopf, M. and Weiss, E. (2012) '*Domestication of Plants in the Old World: The origin and spread of domesticated plants in Southwest Asia, Europe, and the Mediterranean Basin'* , Oxford University Press, UK