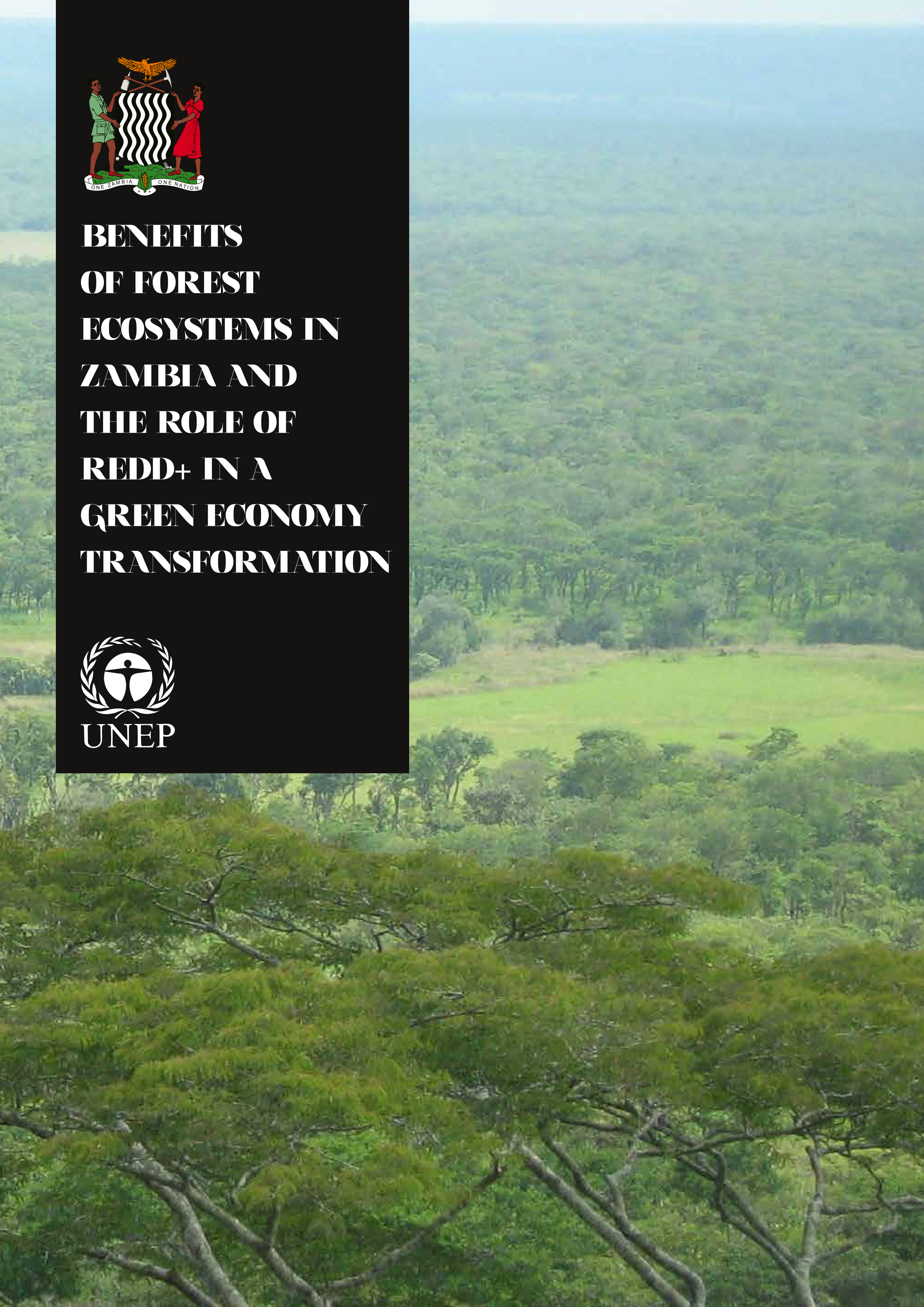
BENEFITS OF FOREST ECOSYSTEMS IN ZAMBIA AND THE ROLE OF REDD+ IN A GREEN ECONOMY TRANSFORMATION



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This work has been designed and implemented under the direction of Dr Pushpam Kumar, Chief, Ecosystem Services Economics Unit, UNEP.

Written by: Jane Turpie[1], Benjamin Warr[2] and Jane Carter Ingram[3]

Edited by: Sun Cho (UNEP) and Ivo Mulder (UNEP)

Production editing by: Deborah Kirby (UNEP)

[1]Anchor Environmental Consultants, Cape Town, South Africa
[2]Betterworld Consulting, Lusaka, Zambia
[3]Wildlife Conservation Society, New York, U.S.A.

Cover photo: Photo taken in the Northern Province of Zambia by Benjamin Warr

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UN-REDD PROGRAMME

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Foreword

Forests play a crucial role in enhancing human well-being and in sustaining the economy of Zambia. They contribute to economic growth, employment, wealth, export revenues, a stable supply of clean water, recreation and tourism opportunities, as well as essential building materials and energy for a wide range of economic sectors. However, Zambia has one of the highest per capita deforestation rates in Africa. The Government's efforts to reduce emissions from deforestation and forest degradation and increase the role of conservation, sustainable management of forests and enhancement of forest carbon stocks (REDD+) have the potential to halt the rate of deforestation in the country.

This can happen if the country manages to successfully implement its national strategy to reduce emissions from deforestation and forest degradation, and, thereby, leverage financing and investments opportunities for REDD+ implementation including through results-based payments. Actions to reduce deforestation could be an important catalysing factor for the country to transition to a Green Economy, especially if REDD+ implementation is embedded in the country's ambitious development and economic objectives. Thus, the potential is great for the forestry sector to play a very important role in the country achieving its Vision 2030 goals.

This report provides an economic rationale for prioritizing REDD+ implementation by showing the significant economic benefits of doing so. Forest ecosystem services that were quantified in this study and which are currently not accounted for in the Gross Domestic Product (GDP) such as sediment retention and erosion control, ecotourism, pollination services and carbon storage, have an economic value equivalent to at least 2.5 per cent of the GDP of Zambia. This represents an undervaluation of 40 to 68 per cent of the total value added of provisioning services such as industrial roundwood, charcoal, firewood, wood processing, pulp and paper and non-wood forest products. With the inclusion of these additional services, the contribution of forests to the Zambian economy rises from 3.8 per cent to 6.3 per cent. The formal and informal contribution of the forestry sector also supports over 1 million jobs related to fuelwood, non-wood forest products and ecotourism, which means that forests support over 60 per cent of rural Zambian households.

At the regional level, Zambia's strategic location makes it an important country within the sub-region in relation to REDD+ and associated trans-boundary ecosystems. These ecosystems become even more important as Zambia holds about 30-40 per cent of the water resources in Southern Africa and shares trans-boundary water resources with eight other countries. At the international level, Zambia has great potential to promote key international development goals, such as reducing carbon emission, through the implementation of targets that will be outlined in its National REDD+ Strategy.

This work, undertaken by UNEP's Ecosystem Services Economics Unit in association with the Zambian Ministry of Lands, Natural Resources and Environmental Protection, is part of a range of activities offered by the UN-REDD Programme to support the Government of Zambia by enabling it to build the economic case for the implementation of key policies and measures for the sustainable management and conservation of the country's forest ecosystems as part of REDD+ implementation. Such measures could include strengthening forest management and enforcement of laws on illegal timber harvesting, supporting community land tenure and strengthening community-based forest stewardship. Other means include improving the efficiency and sustainability of agricultural practices, increasing access to incentives and income generating activities that depend upon forest conservation and managing the demand for charcoal production.

It is envisioned that these findings will further strengthen the resolve of the Government of Zambia to address the drivers of deforestation and forest degradation, and to implement the National REDD+ Strategy as part of the country's broader goals to achieve an Inclusive Green Economy.

Her Excellency Mrs. Christabel Ngimbu
Minister, Ministry of Lands, Natural Resources and Environmental Protection

Achim Steiner
United Nations Under-Secretary-General and Executive Director, United Nations Environment Programme

Executive summary

Introduction

The aim of this study was to undertake a rapid assessment of the value and role of forests in the Zambian economy based on available information in order to inform policy decisions on forest management and the implementation of REDD+ activities in Zambia. The study is part of the country's National UN-REDD Programme. REDD+[1] is a financial mechanism designed to reward developing countries for their verified reductions or removals of forest carbon emissions compared to a forest reference (emission) level that complies with the relevant safeguards.

Forests are an important component of Zambia's natural capital and provide benefits that are critical for rural populations, urban areas, the national economy and the global community. Out of Zambia's total land area of 75.3 million ha, estimates of remaining forest range from 39 million ha (CSO 2013) to 50 million ha (Kalinda *et al.* 2008) or 53 million ha (ZFD 2000). Estimates of deforestation rates range from 113,000 ha in 2012 by Global Forest Watch[2] to 167,000 ha per year in FAO's Global Forest Resource Assessment (FAO 2010) and 250,000 ha per year (ILUA study) to even over 850,000 ha per year (FAO 2001, in Jumbe *et al.* 2008; GRZ 2006a). Zambia has the second highest per capita deforestation rate in Africa and the fifth highest in the world (Aongola *et al.* 2009). The main direct drivers of deforestation are charcoal production, agricultural and human-settlement expansion and illegal exploitation of timber.

The study assessed the values of forests in the form of wood production (for timber, fuel wood and charcoal) and non-wood forest products, such as wild foods and medicines. In addition, regulating and cultural services were included, such as the economic value of nature-related tourism, regulation of the climate through carbon sequestration, the retention of sediment for erosion control, the regulation of water flow and water quality, and support for agricultural production through pest control and pollination. The study assesses the critical role that forest ecosystems play in sustaining and supporting the stocks and flow of ecosystem services to various economic sectors and human well-being in Zambia, as well as addressing potential opportunities that forests offer with respect to transitioning to a green economy, particularly the role of REDD+ in achieving this transformation. It is envisioned that this study will help to elevate the importance of sustainable forest management and conservation in national policy, for example through the national REDD+ strategy.

[1] REDD+ stands for reducing emissions from deforestation and forest degradation in developing countries and the role of conservation, sustainable management of forests, and enhancement of forest carbon stocks.

[2] www.globalforestwatch.org

Approach

This desktop study builds on the existing body of work that has been undertaken in Zambia to estimate the value of ecosystem services, which have mainly been confined to the extraction of timber and fuel wood, non-wood forest products, carbon and, in a broader context, ecotourism. The study has reviewed and synthesized available information gathered through extensive literature reviews of peer-reviewed publications and grey literature and the collection of data and reports in-country and has used these data to update some earlier estimates as well as to produce preliminary desktop estimates of services that have not been valued previously. In some cases this required dealing with contradictory and wide ranging estimates, and poor quality or missing data.

Recognizing that the supply of ecosystem services and their demand varies spatially according to a range of biophysical and socioeconomic factors, our study used a spatial approach as far as possible in order to generate more realistic estimates of the likely variation in the value of ecosystem services and the potential trade-offs involved in forest use and conservation. This required the collation of national and global spatial data and preparation or modification of certain spatial data layers using geographic information systems (GIS).

Based on available empirical and spatial data, in conjunction with assumptions made on the basis of expert understanding of ecosystem services, preliminary estimates of the value of a range of forest ecosystem services were made in two main ways:

- Extrapolation of data based on spatial parameters at the resolution allowed by the data (e.g. by vegetation type, biomass, population density or district), or
- Use of an existing spatial modelling platform, “InVEST”, developed by the Natural Capital Project at Stanford University, USA, which, despite the relatively high level of spatial resolution involved, is not necessarily more accurate in the absence of locally relevant data.

Results

- The value of **wood production** (industrial roundwood and fuel wood) was estimated in this study to be in the order **of US$396 million per annum.** There is a spatial mismatch between supply and harvesting, so that certain areas are estimated to be severely overutilized.
- Estimates of the value of **non-wood forest products** vary considerably but, based on the assumptions applied in this study, we estimated an overall income from non-wood forest products of **US$135.8 million per annum.**
- The value of **carbon** can be estimated in terms of its damage costs, and this social cost of carbon was estimated to be US$29 per tonne, which if aggregated would be in the order of **US$15 million per annum.** In evaluating potential for REDD+ projects, carbon can also be valued in terms of its market value, which we estimate to be in the region of US$6 per tonne. Depending on location, carbon stocks in Zambian forests are potentially worth about US$150 per ha (hectare) on average (once off), but range up to US$745 per ha for intact forests. Annual values of sequestration in degraded areas are about US$16–US$30 per ha per year.
- Based on a model of soil erosion and transport (using InVEST) developed through this analysis, it was estimated that current rates of sediment output are in the order of 250 million tonnes (average 2.23 tonnes per ha), forests retain a further 274 million tonnes, generating a **cost saving in the order of US$247 million per annum.**
- While Zambia’s forests are unlikely to have positive benefits on dry season flows through infiltration or contribute significantly to flood attenuation, the loss of forest cover over large areas could result in reduced precipitation in the region, impacting on flows, water yields and hydropower generation, and driving up the costs of electricity. This should be addressed in future studies.
- Based on the costs of alternative means of pollination, the value of forest pollination services was estimated to be in the order of **US$74 million per annum.**
- Nature-based tourism is the dominant form of holiday tourism to Zambia, and forests are an integral part of the nature-based tourism experience. Estimates of **forest-based tourism range from US$110 million to US$179 million per annum** for direct value added by forest-based tourism.
- In summary, the analysis showed that the **direct and indirect values of forests considered as part of this study (excluding the market value of carbon) are estimated to make a direct contribution equivalent to about 4.7% of gross domestic product (GDP) or US$957.5 million (using 2010 figures).** This is substantially higher than the updated national accounts, released in July 2014, suggest.
- Forestry and tourism-related activities, however, also have multiplier effects on other sectors in the sense that other sectors benefit economically from income generated in the forestry and tourism sectors. The most recent social accounting matrix for Zambia (Thurlow *et al.* 2004) contains very little detail on the forestry sector, but suggests a multiplier of 1.49. Tourism multipliers were taken from WTTC (2012). **When the multiplier effects of forestry and tourism-related activities on other sectors are taken into account, the overall or economy-wide contribution of forests to GDP is estimated to be at least 6.3% or US$1,277 million.** The table below provides a summary of the economic value and employment that forest ecosystem services in Zambia generate on an annual basis.
- The contribution of forest ecosystem services to the Zambian economy that are currently not accounted for in GDP – such as ecotourism, erosion control and

sediment retention, pollination and carbon storage – is estimated to be 2.5% of GDP or US$ 515.4 million annually. It can therefore be stated that **depending on the estimate of the contribution of forests to GDP in Zambia,** which range from 3.7% (Puustjärvi *et al.* 2005) to 6.2% (FAO, 2014)[3], **there is an undervaluation of at least 40 – 68%.**

- Forests are estimated to provide at least 1.4 million jobs, supporting **60% of rural Zambian households** who are heavily dependent upon the use of natural resources to supplement or sustain their livelihoods. **Forest resources contribute to approximately 20% of household incomes** including the market value of subsistence production. The true value of forests, including flows of goods and services for which no reliable data were available, is likely to be considerably higher.

Implications and recommendations

Given the importance of forests to the economy, employment, and livelihoods, it is important that cost-effective ways for conserving and sustainably managing forests are implemented to support *"green economy"* growth, defined by UNEP as *'an economy that results in improved human well-being and social equity, while significantly reducing environmental risks'* (UNEP 2011a). **This study suggests that sustainably managed forests yield benefits worth at least US$25 per ha per year on average, though varying up to over US$700 per ha per year.**

For each province and district of Zambia the rationale for and means by which REDD+ activities can and will be undertaken may be different. Ways to reduce deforestation and forest degradation include strengthening and enhancing management and governance of forests at the local level, introducing measures to reduce the urban demand for charcoal, supporting the development of livelihood and income generating activities that support or rely upon forest conservation and maintenance, and increasing the sustainability and efficiency of agricultural practices. The potential and relative success of each of these strategies depends very much on the ecological, social, economic and political context in which they are implemented. Where appropriate, these approaches should be pursued in concert and can form the pillars of a national REDD+ strategy in Zambia.

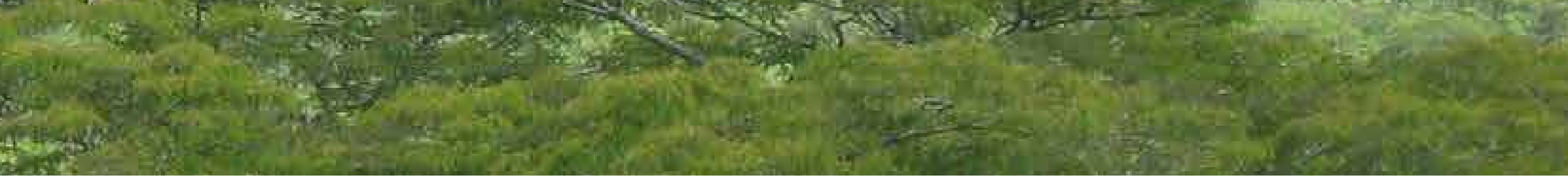
Overview of the economic value of forest ecosystem services and the estimated employment forest ecosystems generate

Type of service/value	Gross output/saving	Direct value added	Total value added	Employment
		(US$ million per year)		('000s people)
Industrial roundwood	35.8	21.5	32.0	10.1
Fuel wood (firewood and charcoal)	598.9	374.3	557.7	>500.0
Non-wood forest products	135.9	115.5	172.1	888.8
Subtotal provisioning services	**770.6**	**511.3**	**761.8**	**1 398.9**
Percentage of GDP 2010		**2.5%**	**3.8%**	
Ecotourism*	197.0	110.2	179.4	16.1
Erosion control and sediment retention**	247	247	247	-
Pollination services**	74	74	74	-
Carbon storage (damages avoided)**	15	15	15	-
Subtotal regulating, supporting and cultural services	**533**	**446.2**	**515.4**	**16.1**
Percentage of GDP 2010		**2.2%**	**2.5%**	
Total	**1 303.6**	**957.5**	**1 277.2**	**1 415.0**
Percentage of GDP 2010		**4.7%**	**6.3%**	

* The low-end estimates are used

** These values are shown without decimals given the higher level of uncertainty

[3] The figures for the contribution of the forestry sector to the Zambian economy differ because there is no harmonization of the type of activities that are included. They can therefore be regarded as partial estimates and include – depending on the study – industrial roundwood, wood processing, pulp and paper, charcoal, firewood and non-wood forest products. The undervaluation is an under estimate because not all regulating, supporting and cultural services could be quantified as part of this study.



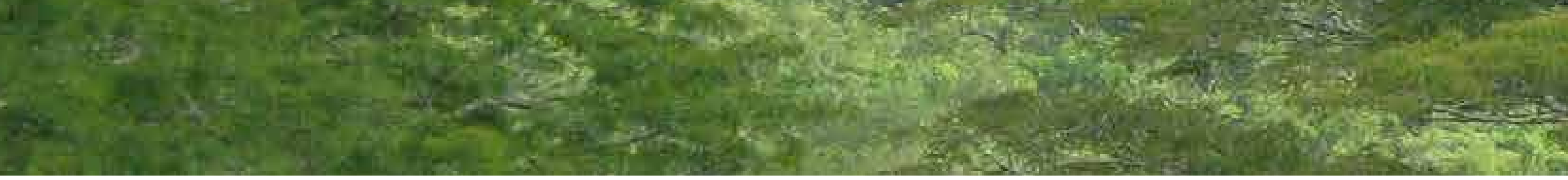
The costs and benefits of implementing REDD+ in Zambia will depend heavily on where implementation takes place and the strategies employed for reducing deforestation. For forest-based initiatives, given the spatial variation in supply and demand for ecosystem services, projects are likely to have different objectives in different areas. It is recommended that considerable focus be placed to address off-site interventions that affect the drivers of deforestation and to improve forest governance and regulatory approaches that seek to limit forest loss and degradation in areas of national importance, such as dam catchment areas, rather than on localized initatives.

Areas where REDD+ results-based payments could yield incomes high enough to cover opportunity costs plus transaction costs (which may vary from US$23 to US$94 per ha) are geographically limited to the north-western areas where this could be achieved through avoided deforestation. Interventions could, however, be more viable generally, and over a broader spectrum of the landscape, through public or private sector payments to secure public benefits of forest conservation. It should also be recognized that the potential carbon income that can be generated through REDD+ initiatives also helps to make public sector investment in forest conservation a more viable prospect.

However, **there are other ways to achieve successful REDD+ results-based actions, for example, by placing greater efforts to improve the agricultural productivity of and value derived from existing cultivated and degraded areas rather than formal expansion into virgin forest areas as is currently the case in Zambia. To this end, further research will need to be undertaken to explore the costs and benefits of alternative options and their spatial location, as well as how actions, policies and measures can best tackle the drivers of deforestation and forest degradation.** While the estimates produced in this study will enable a broad-scale analysis, it is recommended that further research be undertaken to improve understanding of the supply and demand aspects of forest services.

Acronyms and abbreviations

CIFOR	Centre for International Forestry Research
CSO	Central Statistical Office
DEM	Digital Elevation Model
FAO	Food and Agriculture Organization of the United Nations
FSP	Forest Support Project
GDP	Gross domestic product
GVA	Gross value added
GLCN	Global Land Cover Network
GRZ	Government of the Republic of Zambia
ILUA	Integrated Land Use Assessment
IPCC	Intergovernmental Panel on Climate Change
MODIS	Moderate Resolution Imaging Spectroradiometer
NWFPs	Non-wood forest products
NTFPs	Non-wood forest products
PFAP	Provincial Forest Action Plan
REDD	Reducing Emissions from Deforestation and Forest Degradation
REDD+	Reducing Emissions from Deforestation and Forest Degradation, Conservation, Enhancement of Carbon Stocks and Sustainable Management of Forests
SNDP	Sixth National Development Plan
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UN-REDD	United Nations Collaborative Initiative on Reducing Emissions from Deforestation and Forest Degradation in developing countries
USLE	Universal Soil Loss Equation
WTTC	World Travel and Tourism Council
ZESCO	Zambia Electricity Supply Corporation Limited
ZFD	Zambia Forestry Department
ZFAP	Zambia Forest Action Plan



01 Introduction

Zambia is a low-income country that is focused on achieving growth and development to reduce poverty and raise standards of living. As a developing country that is rich in natural resources, there is a danger of achieving short-term growth through 'mining' or overutilizing its remaining renewable resource stocks. This trend is evident in the rapid depletion of Zambia's indigenous forest resources. Zambia has the second highest per capita deforestation rate in Africa, and the fifth highest in the world (Aongola *et al.* 2009). Over the past few decades, Zambia's forest cover has undergone extremely rapid depletion, from 81% of land cover in the mid-1970s to possibly as low as 42% by 2003 (CSO 2013; FAO 2006). This has been fuelled mainly by the urban demand for charcoal and the rural demand for agricultural and natural resources, as well as by timber exploitation and mining. These trends are common among low-income countries, particularly in the tropics, resulting in global deforestation rates in the order of 13 million hectares (or 0.33% of global forest cover) per year (FAO 2012). However, continuing on such a path not only reduces options for future generations but could counter economic progress made, because of the important contribution that forests make to people's livelihoods as well as to several economic sectors.

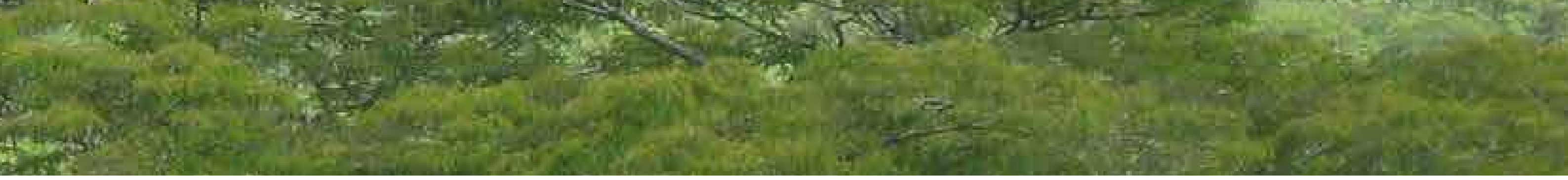
Based on increasing recognition of the important role of natural capital, there has been a shift in the global agenda from sustainable development to that of "green economy" development, defined by UNEP as *'an economy that results in improved human well-being and social equity, while significantly reducing environmental risks'* (UNEP 2011a). Key actions are aimed at preventing the loss of biodiversity and ecosystem services, as well as measures relating to energy efficiency, while recognizing human well-being and social equity as core goals (UNEP 2011a). Achieving policy shifts towards green economic development in low-income countries will require demonstrating the costs of depletion of natural capital, or conversely, the benefits of securing and even restoring natural capital, so that the trade-offs can be made under different development paths.

Zambia's natural capital comprises its forests, which dominate the landscape, its wetlands and rivers, and all the flora and fauna they contain. The value of these ecosystems and their biodiversity are partially, but not fully, appreciated. For example, while forest production is measured to some extent in terms of the size of the forestry sector, its contributions to other sectors and to human well-being is not accounted for. This study focuses on the value of forests, which provide a number of goods and services at the local and national scale as well as at a global scale. As well as timber production, the benefits of forests also include the provision of natural resources such as fuel, raw materials, food and medicine that contribute to the livelihoods and income of rural communities, the provision of services such as carbon storage, regulation of water flows, erosion control, sediment retention, water quality amelioration, pollination and disease regulation, as well as tourism, recreation and other cultural values. The loss and degradation of forests therefore results in a loss of some of these values, which have to be considered alongside the gains that will be made by the competing activities.

It is important to note that the capacity of forests to supply ecosystem services is likely to vary spatially based on variations in topography, rainfall, etc. Similarly, the demand for these services will also vary spatially, based on human population density and other factors. Therefore, the value of services, and hence the trade-offs involved in forest conservation, are also likely to vary spatially, which affects decisions about where to locate forest conservation programmes. Thus, our study has attempted to consider spatial factors in the assessment of forest ecosystem services as far as possible under the existing data constraints. Nevertheless, because of the limitations of available data, this study hopefully forms the precursor to a much more detailed and regular effort to account for the stocks and flows of forest ecosystems in both physical and monetary terms.

The capacity of forests to sequester and store carbon is of particular relevance to the global community in terms of mitigating the potential impacts of climate change. There is considerable potential to achieve this goal through reducing emissions from deforestation and forest degradation (REDD). In 2010 the initiative was expanded to include the role of conservation, sustainable management of forests, and enhancement of forest carbon stocks. This expanded approach is known as REDD+. REDD+ activities were formally adopted as a means of reducing emissions at the 16th meeting of the Conference of the Parties of the United Nations Framework Convention on Climate Change (UNFCCC). Since then, the UN-REDD Programme, which is an inter-agency collaboration between UNDP, FAO and UNEP, is supporting REDD+ in many developing countries. As of February 2015, the UN-REDD programme supports 58 partner countries across Africa, Asia-Pacific and Latin America, including national programmes in 21 partner countries. Zambia is one of the UN-REDD partner countries with a national programme.

The aim of this study, commissioned by UNEP as part of Zambia's REDD+ National Programme, was to undertake a rapid assessment of the value and role of forests in the Zambian economy based on available information, identify the importance of forests in the development of a green economy in Zambia and to inform policy decisions on forest management and the implementation of REDD+ activities in the country. It is envisioned that this study will provide the government with the rationale to elevate the importance of forests in national policy, as well as providing a step towards identification of high-priority areas for interventions through a national REDD+ strategy.



This study has collected, reviewed and synthesized available information relevant for understanding and deriving the values of Zambia's forests and their contribution to the national economy. The approaches used in this study include an extensive literature review of publications, in-country reports, and grey literature; the collection and synthesis of biophysical and economic data found within the country; and the integration of spatial data on forests within Geographic Information Systems (GIS) and ecosystem service models to support spatial analysis of ecosystem services values. Preliminary estimates of the values of forest-based ecosystem services were derived in two main ways:

- Extrapolation of data based on spatial parameters at the resolution allowed by the data (e.g. by vegetation type, biomass, population density or district), or

- Use of an existing spatial modelling platform, "InVEST", developed by the Natural Capital Project at Stanford University, USA, which, despite the relatively high level of spatial resolution involved, is not necessarily more accurate in the absence of locally relevant data.

This study makes significant contributions to the understanding of the value of forests to the national economy of Zambia. Specifically, this is one of the first studies to systematically assess the availability of data/information for a suite of forest ecosystem services and synthesize that information to derive values for each service at a national scale. In addition, for some services, such as forest-based tourism and sediment retention, very little information was available. This required collection of data from proxy sources for tourism and conducting ecosystem service modelling for sediment retention to spatially analyse the distribution of services for which little information was available prior to this study. It is important to note that a major challenge to this study has involved dealing with contradictory and wide-ranging estimates of some ecosystem services. Much effort has been put towards understanding the nature of these differences and deriving more reliable estimates where possible. To that extent the analysis could also function as a prelude to a national natural capital account using the System of Environmental-Economic Accounting – Experimental Ecosystem Accounting (SEEA – EEA) of the United Nations, published in 2013. The SEEA-EEA framework provides guidance how countries can start accounting for the (depreciation or appreciation) of forest carbon and other ecosystem services through a standardized statistical framework. This would enable countries to better account for the economic value of their country's natural capital in national accounts.

This report begins with a description of Zambia's environment, people and economy (Section 2), and the status and trends of its forest resources (Section 3). Following this, we present descriptions and preliminary estimates of a wide range of tangible benefits provided by forests (Section 4). Based on this, we discuss the degree to which GDP indicators fail to reflect the value of this natural capital and its contribution to a range of sectors (Section 5). Finally, we discuss the potential mechanisms, costs and benefits of investing in REDD+ as part of a strategy for a green economy transformation in Zambia (Section 6).

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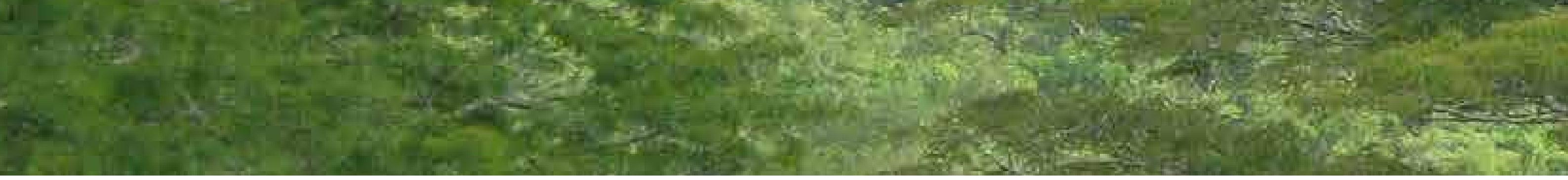


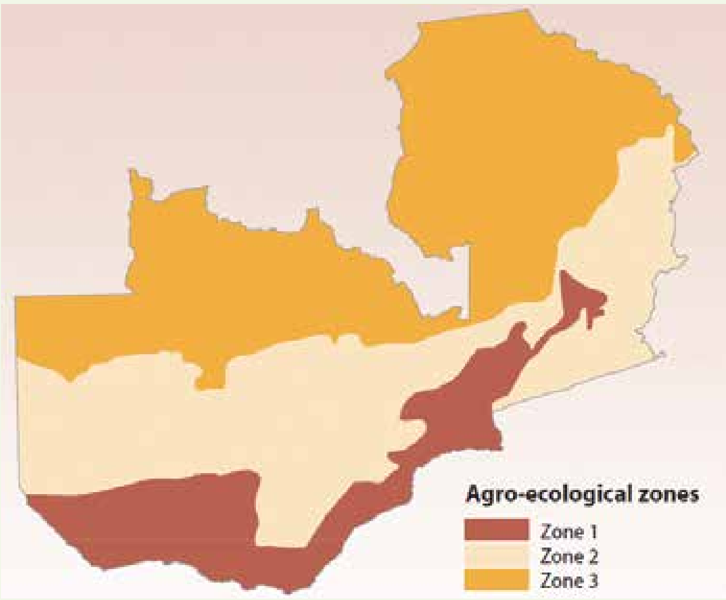
02

Environment, people and economy

2.1
Environmental profile

Zambia is a land-locked country situated on the great plateau of central Africa between 1,000 and 1,600 m above mean sea level, with an average altitude of 1,200 m and a relatively moderate climate. There are three seasons: rainfall occurs mainly between November and April, which is also the main growing season; the period from May to August tends to be cool and dry; and September and October are typically hot and dry (Thurlow *et al.* 2009). The country can be divided into three eco-climatic zones, or agroecological regions, with average annual temperature and rainfall varying mostly by elevation (Campbell *et al.* 2010; Figure 1). Average annual rainfall decreases from 1,000 mm in the north to 600 mm in the south, and the mean annual temperature ranges between 18°C and 20°C (Chapman and Walmsley 2005).

Miombo woodland is the main vegetation type in Zambia, originally covering about 47% of the country (Figure 2). Other dominant ecosystems are floodplain wetlands, Kalahari woodlands and *dambos*, in that order. The hot and dry southern valleys of the Luangwa and Zambezi rivers are dominated by Mopane and munga woodlands. Most of Zambia falls within the Zambezi River Basin, with the remainder falling within the Congo River Basin. The country is characterized by a dense river network, particularly towards the east, providing ample opportunities for the development of hydropower and irrigation, as well as extensive floodplain wetlands on the Chambeshi, Kafue and Zambezi rivers. By 2001, about 32% of the land surface had been altered for agriculture, forestry, mining and settlements (ECZ 2001). Much of the remaining natural capital base[4] has also been degraded by fragmentation, over-exploitation and pollution.



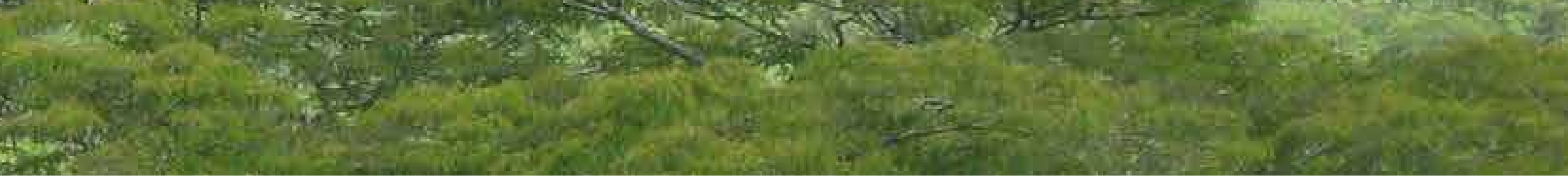
Zone 1 covers 23% of Zambia and includes the major valleys (Gwembe, Lunsemfwa and Luangwa). It has the lowest agricultural potential, with rainfall of less than 800 mm per annum, a short growing season of 80–120 days, and a medium-to-high risk of drought.

Zone 2 covers the Sandveld Plateau, the Kalahari Sand Plateau and the Zambezi floodplains of the Western Province. Rainfall is 800–1,000 mm per annum, and the growing season is 100–140 days. It has a medium-to-low risk of drought. Some 87% of the area is suitable for agriculture, but only half of this is accessible, as the remainder is in national parks, game management areas and forests.

Zone 3 has a mean annual rainfall of 1,000 mm and a growing season of 120–150 days. The risk of drought is almost nil. However, only 52.7% of the land is suitable for cultivation due to the soils being highly leached. Very little of this zone is in national parks, game management areas and forests.

Figure 1. Agroecological zones of Zambia. *Source: Mukosha and Siampale 2009.*

[4] In this report, natural capital refers to natural ecosystems and resource stocks, in whatever condition they are in, and does not include agriculture or plantation forestry.



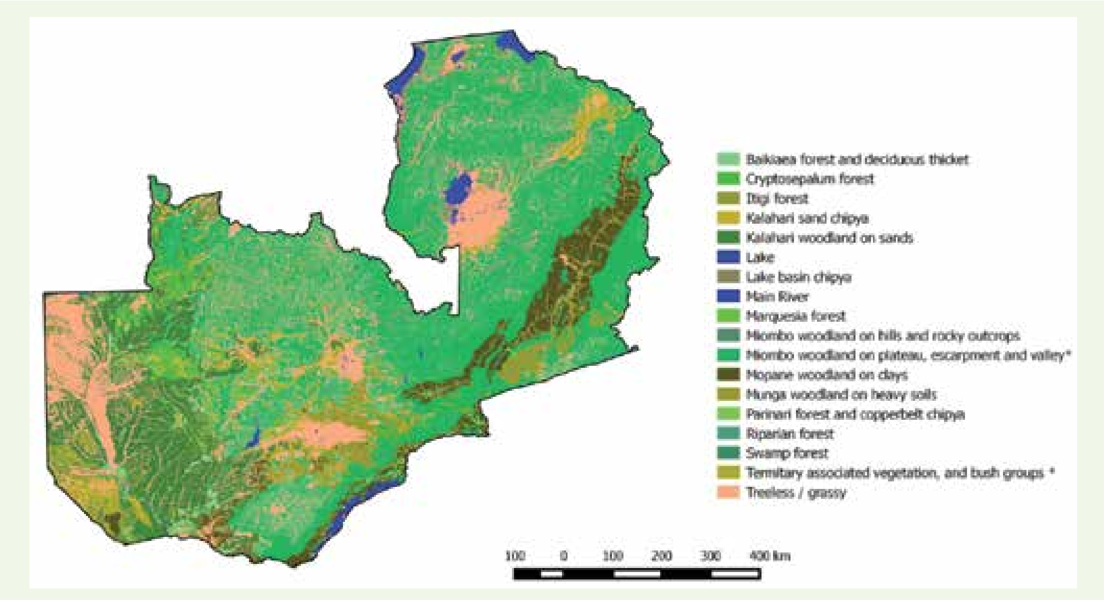


Figure 2. Spatial distribution of Zambia's vegetation types. *Source: Forestry Department, 2010.*

2.2 Population and livelihoods

Zambia's population has grown from 5.7 million in 1980 to just over 13 million people in 2010, of whom 7.9 million (60.5%) reside in rural areas (CSO Census 2012d). Most of the population is concentrated in the Luangwa-Zambezi River valley and surrounding plateau areas in the south-east of the country, and is highest in the cities of Lusaka, Kitwe and Ndola (CSO 2012a). The high rainfall zones and the semi-arid plains of the north-western and western parts of the country are comparatively sparsely populated, and the high rainfall area in the north has intermediate population densities (Figure 3).

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The rural population is largely dependent on subsistence agriculture and natural resources for its livelihood. In 2010, 43.1% of the labour force was in paid employment, 10.5% were unpaid family workers, and 8.1% were unemployed. Unemployment was highest in Copperbelt (24.5%) and Lusaka provinces (22.3%) and lowest in Eastern (4.1%) and Northern provinces (4.9%). Some 60.5% of households were below the poverty line, with rural poverty being much higher than urban poverty (77.9% vs 27.5%). Most (84%) of

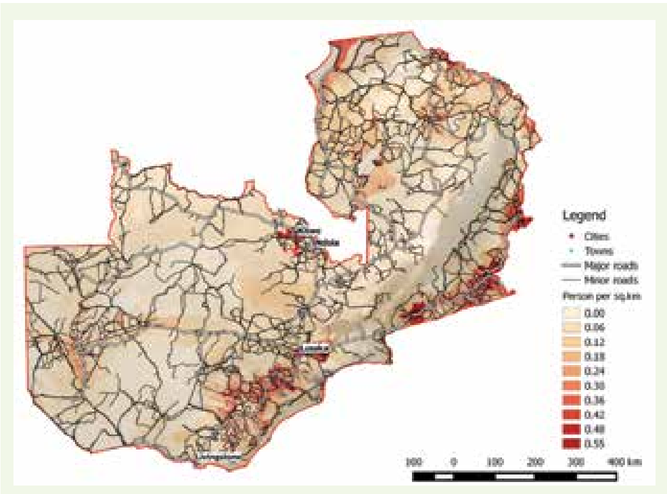


Figure 3. Population density of Zambia shown in relation to cities, towns and road infrastructure[5] .

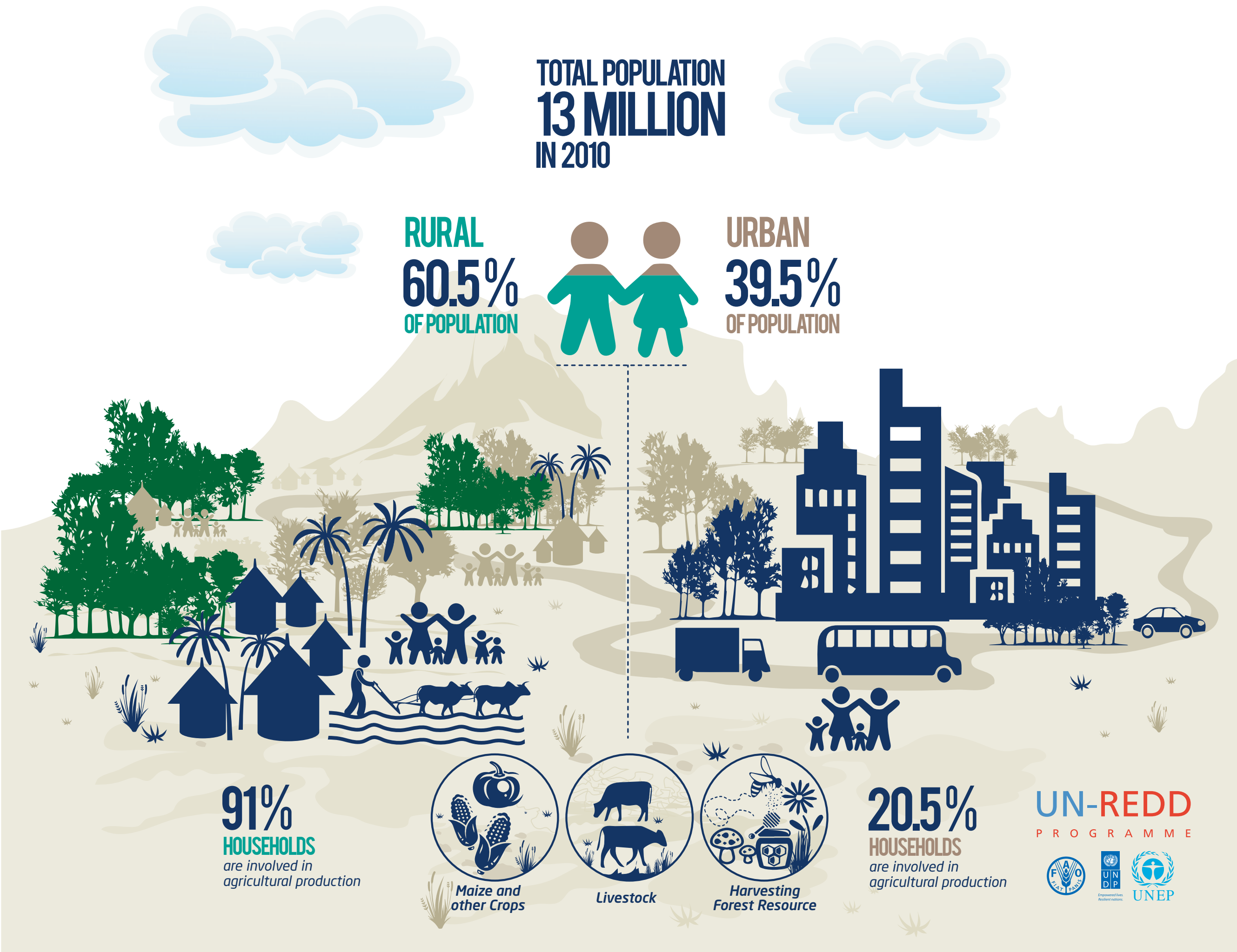
[5] Zambia was divided into nine provinces that were subdivided into 72 districts by the local government administration. Recently Muchinga Province was created to bring the total to 10 provinces and 74 districts. However, most available statistics are applicable to the former arrangement.

the rural population and 20% of the urban population live in traditional houses, though the proportion of the population living in modern houses has been increasing over time. About 62.3% of households have access to safe water sources. Firewood is the most common source of cooking energy in rural areas and most urban households use charcoal.

Crops, livestock production and harvesting of forest resources are the main economic activities throughout most of rural Zambia (ILUA; Mukosha and Siampale 2009), though tourism plays an increasingly important role. Outside urban areas, the greatest population densities roughly correspond to the regions outside protected areas that are most suitable for cultivation. In 2010, the agriculture, forestry and fisheries sector accounted for 66.7% of employment, a reduction from 71% in 2006 (CSO 2012d). Nearly all (91%) rural and 20.5% of urban households were involved in agricultural production, comprising an estimated total of over 1.6 million households. The main agricultural crop is maize, with 2 million tonnes produced in 2010. Some 588,000 households owned a total of 2.6 million cattle as well as other livestock (CSO 2012d).

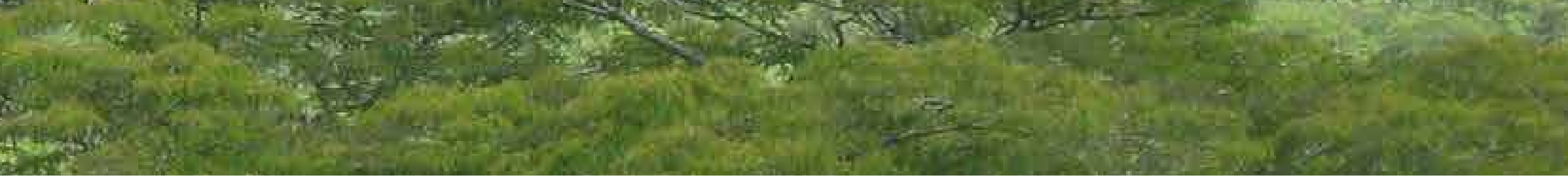
2.3 Economy

After its independence in 1964, Zambia possessed a rich endowment of arable land, water and mineral resources and was one of the most prosperous nations in Africa with good prospects for sustainable development[6]. While it had very poor infrastructure and human capital, a booming copper



Population and livelihoods in Zambia

[6] The Civil Society for Poverty Reduction (CSPR) undated. Poverty reduction strategy paper for Zambia. Unpublished report. http://www.sarpn.org/ CountryPovertyPapers



industry became the country's economic mainstay, and encouraged state-controlled policies. However, in the first 10 years after independence, the economic growth of 2.4% a year was lower than that of its population, leading to declining per capita incomes. After 1975, falling copper prices and the global oil crisis had a severe impact on the economy. The government fell into heavy debt, the economy declined, and poverty rose through the 1980s. In the early 1990s, government policies became more liberal, and aimed at developing a more efficient private sector-led economy. However, by the end of the 1990s, Zambia was one of the poorest nations in the world (Kelly 1999). The prevalence of HIV and AIDS (14% in 2007) has exacerbated the vulnerability of Zambia's poor. Malaria remains the most common cause of death in Zambia (CSO 2012d).

In recent years, however, Zambia's economy has seen significant recovery. GDP growth has averaged 6.4% for the period between 2006 and 2010, and per capita income has grown by an average of 4% over the same period (Figure 4). Inflation has declined from 35.2% at the end of 1996 to 7.9% at the end of 2010 (CSO 2012d). The country's per capita gross national income reached US$970 in 2009, only slightly below the lower middle-income threshold of US$995 (SNDP – GRZ 2011).

Mining, tourism, agriculture and forestry are considered to be the mainstay of Zambia's economy and contributed most economic growth in recent years (Chapman and Walmsley 2005). The agricultural sector, including forestry, accounted for 22% of GDP in 2006, and the wholesale, retail, hotel and restaurant sector, which includes tourism, had the second highest contribution, while mining contributed 5% of GDP. This picture has changed considerably since then (Figure 5). Zambia's GDP in 2010 was Zambian kwacha (ZMK)97 215.9 billion[8], or about US$20,266 million (CSO 2014). While the wholesale and retail trade sector still contributes most to GDP, the agricultural sector was estimated to account for 9.9% of GDP, after mining (12.9%) and construction (10.9%). Nearly two thirds (64.5%) of the agricultural sector contribution and 84.6% of the construction sector contribution is from the informal sector[9] (CSO 2014).

Zambia's economy is heavily dependent on the copper mining industry, with copper exports accounting for over 70% of export earnings (CSO 2012d). While Zambia has diversified its economy from copper dependence to other sectors, especially agriculture, in recent years, the mining sector has experienced rapid growth of about 9% per annum in the last decade, and prospects for further development are high. The mining sector is expected to continue to be a major driver of growth, with spill-over effects in other industries.

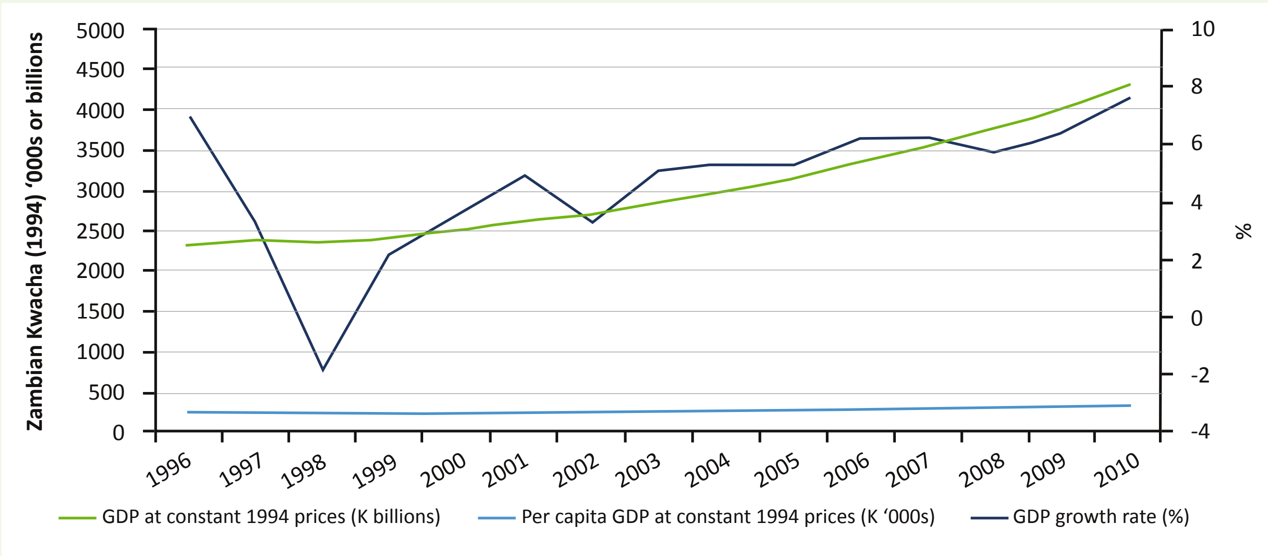


Figure 4. Changes in GDP and GDP per capita from 1996 to 2010, in constant 1994 prices[7]. *Source: CSO 2012d.*

[7] Zambia has in fact recently undertaken surveys to update its national accounts using a 2010 benchmark, but reprojected time series data were not yet available.

[8] It is actually reported as million, not billion, but this seems to be erroneous.

[9] The informal sector production is defined as those productive activities conducted by unincorporated enterprises in the household sector that are unregistered and/or are less than a specified size in terms of employment, and that have some production for market or for own final use.

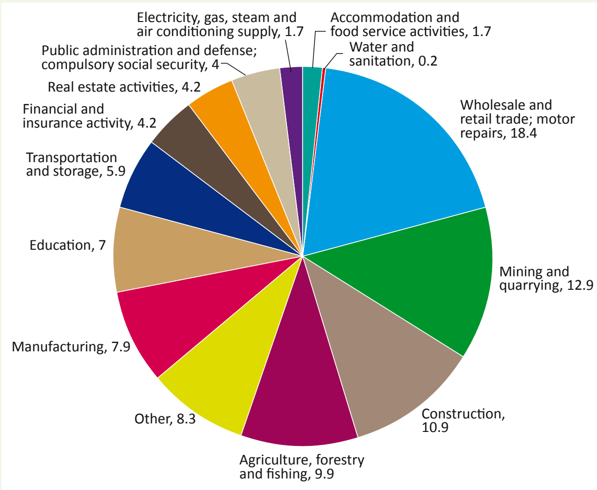


Figure 5. Sectoral contribution to gross domestic product in 2010. *Source: CSO 2014.*

2.4 The forestry sector

Zambia's forestry sector is based on both indigenous and plantation forestry, and includes production of industrial roundwood, wood fuel and charcoal, sawn wood and wood-based panels, pulp and paper, wooden furniture, commercial production and processing of non-wood forest products and subsistence use of forest products. Indigenous forest resources account for the bulk of production in the sector. These resources are harvested under commercial concessions or casual licences from customary land and state-owned forest reserves, and to a small extent from privately owned land. This generates general government revenues in the form of fees for the production and conveyance of timber, charcoal and other forest produce. In addition to indigenous forest resources, the Zambia Forestry and Forest Industries Corporation manages exotic plantations of about 48,000 ha, comprising 38,500 ha of pine and 9,500 ha of eucalyptus (Ng'andwe *et al.* 2006). The sale of plantation produce generates revolving fund revenue for the Forestry Department (ZFD annual reports). The forestry department reports very low incomes, however. Much of the potential income may be being diverted away from government coffers through private taxation of charcoal traders by officials, as is the case in Malawi (Kambewa *et al.* 2007, in Gumbo *et al.* 2013). There is also control over exports, with the export of charcoal and unprocessed roundwood being banned (GRZ 1996). Thus charcoal and roundwood do not contribute to tax revenues, even though many consignments are reportedly smuggled out of Zambia. Only records of the legal timber exports exist (Gumbo *et al.* 2013).

Zambia's national accounts reflect a steady real growth in the forestry sector from 1994 to 2009, which suggests that forestry has contributed to about a third (34%) of agricultural GDP on average over that period, rising to about 37%–38% during the last few years (Figure 6). This suggests that forestry contributed to about 8% of GDP from 2006 to 2009. However, it is important to realize that these figures may not reflect the actual situation very accurately. In compiling the national accounts for the agricultural sector, five subsectors are taken into account – crops, livestock, forestry, fishing and hunting. Food and cash crop production is estimated from the crop forecasting and post-harvest surveys, and prices are estimated based on the 1994 survey using the Consumer Price Index (CPI) for agriculture. Livestock numbers and hunting data are extrapolated from the 1994 survey data and are included with agriculture. Fishery data are based on landings recorded by the Department of Fisheries. According to the International Monetary Fund[10], forestry data are very poor, with estimates derived indirectly by using the output from a sample of enterprises in the manufacture of forestry products. This can be seen from the existing estimates, which reflect an assumed constant growth rate in forestry (Kalinda *et al.* 2008 reported Zambia's Central Statistical Office (CSO) statistics showing a constant growth of 4.3% per year for 2001–2005), and very little change in fisheries after 2000. Only agriculture appears to have been more closely monitored. The CSO has recently finalized the benchmarking of the national accounts statistics to 2010. These data suggest that the forestry sector now comprises 0.8% of GDP.

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[10] http://dsbb.imf.org

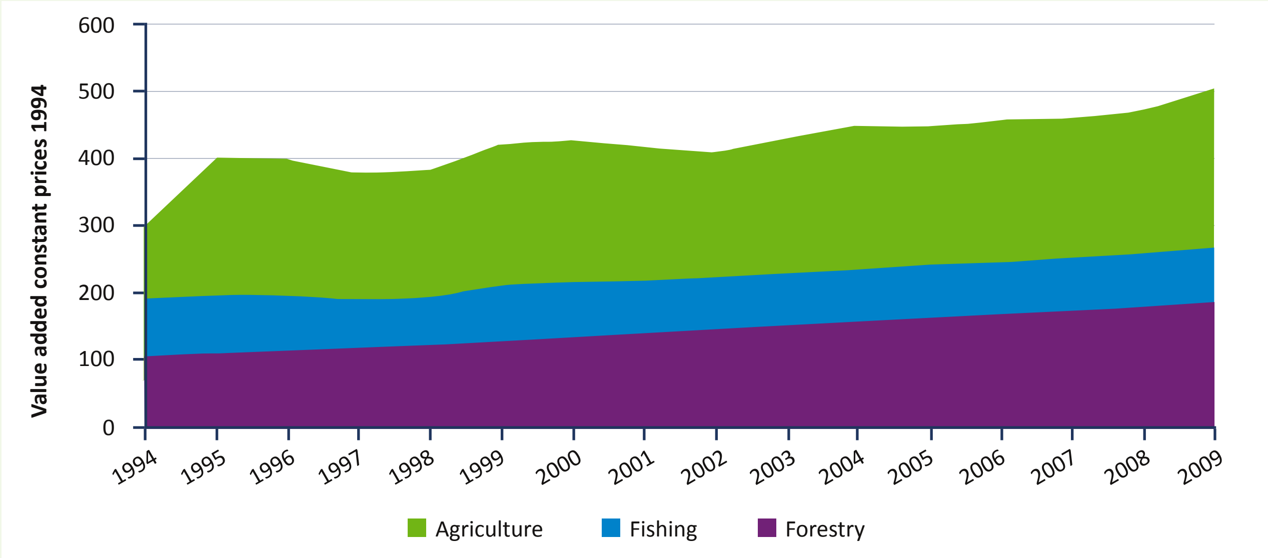
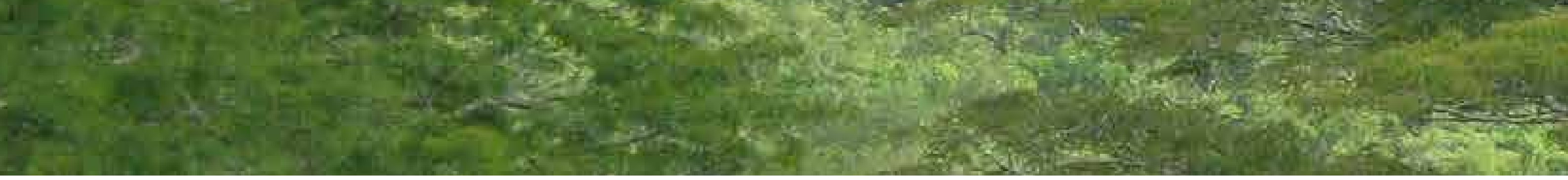


Figure 6. Change in value added by the agricultural subsectors from 1994 to 2009. *Source: CountryStat.*

2.5 Zambia's development path

Zambia's development agenda has been set out in the Sixth National Development Plan (SNDP) (2011–2015). It aims to become a middle income country by 2030 (Vision 2030), mainly through private sector-led broad-based economic growth. It has thus embarked on the Private Sector Development Programme to attract domestic and foreign investment in various sectors. This is to be facilitated by macro-economic and social policies aimed at pro-poor economic growth, low inflation, stable exchange rates and financial stability (CSO 2012d). The SNDP recognizes that Zambia's natural resources could provide an impetus to the development of agriculture, tourism, manufacturing, mining and energy sectors. While mining will continue to be promoted, it also recognizes the need to aggressively diversify the economy to other sectors in order to cushion against the negative effects of external shocks. In all these areas, the government will promote private sector investment and public-private partnerships. Tourism development will focus on improving infrastructure, particularly in the Greater Livingstone area, Kafue National Park and the Northern Circuit, and improving service delivery. Finally, both the Poverty Reduction Strategy Plan and the SNDP emphasize agriculture as an area of great potential for expanding employment and income-generating opportunities in rural areas, and plans include setting aside land for the cultivation of biofuels, cotton and food crops. However, there are concerns that this development path will place increased pressure on remaining forest lands (Gumbo *et al.* 2013).



03

Patterns and drivers of forest loss

Understanding the rates and patterns of deforestation is important for understanding the potential future losses in ecosystem services and identifying places where investment in conservation will be most important. Understanding the drivers of deforestation and forest degradation is important for determining the types of actions required to achieve conservation in priority areas.

3.1 Changes in forest cover and biomass

Forests originally covered over 60 million ha (81%) of the Zambia's total land area of 75.3 million ha. However, indications are that the rate of deforestation has increased markedly in recent years, resulting in significant reduction in forest cover. There are several historical data sets on forest cover in Zambia, which give some indication of trends over time (Figure 7). However, the various inventories have been largely independent of one another, with the result that they have lacked methodological consistency and are therefore not directly comparable (Kamelarczyk 2009). Thus the data have been variously interpreted, with estimates of remaining forest extent ranging from 39 million ha (CSO 2013) to 50 million ha (Kalinda *et al.* 2008) or 53 million ha (ZFD 2000 – spatial data), and estimates of deforestation rates ranging from 250,000 ha per year (ILUA study) to 444,800 ha (FAO, 2005) and even over 850,000 ha per year (FAO 2001, in Jumbe *et al.* 2008; GRZ 2006a). A critical analysis of existing data suggested that the average rate of loss in forest cover from 1969 to 2006 has been about **298,000 ha per year** (Kamelarczyk 2009).

The extent and spatial distribution of forest loss is shown in Figure 8. Most forest loss has taken place in the southern and south-eastern parts of the country, which also correspond to areas of high population density (Figure 3) and high agricultural potential (Figure 1).

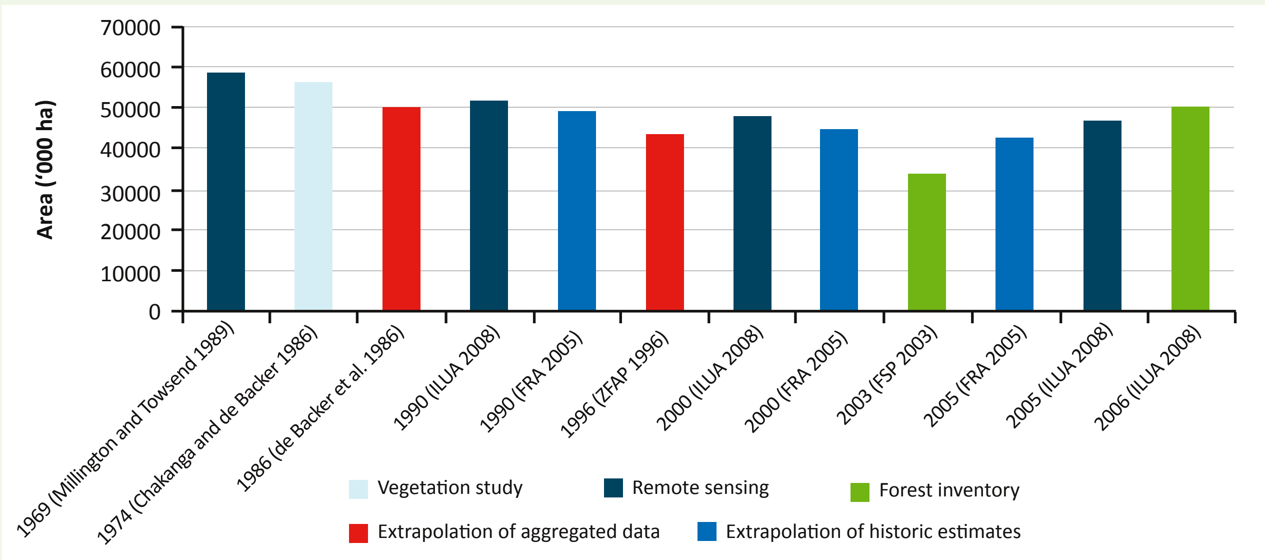


Figure 7. Past studies quantifying forest extent in Zambia and the associated estimates. The methods applied are indicated with colours. The name of the study is provided in parentheses. *Source: Kamelarczyk 2009.*

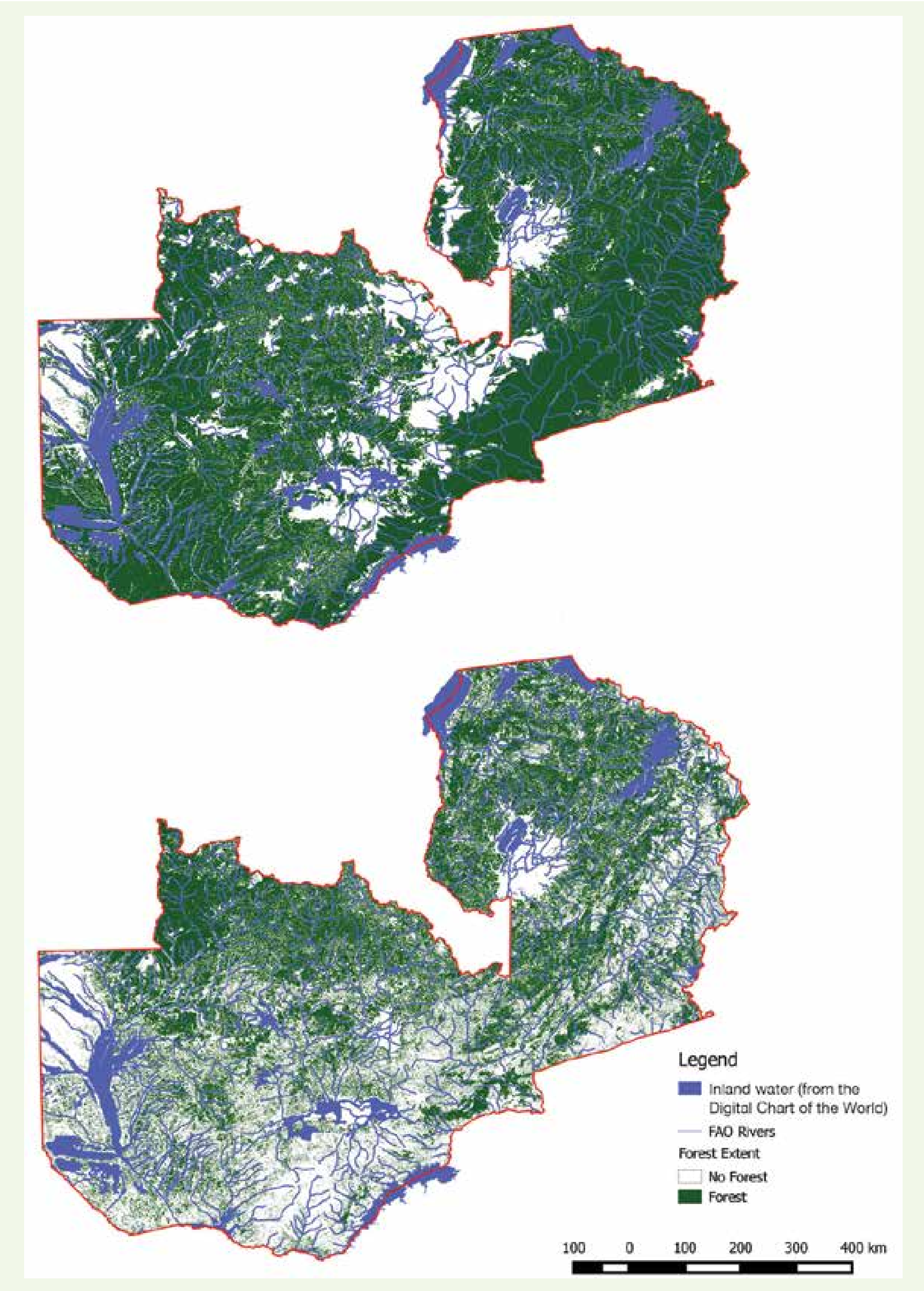


Figure 8. Estimates of forest cover by the Zambian Forest Department (above) and the Global Land Cover Data (below).

It is important to realize that these estimates of forest cover reflect deforestation, e.g. due to agricultural expansion and human settlements, but do not reflect degradation, e.g. due to logging and removal of fuel wood, which affects the overall biomass of remaining forest areas. While there are no consistent studies allowing for accurate comparison, evidence suggests that significant degradation has taken place within the remaining forest area (ZFAP 1997[11]; Kalinda *et al.* 2008). According to Gumbo *et al.* (2013), Baikiaea resources in Sesheke district of Western Province have been severely depleted by a long history of harvesting. There have also been concerns over the stocks of Pterocarpus angolensis, to the extent that the forestry department temporarily banned its export in 2005.

3.2

Drivers of forest degradation and loss

Most of Zambia's forest area (63%) is on customary lands, 24% is on state land, and the remainder is on privately owned land (Mukosha and Siampale 2009). State-owned land includes the national parks and game management areas, both managed by the Zambia Wildlife Authority (Figure 9). There is no licensed extraction of living resources in national parks. Game management areas serve as buffer zones around the national parks, though they are inhabited and a range of activities is permitted within them, including timber extraction, mining and small-scale farming (Richardson *et al.* 2012). Just under 7.7 million ha of forests are in 178 national and 307 local forest reserves managed by the Forestry Department (ZFD 2012; Figure 9).

The national forests, some of which fall within game management areas, are protected forests that are intended to secure forest resources, ecosystem and biodiversity conservation and catchment protection. These form part of the state-owned land and exclude residents and cultivation, but entry and use of forest resources is permitted under licence. Local forest reserves are on customary land and have a similar purpose but with focus on benefiting local communities. Licences are also required for activities, which can include agriculture and the removal of forest products. Some of the forest reserves have been encroached upon by expanding settlements and agriculture and/or have been over-exploited to the extent that they have been de-gazetted (Campbell *et al.* 2010).

Forestry is regulated by the Forest Act No. 39 of 1973, which maintains centralized management, with provincial and district forestry offices[12]. However, forest management has declined significantly over time, and has effectively been non-existent since 1990 (Chidumayo 2001). Indeed, the current situation is that local forestry offices are very short of money and staff are largely office-based and rarely get to visit the concession areas (Leventon *et al.* 2014). This has

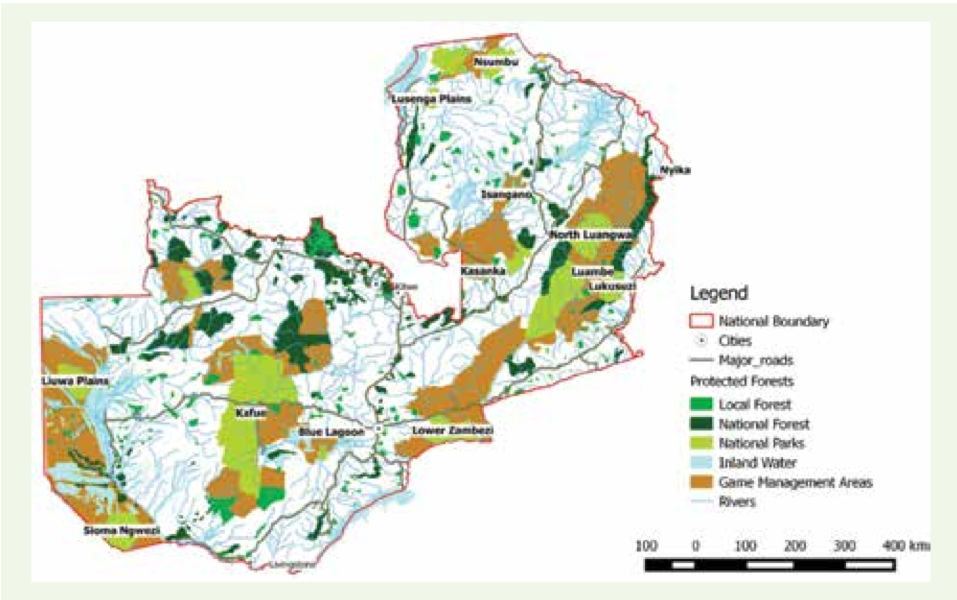


Figure 9. Protected areas, game management areas and forest reserves in Zambia. *Source: GRZ.*

[11] Zambia prepared the Zambia Forestry Action Plan (ZFAP) in 1997. The main components concerns: 1) identification of key issues affecting conservation and sustainable use of forest resources (wood based and non-wood products); 2) Developing short and medium term National Action Programmes; 3) Increasing public awareness on conservation and wise use of forest resources

[12] Although a new Forest Policy was formulated in 1998 which makes provision for decentralized forest management, this has never been enacted.

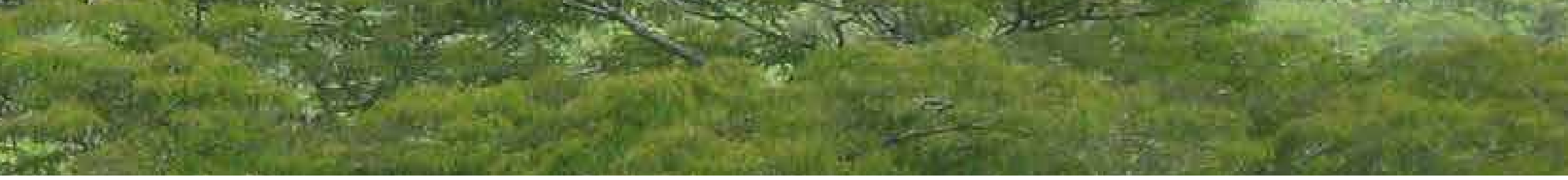


Photo credit: © Benjamin Warr

led to conditions of de facto open access for an estimated 78% of the total forested land in the country, allowing widespread encroachment into forest reserves and conversion of forestland into agriculture (Chidumayo and Aongola 1998; Chidumayo *et al.* 2001; Bwalya 2011).

The loss and degradation of Zambia's forests is attributed mainly to charcoal production, expansion of agricultural land and settlements and the over-exploitation of timber resources. Mining and forest fires also play a role. Smallholder farming is an important source of employment and income for rural Zambians and the pressure to increase the area of the land under agriculture is mounting as population (and demand for food) grows (Vinya *et al.* 2011; Figure 10). In addition, unsustainable farming practices often lead to land degradation and field abandonment, forcing farmers to cut down new areas of forest for farming. Shifting cultivation remains a dominant form of agriculture across the country. In particular, the chitemene system practiced in Northern, Luapula and Central provinces, is a major cause of deforestation (Holden 1993). This continues to be the dominant farming method for households that cannot afford chemical fertilizers (Bwalya 2011). It is sometimes hard to determine the extent to which agriculture versus charcoal production is the main driver of deforestation. The land cleared for agriculture may first be used for charcoal production, as an additional source of income to the farmer. Alternatively, areas burnt for charcoal might then preferentially be used for agricultural expansion, as there is less labour input in clearing the land.

Charcoal is one of the main sources of cooking energy in Zambia, even more so in urban areas where households cannot collect their own firewood from surrounding areas. Charcoal may account for up to 70% of energy used by Zambians as access to electricity is limited and expensive (Kalinda *et al.* 2008). Charcoal production is therefore driven by a very large urban demand. In addition to the vast quantities of charcoal produced for domestic use, considerable amounts are being transported to neighbouring countries via legal as well as illegal channels (Gumbo *et al.* 2013). Although charcoal could be produced sustainably, as was demonstrated through the Forestry Department's coupe system prior to the late 1990s, the current situation is one of severe over-exploitation. Over 80% of the charcoal produced for sale in the country is unlicensed (Bwalya 2011). There is little control over the production process. In rural areas, villagers have expressed fear of the charcoal producers who operate in their areas (Leventon *et al.* 2014).

Household collection of firewood is thought to have a negligible impact of deforestation, as dead biomass is generally collected and only rarely are live trees cut down for drying (Kalinda *et al.* 2008). However, in some areas, the commercial sale of firewood has become viable, leading to much higher rates of extraction.

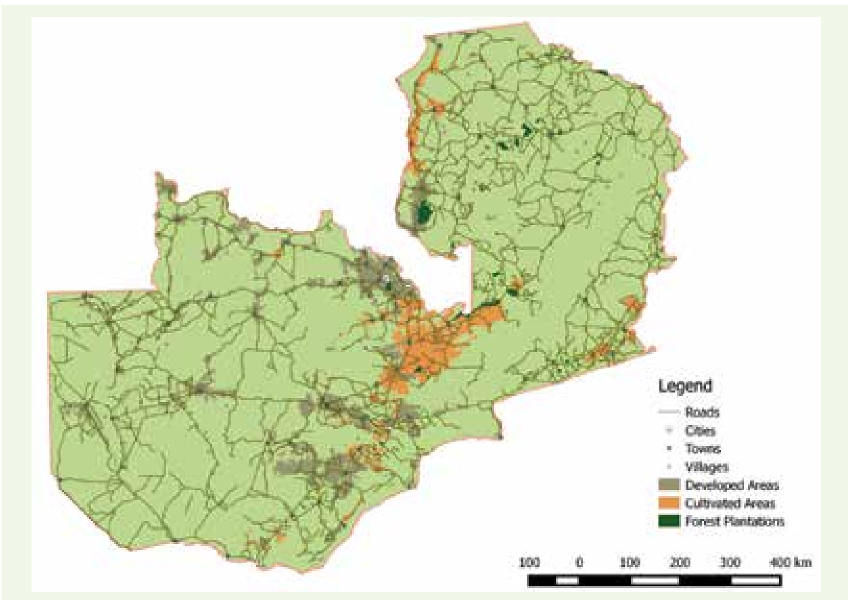


Figure 10. Areas under cultivation, plantation and other development. *Source: Forestry Department.*

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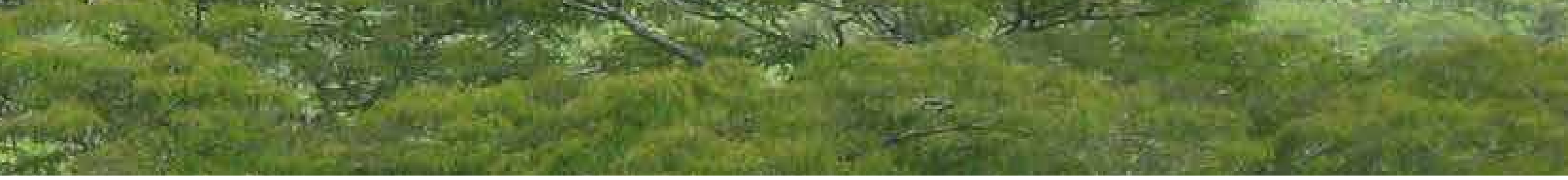
While some argue that current levels of timber extraction are sustainable (Puustjärvi *et al.* 2005), others claim that logging is a major cause of deforestation (Gumbo *et al.* 2013). Like charcoal, if properly managed, logging can be sustainable. However, over-exploitation can be particularly detrimental to targeted species such as Zambian/Zambezi teak (*Baikiaea plurijuga*) (Gumbo *et al.* 2013). The licence application process is lengthy and expensive and, as a result, many pit sawyers and merchants operate illegally (Gumbo *et al.* 2013). Illegal transportation and concealment of roundwood across borders is also known to occur, further bypassing regulation. As a result of uncontrolled logging, timber stocks have reportedly been diminished in many districts (Gumbo *et al.* 2013). The drivers of timber over-exploitation are likely to be internal to Zambia. Globally, timber prices have remained relatively constant in real terms over the last 30 years, and can be expected to continue to do so (Chiabai *et al.* 2011). The influence of mining is also contentious. Some argue that mining has little direct impact, but others argue that the indirect impacts of mining are very significant.

There are many underlying factors that are causing increases in charcoal production, expansion of agricultural land and the over exploitation of timber resources. Extreme poverty adds strain on Zambia's natural forest resources. With few income alternatives, illegal charcoal or timber production becomes more attractive to individuals. Poverty also limits the extent to which households can choose more sustainable alternatives to wood fuel (Vinya *et al.* 2011) and make long-term decisions about land management. Population growth and internal movements of people within Zambia has increased the pressure on previously uninhabited areas of forests both on communal and state land.

Although relevant policies on sustainable use of natural resources do exist within Zambia, the institutional capacity to implement and enforce these polices is lacking (Vinya *et al.* 2013). Minimal support and inadequate resources plague most government departments, rendering them incapable of enforcing policies. Encroachment of people and the establishment of new settlements on state-owned land have led to deforestation within forest reserves and subsequent de-gazetting (Kalinda *et al.* 2008). In addition, unrealistically high fees and difficulty in obtaining licences for charcoal and timber production encourage bribe paying and illegal activities which further promote uncontrolled forest degradation (Gumbo *et al.* 2013). Finally, the current land tenure system in Zambia is thought to contribute highly to the over-exploitation of forest resources (Chishimba *et al.* 2013, Kalinda *et al.* 2008, Vinya *et al.* 2011). Without secure land tenure, there is little incentive for land users to invest in long-term sustainability of forest resources and short-term gains are instead maximized through overutilization.



04 The nature and current value of forest ecosystem services

4.1 Ecosystem services, values and valuation

Forests, like other ecosystems, provide a range of "goods" and "services" and have "attributes" that generate value and contribute to human welfare (Barbier 1994, 2011; Table 1; see Krieger 2001 for a global review on forest ecosystem services). The concept of ecosystem goods and services stems from the perception of ecosystems as natural capital, which contributes to economic production. Goods include harvested resources, such as fish; services are processes that contribute to economic production or save costs, such as water purification; and attributes relate to the structure and organization of biodiversity, such as beauty, rarity or diversity, and generate less tangible values such as spiritual, educational, cultural and recreational value. Goods, services and attributes are often referred to collectively as "ecosystem services", or "ecosystem goods and services". More recently, the Millennium Ecosystem Assessment (2003) defined ecosystem services as "the benefits people obtain from ecosystems" and categorized the services obtained from ecosystems into "provisioning services", such as food and water, "regulating services", such as flood and disease control, "cultural services", such as spiritual, recreational, and cultural benefits, and "supporting services", such as nutrient cycling, which maintain conditions for life on Earth. The first three align well with the definitions of goods, services and attributes described above. Supporting services, although necessary for the generation of final goods and services, are usually ignored in valuation studies to avoid double counting.

The values produced by ecosystem services are also categorized into different types. The Total Economic Value of an ecosystem comprises direct use, indirect, option and non-use values. Direct use values may be generated through the consumptive or non-consumptive use of resources. This includes both consumptive (e.g. resource harvesting) and non-consumptive (e.g. bird watching) activities, whether for income, subsistence or recreation. Indirect use values are values generated by outputs from the ecosystems in question that form inputs into production in other areas, or that contribute to net economic outputs in the economy by saving on costs. These outputs are derived from ecosystem functioning, such as water purification and flood attenuation. Non-use values include the value of having the option to use the resources (e.g. genetic) of ecosystems in the fu-

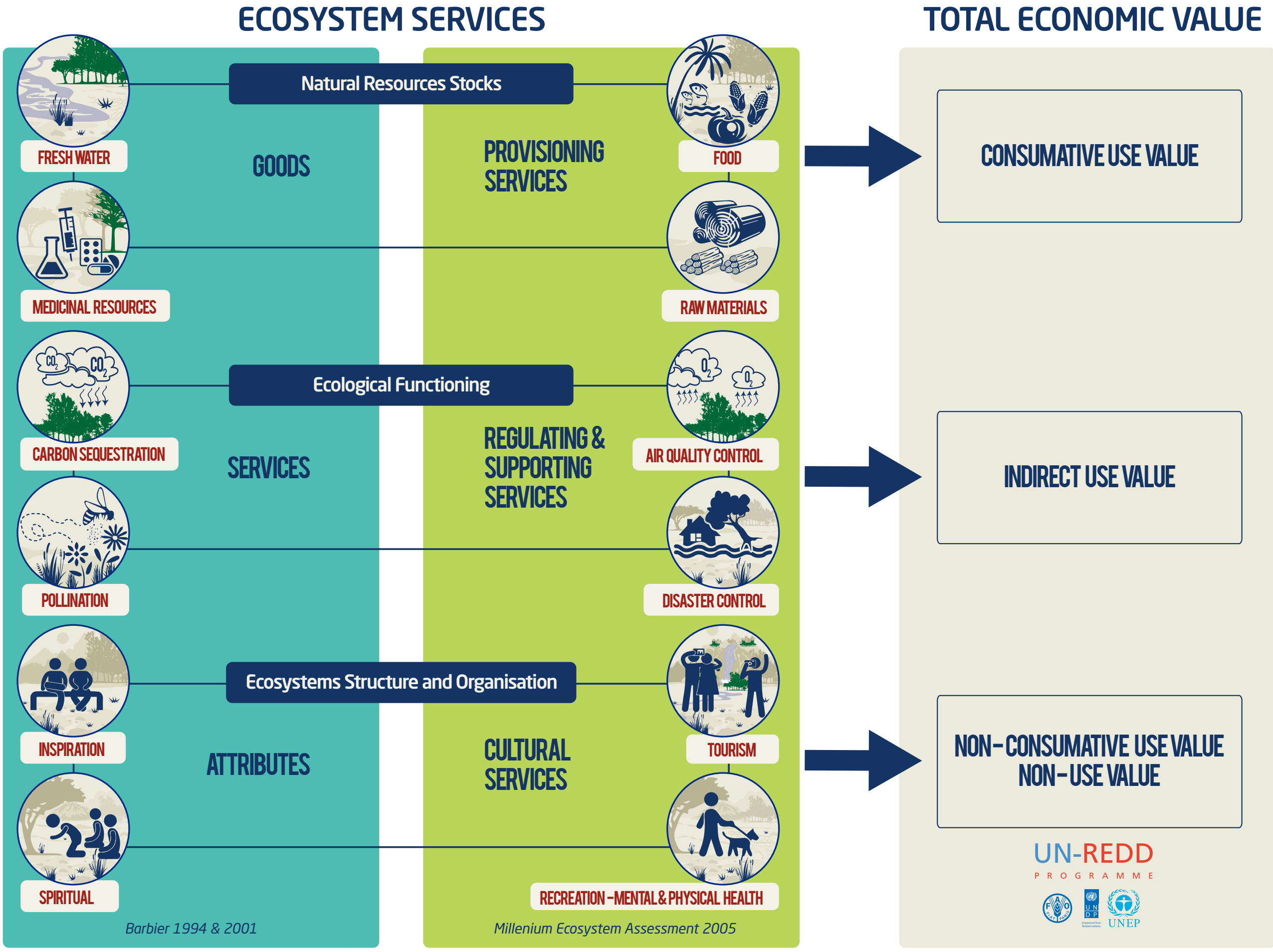
Table 1. The main ecosystem services generated by forests.

Ecological characteristics	Economic characteristics	Services
Stocks of resources	Goods	• Grazing • Fuel wood • Woody raw materials (timber, poles, etc.) • Non-woody raw materials (thatching grass) • Food and medicinal plants • Animals and birds (hunting)
Ecological functions and processes	Services	• Carbon sequestration and storage • Regulation of hydrological flows (infiltration, flood attenuation) • Amelioration of water quality • Erosion control and sediment trapping • Habitat for organisms useful in pollinating and controlling pests of croplands • Refugia/critical habitat for organisms used consumptively or non-consumptively beyond forest areas
Ecosystem characteristics and biodiversity composition	Attributes (aesthetic qualities, biodiversity, rarity, physical features)	• Spiritual and recreational values that manifest in property values and tourism as well as intangible values • Cultural values • Scientific and educational values

ture (option value), and the value of knowing that their biodiversity is protected (existence value). Although far less tangible than the above values, non-use values are reflected in society's willingness to pay to conserve these resources, sometimes expressed in the form of donations. The relationships between the concepts of ecosystem services and values are shown in Table 2.

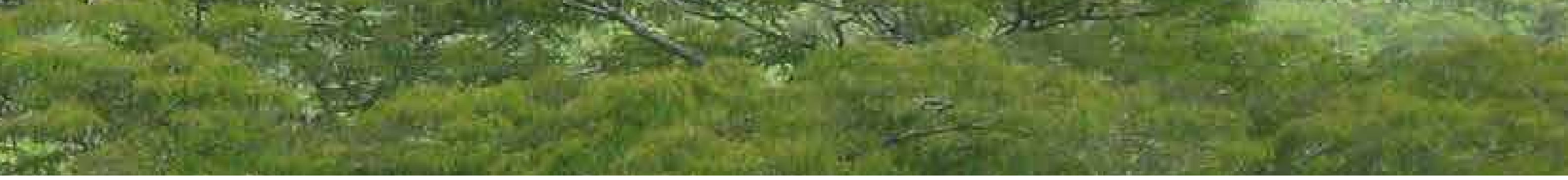
It is important to note that estimation of the aggregate value of ecosystem services at a large geographic scale (exemplified at a global scale by Costanza *et al.* 1997, 2014) is a contentious issue. Apart from the inaccuracy involved, there is little advantage in doing this unless there is a threat to eliminate or alter the system in its entirety, which is seldom the case (Markandya *et al.* 2008; Chiabai *et al.* 2011).

Table 2. Broad relationships between the concepts of ecosystem services and values.



Where there are markets for the services provided by forest ecosystems, the traded market good or service provides a basis for valuing them. There are market values for forest-based services such as timber, wood fuel and charcoal and carbon sequestration/storage. Where markets prices are not available, estimates have to be obtained indirectly. This can be done by looking at related markets. For example, land which is more fertile will trade at a higher price. This price differential reflects the value of soil fertility. Alternatively, unpriced services can be valued by estimating how much it would cost to replace them, or the damages that might be incurred if they were removed. Depending on the purpose of the study, values can also be expressed in different ways. In this study, value was estimated in terms of (i) net private value (ii) gross output value, (ii) direct value added to GDP and (iv) total value added to GDP (see Box 1).

For similar reasons, it is important to understand the geographic variation in supply and demand for ecosystem services, since policies may be more efficient if directed spatially (Bateman *et al.* 2013). The science of describing and valuing ecosystem services has improved considerably by taking spatial variability into account, which has been made possible by the rapid development of satellite data and geographic information systems over the last two decades. It is increasingly appreciated that both the capacity to deliver ecosystem services and the demand for the services that lends them value are governed by spatial factors. These include spatial variation in geophysical parameters as well as in socioeconomic variables, such as population, income and infrastructure.



Box 1.Value measures used in this study.

Net private value is the net financial value (= profit) measured as cash plus in-kind benefits to specified economic players (e.g. households, communities, entrepreneurs or firms). The difference between total annual revenues (also termed gross private values) and their annual expenditures is their net profit or net private value. Private values are measured using simple financial or in-kind transactions. The contribution to local communities, or "**local livelihood value**" was defined as their share of the net private value plus income derived from wages and salaries, rentals and royalties.

Gross output value is the total traded value of goods or services, which are equal to the quantity traded multiplied by the average price.

Value added to national income or GDP comprises **direct value added** and **indirect value added***. Direct value added is the income generated to business owners and employees in the first round of trade after expenditure on intermediate inputs. This is therefore lower than the gross output value. The expenditure on inputs from other sectors then generates another round of income, and so on. These "backward linkages" create a multiplier effect, so that the overall impact is larger than the direct value added alone. The magnitude of these multiplier effects is calculated in input-output models such as social accounting matrices. In this study, ratios and multipliers were based on the literature.

*Note that the terms "direct" and "indirect" in this regard bear no relationship to the terms direct and indirect use values of forests.

Very little has been done to estimate the value of the ecosystem services provided by Zambia's forests (Sileshi *et al.* 2007). In this rapid assessment (roughly three person-months), we have relied entirely on available data as well as understanding generated in the global literature on ecosystem services to formulate our assumptions. It must be made clear that data on Zambia, where they exist, are often uncollated, patchy or of questionable reliability. In some cases this has required careful review of existing data/reports to resolve contradictory and wide-ranging estimates. Our estimates are therefore preliminary, and have been derived in two main ways (described in more detail in the following sections):

- Extrapolation of data based on spatial parameters at the resolution allowed by the data (e.g. by vegetation type, biomass, population density or district), or
- Use of an existing spatial modelling platform, "InVEST", developed by the Natural Capital Project at Stanford University, USA, which, despite the relatively high level of spatial resolution involved, is not necessarily more accurate in the absence of locally relevant data.

More details on the forest ecosystem services valued and methods used to reach these estimates are given in Table 3. Spatial data used in the study are described in Appendix 1.

4.2 Provision of wood products

Key points

- Existing estimates of industrial roundwood and wood fuel production are outdated and lack consistency.
- Estimates of aggregate consumption made through interrogation and triangulation of earlier estimates suggest production of industrial roundwood of 1.1 milion m^3 and fuel wood production of at least 20.65 milion m^3 and probably in excess of 30 milion m^3.
- Provisioning value was estimated on the basis of estimates of stocks, sustainable rate of offtake, current prices and percentage trade value as direct value added to national income
- Based on an estimated maximum allowable cut of 17.5 million m^3, the value of sustainable **wood production** is in the order **of US$396 million per annum**.
- There is a spatial mismatch between supply and harvesting, so that certain areas are estimated to be severely overutilized.

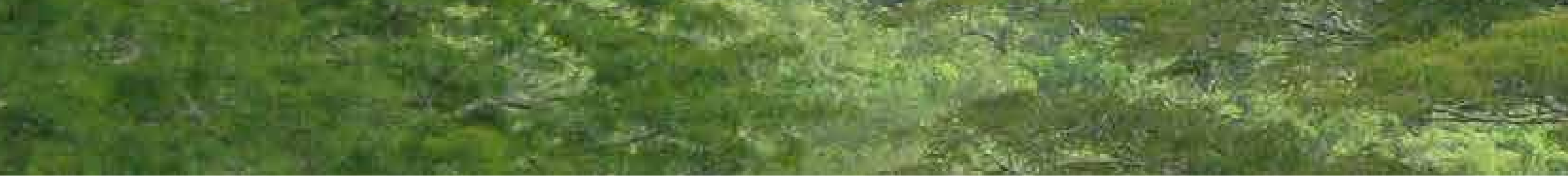
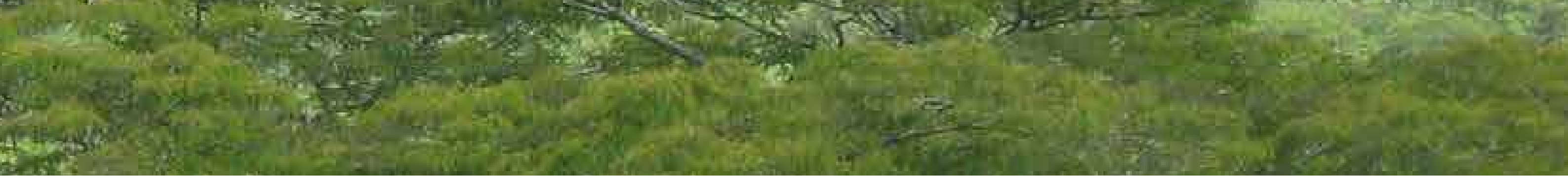


Table 3. Overview of forest ecosystem services valued and methods used.

Type of ecosystem service	How estimate was reached	Secondary data source
Industrial wood	Value was based on sustainable yield rather than current use. This study uses 1) an existing estimate of the maximum allowable cut (Kalinda *et al.* 2008, 17.5 million m^3), which equates to 0.6% of the estimated standing stock, and 2) Kalinda et al.'s estimate of the proportion of roundwood vs. fuelwood. Using prices per m^3 (Gumbo *et al.* 2013), spatial distribution of this value was mapped based on the distribution of forest biomass.	Puustjärvi *et al.* (2005) Ng'andwe *et al.* (2006) Mukosha and Siampale (2009)
Wood fuel	Using prices per m^3 (Gumbo et al. 2013 and CSO 2013), prices per bag or by volume for final products, and conversions was calculated to m^3 equivalents, the resulting figures ranged from \$37 to \$43 per m^3. Based on conservative price estimates, a final figure for gross value added (GVA) was obtained at 62.5% of gross output. The actual wood fuel production is estimated to be twice the sustainable yield. Spatial distribution of this value was mapped based on the distribution of forest biomass.	Puustjärvi *et al.* (2005) Ng'andwe *et al.* (2006) Kalinda *et al.* (2008) CSO (2013)
Non-wood forest products	Comparable data from earlier studies were analysed using district-level information on forest biomass and rural population density. Cash income from forest products was a function of forest biomass and population density; subsistence income was a function of population density. Using these relationships to estimate income at the district level, and drawing on the findings of earlier studies on contributions of different types of resources to cash and subsistence income, overall income from non-wood forest products was estimated for rural households.	Nkomeshya (1998a & 1998b) Emerton (1998) Turpie *et al.* (1999) Mickels-Kokwe (2005) Jumbe *et al.* (2008) Bwalya (2011) Mulenga *et al.* (2011)
Ecotourism	Estimates of the proportion of forest ecosystem value attributable to nature-based tourism were obtained from an earlier unpublished study and updated using recent tourism statistics of the World Travel and Tourism Council (WTTC). The proportion of nature-based tourism within forested areas was estimated on the basis of the spatial distribution of photo uploads in Google Earth.	Hamilton *et al.* (2007) WTTC (2012)
Erosion control and sediment retention	Soil erosion and transport were modelled for Zambia's catchment areas using the InVEST. This involved estimation of a range of parameters relating to the erodibility of soils, and of the impacts of different types of land use and land cover on the erosivity of the soil and its capacity to trap sediments. These estimates were based on the literature and other similar studies. Estimates of the quantities of sediment that were prevented from reaching dams were computed on the basis of, 1) a conversion of tonnes of sediment to changes in dam volume; and 2) international estimates of the costs of dam sedimentation. The overall value was presented on a spatial scale based on the model outputs of relative contribution of each pixel to this service, irrespective of spatial variation in demand – in other words, assuming that the service is fully demanded.	CSO (2013) Tallis *et al.* (2013) GIS layer on dams Basson *et al.* (2009)
Agricultural support services	Total area and production values were collated for crops dependent on pollination; estimates of the number of hives required per hectare were estimated on the basis of values in the literature for other comparable crops; replacement costs were estimated on the basis of the published cost of hiring hives in South Africa.	GRZ (2011) CSO (2012) Land use/land cover GIS data Allsopp *et al.* (2008)
Carbon storage and sequestration	The value of maintaining current carbon stocks was estimated as the damage avoided that would been caused by deforestation and the resultant climate change impacts, using 1) global estimates of the social cost of carbon; and 2) a very rough estimate of the proportion of that cost that would be borne by Zambia, based on GDP estimates for all countries and the expected relative magnitude of impacts in terms of percentage of GDP for developed versus developing countries. Per hectare values of carbon sequestration were also given, based on published rates of regeneration of degraded forests, and discussed in relation to REDD+ projects. The overall rate of sequestration is unknown, however, as it depends on how both intact and degraded forests are being managed and requires more investigation.	MODIS satellite data



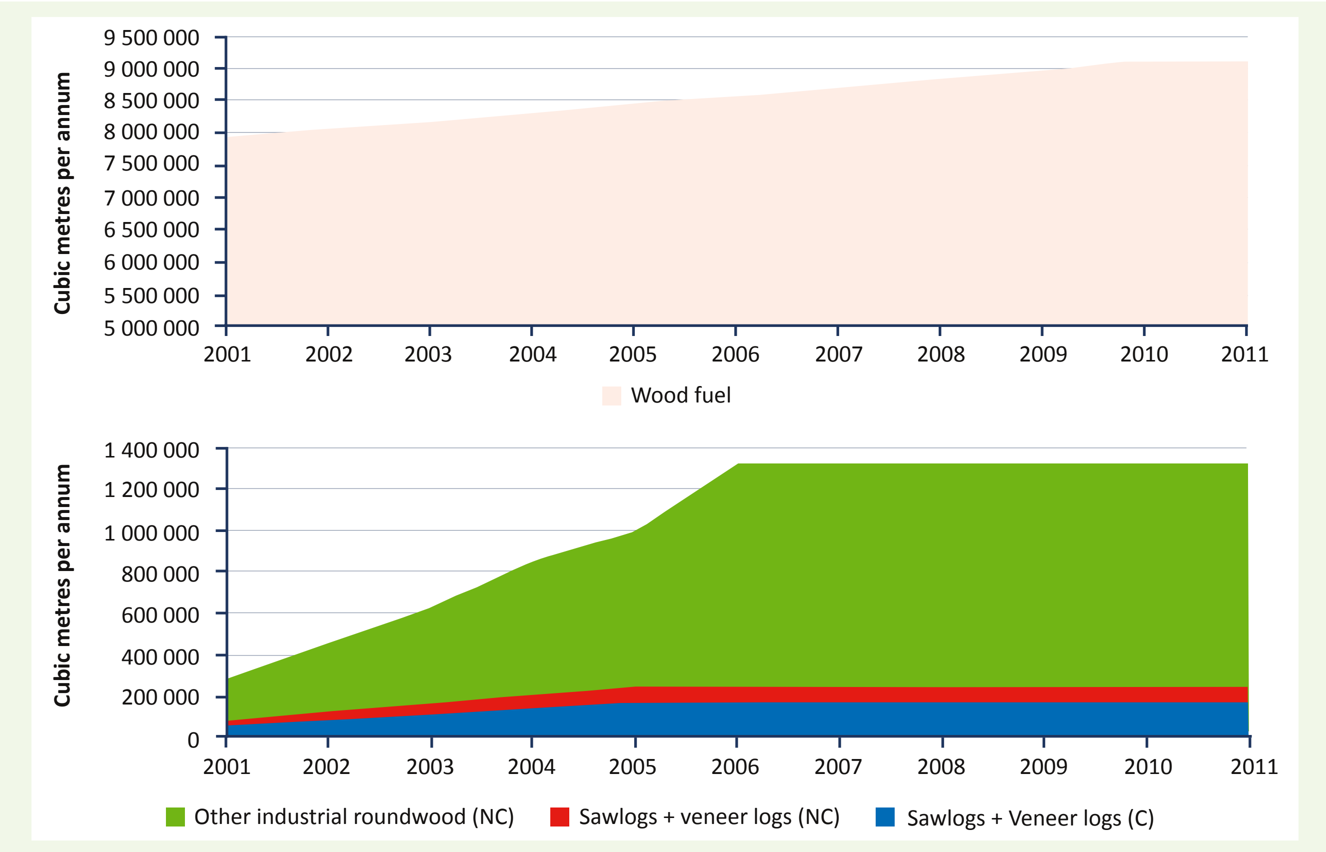


Figure 11. Available statistics of industrial roundwood production in Zambia, 2001–2011. C = coniferous, NC = non-coniferous. *Source: FAO, 2012.*

About 19 species of trees are widely harvested from Zambia's forests for timber and other industrial roundwood production. Of these, the Zambian/Zambezi teak, Kiaat (*Pterocarpus angolensis*) and African rosewood (*Guibourtia coleosperma*) are most sought after species (Kalinda *et al.* 2008; Gumbo *et al.* 2013). A variety of tree species are used for charcoal production, with preferred species being of the genera Brachystegia, Julbernadia and Isoberlinia (Dewees *et al.* 2011, in Gumbo *et al.* 2013). A large number of species are harvested for firewood.

There is a lot of information on industrial roundwood and wood fuel (charcoal and firewood) production in Zambia, but the estimates are far from consistent. Production statistics are collected by the Forestry Department and collated by the Food and Agriculture Organization of the United Nations (FAO). FAO production statistics suggest that wood fuel extraction increased from just under 8 million m^3 in 2001 to 9.1 million m^3 in 2011, and that industrial roundwood extraction increased from 285,000 m^3 to 1.35 million m^3 over the same period (Figure 11). This suggests that in 2011, wood fuel made up 87% of all wood harvested. Of the industrial roundwood, saw timber only made up a small proportion.

The statistics appear to bear no relationship to production estimates from the Forestry Department, which are comparatively low (Table 4). Thus it was necessary to examine various other estimates in more detail. These included two relatively recent studies that have looked at the value of forests to the Zambian economy – Puustjärvi *et al.* (2005) and Ng'andwe *et al.* (2006).

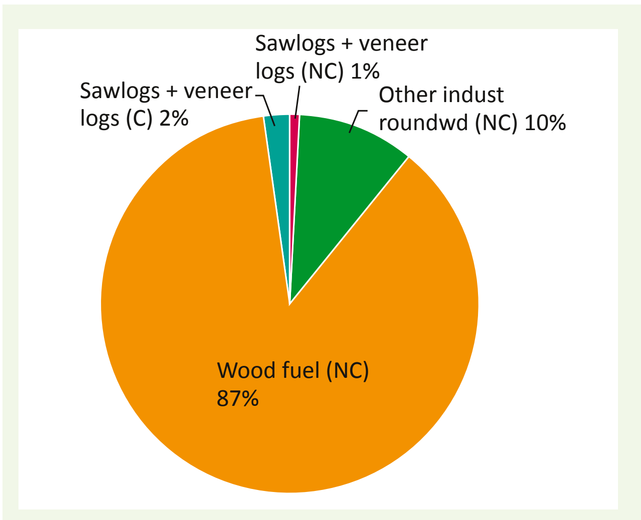


Figure 12. Proportional contribution of different types of products to total roundwood output in 2011. C = coniferous, NC = non-coniferous. *Source: FAO, 2012.*

Table 4. Production data for 2011 (more recent data tables were incomplete). *Source: "Timber production report" – an MS Word doc.*

	Indigenous		Trees/logs (m³)	Regional Plantations			Plantation trees (m³)
	Timber production (m³)	Bush poles (m³)		Sawn timber (m³)	Plantation poles (m³)	Sawlogs (m³)	
Lusaka	113	955	0	-	-	-	-
Copperbelt	269	742	11	5 354	15	0	11
Eastern	253	578	438	3 300	5 661	58	20
Western	15 715	1 351 854	14 904	-	109	-	-
North-western	-	-	-	-	-	-	-
Muchinga	-	-	-	-	-	-	-
Northern	506	3 056	0	1 199	-	4 384	-
Luapula	131	468	0	3 769	1 189	0	1 883
Southern	1 234	-	-	-	843	-	-
Central	52	263	159	-	-	-	-
	18 272	1 357 916	15 513	13 623	7 817	4 442	1 914

4.2.1

Industrial roundwood consumption

Industrial wood consumption (including sawlogs, transmission and fencing poles) was estimated at 3.1 million m³ in 1996 (ZFAP 1997). In a later study, Puustjärvi *et al.* (2005) estimated the production of timber for household consumption using data collected in the mid-1990s, and industrial production was estimated based on data obtained on consumption by furniture manufacturers, the mining industry, Zambia Forestry and Forest Industries Corporation plantations, as well as export data from the CSO (Table 5). In Ng'andwe *et al.*'s (2006) study, forestry production was estimated on the basis of Forestry Department revenues. According to Ng'andwe *et al.* (2006), total removals of industrial roundwood in 2006 were estimated to be in the order of 1.155 million m³, similar to the corresponding FAO statistic of 1.325 million m³ for the same year, but considerably lower than the 1996 estimate of 3.1 million m³.

In spite of the wide ranging estimates of production, Puustjärvi *et al.* (2005) and Ng'andwe (2006) arrived at similar estimates of value added of US$35.9 million and US$40.46 million, respectively. In the latter estimate, plantations accounted for 8% of the timber value and 28% of the value added in manufacturing, so timber from indigenous forests accounted for a value added **of US$24.45 million in 2006,** with an average gross value added (GVA) per m³ of US$29.2 (Table 6).

However, both Puustjärvi *et al.* (2005) and Ng'andwe *et al.* (2006) felt that their estimates were conservative. It is believed that illegally harvested wood (for whatever purpose), far exceeds the official annual wood harvest (Ng'andwe *et al.* 2006).

Table 5. Estimated contribution of forest production and processing to GDP in 2004. Source: Puustjärvi *et al.* 2005.

		Production	Unit price	Trade value	Value added
		(m³)	(US$/m³)	(US$ million)	
Household production	Logs for sawn timber	400 356	110	15.4	10.0
	Poles	92 203	80	7.4	5.5
	Other wood	155 289	75	4.1	3.1
	Subtotal	647 848		26.9	18.6
Industrial timber production and secondary processing*		?		30.1	17.3*
Total					**35.9**

*Likely to be underestimated.

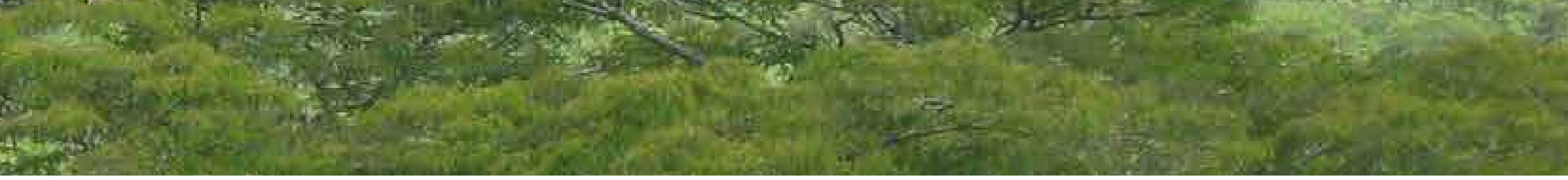


Table 6. Estimated volume and value of industrial roundwood production in 2006. *Source: Ng'andwe 2006.*

	Volume of removals	Unit value	Trade value	Gross value added	GVA by indigenous resources
	('000s m³)	**(US$/m³)**	**(US$ '000s)**		
Household production	777	20	22 320	17 856	17 856
Commercial concessions	59	22	1 188	950	950
Plantations	319	5.94	2 171	1 737	
Manufacturing				19 917	5 642
Total industrial roundwood	**1 155**			**40 460**	**24 449**

4.2.2
Wood fuel consumption

Wood fuel is estimated to account for about 80% of the total energy household balance in Zambia (Kalinda *et al.* 2008). In rural areas, this is mainly through use of firewood, whereas in urban areas, wood fuel use is mainly in the form of charcoal. Estimates of total wood fuel use vary quite widely, especially for firewood (Table 7). In 1996, it was estimated that total wood fuel consumption amounted to 19.4 million m^3 (PFAP 1997). However, later estimates have included some much lower estimates, down to 8.37 million m^3 (Ng'andwe *et al.* 2006). Based on a review of these existing estimates (see Appendix 2), and using more up-to-date census data (2010), we estimated that total wood fuel consumption is in the order of 14.6 million tonnes or **19.45 million m^3** (Table 7). In addition to household consumption, an estimated 1.2 million tonnes of firewood and 48,000 tonnes of charcoal were used in agriculture, industry and mining in 2010 (CSO 2013), adding **1.66 million m^3** to the estimate of national wood fuel consumption. Using the upper bound estimate given above, this suggests a total national consumption of **20.65 million m^3**.

Applying the same logic as used by Kalinda *et al.* (2008), this estimated total would require the clearing of about 170,000 ha of intact forests (79.37 tonnes per ha) per year, or a larger area of secondary forests. Note also that actual extraction is likely to be greater than national consumption, since the illegal export of charcoal, while unquantified, is thought to be significant. Thus it is quite possible that wood fuel production could exceed **30 million m^3**. This would result in clearing of 230,000 ha per year of intact forests. This estimate of wood fuel consumption is about twice the estimated total allowable cut of 15.9 million m^3 per year by Kalinda *et al.* (2008; see following section), which suggests that it is not sustainable, contrary to what is suggested by some authors (Puustjärvi *et al.* 2005; Kalinda *et al.* 2008; Bwalya 2011).

Both Puustjärvi *et al.* (2005) and Ng'andwe *et al.* (2006) estimated the value of wood fuel production in 2004, but arrived at quite different estimates. The trade value was much lower than Puustjärvi's estimate due to applying a lower price (US$10 per m^3 vs US$26 per m^3), but the estimated GVA was very much higher as a multiple of market value (US$4.26 vs US$0.63) and as a value per unit of wood volume (US$42.61 vs US$8.92 per m^3). Nevertheless, after correcting for an error found in the Puustjärvi *et al.* (2005) report, the revised estimated total GVA of **US$340 million** was coincidentally similar to Ng'andwe *et al.*'s estimate of **US$374.9 million**.

Puustjärvi *et al.* (2005) estimated that the forest sector contributed at least 3.7% of Zambia's GDP, and over 161,000 jobs. Subsistence production was estimated to make up 35% of the overall value. Comparative estimates for GDP in 2004 were that agriculture contributed 7.2%, fisheries 2.6%, and mining 8.2% (Puustjärvi *et al.* 2005). It was estimated that over 145,000 people were employed full-time in charcoal production (CSO 2013; Table 8). However, noting that the error in firewood production carried through to this table, it is unclear whether employment estimates are correct. If so, it suggests that involvement in charcoal production has more than tripled: in 1997, it was estimated that 41,000 rural households were involved in full-time charcoal production, and that another 4,500 people were involved in transportation, marketing and distribution (GRZ 1997, in Jumbe *et al.* 2002).

Indeed, there was reportedly a big upsurge in charcoal production during the 1990s due to the economic downturn, as charcoal production offered returns that were nearly five times that of farming (Chidumayo 2001). Since few households specialize in one activity, the actual number of households involved is probably much higher. Chidumayo (2001) reported that about 9,000 households produced charcoal in Chongwe district alone in 2002.

4.2.3
Standing stocks and sustainable yield

Another way of looking at the production value of forests in situations of poor production data is on the basis of their stocks and estimated sustainable yield. Standing stocks of timber and wood fuel (expressed in m^3 per ha) are related to forest biomass (expressed in tonnes per ha) and are derived on the basis of tree densities and dimensions. The relationship with biomass is unlikely to be linear where biomass has been decreased through utilization, since the prime re-

Table 7. Existing estimates of firewood and charcoal consumption in Zambia. Figures in bold are reported estimates, the rest are derived for comparative purposes. See Appendix 1 for further explanation.

Source	PFAP (1997)	FSP (2004)	Puustjärvi et al./SAVCOR (2005) main text	Puustjärvi et al./SAVCOR (2005) Annex 3, cited in CSO 2013	CSO 2013 (Dept. of Energy)1	FAO Yearbook 2004 in CSO (2013)	Ng'andwe et al. (2006)	Kalinda et al. 2008	Kalinda' s estimates adjusted to 2010 census data	Estimate based on 1996 per capita consumption
Year of estimate	**1996**	**2003**	**2004**				**2006**	**2008**	**2010**	
Firewood (million tonnes)		7.12	1.79	8.21	9.25			1.32	2.05	9.36
Firewood (million m^3)		9.49	2.384	10.944	12.33			1.76	2.73	12.48
Wood for charcoal (million tonnes)		6.78	10.68	0.40	4.74			5.80	4.23	5.22
Wood for charcoal (million m^3)[2]		9.04	14.24	0.54	6.31			7.73	5.64	6.97
Charcoal (million tonnes)		1.63	2.565	0.10	0.95			1.39	1.01	1.25
Charcoal (million bags – 33kg)[3]		49.32	77.70	2.925	28.70			42.18	30.73	38.00
Total wood fuel (million tonnes)									6.28	14.59
Total wood fuel (million m^3)	**19.40**	**18.53**	**16.63 (n/a)**	**11.48 (n/a)**	**18.65**	**11.57**	**8.80**	**9.49**	**8.37**	**19.45**

1 Part of a projected 10-year time series.

2 Assuming an average density of 750 kg per m^3.

3 The "50 kg" bags of charcoal weigh 33 kg (Gumbo *et al.* 2013).

4 The Puustjärvi *et al.* (2005) study detailed its calculations in Annex 3. While firewood production had been escalated from 9.49 to 10.94 in the annex, the main text used a figure of 2.383 million m^3, in an apparent error. Erroneous value is underlined.

4 From the Puustjärvi *et al.* (2005) Annex 3 cited above, an error in one of the tables, where kg charcoal had been mislabelled as millions of bags, led to its being misreported in the CSO study, but the correct figure was used in the main report. While their estimate is based on the FSP's 49.3 million bags, it was derived using an assumption of 50 kg per bag, whereas our estimates are based on 33 kg per bag. Erroneous value is underlined.

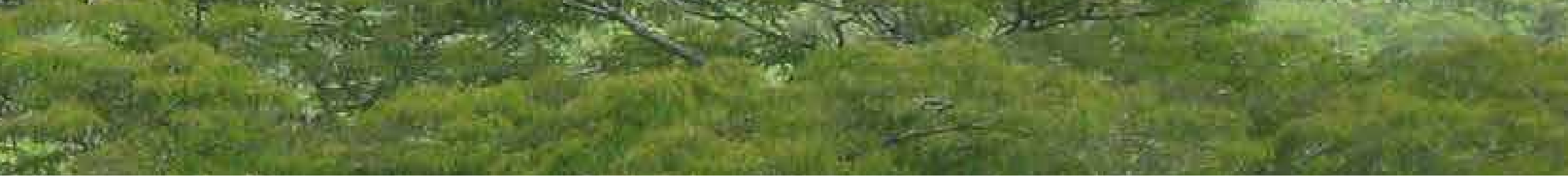


Table 8. Estimated contribution of forest production and processing to GDP in 2004. *Source: Puustjärvi et al. 2005.*

	Production	Estimated wood used (derived)	Trade value	Value added	Full-time employment
		(million m³)	(US$ million)		(Number of people)
Firewood (m³)	2 383 000*	2.4	62	46.5	6 847
Charcoal (kg)	2 564 million	14.2	211	126.5	145 831
Original total		**16.6**	**273**	**173.0**	
Corrected estimates based on Annex 3:					
Firewood (m³)	10 940 000	10.9	285	213.5	
Charcoal (kg)	2 564 million	14.2	211	126.5	
Corrected total		**25.2**	**496**	**340.0**	

*This was an error (see above).

sources will generally be taken first. In other words, an area with half its original biomass will probably have less than half its original timber resources.

Standing stocks

Wood biomass in miombo (semi-evergreen) woodlands can be up to 90 m³ per ha in closed forests (Chidumayo 1990; Pohjonen 2004). About 90% of the biomass consists of cord wood suitable for charcoal production; the rest consists of small stems and twigs (Chidumayo 1990). Estimates for standing stocks have varied considerably (Table 9). Based on our analysis, we have selected the Integrated Land Use Assessment (ILUA) -based estimates for use in this study. These estimates are more than double those of the FAO study. Of the estimated 2,941 million m³ estimated by Mukosha and Siampale (2009), **2,785 million m³** (94.7%) **is in forests**, with the majority (2,128 million m³) being in miombo forests.

Commercial timber volume is made up of the trees of over 30 cm diameter at breast height (dbh) (1.3 m from the ground). Mukosha and Siampale (2009) estimated the total commercial timber volume to be 340 million m³ in forests, and **365.8 million m³ of timber stock** if all land types are included. This suggests that the balance of **2,575 million m³ is the wood fuel stock**. An anonymous government report[13] from 2013 reported a total gross volume of 2,954 million m³ (similar to the ILUA estimate) but a total commercial volume of 1,047 million m³.

Annual increment and sustainable yield

The rate of growth of relatively intact natural forests in national parks is very low, ranging from 0.7 to 2 m³ per ha per annum (Mulombwa 1999). Growth rates in utilized indigenous forests in 1996 were much higher, reflecting a situation of reduced standing stocks, and were exceptionally high in

Table 9. Estimates of standing stocks in Zambian forests.

Year	Stocks	Stocks	Industrial roundwood	Wood fuel	Source
	(million tonnes)	(million m³)			
1996	3 682	4 909	611	4 298	ZFAP 1997, Mulombwa 1999
1999	3 091	4 121	513	3 608	Forestry Dept. 1999, in Mulombwa 1999
2002?*	2 927	3 903	485	3 417	CSO 2013
2004	1 050	1 400	174	1 226	FAO 2006
2006/7	2 206	2 941	366	2 575	Kalinda *et al.* 2008 (in Bwalya 2011), Mukosha and Siampale (2008)

*Based on Inventory of Wood Used in Charcoal Production in Zambia, Prof. Chidumayo (undated), plus data on dambo and cropland areas from 2002 and 1974, respectively.

[13] "Submission of the preliminary report on findings and recommendations on timber licensing suspension – concession inspections and stakeholder consultations".

open forests (Table 10). Based on estimates in Mulombwa (1999), the annual increment outside protected areas could have been about 800 million m^3 in 1999. Note that the source tables did not include the area or total growing stocks, so stocks per unit area were derived and may be inaccurate. Moreover, the estimates vary substantially. A more recent estimate puts the annual increment for all forests at about 597 million m^3 (Kalinda *et al.* 2008). Given that national parks account for at least 13% of the growing stock (Mulombwa 1999), this suggests that the increment outside national parks would be about **519 million m^3**.

Siampale (1997, in Puustjärvi *et al.* 2005) estimated the allowable cut of commercial forests to be 15 million m^3 per annum, based on mean annual increment. Given that the forest area is estimated to have been decreasing by some 300,000 ha annually, this would suggest that by now, the sustainable annual cut could have been reduced to less than 12 million m^3. However, more recently, the maximum allowable cut has been estimated to be 17.5 million m^3 per year, of which 1.6 million m^3 are commercially valuable timber species (Kalinda *et al.* 2008). The total is some 0.6% of the estimated standing stock, a bit more conservative than the estimated sustainable yield of 1% of standing stocks used in the preliminary Kenyan forest accounts (Kenya Forest Service 2009).

4.2.4

Estimated wood production value of forests

Based on the above estimate, the sustainable GVA of Zambia's forests is in the order of US$396 million per annum, the forestry contribution to the asset value being US$3,886 million (Table 11). Current annual contribution to the economy may be higher than this but does not reflect the depreciation of natural capital. Forests are restorable, and with the right policy interventions, the annual contribution could increase over time, along with the value of the asset base. It is interesting to note that the estimated value of current use is not much higher than estimates based on standing stocks. This may be because the current use estimate is likely to underestimate informal and illegal use of resources.

Based on the simple assumption that the overall value is distributed in proportion to biomass outside national parks and game management areas, the estimated spatial distribution of the service under conditions of sustainable management is shown in Figure 13 and summarized by province in Table 12.

Table 10. Growing stock and increment rate of indigenous forests and estimated total annual increment based on area. Source: Mulombwa 1999; Area of Forest Reserves and Open forests from the Zambia Forestry Department Audit Report 2012; Kalinda *et al.* 2008 for 2006/2007.

Category	Area	Percentage of forest area	Reported growing stock	Derived Growing stock	Reported increment rate	Increment as % of stock	Total increment
	(ha)		(million m^3)	(m^3 per ha)	(m^3)		(million m^3)
Forest reserves	7 665 000	15.3	779	101.6	12.2	12	94
Open* forests	31 561 765	63	2 798	88.7	22.4	25.3	707
National parks	6 400 000		544	85.0	1.6	1.88	0
Total 1999	45 626 765		4 121				800
Zambian forests			2 954				597
Total 2006/2007			2 954				597

*In the sense of land management.

Table 11. Estimated value of standing stocks.

	Maximum allowable cut	Price per m^3	Trade value	GVA	NPV
	(million m^3)		(USS$ million per annum)		(US$ million)
Industrial roundwood	1.6	22	35.8	21.5	210.6
Wood fuel	15.9	40	630.9	425.7	4 179 .4
	17.5		666.6	447.1	4 390 .0

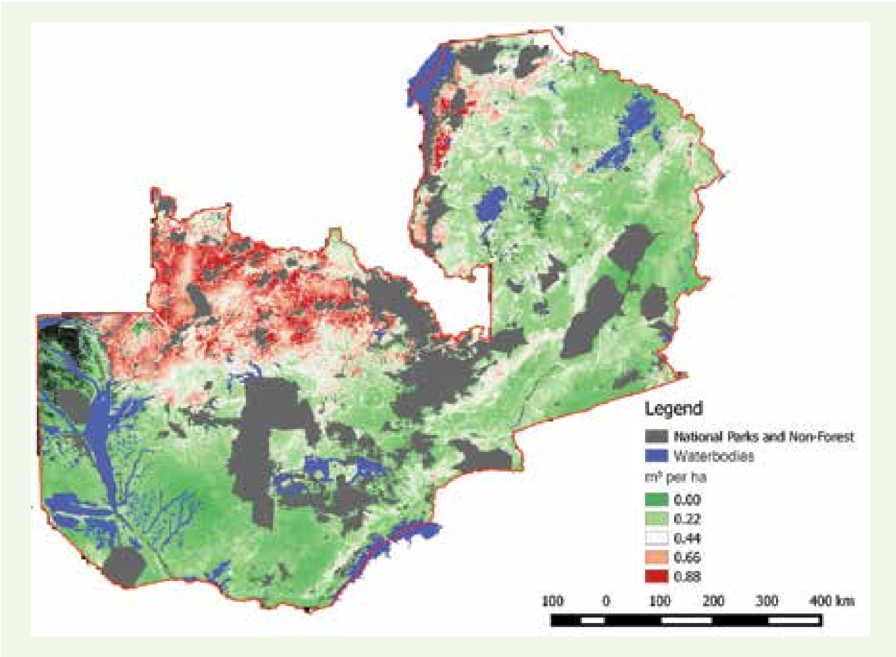


Figure 13. Estimated spatial variation in the sustainable yield of roundwood resources (timber, poles and fuel wood), expressed in physical terms (m^3 per ha per year). *Source: this study.*

Table 12. Estimated distribution of the maximum allowable cut, based on Kalinda *et al.* 2008.

Province	Total volume		Maximum allowable cut		
			Total	Timber	Wood fuel
	(million m^3)	(percentage)	(million m^3)		
Central	485.9	17	2.9	0.3	2.6
Copperbelt	173.3	6	1.0	0.1	0.9
Eastern	264.8	9	1.6	0.1	1.4
Luapula	158.3	5	0.9	0.1	0.9
Lusaka	88.8	3	0.5	0.0	0.5
North-western	904	31	5.4	0.5	4.9
Northern	345	12	2.1	0.2	1.9
Southern	135.2	5	0.8	0.1	0.7
Western	385.4	13	2.3	0.2	2.1
Total	**2 940.7**		**17.5**	**1.6**	**15.9**

It is important to note that although the overall values are similar, there is likely to be a strong mismatch between our spatial estimate of forest provisioning value and the spatial pattern in the actual harvest of wood products. Whereas the spatial distribution of commercial timber harvesting tends to track that of the standing stocks outside protected areas, it is unlikely that informal production or charcoal production follows the same pattern. Charcoal production has relatively small margins (Gumbo *et al.* 2013), and profitability is likely to be significantly affected by distance from markets. Thus, some forests may be exploited at sustainable levels, or even underexploited, while those near populous areas are expected to be over-exploited. While the map of forest value based on current standing stocks would put greater value on the more remote north-western areas where biomass is still relatively high (Figure 13), a map based on current use would reflect relatively high values in the more depleted areas, where resources are expected to be being mined. Indeed, based on the assumption that availability of targeted timber species would determine where logging operations take place, that most firewood harvesting takes place within a few kilometres of the user households who collect it themselves, and that charcoal production activities are likely to be concentrated in the suitable forest areas closest to

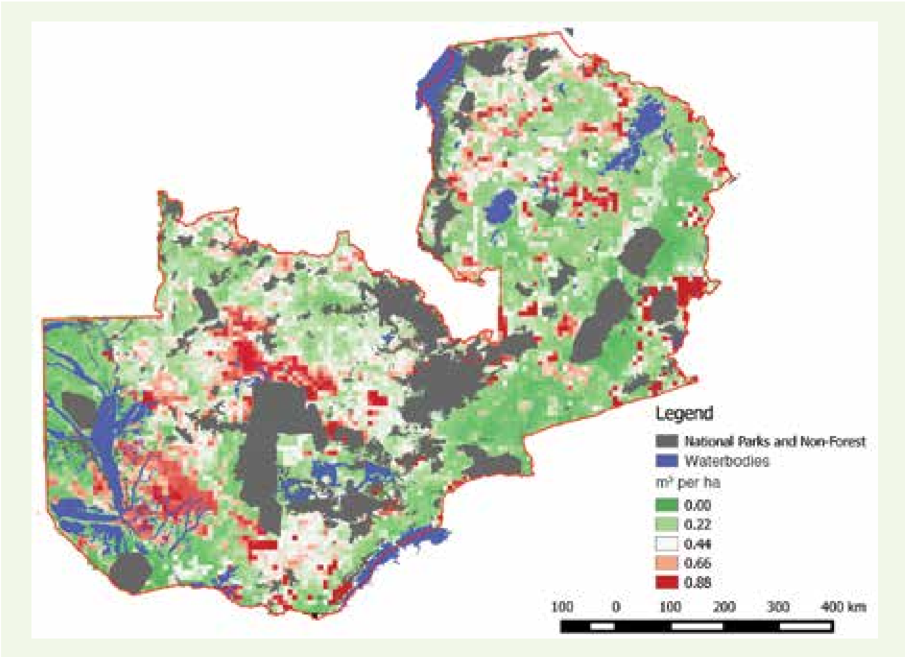


Figure 14.Estimated spatial distribution of annual harvest of wood products. *Source: this study.*

urban areas (but presumably largely beyond the areas used by households for firewood), the estimated pattern of use is almost the opposite of the former pattern (Figure 14).

In both cases, the asset value would reflect the former pattern, as it would have to be assumed that the flow of values would not be sustained in the over-exploited areas. It is of particular interest to this study, however, to compare the two maps to determine the areas that are over-exploited and therefore being mined. This difference map (Figure 15) provides an indication of the potential gains to be had from management interventions but also the short-term opportunity costs of forest conservation to local communities, which will provide some indication of the potential difficulty of perceived value and therefore of implementation.

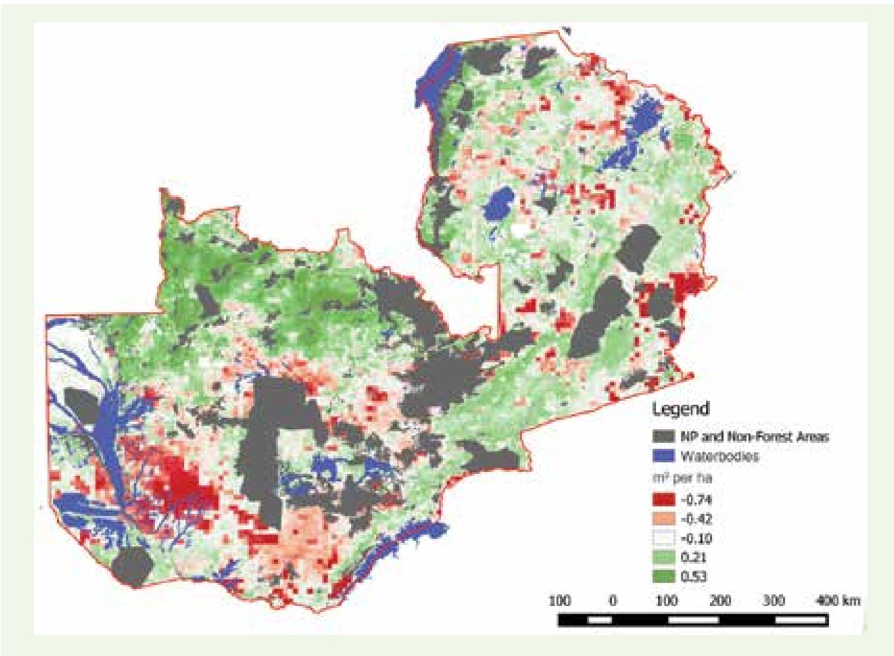
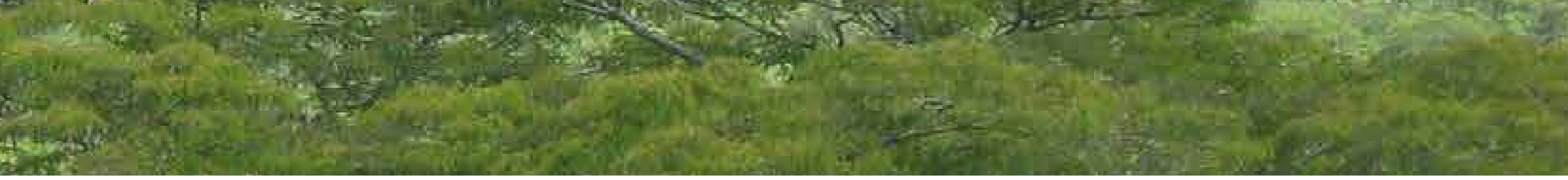


Figure 15.Estimated pattern of over- and under-exploitation of forest wood biomass. *Source: this study.*



4.3
Provision of non-wood forest products

Key points

- A wide range of plant and animal species are collected for use as raw materials in house construction, thatching and craft production, as well as for food and medicinal use.
- While much of this is used on a subsistence basis, these resources also contribute to household cash income, supplementing income from charcoal and timber.
- There are a number of estimates of use and value at local to regional scales, but no estimates of the resource base or sustainable yields.
- Based on 13 local studies, average income from non-wood forest products was found to be correlated with rural population density, while forest biomass was not a significant factor.
- Extrapolated at the district level, this suggested that overall income to rural households from non-wood forest products is in the order of **US$135.8 million per annum,** including subsistence production.

The resources obtained from forests are typically separated in one of two ways. Studies that distinguish between timber production and non-timber forest products, which include wood fuel, tend to do so because the former tended to be carried out as a formal commercial activity, while the latter tended to form an important part of rural subsistence livelihoods. Alternately, one can distinguish between all roundwood production (which includes wood fuel) and non-wood forest products. This makes sense from a resource perspective because different types of wood production come from overlapping components of the resource base, and because of the important commercial role of charcoal. There are elements of subsistence, small- and large-scale commercial production with most forest products in Zambia, with a tendency for timber and charcoal production to be commercial and for firewood and non-wood forest products to be collected by rural households on a subsistence basis or for sale on a small scale. The main disadvantage of this approach is that wood fuel production is often included in aggregated assessments of the value of forest product use.

Non-wood forest products include a range of plant and animal species collected for use as raw materials in house construction, thatching and craft production, as well as for food and medicinal use. Wild foods include wild honey, mushrooms, tubers, berries, edible caterpillars and bush meat. In addition to permission from local chiefs, collection of some of these resources (e.g. caterpillars, honey), requires a collection permit from the Department of Forestry, or in the case of game, from the Zambia Wildlife Authority. Hunting in game management areas is allowed under a national hunting licence and, in community areas, under a District Hunting Licence (Hamilton *et al.* 2007, 2014). However, it is generally acknowledged that officially sanctioned use of plant and animal resources is probably only a fraction of overall use, and that access to most resources is de facto open access.

Unlike in the case of wood resources, no ecological studies have been undertaken to estimate the availability and supply of non-wood forest products, so it is not possible to estimate the asset value based on stocks and productivity. However, the use of non-wood forest products in Zambia has been documented in several localized studies as well as a few larger scale assessments. While a number of these have been published, many are unpublished studies, not all of which are still in circulation.

Zambia's forests and woodlands not only provide important sources of food and materials for subsistence purposes, they also make a significant contribution to rural household income. Wood products (timber, construction poles and charcoal), thatching grass and reed mats are the most commonly sold forest-based commodities, and relatively little income is derived from wild foods (e.g. mushrooms, caterpillars, fruits) or medicinal products (Bwalya 2011). The latter tend to be collected by traditional healers who come from urban areas, and are mostly collected close to towns (Bwalya 2011). There is also gender differentiation in that women tend to collect the non-wood products (wild foods, mushrooms, edible caterpillars, etc.) mainly for subsistence use, while men harvest wood products, wild honey and other non-wood forest products for sale (Bwalya 2011). Honey harvesting is a fairly well organized activity especially in North-western Province, where about 6,000 beekeepers produce some 600 tonnes of honey and 100 tonnes of wax annually (Ng'andwe *et al.* 2006).

Multiple studies have tried to capture these uses and address the importance of forests for rural households and livelihoods. Thus, quantitative estimates exist for a range of districts, usually from multiple sites within the districts (Table 13). While some studies provided detailed information from their study areas, the data in Bwalya (2011) were largely reported in aggregate format. Nevertheless, it was possible to derive estimates in most cases based on the data presented in the studies. Some of these studies have provided breakdowns of the contribution of different types of forest resources to the value of forest-based production by rural households. While the pattern varied between study areas, analysis of data in Jumbe *et al.* (2008) suggest that, on average, wood products contributed about half of cash income from forest products, with non-wood forest products providing the rest. A similar pattern was found for overall production including subsistence, but the composition of wood products was different in that firewood provided almost no income, but made up half of the subsistence value of wood harvesting (Figure 16).

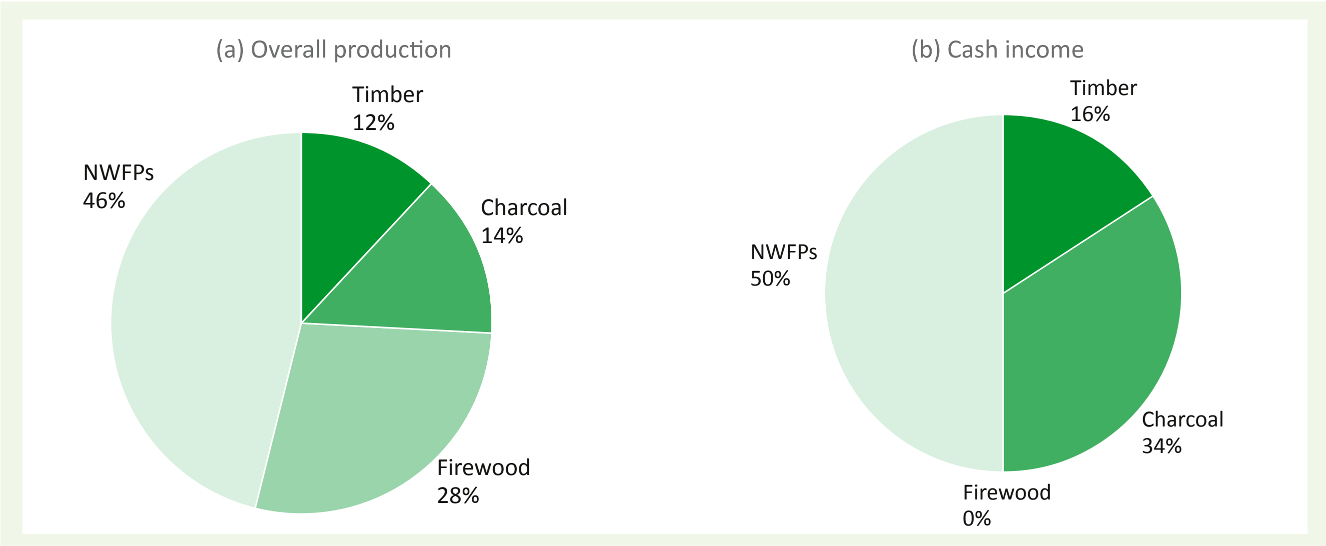


Figure 16. Average percentage contribution of different types of forest products to (a) overall (cash plus subsistence) production and (b) cash income. *Source: Data from Jumbe et al. 2008.*

NWFPs = non-wood forest products.

In the study by Mickels-Kokwe (2005), non-wood forest products made up 69% and 94% of cash income from forest products in Luapula and North-western Province, respectively, with timber making up the balance. However, their study did not report on any wood fuel production. In fact, the proportion of households selling different non-timber forest products in different parts of Zambia suggested that wood fuel was the most important source of income from non-timber forest products in all but the North-western Province (Mulenga *et al.* 2011; Table 14).

Mulenga *et al.* (2011) described the contribution of non-timber forest products to rural household cash income in Zambia based on country-wide data from over 8,000 households collected as part of the ILUA study in 2005–2008. Only 6% of households reported deriving any cash income from forest products other than timber, and the majority of this income was from charcoal production (Table 14). Income data were only provided for the 16 districts where households derived more than 10% of their cash income from non-timber forest products on average. These households earned 33% of their cash income from non-timber forest products to the value of about US$344 per capita per annum (our derivation). Of this, fuel wood (firewood and charcoal) accounted for 37%, ants and caterpillars, 19%, wild honey, 12% and mushrooms, 8%. Given that these households made up 15.6% of the national sample, this suggests that average cash income from non-timber forest products across Zambia is at least US$274 per household per annum and US$417 million in aggregate, of which US$154 million is attributed to sale of wood products (mainly charcoal). If, however, the values should have been expressed as per household values, then cash income from forest products would amount to US$53 per household on average, which is more in line with earlier estimates. This would imply an aggregate cash income of US$82 million from non-timber forest products across all rural Zambian households (based on 2010 census data).

If the ratios suggested by Mickels-Kokwe are correct, then the reported per capita values would suggest an average overall value (including subsistence consumption) of US$730 per household per annum, and an aggregate value of US$1,112 million for non-timber forest products. If, however, the values should have been expressed as per household values, then the latter values would amount to US$143 per household, and US$218 million as the value of aggregate household production of non-timber forest products (Table 15).

Jumbe *et al.* (2008) found that poorer households tended to harvest more, while richer households tended to derive more income from forest products. Mulenga *et al.* (2011) also found that poor households were more reliant on non-timber forest products for income in terms of proportion of total household cash income, but wealthier households earned more money from non-timber forest products.

The contribution of forest products to household livelihoods varies geographically, temporally, and across households (Bwalya 2011). The key factors influencing dependence on natural resources are access to markets, household income from other sources, the stock and opportunity cost of labour, and the availability of forest exit options to the household (Bwalya 2011). Forest products, especially charcoal, are the major sources of forest income for households living near urban centres, with income increasing with proximity to urban markets (Bwalya 2011). Richer households tend to target high value forest activities such as timber, while poorer households are involved in gathering foods and other resources and producing charcoal (Bwalya 2011).

No spatial analysis has been undertaken on variation in income from forest products. In this study, data in Table 13 were analysed in relation to average forest biomass and the rural and urban populations of each district. The earlier data

Table 13. Existing estimates of the value of household production of forest products and their contribution to cash income in different districts. Values computed based on data presented in the reports, inflated to 2010 values and converted to US$.

Source	Year	Province	District	Place	Gross value of household production (cash + subsistence)			Household cash income		
					Total	Forest	% forest	Total	Forest	% forest
Nkomeshya 1998a, b; Emerton 1998 (net income)	1998	Central	Kapiri Mposhi		103.32	23.27	22.5	92.37	12.32	13.3
		Luapula	Mansa		36.03	24.64	68.4	30.55	19.17	62.7
		Copperbelt	Kalulushi	Lumpuma-Mukutuma	132.56	12.18	9.2	124.21	3.83	3.1
Turpie *et al.* 1999 (net income)	1998	Western	Mongu	Floodplain edges			14.5			
Mickels-Kokwe 2005 (cash income only, excluding wood fuel)	2003	Luapula				21.04		52.85	7.89	14.9
		North-western				29.62		48.68	11.11	22.8
Jumbe *et al.* 2008 (gross income)	2005	Northern	Kasama	Paul Kalema		221.08			61.15	
		Northern	Kasama	Nseluka		131.63			13.33	
		Muchinga	Mpika	Kopa		189.62			59.63	
		Muchinga	Mpika	Lwitikila		116.97			53.49	
		Copperbelt	Ndola	Katanino		231.78			102.08	
		Central	Mumbwa	Lutale		182.60			66.44	
		Central	Mumbwa	Nalusanga		146.81			48.82	
		Central	Mumbwa	Chibuluma		128.95			23.09	
Bwalya 2011 (cash income only)	2006?*	Luapula	Mansa	Lukangaba in Mansa		254.79		-	95.54	14.6
		Central	Mkushi	Myafi		60.11			22.54	3.4
		Central	Mkushi	Chaba		110.09			41.28	6.3
		Eastern	Petauke	Nyampande		268.77			100.79	15.4
		Central	Kapiri Mposhi	Chibwe		78.64			29.49	4.5

* Exchange rate was ZMK 4,000 to US$ 1.

Table 14. Overall percentage of households deriving cash income from non-timber forest products. *Source: Mulenga et al. 2011.*

Province	Percentage of households with income from NTFPs	Percentage of NTFP households with income from			
		Wood fuel	Ants and caterpillars	Mushrooms	Wild honey
Central	6	98	2	4	2
Copperbelt	8	85	5	15	2
Eastern	2	79	0	8	13
Luapula	9	64	31	18	1
Lusaka	4	100	0	0	0
Northern	2	65	26	6	6
North-western	15	5	75	24	19
Southern	7	84	0	15	7
Western	7	97	0	7	0

Table 15. Estimated overall and cash income value of forest products by rural households based on interpretation of information and percentage contribution of non-timber forest products to cash income in Mulenga *et al.* 2011, and expanded to all forest products and gross production values based on ratio of Mickels-Kokwe (2005) and estimated contributions of different forest products to overall and cash income in Jumbe *et al.* 2008.

	Non-wood forest product value			
	Based on per capita values		Based on assumption that values are per household	
	Overall	Cash	Overall	Cash
Per household	730.30	344.15	143.20	53.70
Aggregate value excl timber	1 112.20	417.07	218.08	81.78
Timber	209	72.08	41	14.13
Charcoal	448	154.32	88	30.26
Firewood	7	2.82	1	0.55
Non-wood forest products	657	262.76	129	51.52
Total forest products	1 321.38	491.98	259.09	96.47
Total wood products	664.08	229.22	130.21	44.95
Total non-wood forest products	657.30	262.76	128.88	51.52

were excluded because they were net values. Income from forest products did not increase linearly in forest biomass, but followed a U-shaped relationship, with a high degree of variability in areas of higher average biomass. Cash income from forest products increased linearly with district population density. Overall, there was a significant relationship between cash income from forest resources (FC) and forest biomass (B) and population density (D), as follows:

$$FC = 83.4-0.7*B +1.27*D \ (d.f. = 12; p<0.05)$$

The above relationship was driven mainly by population density. This was expected, since income is easier to generate near markets. While we expected to find a positive relationship between subsistence income and forest biomass, this was not the case. In fact, subsistence income (FS) and total forest-based income (FI) was also positively related to population density.

$$FS = 72.59+2.06*D \ (d.f. = 12; p<0.05)$$

$$FI = 100.62+3.64*D \ (d.f. = 12; p<0.05)$$

This could be due to the fact that land is in shorter supply where population densities are higher, given that reliance on forest products is negatively related to access to and income from agricultural land, but it could also be partly due to the fact that some of the estimates of subsistence value were derived from cash income. Therefore, we did not manage to obtain a very satisfactory model for extrapolation of non-wood forest value. Nevertheless, using this somewhat crude means of extrapolation as being potentially more reliable than an average, we obtained an overall estimated value for rural household production of **wood products of US$150 million** and for **non-wood forest products of US$135.8 million per annum**. This assumes that such income only accrues to rural households. The wood estimate was less than a third of our earlier estimate for wood fuel – see section 5.3 – possibly because much of this accrues to urban households. The distribution of the estimated non-wood forest products value is shown in Figure 17.

4.4 Carbon storage

Key points

- Above-ground biomass for the whole country was estimated based on the Moderate Resolution Imaging Spectroradiometer (MODIS) satellite data to be 5,506 million tonnes, equivalent to 2,533 million tonnes of carbon. Of this 2,142 million tonnes of carbon fall within forest areas (as demarcated by ZFD).

- There are multiple ways to estimate the value of carbon. One way to do this is by estimating the social cost of carbon (estimated to be US$29 per tonne), which is based on the impacts of climate change on a country's GDP aggregated at global scale. Preventing the release of forest carbon emissions may lead to a reduced loss to the economy in the order of **US$ 15 million per annum.**

- In evaluating potential for REDD projects, carbon can also be valued in terms of its market value, which we estimate to be in the region of US$6 per tonne. Depending on location, carbon stocks in Zambian forests are potentially worth about US$150 per ha on average (once off), but range up to US$745 per ha for intact forests. Annual values of sequestration in degraded areas are about US$16–US$30 per ha per year.

Forests are understood to make a significant contribution to global climate regulation through the sequestration and storage of carbon. About half of the biomass of forests, both above and below ground, comprises carbon. Furthermore, carbon accumulates in the soils under forests as a result of leaf litter. When forests are degraded or cleared, much of this carbon is released into the atmosphere, especially if the degradation is for fuel wood production or due to burning for grazing (Hoffa *et al.* 1999). These emissions contribute to global climate change, which is expected to lead to changes in biodiversity and ecosystem functioning, changes in water availability, more frequent and severe droughts and floods, increases in heat-related illness, and impacts on agriculture and energy production (IPCC 2007). These impacts will affect economies and human well-being on a global scale, but more so in developing countries that are more reliant on land and natural resources (Tol 2012). Adaptation to these changes could come at a high cost. Thus, any reduction in the rate of deforestation has a benefit to society in terms of reducing the potential impacts of climate change. While this is a global benefit, it is a benefit that will be disproportionately enjoyed by developing nations, including Zambia.

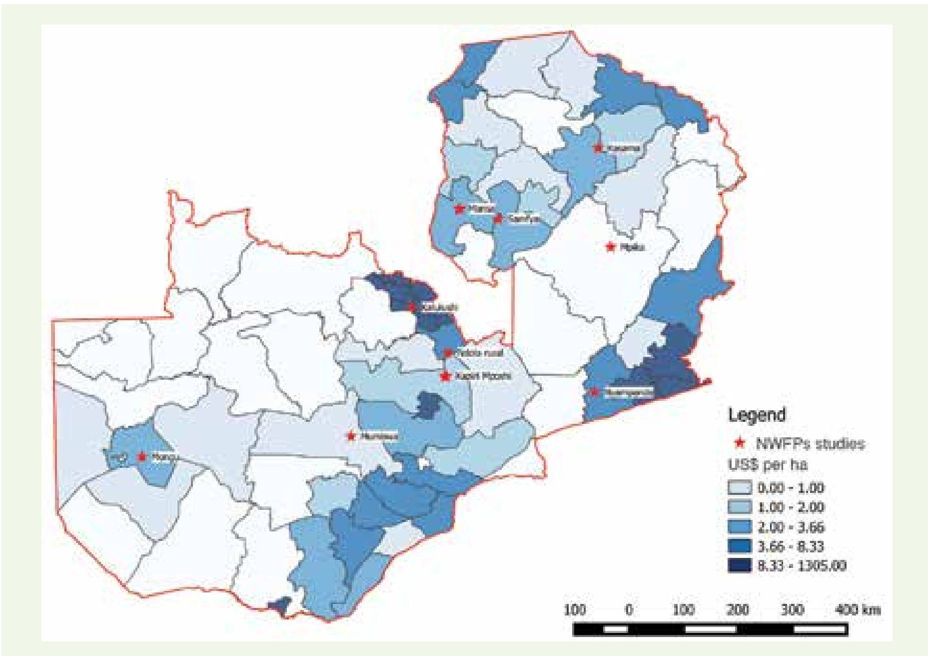
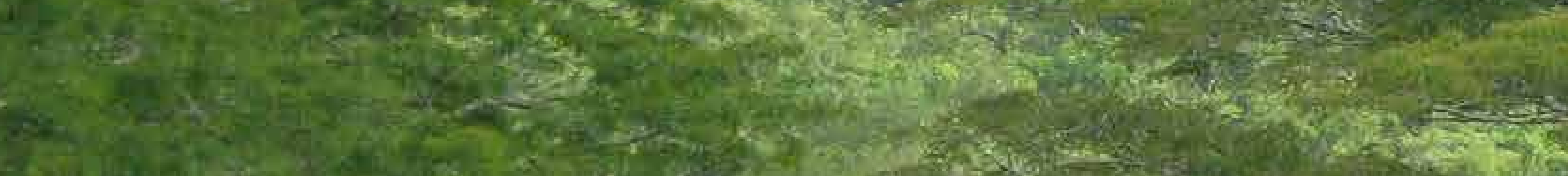


Figure 17. Estimated average non-wood forest product value per ha of forest area within each district. Red stars indicate location of studies providing data on non-wood forest products. *Source: this study.*



A substantial amount of research been carried out in recent years to estimate the social costs of carbon emissions. Furthermore, since the Kyoto Protocol, the development of emissions trading on a global scale has spawned markets for carbon sequestration and storage. In recent years, this has extended to markets for carbon that is secured or sequestered as a result of reduction of deforestation and degradation of forests. This has created opportunities for obtaining more tangible benefits from forest conservation that can potentially offset the benefits gained from damaging activities. Thus, the benefits of carbon storage can be valued in one of two ways depending on the analytical context: based on the social cost of carbon emissions, or based on market prices. In an ideal world, these values would be similar.

Carbon stocks can be estimated based on satellite data or empirical field data. While the latter are considered superior in many respects, both approaches have their limitations (Kamelarczyk 2009). Until recently, there have been very few empirical estimates of the carbon stocks and rates of sequestration in Zambian forests. The FAO (2005) reported a total biomass carbon stock in forest of 1,156 million tonnes (average 27 tonnes of carbon per ha). Then, as part of a UN-REDD programme study, Kamelarczyk (2009) used the ILUA dataset to estimate carbon stocks in Zambia. For Zambian forests (66% of land area), this study estimated above-ground carbon to be in the range of 15–24 tonnes per ha, with a total of 750–1,219 million tonnes of carbon. Above- and below-ground carbon was estimated to be in the range of 960–1,561 million tonnes, and the total carbon stock (including biomass, dead wood, litter and soil) was estimated to be between 2,652 and 3,323 million tonnes. Including other wooded lands, other lands and wetlands, the total biomass carbon was estimated to be between 1,019 and 1,720 million tonnes, and the total carbon stock in biomass and soil was estimated to be between 2,899 and 3,671 million tonnes.

UNEP and WCMC (2010) mapped the distributions of soil carbon and biomass carbon using a range of continental and global assessments based on satellite imagery, such as Ruesch and Gibbs (2008), Baccini *et al.* (2008)[14], GRZ (2009), FAO (2010) and Scharleman *et al.* (cited as in preparation). They estimated Zambia's terrestrial carbon stocks to total about 9.7 Gt (9,700 million tonnes), of which 3.2 Gt are biomass carbon (above- and below-ground) and 6.5 Gt are in the top 1 m of soils. These estimates were 2.3 and 3 times those of the average estimates of Kamelarczyk (2009) for biomass and soil carbon, respectively.

In this study, above-ground biomass for the whole country was estimated, based on the MODIS satellite data, to be 5,506 million tonnes, equivalent to 2,533 tonnes of carbon. Of this, 2,142 million tonnes of carbon were estimated to fall within forest areas (as demarcated by ZFD), the spatial distribution of which is shown in Figure 18. Note that this does include some transformed areas. Interestingly, this estimate is intermediate between those of the two above studies.

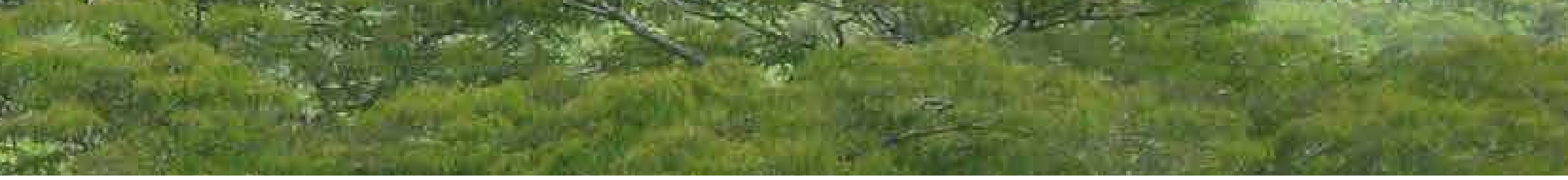
There are many studies that have attempted to put a value on the carbon stored in forests at national or global scales. The values per unit of carbon used in these studies vary considerably, as do estimates of the social cost of carbon emissions and the market price of carbon. For example, initial estimates of forest value in the USA used values of US$65 per tonne (Dunkiel and Sugarman 1998; Loomis and Richardson 2000, in Krieger 2011), whereas more recent estimates use values under US$10 per tonne.

Estimates of the social cost of carbon are based on the impacts of climate change on country GDP outputs aggregated at a global scale. A recent estimate puts this value at US$29 per tonne of carbon in 2015, and this is expected to rise at about 2% per year (Tol 2012). These impacts are not evenly shared across the globe. While developed countries emit more carbon, developing countries are expected to incur proportionally greater costs in terms of percentage of GDP.

The IPCC (1996) estimated damages to be in the order of 1% of GDP for developed countries, whereas developing countries were expected to suffer larger percentage damages so that mean global losses would be 1.5% to 3.5% of world GDP. Given that Zambia's GDP amounts to 0.08% of the GDP of low and middle income countries, this means that Zambia's share of the global costs of climate change due to a tonne of carbon being emitted would be less than 0.02%. Thus, while the loss of Zambia's entire forest estate could generate global damages worth US$62 billion, the damage costs accruing to Zambia might only be US$15 million per annum. From Zambia's perspective, there is relatively little economic incentive to prevent further losses of forests **on the grounds of mitigating climate change damages**, suggesting that other more locally relevant incentives need to be found in order to serve this global interest. Nevertheless, it should be borne in mind that the social impacts that are not reflected in GDP figures would be far more serious in developing countries, where people rely on land and natural resources for their livelihoods and where governments lack the resources to provide social welfare or to adapt to climate change through early warning systems and infrastructure.

However, since the inception of the Kyoto Protocol, the sequestration and storage of carbon by ecosystems has become a valuable commodity on a global scale (Cihlar 2007), which means that securing or restoring carbon stocks can yield benefits locally. Thus, many recent forest valuation studies have used the market value of carbon to estimate the value of forests. In 2005, the average price of carbon was in the region of US$14 per tonne (median value, Tol 2005). However, following the global economic crisis of 2008, market prices of carbon have decreased to the point of collapse of the Clean Development Mechanism. Prices in the voluntary market have been less impacted, but there is still a degree of uncertainty in this market. The State of the Voluntary Carbon Market Report suggests that ex post credits (payment after restoration) in Africa are US$8 per tonne (Peters-Stanley and Yin 2013). Ex ante carbon credits (payment in advance of restoration) may get about US$4 per tonne. Thus, we have used a mean value of US$6 per tonne, but this should be interpreted as a range of US$4–US$8 per

[14] This estimate has recently been updated (Baccini *et al.* 2013).)



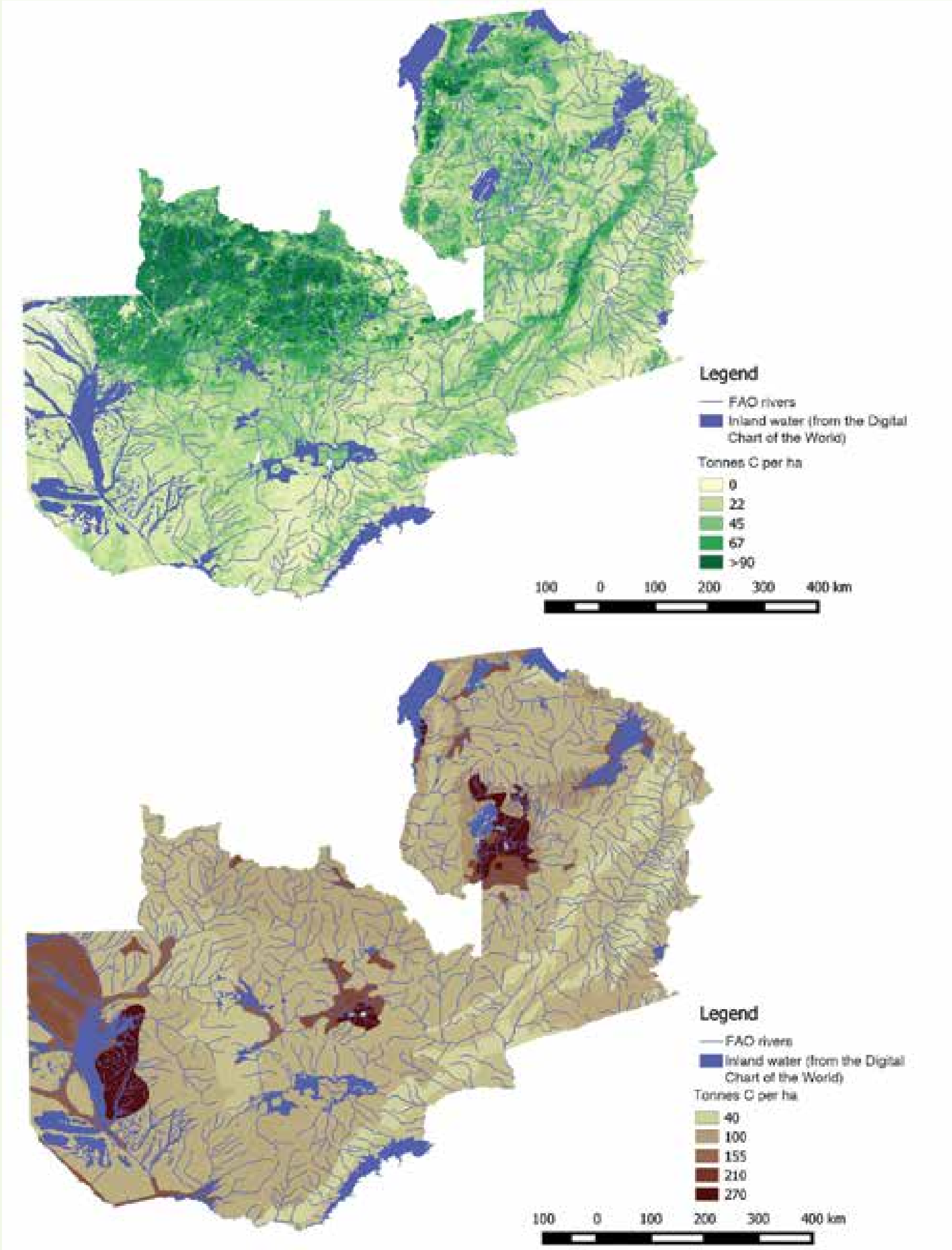


Figure 18. Estimated distribution of above-ground carbon (above) and soil carbon (below). *Source: this study.*

tonne. Note, however, that carbon prices are projected to increase in future, possibly to as high as US$37–US$114 per tonne by 2050 (Chiabai *et al.* 2011).

Our estimates suggest that above-ground carbon stocks in Zambia's forests amount to some 2,142 million tonnes, averaging 33 tonnes per ha. Average values per district range from 7 to 61 tonnes per ha, and at a finer scale, estimates of average carbon storage range up to 124.7 tonnes per ha. In an empirical study, Kalaba *et al.* (2013) found that undisturbed miombo woodlands stored 39.6 tonnes of carbon per ha in above-ground biomass, which, based on ratios in Kamelarczyk (2009), would equate to 108–140 tonnes of carbon (average 124 tonnes) per ha in total. This suggests that our estimates are in the right range.

Thus, depending on location, carbon stocks in Zambian forests are potentially worth about **US$150 per ha on average, but ranging up to US$745 per ha for intact forests.** However, this is not to say that the country's carbon stocks are worth US$15 billion (total carbon stock x US$6): US$6 is a marginal value determined by current levels of supply and demand. Although similar dollar values were used (US$6 per tonne in Kenya, US$5–US$15 per tonne in Panama), these values are

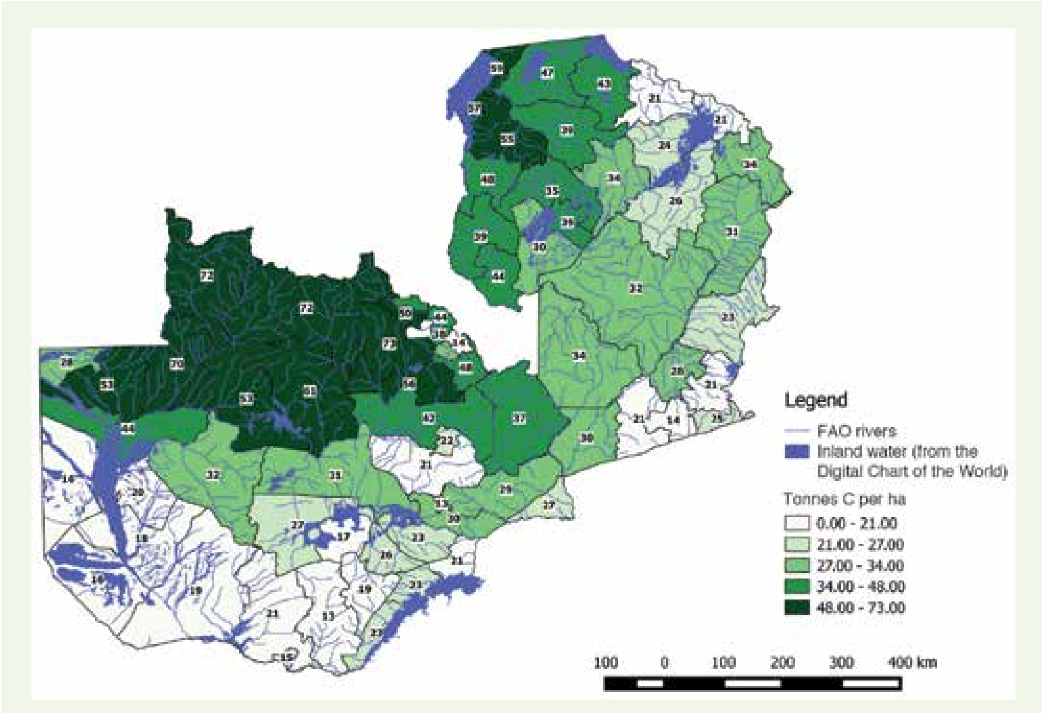


Figure 19. Average above-ground carbon per ha in ZFD 2000 forest areas only (excluding cultivated and developed areas). *Source: this study.*

somewhat lower than those estimated for Kenya's montane forests and Panama's tropical forests, which were estimated to store in the order of 190 and 322 tonnes per ha, respectively (UNEP 2012; Midler *et al.* 2013).

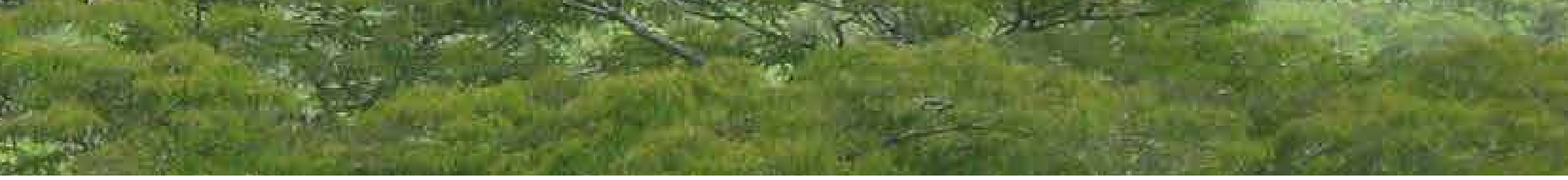
It is important to note that these are the values of stocks, and are not annual flows of values. They can be treated as net present values as for the asset value based on any ecosystem service, which is equivalent to about **US$15 per ha per year** (based on an 8% discount rate over 20 years). However, if one considers the sequestration of carbon by intact and recovering forests, then this is an annual value in addition to the storage value described above. Kalaba *et al.* (2013) found that above-ground carbon stocks in agricultural and charcoal fallows accumulated at a rate of 0.98 and 1.42 tonnes per ha per year, respectively, and reached similar levels to undisturbed miombo woodlands after about 20 years (although their biodiversity did not recover as quickly). Extending this to total carbon, this could yield sequestration rates of 2.7 to 5 tonnes per ha per year, and value flows of **US$16 to US$30 per ha per year** over 20 years. Data on the extent of such fallows were not available for this study.

4.5 Flow regulation

Key points

- Forests can play an important role in the hydrological cycle, but the nature and extent of this role is context specific.
- Zambia's forests are unlikely to have positive benefits on dry season flows through infiltration or contribute significantly to flood attenuation.
- Nevertheless, further investigation is required to determine whether the loss of forest cover over large areas could result in reduced precipitation in the region, impacting on flows, water yields and hydropower generation, and driving up the costs of electricity.

Forests are generally understood to play an important role in the hydrological cycle, which has a bearing on the quantity and quality of water available for use in agriculture, industry, power generation and domestic water supply, as well as on the impacts of floods (Sedell *et al.* 2000, in Krieger 2001). However, one has to be very careful in the interpretation of forest impacts on water yield, as this is sometimes based on the rationale that a large proportion of runoff comes from forested areas (e.g. see Krieger 2001), rather than on a consideration of the impacts of forest cover on water supply.



In general, it is understood that forests play a moderating role in regulating water runoff in a way that enhances water yields. Forests intercept runoff during high rainfall periods, facilitating infiltration of this runoff into groundwater, and through the gradual release of that groundwater, can enhance dry season flows. Where this is the case, forests can have important implications for water yields and economic outputs. However, this is not always the case. Of the rainfall and surface runoff that is intercepted by forests, part infiltrates into the ground, and the rest is lost to evapotranspiration. In some situations, the rate of evapotranspiration may be high enough to lead to reductions in dry season flows. In fact, it has generally been found that forests reduce stream flows (Blumenfeld *et al.* 2009). Bruijnzeel (2004) summarized available evidence on the hydrological impacts of deforestation and afforestation, and found that conversion of tropical forest to pasture generally produced permanent increases in stream flow (150–300 mm per year depending on rainfall, citing evidence from Zambia (Mumeka 1986).

The nature of this hydrological balance is highly context specific, and depends on factors such as the hydraulic characteristics of the soil, rainfall and slope. Where soils have low infiltration potential, the effect of forests on dry season flows is likely to be negative. Thus it is difficult to estimate the value of forest hydrological services without detailed hydrological studies of the area being valued. While stream flow data have been collected in Zambia since the 1940s, this effort collapsed after the 1980s, along with lack of maintenance of the country's approximately 600 gauging stations (Hans Beuster, Zambia-based hydrologist, pers. comm.). Unfortunately, most recorded changes in forest cover have occurred since then. Earlier, localized studies (e.g. Mumeka 1986, Meher-Homji 1991) yielded conflicting results. More recent studies have suggested that deforestation does not lead to a decrease in dry season flows, and probably results in increased flows (Cohen *et al.* 2013; Beuster, pers. comm.). In a valuation study of Panama forests, which have been the subject of several hydrological studies, the value of hydrological services ranged from strongly negative to strongly positive values, with an overall average negative value (Midler *et al.* 2013). Given the available evidence and the fact that Zambia does not have high relief or very high rainfall in relation to evaporation, if is quite likely that its forests do not improve dry season flows, and therefore have little or no positive value in contributing to water yields.

Forests can also play a role in the attenuation of small, local floods by slowing the movement of water through the landscape. Where forests occur in floodplains they can cause enough resistance to mitigate larger floods. No studies have been carried out on the extent to which forest cover may play a role in influencing the magnitude of floods and mitigating their damages. However, it is likely that forests do not have a major role to play in flood attenuation in Zambia, while floodplain wetlands are probably very important in this regard.

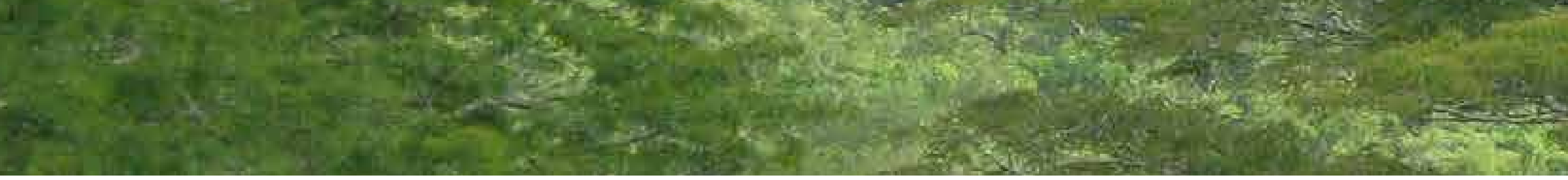
While there is uncertainty about the short-term effects of local forest loss on immediate flow generation, there is little doubt that loss of forest cover and forest degradation over large areas (extending beyond the borders of Zambia) would result in reduced precipitation as the relative humidity of the air declines. A reduction in precipitation would have a negative impact on flows, water yields and electricity generation, and drive up the costs of electricity in Zambia. Given the very high level of dependence of the Zambian economy – in particular copper smelting and retail activities – on electricity, this could have measurable impacts. Such an analysis, requiring a detailed model of climatic impacts of deforestation over vast areas on water yield as well as economic analysis of the potential (marginal) impacts on sectors that are highly dependent on (hydropower) electricity is beyond the scope of this report, but should not be overlooked in subsequent more detailed analyses.

4.6 Erosion control and sediment retention

Key points

- Forests prevent erosion by stabilizing soil and by intercepting rainfall, thereby reducing its erosivity.
- Soil erosion and transport was modelled for Zambia's catchment areas using InVEST, and the value of sediment retention was based on international estimates of the costs of dam sedimentation.
- It was estimated that current rates of sediment output are in the order of 250 million tonnes (average 2.23 tonnes per ha), and that forests retain 274 million tonnes, generating a **cost saving of US$247 million per annum.**

Vegetative cover prevents erosion by stabilizing soil and by intercepting rainfall, thereby reducing its erosivity (de Groot *et al.* 2002). This is particularly effective where soils are highly erodible. Though not to the same extent as wetlands, forests may also capture the sediments that are eroded from agricultural and degraded lands and transported in surface flows, preventing them from entering streams and rivers (Blumenfeld *et al.* 2009). This protects downstream users from the impacts of sedimentation, which can include impacts on water storage capacity, agricultural productivity, hydropower generation and navigability of rivers (Pimentel *et al.* 1995). Some studies also emphasize the role of forests in retaining soil fertility, which is lost when forests are converted to agricultural use. This function has been valued in terms of the potential cost of using fertilizers to replace lost soil fertility (e.g. US$490 per ha in Brazil (Torras 2000), and applied in Midler *et al.* (2013)). However, in Zambia, forests are completely cleared for agriculture. Thus, fertile soils in intact forests have no agricultural value until the forests are removed. The agricultural potential of forest soils is in fact one of the opportunity costs of forest conservation, not vice versa.



In Zambia, the main off-site costs of erosion are likely to be associated with dam sedimentation, affecting water available for agricultural and hydropower production and/or reducing downstream flows, during the dry season. Globally, the overall annual costs of dams are around US$57 billion and the benefits are in the order of US$175 billion to US$225 billion[15] (Basson *et al.* 2009). Reservoir sedimentation has been estimated to account for about 37% of the annual costs (i.e. US$21 billion) in terms of replacement cost (Basson *et al.* 2009).

Most of Zambia's storage capacity is in a few large dams used for hydropower generation. The state-owned Zambia Electricity Supply Corporation Limited (ZESCO) supplies 80% of Zambia's power. Nearly all of this (99.6%) is from hydropower generation, with diesel generation making up the remainder (CSO 2013; Table 16). The main government-owned hydropower stations are at Kariba Dam, Kafue Gorge and Victoria Falls. In addition, there are four mini-hydropower stations. The Kariba Dam is shared with Zimbabwe, but each country has its own turbines, on the north and south side, respectively. In addition, a private company, the Lunsemfwa Hydro Power Company owns hydropower plants at Mulungushi Dam, Mita Hills Dam and Lunsemfwa Falls near Kabwe in Central Province, and is the only private power-generating company that is a member of the Southern African Power Pool. These facilities have a combined capacity of 56 MW at present. Zambia is still in the process of harnessing its considerable hydroelectric power potential. ZESCO is building a power station at the Itezhi-tezhi Dam, which was originally built in order to augment dry season flows for the hydropower station of the Kafue Gorge Dam, 260 km downstream. ZESCO is also planning further developments in the Kafue Gorge Lower (750 MW) and the Batoka Gorge (800 MW). Lunsemfwa Hydro Power Company, which also owns the Muchinga Power Company, plans to upgrade and increase its outputs to 350–420 MW (aguaimara.com) including a further 300 MW on the Lunsemfwa River.

While several of the smaller generation plants rely on run-of-river flows, the bulk of Zambia's hydropower generation relies on a few large reservoirs – the Mulungushi (built in 1925), Mita Hills (from the 1950s), Kariba (1959), Kafue (1971), and the Itezhi-tezhi (1978) (Table 16). Of these, the Kariba Dam is one of the largest hydroelectric power reservoirs in the world. It has a capacity of 180,000 million m^3 (180 km^3) of which about half is in Zambia. The combined hydropower reservoir capacity in Zambia is 94,826 million m^3, of which more than 99% is the Zambian half of Kariba Dam. Installed capacity is not proportional to storage capacity, however, and two dams, Kariba and Kafue, account for 58% and 31% of reservoir-based installed capacity, respectively[16].

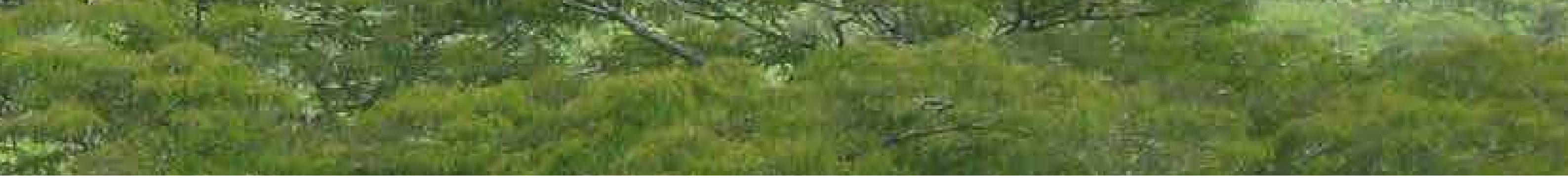
Table 16. Installed and available hydropower generation capacity in Zambia. *Sources: CSO 2013 – Energy Statistics 2000–2011; FAO Aquastat database.*

Type	Reservoir/station name	Storage capacity (million m^3)	Installed capacity (MW)	Available capacity (MW)	Percentage of installed capacity from reservoir
ZESCO (main)	Kafue Gorge	785	530	315	
	Itezhi-tezhi	4 925	120*	971	31
	Kariba North	94 000	990	90	7
	Victoria Falls	n/a	108		58
	Sub-total		**1 628**	**1 376**	
ZESCO (mini)	Lusiwasi	n/a	12	8	
	Musonda Falls	n/a	5	4	
	Chishimba Falls	n/a	6	5	
	Lunzua River	n/a	0.75	0.75	
	Sub-total		**23.75**	**17.75**	
Lunsemfwa Hydro Power Company (private)	Mulungushi	41.4			3
	Mita Hills/Lunsemfwa	1 382			
	Sub-total	**94 826**	**56**	**56?**	

*Planned to have been installed by 2013.

[15] Basson *et al.* (2009) valued electric power supply at US$0.05 per TWH.

[16] For details on dams, see bscw-app1.let.ethz.ch



In addition to these large dams, Zambia also has at least 546 smaller reservoirs for agricultural water supply[17]. The 173 dams for which capacity data were available accounted for a total of 23 million m^3, suggesting a total storage capacity of about 78 million m^3.

Sedimentation of dams is inevitable to some extent, since there is some erosion of catchment areas even under natural conditions. As catchments become developed for agriculture and forestry, so rates of erosion and sediment loads increase. The average sediment content of rivers globally is about 0.6 to 0.75 tonnes per 1,000 m^3 of water, although this varies according to the catchment characteristics and discharge (Basson *et al.* 2009). Dams are usually designed to cope with a certain amount of sediment input, but are nevertheless expected to have a finite lifespan. In the case of hydropower dams, efforts are made to extend this lifespan by including "dead storage" capacity which is designed for sediment accumulation. On average, sediment accumulation in dams occurs at a rate of 0.8% of the total storage per year (Basson *et al.* 2009), again varying with location. In the case of hydropower dams, part of this is in dead storage, and the loss of power supply is not proportional to the loss of live storage. Globally, the annual loss of power supply tends to be in the range of 0.6% of a total investment of about US$1,000 billion for live storage, i.e. US$6 billion per year (Basson *et al.* 2009). This suggests that live storage is worth about US$250m per km^3. Eventually the dams have to be replaced by new dams. At a cost of the total storage capacity (dead and live) and at a global investment of US$1,700 billion, the annual cost of replacement is 0.8% x US$1,700 billion = US$13.6 billion per year.

In Zambia, the average rate of sediment accumulation is 0.63% of total storage per year, and at this rate, the storage capacity of hydropower dams will be reduced to 60% of current capacity within 50 years[18] (Basson *et al.* 2009). At about US$0.25 per m^3 of storage in hydropower dams and US$0.5 per m^3 in agricultural dams, the annual replacement cost of such an impact is approximately US$150 million per annum. This is a very high proportion of the revenues to ZESCO of about US$250 million (2007). These estimates suggest that about 330 million tonnes of sediment are deposited in dams annually.

These estimates are for current conditions, where basal sedimentation loads have already been elevated by land use changes. However, there is no existing information on the degree to which deforestation has been responsible for these costs. In this study we estimated the degree to which forests prevent soil erosion and the transport of sediments to dams using the InVEST Sediment Retention module, Version 3.0.0[19]. The model calculates the average annual soil loss from a delineated catchment area (watershed) to determine the quantity of soil that is transported out of the catchment. It also estimates the ability of each parcel to retain sediment as a function of vegetation cover and management practices. A more detailed description of the model can be found in the InVEST User Guide (Tallis *et al.* 2013).

The details of the data and assumptions used in this study are given in Appendix 3[20]. By comparing the modelled sediment outputs per catchment under current land cover versus fully transformed land use, it was possible to estimate the difference made by forests to the sediment loads transported to dams (Figure 20).

The modelled outputs suggested that current rates of sediment output are in the order of 250 million tonnes (average 2.23 tonnes per ha), and the estimated sediment retention is in the order of 274 million tonnes (average 2.88 tonnes per ha per year). Depending on the type of dam affected, this potentially generates savings of US$123 million to US$247 million per year (average US$1.2–US$2.9 per ha per year). These estimates are low compared to the 330 million tonnes estimated above and to sediment retention rates estimated in other studies, such as the valuation study in Panama that was crried out by UNEP as part of the UN-REDD Programme and which found 14 tonnes per ha, valued at US$6 per ha (UNEP, 2014).

and may be due to the relatively crude nature of our underlying elevation and hydrological models, as well as the sensitivity of the model to the assumptions. Note that our estimate also does not include the potential damage to hydropower facilities that use in-stream flow, which may also be impacted by elevated sediment loads through damage to turbines.

Sedimentation costs can also be valued in terms of estimated impacts on gross income from hydropower generation (e.g. Aylward 2002; Porras *et al.* 2001, in Midler *et al.* 2013)[21]. However, as noted by Basson *et al.* (2009), one has to be cautious in applying this approach due to the non-linearity of the relationship between storage capacity and power generation. Nevertheless, it is important to note that the value of soil retention by forests is likely to vary greatly by location due to the very different ratios of storage capacity to hydropower output of the different reservoir-based hydropower facilities. Further work is required to refine these estimates.

[17] This is based on available spatial databases, and is likely to be incomplete.

[18] Note: Basson *et al.* (2009) reported 127,150 Mm^3 (2006 capacity) to 77,154 Mm^3 by 2050 for Zambia, but the starting capacity is that of the entire Zambezi river bRiver asin. Mw^3 stands for cubic megameter

[19] http://www.naturalcapitalproject.org/InVEST.html

[20] In addition, a comprehensive overview of the modules, their data requirements, in-built methods and procedures for interpretation of model results are provided for InVEST online: (http://ncp-dev.stanford.edu/~dataportal/invest-releases/documentation/current_release/)

[21] Midler *et al.* (2013) multiplied the retention capacity of forests by the average annual revenue per m^3 of water – we caution that these measures usually pertain to flows rather than storage capacity, so this analysis may be flawed.

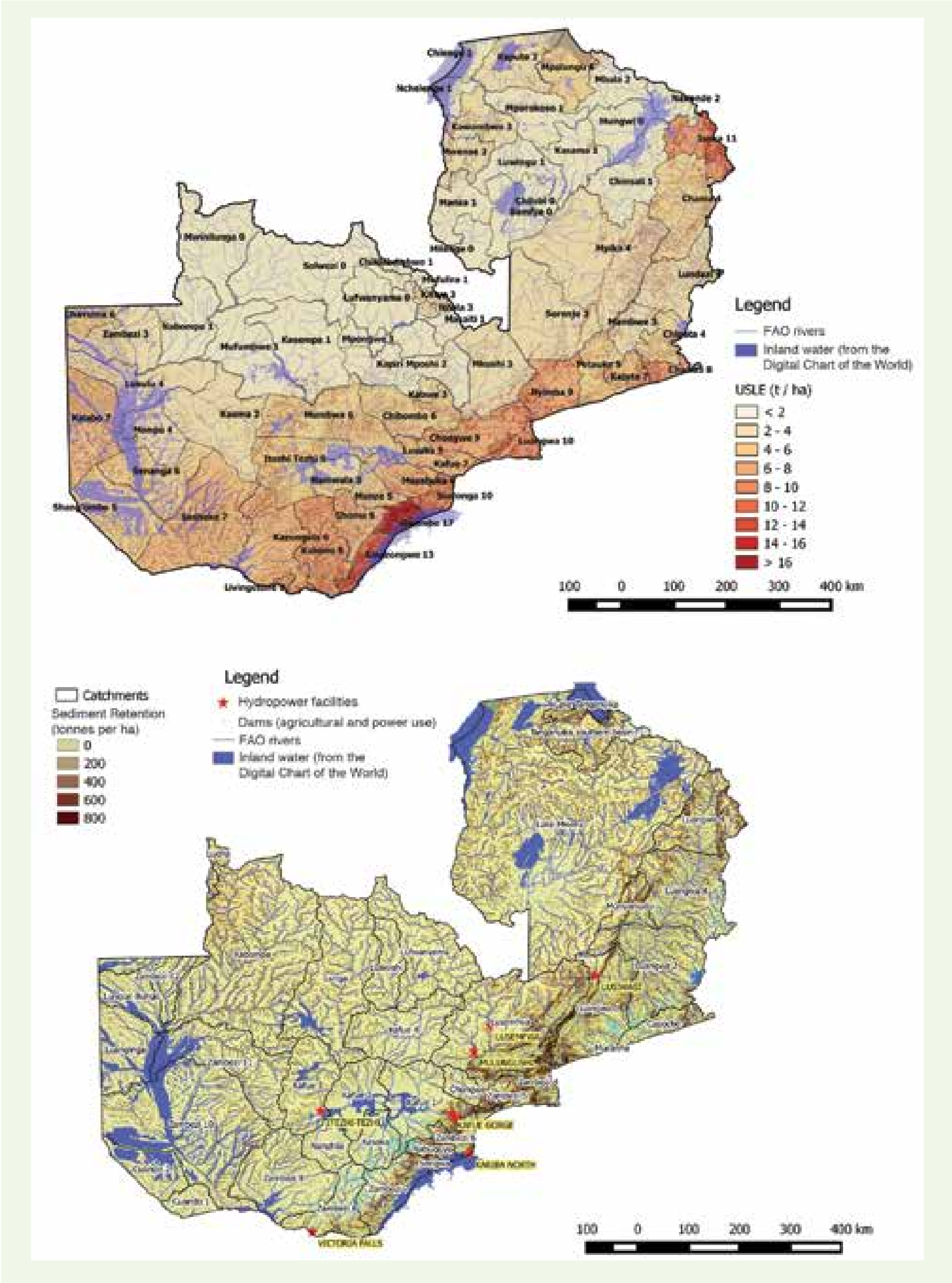
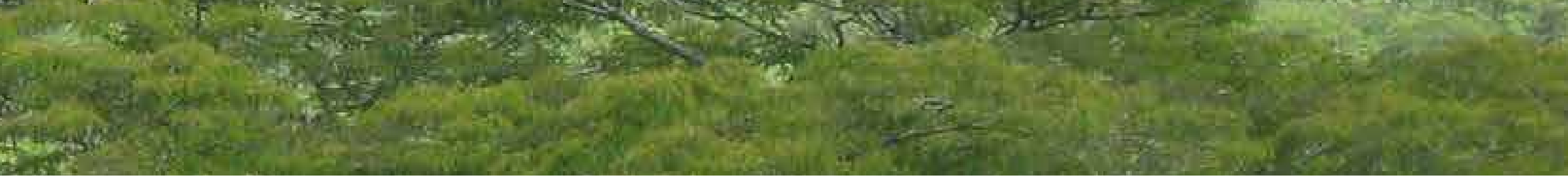


Figure 20.Estimated sediment yield per ha per year (above) and the retention rate by forests per ha per year, shown in relation to catchments and hydropower facilities, in detailed spatial resolution (below). *Source: this study.*

Photo credit: © Benjamin Warr



4.7
Water quality amelioration

Key points

- Forests are expected to play a minor role in the amelioration of water quality because of their location in the landscape, but it is important to note that the agricultural and mining activities that replace forests impact negatively on water quality.

Protecting natural forests can protect drinking water supplies, inasmuch as it prevents damaging land uses with their inputs of nutrients, pesticides and chemicals (Blumenfeld *et al.* 2009). This service is linked to the sediment retention service described above, since suspended sediments also add to water treatment costs. Vincent *et al.* (2014) recently undertook a study of the influence of forests on water treatment costs in Malaysia using time series data of land cover and water treatment cost. Their study found that while conversion to agriculture incurs a significant increase in water treatment costs, forests themselves did relatively little to remove nutrients, probably because of their location in the landscape. Such time series data were not available for this study, but it would be expected that a similar result would be found for forests and that Zambia's large floodplain wetlands would play the greatest role in water quality amelioration. Nevertheless, it is important to realize that the degradation and loss of forests is caused by activities that will increase pollutant loads in rivers. Thus, forest conservation can help to ensure water quality in this regard. This was also observed by Bäumle and Nkhoma (2008) in their description of the groundwater resources around Lusaka.

4.8
Agricultural support services (pest control and pollination)

Key points

- Forests provide habitat for insects that pollinate certain crops and for organisms that prey on agricultural pest species, thus reducing agricultural input costs.
- These relationships are poorly understood, not only in Zambia.
- The value of pollination services was estimated based on the output of crops, their degree of dependence on insect pollination, and the costs of alternative means of pollination obtained from the international literature.
- The value of forest **pollination services** was estimated to be in the order of **US$74 million per annum**.
- This service would be supplied by between 330,000 and 980,000 ha of forest land surrounding agricultural areas.
- The contribution of forests to agricultural pest control is unknown.

It has been estimated that as much as 30% of worldwide food production is reliant upon pollination by insects that rely on natural vegetation (de Groot *et al.* 2002; Kremen *et al.* 2002). Pollination and the control of agricultural pests and diseases by organisms that depend on forest habitats are generally recognized ecosystem services that are mentioned in the literature on Zambian forests, but no empirical research has been carried out on them in Zambia. Little empirical research has been carried out, and the value estimates of these services are based on assumptions and studies from elsewhere (e.g. Morse and Calderone 2000; Kremen *et al.* 2002; Losey and Vaughan 2006).

In Zambia, agricultural production was estimated to generate a gross output of US$2,879 million in 2010, with a value added of US$1,765 million, forming 9% of national GDP (CSO 2014). Maize and cassava are the two main staples in Zambia and dominate crop production (GRZ 2011; Table 17). Maize is predominant in central, southern and eastern Zambia and cassava is more important in northern and western Zambia (FAO 2002). Unlike maize, cassava is almost entirely produced by small-scale farmers (Mkumbira 2008), and is not included in the annual crop forecasts (e.g. CSO 2012e).

Of the crops summarized in GRZ (2011) and CSO (2012e), most are wind pollinated, including all the grain crops such as maize and rice. In the case of root crops such as sweet potato and cassava, production is not directly dependent on pollination, since the plants are usually propagated with cuttings, although pollinators are required in breeding programmes (Roubik 1995). However, a few crops are directly dependent on insect pollination, including cotton, sunflower, soya beans, cow peas and paprika. Based on the combined data from GRZ (2011) and CSO (2012e), these crops make up only about 6% of Zambia's production by weight (data on the value of output per crop could not be found). Fruit crops such as mangos also require insect pollination, but no data were available on the production of these.

Many studies have estimated the value of pollination services using data on the dependency of crops on honeybee pollination (e.g. Johansmeier and Mostert 2001), and multiplying this by the annual production value of crops in an area (e.g. Morse and Calderone 2000; Losey and Vaughn 2006). However, a better way to evaluate the service is to determine what costs would be incurred if those services were no longer available (Allsopp *et al.* 2008). This means

Table 17. Estimated agricultural production in 2012 from two sources.

Crop	Area planted (ha)	Expected production (MT) (CSO 2012e)	Estimated production (MT) (SNDP 2011)	Insect pollinated
Cassava	No data	No data	4 425 168	-
Maize	1 284 786	2 884 840	2 852 687	-
Seed cotton	314 497	269 502	269 502	Yes
Wheat	37 230	253 522	253 522	
Soya beans	86 223	203 038	203 038	Yes
Sweet potatoes	42 847	163 484	163 484	
Groundnuts	184 397	113 026	113 026	
Mixed beans	88 673	55 301	55 301	
Rice	31 388	45 321	45 321	
Irish Potatoes	1 903	32 066	No data	
Millet	35 828	28 446	28 446	
Virginia tobacco*	10 725	24 250	7 067	
Sunflower	40 870	20 468	20 468	Yes
Sorghum	18 685	15 379	15 379	
Barley	2 142	15 295	No data	
Burley tobacco	3 161	7 067	No data	
Bambara nuts	5 181	4 712	No data	
Pineapple	1 198	4 689	No data	
Cowpeas	4 869	2 139	No data	Yes
Paprika	680	965	No data	Yes

*Note there is a mix-up between Virginia and Burley tobacco in the reported data.

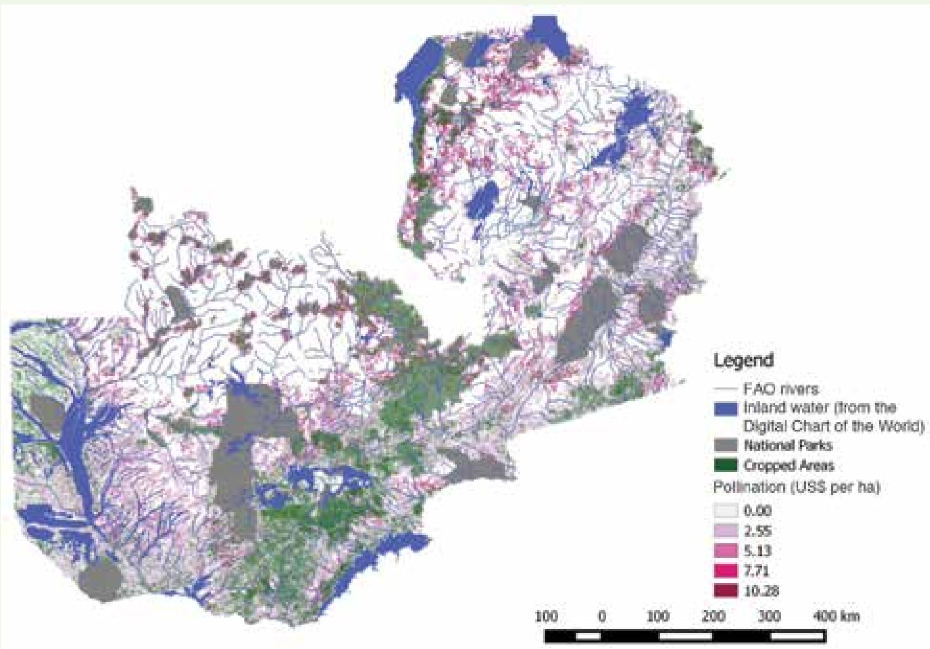
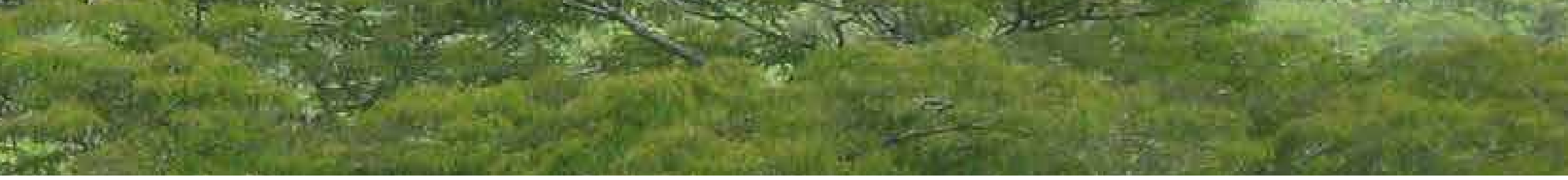


Figure 21. Estimated spatial distribution of the value of crop pollination services supplied by forests. *Source: this study.*



bringing in pollinators from elsewhere, or using hand pollination. Based on estimates of the number of hives required per ha (Bwalya 2009), and the cost of hiring hives in South Africa (US$26; Allsopp *et al.* 2008), the replacement cost for these services was estimated to be in the order of **US$74 million per annum.** This provides a relatively conservative but realistic estimate of the value of pollination services. This value is not evenly spread among Zambia's forests, but would be supplied by forest areas adjacent to farming areas. Based on studies of the range of densities of bee colonies in natural areas (Jaffé *et al.* 2009), it is estimated that the service would be supplied by between 330,000 and 980,000 ha of forest land surrounding agricultural areas. The estimated distribution of the value of pollination services supplied by forests is shown in Figure 21. In addition to pollination, natural habitats provide some degree of control of agricultural pests through predation. However, very little is known about this service globally, let alone locally, and estimation of this value will require further empirical investigation.

4.9
Ecotourism

Key points

- Zambia aims to become a major tourist destination of choice with unique features that will contribute to sustainable tourism, economic growth and poverty reduction.
- Nature-based tourism is the dominant form of holiday tourism to Zambia, and forests are an integral part of the nature-based tourism experience.
- The contribution of forests to the value of tourism was estimated on the basis of a prior unpublished estimate of ecotourism value, a recent estimate of tourism value (World Travel and Tourism Council (WTTC)), and the distribution of tourism activity as indicated by the densities of photographs uploaded to Google Earth's Panoramio layer.
- The direct value added by **forest-based tourism** is estimated to be in the range of **US$110 million to US$179 million per annum**.

Tourism is a very important economic stimulus for the country's economy through its direct linkages with the transport and hospitality industries and indirect linkages to other sectors. The government's long-term vision for the tourism sector is to ensure that Zambia becomes a major tourist destination of choice with unique features that will contribute to sustainable tourism, economic growth and poverty reduction (Zambia Tourism 2013).

Nature-based tourism is the dominant form of holiday tourism to Zambia, and forests are an integral part of this. Zambia's nature-based tourism is dominated by two main products –Victoria Falls, which received 120,000 visitors in 2005, and wildlife safaris, which received 30,000 visitors in 2005 (Hamilton *et al.* 2007[22]). Adventure tourism is a third important product, which is centred in Livingstone and linked to the activities accessed by visitors to both the Zambian and Zimbabwean side of Victoria Falls.

Wildlife tourism is concentrated in the country's 19 national parks and 34 game management areas (Figure 9). More than 61,000 people visited national parks in 2005, of which close to 42,000 were international visitors (Table 18). The South Luangwa and Mosi-oa-Tunya (next to Victoria Falls) were the most frequently visited parks (Table 19).

Table 18. Tourist visits to the national parks: 2003–2005. *Source: Hamilton et al. 2007.*

Type of tourist	2003	2004	2005
International	40 388	38 821	41 964
Local	12 152	15 157	19 436
Total	**52 540**	**53 978**	**61 400**

Table 19. Number of visitors to national parks: 2003–2005. *Source: Hamilton et al. 2007.*

Park	2003	2004	2005
Lower Zambezi	4 413	6 059	6 040
Mosi-oa-Tunya	23 497	17 762	19 972
South Luangwa	19 728	23 929	25 814
Kafue	3 812	3 789	6 202
Lochnivar	390	415	784
Other parks *	700	2 024	2 588
Total	**52 540**	**53 978**	**61 400**

While wetland and floodplain areas are important features of some of the larger parks, as these afford excellent opportunities for wildlife viewing, forests and woodlands are dominant in the game management areas, which serve as buffer zones between national parks and farming areas. These are the main areas used for hunting tourism. The game management areas have received government and donor support over the last 20 years for community-based natural resource management. Hunting in the game management areas, game ranches and open areas is generally carried out by private safari operators and generates about US$1.6 million from concession and trophy fees and other related fees (Hamilton *et al.* 2007). Some 90% of the Zambia Wildlife Authority hunting revenue is generated from approximately 10% of the available hunting quota. It is also

[22] We also obtained a later version of this draft report dated 2014, but it appears to cover the same material as the original, so we have used the original date.

of interest here that game management areas are variably classified as "Prime", "Secondary", or "Depleted", depending on the abundance and variety of wildlife species available.

In order to evaluate how nature-based tourism is distributed geographically in relation to forests, we used the density of photograph uploads on Google Earth's Panoramio as a proxy indicator of the spatial distribution of tourist activity and sources of satisfaction. Using a macro, the number of photographs was summarized spatially using a grid of 20 x 20 km. Data were log-transformed and the pattern was interpolated using an ordinary kriging method in a GIS platform. The resulting pattern shows that by far the most activity is within Victoria Falls, Lusaka, mining areas and Luangwa valley (Figure 22). Of course, photographic uploads are potentially done by all types of people, not just ecotourists, but, given the technology involved, they are likely to be dominated by international visitors in Zambia for both business and leisure purposes. It was assumed that the high density of photographs in the mining areas and towns were not forest-based tourism (Livingstone tourism is nature-based but is focused on Victoria Falls). The remaining photograph uploads were mainly in national parks and their immediate surrounds. Based on this, it was estimated that 74% of nature-based activity was attributed to forested areas.

Based on a survey of visitors, Hamilton *et al.* (2007) estimated that at least 88% of visitors on holiday trips were nature tourists visiting Victoria Falls, viewing wildlife or taking an adventure trip, and that 176,000 of the 669,000 visitors to Zambia in 2005 were nature-based tourists (26%). These tourists spent an average of 6.9 days in Zambia, and spent some US$1,100 per trip. Using an input-output model, the expenditure by a nature tourist was estimated to generate about US$1,300 worth of wages and net income of unincorporated business, US$420 in tax revenue, and US$425 worth of imports of goods and services (Hamilton *et al.* 2007).

An estimated 54,000 jobs were created, equivalent to one full-time-equivalent job for every three nature tourists. The total (direct + indirect) value added by nature-based tourism in 2005 was estimated to be in the order of US$403 million (Table 20). Nature-based tourism expenditure was estimated to contribute 7.5% of GDP, 18% of exports, 7% of wages and net income of unincorporated business, 8% of government revenues, nearly 10% of formal sector employment, and 5% of imports.

Table 20. Direct and indirect economic impact of nature-based tourists in 2005. *Source: Hamilton et al. 2007.*

	Economic impact of nature-based tourists (US$)	
	One tourist	**176,000 tourists**
Value added (direct + indirect)	2 288	403 million
Indirect taxes	152	27 million
Corporate taxes	265	47 million
Imports	425	75 million

Tourism arrivals in Zambia have increased from 669,000 in 2005 to over 920,000 in 2011 (Figure 23). In 2011, tourism is estimated to have made a direct contribution of US$397 million and a total contribution of US$907 million to the Zambian economy (Table 21). Leisure travel spending (in-

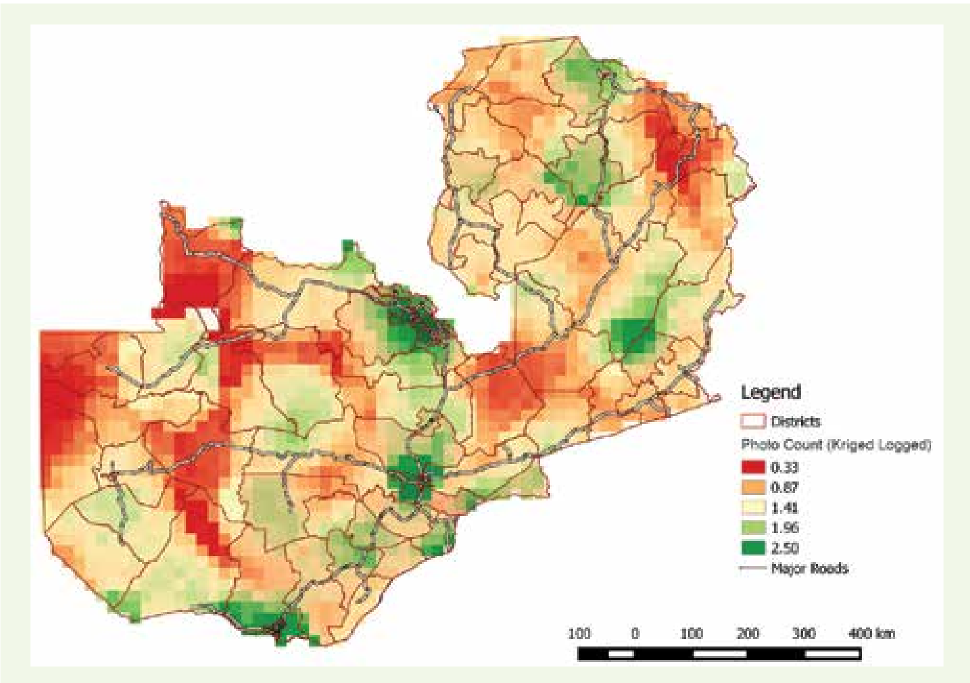
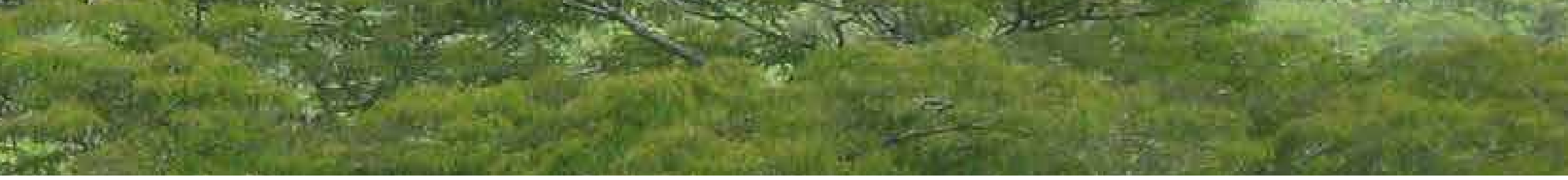


Figure 22. Distribution of photographs uploaded to Google Earth's Panoramio layer as an indication of the spatial geography of visitor focus. *Source: this study.*



bound and domestic) generated 48.2% of direct travel and tourism GDP in 2011 (Zambian Kwacha (ZMK) 1,639.8 billion) compared with 51.8% for business travel spending (ZMK1,762.7 billion). Domestic travel spending generated 71.6% of direct travel and tourism GDP in 2011 compared with 28.4% for visitor exports (i.e. foreign visitor spending or international tourism receipts) (WTTC 2012).

million for total value added (Table 22). Similarly, a large range of estimated employment impacts (direct + indirect) was obtained based on the two studies. This highlights the need for more up-to-date empirical studies of the tourism sector. Upper-bound estimates of the total value added by forests is shown for each of the main attraction areas (parks and their immediate surrounds) in Figure 24.

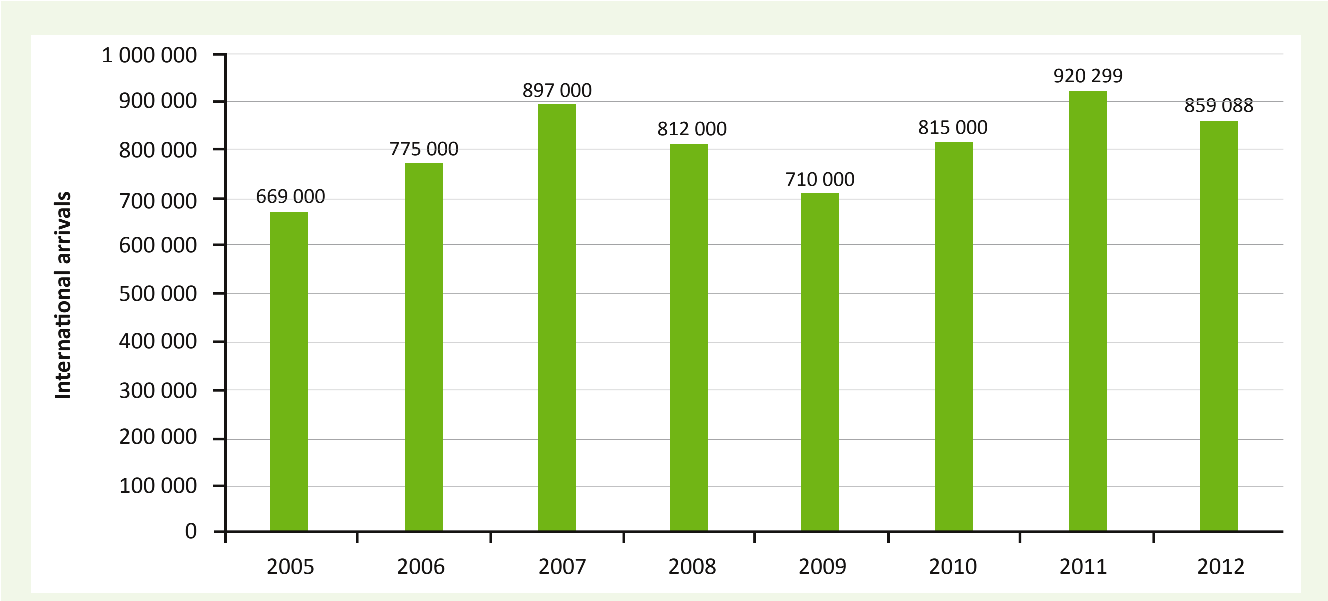


Figure 23. Tourism arrivals to Zambia from 2005 to 2012. *Source: Zambia Tourism 2013.*

Tourism also provides many jobs, including a significant proportion of jobs for women. According to the WTTC (2012), travel and tourism in Zambia in 2011 generated 22,000 jobs directly (1.4% of total employment). This includes employment by hotels, travel agents, airlines and other transport services, as well as restaurant and leisure industries directly supported by tourists. Including the wider effects from investment, the supply chain and induced income impacts, a total of 58,000 jobs were created in 2011 (3.7% of total employment).

Based on the findings of Hamilton *et al.* (2007) and the distribution of tourism activity, it is estimated that there were 242,000 nature-based tourism visitors to Zambia in 2011, and that 74% of tourism expenditure was attributed to forested areas. The impacts of this expenditure were estimated using the very different multipliers in Hamilton (2007) and in WTTC (2012). While Hamilton used an expenditure to total value added multiplier of 2.1, the WTTC (2012) study suggests an equivalent multiplier of 1.29, or 2.29 for direct value added to total value added (Table 21). This generated a range of estimates from **US$110 million to US$179 million** for direct value added and from US$252 million to US$410

Photo credit: © Benjamin Warr

Table 21. Estimated contribution of tourism to the economy in 2011. *Source: WTTC 2012.*

	Category	ZMK (billion) 2012	US$ (million)
1	Visitor exports	952.6	198.6
2	Domestic expenditure	2 404.2	501.2
3	International tourism consumption (= 1 + 2 + government individual spending)	3 402.5	709.4
4	Purchase by tourism providers, including imported goods (supply chain)	-1 444.2	-301.1
5	**Direct contribution of travel and tourism to GDP (= 3 + 4)**	**1 903.5**	**396.9**
Other final impacts (indirect and induced)			
6	Domestic supply chain	1 137.6	237.2
7	Capital investment	318.4	66.4
8	Government collective spending	323.3	67.4
9	Imported goods from indirect spending	-143.6	-29.9
10	Induced	812.3	169.4
11	**Total contribution of travel and tourism to GDP (sum of 5 to 10)**	**4 351.4**	**907.2**
Employment impacts		**People ('000s)**	
12	Direct contribution to employment	21.9	
13	Total contribution to employment	57.9	

Table 22.Estimated tourism value attributed to forested areas of Zambia.

	WTTO 2012 multiplier	Hamilton 2007 multiplier
Estimated number of nature-based tourists	242 000	
Total expenditure attributed to forested areas (US$ million)	197.0	
Direct value added (US$ million)	110.20	179.38
Total value added (US$ million)	251.88	410.00
Employment (people)	16 100	59 700

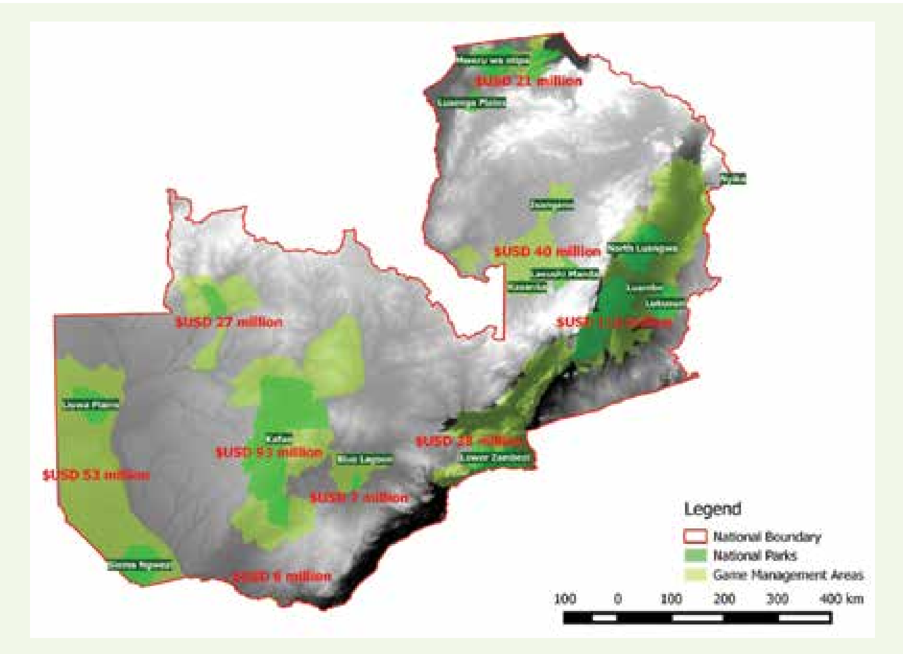
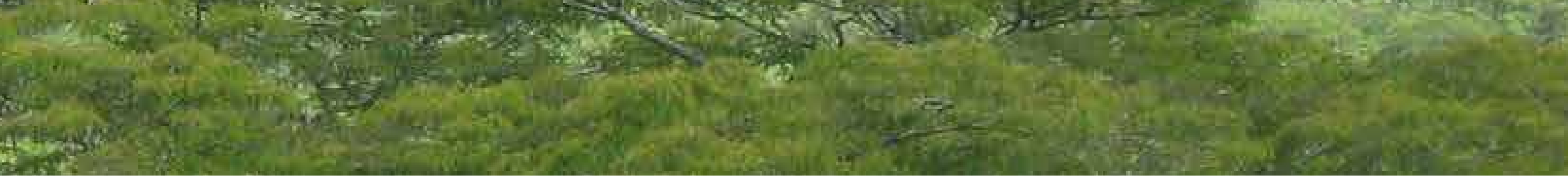


Figure 24. Estimated value of the different parks and associated game management areas. *Source: this study.*



05

Overall contribution of forests to the economy

5.1

Contribution to national income

The updated national accounts, released in July 2014, suggest that forestry comprised only 0.8% of Zambia's GDP in 2010, or **US$156 million** of a total GDP of US$20.3 billion[23] (CSO 2014). However, standard national accounting systems do not reflect all of the values generated by natural systems – particularly regulating, supporting and cultural services – nor do they account for any depreciation in natural capital. If the benefits of forests to downstream sectors, and hence their contribution to economic development, were better understood, this would help to ensure optimal public investment in forest management (Jumbe *et al.* 2008; Kalinda *et al.* 2008). Given the poor knowledge of the value of this sector, it is not surprising that the forestry sector is severely under-funded and under-capacitated.

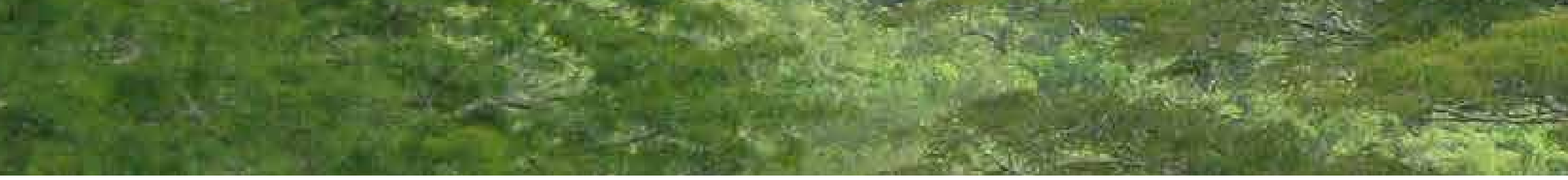
There are several estimates of the contribution of forests to GDP in Zambia, but all of these have been partial estimates. In 2003, the forest sector was reported to contribute 5.4% to GDP (CSO 2003, in Kalinda *et al.* 2008). In 2004, the forest sector (including forestry and forest industries) was estimated to contribute US$209 million, or 3.7%, to Zambia's GDP. Of this, charcoal, firewood and household production of timber and non-timber forest products accounted for 2.2%, 0.8%, 0.3% and 0.1%, respectively, and forest industries (primary and secondary processing) accounted for 0.3% (CSO 2004, in Puustjärvi *et al.* 2005). These estimates included subsistence consumption valued at market prices, but were nevertheless based on very poor data and considered to be underestimated (Puustjärvi *et al.* 2005). In order to address this gap, Ng'andwe *et al.* (2006) undertook a national survey of the industry and households engaged in forest-related activities and estimated that the direct value added by forestry was US$421 million in 2006, contributing 5.2% of GDP (Table 23). Another (partial) estimate of the contribution of the formal forestry sector was provided by FAO (2014), which estimated that the contribution of roundwood production, wood processing and pulp and paper contributed 6.2% of GDP.

The lack of actual data in the estimation of the forestry contribution to national accounts is reflected in the growth rate of the forestry sector, which was 4.3% in every year from 2001 to 2005 (as reported in Kalinda *et al.* 2008). This is in stark contrast to the report by Ng'andwe *et al.* (2006) in which the forestry sector contribution to GDP was estimated to increase by between 22% and 94% per year from 1.1% of GDP in 2001 to 5.2% in 2006 (Ng'andwe *et al.* 2006). Citing the 2003 contribution of 5.4%, Kalinda *et al.* (2008)

Table 23. Contributions of forest-related subsectors to GDP in 2006. *Source: Ng'andwe et al. 2006.*

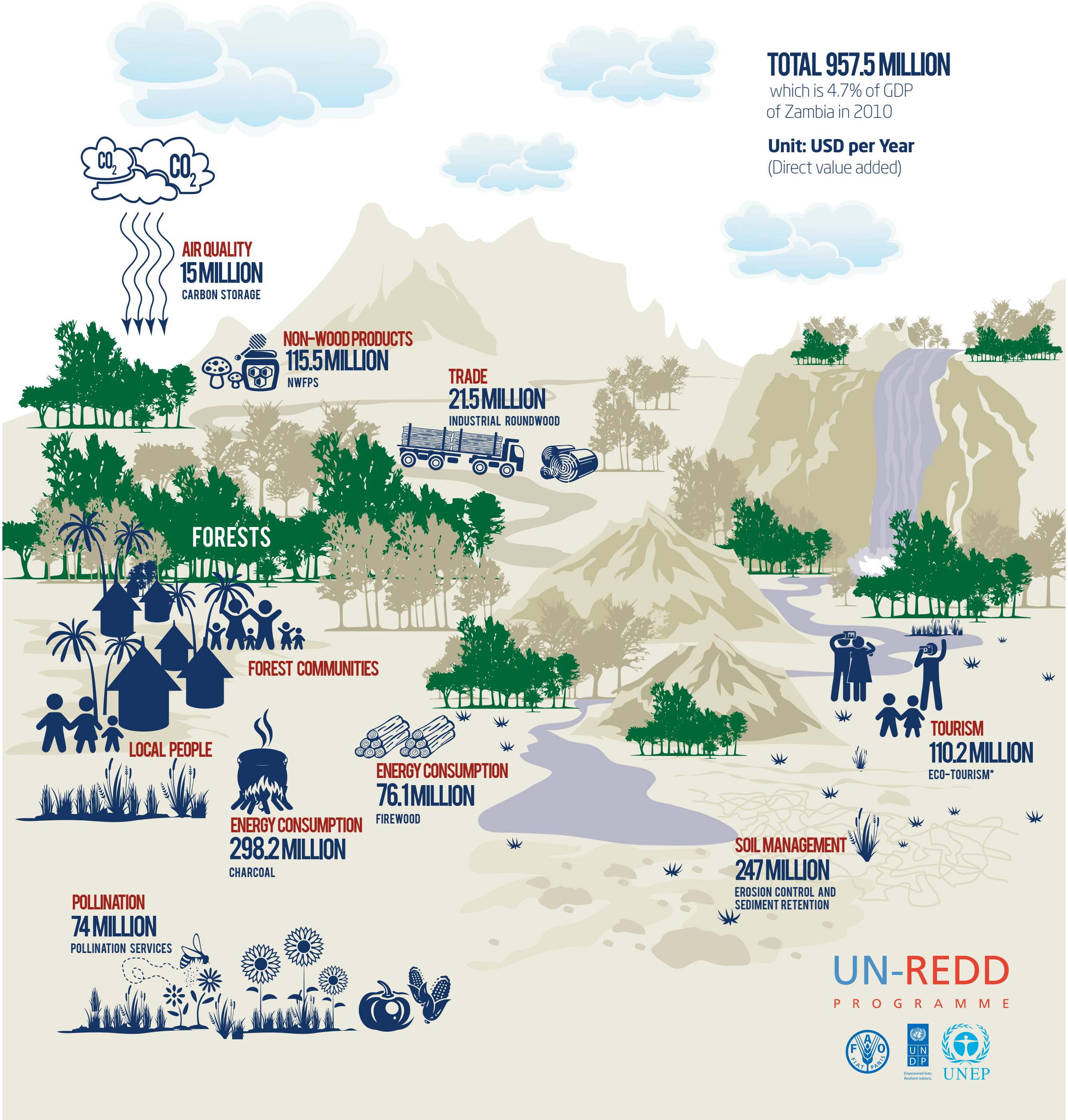
Category	GVA (US$ '000s)	Share of GVA (Per cent)	Share of GDP in 2006 (Per cent)
Forestry (indigenous and plantations)	2 253	0.5	0.03
Manufacturing (wood and wood projects)			
Formal processing	14 716	3.5	0.2
Informal processing	22 320	5.3	0.3
Non-wood forest products	156	0.04	0.0
Wood energy	374 900	89.0	4.6
Exports of wood	7 000	1.7	0.1
Total forestry sector	**421 345**	**100**	**5.2**

[23] Our US $ estimate, based on an exchange rate of ZMK4,797 to US$1.



surmised that the direct contribution of the forest sector to GDP would exceed 5.7% if all the direct and indirect values of forests were taken into account, including forest contributions to tourism, flow regulation, water supply and agriculture. However, the basis for their estimate was not explained. Most reports on Zambia's forests still cite the 2004 figure of 3.7% of GDP cited by Puustjärvi *et al.* 2005, including recent reports (e.g. Gumbo *et al.* 2013), or the estimate of 5.2% by Ng'andwe *et al.* (2006).

The estimates generated in this study, summarized in Table 24, suggest that the forestry sector generates a direct value added in terms of industrial roundwood, fuel wood and non-wood forest products of some US$511 million, more than three times higher than the official estimate, but in line with the estimate by Ng'andwe *et al.* (2006). However, now that the GDP estimate has been re-estimated to about double that of earlier projections, this figure represents a smaller percentage of around 2.5% of GDP. In addition,



Contribution to national income (direct value added in US$ per year)

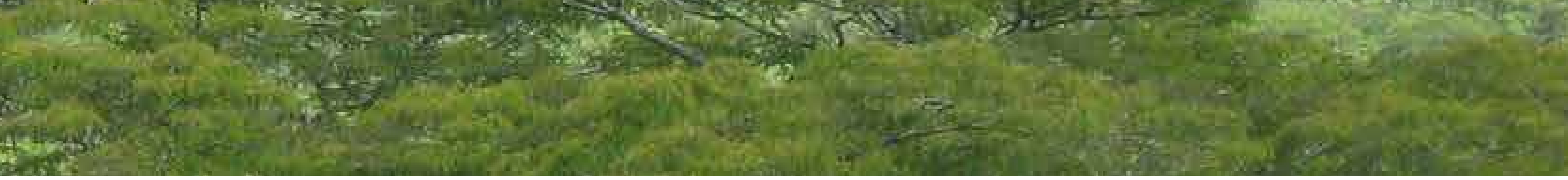


Table 24. Preliminary estimates of the main current values of Zambia's forests to the national economy based on values derived during this assessment (explained in Section 4).

Type of service or value	Gross output or saving	Direct value added	Total value added	Employment
	(US$ million per year)			('000s people)
Industrial roundwood	35.8	21.5	32.0	10.1
Fuel wood (firewood and charcoal)	598.9	374.3	557.7	>500.0
Non-wood forest products	135.9	115.5	172.1	888.8
Subtotal provisioning services	**770.6**	**511.3**	**761.8**	**1 398.9**
Percentage of GDP 2010		**2.5%**	**3.8%**	
Ecotourism*	197	110.2	179.4	16.1
Erosion control and sediment retention**	247	247	247	-
Pollination services**	74	74	74	-
Carbon storage (damage avoided)**	15	15	15	-
Subtotal regulating, supporting and cultural services	**533**	**446.2**	**515.4**	**16.1**
Percentage of GDP 2010		**2.2%**	**2.5%**	
Total	**1 303.6**	**957.5**	**1 277.2**	**1 415.0**
Percentage of GDP 2010		4.7%	6.3%	

* The low-end estimates are used.

** These values are shown without decimals, given the higher level of uncertainty

nature-based tourism activities associated with forested areas were estimated to contribute at least US$110 million in direct value added to GDP through tourism. While there is no "tourism sector" in the national accounts, this represents at least 32% of the US$341.9 million generated in the "accommodation and food service activities" sector. The non-market values of forests were estimated to be at least US$336 million, equivalent to a further 1.7% of GDP, which are effectively savings in the agriculture, water supply and electricity sectors, as well as in several of the secondary sectors. **Together these regulating, supporting and cultural services represent 2.2% of GDP in terms of direct value added, which is currently not accounted for in Gross Domestic Product (GDP) by means of the System of National Accounts (SNA). In total, the direct and indirect values of forests were estimated to make a direct contribution of US$958 million, equivalent to at least 4.7% of GDP.**

Forestry and tourism-related activities also have multiplier effects on other sectors. The most recent social accounting matrix for Zambia (Thurlow *et al.* 2004) contains very little detail on the forestry sector, but suggests a **multiplier of 1.49**. Tourism multipliers were taken from WTTC (2012). **Based on these estimates, the overall, or economy-wide, impact of forests on GDP was estimated to be at least US$1.28 billion, or 6.3% of GDP.** Of this figure, 2.5% is the contribution of forest ecosystem services that are currently not accounted for in GDP. This represents an undervaluation of 40 – 68% depending on the estimate of the contribution of forests to GDP in Zambia, which range from 3.7% (Puustjärvi *et al.* 2005) to 6.2% (FAO, 2014) of GDP.

The broad spatial distribution of this aggregate value is shown in terms of value per ha in Figure 25. Areas of higher value are mainly in the north-east and south-east of the country. A similar spatial pattern is seen when value is expressed in terms of value per tonne of above-ground carbon, with values ranging up to about US$40 per tonne (Figure 25).

5.2 Contribution to employment

In addition to their contribution to national income, forests make an important contribution to employment. Employment in the government Forestry Department itself is not major, having dropped from 1,534 to 974 employees in 2006 as a result of restructuring, and the Zambia Forestry and Forest Industries Corporation employed about 2,000 people in 2006 (Ng'andwe *et al.* 2006). However, it has been estimated that more than 60% of the economically active population earn their living from forest-related activities (Ng'andwe *et al.* 2006). They estimated that a total of 1,050,906 people were employed in the production of charcoal, non-wood forest products and timber, and in manufacturing wood products, of whom 152,000 were in charcoal production. More recent estimates put the latter at over 500,000 (Mwitwa and Makano 2012). In addition, forestry-based tourism is estimated to add at least another 16,100 jobs. **Thus, forests directly create at least 1.4 million**

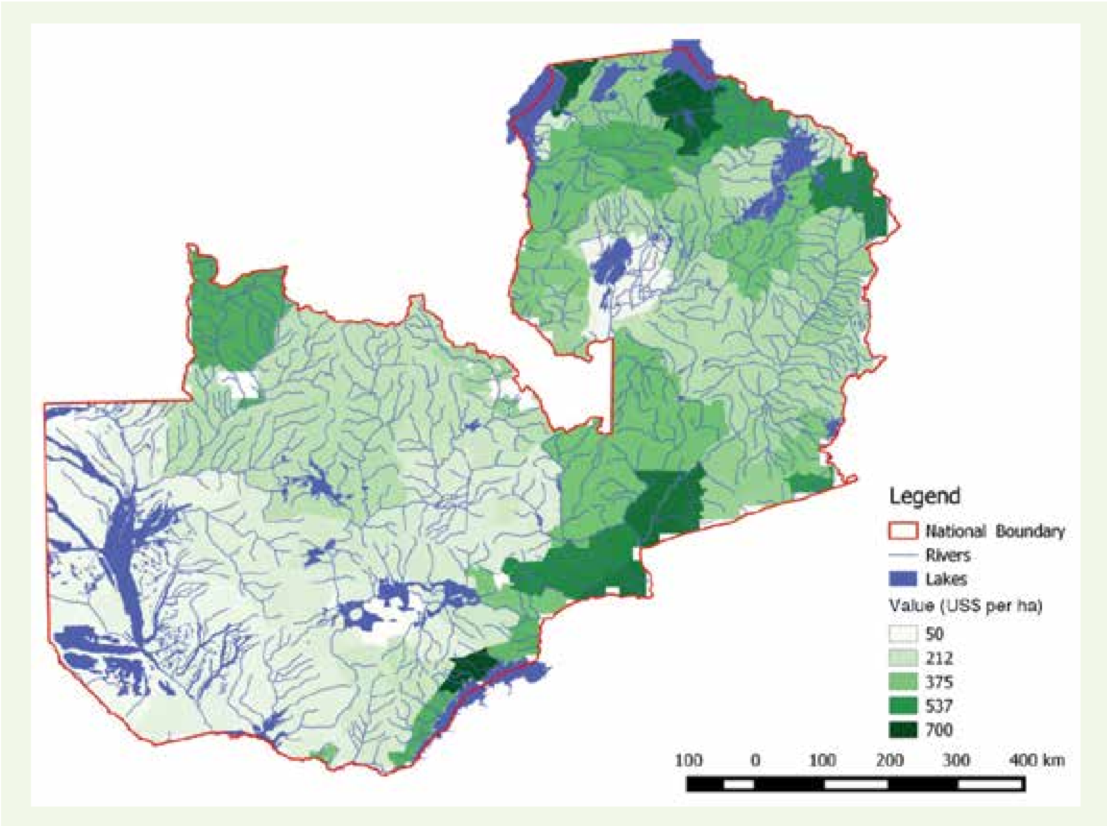


Figure 25. Broad spatial distribution of the aggregate value of forest ecosystem services, expressed as US$ per ha per year.

jobs. Nevertheless, it is important to note that there needs to be a shift of some of these jobs out of charcoal production and into less damaging forest-related activities if these levels of employment are to be sustained.

5.3 Contribution to livelihoods

One of the most important roles of forests in Zambia is their contribution to the livelihoods of a large proportion of Zambia's population. Zambia has very high levels of poverty, with most poor households being located in its rural areas. Because a large proportion of natural resources in Zambia, including both forest and wetland resources, are effectively subject to open access, these resources act as safety nets to households that have little or no other means of income, and as a means of reducing risks and smoothing income by providing the option for deriving food and income from multiple sources. These resources effectively reduce the need for welfare payments by the government to poor households. It is estimated that over 75% of rural Zambian households make use of natural resources to supplement or sustain their livelihoods. Forest resources have been estimated to comprise some 20% of household incomes, including the market value of subsistence production (Nd'angwe *et al.* 2006). The problem is that as populations have continued to grow and increase in density in rural areas, so the resources around villages have been depleted so that households are finding it more difficult to access these benefits (Leventon *et al.* 2014). However, charcoal production is a lucrative form of income for households. This makes it worthwhile to travel further to engage in charcoal production than for many other resources. In addition to production, demand for transportation and marketing of charcoal by bicycle and truck creates the most jobs in rural areas (Mwitwa and Makano 2012; Gumbo *et al.* 2013).

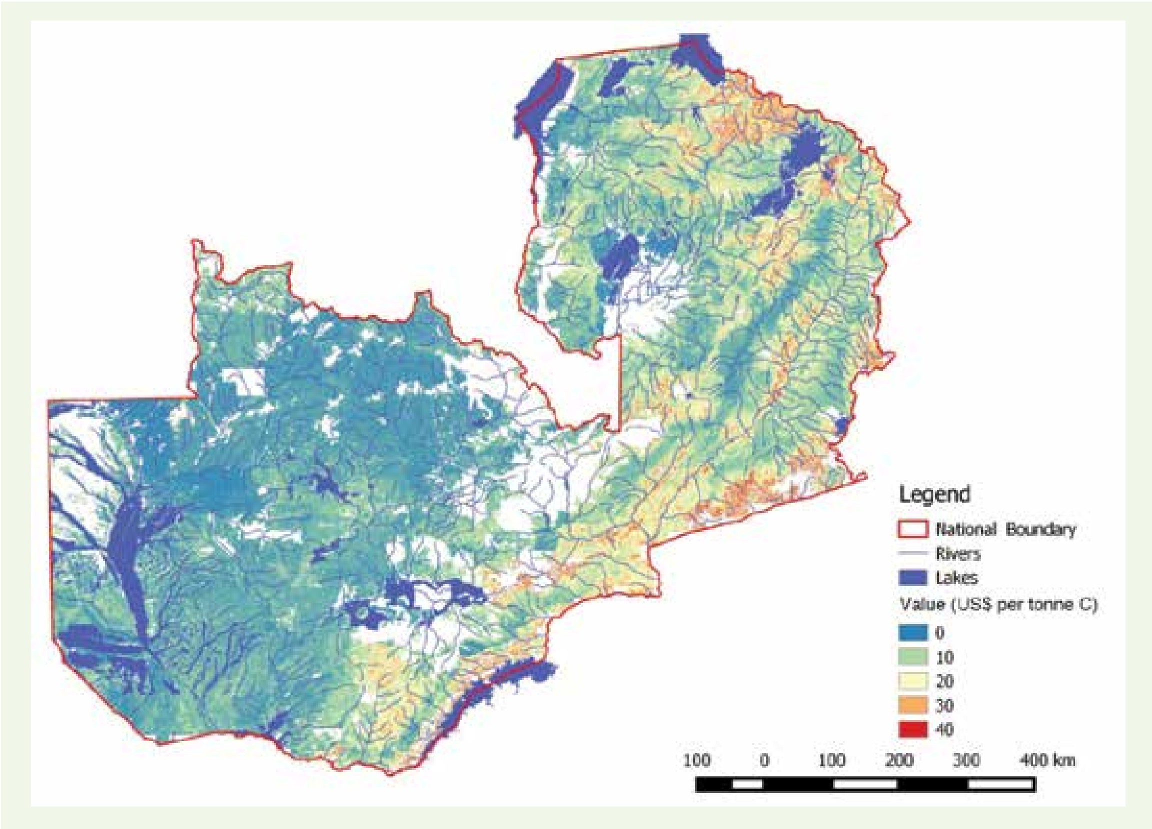
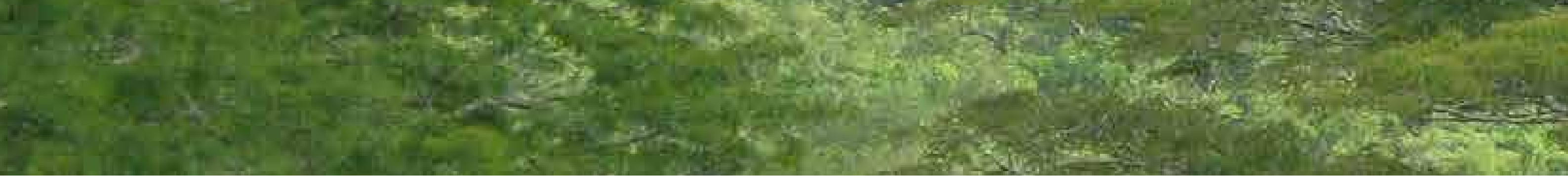


Figure 26.Broad spatial distribution of the aggregate value of forest ecosystem services, expressed as US$ per tonne of above-ground carbon.



06

Potential benefits of REDD+ in green economy transformation in Zambia

6.1

The objectives of REDD+ and its role in green economy transformation

The Green Economy provides a useful framework within which REDD+ can prosper. For example, governments can take advantage of REDD+ performance-based and verifiable and accountable systems to provide lessons learned to Green Economy initiatives such as Inclusive Wealth Accounting (IWA) and the UN-endorsed System of Environmental-Economic Accounting Experimental Ecosystem Accounting (SEEA-EEA). While the term "green economy" originated more than two decades ago in the "Blueprint for a Green Economy" (Pearce *et al.* 1989), global interest in this concept intensified following the global financial crisis in 2008, when calls were made in the global policy arena for a "Global Green New Deal" as a long-term strategy for moving national economies out of the crisis (Barbier 2010). The main objectives were economic recovery, poverty reduction, reduced carbon emissions and decreases in ecosystem degradation. Following this, the Green Economy Report, published by UNEP (2011a), developed the concept of a "green economy", analysed its key sectors and provided recommendations for action. According to this report, a green economy is *"an economy that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities"* (UNEP 2011a). A green economy aims to achieve a resilient and equitable development path that reduces carbon dependency, promotes resource and energy efficiency and reduces environmental degradation. Key actions are aimed at preventing the loss of biodiversity and ecosystem services, as well as measures relating to energy efficiency, while recognizing human well-being and social equity as core goals promoted by income growth and increasing employment (UNEP 2011a).

According to the Green Economy Report (UNEP 2011a), priority policy interventions could include:

- Addressing environmental externalities and market failures;
- Removing government subsidies that stimulate unsustainable production, resulting in the depletion of natural resource stocks and over-exploitation;
- Promoting investment and spending in areas that stimulate a green economy, such as new technologies, infrastructure and green industries;
- Improving regulation and enforcement to reduce harmful and unsustainable behaviour; and
- Strengthening international frameworks that regulate economic activity and trade to help drive green economic development.

REDD+ activities can include several, if not all, of the above types of initiatives, and can therefore have a significant role to play in green economy transformation. Given the importance of forests to the economy, employment, and livelihoods, it is important that cost-effective ways for conserving and sustainably managing forests are implemented to support Green Economic growth.

6.2

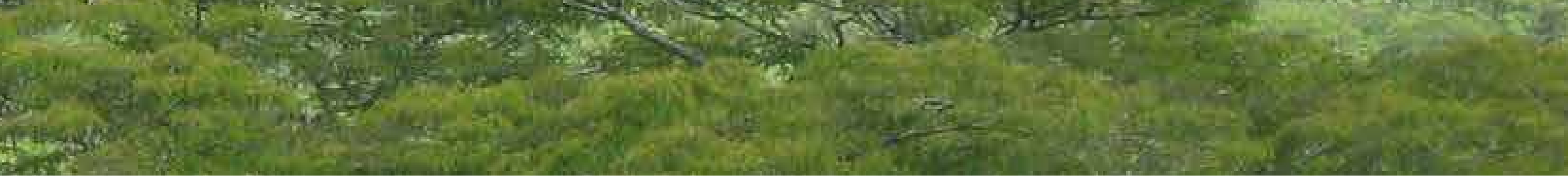
Options for reducing deforestation and forest degradation and loss

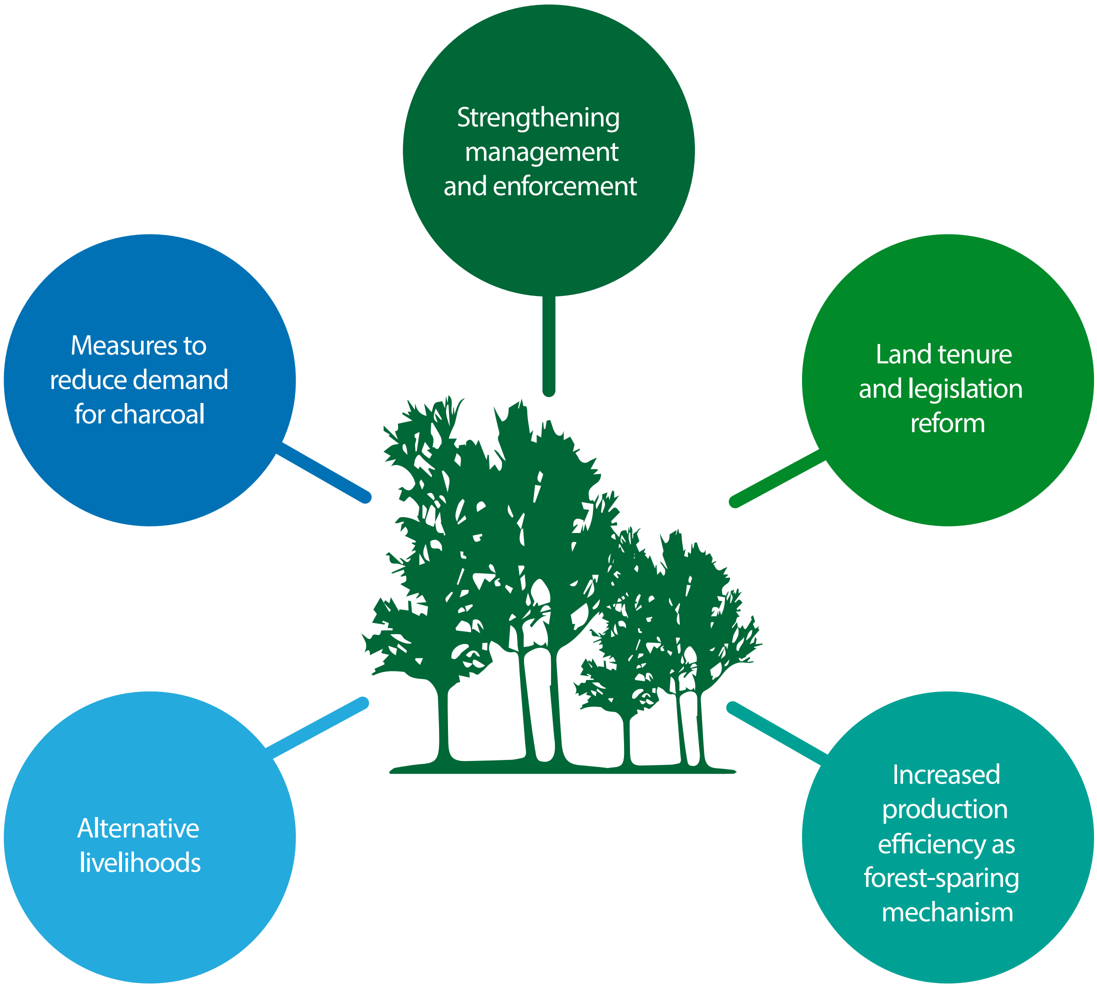
Several types of actions are required to bring about more sustainable use of forests and slow the rate of forest loss in Zambia, as outlined below.

6.2.1

Strengthening management and enforcement

According to Leventon *et al.* (2014), only 10%–20% of wood harvesting is legal in Zambia. Given that illegal exploitation is the primary threat to Zambia's forests, irrespective of what other strategies are implemented, there is a critical need to streamline licensing procedures and increase moni-



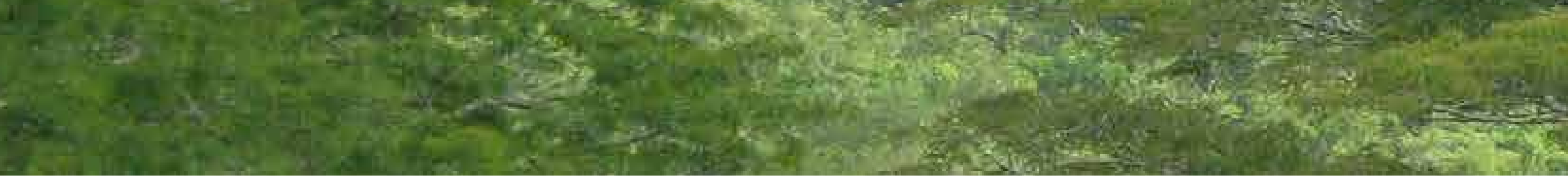


Options for reducing deforestation and forest degradation in Zambia

toring and enforcement activities so as to limit illegal timber logging and charcoal production (Kalinda *et al.* 2008). There is also a need for the ZFD to work hand in hand with agriculture to legislate and enforce sustainable agricultural practices. Improved law enforcement has the advantage that it does not require any compensation, and could have a major impact on the health of Zambia's forest ecosystems.

6.2.2
Land tenure and legislative reform

Decentralizing forest management to the local level will facilitate participation of local communities and user groups in sustainable forest management. Recognizing the damaging effects of over-exploitation on local livelihoods as well as ecosystems and biodiversity, efforts to improve forest management at the local level have already taken place throughout the region in the form of community-based natural resource management, joint forest management and sustainable forest management initiatives. The common goal in these initiatives is the devolution of authority, in part or entirety, to local communities, in order to foster stewardship over resources. In some areas, such as in Namibia, this has worked well, due to the simultaneous evolution of national policy and legislation to support such initiatives, coupled with significant and ongoing inputs from government and non-government organizations. In some areas, in spite of the transfer of rights to communities, efforts have failed for other reasons, such as difficulties in delineating communities or the elite capture of benefits. Indeed, the success of initiatives to improve the management of common property resources is highly dependent on the existence of a range of enabling conditions (Oström 2007), of which clear property rights is just one element. There is evidence of willingness on behalf of communities to take the lead in organizing themselves into decision-making structures with the assistance of community-based non-governmental organizations. Thus, one clear action that is a prerequisite for better forest management would be the introduction of a new Forest Act. systems of payment for ecosystem services.



6.2.3

Increased production efficiency as a forest-sparing mechanism

Increasing the efficiency of agricultural and charcoal-making practices is based on the premise that this will reduce the rate at which people need to encroach into forest areas in order to meet their production needs. For rural households whose production capacity is limited by availability of household labour and is primarily for subsistence purposes, this is potentially a workable notion if it reduces the need for slash-and-burn practices. Whether agriculture is the primary driver of forest loss, or follows forest thinning for charcoal, this is likely to be an important intervention, with added benefits of contributing to household food security. Increased agricultural production is also likely to reduce reliance on forest income, as was found by Bwalya (2011) in Zambia. In some areas, agroforestry may yield even greater benefits (Sileshi *et al.* 2007).

The equivalent idea for charcoal is to introduce production systems that raise the efficiency of charcoal production from about 10% to about 30%. However, it is unlikely that this will reduce deforestation, given that a more efficient system will increase the profitability of charcoal making and increase the large supply of would-be producers, combined with the fact that demand for charcoal and energy in Zambia is growing with increasing population and urbanization. Furthermore, charcoal is in short supply in neighbouring countries, creating further economic opportunity for Zambians. Thus, the introduction of so-called "eco-charcoal" technology carries a considerable risk of compounding existing problems. The level of risk will depend on the accessibility and affordability of the technology, as well as the ability to maintain control over users.

6.2.4

Alternative livelihoods

Although empowered communities can be assumed to have a vested interest in sustainably managing the forests upon which they rely, this is not always sufficient to bring about sustainable management of forests under conditions of extreme poverty, as is found in many rural areas of Zambia. Under such conditions, people cannot be relied upon to desist from damaging activities if these are their means of immediate survival. Further interventions will be needed to raise the welfare of these communities in order to reduce pressure on natural resources.One option is to create new businesses and livelihood opportunities that rely on the maintenance of intact forests. The creation of "green enterprise" opportunities, such as beekeeping and joint ventures in sustainable hunting and photographic tourism, can make it attractive to avoid activities that are damaging to the forest. The approach depends on community cohesiveness and strong leadership, as it requires cooperation in order to succeed (Ingram *et al.* 2014).

6.2.5

Measures to reduce demand for charcoal

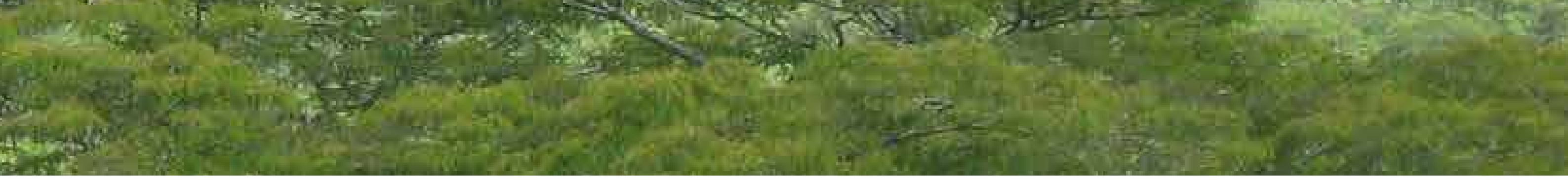
The most critical intervention will be to tackle the demand for charcoal in urban areas that drives charcoal production in forest areas. Demand could be reduced by the introduction of alternative means of cooking, which could take the form of electricity or gas supply, or the introduction of LPG cookers or stoves that use charcoal more efficiently.These could be new methods that are cheap and effective, or existing options that are subsidized to increase their uptake. This approach does carry risks. Uptake of more efficient cook stoves may not have the expected level of impact on charcoal production due to the "rebound effect" where people become less thrifty over the use of the resource if the more efficient technology makes it cheaper to cook. There may also be some degree of leakage, in that forest resources not used for charcoal may be utilized for other purposes. A further risk is one of cultural resistance to new technologies. However, this option has the further advantage of reducing carbon emissions and improving air quality in urban areas and, given the potential of a major positive outcome, is one that deserves considerable research and development.

6.3

Role and viability of REDD+ in a forest conservation strategy

The potential and relative success of the various possible interventions depends very much on the ecological, social, economic and political context in which they are implemented, and the amount of research involved in their strategic design. Addressing forest policy and legal framework and governance systems and the key drivers of deforestation, especially charcoal demand, should be the main focus of a forest conservation strategy. Nevertheless, interventions are likely to be more successful and cost-effective when most or all of the measures discussed above are applied in concert. REDD+ results-based payments or finance can contribute to the funding of many of these actions in selected locations as long as they can demonstrate verified reductions or removals of forest carbon emissions compared to a forest reference (emission) level that complies with the Cancun Safeguards.

It has been estimated that the cost of most (80%) of avoided deforestation is less than US$5 per tCO2 (tonne of carbon dioxide emission equivalent) (Strassburg *et al.* 2009). In a recent study in Zambia, the estimated opportunity costs of avoiding conversion of a hectare of high density natural forest to small-scale agriculture (US$2.6 per tCO2), high intensity charcoal use (US$1.1 per tCO2) and timber logging (US$2.2 per tCO2) and the combination of charcoal and small-scale agriculture (US$4.6 per tCO2) were low enough to suggest that REDD+ was a viable proposition (Chishim-



ba *et al.* 2013). The details behind these figures were not spelled out, but they suggest that the opportunity costs are in the region of US$21–US$88 per ha[24].

The above does not include the costs of project implementation. There is very little precedent in Zambia from which to draw information on implementation costs (see Box 2 on existing iniatives), but the costs of pilot REDD+ projects being implemented with a focus on specific project areas range from about US$1.70 to US$6 per ha. In Tanzania, project costs are US$3.9 to US$8.9 per ha (UN-REDD 2012). The costs of effective forest management are estimated by the Tanzania Forest Service to be US$8.3 per ha (Fisher *et al.* 2011).

Romero *et al.* (2012) found that REDD+ projects are not financially attractive to private investors because of the low returns and high risks involved, and suggested that they would best succeed though public-private partnerships. Indeed, the income from the sale of carbon credits often does not adequately compensate the opportunity costs foregone, but government support can be justified due to the many other public benefits of implementing REDD+. For example, it was shown in one Indonesian case study that the sales of credits only needed to cover 22% of the project costs in order for REDD+ to be economically viable (Warr and Sarrado 2009). Similarly, as the estimates generated in this study show (Figures 25 and 26), investing in forest conservation and sustainable management in Zambia could result in climate benefits through carbon sequestration while also securing other socially and economically valuable benefits provided by forests. Thus, payments and investments in forests through a REDD+ mechanism could be a cost-effecive way to meet multiple social and development goals.

The potential income from REDD+ results-based payments or finance will vary spatially depending on the biomass and status of existing forest resources, and whether the interventions involve protection of existing stocks, recovery of depleted stocks, or some combination (see Figure 27).

Box 2. Existing REDD+ projects in Zambia.

Forestry, Climate Change and Natural Resource Management Projects in Zambia, Government of Finland: Decentralized Natural Resource Management Programme

This programme will operate in four to five clusters comprising two to three districts with initial budget estimates of 700,000 Euro per district over a four-year period. The total budget is expected to be 10 to 13 million Euro over the period (2013–2017). Activities will consist of four components: (1) local natural resource management; (2) district, chiefdom and community development; (3) research and development; (4) programme coordination, support and policy.

Pilot Programme on Climate Resilience

This project seeks to promote private sector investment in climate change adaptation in a range of economic sectors (agriculture, water and energy) within the Kafue and Barotse sub-basins, including (1) micro-finance; (2) weather index-based insurance projects: (3) information dissemination systems; (4) strengthening capacity for climate resilient activities.

UNDP/GEF Multi-Focal Area Project: *Strengthening Management Effectiveness and Generating Multiple Environmental Benefits within and around Protected Areas in Zambia*

This project seeks to ensure that the biodiversity and carbon sinks of Zambia are better protected from threats through improved management effectiveness at the institutional level, sustainable forestry management practives and integrated land use planning at the local level, and application of appropriate low-carbon, biomass-energy technologies.

Low Emission Capacity-Building, EU-UNDP: *Climate Change Capacity-Building Programme*

The objective of this programme is to develop capacities (institutional, financial, human and research) required for articulation of a low-carbon, climate-resilient development pathway.

BioCarbon Partners, Lower Zambezi and Luangwa REDD+ Projects

BioCarbon Partners is conducting Zambia's first REDD+ project in the Lower Zambezi and is expanding its activities into the lower Luangwa Conservancy and other regions surrounding the South Luangwa National Park supported by USAID.

[24] Assuming "high density forest" = 70 tonnes per ha, and 1 tonne of carbon stored = 3.67 tonnes of carbon dioxide emission equivalent.

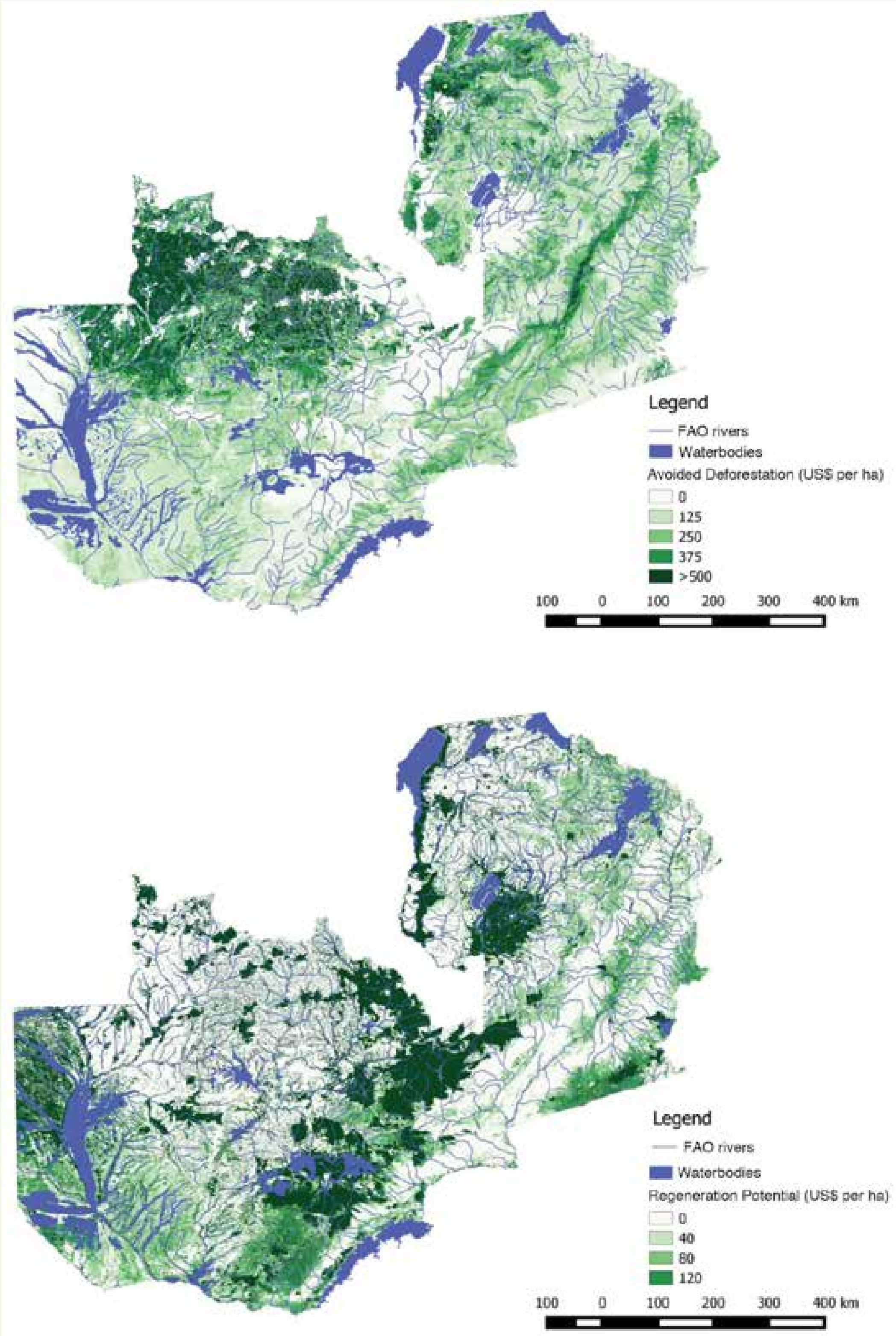
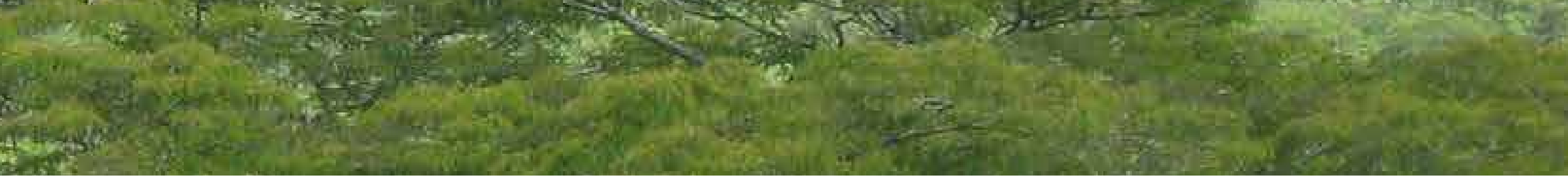


Figure 27. Spatial variation in potential total (not annual) income per ha (a) from avoided deforestation and (b) from forest regeneration.



Using a rough rule of thumb that the annual income derived over twenty years would be about a tenth of the total values, this suggests that the areas where avoided deforestation would yield incomes high enough to cover opportunity costs plus transaction costs in excess of US$37.50 per ha per year (i.e. in the lower range of opportunity + transaction costs, which may vary from US$23 to US$94 per ha) are **geographically limited to the north-western areas of Zambia** where this could be achieved through avoided deforestation.

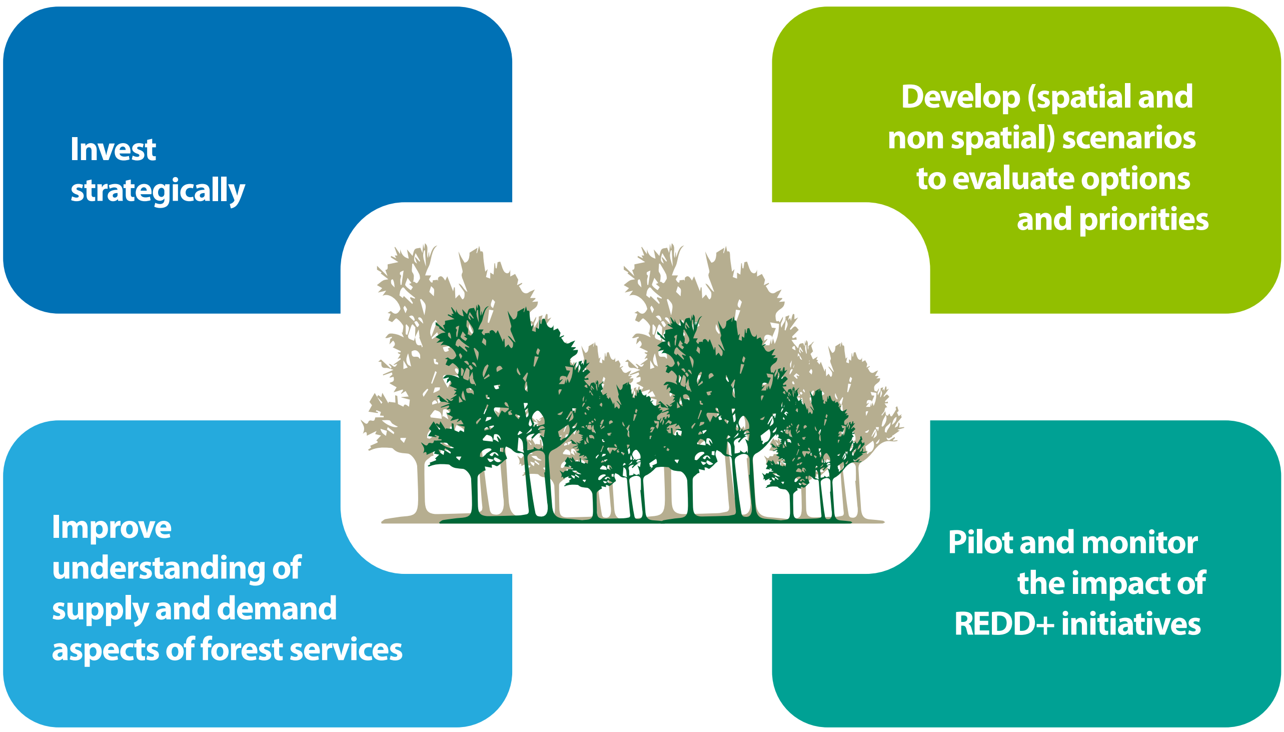
Such interventions could, however, be more viable if the public or private sector also contributed payments in return for securing public benefits. This study suggests that sustainably managed forests yield benefits worth at least US$25 per ha per year on average, though varying up to over US$700 per ha (Figure 25). **If these benefits are taken into consideration, REDD+ activities are likely to be more generally viable, and in situ conservation activities will also be viable across a broader spectrum of the landscape.** The consideration of benefits other than carbon sales, for which this study has made an initial estimation, is therefore important in determining the viability of REDD+ initiatives from an economic point of view. It should also be recognized that the carbon income that can be generated through REDD+ initiatives also helps to make public sector investment in forest conservation a more viable prospect.

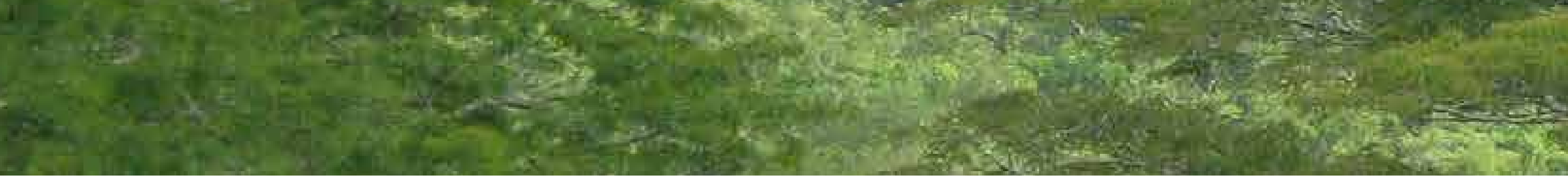
6.4 Recommendations

6.4.1 Invest strategically

Based on available evidence on the success of in situ initiatives, it is recommended that REDD+ results-based actions should focus on (a) addressing off-site interventions that affect the drivers of deforestation, and (b) improving forest governance and regulatory approaches that seek to limit forest loss and degradation in areas of national importance, such as dam catchment areas.Efforts should also be made to improve the agricultural productivity of and value derived from existing cultivated/degraded areas, rather than formal expansion into virgin forest areas as is currently the case in Zambia.

For each province and district of Zambia, the rationale for and means by which REDD+ actions can and will be undertaken may be different. Where forests are largely intact and where the potential for timber extraction is highest in the North-western Province, the REDD+ priority should be to develop and enforce sustainable forestry, but also to ensure that the energy needs of the large in-migrating population are met sustainably. Where demand for charcoal is greatest, in more densely populated Central, Southern and Eastern provinces where forest cover has already been significantly reduced and degraded, REDD+ actions must immediately address the issue of charcoal demand. In these areas, where forest ecosystem services also make significant contributions to Zambia's agriculture and hydropower production, REDD+ actions will also need to focus on curbing agricultural expansion.





For several regions of Zambia, success in REDD+ implementation will require careful thought on the close inter-linkages and interdependence between ecotourism, forest conservation and sustainable rural economic development. The eight regions surrounding national parks show considerable variation in tourism, revenues being highest (per ha) for Livingstone, Lower Zambezi, and South Luangwa national parks. Clearly, forest conservation efforts maintain the potential for tourism, but it is vital for both the forests and for wildlife populations that communities obtain tangible benefits from both tourism and forest conservation in light of the fact that other economic development trajectories (such as agriculture) are not available to them.

6.4.2

Develop (spatial and non-spatial) scenarios to evaluate options and priorities

Cost-benefit analyses will need to be undertaken for a range of options that not only include institutional reforms and on-site interventions, but also interventions to address urban charcoal demand. The utility of any cost-benefit analysis will depend on (a) a rigorous approach involving the development of comprehensive and spatially-explicit scenario analysis with multiple stakeholders, (b) realistic expectations as to what can be achieved with different levels of REDD+ results-based payments/finance under the circumstances in which they are applied, and (c) consideration of spatial and temporal variation in the estimation of costs and benefits.

Whether or not the interventions are on-site, it will be useful to determine the priority areas that REDD+ could target in order to achieve the greatest net benefits. These would be characterized by the level of threat (and hence the degree to which deforestion and degradation can be avoided), as well as the co-benefits that will arise from the intervention. Consideration will need to be given to how forests interact with the wider economy to create jobs to decrease risk in regional economic activities, for example through flood protection, erosion control, tourism, or supporting agricultural pollinators.

6.4.3

Improve understanding of supply and demand aspects of forest services

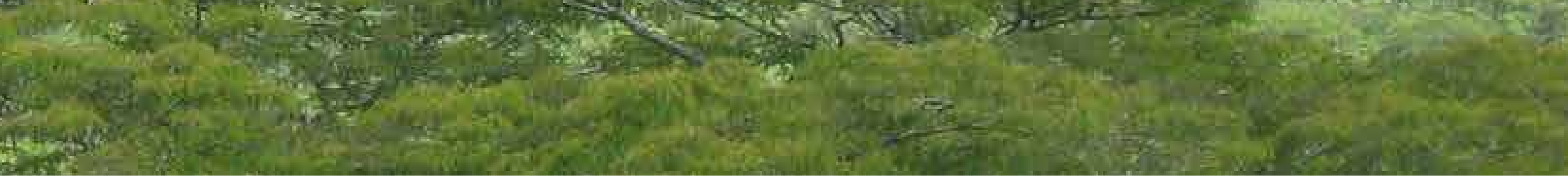
The considerable number of spatial maps developed for this report are an important contribution in supporting this process, by revealing the heterogeneity of ecosystem benefits across Zambia, as well as elucidating some of the potential risks and associated costs of further forest loss. Taken in combination, they provide a powerful tool to aid the decision-making process. However, future analyses would also benefit from improvement to these estimates and filling in gaps, such as through empirical studies and more detailed modelling work, especially in terms of hydrological processes. Gaps in understanding include the effects of finer-scale landscape configuration and forest fragmentation on provision of ecosystem services and their value.

In addition, consideration should be given to potential changes in values (incuding increases in value) that might occur as a result of ongoing or potential changes in supply or demand factors, including population growth and infrastructural investments, in order to better inform an integrated systems modelling approach. For example, the future tourism potential of undeveloped areas could be considered.

6.4.4

Pilot and monitor the impact of REDD+ results-based actions

Very little is understood of the actual impacts of alternative forest conservation strategies, both on the rate of forest degradation and on the affected communities. Programmes of ongoing research are critical to the future successs of these iniatives, and it is imperative that monitoring and evalution is an ongoing aspect of project implementation. Various types of initiatives should be carefully piloted. In addition to the various types of initiatives discussed above, these could include novel projects such as the development of sources of bioenergy for local consumption on degraded or deforested land in order to simultaneously address the issues of generating income opportunities and reducing charcoal demand and deforestation.



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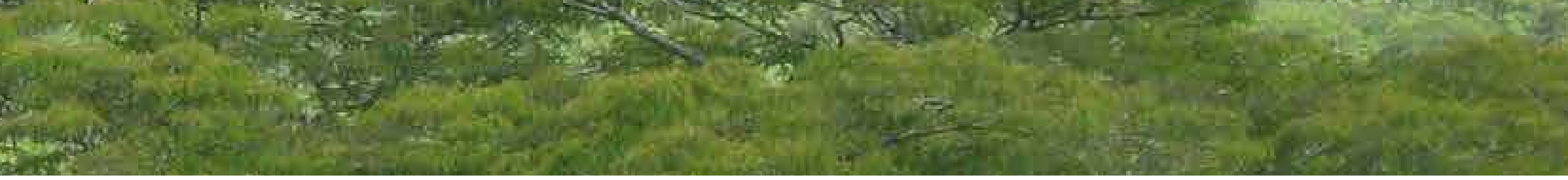

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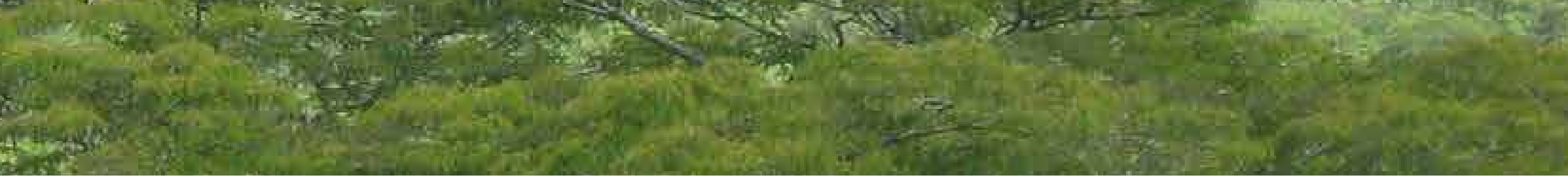

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Appendices

1. GIS layers used in invest modelling

The following GIS datasets were used for this report.

Hydrology

HydroBASINS

HydroBASINS is a global river and lake catchment layer derived from HydroSHEDS and the Global Lakes and Wetlands Database. HydroBASINS provides the most accurate hydrographic information for river and lake catchments at the global scale in a consistent format.

Download: http://project.freshwaterbiodiversity.eu/index.php/global-hydrobasins

All watersheds (catchments) contributing water (and sediment) to Zambia from surrounding countries were extracted for use in subsequent modelling (Figure 30) and grouped. The groupings delineate functionally distinct catchments draining into specific waterbodies, such as lakes and swamps (Figure 31).

HydroSHEDS (Digital Elevation Model and Stream Network)

HydroSHEDS is a mapping product that provides hydrographic information for regional- and global-scale applications in a consistent format derived from the Shuttle Radar Topographical Mission.

Download: http://hydrosheds.cr.usgs.gov/index.php

The stream network was extracted for all watersheds considered (Figure 32).

FAO Rivers and Digital Chart of the World Inland Waters

The FAO rivers database was used to display major rivers and the Digital Chart of the World Inland Waters. This resource was used primarily for display purposes as it does not have the detail of the HydroSHEDS stream network data required for the hydrological modelling described below.

Download: http://www.fao.org/nr/water/aquastat/gis/index2.stm

We present this data, plotting the location of major hydroelectric power facilities (Figure 33).

Soils

The Harmonized World Soil Database is a 30 arc-second raster database with over 15,000 different soil mapping units that combines existing regional and national updates of soil information worldwide (FAO/IIASA/ISRIC/ISS-CAS/JRC 2012). The raster map is linked to the harmonized soil property database. Soils are spatially distributed into major soil classes which comprise dominant and sub-classes (or soil units) with data describing organic carbon, pH, water storage capacity, soil depth, cation exchange capacity of the soil and the clay fraction, total exchangeable nutrients, lime and gypsum content, sodium exchange percentage, salinity, textural class and granulometry. The spatial distribution of sub-classes within classes is not provided. The reliability of the information contained in the database is variable.

Download: http://www.isric.org/data/harmonized-world-soil-database-version-10

Meteorological data

The WorldClim database provided data of precipitation, mean, minimum and maximum temperature (Hijmans, Cameron *et al.* 2005).

Download: http://data.biogeo.ucdavis.edu/data/climate/worldclim/

Data of potential evapotranspiration were obtained from (Trabucco and Zomer 2009). The Global Potential Evapo-Transpiration (Global-PET) and Global Aridity Index (Global-Aridity) datasets provide FREE high-resolution global raster climate data related to evapo-transpiration processes and rainfall deficit for potential vegetative growth.

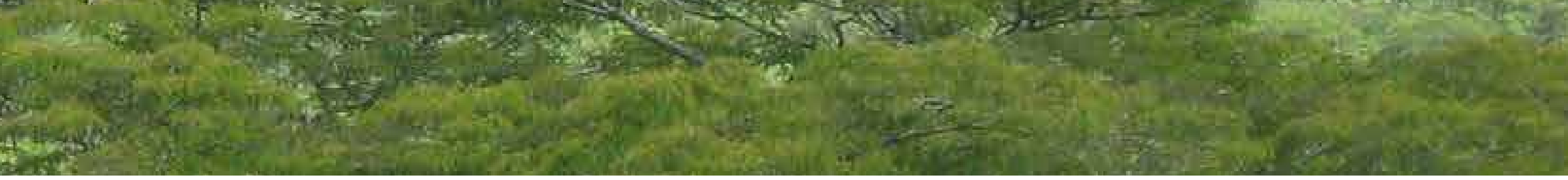
Carbon

Above-ground (forest) carbon

Above-ground biomass data for 2007 was derived from recent MODIS satellite imagery (2007) at 500 m resolution, with LIDAR (Light Detection and Ranging) data sets from the Geoscience Laser Altimeter System satellite and new forest inventory data sets analysed and published by the Wood Hole Research Centre (Baccini *et al.* 2008).

Download: http://www.whrc.org/mapping/pantropical/carbon_dataset.html

The Wood Hole Research Centre produced the first above-ground biomass map at 1 km resolution for tropical Africa, utilizing images from the MODIS satellite (2000 to 2003) along



with data from recent forest inventories covering the period from 2000 to 2003. The two datasets permit an assessment of the change in above-ground carbon (2000 to 2007).

Download: http://www.whrc.org/mapping/pantropical/carbonmap2000.html

Above-ground woody biomass was converted into above-ground carbon (tonnes per ha) using a correction factor of 0.46 (Figure 43).

For the purposes of estimating total carbon stocks for this report, it was necessary to exclude all non-forest carbon. We did this using land cover classifications of Zambia provided by both the Zambia Forestry Department and the Global Land Cover Network (GLCN) Land Cover Classification System.

Below-ground (root) carbon

A common approach to estimate below-ground biomass is to use an estimate of the "root to shoot" ratio of below-ground to above-ground biomass. Default estimates of the root to shoot ratio given in Table 4.4 on p. 4.49 of IPCC ((IPCC) 2006) were used to estimate above- and below-ground biomass carbon for the year 2000 (Ruesch and Gibbs 2008).

Download: http://cdiac.ornl.gov/epubs/ndp/global_carbon/carbon_documentation.html

Below-ground (soil) carbon

The Harmonized World Soil Database was used to provide data describing soil organic carbon content (tonnes per ha) (Hiederer and Kochy 2011) Figure 44.

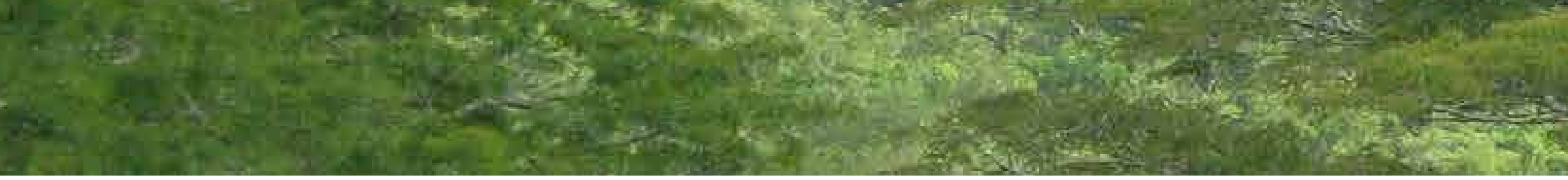
Download: http://eusoils.jrc.ec.europa.eu/library/Data/_Datarequest/HWSD_OC.cfm

Land use and land cover maps

Two data sources for land cover and land use were obtained. The first land use and land cover data was provided by (GLCN 2008). GLCN is an initiative of FAO and UNEP. GLCN uses a widely adopted standard for land cover classification which provides thematic legends which are compatible with the FAO-UNEP Land Cover Classification System (FAO 2000). This data was essential for modelling of soil loss and sedimentation, as it covered all catchments extending beyond the national boundary of Zambia (Figure 34). The resulting map contained 21 land cover and land use types.

Code	Descriptor
14	Rain-fed Shrub Crop(s)/Rain-fed Tree Crop(s)/Rain-fed Herbaceous Crop(s)
20	Cultivated and Managed Terrestrial Area(s)/Natural and Semi-Natural Primarily Terrestrial Vegetation
30	Natural and Semi-Natural Primarily Terrestrial Vegetation/Cultivated and Managed Terrestrial Area(s)
40	Broadleaved Evergreen Closed to Open Trees/Semi-Deciduous Closed to Open Trees
50	Broadleaved Deciduous Closed to Open (100–40)% Trees
60	Broadleaved deciduous (40– (20–10))% woodland
70	Needle-leaved Evergreen Closed to Open (100–40)% Trees
90	Needle-leaved Evergreen (40– (20–10))% Woodland/Needle-leaved Deciduous (40– (20–10))% Woodland
100	Broadleaved Closed to Open Trees/Needle-leaved Closed to Open Trees
110	Closed to Open Trees/Closed to Open Shrubland (Thicket)/Herbaceous Closed to Open Vegetation
120	Closed to Open Shrubland (Thicket)/Herbaceous Closed to Open Vegetation/Closed to Open Trees
130	Broadleaved Closed to Open Thicket
140	Herbaceous Closed to Open Vegetation
143	Grassland/Crops/Bare soil
150	Sparse Trees/Herbaceous Sparse Vegetation/Sparse Shrubs
160	Closed to Open (100–40)% Trees/Water Quality: Fresh Water
170	Closed to Open (100–40)%/Closed to Open (100–40%)/Broadleaved Evergreen Trees on Permanently Flooded Land (With Daily Variations)/Water Quality: Saline Water/Closed to Open (100–40)% Semi-Deciduous Woodland on Permanently Flooded Land
180	Closed to Open Shrubs on Permanently Flooded Land/Closed to Open Shrubs on Temporarily Flooded Land/Closed to Open Herbaceous Vegetation on Permanently Flooded Land/Closed to Open Herbaceous Vegetation on Temporarily Flooded Land/'Closed to O
185	Wetland
190	Artificial Surfaces and Associated Area(s)
200	Bare Area(s)
210	Natural Waterbodies / Artificial Waterbodies

Figure 28. Land use and land cover types from the GLCN Land Cover Classification System (2005)



The second land use and land cover data was provided by ZFD and is described in detail in the ILUA report (FAO 2009). The Ministry of Land developed the maps. Landsat 5 TM and ETM+ images were used. Classification of the images was done by visual interpretation. The resulting land use maps contained 18 land cover types (Figure 35), which were grouped into six 'natural' land cover groups and three 'developed' land cover types (Figure 37).

Population density

The GPWv3 database depicts the distribution of human population across the globe (Center for International Earth Science Information Network and Columbia University and Centro Internacional de Agricultura Tropical (CIESIN 2005). The gridded data set is constructed from national or sub-national input units (usually administrative units) of varying resolutions. The native grid cell resolution is 2.5 arc-minutes, or ~5km at the equator. Separate grids are available for population count and density per grid cell for years 1990, 1995 and 2000, with projections for 2010 and 2015.

Download: http://sedac.ciesin.columbia.edu/data/collection/gpw-v3

Code	Forest Group	Forest Type
1	Deciduous forest	Baikiaea forest and deciduous thicket
		Kalahari sand chipya
		Kalahari woodland on sands
2	Evergreen forest	Mopane woodland on clays
		Lake basin chipya
		Swamp forest
		Riparian forest
		Cryptosepalum forest
		Marquesia forest
3	Semi-evergreen forest	Miombo woodland
4	Other natural Forest	Termitary associated vegetation
		Munga woodland on heavy soils
5	Grasslands	Treeless / grassy
6	Inland water	
7	Forest plantations	
8	Cultivated areas	
9	Developed areas	

Figure 29. Zambia forest types and groups (Ministry of Land, 2007)

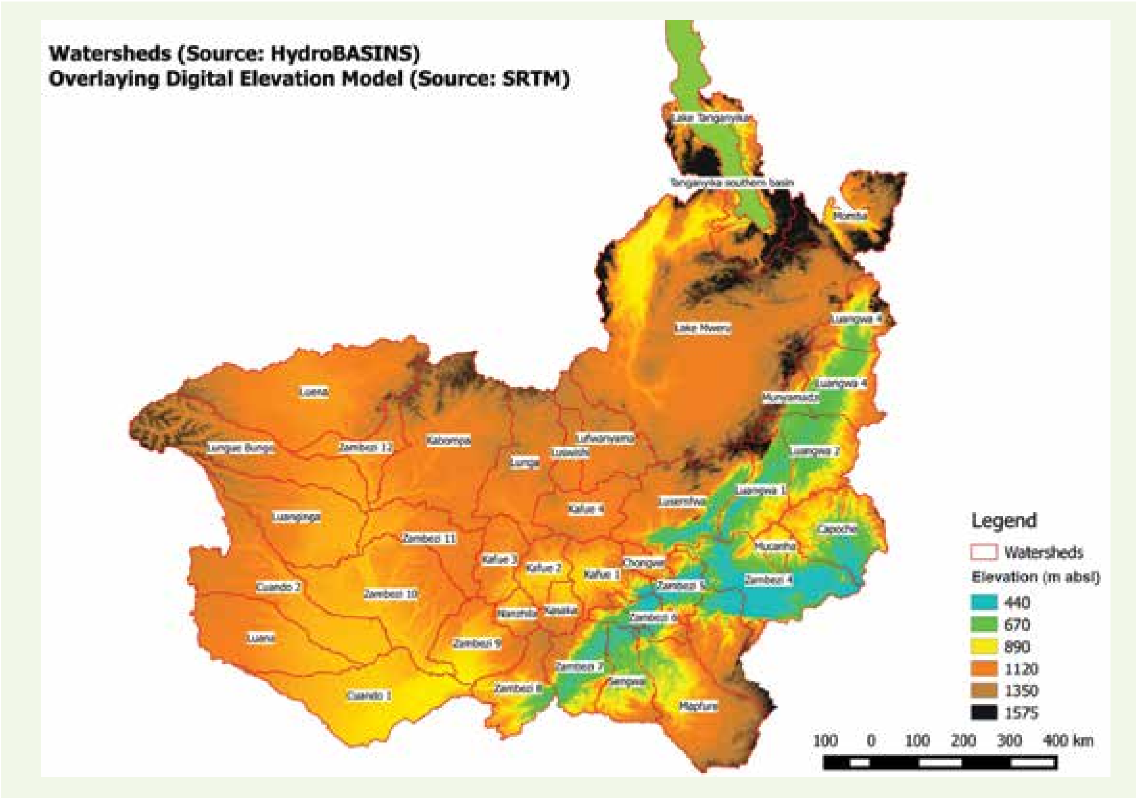


Figure 30. Delineated watersheds within and overlapping Zambia national boundaries.

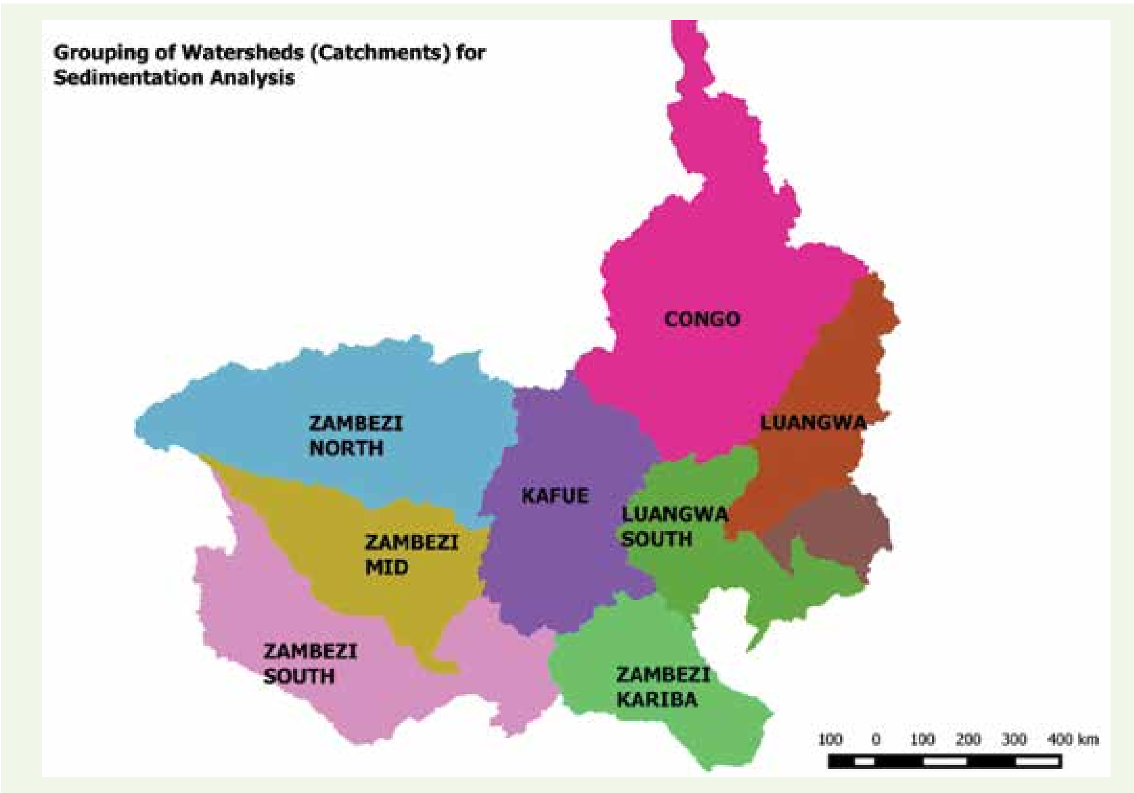


Figure 31. Watersheds grouped to form catchments for modelling.

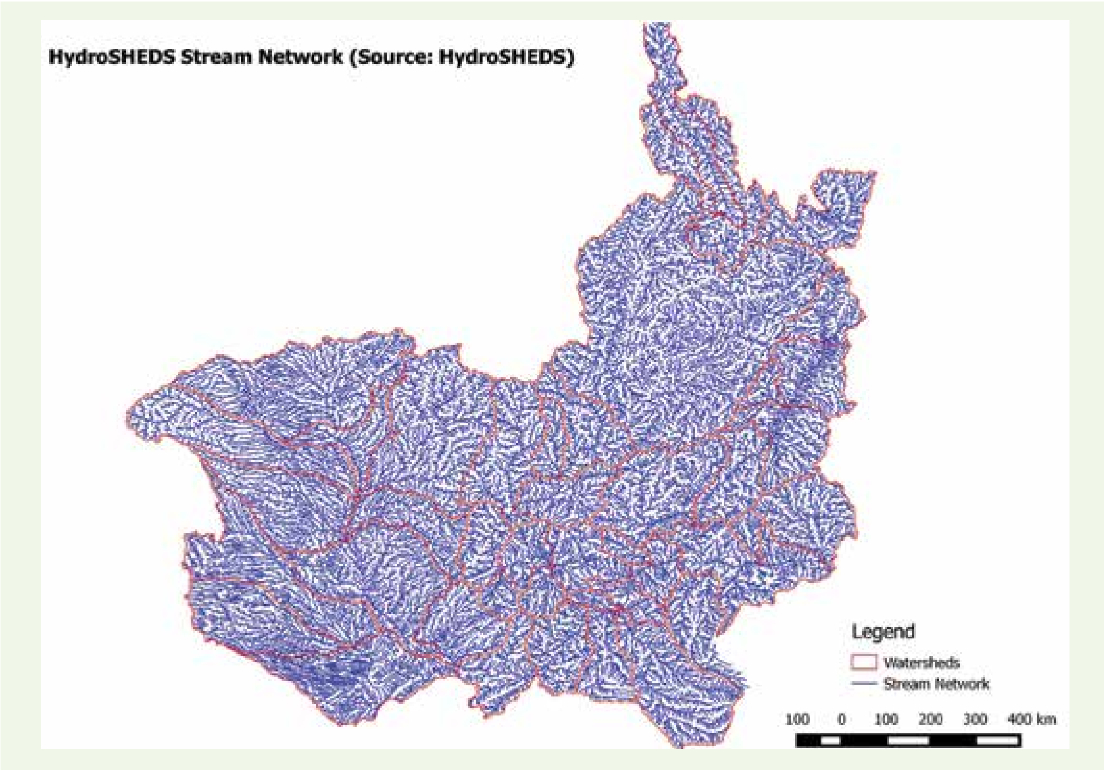


Figure 32. HydroSHEDS stream network

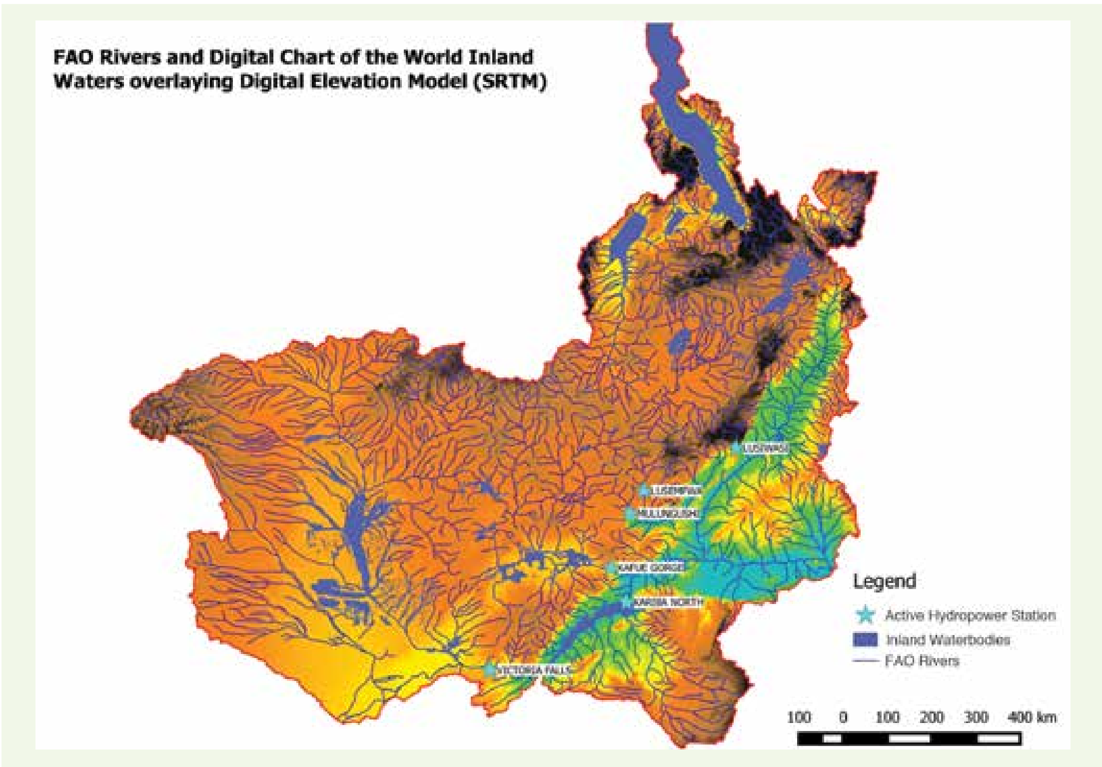


Figure 33. FAO major rivers and Digital Chart of the World inland waters with major hydroelectric power installations.

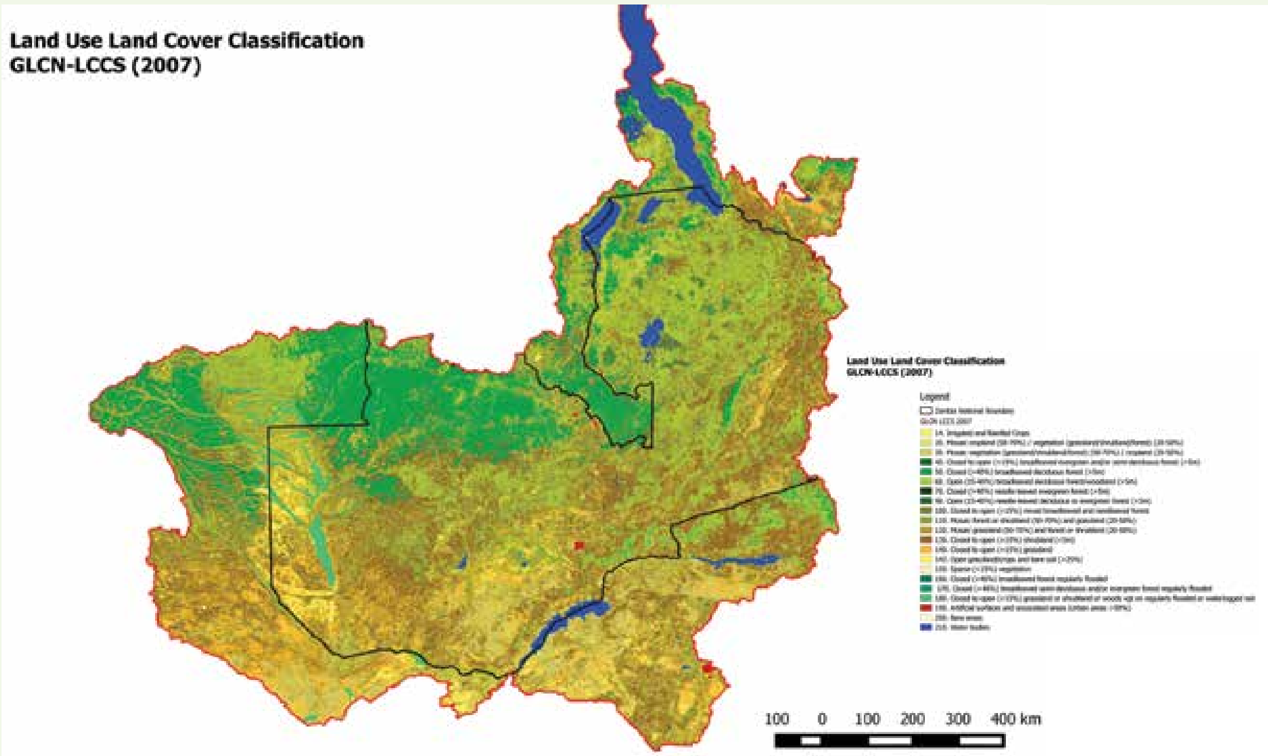


Figure 34. Land use/land cover with GLCN Land Cover Classification System (2007

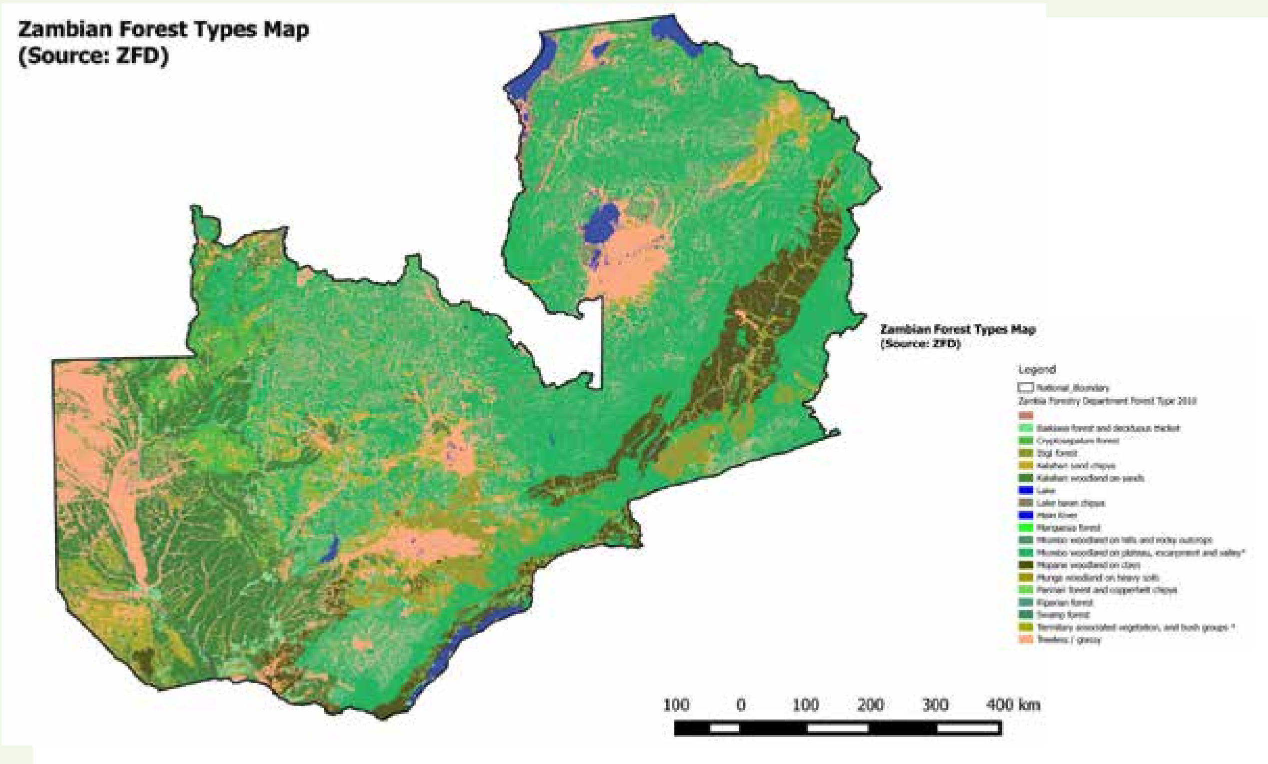


Figure 35. Zambia forest types. *Source: ZFD.*

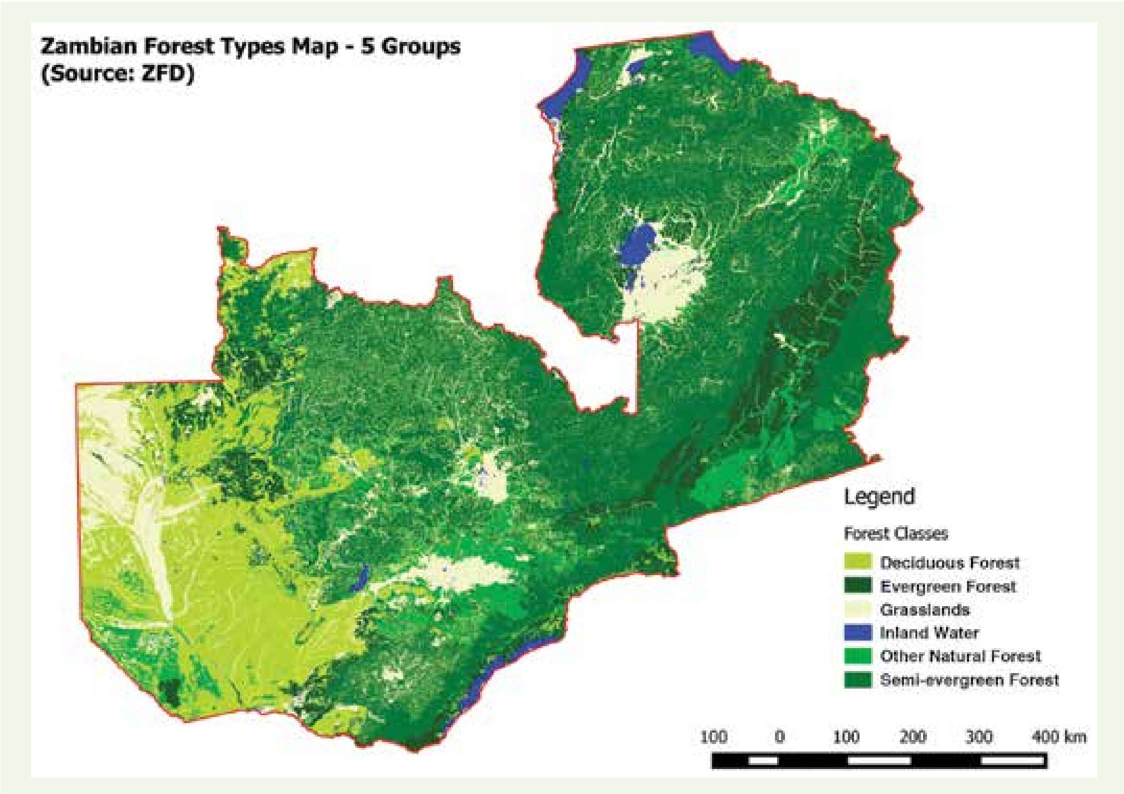


Figure 36. Zambia forest types – five groups

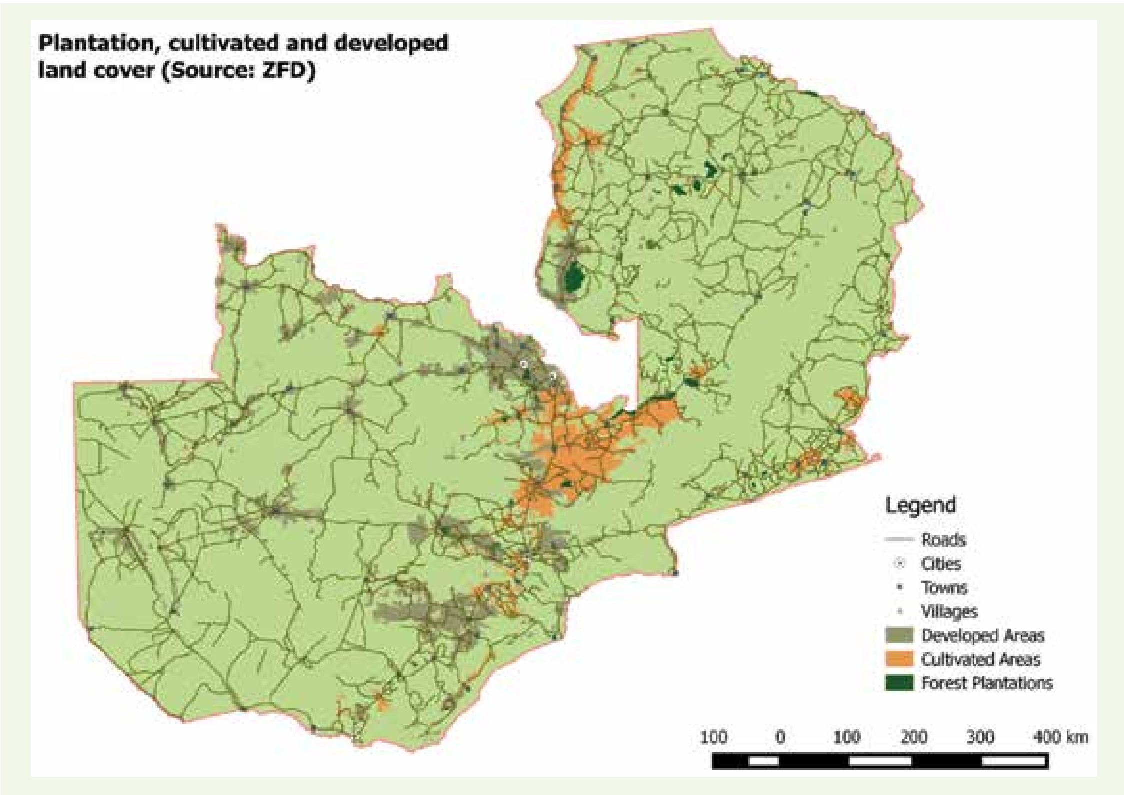


Figure 37. Zambia plantation, cultivated and developed land cover types.

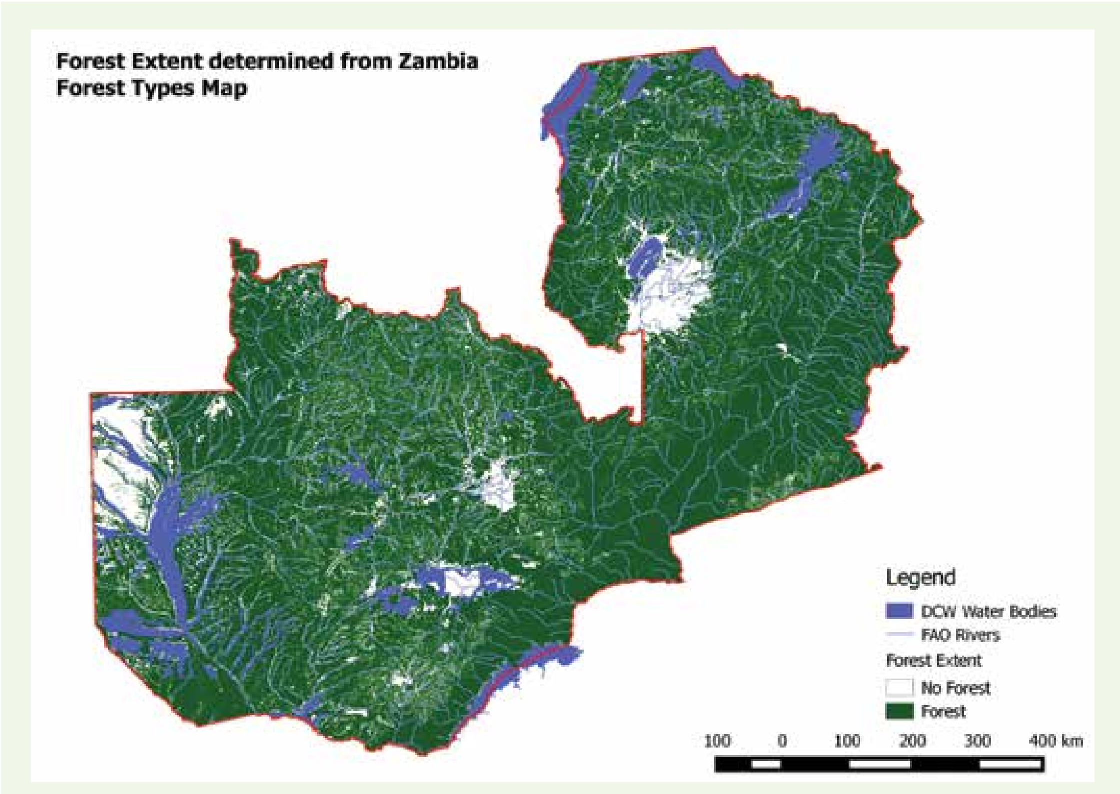


Figure 38. Forest extent determined from forest types map.

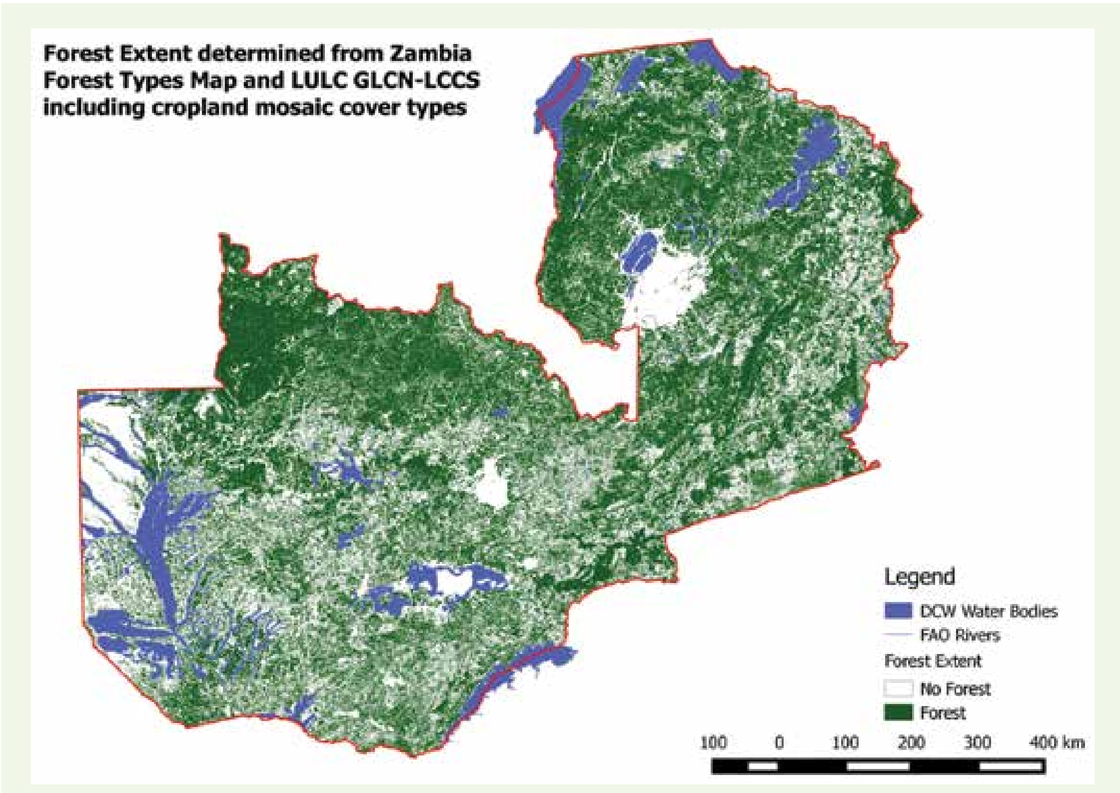


Figure 39. Forest extent determined from Forest Type Map and GLCN-LCCCS including cropland-forest mosaic cover types

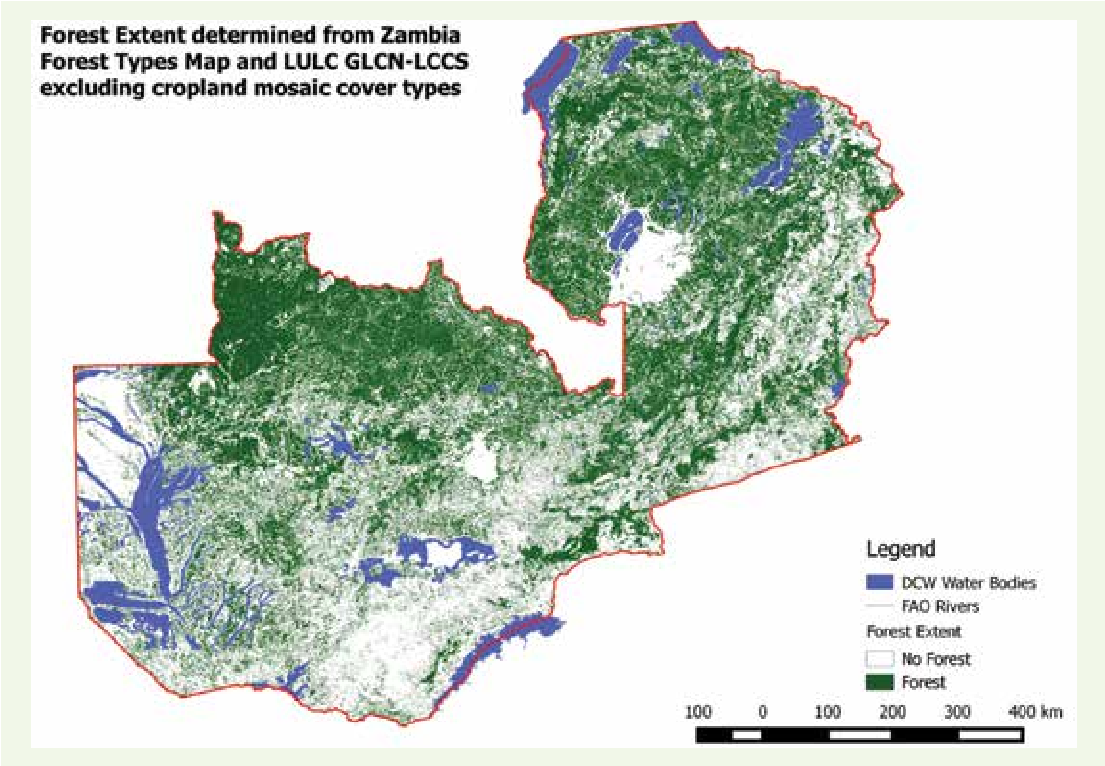


Figure 40. Forest extent determined from Forest Type Map and GLCN-LCCCS excluding cropland-forest mosaic cover types.

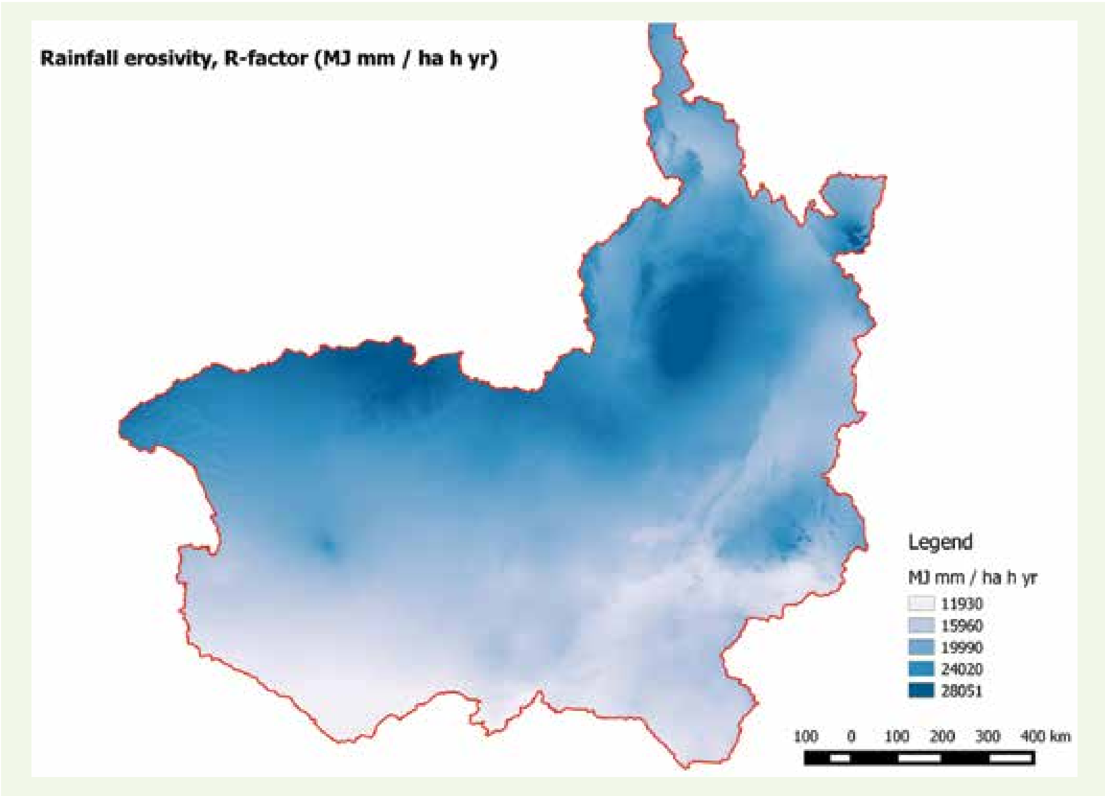


Figure 41. Rainfall erosivity.

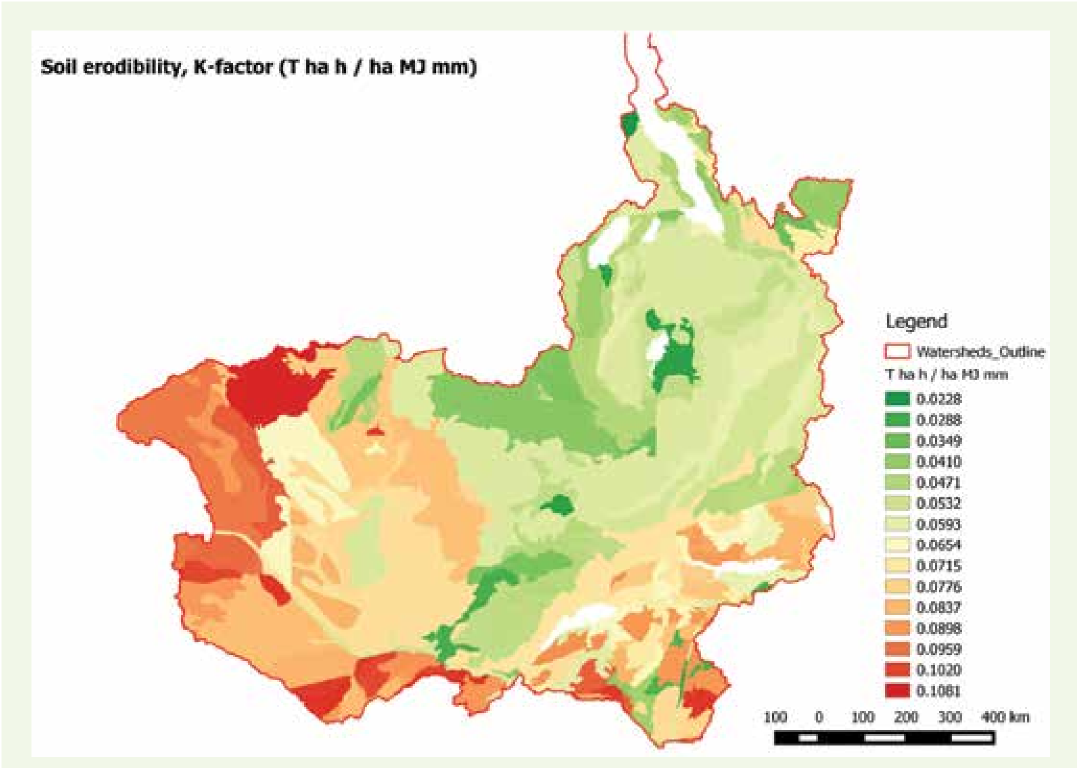


Figure 42. Soil erodibility USLE K-factor.

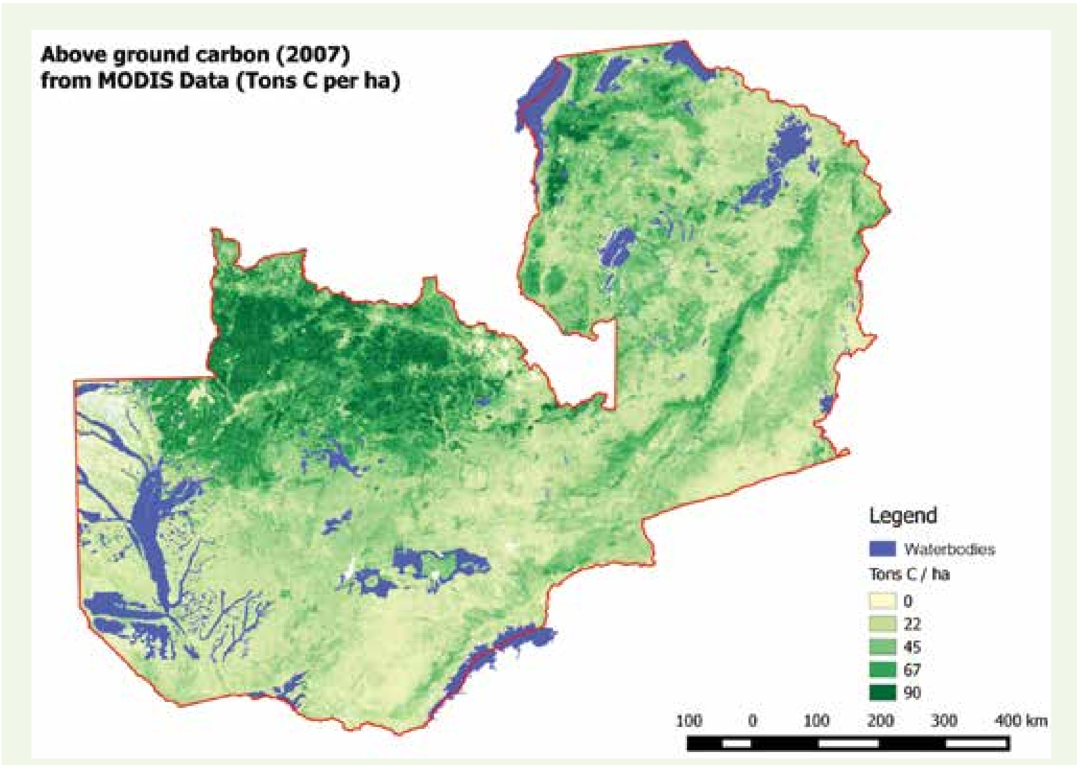


Figure 43. Above-ground carbon (tonnes per ha).

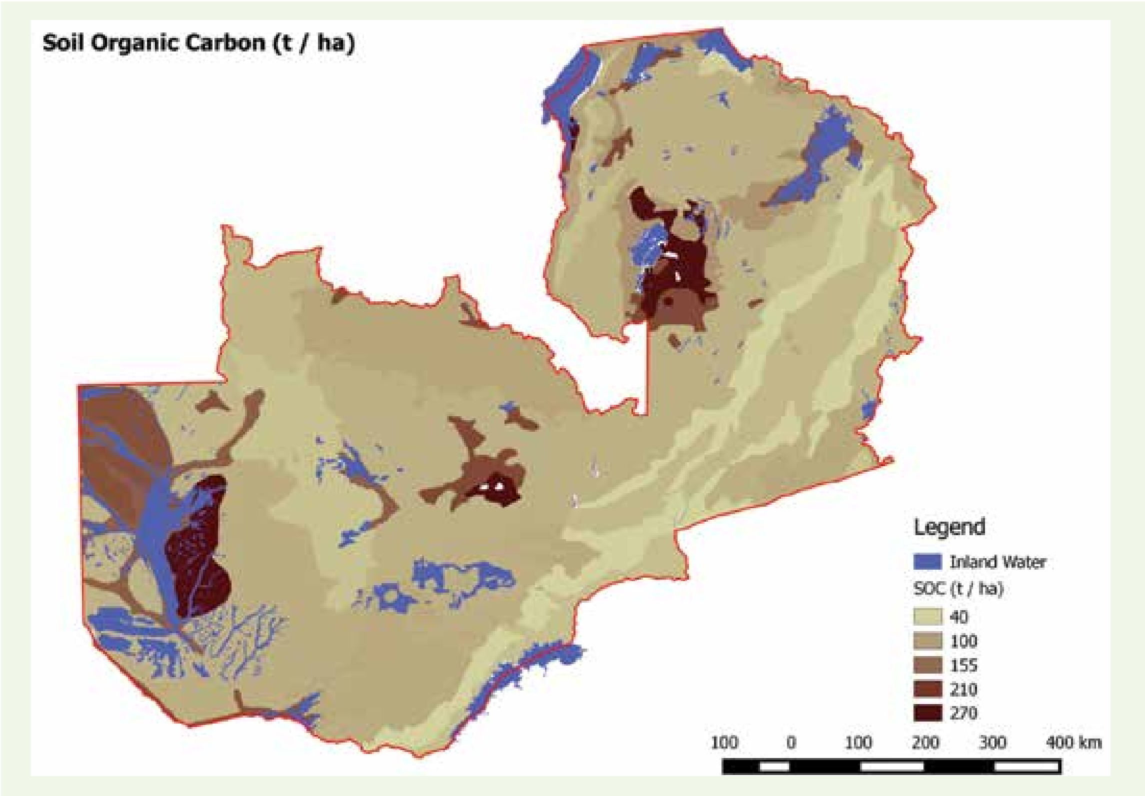


Figure 44. Soil organic carbon.

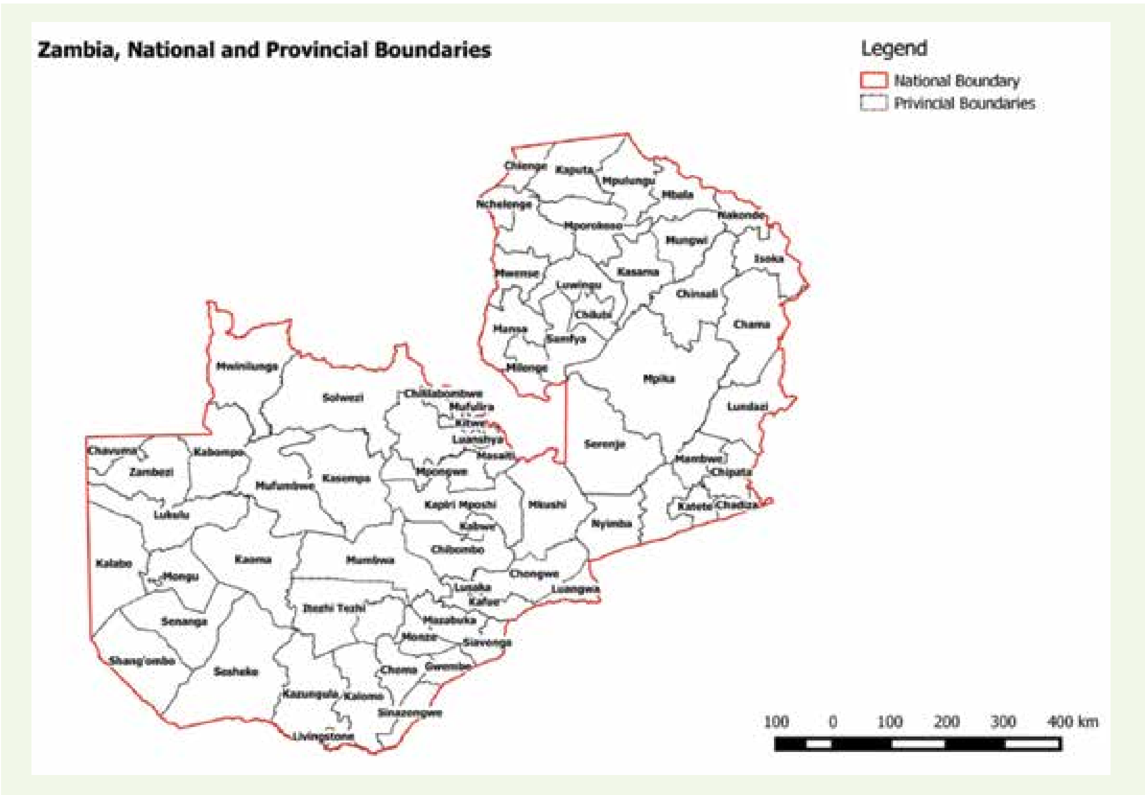
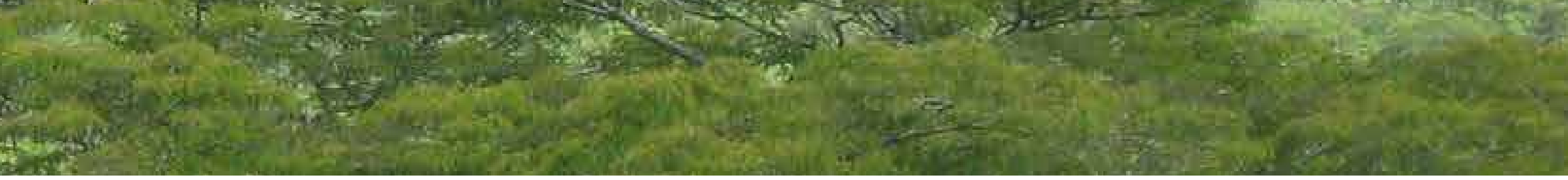


Figure 45. National and Provincial boundaries of Zambia



2. Critique of wood fuel production estimates

Wood fuel is estimated to account for about 80% of the total energy household balance in Zambia (Kalinda *et al.* 2008). In rural areas, this is mainly through use of firewood, whereas in urban areas, wood fuel use is mainly in the form of charcoal. Estimates of total wood fuel use vary quite widely (Table 7). In 1996, it was estimated that total consumption amounted to 19.4 million m^3 (PFAP 1997). However, later estimates have included some much lower figures, down to 8.37 million m^3 (Ng'andwe *et al.* 2006). Estimates of charcoal production tend to be within a narrower range than those of firewood production.

Estimates of firewood and charcoal production in 2003 were generated based on a field survey conducted by the Forest Support Project (FSP 2004). These estimates were provided in terms of m^3 of firewood and bags of charcoal, and suggest a total consumption of 9 million m^3. In 2005, the SAVCOR study (Puustjärvi *et al.* 2005) estimated production for 2004 based on the FSP findings and estimated escalation of demand. Their estimates of wood used in charcoal production are higher than our derived estimates because they assumed that a bag weighed 50kg, whereas in this study, 33kg is used (Gumbo *et al.* 2013). Nevertheless, serious errors were found both in the appendix and main text (see Table 7 for details), resulting in major computational errors in the Puustjärvi study and reporting errors in the CSO (2013) Energy Statistics 2001–2010 publication. This might have been the basis of the relatively conservative estimate of charcoal production by the Department of Energy which cites the latter as the basis of its calculations (CSO 2013). In 2006, Ng'andwe *et al.* (2006) also based their estimates on Puustjärvi *et al.*'s (2005) study, from which they derived a low estimated production of 8.8 million m^3, which is even lower than the 11 million m^3 we derived from the annex if taken at face value. Their adjustments were not described except to say that they felt the prices had more than doubled, but undoubtedly existing errors were further compounded.

The most recent estimates of wood fuel production have been provided by Kalinda *et al.* (2006), which made use of data collected in the ILUA field study carried out during 2006/7. However, since quantitative estimates of wood fuel production were not collected in the latter, the estimates also relied on previous studies. Charcoal production was estimated based on Chidumayo' s (1997) estimate that consumption was 1,046 kg per capita per year in urban households and 100 kg per capita in rural households, and that 85% of the urban population depends on charcoal for energy (GRZ/FNDP 2006 in Kalinda *et al.* 2008). This resulted in an estimated total consumption of 1.392 million tonnes of charcoal per annum.

Assuming a 4% loss at the production area, and a charcoal to cordwood biomass ratio of 0.25[25], this translated to 5.81 million tonnes of wood. Adjusted for more recent estimates of population (in which rural households outnumber urban households, rather than the other way round as reported in the Kalinda *et al.* study), the updated estimate would be 4.23 million tonnes of wood used for charcoal production.

[25] This could underestimate the amount of wood used. According to Kapiyo (1996, in Mulombwa 1998),) earth kilns are only 10% efficient.

Table 25. Existing estimates of firewood and charcoal consumption in Zambia. Figures in bold are reported estimates, the rest are derived for comparative purposes.

Source	**PFAP (1997)**	**FSP (2004)**	**Puustjärvi et al./ SAVCOR (2005) main text**	**Puustjärvi et al./ SAVCOR (2005) Annex 3, cited in CSO (2013)**	**CSO (2013) (Dept. of Energy)1**	**FAO Yearbook 2004 in CSO (2013)**	**Ng'andwe (2006)**	**Kalinda et al. (2008)**	**Kalinda's estimates adjusted to 2010 census data**	**Estimate based on 1996 per capita consumption**
Year of estimate	**1996**	**2003**	**2004**	**2004**	**2004**	**2004**	**2006**	**2008**	**2010**	**2010**
Firewood (million tonnes)		7.12	1.79	8.21	9.25			1.32	2.05	9.36
Firewood (million m^3)		9.49	2.384	10.944	12.33			1.76	2.73	12.48
Wood for charcoal (million tonnes)		6.78	10.68	0.40	4.74			5.80	4.23	5.22
Wood for charcoal (million m^3)[2]		9.04	14.24	0.54	6.31			7.73	5.64	6.97
Charcoal (million tonnes)		1.63	2.565	0.10	0.95			1.39	1.01	1.25
Charcoal (million 33-kg bags)[3]		49.32	77.70	2.925	28.70			42.18	30.73	38.00
Total wood fuel (million tonnes)									6.28	14.59
Total wood fuel (million m^3)	19.40	18.53	16.63 (n/a)	11.48 (n/a)	18.65	11.57	8.80	9.49	8.37	19.45

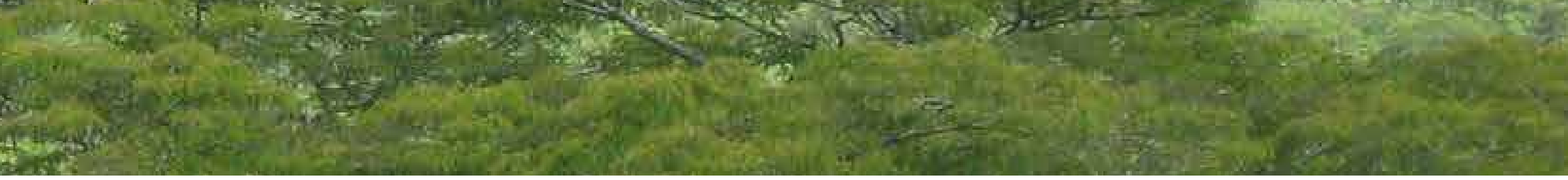
1 Part of a projected 10-year time series.

2 Assuming an average density of 750 kg per m^3.

3 The "50 kg" bags of charcoal weigh 33 kg (Gumbo *et al.* 2013).

4 The Puustjärvi *et al.* (2005) study detailed its calculations in Annex 3. While firewood production had been escalated from 9.49 to 10.94 in the annex, the main text used a figure of 2.383 million m^3, in an apparent error. Erroneous value is underlined.

5 From the Puustjärvi *et al.* (2005) Annex 3, cited above, an error in one of the tables, where kg charcoal had been mislabelled as millions of bags, led to its being misreported in the CSO study, but the correct figure was used in the main report. While their estimate is based on the FSP's 49.3 million bags, it was derived using an assumption of 50 kg per bag, whereas our estimates are based on 33 kg per bag. Erroneous value is underlined.



While Kalinda *et al.*'s estimate of charcoal production was considerably lower than some earlier estimates, their estimate of firewood production was very much lower – about five times – than earlier estimates (Table 7). Based on the fact that at least 86% of rural households used firewood (ILUA data), and the estimated household firewood consumption of 125 head loads or 1,562 kg dry firewood per year (Bwalya 2006), and projected population data for 2008, Kalinda *et al.* (2008) estimated a total firewood consumption of 1.32 million tonnes. Using more recent census data, this would translate to just over 2 million tonnes (2.73 million m^3) of firewood in 2010. Some of the discrepancy between estimates may relate to different authors multiplying consumption by individuals versus by households. For example, Kalinda *et al.* (2008) referred to "per capita household consumption", then extrapolated this by number of households. Information on consumption rates further suggest that Kalinda *et al.*'s firewood consumption estimates could have been underestimated by five times (average household size is 5.2).

48,000 tonnes of charcoal were used in agriculture, industry and mining in 2010 (CSO 2013), adding 1.66 million m^3 to the estimate of national wood fuel consumption. Using the upper-bound estimate given above, this suggests a total national consumption of **20.65 million m^3**.

Applying the same logic as used by Kalinda *et al.* (2008), this estimated total would require the clearing of about 170,000 ha of intact forests (79.37 tonnes per ha) per year, or a larger area of secondary forests. Given that the estimated rate of loss is 300,000–450,000 ha per year, this estimate of production would seem fairly plausible. Indeed, actual extraction is likely to be greater than national consumption, since the illegal export of charcoal, while unquantified, is thought to be significant. Thus it is quite possible that wood fuel production could exceed **30 million m^3.** This would result in clearing of 230,000 ha per year of intact forests. Note that this estimate of wood fuel consumption is about twice the estimated total allowable cut of 15.9 million m^3 per year by Kalinda *et al.* (2008; see following section), which suggests that it is not sustainable, contrary to what is suggested by some authors (Puustjärvi *et al.* 2005; Kalinda *et al.* 2008; Bwalya 2011).

Table 26. Household consumption figures used as the basis of early and later estimates of wood fuel consumption.

	Kalumiana (1996)	**PFAP (1997)**	**Kalinda *et al.* (2008)**	**Equivalent per capita applied in study (kg)**
	Per capita consumption[1] (kg)		**"Per capita household consumption" (kg)**	
Firewood				
Urban		240	0	0
Rural	1 070.7	1 025.4	1 562[2]	306
Charcoal				
Urban	179.9	131	1 046	205
Rural	72.8	72.8	100	20

1 Note that the PFAP estimates are averages for all households, whereas Kalinda applied the charcoal estimates to 85% of the population.

2 Based on 125 headloads per year in Bwalya (2006, cited in Kalinda *et al.* 2008).

If one applies the original per capita consumption data reported in the PFAP (1997) to the 2010 population, then a much higher estimate of 14.6 million tonnes of wood fuel consumption is obtained, equivalent to an estimated **19.45 million m^3**, which is comparable to some other estimates, including that of PFAP (1997). In addition to household consumption, an estimated 1.2 million tonnes of firewood and

In 2010, the price of charcoal was about 28,356 Kwacha per bag (CSO 2013). We estimated that it takes roughly 0.18 m^3 of wood to produce a bag of charcoal. Therefore

Table 27. Estimated firewood and charcoal consumption by different sectors in 2010 (CSO 2013).

	Firewood		**Charcoal**	
	('000s tonnes)	**Per cent**	**('000s tonnes)**	**Per cent**
Rural (households)	8 334.02	80.0	179.72	15.0
Urban (households)	883.2	8.5	970.5	81.0
Agriculture	364.61	3.5	0	0.0
Industry	835.49	8.0	45.89	3.8
Mining	0.21	0.0	2.04	0.2
Total	**10 417.52**		**1 198.14**	

about ZK154,700 (US$39) of charcoal is produced from 1 m^3 of wood. While most of the firewood is cut for own household use, most charcoal is transported and sold in urban areas, generating further income along the way. Prices of 50-kg bags (which actually weigh 33 kg) vary from as little as ZK13,000 in remote villages where they are cut to ZK30,000 in bigger towns (Gumbe *et al.* 2013). Furthermore, this charcoal is then often repackaged into plastic bags and sold for about ZK1,000 per kg (Gumbe *et al.* 2013). The latter translates to ZK180,000 (US$45) per m^3. In comparison, the price of firewood (escalated using the same pattern as published for charcoal in CSO 2013) was estimated to be ZK 208,000 (US$ 52) per m^3 in 2010. This is an overestimate of its value, however, as firewood has little market value in the areas where most of it is consumed, even though sales of firewood have increased in recent years (Kalaba *et al.* 2012).

There are two estimates of the total value of wood fuel production in Zambia. Puustjärvi *et al.* (2005) estimated the value of firewood and charcoal production in 2004 based on a field survey carried out in 2003 (FSP). The overall estimated production of about 16.6 million m^3 (based on our conversion from charcoal mass) was estimated to have a market value of US$273 million and generated a GVA of US$173 million. It was estimated that about 5% of firewood and 90% of charcoal is traded. Correcting for the above-mentioned error in firewood quantity, the revised total would be **US$340 million.**

In the second study, using an estimated extraction of 8.798 million m^3 in 2005, Ng'andwe *et al.* (2006) estimated that wood fuel production had a market value of US$87.98 million, and generated a GVA of US$374.9 million in 2006. The trade value was much lower than Puustjärvi's estimate, due to applying a lower price (US$10 per m^3 vs US$26 per m^3), but the estimated GVA was very much higher as a multiple of market value (US$4.26 vs US$0.63) and as a value per unit wood volume (US$42.61 vs US$8.92 per m^3). The overall (corrected) estimates of value were similar, in spite of large differences in estimates of production as well as value.

Puustjärvi *et al.* (2005) estimated that the forest sector contributed to at least 3.7% of Zambia's GDP, and over 161,000 jobs. Subsistence production was estimated to make up 35% of the overall value. Comparative estimates for GDP in 2004 were that agriculture contributed 7.2%, fisheries 2.6%, and mining 8.2% (Puustjärvi *et al.* 2005). It was estimated that over 145,000 people were employed full-time in charcoal production (CSO 2013). However, noting that the error in firewood production carried through to this table, it is unclear whether employment estimates are correct. If so, it suggests that involvement in charcoal production has more than tripled: in 1997, it was estimated that 41,000 rural households were involved in full-time charcoal production, and that another 4,500 people were involved in transportation, marketing and distribution (GRZ 1997, in Jumbe *et al.* 2002). Indeed, there was reportedly a big upsurge in charcoal production during the 1990s due to the economic downturn, as charcoal production offered returns that were nearly five times that of farming (Chidumayo 2001). Since few households specialize in one activity, the actual number of households involved is probably much higher. Chidumayo (2001) reported that about 9,000 households produced charcoal in Chongwe district alone in 2002.

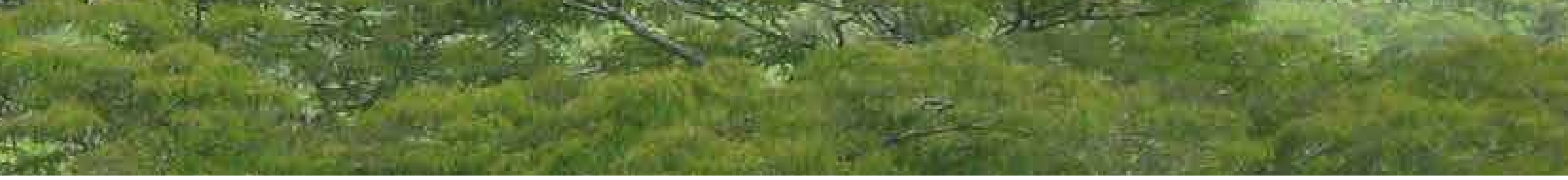
Table 28. Estimated contribution of forest production and processing to GDP in 2004. *Source: Puustjärvi et al. 2005.*

	Production	Estimated wood used (million m^3, derived)	Trade value	Value added
			(US$ million)	
Firewood (m^3)	2 383 000*	2 4	62	46.5
Charcoal kg	2 564 million	14 2	211	126.5
Original total		16 6	273	173.0
Corrected estimates based on Annex 3:				
Firewood (m^3)	10 940 000	10.9	285	213.5
Charcoal kg	2 564 million	14.2	211	126.5
Corrected total		25.2	496	340.0

* This was an error (see above).

Table 29. Estimated total wood fuel production and employment in 2004. *Source: Puustjärvi et al. (2005) in CSO (2013).*

	Production	Productivity (m^3 or kg/employee)	Full-time employment	Percentage of total
Firewood (1,000 m^3)	2 383	348	6 847	4.2
Charcoal (kg)	2 564 484	17 585	145 831	90.4



3. Soil erosion and sedimentation modelling

We used the InVEST modelling tools (Sediment Retention module, Version 3.0.0) to estimate soil loss and sedimentation as a function of vegetation cover, precipitation, management practices and topography. The InVEST Sediment Retention calculates the average annual soil loss from a delineated parcel of land (watershed) to determine the quantity of soil that arrives at the outflow of the watershed. It also estimates the ability of each parcel to retain sediment as a function of vegetation cover and management practices, and permits an assessment of the cost of removing the accumulated sediment from a reservoir on an annual basis. A more detailed description of the model can be found in the InVEST Users Guide (Nelson and Ennaanay *et al.*, 2013).

At the core of the sediment retention model is the Universal Soil Loss Equation (f), which estimates the potential for sediment to move when accounting for rainfall intensity, soil erodibility, land management practices such as terracing, and the relationship between the slope of the landscape and the potential length sediment could move when motion occurs (Wischmeier and Smith 1978). The general form of the USLE is:

$$A = R * K * LS * C * P$$

Where,

A: Average annual soil loss (tonnes per ha*yr)
R : Rainfall and runoff erositivity
K: Soil erodibility
LS: Slope length-gradient factor
C: Crop and management factor
P: Support practice factor

The USLE has some very important limitations that must be clarified. It is not a mechanistic model of soil erosion. It only predicts erosion caused by sheet wash and does not model turbulent flow, rill erosion or, indeed, wind erosion. The validity of the model and the coefficients used within in it should ideally be determined from data and calibrations from field experiments conducted on soils of the region of interest. As far as we can determine, there are no published studies for Zambia to determine suitable parameters or justify the validity of the model. All model results must therefore be considered with caution. The USLE does provide a good first indication of the potential for soil loss under different conditions and, because of its relative ease of application within a GIS environment, can provide a useful overview of the spatial distribution of possible soil loss at a range of spatial scales.

The InVEST module is restricted by the number of pixels and therefore the size of watershed (scale) for a given pixel size (resolution) that can be processed in a single run. The size of the area of interest is 1,357,964 km^2. Modelling at this scale in a single run is not possible. We divided the entire area into nine major catchments comprising 43 smaller sub-catchments, and resampled the digital elevation model (DEM) from its original 90 m pixel size to 250 m pixel size suitable for a national-scale analysis using GRASS algorithm *r.resamp.rst*, which uses a regularized spline with tension and smoothing to maintain the topographic characteristics of the input raster.

Data and biophysical parameters

The sediment retention module requires input data in the form of raster layers (gridded data) describing soil erodibility (K-factor), precipitation erosivity (R-factor), slope (S), land cover type, and stream network, a vector layer delineating catchments (watersheds) and tables of biophysical parameters describing the effect of vegetation in intercepting rainfall energy (c) and of management practices in mitigating soil loss (p) as well as of land cover type in trapping released sediment (*sediment retention efficiency*).

Soil erodibility (K-factor)

Soils information (erodibility (K-factor)) was used in the USLE (Wischmeier and Smith 1978) within the InVEST Sediment Retention Model (Version 3.0.0.) to determine potential rates of erosion and sediment yield and for soil carbon estimates (Nelson *et al.* 2013). The Harmonized World Soil Database provides a dominant soil class and as many as four sub-classes. Erodibility (K-factor) was estimated using the formula:

$$K\text{-factor} = 27.66*m^{1.14*}10^{-8*}(12 - a) + (0.0043*(b - 2)) + (0.003*(c - 3))$$

Where,

m = (% silt + % (very) fine sand) * (100 - % clay)
a = % organic matter = organic carbon *1.724
b = structure code (Table 30)
c = profile permeability code

A spatial average of erodibility, K-factor for polygons delineating each soil class, was estimated by averaging k-values based on the percentage cover of each soil subclass within the soil unit. The resulting map is presented in Figure 42.

Table 30.USLE k-factor soil structural code for determination of parameter b.

Harmonized World Soil Database code	Value	Structure class	Structure code
1	Very poor	Solid	4
2	Poor	Slightly structured	3
3	Imperfectly	Slightly structured	3
4	Moderately well	Fairly structured	2
5	Well	Fairly structured	2
6	Somewhat excessive	Very structured or particulate	1
7	Excessive	Very structured or particulate	1

Table 31. USLE k-factor soil permeability code for determination of parameter c.

Harmonized World Soil Database code	Texture class	Typical infiltration rate (inches per hour)	Grouping	Infiltration rate (inches per hour)	Infiltration class
1	Clay(heavy)	0.02	0.0015 to 0.06	Very slow	6
2	Silty clay	0.04	0.0015 to 0.06	Very slow	6
3	Clay (light)	0.05	0.0015 to 0.06	Very slow	6
4	Silty clay loam	0.06	0.06 to 0.2	Slow	5
5	Clay loam	0.09	0.06 to 0.2	Slow	5
6	Silt		0.06 to 0.2	Slow	5
7	Silt loam	0.17	0.06 to 0.2	Slow	5
8	Sandy clay		0.2 to 2	Moderately slow	4
9	Loam	0.27	0.2 to 2	Moderately slow	4
10	Sandy clay loam	0.52	0.2 to 2	Moderately slow	4
11	Sandy loam	1.02	0.2 to 2	Moderate	3
12	Loamy sand	2.41	2 to 6	Moderately rapid	2
13	Sand	8.27	2 to 6	Moderately rapid	2

Source: USDA NRCS, Soil Quality Test Kit Guide, July, 2001.

Rainfall erosivity (USLE R-factor)

Rainfall erosivity (R-factor) reflects the fact that the greater the intensity and duration of the rain storm, the higher the erosion potential. Many different approaches and formulas have been proposed requiring different data describing the intensity and the duration of rainfall. For Zambia, empirically determined rainfall erosivity formulae were developed for a selection of towns, but these formulae are relevant only for single storm events (Pauwelyn *et al.* 1988). An alternative method was developed which requires data describing the mean number of days with rains, and the mean maximum daily rainfall per month (Lenvain *et al.* 1988).

Due to limited data availability, we applied the method to approximate rainfall erosivity requiring only annual precipitation data, described in the InVEST Users Guide (Nelson, Ennaanay *et al.* 2013), where *R = a * precipitation (mm)* (Roose 1996) (Figure 41). We also estimated erosivity using a method requiring monthly precipitation data (Arnoldus 1980; Segura *et al.* 2014). The monthly method provided erosivity values that were 40 times larger than the Roose (1996) method and in turn generated soil erosion estimates (tonnes per ha) for watersheds that were extremely large. As an example, for the Zambezi 5 catchment, the average tonnes per ha of soil lost to sheet erosion under the baseline conditions exceeded 448 tonnes per ha over a total area of 1,186,547 hectares. To put this into perspective, extensive field trials in Ohio, in the USA, on a silt loam soil on a

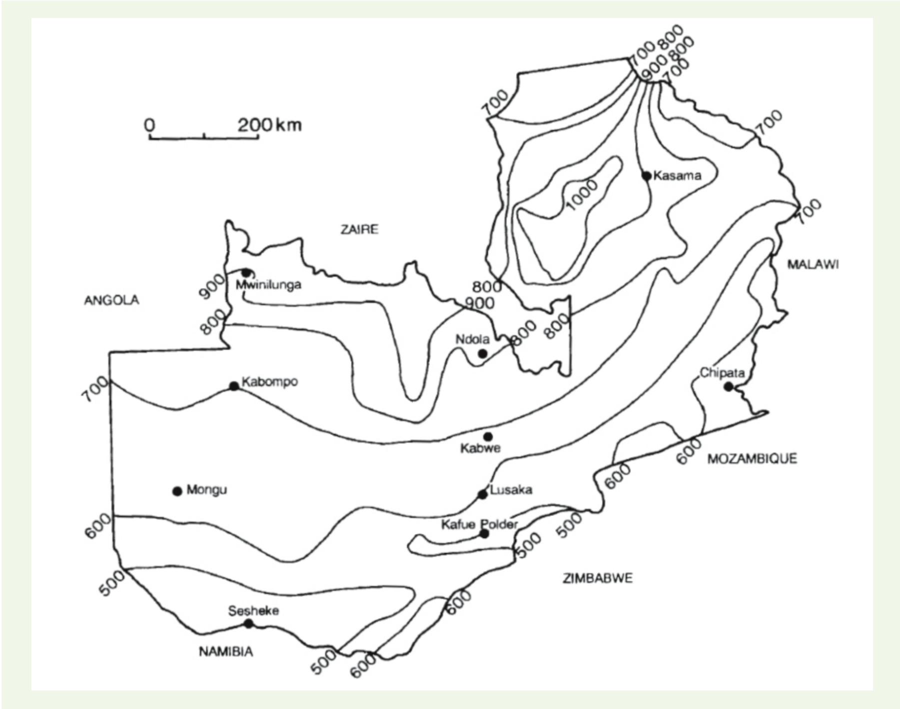


Figure 46. Iso-erodent map developed by (Lenvain, Sakala *et al.* 1988).

12˚ slope with average annual rainfall of 960 mm generate 246 tonnes per ha soil loss under continuous maize cropping, 105 tonnes per ha under maize rotation, 28.2 tonnes per ha under wheat rotation and only 0.05 tonnes per ha under permanent pasture (Wild 1988). Similar studies conducted on Oxisols yielded mean annual soil loss of <1 tonne per ha when subjected to approximately 1,200 mm of rainfall (Nill *et al.* 1996).

A total of 400 tonnes per ha soil loss corresponds to 10 cm soil loss per annum over ~25% of the total land area (assuming a soil bulk density of 1.8 g per cm) in an area where less than 10% of the soils are cultivated and where the average slope is only 7˚. While loss of 10 cm of soil per annum is certainly possible in extreme cases, for example on a steep slope under bare fallow, there is no evidence to indicate that such large losses are occurring annually over 20% of the land surface. If they were to occur, the upper layers of the soil would be removed very rapidly (over a few years) and further soil loss would halt as supplies of soil were gone. In contrast, the results of the sedimentation module parameterized using R-erosivity and calculated using the Roose (1996) method lie in a realistic range. Taking again the Zambezi 5 catchment, predicted soil loss using this method is 11.18 tonnes per ha averaged over the entire catchment. This corresponds to 10 cm soil loss per annum over 0.62% of the total area (7,369 ha), or 5cm over 1.24%, and so on.

Topography (LS-factor)

Topographical information, the length of slope, L, and the percentage slope, S, were obtained from the DEM described. The DEM required some significant processing prior to use within the sedimentation module. For the module algorithm to work, it is necessary to ensure a unique flow path across the DEM. This can be ensured by two DEM processing 'hydrological conditioning' algorithms called – 'burning' or 'carving' and 'depression filling' ' or sink removal'. Burning involves artificially incising a stream network into the DEM, while depression filling seeks to remove locations within the DEM which represent 'holes' which will confuse flow path algorithms within the sedimentation module. These operations were completed within the GRASS open-source GIS processing software. The GRASS module r.carve takes stream vector data, transforms it into a raster and subtracts a fixed depth from the DEM (Mitasova *et al.* 1999). The subtracted depth is not a value that reflects any reality, rather a large number (we used 100 m) to ensure that the stream network is adequately carved into the DEM. The algorithm automatically ensures that there are no flat areas in the streams, but does not ensure that there are no flat areas elsewhere on the DEM. To ensure that this is the case, a second algorithm r.fill.dir was applied to the output of the carve operation. This algorithm, which filters and generates a depressionless elevation map and a flow direction map from a given elevation raster map, was iterated until it indicated that no depressions had been identified.

Cover and management (C-factor) and practice (P-factor)

The cover and management (C-factor), practice (P-factor) and sediment retention coefficients used are provided below. A higher value for C-factor indicates increased erosion risk, a lower value for sediment retention (sedret_eff) indicates less efficient retention of sediment.

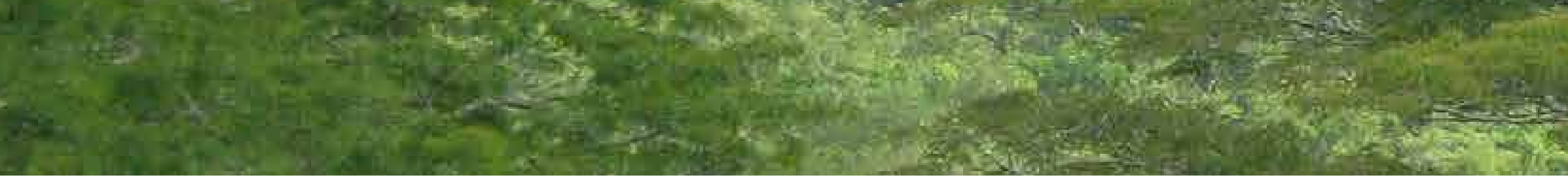


Table 32. Cover and management (C-factor) and practice (P-factor)

lucode	Land Use Land Class Description	usle_c	usle_p	sedret_eff
14	Rain fed Shrub Crop(s) / Rain fed Tree Crop(s)/Rain-fed Herbaceous Crop(s)	0.07	1	0.3
20	Cultivated and Managed Terrestrial Area(s)/Natural And Semi-Natural Primarily Terrestrial Vegetation	0.07	1	0.8
30	Natural And Semi-Natural Primarily Terrestrial Vegetation/Cultivated and Managed Terrestrial Area(s)	0.1	1	0.8
40	Broadleaved Evergreen Closed to Open Trees/Semi-Deciduous Closed to Open Trees	0.001	1	1
50	Broadleaved Deciduous Closed to Open (100–40)% Trees	0.001	1	1
60	Broadleaved Deciduous (40– (20–10)%) Woodland	0.001	1	1
70	Needle leaved Evergreen Closed to Open (100–40)% Trees	0.001	1	1
90	Needle leaved Evergreen (40– (20–10)%) Woodland/Needle-leaved Deciduous (40–(20–10)%) Woodland	0.001	1	1
100	Broadleaved Closed to Open Trees/Needle-leaved Closed to Open Trees	0.001	1	1
110	Closed to Open Trees/Closed to Open Shrubland (Thicket)/Herbaceous Closed to Open Vegetation	0.1	1	1
120	Closed to Open Shrubland (Thicket)/Herbaceous Closed to Open Vegetation/Closed to Open Trees	0.1	1	1
130	Broadleaved Closed to Open Thicket	0.001	1	1
140	Herbaceous Closed to Open Vegetation	0.1	1	1
143	Grassland/Crops/Bare Soil	0	1	0.5
150	Sparse Trees/Herbaceous Sparse Vegetation/Sparse Shrubs	0	1	0.3
160	Closed to Open (100–40)% Trees/Water Quality: Fresh Water	0	1	1
170	Closed to Open (100–40)% Closed to Open (100–40)% Broadleaved Evergreen Trees On Permanently Flooded Land (With Daily Variations) Water Quality: Saline Water/ Closed to Open (100–40)% Semi-Deciduous Woodland On Permanently Flooded Land	0	1	1
180	Closed to Open Shrubs on Permanently Flooded Land/Closed to Open Shrubs on Temporarily Flooded Land./Closed to Open Herbaceous Vegetation on Permanently Flooded Land/Closed to Open Herbaceous Vegetation on Temporarily Flooded Land/ Closed to Open	0	1	1
185	Wetland	0	1	1
190	Artificial Surfaces and Associated Area(s)	0	1	0
200	Bare Area(s)	0	1	0
210	Natural Waterbodies/Artificial Waterbodies	0	1	1

Method and simulation checks

The biophysical data was prepared as inputs to the InVEST sedimentation module and was set up for each of the nine catchments (watersheds) in Figure 31. It was advised by the InVEST modelling team that "*the stream network generated by the model from the DEM should closely match the streams on a known correct stream map*" (*Nelson et al.* 2013). This can be achieved by adjusting the '*threshold flow accumulation*' value input to the model. This parameter defines the number of upstream cells that must flow into a cell before it is considered part of a stream. Larger values of the threshold will produce coarser stream networks with fewer tributaries; smaller values will produce more tributaries.

As a detailed example, we present the results for a 60 km by 60 km region in the Luangwa valley, covering the plateau, the escarpment and the valley. The stream network is well reproduced (threshold value = 150) (Figure 47). The LS-factor is highest on the steep long slopes down the escarpment (Figure 48). Potential erosion is greatest in these areas (Figure 49) as is the importance of vegetation in first stopping rainfall energy from impacting the soil and loosening soil particles, but also in retaining sediment as it flows overground (Figure 50, Figure 51 and Figure 52).

It is important to note that the values of tonnes per pixel must be rescaled downwards to be interpreted as tonnes per ha by a factor of 6.25, as the simulated pixel size is 250 m x 250 m (62,500m^2).

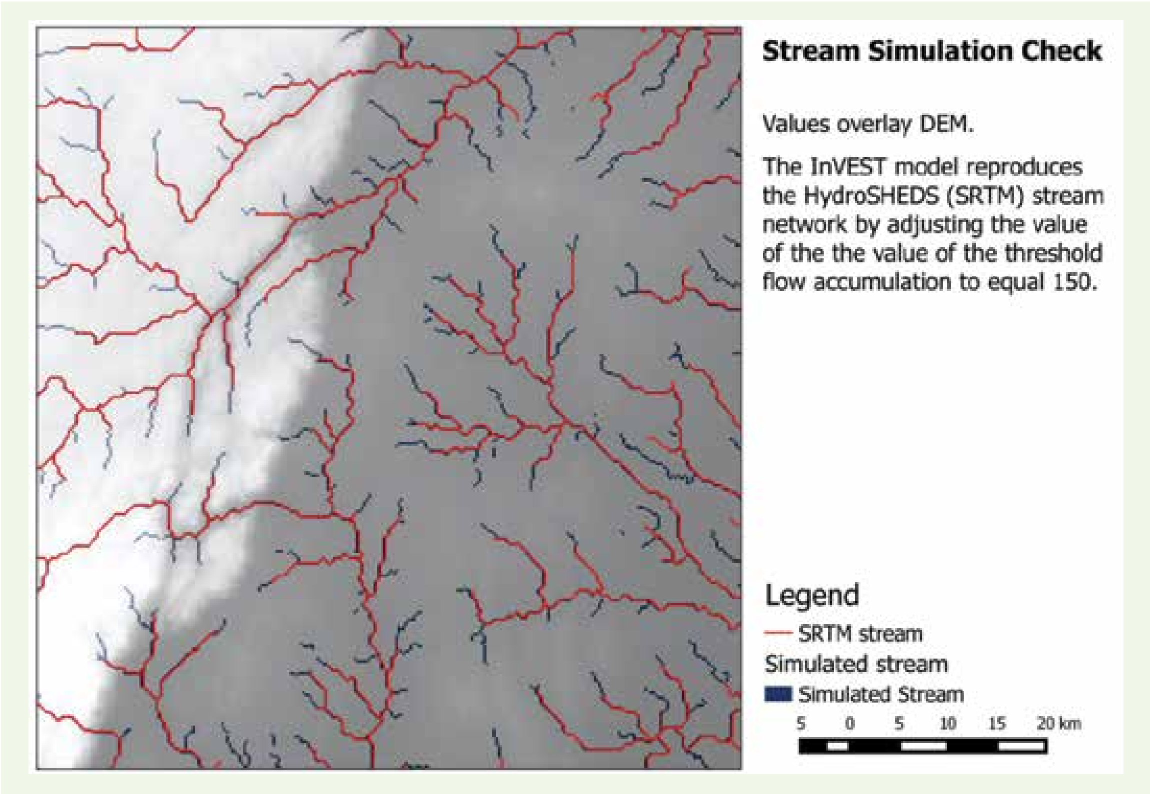


Figure 47. Verification on correct InVEST module stream simulation.

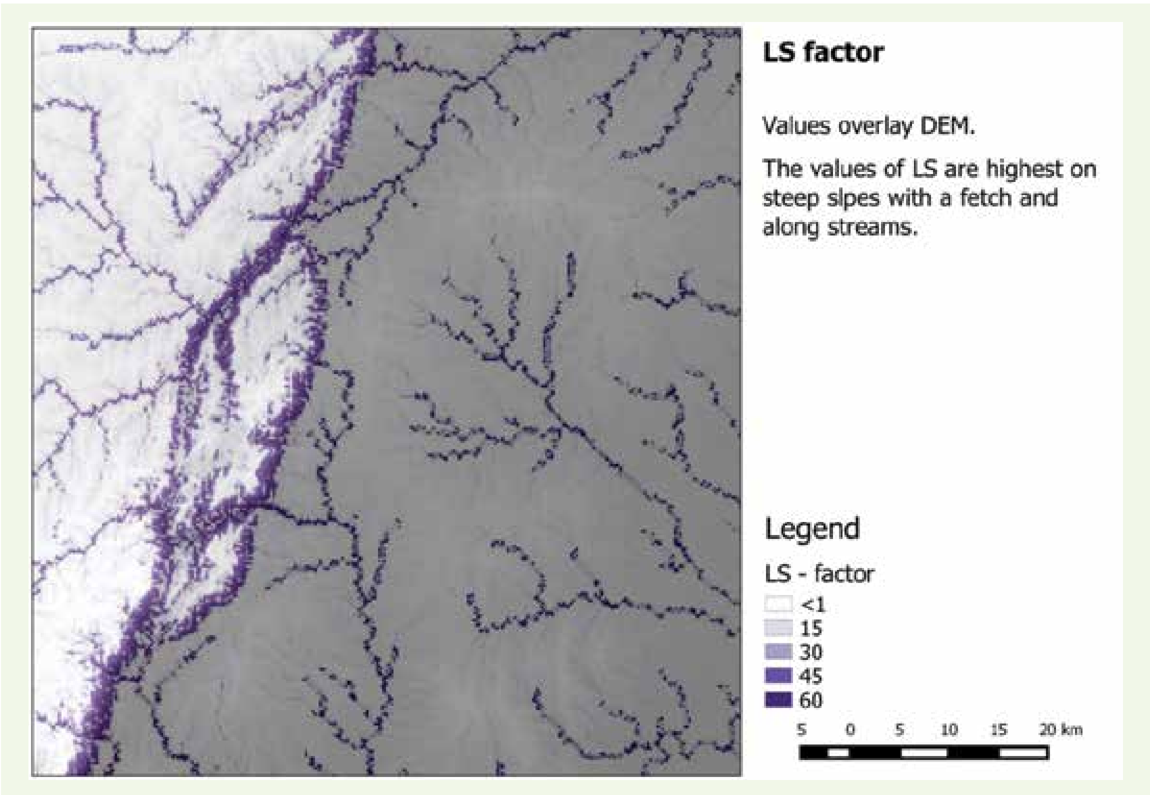


Figure 48. LS-factor.

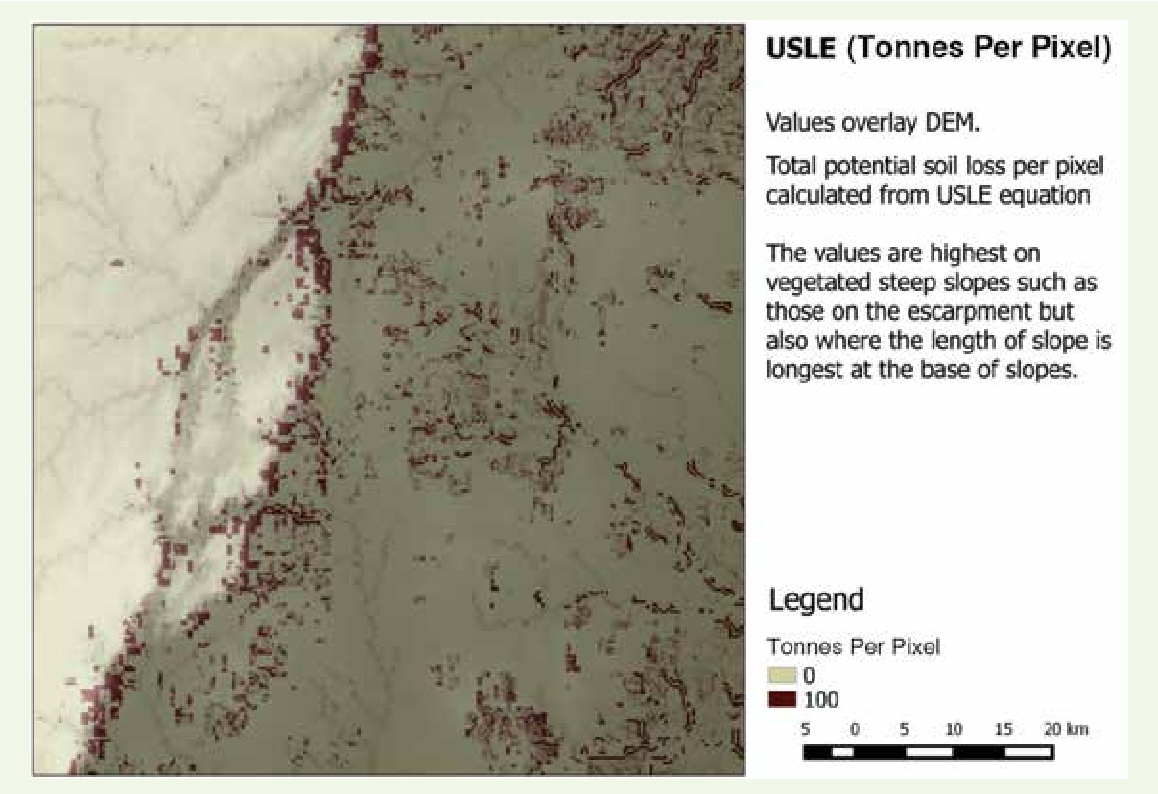


Figure 49. USLE output.

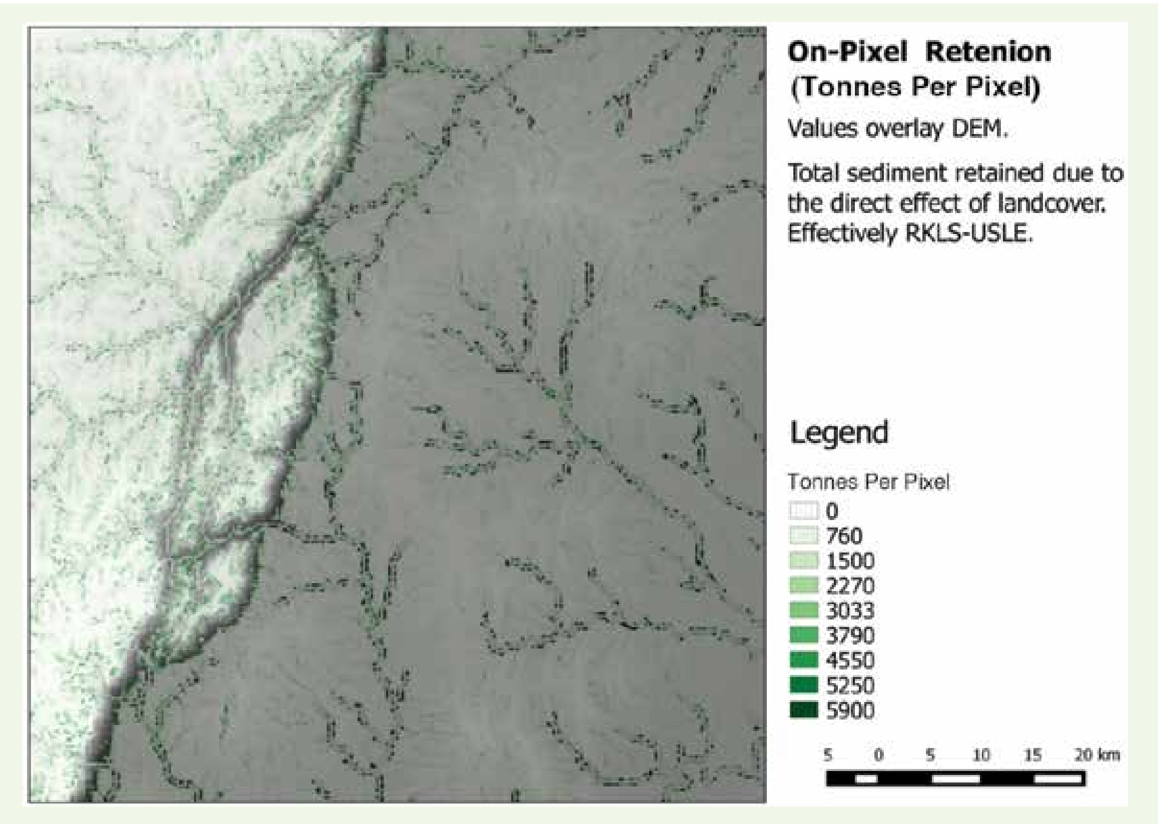


Figure 50.On-pixel retention output.

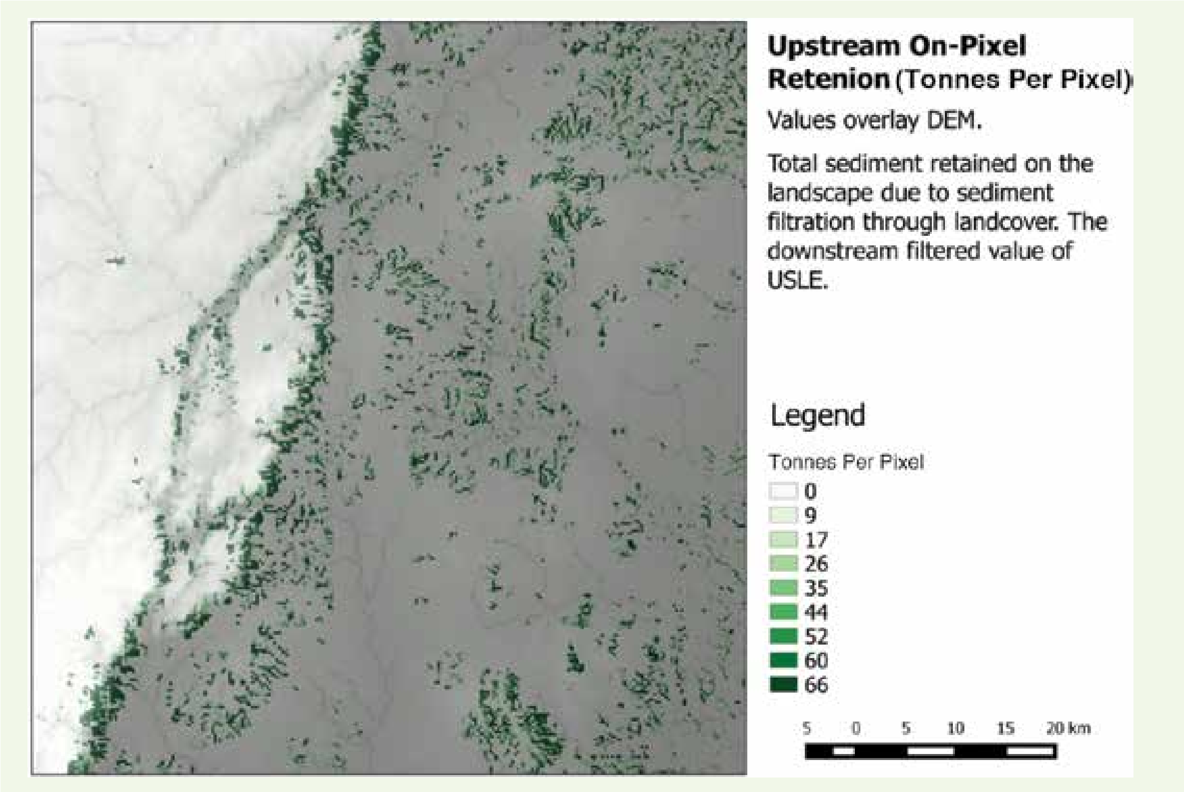


Figure 51. Upstream on-pixel retention.

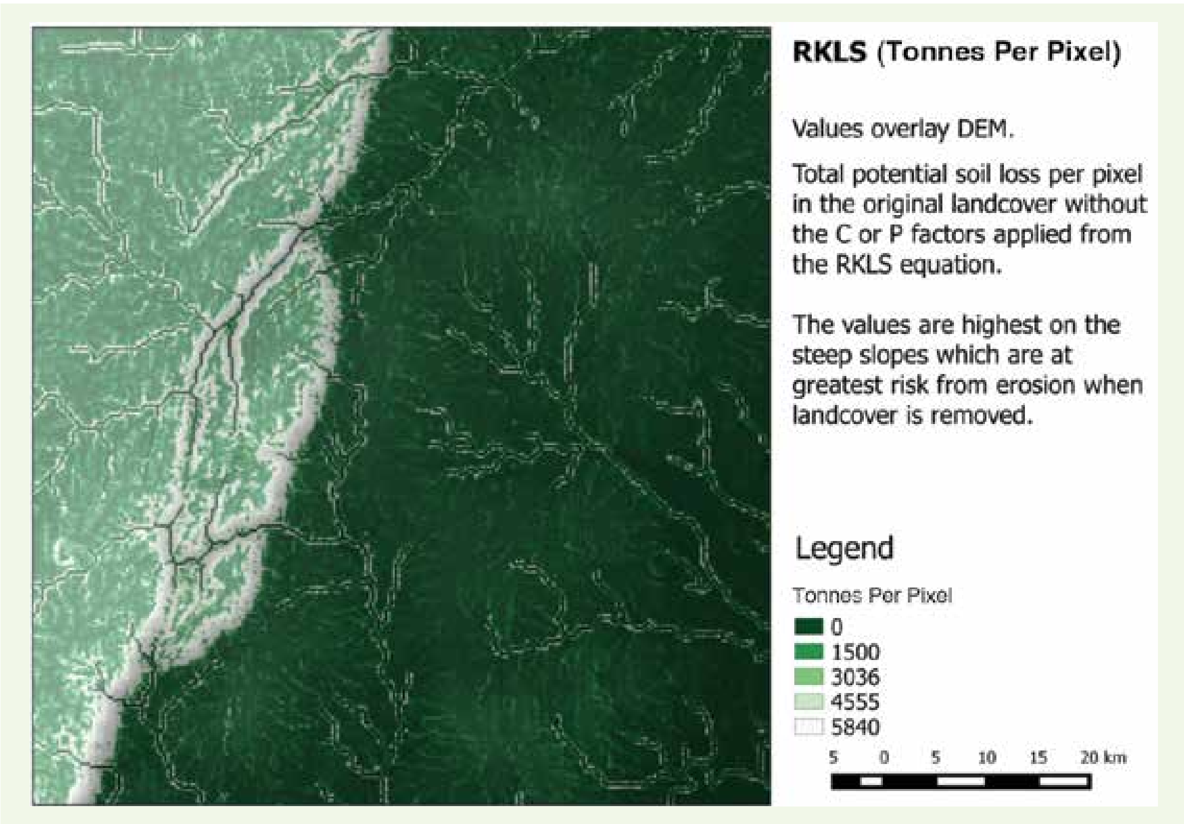
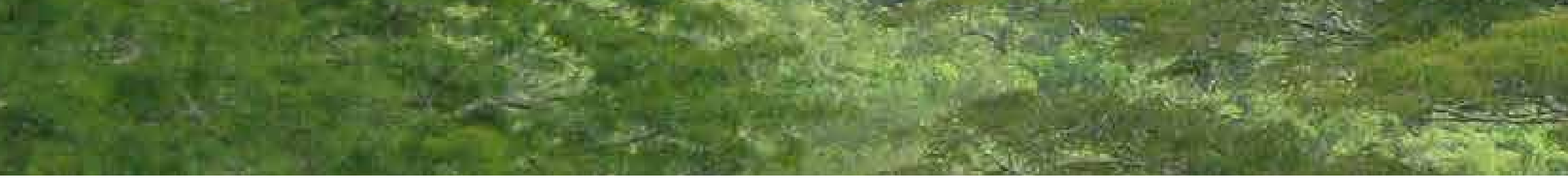


Figure 52. RKLS output.



Recommendations

The recommendations made here are pertinent to (a) the types of data that should be collected to fill important data gaps, (b) the way that data is stored, and (c) the 'optimal' approach to use the data for ecosystem service valuation as a component of REDD+.

More reliable information is needed to describe land use. Using classifications derived from remotely sensed imagery, it is difficult to distinguish between dryland forest (mopani), savannah woodland (where there is a significant percentage cover of grass), degraded forest and the mosaic of cropland and forest. The landcover classifications can be significantly improved through (a) fusion analysis of multi-sensor data, and (b) more intense ground-truthing. It is essential to be able to distinguish between natural grassland with trees and heavily impacted forest consisting of small-scale farming with isolated trees.

Higher resolution data are needed to describe soils, and much better Zambia-specific data are required to calibrate soil-erosion models. We call into question the accuracy of the USLE when little or no published research describing field trials on suitable plots has been conducted with cover and management practices typical for Zambia.

The process of locating, access, downloading and preparing the data used in this study was extremely time consuming. While nearly all data were stored online on public access sites, very rarely was the data presented in a format that was immediately amenable to analysis. Software models are extremely sensitive to errors in input data. Nearly all of the data used in this analysis required a significant amount of cleaning and checking to be useable.

Perhaps more importantly for independent researchers and students seeking to contribute to the body of knowledge concerning Zambian forests and ecosystem services, the download cost would be extremely prohibitive.

While it is not always true that an increase in resolution will result in an improvement in the quality of the results, it is evident that use of higher-resolution digital elevation data (Aster, 30 m pixel size) would have been preferable to the SRTM data used in this study. Aster data was not used for two reasons. Firstly, time, and secondly, computing power. More time and more powerful computers are required if these simulations are to be conducted using the highest resolution DEM data available. No doubt this would improve the quality of the results, but the number of pixels to analyse will be prohibitive.

This observation really summarizes our principle recomendataion concerning data and modelling. The quality of any analytical results will only ever be as good as the data and the model used to provide them. More fundamental scientific research is required within all regions of Zambia at a resolution suitable for generating reliable inputs and calibrations to biophysical and economic models of the environment. Such models are necessary to provide more robust and precise measurements of crtical ecosystem characteristics, functioning and flows. Similarly, more effort is required to develop models that integrate and link the biophysical, economic and social components to enable decision-makers to make reliable informed decisions.

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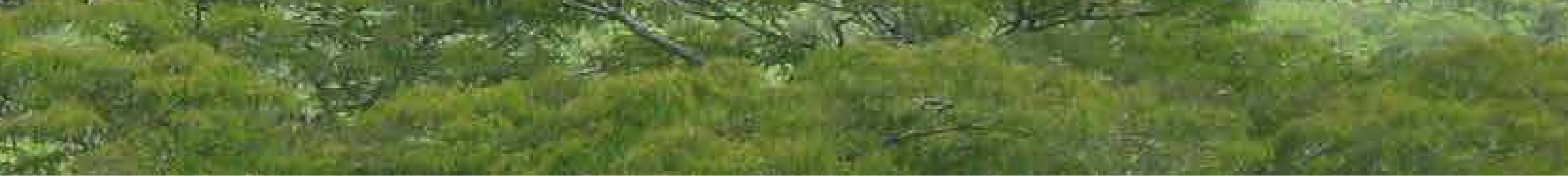

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4. Spatialization of timber extraction and pollination services

The problem is to take a national-scale estimate of the value of an ecosystem good or service, often derived as the sum of district-level data or from the national accounts, and to spatialize this in such a way as to enable prioritization of specific REDD+ activities in specific localities.

Total values of estimated sustainable yield, actual timber extraction and pollination services were spatialized using a weighting method. For sustainable yield, we simply assumed that extraction was proportional to biomass and multiplied each pixel by the ratio of sustainable yield to total forest biomass (m^3). Areas with the most biomass have the highest sustainable yield and vice versa. However, it is unreasonable to expect actual extraction patterns to follow this idealized spatial pattern. Lacking detailed information on the location and actual extracted amounts of timber from forest concessions, we used spatial data describing the Human Appropriation of Net Primary Productivity (HANPP) (Haberl *et al.* 2007).

$$Total\ Extracted\ Timber = \sum_{ij}^{n} \left\{ \frac{biomass_{ij}}{1} * \frac{HANPPweight_{ij}}{1} * \frac{Total\ Extracted\ Timber}{\sum_{ij}^{n}(biomass_{ij} * HANPPweight_{ij})} \right\}$$

Pollination services were spatialized using a similar approach. The value of forest pollination ecosystem services to the agricultural sector was spatialized using geographic data describing the extent of crops across Zambia. This came from two sources: (1) the Zambia Forest Department (2000) land cover classification, which defined zones as 'Cultivated' with an annual crop, and (2) land cover categories from the GLCN (2005). We used both because they provided complimentary information and neither provided a 'perfect' spatial description of known cropping activities. The ZFD map describes large homogenous regions surrounding known locations of higher population density, but does not distinguish small patches of cropping activities. This is because a visual classification process was used and there is a limit to the ability of a small team of classifiers to identify every small patch of agricultural activity across the entire country. In contrast, the GLCN map was created through automatic supervised classification and was able to define these small patches but, being based on imagery from a single date, is not able to capture all agricultural areas, certainly those that have been harvested or left in fallow. Finally, we excluded all areas within national parks. We did this for two reasons. Firstly, agricultural activity is not permitted within national parks, but secondly because the GLCN map confused mopani woodland with a mosaic crop and tree/shrub cover class extending across a large part of the Luangwa National Parks (North and South). This provided us with a map showing the extent of cropped land across which the total value of pollination services (US$74 million) could be extrapolated.

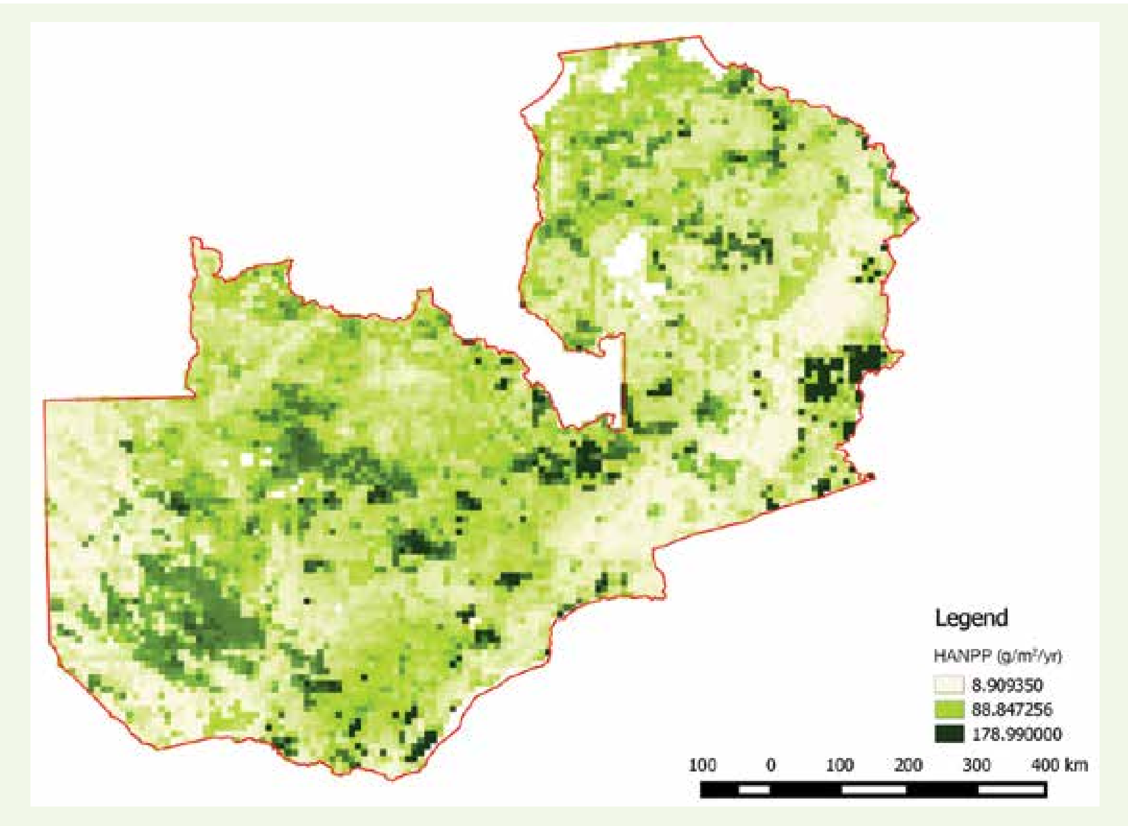
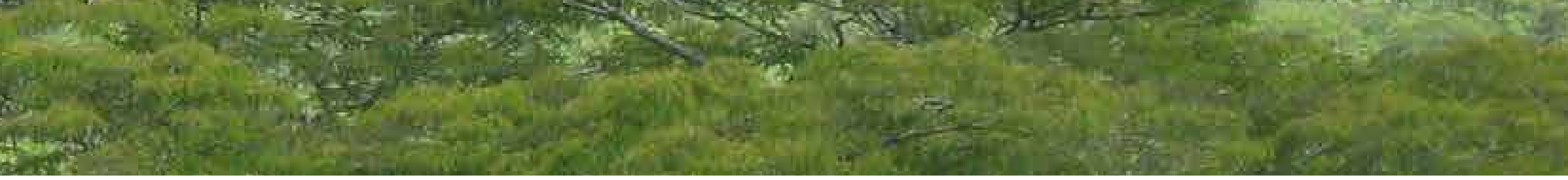


Figure 53. Human-appropriated net primary productivity (Haberl *et al.* 2007).



We used both biomass and HANPP maps to do this. The formula was used was:

$$Total\ Pollination\ Service = \sum_{ij}^{n}\left\{\frac{1/biomass_{ij}}{1} * \frac{HANPPweight_{ij}}{1} * \frac{Total\ Extracted\ Timber}{\sum_{ij}^{n}(1/biomass_{ij} * HANPPweight_{ij})}\right\}$$

We assumed here that the supply of bees is proportional to the amount of biomass at a given location. As the value of a service is proportional to its scarcity, we used the inverse of biomass. We multiplied this by HANPP. Because the cropped area is rarely a homogeneous cover of monoculture crops, but in reality a complex mosaic of small-scale agriculture and forests, the HANNP measure in these areas reflects demand for agricultural and forest offtake, both of which require bees to a varying extent. So our weighting reflects the spatial variability in supply of pollination services modified by the spatial variability in the demand for these services.

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