UGANDA BUREAU OF STATISTICS

THE REPUBLIC OF UGANDA

PHYSICAL AND MONETARY ECOSYSTEM SERVICES AND ASSET ACCOUNTS FOR UGANDA 1990-2015

July 2023

FOREWORD

It is with great pleasure that I present the first ever Ecosystem Account (EA) for Uganda. Ecosystem accounts (EA) involves accounting for ecosystem extent and condition, flows of ecosystem services, and the resultant asset value of ecosystems. The accounts were compiled using the System of Environment Economic Accounting, Ecosystem Accounts (SEEA EA) frame work and the international System of National Accounting (SNA).

These accounts summarise the physical and monetary value flows of ecosystem services and the ecosystem asset values for each of 10 major ecosystem types, including farmland and urban green spaces, for the period 1990 to 2015. The report presents the background, methods and spatial results from the accounting tables of ecosystems at national scale. The ecosystem types were delineated from land cover accounts: open water, wetland, grassland, bushland, woodland, natural forest, plantation forest, farmland, built-up area and bare.

This first EA presents the estimates of Ecosystem service economic contribution and the impact of economic activity on the environment The ESA was developed for years 1990 to 2015 because of the availability of data and consistence with previously published Ecosystem Extent accounts.

The main purpose of this account is to aid policy-makers to ensure that the benefits which are derived from the ecosystems are included in their decisions. Therefore, this first EA is most welcomed by the policy makers as an instrument for policy formulation in strategic planning and evidence-based decision making.

I am confident that the EA report 2023 will provide greater insights and necessary information on the environmental economic contribution and impact which is of great importance to the diverse stakeholder and partners.

Finally, I would like to express my gratitude to the World Bank for their great leadership and continued technical support, Ministry of Finance Planning and Economic Development and all the NCA TWG member and partners for their guidance and support in the development of the Uganda's Ecosystem Services and Assets Accounts 2023.

Therefore, I recommend this report that virtually brings ecosystem interaction with the economy to all those interested in understanding Uganda Natural capital.

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The compilation of these accounts would not have been possible without the generous cooperation of the Ministry of Finance, Planning and Economic Development (MoFPED), the National Planning Authority (NPA), the National Forestry Authority (NFA), the Ministry of Water and Environment (MWE), the National Environment Management Authority (NEMA) and the Uganda Wildlife Authority (UWA), who provided the statistics used in the accounts and assisted with their interpretation.

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Cover photo: Beautiful Uganda. Credit: Bradt Guides; www.bradtguides.com

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Introduction

Ecosystem accounting (EA) involves accounting for ecosystem extent and condition, flows of ecosystem services (both physical and monetary), and the resultant asset value of ecosystems, in a way that is compatible with the international System of National Accounting (SNA). They help policy-makers to ensure that the benefits which are derived from ecosystems are included in their decisions.

Although Uganda is known for supporting extraordinary biodiversity, very little intact natural vegetation or wildlife now remains outside of protected areas, its lakes, rivers and wetlands are increasingly degraded, and soil fertility is declining. Its rapid population growth poses further challenges for meeting sustainable development goals.

These accounts summarise the physical and monetary value flows of ecosystem services and the ecosystem asset values for each of 10 major ecosystem types, including farmland and urban green spaces, for the period 1990 to 2015. Values are summarised at national scale, for each of the country's eight major river basins, and for each of its 146 local administrative units (135 districts and 11 cities). The accounts are in the form of a spreadsheet. This report presents the context, methods and spatial results, but only replicates the accounting tables for ecosystems at national scale.

Methodological framework

For these accounts, ten ecosystem types were delineated from land cover data: open water, wetland, grassland, bushland, woodland, natural forest, plantation forest, farmland, built-up area and bare. Within these, the detailed land cover data (NFA, 2017) and vegetation maps (van Breugel et al., 2015) were also used in estimating spatial variation in ecosystem service delivery where relevant.

Monetary values of ecosystem service flows are expressed in terms of "exchange values", which is the amount that is paid by the users of ecosystem services to the owners of those services, or that would be paid if a market existed. In some cases, the benefit to which the environmental input contributes is accounted for in the SNA (e.g. tourism), but in others it is not (e.g. recreation in open access green space areas). In the former case, the value is equivalent of an intermediate expenditure incurred in the production of an SNA product and does not alter GDP. In the latter, it is the equivalent of a final expenditure for a benefit that is outside of the SNA production boundary and is additional to measured GDP. For ecosystem services that are consumed purposely (provisioning and cultural services), the benefits are valued in terms of the residual value (or resource rent) after all human inputs are accounted for. Services that are consumed inadvertently (regulating services) are valued in terms of avoided costs (costs that would be incurred if the service was lost).

The asset value of ecosystems was calculated as the summed net present value (NPV) of expected future flows of all ecosystem services that are generated by a particular ecosystem asset over 100 years, using a social discount rate of 4.04%. Asset values took sustainability into account as far as possible. All values are expressed in constant 2017 prices in Ugandan shillings (UGX).

Summary of findings

In physical terms, the use of provisioning services increased substantially, ranging from a 25% increase for crops to a 300% increase for water supply (Table I). This can be at least partly attributed to the fact that population doubled over this time period (i.e. increased demand). In comparison, the use of regulating services did not increase much, apart from the water flow regulation service (likely due to supply constraints). The most significant increase was that of the ecosystem contribution to tourism value. This was not expressed in physical terms, but the value increased by 6016% over the 25-year span of the accounts and is attributed to an increase in national and international demand as a result of investments in parks and tourism facilities.

In monetary terms, the value flows of all services increased. All provisioning services at least doubled in value. The percentage increases in value for water, flow regulation, sediment and nutrient retention services were the same as for physical flows, since no real price changes were recorded. The value of carbon retention more than doubled due to the increased price of carbon. Tourism value had by far the highest increase of any ecosystem service. The total monetary value of ecosystem services was 16 783 billion (UGX 2017) in 1990 and 32 057 billion in 2015 (UGX 2017); Uganda's GDP was 25 279 billion in 1990 (UGX 2017) and 101 797 billion (UGX 2017) in 2015. Hence, ecosystem services had a value equivalent to 66% to GDP in 1990 and 31% in 2015.

Table I. Summary and comparison of the results at national scale for 1990 and 2015

	Physical			Monetary (UGX billions)		
	1990	**2015**	**% increase**	**1990**	**2015**	**% increase**
Crops (kt/y)	16 269	20 316	25%	4 240	7 829	85%
Grazed biomass (kt/y)	9 069	26 760	195%	2 866	5 743	100%
Wood (kt/y)	15 315	38 760	153%	184	3 272	1683%
Wild fish (kt/y)	245	455	86%	0.1	0.6	503%
Other wild resources (kt/y)	352	388	10%	147	415	182%
Water supply (ML/y)	140 021	560 577	300%	85	338	300%
Water flow regulation (ML/y)	5 870	12 047	105%	5.7	12	105%
Sediment retention (million m^3/y)	929	1 094	18%	4 212	4 959	18%
Nutrient retention (ktP/y)	3 366	3 504	4%	201	209	4%
Carbon retention (MtC)	2 171	1 943	-11%	4 840	9 064	87%
Tourism value (UGX millions/y)	3 530	215 923	6016%	3.5	216	6016%
Total value	**-**	**-**	**-**	**16 783**	**32 057**	**91%**

The monetary value of ecosystem services flows per ha in 1990 and 2015, expressed in constant 2017 UGX (i.e. correcting for inflation), is shown graphically in Figure I. All ecosystem types increased in value per unit area from 1990 to 2015 except for "Bare", largely attributable to the increase in numbers of people demanding services from them. The largest monetary value per ha, both in 1990 and 2015 comes from forests and wetlands. The largest percentage increases (per ha) between 1990 and 2015 were recorded in "Open Water", "Plantation", and "Wetland".

The asset account records the monetary value of opening and closing stocks of all ecosystem assets within an ecosystem accounting area and additions and reductions in those stocks. These are the net present values of projected annual flows of ecosystem service value over time, taking into account sustainability of flows as far as possible. The value of the ecosystem assets was estimated to be UGX 387.6 trillion in 1990 and UGX 682.9 trillion in 2015 (both in constant 2017 UGX; Table I). Some UGX 71.6 trillion was lost as a result of decreases in the areas of forest, woodland, wetland and open water. This was offset by the increases in demand for services, resulting in an overall increase in the value of ecosystem services. In other words, ecosystems are becoming more and more valuable to people. However, the overall asset value of ecosystems per capita declined by 17.7%, which means that ecosystems are not being adequately managed to keep pace with the demands on them, or natural capital is not managed sustainably.

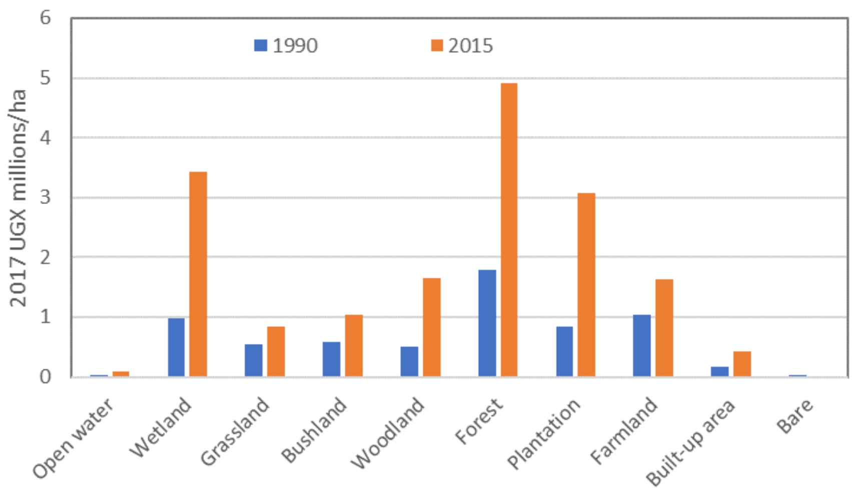

Figure 1. Average monetary value of ecosystem service flows per ecosystem type per ha per year in 1990 and 2015. Values expressed in constant 2017 UGX millions per ha per year.

Policy implications

The findings suggest that ecosystems have been pushed close to or beyond their tipping points, and will not be able to provide ecosystems each additional Ugandan with the same, or more, services. Uganda needs to ensure that standards of living are increased without further degrading and depleting its natural assets. This will require substantial investments in restoration and increased protection of natural capital, as well as investments in education and measures to reduce population growth.

Next steps

The Ecosystem Accounts were compiled over a period of 6 months, from engaging with government on data for the accounts, inspection of the existing data and accounts, to spatial modelling, and compilation of complex accounting tables down to the resolution of 146 districts and cities. As such, the study had to be limited in scope to achieve this. While significant progress was made in extending the previous work, there is still more to be done to complete these, and there are aspects that deserve further consideration, some of which have little precedent globally. Coverage should be extended to include services such as pollination, flood attenuation, and local recreation/other experiential use of ecosystems, as well as urban air temperature regulation and air quality regulation. Another important service to be considered is the contribution of the country's tropical high forests to regional climate regulation (particularly rainfall).

In addition, these accounts are already seven years out of date. It will be important to begin in earnest to bring them closer to the present. This is now possible with the recent completion of the Uganda Land Cover for 2021. The latest land cover data are at much higher resolution (10m) than the previous series (30m), due to the launch of new satellites in 2015. This will also allow for the incorporation of new datasets, such as the recent national livestock census.

Future work should also focus on the empirical estimation of ecosystem condition and its incorporation into the ecosystem accounts. This will allow for refined estimates of ecosystem services flows as well as asset values.

EXECUTIVE SUMMARY

Introduction

Ecosystem accounting (EA) involves accounting for ecosystem extent and condition, flows of ecosystem services (both physical and monetary), and the resultant asset value of ecosystems, in a way that is compatible with the international System of National Accounting (SNA). They help policy-makers to ensure that the benefits which are derived from ecosystems are included in their decisions.

Although Uganda is known for supporting extraordinary biodiversity, very little intact natural vegetation or wildlife now remains outside of protected areas, its lakes, rivers and wetlands are increasingly degraded, and soil fertility is declining. Its rapid population growth poses further challenges for meeting sustainable development goals.

These accounts summarise the physical and monetary value flows of ecosystem services and the ecosystem asset values for each of 10 major ecosystem types, including farmland and urban green spaces, for the period 1990 to 2015. Values are summarised at national scale, for each of the country's eight major river basins, and for each of its 146 local administrative units (135 districts and 11 cities). The accounts are in the form of a spreadsheet. This report presents the context, methods and spatial results, but only replicates the accounting tables for ecosystems at national scale.

Ecological and socio-economic context

Uganda covers an area of 241 550 km^2, with waterbodies making up 17% of this area. It ranges in altitude from 621 m to 5109 m and is characterised by the presence of many lakes, including parts of the great lakes, including Lake Victoria. Eight major river basins are recognised, all but one being part of the larger White Nile Basin. The country has a tropical climate with seasonal rainfall and a large rainfall gradient, with arid areas in northeast of the country. The area was originally dominated by dry *Combretum* wooded grassland (21% of land area) and Lake Victoria rainforest (20% of land area), interspersed with evergreen bushland and wooded grasslands, which supported an exceptional degree of terrestrial biodiversity, ranking in the top ten countries in the world. People have now cleared most of this for agriculture and settlements, and very little intact natural vegetation or wildlife remains outside of protected areas. Natural forest, which once covered 54% of the country, was reduced to 24% by 1990 and 8% by 2015. Soils in the agricultural areas are reportedly declining in fertility. Similarly, the lakes, rivers and wetlands once supported over 600 fish species and a host of other biodiversity. Unfortunately, excessive nutrient runoff from cities and agricultural areas, introduction of alien invasive species, loss of fringing wetland nursery areas and overfishing have undermined productivity and led to hundreds of extinctions of species found nowhere else.

Uganda has acknowledged the risk of overexploitation of their resources and incorporated environmental sustainability and sustainable development into their national policies and long-term strategies. Nevertheless, the country's focus tends to be on developing productive primary sectors such as mining, agriculture and plantation forestry and does not emphasise the need to secure biodiversity and ecosystem services.

Uganda's population grew from 13 million in 1980 to 17 million in 1991 and 35 million in 2014. The population is mostly rural (76%) and many are poor (42%). Malnutrition has increased over the past two decades. Most employment is in agriculture, and more than 60% of land is under communal tenure. Water security is relatively high, with most water supply from lakes, plus over 200 (mainly small) dams as well as use of groundwater throughout the country. However, only 28% of the population has access to electricity, and some 88% of energy consumption is from biomass fuels (mainly wood). While the 22 UWA national parks and wildlife reserves are largely intact, many of the over 600 locally-managed forest reserves have been partially or completely deforested.

Methodological framework

Ecosystems and ecosystem services

An ecosystem is a community of organisms interacting with one another in their non-living environment. Ecosystems can be delineated based on a higher level of biological interaction within them than between them and adjacent systems, and can be recognised at different spatial scales, the broadest of which are biomes. In the SEEA EA (UN et al.,2021), ecosystems include not only natural types, such as wetlands and grasslands, but also man-made ecosystems such as agricultural fields, reservoirs and urban parklands. For these accounts, ten ecosystem types were delineated on the basis of the land cover data: open water, wetland, grassland, bushland, woodland, natural forest, plantation forest, farmland, built-up area and bare. These were based on the 13 land cover classes, but combining classes that reflected a difference in condition for the same broad ecosystem type. For some, shorter names are used in the accounts (i.e. forest, plantation). Although the supply and use of ecosystem services was summarised at the level of the 10 broad ecosystem types, it should be noted that both the detailed land cover data and the national vegetation map were used in estimating spatial variation in ecosystem capacity to deliver certain services, where relevant.

Ecosystem services considered included harvested wild resources and ecosystem inputs to cultivated crop and reared animal production (provisioning services), the characteristics or attributes of ecosystems that are valued for various experiential uses, such as recreation and tourism (cultural services) and the ecological functions that save costs in the provision of conventional economic goods and services, such as water purification (regulating services). A slightly modified version of the SEEA EA's (2021) full reference list is provided below with slight modification (cultural services are groups as "experiential services"). Services included in these accounts are highlighted in bold. Note that the list is not exhaustive, and is not yet well tested in natural capital accounting, and is thus expected to be refined over time.

PROVISIONING SERVICES

- **Biomass provisioning services**
  - **Crop**
  - **Grazed biomass/Livestock**
  - **Aquaculture**
  - **Wood**
  - **Wild fish and other natural aquatic biomass**
  - **Wild animals, plants and other biomass**
- Genetic material services
- **Water supply**
- Other provisioning services

REGULATING SERVICES

- **Global climate regulation**
- Rainfall pattern regulation (at sub-continental scale)
- Local climate regulation
- Air filtration
- Soil quality regulation
- **Soil and sediment retention**
- Solid waste remediation
- **Water purification**
  - **Retention and breakdown of nutrients**
  - Retention and breakdown of other pollutants
- **Water flow regulation**
  - Base flow maintenance
  - Peak flow mitigation
- Flood control
- Storm mitigation
- Noise attenuation
- Pollination
- Biological control
  - Pest control
  - Disease control
- Nursery population and habitat maintenance

CULTURAL SERVICES

- **Experiential-related services**

Monetary values of ecosystem service flows are expressed in terms of "exchange values", which is the amount that is paid by the users of ecosystem services to the owners of those services, or that would be paid if a market existed. In some cases, the benefit to which the environmental input contributes is accounted for in the SNA (e.g. tourism), but in others it is not (e.g. recreation in open access green space areas). In the former case, the value is equivalent of an intermediate expenditure incurred in the production of an SNA product and does not alter GDP. In the latter, it is the equivalent of a final expenditure for a benefit that is outside of the SNA production boundary and is additional to measured GDP. For ecosystem services that are consumed purposely (provisioning and cultural services), the benefits are valued in terms of the residual value (or resource rent) after all human inputs are accounted for. Services that are consumed inadvertently (regulating services) are valued in terms of avoided costs (costs that would be incurred if the service was lost).

The asset value of ecosystems was calculated as the summed net present value (NPV) of expected future flows of all ecosystem services that are generated by a particular ecosystem asset over 100 years, using a social discount rate of 4.04%. For harvested resources, this took sustainability of use into account. All values are expressed in constant 2017 prices in Ugandan shillings (UGX).

The basic spatial unit for mapping was a grid cell of 100x100 m. Ecosystem service flows and asset values were summarised for each ecosystem accounting area (EAA). Ecosystem accounts were compiled for the following EAAs:

- National (1 EAA);
- Drainage basins (9 EAAs – 8 major basins plus the remaining areas); and
- Districts (including cities) (146 EAAs).

Ecosystem services and benefits

Crop provisioning services

Crop provisioning services are the ecosystem contributions to the growth of cultivated plants. Because the ecosystem contribution is difficult to quantify in a single physical measure, the tonnage of crops produced is used as the physical measure. The service is valued in terms of resource rent.

Most crop production data are at national scale, apart from 2018 data by agricultural region and the 2008/9 census which summarises production at district level. The finer-scale datasets exclude coffee, tea, sugar, tobacco and cotton. Production of each crop was estimated per district using a combination of national time series data, regional or district-level data, and supplementary information on where crops are grown for those which had never been reported at district scale. Crops were mapped to farmland using the underlying land cover information on commercial versus small scale farmland as appropriate. In the case of sugar, tea, coffee, tobacco, and cotton, all use of the ecosystem service was accrued to industry. For the remaining 15 crops considered, the proportion allocated to households and industry was based on information in the Land and Soil Improvement Accounts.

Crop prices were taken from the Land and Soil Improvement Accounts for 2009 and 2018 (NEMA, 2021a), converted to constant UGX 2017 and extrapolated to 1990 and 2015. Data from the 2008 Agricultural Census was used to estimate input costs in the calculation of resource rent.

The extent of farmland increased from 35% of national area in 1990 to 44% in 2015. While only part of this is planted (estimated 80% in 2015), the values expressed per unit area pertain to the whole area. During the accounting period, there was a notable increase in the production of tobacco, tea and sugar. Maize and rice production also increased markedly, by over 5-fold. Overall, the value of the service increased from UGX 4240 billion in 1990 to UGX 7829 billion in 2015.

Grazed biomass/Livestock provisioning services

Livestock provisioning services are the ecosystem contributions to the reared animal production. Only ruminant livestock are generally considered for this service. As for crops, the reduction of a complex set of services (fodder, shade, water etc) to a single physical measure is difficult, and a proxy measure is also difficult, given that livestock products are varied (e.g. milk, meat, hides) and difficult to reduce to a single measure such as tonnes. In this study, the stocks of animals supported are estimated and mapped for information purposes, but for accounting purposes, the service flow was quantified in physical terms as tonnes of biomass consumed by livestock per year, although noting that this is not the only aspect of the service. The monetary value is estimated as the resource rent of livestock production and does encapsulate all of the ecosystem inputs, including fodder, water, shade, etc.

Grazed biomass per hectare was highest in the northeast of the country and also high in some wetter parts of the country, such as around Mount Elgon and Rwenzori. The total value was estimated to be UGX 2866 billion in 1990 and UGX 5743 billion in 2015.

Wood provisioning services

Wood provisioning services are the ecosystem contributions to the growth of woody biomass harvested from natural and cultivated (plantation) areas for various uses including timber and energy. The wood provisioning service used was quantified in physical terms as the amount of wood harvested for timber, poles, firewood and charcoal by households or businesses, inclusive of any discarded biomass. The service was valued in terms of the resource rent. All monetary values were calculated using basic prices, as stipulated in the SNA, and thus do not include any transport costs or margins added by wholesalers or retailers.

Commercial use of wood was obtained from national statistics and mapped to the landscape in proportion to estimated available stocks of wood suitable for these purposes. Household use of wood was estimated based on spatial estimates of household demand mapped to 100m resolution, and the suitable, available stocks within walking range. The projection of future flows of this service (for asset value calculation) were adjusted based on level of estimated use in relation to the estimated sustainable yield.

Wood harvested for commercial timber production increased dramatically from 0.3 million tonnes in 1990 to 2.5 million tonnes in 2015. Over the same period, the available standing stock in land cover types suitable for timber harvesting declined by 74% due to significant conversion of forest and woodland, and to a lesser extent the formal gazettement of additional protected areas in the forested regions of Uganda. The commercial harvest of poles increased significantly from 108 000 t in 1990 to 439 000 t in 2015, while harvesting of poles by rural households was estimated to increase from 614 000 t in 1990 to 842 000 t in 2015. The harvest of wood for charcoal production increased fivefold between 1990 and 2015, but wood stocks available for charcoal harvesting declined by 55%. Firewood use by households was estimated to consume around 10 million tonnes of woody biomass in 1990, increasing to 17 million tonnes in 2015. An additional 1.8 million tonnes of woody biomass were harvested for commercial firewoood sales in 1990, increasing to 6.0 million tonnes in 2015. Overall wood harvesting was highest in North Buganda subregion (north of Kampala), where harvesting as a proprotion of available stocks was estimated to be very high. This region includes several of the districts which make the greatest contribution to Kampala's charcaol supply.

Wild fish and other natural aquatic biomass provisioning services

Wild fish provisioning services are the ecosystem contributions to the growth of these organisms that are captured in uncultivated production contexts. Fish catch data were extracted from Uganda's 2001 to 2018 Fishery Accounts. Fish prices were calculated from the physical and monetary supply and use tables in the Fishery Accounts. Sustainability adjustments were made based on the total additions to fish stock and total yield reported in the Fishery Accounts.

Wild animals, plants and other biomass provisioning services

This service is the ecosystem contributions to the growth of wild animals, plants and other biomass captured and harvested in uncultivated production contexts. This account focuses on use by households who harvest wild plant and animal resources (other than wood and fish) for own consumption or informal trade and does not include sport hunting or bioprospecting. The use is quantified based on spatial estimates of the availability of resources across the landscape, coupled with spatial estimates of the aggregate household demand for resources. All of the harvestable resources were considered fully available outside of protected areas. The assumed availability was reduced to 10% of standing stocks in national parks, 20% in other UWA protected area categories (game reserves and wildlife sanctuaries) and 50% in forest reserves. Separate estimates are made for use of wild medicines, wild fruits and vegetables, mushrooms, wild honey, bushmeat, thatch, reeds and sedges and bamboo. The supply of these harvested resources is a final ecosystem service and is valued as the equivalent market value of the harvest, less the costs of harvesting. In order to adjust for sustainability in the asset value calculation, the sustainable yield of bush meat and thatching grass was estimated to be 30% of stocks.

The service was estimated to be worth some UGX 147 393 million in 1990 and UGX 414 934 million in 2015 (in constant 2017 UGX. The increase in value of constant 2017 UGX 267 541 million over the 25-year period suggests an annual rate of increase of 4% per year from 1990 to 2015. Wild plant foods were found to be the most valuable resource harvested across the country followed by wild medicines and bushmeat. While wild plant foods were the most valuable, the increase in the value of these resources was lower than for thatching grass, reeds and sedges, and mushrooms, suggesting that these resources have become more valuable over time. This is as a result of increased numbers of people demanding these resources, as well as their increasing scarcity, which leads to real increases in price.

Water provisioning services

Water is included as a provisioning service as per the SEEA EA. The amount of water supplied from open water ecosystems (rivers, reservoirs and lakes) was quantified based on data in the Water Accounts (2015-2018), census and land cover data. Surface water abstraction was estimated to be 140 Mm^3 in 1990 and 561Mm^3 in 2015, worth UGX 84.5 billion and UGX 338 billion, respectively.

Global climate regulation: Carbon retention

Global climate regulation services are ecosystem contributions to reducing concentrations of greenhouse gases in the atmosphere through the removal (sequestration) from the atmosphere and retention (storage) of carbon in biomass and soils. Given the declining status of ecosystems in Uganda, this account focuses on the retention aspect. Carbon retention is valued in terms of the global social cost of carbon (i.e. avoided climate change damage costs), based on the modest estimates of Nordhaus (2017) and converted to an annual flow.

This account draws on the physical carbon accounts that were compiled for 1990 – 2015, while adding additional spatial detail to the carbon stock estimates based on changes in land cover, the biomass data collected in the Ugandan National Biomass Surveys and other improved data sources.

The initial results indicated a slight decline in total carbon retention between 1990 and 2015, despite significant losses of high biomass woody ecosystems. However, this was driven by an implausible 51% increase in wetland area between 1990 and 2015, driven by an apparent change in how wetlands were mapped in the land cover data after 1990. Given that wetlands have high carbon biomass, this discrepancy had a disproportionately large effect on carbon retention estimates. Thus, an adjustment was made to the 1990 land cover, by imposing the 2015 wetland extent over the 1990 land cover. Given that wetland extent is widely reported to have declined over time in Uganda, this approach still likely underestimates the area of wetland in 1990. The resulting carbon storage estimate for 1990 can thus be considered conservative.

Following the above adjustment, total carbon retention in Uganda decreased slightly from 2171 Megatonnes (Mt) in 1990 to 1943 Mt in 2015. The value of carbon retention is estimated to have increased from UGX 4.8 trillion in 1990 to 9.1 trillion in 2015 (constant 2017 UGX). This increase is largely as a result of the real increase in value of carbon over time. This value is recorded as accruing to government.

Soil and sediment retention services: Soil erosion control

Soil erosion control services are "the ecosystem contributions, particularly the stabilising effects of vegetation, that reduce the loss of soil (and sediment) and support use of the environment (e.g. agricultural activity, water supply). The benefits of this service include reduced impacts on reservoir storage capacity, water transport areas, urban drainage systems, water treatment costs and hydropower maintenance costs. In this account, sediment retention services are measured in terms of the avoided export of sediment to rivers and lakes relative to a no-service scenario, measured in cubic metres of sediment. The service is valued in terms of the avoided costs of constructing measures to prevent damaging sediments from reaching waterbodies where the service would be demanded.

Sediment outputs were modelled using the InVEST Sediment Delivery Ratio (SDR) model, which estimates potential annual soil loss using the Universal Soil Loss Equation (USLE), using inputs on topography, rainfall erosivity, soil erodibility and land cover, together with a factor that estimates how much of this sediment reaches a watercourse. The amount retained was estimated as the difference between sediment exports under the 1990 and 2015 land cover, and that of a bare landscape scenario. The actual use of the service is only where it saves on potential damage costs. This could be widespread but was conservatively limited to the catchment areas of natural and man-made waterbodies whose value would be impacted by a loss of storage capacity. This excluded the larger lakes (Victoria, Albert and Edward).

It was estimated that mean sediment export across Uganda increased from 10.0 t/ha/year in 1990 to 11.8 t/ha/year in 2015, reflecting the expansion of agriculture at the expense of less erosion-prone natural land cover classes. Conversely, the amount of sediment retained relative to a bare landscape declined from 201.6 t/ha/year in 1990 to 198.6 t/h/year in 2015. In other words, sediment export would have been around 20.1 times higher in 1990 and 16.8 times higher in 2015, in the total absence of vegetation cover.

Within dam and selected lake catchment areas specifically, it was estimated that the presence of vegetation reduced sediment export by some 929 million tonnes in 1990 and 1094 million tonnes in 2015. The increase in avoided sediment export from 1990 to 2015 reflects the expansion of dams in Uganda, resulting in a 10.6% increase in the area over which the sediment retention service was estimated to be demanded. Interestingly, the average amount of sediment retained by vegetation within dam and lake catchments also increased from 180.6 t/ha in 1990 to 192.2 t/ha in 2015, even though average sediment retention across Uganda overall decreased with the conversion of natural habitats to cultivation. This increase in sediment retention/ha can be explained by the construction of dams between 1990 and 2015 in areas with high erosion potential (*e.g.* western Uganda), resulting in high sediment retention values in these new dam catchment areas.

The value of sediment retention was estimated to be UGX 4.21 billion in 1990 and UGX 4.96 billion in 2015 (constant 2017 UGX). The increase in the value of the service is largely due to the higher number of dams in 2015, which increased the area over which the sediment retention service was demanded.

Water quality regulation services: Nutrient retention

Water purification services are the ecosystem contributions to the restoration and maintenance of the chemical condition of surface water and groundwater bodies through the breakdown or removal of nutrients and other pollutants by ecosystem components. As a final service to raw water users, it can be measured in terms of the quantity of anthropogenically introduced pollutants removed, and is valued in terms of avoided costs, such as costs to human health or increased water treatment costs. It can also be valued as an intermediate service to the supply of other ecosystem services (e.g. fish) from downstream aquatic ecosystems. In these accounts, we estimate the final ecosystem service value of nutrient removal to raw water users. This is valued in terms of the avoided replacement costs in the form of artificial treatment wetlands.

The water quality amelioration service was estimated using the InVEST Nutrient Delivery Ratio (NDR) model. This combines measures of nutrient input across the landscape, retention capacities for the various land cover classes and the characteristics of downslope pathways to determine the mass of nutrients that is eventually exported into watercourses. In addition to the basic inputs for the seasonal water yield model, the model also required inputs on the nutrient (phosphorous) additions to each pixel in kg/ha/year. The total phosphorus retained by the natural landscape was calculated as the difference between the load of phosphorus that was exported from each cropland and urban pixel, and the load that was eventually exported to a watercourse.

It was assumed that demand for the service is limited to the catchment areas of lakes and dams. High nutrient retention is associated with natural habitats situated in areas otherwise dominated by cultivation with high levels of fertiliser use, such as natural habitats fringing Lake Victoria and wetlands in the western part of the Lake Kyoga system. Nutrient retention by these ecosystems has a direct impact on reducing nutrient pollution of these key surface water sources.

The total amount of phosphorous removed by natural ecosystem in dam and lake catchment areas increased slightly from 3.37 million tonnes in 1990 to 3.50 million tonnes in 2015. Even though the extent of natural ecosystems declined over this period, this was outweighed by the increase in the amount of phosphorous removed per hectare of remaining natural area, since the expansion of cultivated and built-up areas significantly increased the overall export of phosphorous in 2015. The service was estimated to be worth UGX 201 billion in 1990 and UGX 209 billion in 2015. Wetlands accounted for the highest share of this value in 2015. Their lower share in 1990 is likely an artefact of the fact that wetlands were underrepresented in the 1990 land cover.

Water flow regulation services

Flow regulation services are defined here as the ecosystem contributions to the regulation of the timing of surface, subsurface and groundwater flows into rivers and lakes through mediating the infiltration of rainwater, affecting the seasonal variation in flows and water levels, and hence the accessibility of water to users. The service is usually best quantified in physical terms as the amount of rainfall infiltrating into the ground. It is typically valued in terms of the cost savings in obtaining water for use, such as reduced infrastructure costs and/or reducing the necessity to purchase water during the dry season, relative to a scenario without this service. This is a final ecosystem service to water service providers and water users that obtain their water directly from ecosystems.

The landscape capacity to regulate annual groundwater recharge was mapped using the InVEST Seasonal Water Yield (SWY) model, which takes land cover into account. To estimate the ecosystem contribution to enhancing groundwater recharge, groundwater recharge was modelled for a bare land scenario. The difference in groundwater recharge between the bare ground scenario relative to under 1990 and 2015 land cover, was then used to value the contribution of ecosystems to enhancing groundwater recharge in the two accounting years. Only the ecosystem contribution to demanded groundwater recharge was valued, based on the groundwater abstraction estimates provided in the Water Accounts. The final service flow mapped in physical terms was the thus the ecosystem contribution to demanded groundwater recharge. This was valued using a replacement cost, based on the cost of construction dams to store an equivalent amount of water to the additional recharge facilitated by ecosystems.

Total groundwater use was estimated to have increased by 2.6 times between 1990 and 2015, with households the major user of groundwater. Overall, total groundwater abstraction from the selected sectors was estimated to be 0.3% of total modelled annual recharge in 1990. This increased to 0.8% of annual recharge in 2015, reflecting the increase in groundwater abstraction and the overall decline in annual recharge resulting from land cover changes.

The ecosystem contribution to the regulation of abstracted groundwater flows was estimated to be 5.87 Mm^3 in 1990, increasing to 12.05 Mm^3 in 2015. The water flow regulation replacement cost was valued at UGX5668 million (constant 2017 UGX) in 1990 and at UGX11 632 million (constant 2017 UGX) in 2015. This does not include cost savings users of raw surface water, although these are expected to be relatively modest given that most surface water is drawn from large lakes (for which the service is not demanded). The highest values are associated with some of the wettest parts of the country, including the forested slopes of Mount Rwenzori and Mount Elgon as well as grassland areas higher up on these mountains. Even though forests have high evapotranspiration rates, the large reduction in runoff losses relative to bare ground is enough to compensate for this, resulting in highly positive groundwater recharge values relative to bare ground.

Experiential services: Tourism value

Ecosystems offer the opportunity for a range of experiential services that are often enjoyed simultaneously, such as recreation, education and spiritual fulfilment. The ecosystem service is the ecosystem contribution to these benefits, that are obtained through joint use of ecosystem and human inputs and is a final ecosystem service. They are typically quantified in terms of user days and valued in terms of resource rents, where markets exist, and simulated exchange value where they do not. While experiential services include both local use and tourism, this account is limited to estimating the ecosystem contribution to tourism that is recorded in the SNA. Estimation of this service involved estimating the total resource rent of attraction-based tourism expenditure from national statistics, and then disaggregating the value in proportion to the spatial pattern of geotagged photographs uploaded to the internet and their content. This involved the initial step of estimating tourist expenditure in 1990 and 2015 for Uganda as a whole, as well as the visitor numbers and expenditures in national parks in those years.

The total value of the ecosystem contribution to tourism was estimated to have grown from UGX 3 530 million in 1990 to UGX 215 923 million in 2015. In 2015, natural ecosystems made up 69% of this value. The tourism value of rural agricultural land was estimated to be UGX 48 894 million, and urban greenspace areas were worth UGX 16 842 million in 2015, representing 23% and 8% of the total value, respectively. Among natural ecosystem types, grasslands had the highest total tourism value in 2015 but forest ecosystems had the highest per hectare value, followed by wetlands and woodlands. Farmland had the lowest per hectare tourism value of any ecosystem.

Total tourism value and the per hectare value was highest in The Lake Edward Basin, which is largely attributed to the fact that Mgahinga Gorilla NP and Bwindi Impenetrable NP are situated in this basin. The Kidepo Basin had the lowest total tourism value because of its size but had a relatively high per hectare value because of the Kidepo Valley NP situated in this basin. The per hectare value was lowest in the Aswa Basin.

Summary of findings

In physical terms, the use of provisioning services increased substantially, ranging from a 25% increase for crops to a 300% increase for water supply (Table II). This can be at least partly attributed to the fact that population doubled over this time period (i.e. increased demand). In comparison, the use of regulating services did not increase much, apart from the water flow regulation service (likely due to supply constraints). The most significant increase was that of the ecosystem contribution to tourism value. This was not expressed in physical terms, but the value increased by 6016% over the 25-year span of the accounts and is attributed to an increase in national and international demand as a result of investments in parks and tourism facilities.

In monetary terms, the value flows of all services increased. All provisioning services at least doubled in value. The percentage increases in value for water, flow regulation, sediment and nutrient retention services were the same as for physical flows, since no real price changes were recorded. The value of carbon retention more than doubled due to the increased price of carbon. Tourism value had by far the highest increase of any ecosystem service. The total monetary value of ecosystem services was 16 783 billion (UGX 2017) in 1990 and 32 057 billion in 2015 (UGX 2017); Uganda's GDP was 25 279 billion in 1990 (UGX 2017) and 101 797 billion (UGX 2017) in 2015. Hence, ecosystem services had a value equivalent to 66% to GDP in 1990 and 31% in 2015.

Table II. Summary and comparison of the results at national scale for 1990 and 2015

	Physical			Monetary (UGX billions)		
	1990	2015	% increase	1990	2015	% increase
Crops (kt/y)	16 269	20 316	25%	4 240	7 829	85%
Grazed biomass (kt/y)	9 069	26 760	195%	2 866	5 743	100%
Wood (kt/y)	15 315	38 760	153%	184	3 272	1683%
Wild fish (kt/y)	245	455	86%	0.1	0.6	503%
Other wild resources (kt/y)	352	388	10%	147	415	182%
Water supply (ML/y)	140 021	560 577	300%	85	338	300%
Water flow regulation (ML/y)	5 870	12 047	105%	5.7	12	105%
Sediment retention (million m^3/y)	929	1 094	18%	4 212	4 959	18%
Nutrient retention (ktP/y)	3 366	3 504	4%	201	209	4%
Carbon retention (MtC)	2 171	1 943	-11%	4 840	9 064	87%
Tourism value (UGX millions/y)	3 530	215 923	6016%	3.5	216	6016%
Total value	**-**	**-**	**-**	**16 783**	**32 057**	**91%**
Equivalent to GDP	**-**	**-**	**-**	**66%**	**31%**	**-**

The average monetary value of ecosystem service flows per ecosystem type per ha per year in 1990 and 2015 (expressed in constant 2017 UGX millions) is shown graphically in Figure II. All ecosystem types increased in value from 1990 to 2015, except for "Bare", largely attributable to the increase in numbers of people demanding services from them. The largest monetary value per ha, both in 1990 and 2015 comes from forests and wetlands. The largest percentage increases (per ha) between 1990 and 2015 were recorded in "Open Water", "Plantation", and "Wetland".

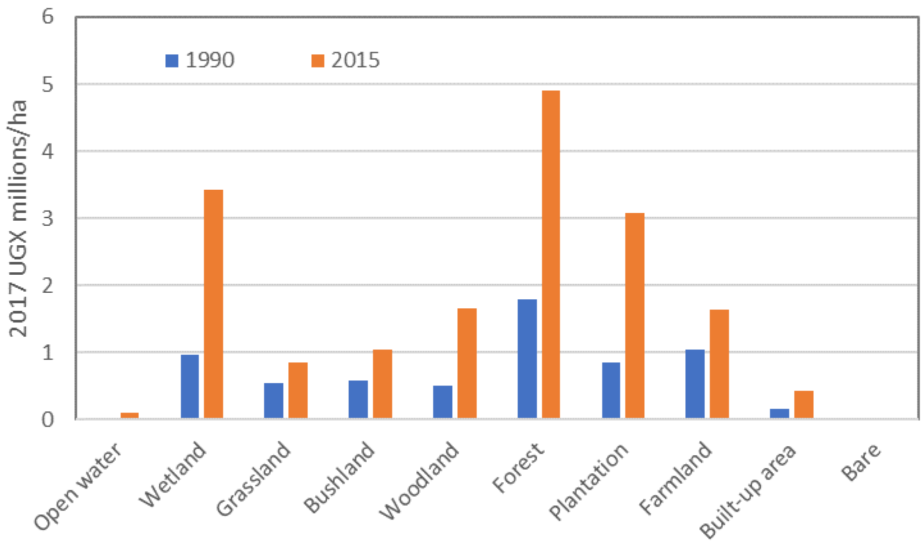

Figure II. Average monetary value of ecosystem service flows per ecosystem type per ha per year in 1990 and 2015. Values expressed in constant 2017 UGX millions per ha per year.

The asset account records the monetary value of opening and closing stocks of all ecosystem assets within an ecosystem accounting area and additions and reductions in those stocks and is shown at national scale in Table III. These are the net present values of projected annual flows of ecosystem service value over time, taking into account sustainability of flows as far as possible. The value of the ecosystem assets was estimated to be UGX 387.6 trillion in 1990 and UGX 682.9 trillion in 2015 (both in constant 2017 UGX; Table II). Some UGX 94.3 trillion was lost as a result of the degradation and loss of ecosystem areas, with the greatest losses being in woodland and forest. The value of losses was offset by the increases in demand for services per unit area, resulting in an overall increase in the use and value of ecosystem services. In other words, ecosystems are becoming more and more valuable to people. However, the overall asset value of ecosystems per capita declined by 17.7%. Per capita asset value decline was particularly strong in woodlands (-66%) and forests (-37%). In spite of the overall increase in area, the per capita asset value of farmland also declined from 1990 and 2015, by 11%. On the contrary, the per capita asset value of plantations and built-up areas increased drastically, reflecting the areas where the country has focused its investments.

Table III. Ecosystem monetary asset account 1990-2015. NPV calculated using an asset lifespan of 100 years and a discount rate of 4.04%. All values expressed in constant 2017 UGX billions apart from per capita value in UGX millions.

	Open water	Wetland	Grassland	Bushland	Woodland	Forest	Plantation	Farmland	Built-up	Bare	Total
Opening stock (1990)	**2 064**	**20 403**	**66 270**	**21 544**	**43 297**	**41 580**	**656**	**191 623**	**140**	**3**	**387 580**
Change in ecosystem condition											
Enhancement											
Degradation			-16 580	-919	-935	-113	-40	-3 829	-22	-2	-22 440
Change in ecosystem extent (ecosystems conversions)											
Additions			315	8 218			3 428	61 184	718	1	73 864
Reductions	-7	-5 298			-45 211	-21 373					-71 890
Other changes in volume of ecosystem assets											
Catastrophic losses											
Reappraisals	6 652	21 904	42 186	13 577	23 725	16 055	962	53 777	242	2	179 083
Revaluation	-2	26 114	11 812	3 768	10 942	19 767	3 073	60 897	339	-2	116 441
Net change in value	6 642	42 720	37 733	24 644	-11 479	14 336	7 423	172 030	1 277	0	275 058
Closing stock (2015)	**8 706**	**63 123**	**104 002**	**46 188**	**31 818**	**55 916**	**8 079**	**363 653**	**1 417**	**3**	**682 905**
Closing stock (2015) per capita (in million)	244	1 769	2 915	1 295	892	1 567	226	10 194	40	0	19 143
Net change %	322	209	57	114	-27	34	1 132	90	910	-6	76
Net change % per capita	97	45	-27	0.2	-66	-37	476	-11	372	-56	-18

Policy implications

The findings suggest that most types of ecosystems are not being adequately managed to keep pace with the demands on them and will not be able to provide ecosystems each additional Ugandan with the same, or more, services. Uganda needs to ensure that standards of living are increased without further degrading and depleting its natural assets. This will require substantial investments in restoration and increased protection of natural capital, investments into improving the productivity of existing farmland, and investments in education and other measures to reduce the rate of population growth.

Next steps

The Ecosystem Accounts were compiled over a period of 8 months, from engaging with government on data for the accounts, inspection of the existing data and accounts, to spatial modelling, and compilation of complex accounting tables down to the resolution of 146 districts and cities. As such, the study had to be limited in scope to achieve this. While significant progress was made in extending the previous work, there is still more to be done to complete these, and there are aspects that deserve further consideration, some of which have little precedent globally. Coverage should be extended to include services such as pollination, flood attenuation, and local recreation/other experiential use of ecosystems, as well as urban air temperature regulation and air quality regulation. Another important service to be considered is the contribution of the country's tropical high forests to regional climate regulation (particularly rainfall).

In addition, these accounts are already seven years out of date. It will be important to begin in earnest to bring them closer to the present. This is now possible with the recent completion of the Uganda Land Cover for 2021. The latest land cover data are at much higher resolution (10m) than the previous series (30m), due to the launch of new satellites in 2015. This will also allow for the incorporation of new datasets, such as the recent national livestock census.

Future work should also focus on the empirical estimation of ecosystem condition and its incorporation into the ecosystem accounts. This will allow for refined estimates of ecosystem services flows as well as asset values.

ABBREVIATIONS & ACRONYMS

AfSIS	Africa Soil Information Service
ASCC	Annualised social cost of carbon
AMC	Antecedent moisture conditions
BSU	Basic spatial unit
CBD	Convention on Biological Diversity
CO_2.	Carbon dioxide
CWMA	Community wildlife management areas
GDP	Gross domestic product
PUD	Photo user day
CDO	Cotton Development Organisation
CIAT	International Center for Tropical Agriculture
CFR	Central Forest Reserve
CICES	Common International Classification of Ecosystem Services
CN	Curve number
δ	Discount rate
DICE	Dynamic Integrated model of Climate and the Economy
DRC	Democratic Republic of Congo
EA	Ecosystem asset
EAA	Ecosystem accounting area
ECT	Ecosystem condition typology
ES	Ecosystem service
ET	Ecosystem type
ET_0	Reference evapotranspiration
FAO	Food and Agriculture Organization
FAOSTAT	FAO Statistical Databases
FEGS-CS	Final Ecosystem Goods and Services Classification System
FEWS NET	Famine Early Warning System Network
FSSD	Forest Sector Support Department
GIS	Geographic information systems
GOS	Gross operating surplus
GoU	Government of Uganda
IAM	Integrated assessment model
IDEEA	International Design and Engineering Education
InVEST	Integrated Valuation of Ecosystem Services and Trade-offs
IPCC	Intergovernmental Panel on Climate Change
Kc	Crop evapotranspiration coefficient
LFR	Local forest reserve
MCM	Million cubic metres
Mm	Millimetres
Mt	Megatonne
MSUT	Monetary supply and use table
MTWA	Ministry of Tourism, Wildlife and Antiquities
MWE	Ministry of Water and Environment
NCA	Natural capital accounting
NDC	Nationally-determined contributions
NDP	National Development Plan
NAADS	National Agriculture Advisory Services
NESCS	National Ecosystem Services Classification System (US)
NEMA	National Environmental Management Authority
NFA	National Forestry Authority
NP	National park

NPA	National Planning Authority
NPAEEA	National Plan of Action on Environmental Economic Accounting
NPV	Net present value
NTFP	Non-Timber Forest Product
NWSC	National Water Supply Company
MAAIF	Ministry of Agriculture, Animal Industry and Fisheries
PSUT	Physical Supply and Use Table
PNV	Potential natural vegetation
REDD+	Reducing Emissions from Deforestation and Forest Degradation
SCC	Social cost of carbon
SDR	Sediment delivery ratio
SEEA	System of Environmental-Economic Accounting
SEEA-CF	System of Environmental-Economic Accounting - Central Framework
SEEA-EA	System of Environmental-Economic Accounting – Ecosystem Accounting
SNA	System of National Accounts
SWY	Seasonal water yield
t	Tonnes
THF	Tropical High Forest
TLU	Tropical livestock unit
UBOS	Uganda Bureau of Statistics
UGX	Ugandan Shillings
UNRA	Uganda National Roads Authority
UWA	Uganda Wildlife Authority
UN	United Nations
UNECA	United Nations Economic Commission for Africa
UNEP	United Nations Environment Programme
UNEP-WCMC	UNEP World Conservation Monitoring Centre
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change (UNFCCC)
URA	Uganda Revenue Authority
USAID	United States Agency for International Development
USD	United States dollar
UWA	Uganda Wildlife Authority
WAVES	Wealth Accounting and the Valuation of Ecosystem Services
WWF	Worldwide Fund for Nature
ZARDI	Zonal Agricultural Research and Development Institute

GLOSSARY

Basic spatial unit: a geometrical construct representing a small spatial area (UN et al., 2021; para 3.72).

Biodiversity: the variability among living organisms and the ecological complexes of which they are part. This includes variation within species, the diversity of species within ecosystems and the diversity of ecosystem types in nature (Convention on Biological Diversity; www.cbd.int).

Carbon sequestration: the process of capturing and storing atmospheric carbon dioxide. Natural carbon sequestration processes can be supported through changes in land use and agricultural practices, including forest restoration and the conversion of annual cropping systems and livestock grazing land into agroforestry systems.

Catchment: an area where water is collected by the natural landscape. Precipitation that falls in a catchment runs downhill into creeks, rivers, lakes, oceans, or into built infrastructure, such as reservoirs. In this document, the terms catchment and watershed are used interchangeably.

Discount rate: the interest rate used in discounted cash flow analysis to determine the present value of future cash flows.

Ecological infrastructure: nature's equivalent of grey or engineered infrastructure. It forms and supports a network of interconnected structural elements such as catchments, rivers, riparian areas and natural corridors supporting habitats and movement of animals and plants.

Economic unit: Economic entity engaging in economic activities and in transactions with other entities (SNA, 2008; para 4.2). In ecosystem service accounts economic units are the users/beneficiaries of the ecosystem services. Economic units may be classified by sector (e.g., financial enterprisers, non-financial enterprisers, government, households and not-for-profit institutions supporting households (NPISH), or by industry based on the goods and services produced (e.g., agriculture, mining, manufacturing, health, education, etc.). In these accounts, the economic units are classified as being either industry, government, or households.

Ecosystem accounting area: the geographical territory for which an ecosystem account is compiled (UN et al., 2021; para 2.12).

Ecosystem asset: The primary spatial units for ecosystem accounting. Ecosystem assets (EAs) are contiguous spaces of a specific ecosystem type characterized by a distinct set of biotic and abiotic components and their interactions. The definition of ecosystem assets is a statistical representation of the general definition of ecosystems from the CBD (UN et al., 2021; para 3.5).

Ecosystem condition: the quality of an ecosystem measured in terms of its abiotic and biotic characteristics (UN et al., 2021; para 2.13).

Ecosystem extent: the size of an ecosystem asset (UN et al., 2021; para 2.13).

Ecosystem services: are the contributions of ecosystems to the benefits that are used in economic and other human activity. In this definition, use incorporates direct physical consumption, passive enjoyment and indirect use (UN et al., 2021; para 2.14). Benefits are the goods and services that are ultimately used and enjoyed by people and society (UN et al., 2021; para 2.15).

Ecosystem type: Each ecosystem asset is classified to an ecosystem type. An ecosystem type reflects a distinct set of abiotic and biotic components and their interactions (UN et al., 2021; para 3.6).

Gross operating surplus: Defined in the context of national accounts as the contribution of capital to production (SNA, 2008; para 20.28). It is gross output less the cost of intermediate goods and services to give gross value added, and less compensation of employees and taxes and subsidies on production and imports. It is gross because it makes no allowance for consumption of fixed capital (European Statistical System, ESS).

Land cover: The observed physical and biological cover of the Earth's surface which includes natural vegetation and abiotic (non-living) surfaces.

National Biomass Survey: A two-stage biomass inventory process that combines (i) spatial analysis to determine and stratify land use/land cover and (ii) inventory of biomass resources based on sample plots to quantify the stock of biomass in a country or region. The survey was conducted every five years between 2000 and 2015, moving to every two years thereafter.

Natural capital: the stock of renewable and non-renewable resources (e.g., plants, animals, air, water, soils, minerals) that combine to yield a flow of benefits to people.

Natural capital accounting: the process of measuring the total stocks and flows of natural resources and services in a given ecosystem or region. Accounting for such goods may occur in physical or monetary terms.

Resource rent: Resource rent (also known as economic rent) is defined as a surplus value, i.e., the difference between the price at which a resource, or the output from it, can be sold, and its respective extraction and/or production costs, including normal returns. In ecosystem accounting, the resource rent method estimates a value for an ecosystem service by taking the gross value of the final marketed good to which the ecosystem service provides an input and then deducting the cost of all other inputs, including labour, produced assets and intermediate inputs (UN et al., 2021; para 9.36).

SEEA Central Framework. A multipurpose conceptual framework for understanding the interactions between the economy and the environment. It provides concepts, definitions and classifications to support integrated accounting for physical flows (natural inputs from, and residual flows to, the environment such as water, energy, air emissions and solid waste); environmental transactions and transfers (e.g., environmental taxes, environmental subsidies and environmental protection expenditure); and individual environmental assets (e.g., mineral and energy resources, timber, fish, land, soil and water; UN et al., 2021; para 1.35).

SEEA Ecosystem accounting: A spatially-based, integrated statistical framework for organizing biophysical information about ecosystems, measuring ecosystem services, tracking changes in ecosystem extent and condition, valuing ecosystem services and assets and linking this information to measures of economic and human activity (UN et al., 2021; para 1.3).

Sustainable: managing the use and protection of natural resources in a way (or at a rate) which enables social, economic and cultural well-being while ensuring these resources are sustained for future generations and any adverse effects on the environment are minimised.

System of National Accounts (SNA): The internationally agreed standard set of recommendations on how to compile measures of economic activity in accordance with strict accounting conventions based on economic principles (SNA, 2008; para 1.1). The SNA provides a comprehensive and detailed record of the complex economic activities taking place within an economy and of the interaction between the different economic agents, and groups of agents, that takes place on markets or elsewhere (SNA, 2008; para 1.1).

1. INTRODUCTION

ECOSYSTEM ACCOUNTING

The System of Environmental-Economic Accounting (SEEA; UN, 2014a) provides a framework for accounting for all natural capital assets, including minerals, land, soil, water, energy, carbon, renewable resources (e.g. forestry, fisheries) and ecosystems, based on stocks and physical flows and the monetary values of these. It also involves recording flows of emissions and effluents, and monetary flows such as environmental protection expenditures, taxes and subsidies. The importance of this is that it allows for the development of relevant environmental indicators that can be integrated into the macroeconomic framework of the System of National Accounts - 2008 (EC et al 2009), that produces indicators such as GDP and the integration means that better indications for sustainability can be produced (European Commission, 2019), and for use in tracking progress towards international commitments and targets for sustainable development, biodiversity and addressing climate change.

The initial focus of environmental accounting was on the development of resource accounts, such as minerals and forestry, which are by now well established in many countries. The SEEA Ecosystem Accounting (SEEA-EA) methods have been in development for several years, and the physical accounting was standardized in 2021 (UN et al., 2021). Ecosystem accounting is a major element of natural capital accounting, incorporating some of the elements listed above (e.g. forestry, fisheries), but also broadening this to include the valuation of wider range of ecosystem services and linking these flows to the extent and condition of ecosystems. Ecosystems are accounted for as assets that provide ecosystem services to people (Hein *et al.* 2016). Using accounting principles, these assets (stocks) and ecosystem services (flows) are systematically accounted for in physical and monetary terms, to monitor changes over time.

Ecosystem accounting involves the compilation of five core sets of ecosystem accounts (UN et al., 2021; Figure 1.1). These do not depend on SNA accounts for their compilation and can be considered as satellite accounts of the SNA. The five ecosystem accounts are compiled sequentially, as follows:

- **Ecosystem extent accounts** record and organise data on the spatial extent of different ecosystem types to determine the trends and spatial distribution of ecosystems (termed" ecosystem assets") within an ecosystem accounting area (such as a country or river basin).
- **Ecosystem condition accounts** record the condition or health of ecosystems based on a set of biophysical indicators, against a reference condition (e.g. characteristics of a natural ecosystem prior to any human influence, or of a cultivated system prior to loss of soil nutrients). This influences the capacity of an ecosystem to supply ecosystem services. The SEEA provides an Ecosystem Condition Typology (ECT) for assessing the condition of abiotic and biotic ecosystem characteristics and landscape level characteristics.
- **Ecosystem services flow accounts (in physical terms)** record the flow of ecosystem services in physical units (e.g. m^3, tonnes) and the use of these services by economic units (e.g. households, government etc.), usually in annual terms. These are captured in Physical Supply and Use Tables (PSUTs). They also allow for the recording of intermediate service

flows between ecosystem assets.[1]

- **Ecosystem services flow accounts (in monetary terms)** record the above in monetary terms, using a standard currency.
- **Ecosystem monetary asset accounts** record information on stocks and changes in stocks of ecosystem assets, in monetary terms. This involves estimating the present value expected future flows of ecosystem services over the long term. Changes in asset value due to ecosystem enhancement, degradation or conservation are included in this account.

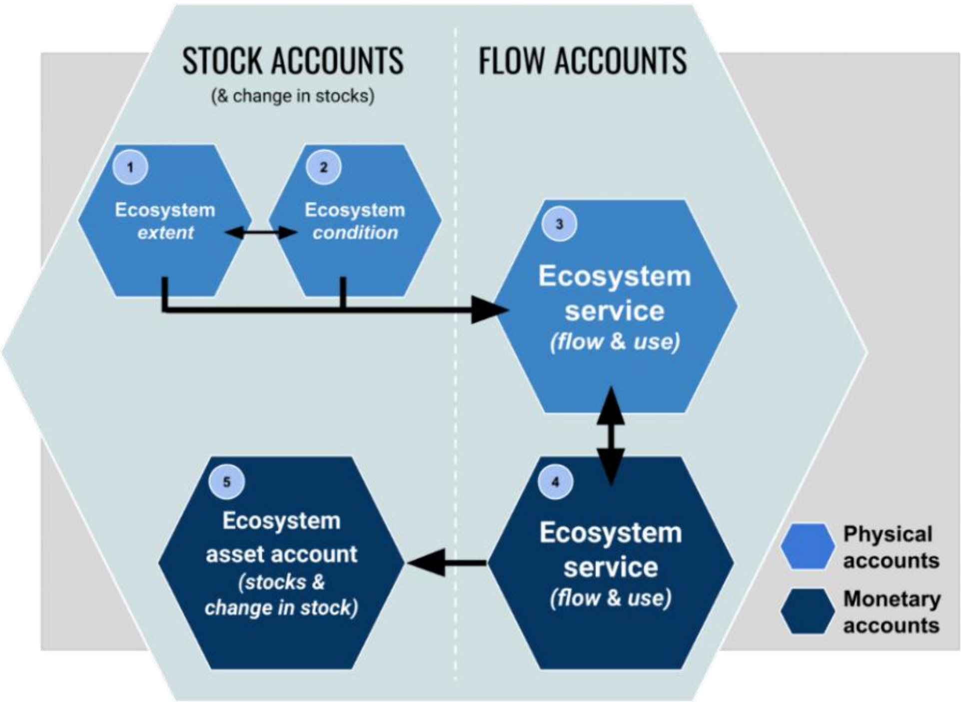

Figure 1.1. The five ecosystem accounts and how they relate to each other. SOURCE: HTTPS://SEEA.UN.ORG.

Along with the five core accounts, ecosystem accounting can also include the compilation of related thematic accounts, such as land (cover, change, ownership etc.), carbon, ocean, nutrients, nature-based tourism, protected areas, water resources, and biodiversity (including species accounts).

Key concepts for the SEEA EA are:

- Ecosystem Accounting Areas (EAA) – the geographical area for which an ecosystem account is compiled (*e.g.* a district, drainage basin *etc.*). It serves as an accounting boundary around a set of ecosystem assets, such that the sum of the areas of the ecosystem assets is equal to the total area of the EAA.

[1] For SEEA EA there is a need to account for intermediate ecosystem services in order to fully capture the interferences and connections between assets and flows in order to develop appropriate policies for these (UN et al., 2021)

- Ecosystem Assets (EA) – are the primary spatial units for ecosystem accounting. They are defined as contiguous areas of a particular ecosystem type characterised by a distinct set of biotic and abiotic components and the interactions among them. This definition serves as a statistical representation of the general definition of ecosystems from the CBD. Ecosystem assets are ultimately the ecological entities about which information is sought, and about which statistics are compiled.

- Basic spatial units (BSU) – a geometrical construct which provides a fine-level data framework within which information about a range of characteristics can be incorporated. A typical example would be a grid cell. The BSU can be used in GIS to ensure consistent delineation of ecosystem assets throughout the accounting process.

- Economic units – encompass the various institutional types includes in the national accounts, for example businesses, governments and households. Ecosystem services are recorded as flows between ecosystem assets and economic units. These economic units are the final use of a given ecosystem service.

POTENTIAL USEFULNESS FOR UGANDA

Ecosystem accounts help policy-makers to account for the economic value of biodiversity and ecosystem services and ensure that the benefits which are derived from ecosystems are included in their decisions, for example regarding land use planning, poverty reduction and environmental policies. It highlights changes in the environment's contribution to the economy and shows the impact that degrading ecosystems could have on economic growth.

Incorporating ecosystem values into macro-economic models and national decision-making processes helps to better manage progress towards sustainable development, as it creates a link between economy, society and the environment. The ecosystem accounts can be used in combination with traditional macroeconomic indicators to track Uganda's progress towards the Sustainable Development Goals (SDGs), its Strategic Program for Climate Resilience (SPCR) and Nationally Determined Contribution for climate change mitigation and adaptation under the United Nations Framework Convention on Climate Change (UNFCCC), and its obligations for biodiversity conservation under the Convention of Biological Diversity's (CBD) Post-2020 Global Biodiversity Framework (GBF). In particular, the ecosystem accounts could be used in conjunction with species distribution data to inform the location of additional reserves and contribute to Uganda's pursuit of the 30% by 2030 goals for protected area coverage, under the post-2020 GBF.

ECOSYSTEM ACCOUNTING PROGRESS IN UGANDA

The Government of Uganda has been at the forefront of establishing natural capital accounting (NCA) in Africa. Shortly after the country released its 2017 Uganda Green Growth Development Strategy, Uganda embarked on an NCA programme with the support of the World Bank as well as the United Nations Statistical Division (UNSD) and the UN Environment Programme World Conservation Monitoring Centre (UNEP-WCMC). In collaboration with the World Bank and UNSD, Uganda launched its National Plan for Advancing Environmental-Economic Accounting (NP-AEEA) which acknowledges that economic growth is relying on benefits derived from the environment (GoU, 2019a) and aims to improve decisions relating to sustainable development and green growth.

The implementation of natural capital accounting in Uganda has been supported through the World Bank's Wealth Accounting and the Valuation of Ecosystem Services (WAVES) partnership. WAVES aims to improve policy- and decision-makers' understanding of how the economy and ecosystems are linked and increase the use of information on natural assets and ecosystem services in national development planning, green growth strategies, and achieving the SDGs. Uganda benefited from the initial implementing countries, including Botswana, Columbia, Costa Rica, Madagascar, and the Philippines, which from the start focused on the use of natural capital accounting in government decision-making, rather than pure account production (WAVES, 2022). A global training and knowledge sharing platform was created to exchange lessons learned across implementing countries. WAVES has been putting a strong emphasis on institutional engagement, capacity building and policy dialogues across implementing countries (WAVES, 2020), encouraging partnerships on national and international levels. The aim is to mainstream the use of natural capital accounting into development and the national accounts.

The initial steps towards ecosystem accounts in Uganda have included integrated accounting for agricultural production, land and soils, wild fish and aquaculture resources, wood resources, water, and biodiversity and tourism accounts. The country has also produced ecosystem extent accounts and physical ecosystem service accounts for a selected set of ecosystem services. These various accounting studies, and the role of the WAVES programme and other capacity-building support, are briefly outlined below.

In 2018, the country received a two-year grant from the World Bank's Wealth Accounting and Valuation of Ecosystem Services (WAVES) programme to develop NCA and perform analysis relating to issues around natural capital. This led to considerable progress in the establishment of natural capital accounts, including land asset accounts (GoU, 2019b) and wood asset and forest resource accounts (GoU, 2020a)s, as well as finalization of the National Plan of Action on Environmental Economic Accounting (NPAEEA) (GoU, 2019a). These initial accounts served as a proof of concept and were aimed at policy- and decision-makers to include in future plans, such as in the National Development Plan (NDPIII).

The United Nations Statistics Division (UNSD) has also supported UBOS in establishing water accounts for 2015 to 2018 (UBOS, 2019). Water accounts were prioritised as water resources had experienced increasing pressures from agricultural, industrial and urban users. Agricultural production is mostly rain fed and the electricity sector relies largely on hydro-power generation, hence environmental changes need to be considered in economic management, particularly in industries which are strongly reliant on ecosystems. Additionally, UNEP-WCMC and other donors have supported the development of several sets of accounts in Uganda, including fishery resource accounts (NEMA, 2021b), biodiversity and tourism accounts (NEMA, 2021c) and land and soil improvement accounts (NEMA, 2021a).

The above studies fall within the NCA framework and can provide useful input information for the production of ecosystem accounts. Ecosystem accounting *per se* has been limited to two reports in Uganda, namely the 2017 Experimental ecosystem accounts (UNEP-WCMC & IDEEA, 2017) and the 2020 "Towards Ecosystem Accounting for Uganda" report (GoU, 2020b). The 2017 study includes ecosystem extent accounts and selected biodiversity accounts, including proxy species accounts (based on habitat extent) for key wildlife and non-timber forest product (NTFP) species. The 2020 ecosystem service accounting study (GoU, 2020b) was produced under the WAVES programme and serves as a benchmarking report that shows the progress on developing Experimental Ecosystem Accounts for forest and wetland ecosystems. It also describes the results of the first iteration for experimental ecosystem service accounts in Uganda using the Integrated Valuation of Ecosystem Services and Trade-offs (InVEST) suite of models.

Uganda is now moving to the stage of ecosystem accounts implementation, with more comprehensive accounts designed to inform ongoing policy processes, such as their Nationally-determined contributions (NDC) under the United Nations Framework Convention on Climate Change (UNFCCC), and their Reducing Emissions from Deforestation and Forest Degradation (REDD+) programme. In particular, it will support the component in the investment project "Investing in Forests and Protected Areas for Climate-Smart Development" that aims at increasing revenues and jobs from protected areas through targeted investments in tourism and productive forestry, as well as restoration of degraded natural forests and habitats in forest reserves. The lending project will focus on improving the management of forests, increasing revenues for sustaining forests and supporting resilient livelihoods.

This study builds on the following:

- 2017 **Experimental ecosystem accounts**, which summarise land cover, vegetation type diversity and representation of biomes in the subregions and in protected areas (1990-2015) (UNEP-WCMC & IDEEA, 2017);
- 2019 **National land physical asset account**, which summarises land cover within 7 forest landscapes, 4 Water Management Zones, 4 agroecological zones, 7 climate zones, 4 protected area types & private land, 4 regions, 11 subregions and 112 districts (1990-2015) (GoU, 2019b);
- 2019 **Water accounts**, which summarises the supply and use of surface, ground and rain water by 15 economy subsectors in physical quantities, at national scale (2015-2018) (UBOS, 2019);
- 2020 **Wood asset and forest resources accounts**, which summarise the extent and value of the 5 forest land cover types, and physical and monetary wood supply and use tables, for 4 protected area types & private land, and 4 subregions. (1990-2015) (GoU, 2020a);
- 2020 partial **Ecosystem accounts**, which summarise land cover by 8 drainage basins, wetland areas by 13 land cover types and by 4 protected area types & private land, and also provide accounts in physical terms for carbon storage, water runoff and sediment retention for 8 drainage basins (1990-2015) (GoU, 2020b);
- 2021 **Fisheries accounts**, which provide condition of Lake Victoria (2011-2018) and physical and monetary accounts for wild capture fisheries by 7 lake or river systems and for aquaculture (2001-2018) (NEMA, 2021b);
- 2021 **Biodiversity and tourism accounts**, which provide land cover, visitor numbers and tourism revenues for 12 protected areas (2011-2019) (GoU, 2021a); and
- 2021 **Land and soil improvement accounts**, which account for ecosystem extent (2005-2015) for 4 agricultural zones; soil nutrient inputs, uptake and losses in croplands, and crop and livestock production in physical and monetary terms (2009-2018) for 4 agricultural zones, as well as biomass and soil organic carbon by 6 amalgamated IPCC landcover classes (1990-2015) (NEMA, 2021a).

SCOPE OF THIS REPORT

The main aim of this study was to build on the above and other relevant work to develop a fuller set of national ecosystem service and asset accounts to complement the ecosystem extent accounts, following SEEA-EA guidelines.

The accounts summarise the physical and monetary value flows of ecosystem services and the ecosystem asset values for each of 10 major ecosystem types. Values are summarised across three levels of EAAs: (1) at national scale, (2) for each of the country's eight major river basins, and (3) for its current (as at 2022) 146 local administrative units (135 districts and 11 cities). The accounts cover the same time period as most of the preceding work (1990-2015).

The ecosystem accounts quantify ecosystem services from all ecosystem types including cultivated and planted areas, urban areas and man-made lakes as well as natural (or semi-natural) terrestrial and aquatic ecosystems. Spatial models were developed to quantify and value the supply of ecosystem services from different ecosystem assets across the country. The spatial models were used to highlight the spatial variability in the supply and use of different ecosystem services even within a given ecosystem type. Finally, the ecosystem monetary asset accounts were created to account for changes in the value of ecosystem assets across the accounting periods.

It should be noted that the actual accounts are in the form of a spreadsheet. This report presents the context, methods and spatial results, but only replicates the accounting tables for ecosystems at national scale.

STRUCTURE OF THE REPORT

The document is structured as follows:

Chapter 2 Ecological and socio-economic context provides context by providing a brief overview of the country's topography, geography, environment and socioeconomic characteristics. The main environmental issues in the country are also outlined here.

Chapter 3 Methodological framework provides an overview of the spatial framework and ecosystem service classification framework used in this study, the ecosystem services included in the valuation, the valuation approach and the time frame and accounting framework.

Chapter 4 Ecosystem services and benefits presents an explanation of each of the ecosystem services that are accounted for in this study, followed by a brief description of the methods used for quantification and valuation (readers are referred to appendices for details), and then provides the physical and monetary accounting tables generated for each of the two time periods (1990 and 2015). The chapter also provides summary information on the accounts at District level.

Chapter 5 Summary of the accounts presents the ecosystem supply and use tables and the overall ecosystem asset value account for Uganda, along with a summary and discussion of the overall results and their policy implications.

Chapter 6 Next steps provides some recommendations for the way forward.

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2. ECOLOGICAL AND SOCIO-ECONOMIC CONTEXT

THE NATURAL ENVIRONMENT

EXTENT, TOPOGRAPHY AND DRAINAGE

Uganda covers an area of 241 550 km², with waterbodies making up 17% of this area (Figure 2.1). It shares a border with Kenya to the east, the Democratic Republic of Congo (DRC) to the West, Tanzania to the south, Rwanda to the southwest and South Sudan to the north. The Equator traverses Uganda dividing the country between the northern and southern hemisphere. A large plateau dominates much of Uganda, which has a gradual decrease in elevation from 1500 m in the south to about 900 m in the northeast (Ingham *et al.*, 2022).

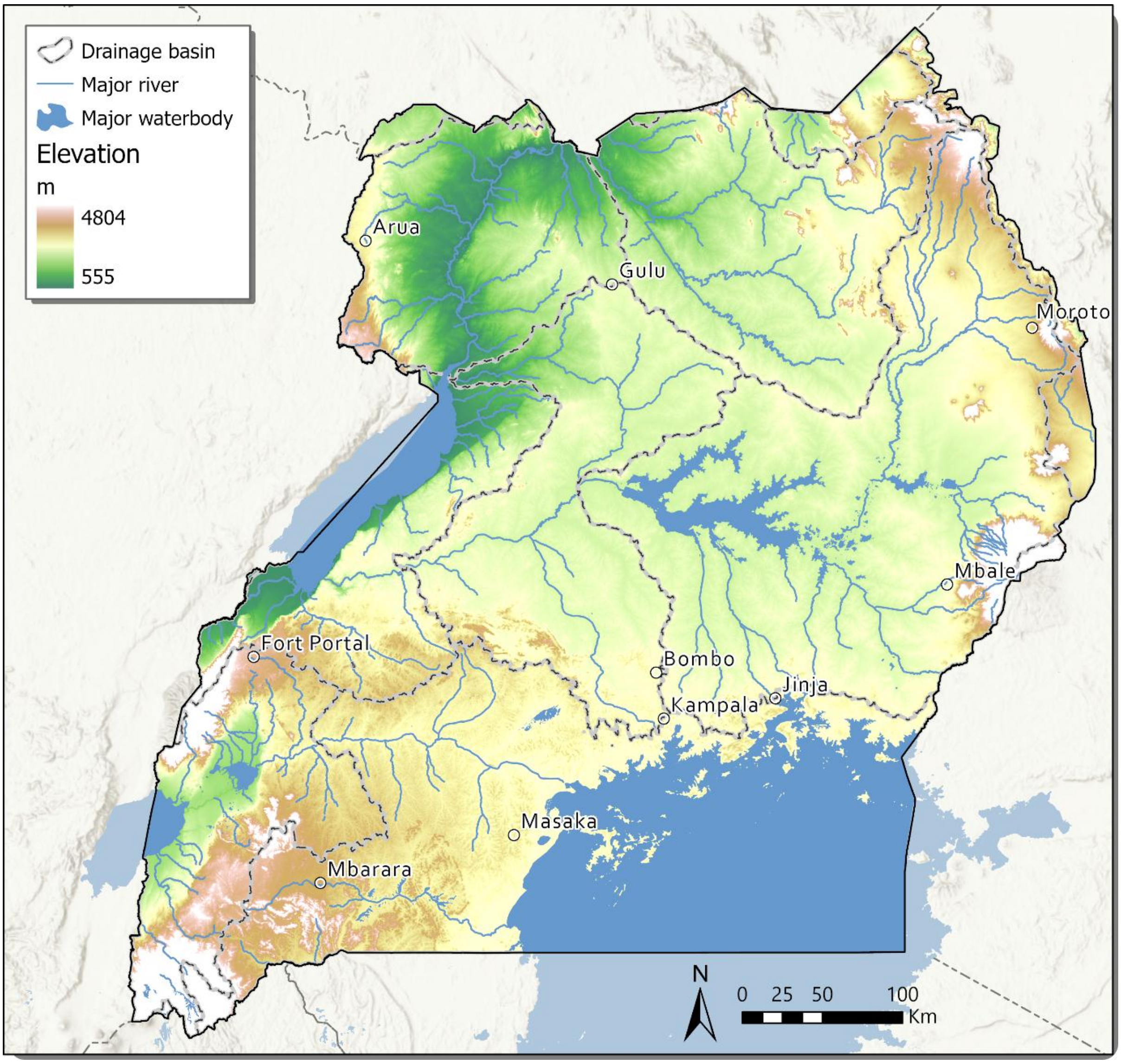

Figure 2.1. Topography and drainage of Uganda.

Mountain ranges surround the plateau, with parts of the Albertine Rift, including The Virunga Mountains, Ruwenzori Range and Western Rift Valley, to the west, the Imatong Mountains in the north, and Mounts Elgon, Kadam, Morungole and Moroto in the east. Mount Stanley, in the Ruwenzori Range at the border between Uganda and the DRC, is the highest mountain in Uganda and the third highest in Africa with an elevation of 5109 m. Mount Elgon, a solitary extinct volcano near the Kenyan border, has a peak elevation of 4321 m. Uganda's lowest point is 621 m at Lake Albert.

Virtually all of Uganda falls within the Nile Basin, with the exception of a sliver along the country's north-eastern border which drains into Lake Turkana. Uganda has abundant water resources and many rivers and lakes, with four of the African Great Lakes situated within or across its borders. The largest of these, and second largest inland lake in the world, is Lake Victoria with an area of 69 000 km² (Nsubuga, Namutebi & Nsubuga-Ssenfuma, 2014), located across south-eastern border (Figure 2.2). About 45% of Lake Victoria falls within Uganda, with the remainder shared with Kenya and Tanzania, while the lake's drainage basin also extends into Burundi and Rwanda (MWE, 2014).

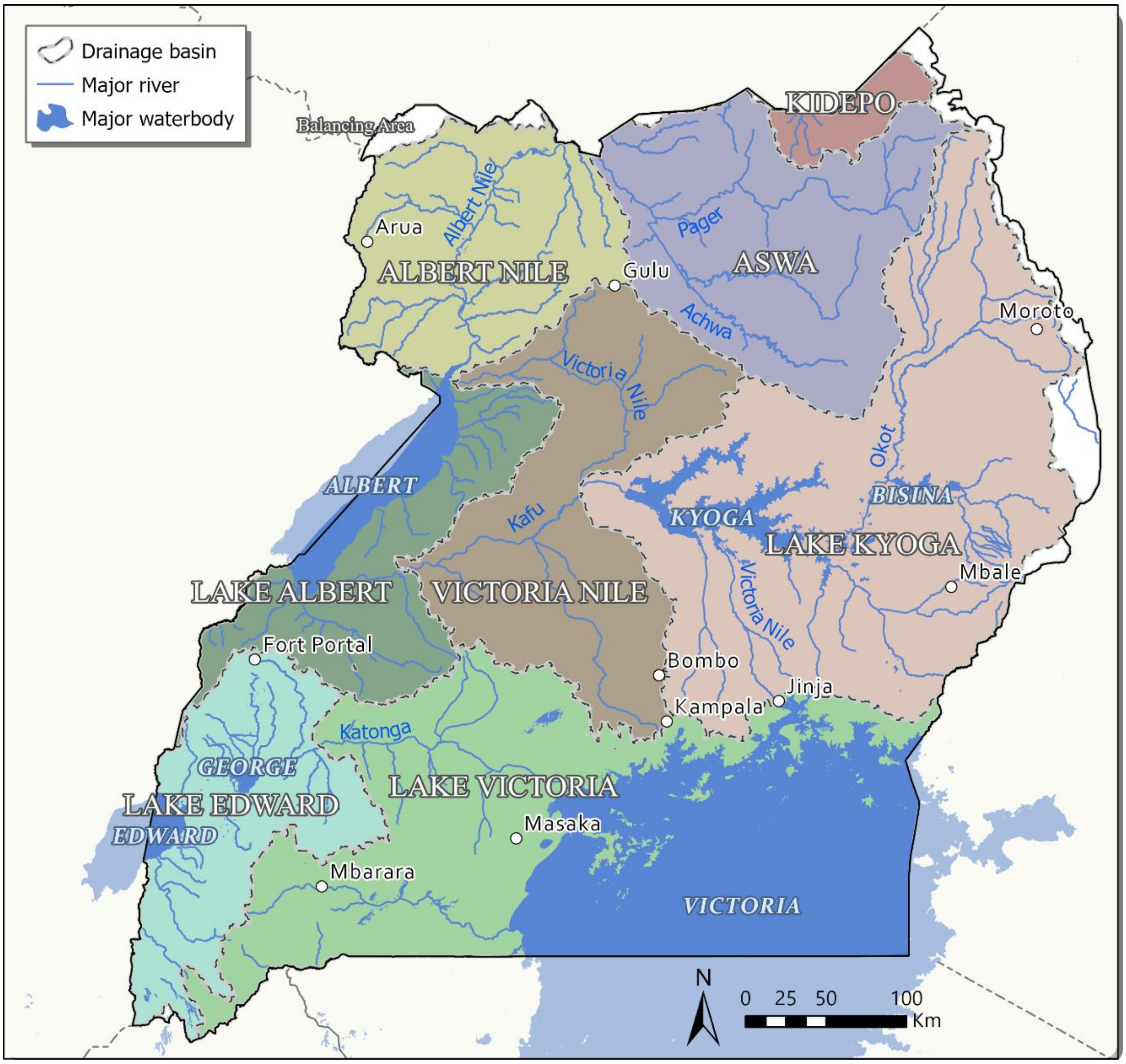

Figure 2.2. Major drainage basins, rivers and lakes of Uganda.

Five other major lakes in Uganda include Lakes Edward and George in the southwest, Albert in the west, Kyoga in the centre, and Bisina in the east (Figure 2.2). Both Edward and George are shared with the Democratic Republic of Congo. There are 149 smaller lakes across the country (Nsubuga *et al.*, 2014). These are interconnected by seven major rivers across the country. The Okot River in the east drains the north-eastern highlands southward into Lake Kyoga. The Victoria Nile begins at Lake Victoria and flows northward through Lake Kyoga until draining into Lake Albert. The Kafu River in the west flows eastward and then northward before joining the Victoria Nile. The Albert Nile flows from Lake Albert northward into South Sudan. The northern Pager River drains the northern highlands westward before joining the Achwa River and flowing northward to join the Nile in South Sudan. The channel of the Katonga River, in the south of Uganda, connects Lakes Victoria and George. However, the river typically reaches a wetland that drains back into Lake Victoria.

Although almost all of Uganda falls within the Nile Basin, the country has been divided into eight major subnational basins (Figure 2.2); Lake Victoria, Victoria Nile, Lake Kyoga, Lake Edward, Lake Albert, Aswa, Albert Nile and Kidepo. All, except Kidepo, are a part of the larger White Nile Basin. The Kidepo Basin drains into Kenya's Lake Turkana Basin. Relatively small areas along the northern and eastern border are not within the major basins (the white areas in Figure 2.2). These areas were termed balancing areas in previous natural capital accounts.

For the most part, Uganda is relatively well-endowed with water resources with high precipitation and extensive lake and wetland systems over much of the country. However, some regions are prone to water stress, particularly the semi-arid northeast of the country where most watercourses are seasonal and runoff is low, as well as drier districts in the southwest of Uganda (MWE, 2014; Nsubuga *et al.*, 2014). Conversely, flooding is a widespread issue in some areas, particularly in El Niño years, with Kampala and the Lake Victoria and Kyoga basins being some of the worst affected areas (USAID, 2021). Uganda's water resources are also affected by transboundary issues, most notably pollution and eutrophication of Lake Victoria which is driven by both local activities in Uganda and activities in other countries that fall within the lake's basin (MWE, 2014). Overall, it is estimated that 35% of Uganda's water resources originate in neighbouring countries, highlighting the vulnerability of Uganda to water availability or quality challenges arising in upstream countries (USAID, 2021). The Karmamoja region of northeast Uganda already experienced 12 droughts between 1991 and 2011,

CLIMATE

The majority of Uganda has a tropical climate, with high rainfall and two rainy seasons per year (March to May and September to December). The average total annual precipitation is 1218 mm with 41.9 mm in the driest month (January) and 159.3 mm in the wettest month (April) (Harris *et al.*, 2020). Rainfall patterns vary strongly across the country due to its varying topography and large water bodies. Areas of particularly high rainfall are associated with the Ruwenzori Range, Mount Elgon and Lake Victoria (Figure 2.3). The north-east has a more semi-arid climate and experiences only one rainy season per year and less than 500 mm of rain per year, far less than the rest of the country. This, as well as limited perennial surface water, makes this region vulnerable to water scarcity, which likely will be exasperated by climate change (USAID/SWP 2021).

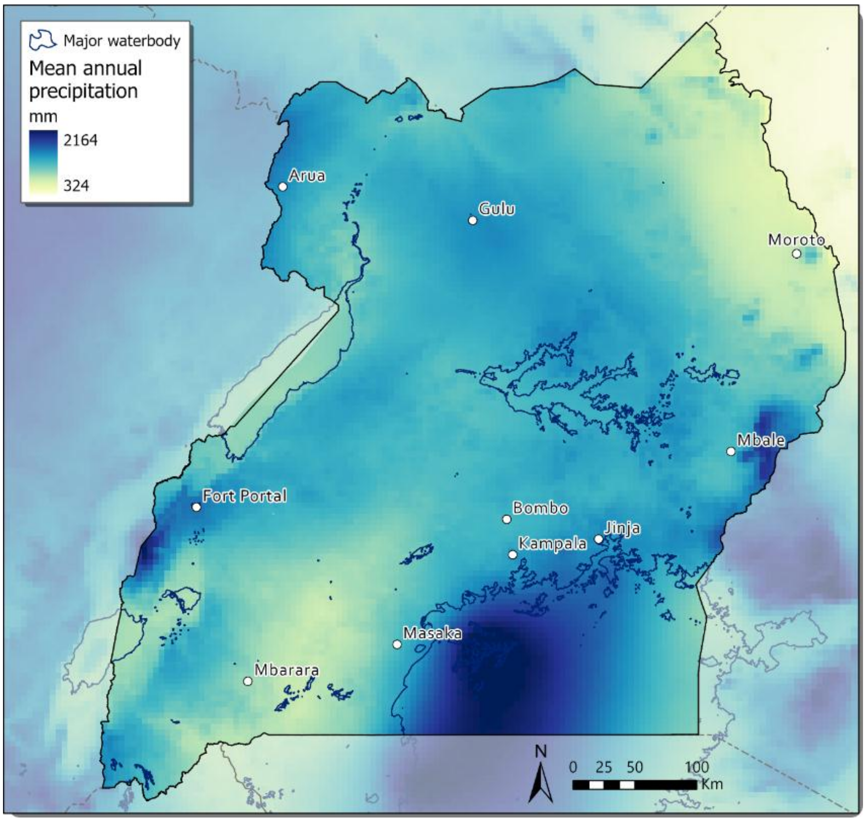

Figure 2.3. Mean annual precipitation across Uganda. Data source: WorldClim (Fick & Hijmans, 2017).

Overall, Uganda has experienced a statistically significant decline in rainfall over the past 60 years, with more frequent and long-lasting drought in western, northern and north-eastern Uganda (World Bank Group, 2021). Significant uncertainty is associated with future rainfall predictions for Uganda. In general, rainfall is projected to increase in wetter areas in the southern and central Uganda with climate change, while drier areas in the north and northeast are expected to become even more dry and suffer higher risks of drought (USAID, 2021; World Bank Group, 2021). The former change could increase flood risks in already flood-prone regions of Uganda, while drying in the north and northeast will make agriculture and livestock-rearing even more challenging in these drier regions (USAID, 2021). Flooding is already a common occurrence in Uganda and experienced most in the Lake Victoria and Kyoga Basins. These events are more common in El Niño years and likely to intensify with increasing rainfall under climate change (USAID/SWP 2021).

Temperatures are moderate throughout the year with a mean annual temperature of 22.1°C, a mean minimum temperature in the coolest month (July) of 15.8°C and a mean maximum temperature in the warmest month (February) of 30.4°C (Harris *et al.*, 2020). The low-lying areas in the northwest experience the highest mean temperatures. In contrast, the peaks of the Ruwenzori Range and Mount Elgon have mean temperatures below 7°C. Temperatures in this region are predicted to increase by 1.8 to 3.7°C in the upcoming decades due to climate change. Already, a 1.3°C in average temperatures has occurred across Uganda as a whole since the 1960s (World Bank Group, 2021). The significant projected increase in high heat data could have serious negative consequences for human health, livestock and agriculture, particularly in the north of the country where temperatures are already high and future rainfall is expected to decline.

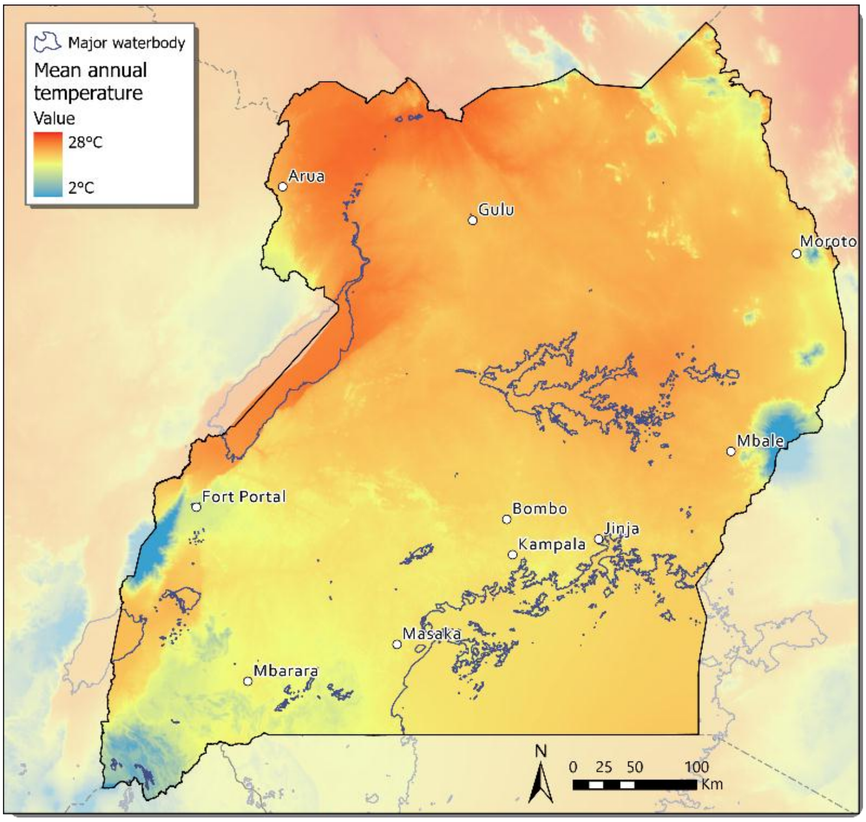

Figure 2.4. Mean annual temperatures across Uganda. Data source: : WorldClim (Fick & Hijmans, 2017)

TERRESTRIAL ECOSYSTEMS & BIODIVERSITY

Before significant human development, the dominant natural vegetation types in Uganda were dry *Combretum* wooded grassland covering about 21% of the land area, spread across the warmer and drier areas, and Lake Victoria rainforest which covered about 20% of the land area with extensive stretches around Lake Victoria and to the south and east of the country (Figure 2.5). However, by the end of the 20th century most of this forest had been cleared for agriculture (Struhsaker, 1987). This area also contained numerous wetlands and swamps lining the vast river network, which too have since been degraded or converted. Evergreen bushland occurred between areas of rainforest and formed a large expanse in the south. The low-lying north was dominated by *Vitellaria paradoxa*[2] (shea) wooded grasslands (12%), edaphic[3] grasslands and wooded grasslands (12%), and moist *Combretum* wooded grasslands (9%). This area also encompassed small sporadic patches of palm wooded grassland. *Acacia-Commiphora* bushland, dotted with patches of dry montane forest, formed a belt in the drier highlands along the north-eastern border. The more southerly mountains were covered by Afromontane rainforest which gave way to ericaceous and alpine vegetation with increasing altitude (Figure 2.5). Bamboo could be found in a few small areas in lowland and montane vegetation across

[2] The scientific name of the shea tree has changed from *Butyrospermum parkii,*

[3] Caused by soil conditions rather than by fire

Uganda. Increases in population density and agriculture mean very little intact natural vegetation, especially forest, now remains outside of protected areas.

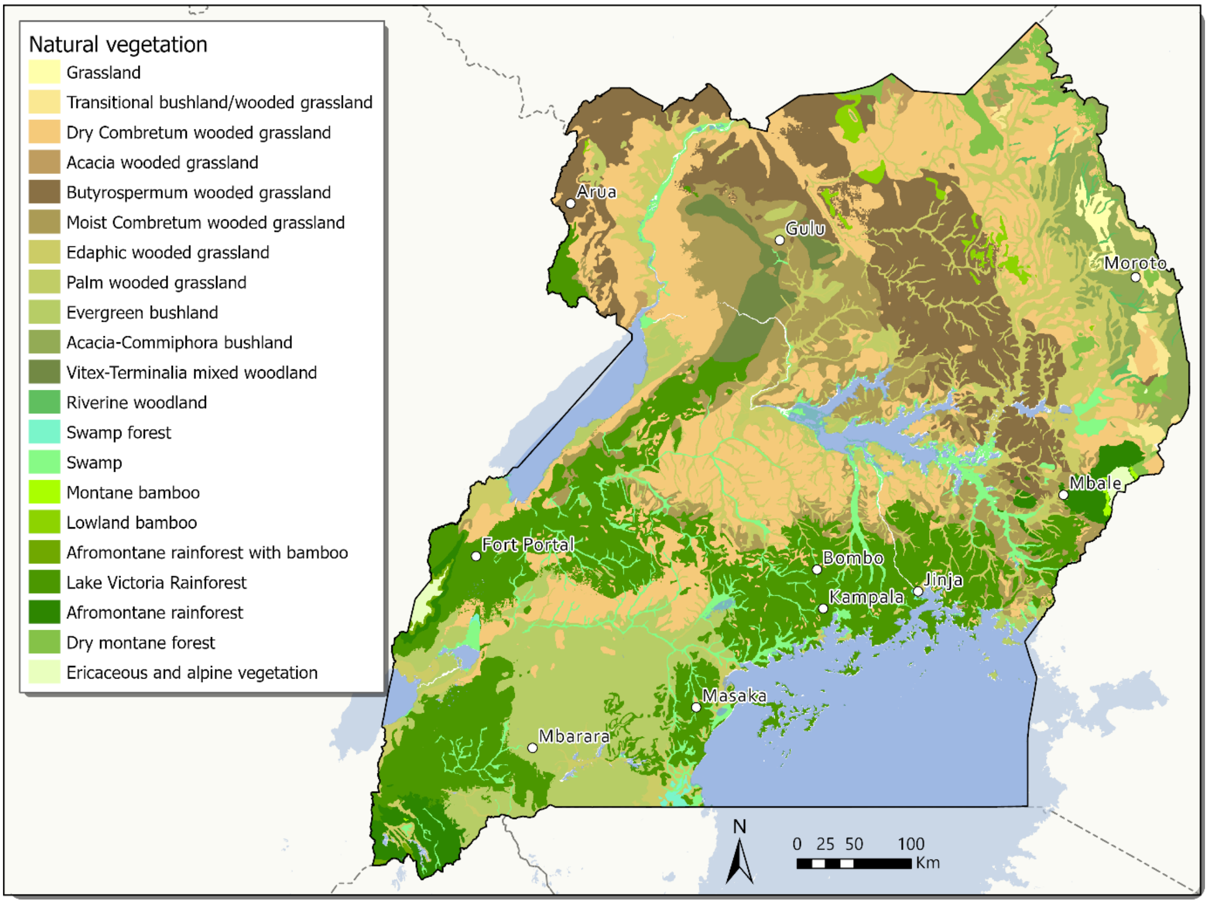

Figure 2.5. Natural vegetation map of Uganda. Data source: (van Breugel et al., 2015)

Due to the variety of topography and habitats, Uganda has an exceptional degree of terrestrial biodiversity, ranking in the top ten most biodiverse countries. Over 50% of the bird species, 39% of the mammal species and 19% of the amphibian species found in Africa occur in Uganda (NEMA 2016). In addition, there are more endemic and globally threatened vertebrates found in the Albertine Rift than any other region in Africa (Plumptre et al., 2007). The remnants of Uganda's montane rainforest are home to 54% of the remaining mountain gorilla population (NEMA, 2016). Other iconic wildlife species include chimpanzee, elephant, lion, cheetah, leopard, buffalo, giraffe and roan antelope to name a few.

The soils in Uganda are relatively fertile. Unfortunately, due to erosion, leaching and biological degradation, soil nutrients levels have been severely depleted affecting their productivity potential.

AQUATIC ECOSYSTEMS & BIODIVERSITY

The remarkable biodiversity of Uganda's terrestrial ecosystems is mirrored by its aquatic biodiversity. The multitude of lakes, rivers and wetlands create diverse, productive habitats. Most rivers, barring the Nile, are slow flowing and swampy. Wetlands are a prominent feature in Uganda. There is substantial seasonal variation in the rates of flow of the perennial rivers and most of the smaller rivers dry up in the dry seasons. Uganda once supported over 600 species of fish, including 292 endemic species of cichlid in Lake Victoria. Swamps and floodplains provide critical breeding and nursery habitats for many fish species (NEMA, 2016).

Unfortunately, the accumulation of untreated municipal and industrial waste and agricultural run-off into aquatic habitats, such as Lakes Victoria and Kyoga, has resulted in eutrophication, hypoxic zones, and mass fish die offs (USAID/SWP 2021). This, in combination with overharvesting and invasive alien species, has caused the extinction of about 150 species of cichlid, 100 of which were endemic, in Lake Victoria (NEMA, 2016).

Wetlands are being rapidly degraded due to urban expansion and agricultural activities, with more than 40% destroyed since 1994 (USAID/SWP 2021). As a result, important services such as flood attenuation, and water quality amelioration and habitat for biodiversity are being diminished.

POLICY ENVIRONMENT

Uganda has acknowledged the risk of overexploitation of their resources and incorporated environmental sustainability and sustainable development into their national policies and long-term strategies. Several policies, including environmental, water, wildlife and forestry policies, have been reformed to better align with the country's national development objectives and a sustainable future. Uganda is also party to a number of international agreements which aim for sustainable development and environmental protection.

BIODIVERSITY

Uganda is signatory to the Convention on Biological Diversity (CBD), which means that it has committed to preparing and regularly updating a National Biodiversity Strategy and Action Plan (NBSAP) to achieve goals and targets including those set out in the Aichi Targets for 2020, and the subsequent Post-2020 Global Biodiversity Framework. Note that Aichi Biodiversity Target 2 entailed integrating biodiversity values into national and local development and poverty reduction strategies and planning processes. It also required including biodiversity in national accounting and reporting systems and in economic and spatial planning.

CLIMATE CHANGE

Uganda has committed to the United Nations Framework for the Convention on Climate Change (UNFCCC) and regularly reports on the country's greenhouse gas emissions. Uganda also launched the Strategic Program for Climate Resilience (SPCR) which aims to incorporate climate risks into long-term policy decision-making. The SPCR programme helps Uganda mainstream climate concerns into policies and to achieve their NDCs.

SUSTAINABLE DEVELOPMENT GOALS (SDGS)

In 2015, Uganda adopted the 2030 Development Agenda titled "Transforming our world: the 2030 Agenda for Sustainable Development". The Sustainable Development Goals (SDGs)require reporting on internationally agreed upon indicators, to improve national development. Currently, around 40 indicators for nine SDGs can use SEEA information. The 2030 Agenda for Sustainable Development stipulated by the UN in 2015 sets out 17 SDGs with a total of 169 targets. The National Environmental Management Authority (NEMA) releases a State of the Environment report twice a year which informs the SDG reporting. However, better data is needed to improve monitoring progress. Ecosystem accounting helps to track the progress of achieving the SDG goals as it provides a standardised framework for measuring achievements in terms of biodiversity and sustainability.

Uganda's Green Growth Development Strategy (UGGDS) provides an action plan on how to realise Uganda's Vision 2040 and the National Development Plan. The main aims of the UGGDS are to follow a low-emissions growth path, use resources efficiently, become climate resilient, use natural capital optimally, and improve food security (GoU, 2019a). Implementing the UGGDS requires a supportive institutional, governance and finance environment.

PEOPLE, ECONOMY, LAND TENURE AND ADMINISTRATION

POPULATION

Uganda's population grew from 13 million in 1980 to 17 million in 1991 and had increased to 35 million by 2014 (Figure 2.6). The country's growth rate remains high and was recorded as 3.1% in 2014. Uganda now hosts 1.5 million refugees (UNHCR & GoU, 2022), making it the third-largest refugee population in the world (UNHCR, 2022). These refugees, mostly in the west of the country, place additional demands on national resources.

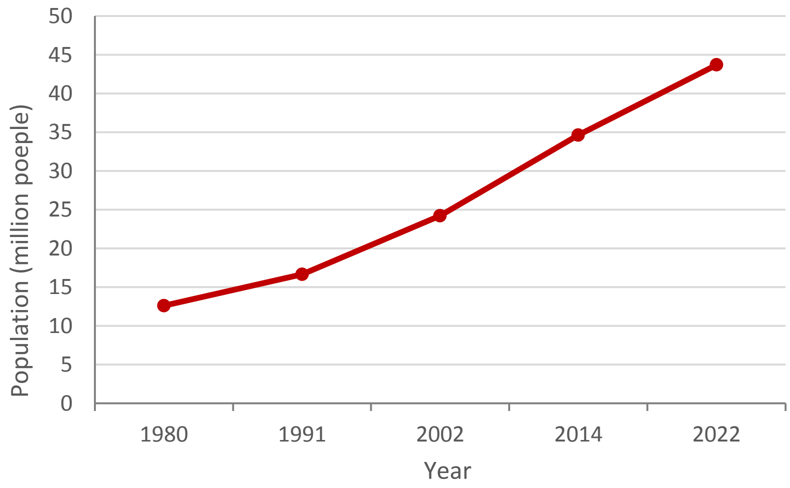

Figure 2.6. Population of Uganda, 1980-2022 (Source: UBOS)

Kampala, the capital of Uganda, is the most populated city, with a population of 1.5 million people in 2022. This is followed by Nansana (365 000 people) and Kira (317 000 people; UBOS, 2016a). Despite rapid urbanisation, the population remains predominantly rural (76%) and many are poor (41.7 %). While there has been an increase in life expectancy in recent years (2008-2018, UNECA 2020), malnutrition increased between 2004-2018. Rapid population growth decreased per capita food production (UNECA 2015). Overall, the density of people is highest in the southeast, around Kampala, Entebbe, Jinja and Mbale, and lowest in the relatively arid northeast (Figure 2.7).

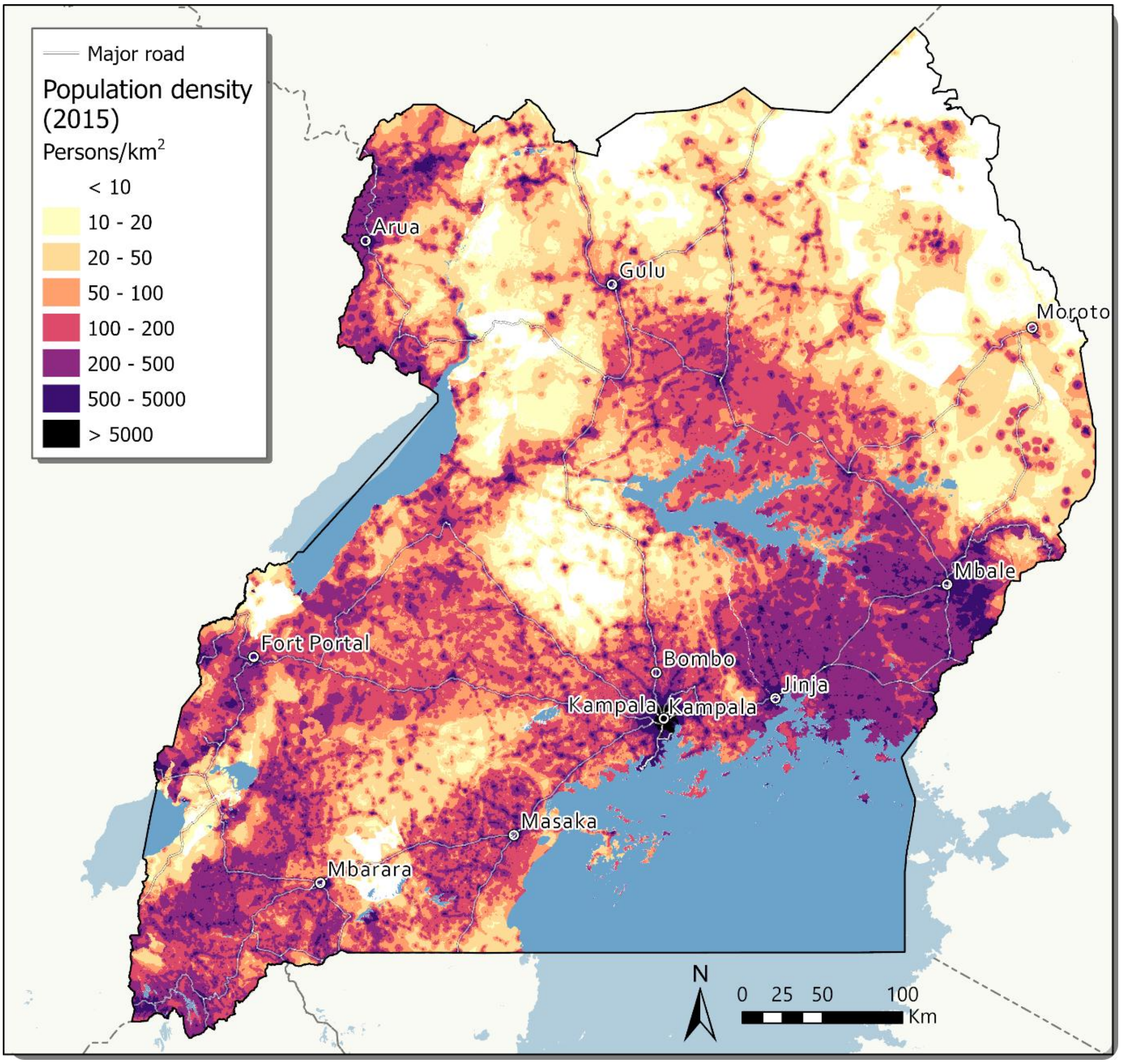

Figure 2.7. Population density map of Uganda, in 2015 (Source: data derived from www.worldpop.org)

ECONOMY AND LIVELIHOODS

Uganda's economy is centred on its natural resources, which include fertile soils, substantial oil reserves, and mineral deposits. The majority of the rural population engage in subsistence agricultural production, with heavy reliance on the harvesting of natural resources. Agriculture is thus the main economic sector, which employs the majority of the work force. The agricultural sector is particularly reliant on the health of ecosystems, as it depends on natural services such as pest control, pollination, and soil fertility maintenance. To meet growing food demands, farmland increased by 20% - from 8 473 262 ha in 1990 to 10 530 465 ha in 2015. Uganda also has a small industrial sector. In general, economic output is constrained by its limited capacity to invest in human capital, technological and infrastructure development as well as governance issues. The country relies on donor support and concessional loans.

WATER AND ENERGY INFRASTRUCTURE

As of 2017, it was estimated that 68% of Uganda's population had access to safe water sources (MWE, 2017). The United Nation's Sustainable Development Goal 6 envisions availability and sustainable management of water and sanitation for all (United Nations, 2005). Creating national ecosystem accounts helps to estimate the value of water-related ecosystems and can inform policies on watershed protection to safeguard future water provisioning services. Groundwater is the major source of water for the rural population (UN, 2017). This is reflected in Figure 2.8, which shows boreholes and wells are spread throughout Uganda, with the highest density of these water supply infrastructure types associated with the country's most densely populated rural areas. As of 2015, MWE data indicated that there are over 200 functional dams in Uganda. However, most of these are small earth dams which do not make a major contribution to national water supply. The highest density of dams is found in the relatively dry region around Mbarara in the southwest of Uganda, while dams are also fairly widespread in the drier northeast of the country (Figure 2.8).

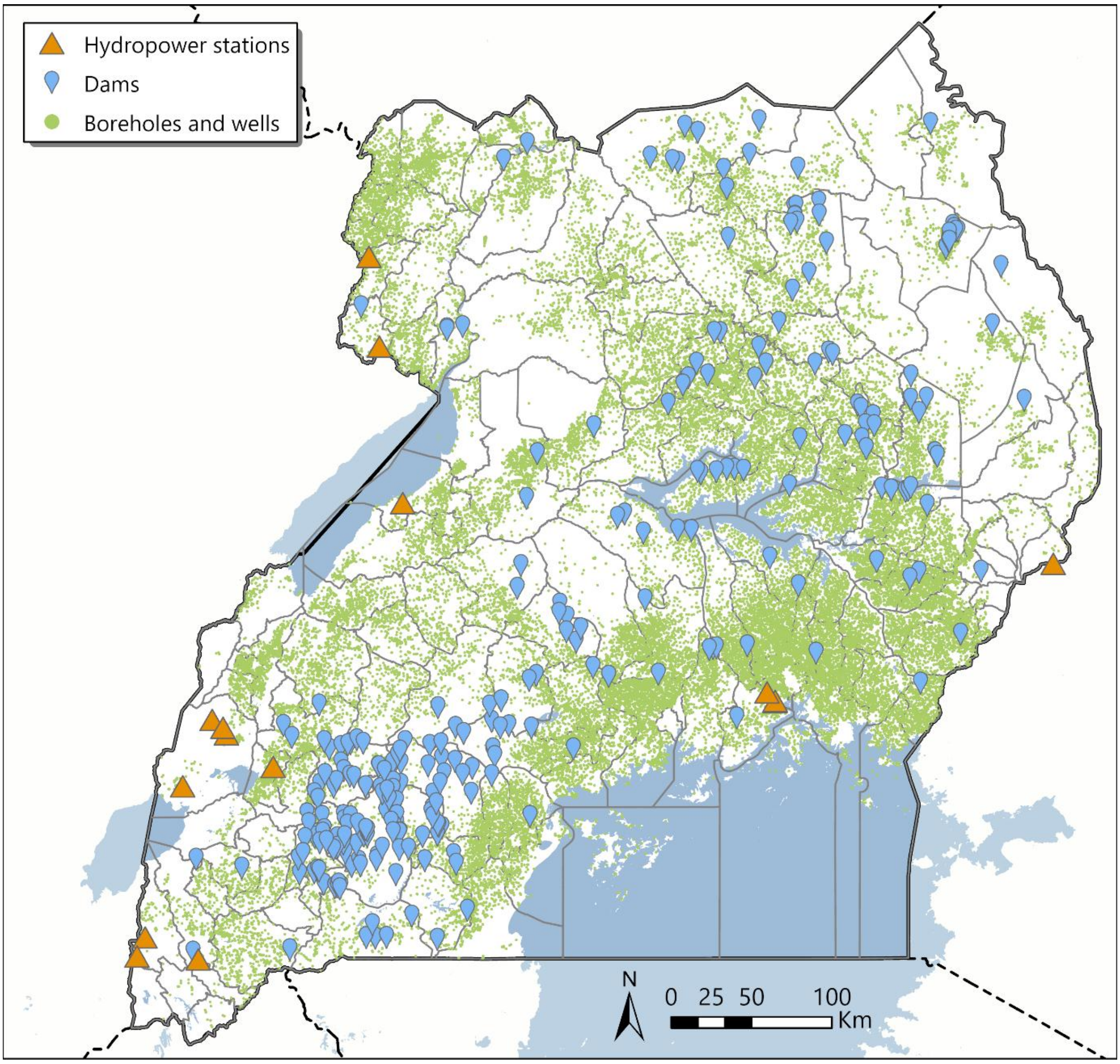

Figure 2.8. Map of dam, hydropower station, borehole and well locations. (Sources: Dam, borehole and well locations from MWE dataset)

Uganda's electricity generation capacity has expanded rapidly in recent years, rising from 317 MW in 2002 to 1182 MW in 2019 (MEMD, 2019). Despite this, only 28% of the population has access to electricity, with electricity accounting for just 2% of primary energy use in Uganda in 2019, with biomass fuels accounting for the vast majority (88%) of energy consumption. According to the Electricity Regulatory Authority (ERA), hydropower accounted for around 82% of Uganda's electricity production in 2020, with the remainder made up by thermal power (8%), cogeneration (5%) and grid-connected solar (5%) (ERA, 2020). The majority of hydropower generation comes from the series of hydroelectric power stations built to harness the outflow of the Nile from Lake Victoria at Jinja. All other hydropower stations in the rest of the country are small, with generation capacities of 18 MW or less. They are generally located in high rainfall regions of Uganda, with a notable cluster of stations downstream of Mount Rwenzori (Figure 2.8). The current generation is estimated to be around 10% of the technically feasible hydropower potential in the country (Aqua Media International, 2021).

LAND TENURE AND ADMINISTRATION

LAND TENURE

According to the National Constitution, land in Uganda belongs to the citizens of Uganda and is vested to them under four land tenure systems, namely: (a) customary; (b) freehold; (c) mailo; and (d) leasehold. Land under customary tenure is a communal land system where people tend not have land titles but do mark out land that they use. This land covers over 60% of the country. Freehold and mailo land involve permanent land titles for which only Ugandan citizens are eligible (mailo land has a peculiar history and is limited to Central Uganda). Leasehold land is land leased by individuals or companies from customary, freehold or mailo owners, with leases limited to 49 - 99 years[4]. The Constitution states that the Government may regulate the use of land (NEMA, 2021a). Unfortunately, there is no map of Uganda's different land tenure systems.

PROTECTED AREAS

According to data from the World Database on Protected Areas, around 16% of Uganda falls within protected areas (UNEP-WCMC & IUCN, 2022). The protected area estate includes 11 national parks and 11 wildlife reserves, four wildlife sanctuaries, five community wildlife management areas (CWMAs). In addition, there are over 600 forest reserves (Figure 2.9). However, many forest reserves have been settled and partially or completely converted to agriculture, thus no longer effectively functioning as protected areas. The wildlife protected area estate is managed by Uganda Wildlife Authority (UWA), the central forest reserves (CFRs) are managed by the National Forestry Authority (NFA) and the local forest reserves (LFRs) by local governments and communities. These protected areas, particularly the national parks, are some of Uganda's key tourism drawcards and account for the bulk of the country's nature-based tourism value.

National parks are largely managed as no-take protected areas. However, there are provisions for limited legal access to state protected areas for natural resource harvesting purposes. Under these arrangements, the UWA allows communities limited access to parks to collect resources such as thatching grass, medicinal plants, and honey (Tolbert *et al.*, 2019). Harvesters are only granted permission following registration and authorization, and the quantities and types of resources permitted for harvesting are limited to avoid negative environmental impacts. Detailed ecosystem

[4] www.ecolandproperty.com

accounts on district level can help with determining changes in ecosystem extent and determine levels of sustainable use.

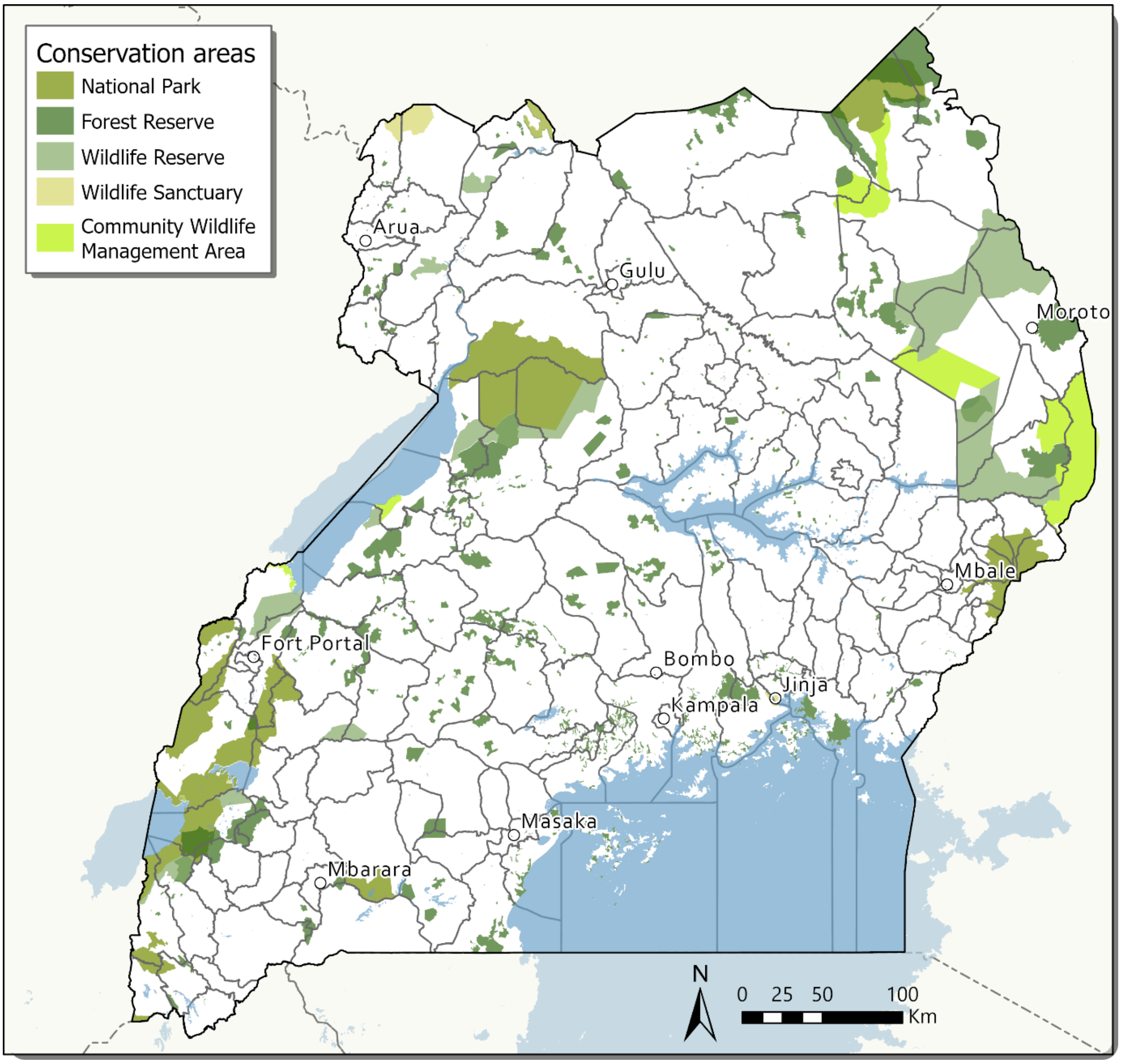

Figure 2.9. The conservation areas of Uganda, classified as National Parks, Forest Reserves, Wildlife Reserves, Wildlife Sanctuaries, and Community Wildlife Management Areas, as of 2020 (Source: World Database of Protected Areas).

ADMINISTRATIVE DISTRICTS

Uganda has been slowly devolving its administration to smaller spatial areas over time. In 1990, there were just 33 districts. By 2015, these had been further divided into 113 districts. Subdivision of districts has continued since then, with Uganda currently divided into 135 districts plus 11 cities which are at the same administrative level (Figure 2.10). These accounts use the most recent districts, since this will be most practical for the current administration and for accounting going forward.

To facilitate the analysis of sub-national activity at broader scales, Uganda's districts are grouped into 15 subregions with similar characteristics (GoU, 2019b). For example, certain statistical data is only available at subregional level. The subregions are themselves aggregated into four regions. However, there is no formal tier of government attached to Uganda's regions or subregions, as they are primarily statistical divisions.

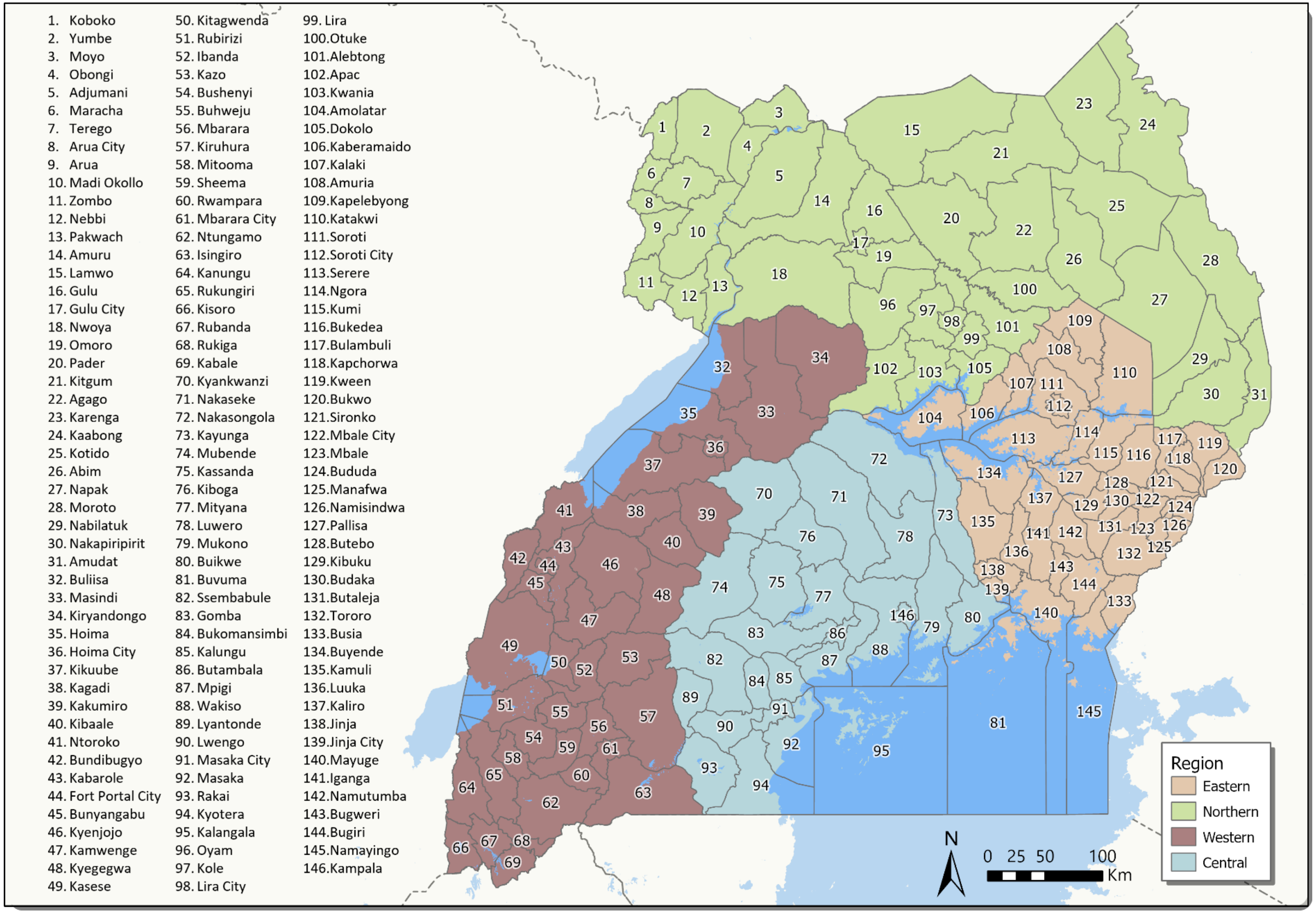

Figure 2.10. The four regions and 146 districts of Uganda as at 2020 (Source: UBOS). Note that these accounts are summarised for the present districts rather than the districts as at 2015, to be of more practical value.

AGRICULTURAL ZONES ("ZARDIS")

The country is divided into ten zones (groups of districts) that are served by the Zonal Agricultural Research Development Institutes. These were used as the accounting areas in the Land and Soil Improvement accounts, which reported on four of them: Abi, Buginyanya, Mbarara and Mukono.

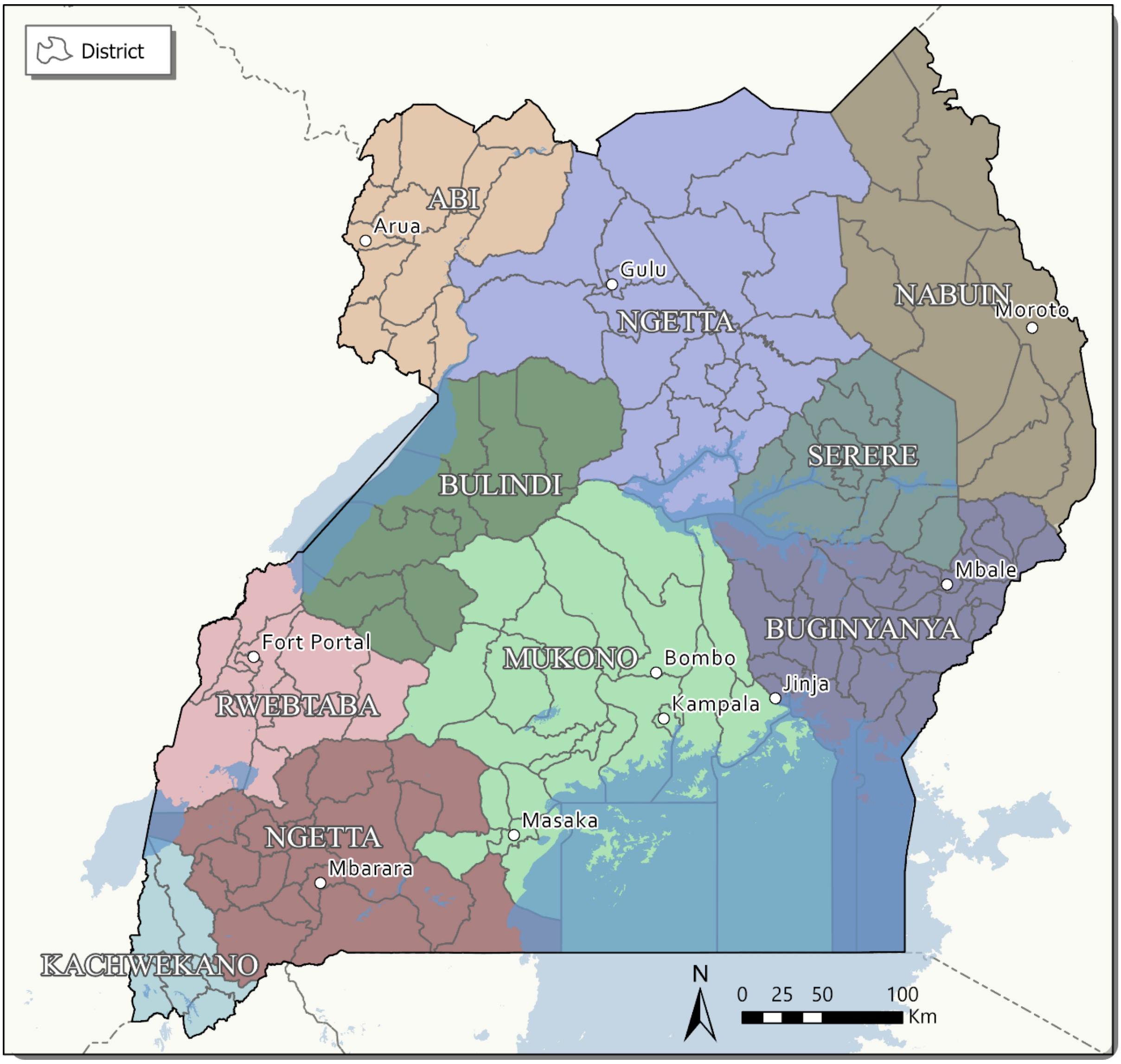

Figure 2.11. Areas served by the Zonal Agricultural Research Development Institutes (ZARDI), (Data Source: MAAIF 2018)

LAND COVER

The way in which human activities have altered the natural land cover has been analysed using satellite data and is presented in Uganda's Land Accounts (GoU, 2019b). These show that, by 1990, 35% of land area was under human modified landscapes, and this had grown to 45% by 2015. Natural forest, which once covered 54% of the country, was reduced to 24% by 1990 and 8% by 2015 (Figure 2.12). The national-scale land account is shown in Table 2.1 for ease of reference in this document.

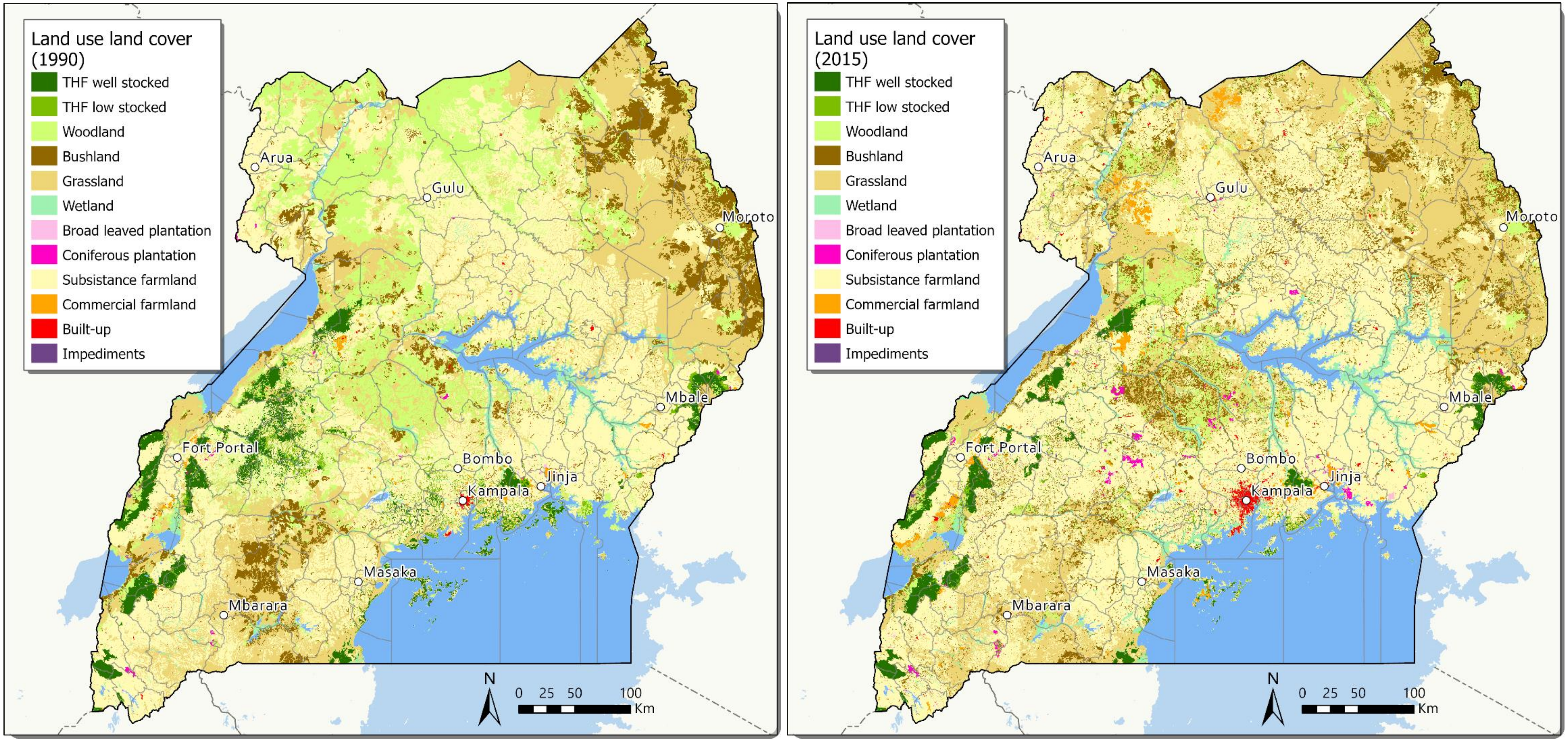

Figure 2.12. Land cover maps of Uganda for 1990 and 2015. (Data source: UBOS)

Table 2.1. National physical asset accounts for land, 1990-2015, in hectares. Source: Based on GoU (2019).

National land cover stocks	Open water	Wetland	Grassland	Bushland	Woodland	Tropical high forest low stock	Tropical high forest well stock	Broad-leaved plantation	Coniferous plantation	Commercial farmland	Small-scale farmland	Built up area	Impediments
Opening stock (1 Jan. 1990)	3,689,603	484,031	5,115,477	1,422,263	3,974,523	273,062	651,111	18,682	16,384	68,447	8,401,602	36,572	3,741
Additions	57,882	493,471	1,170,999	3,324,510	1,111,145	158,163	186,030	8,059	3,787	59,297	1,953,081	13,213	1,799
Reductions	66,593	138,960	3,492,509	738,857	2,250,920	204,673	133,210	16,896	8,673	24,417	1,438,574	23,469	3,683
Net gain/reduction	(8,710)	354,512	(2,321,510)	2,585,652	(1,139,775)	(46,511)	52,820	(8,838)	(4,886)	34,881	514,506	(10,256)	(1,884)
Opening stock (1 Jan. 2000)	3,680,892	838,542	2,793,967	4,007,916	2,834,747	226,551	703,930	9,845	11,498	103,327	8,916,109	26,315	1,857
Additions	62,147	217,502	2,538,925	1,534,777	1,319,547	124,979	68,654	13,107	11,489	45,672	1,525,134	78,141	7,541
Reductions	36,550	303,002	1,269,274	2,573,989	1,376,233	159,835	171,626	8,166	4,246	42,369	1,593,548	7,186	1,594
Net gain/reduction	25,598	(85,500)	1,269,652	(1,039,212)	(56,686)	(34,857)	(102,972)	4,941	7,243	3,303	(68,414)	70,956	5,947
Opening stock (1 Jan 2005)	3,706,490	753,042	4,063,619	2,968,704	2,778,062	191,694	600,959	14,786	18,741	106,630	8,847,695	97,271	7,804
Additions	35,251	296,031	2,644,084	1,593,059	678,877	90,494	87,904	18,460	33,710	65,861	2,328,810	48,049	9,001
Reductions	52,373	238,623	1,639,403	2,189,972	2,008,061	161,432	123,911	12,251	8,708	37,576	1,404,221	46,870	6,191
Net gains/reduction	(17,121)	57,408	1,004,681	(596,913)	(1,329,184)	(70,938)	(36,008)	6,209	25,002	28,286	924,589	1,179	2,809
Opening stock (1 Jan 2010)	3,689,369	810,450	5,068,300	2,371,791	1,448,878	120,756	564,951	20,995	43,743	134,916	9,772,284	98,450	10,614
Additions	72,621	161,431	1,566,083	1,094,221	441,480	59,186	37,951	34,128	27,538	153,258	1,782,267	70,790	4,962
Reductions	12,408	256,400	1,537,011	1,498,778	677,407	78,078	73,778	10,886	7,795	32,324	1,279,582	33,673	7,795
Net gain/reductions	60,213	(94,970)	29,072	(404,557)	(235,927)	(18,892)	(35,827)	23,242	19,743	120,935	502,685	37,117	(2,834)
Closing stock (31 Dec. 2014)	3,749,581	715,481	5,097,372	1,967,234	1,212,951	101,864	529,124	44,237	63,486	255,850	10,274,969	135,567	7,780

3. METHODOLOGICAL FRAMEWORK

OVERVIEW

In this section, we provide a brief overview of ecosystems and ecosystem services, their valuation for accounting, the spatial framework for analysis, and how accounting tables are compiled and interpreted. The SEEA EA (UN et al., 2021) provides the overarching conceptual framework using a range of data sources and methods that area described below.

ECOSYSTEMS AND ECOSYSTEM SERVICES

ECOSYSTEMS

An ecosystem is a community of organisms interacting with one another in their non-living environment. Ecosystems can be delineated based on a higher level of biological interaction within them than between them and adjacent systems. This can be recognised at different spatial scales, the broadest of which are biomes. Within the terrestrial realm, biomes are distinguishable on broad structural characteristics, mainly the relative abundance of different plant growth forms. The SEEA EA recommends that ecosystem accounting uses biomes or the next tier of classification, which is based on functional groups. These accounts summarise ecosystem services and values at the level of biomes.

In the SEEA EA, ecosystems include not only natural types, but also man-made ecosystems such as agricultural fields, reservoirs, urban parklands, etc. Indeed, the distinction between natural and modified ecosystems is difficult, since they exist on a continuum, from those with very little or no human inputs, through various degrees of management, to those which are highly modified, and bearing very little resemblance to the natural state.

For these accounts, ten ecosystem types were delineated on the basis of the land cover data (Table 3.1).[5] Uganda's land cover classes were considered to provide a reasonable delineation of ecosystem types. That is, the different land cover types generally reflect distinct sets of abiotic and biotic components and their interactions (UN et al., 2021). This is in line with previous ecosystem accounting work, which used land cover classes as a suitable means of delineating ecosystem types, as is often done in the Ugandan context (GoU, 2020b). The 13 land cover classes were combined into 10 ecosystem types because certain land cover divisions were not considered to represent distinct ecosystem types as per the SEEA definition. For example, well-stocked and low stocked tropical high forest were combined as they do not represent separate communities with distinct sets of biotic components and interactions, but rather the distinction is made on condition. Similarly, subsistence and commercial farmland are different conditions of farmland. A cross-walk of the original land cover classes and ecosystem types, including the area of each land cover class and ecosystem type in 1990 and 2015, is provided in the Appendix.

[5] Some ecosystem extent accounts have used vegetation maps to delineate ecosystems, but most use land cover classes. We elected to use the latter, since this accommodates the fact that ecosystems do shift over time. For example, if a wetland area expands into a former grassland area, it would remain classified as grassland (actually degraded grassland) in a static vegetation map-based approach but would be reclassified as wetland in a land cover-based approach.

While the 10 ecosystem types were used for accounting across all services, it should be noted that the underlying modelling and mapping of services used the underlying land cover data (as a measure of condition) and the national vegetation map (van Breugel *et al.*, 2015) in estimating ecosystem capacity to deliver services. In some cases, further differentiation within ecosystem types was also made through the integration of land cover and vegetation map data. For example, vegetation map data was used in combination with land cover to map ecosystem capacity to supply different kinds of wild products, as the stocks of these resources vary within vegetation types at a sub-land cover class level.

Table 3.1. Ecosystem types used in these accounts and their derivation from the land cover data. Land cover class descriptions from Drichi (2002)

Land cover classes (13)	Ecosystem types (10)
Open water – Lakes, rivers and ponds	Open water
Wetlands – wetland vegetation; swamp areas, papyrus and other sedges	Wetland
Grassland – rangelands, pastureland, open savanna; may include scattered trees shrubs, scrubs and thickets.	Grassland
Bushland - bush, thickets, scrub (average height < 4m)	Bushland
Woodland – trees and shrubs (average height > 4m)	Woodland
Tropical High Forest (THF) well stocked – tall multistorey trees, closed canopy cover	Natural forest*
Tropical High Forest (THF) low stocked – THF that has been depleted/encroached	
Coniferous Plantations and woodlots – planted coniferous trees,	Plantation forest*
Broad-leaved Plantations and woodlots – planted deciduous trees/broadleaves ("hardwood")	
Uniform commercial farmland – mono-cropped, non-seasonal farmland usually without any trees for example tea and sugar estates	Farmland
Subsistence farmland – mixed farmland, small holdings in use or recently used, with or without trees	
Built up area – Urban or rural built-up areas	Built-up area
Impediments (bare rocks and soils)	Bare

*Shortened names are used for these in these accounts for ease of presentation – "Forest" and "Plantation", respectively.

It should be noted that the classification of wetlands in the land cover data improved dramatically in 2015. This revealed that large areas were erroneously classed as grassland or other land cover types instead of wetlands in the 1990 land cover dataset. Taken at face value, the land cover data suggest that the area of wetlands in Uganda increased by 51% from 1990 to 2015, which is in direct contrast to the literature which reports widespread declines in wetland area over that period (GoU, 2016; Kayima, Mayo & Nobert, 2018; Wasswa, Kakembo & Mugagga, 2019; Kakuba & Kanyamurwa, 2021). Therefore, an adjustment was made to the 1990 land cover to include areas classified as wetlands in 2015 (unless the area had been classified as water in 1990). This is still a conservative estimate of wetland cover in 1990, but not as drastic an underestimate as would be derived from the unmodified land cover data.

ECOSYSTEM SERVICES

Ecosystem services in the ecosystem accounting context concern (i) the supply of ecosystem services to users; and (ii) the contribution of ecosystem services to benefits (i.e., the goods and services ultimately used and enjoyed by people and society) (UN et al., 2021). Ecosystem services considered included the goods that are harvested (provisioning services), the characteristics or attributes of ecosystems that are valued for various experiential uses (cultural services) and the ecological functions that save costs in the provision of conventional economic goods and services (regulating services).

The benefits obtained from ecosystems were largely taken for granted before the concept of ecosystem services emerged in the 1980s and 1990s (Ehrlich & Mooney, 1983; Costanza *et al.*, 1997; Daily, 1997). Since then, a number of conceptual frameworks and classification systems for ecosystem services have been proposed,[6] and the development of a standardised approach to classify and value ecosystem services remains a serious challenge (Potschin *et al.*, 2016; La Notte *et al.*, 2017; UN et al., 2021). The SEEA EA provides a reference list of ecosystem services to be considered in ecosystem accounting. These do not include minerals or abiotic services (such as wind energy or hydropower), which are not produced by extant ecosystems. However, they do include water as a provisioning service.[7]

An important aspect of understanding and selecting ecosystem services for inclusion involves understanding the difference between the **final services** that generate benefits, and **intermediate or underlying services** that support the provision of final services. The focus for national-level accounting is on final ecosystem services, all of which have a direct link with economic units. Economic units broadly consist of industry, government and households. Industry is further divided into agriculture, forestry and fisheries, water supply, trade, catering & accommodation, and other industries. Where intermediate services involve provision of services from one ecosystem to another (like a wetland providing a nursery area for a lake fishery), then it is worth accounting for these. But where they are integrally part of the same system, they are considered to be internal, and are not accounted for.

It is also important to recognise when an ecosystem service is an input to production and consumption in the SNA and when it is directly consumed without conversion into an SNA product. Accounting for the former does not increase GDP, but accounting for the latter would do so.

For this study, a list of the major types of ecosystem services[8] was devised based largely on SEEA-EA Table 6.3, with some modification for certain services based on the international literature and classification systems as well as our understanding of ecosystem services and the study area (Table 3.2).

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[6] The more widely cited examples include the Millennium Ecosystem Assessment (2005), The Economics of Ecosystems and Biodiversity (TEEB; 2010), Final Ecosystem Goods and Services Classification System (FEGS-CS, 2015), National Ecosystem Services Classification System (NESCS, 2015) and Common International Classification of Ecosystem Services (CICES, 2017).

[7] This is somewhat controversial, since many authors would argue that water is not produced by ecosystems. Rather, the the pathways, timing and quality of flows are influenced by ecosystems, which is a regulating service that often reduces the cost of obtaining water. Inclusion of water as a provisioning service (a good) as well as the regulating services described also requires taking care to avoid double counting, and dealing with the complication that these services are separated spatially. However, since ecosystem perturbations can also reduce water availability through increased transpiration (e.g. by invasive alien plants), the inclusion of water provisioning does allow for accounting for these effects.

[8] Note that it can be misleading to state or compare the "number" of ecosystem services included in a study, since the types of services discussed are nearly always groupings that could be subdivided in various ways.

Table 3.2. The ecosystem services in the SEEA-EA reference list, with a brief summary of each service based on the descriptions in the SEEA-EA. Services included are in bold type. For these services, an explanation is provided of how the service flow is measured in physical terms. The services marked with an asterisk were not included in this iteration of the accounts due to data or resource constraints.

Broad category	Ecosystem service	Description	Physical measure (all per ha and per year)
Provisioning services	**Crop** provisioning services	In situ ecosystem inputs to crop production.	Total harvested production (kg) is used as a proxy measure for the various ecosystem inputs which are difficult to quantify
	Aquaculture provisioning services	In situ ecosystem inputs to aquaculture production	
	Grazed biomass/Livestock provisioning services	Ecosystem contributions to the growth of grazed biomass that is an input to the growth of cultivated livestock.	Tons of grazed biomass
	Wood provisioning services	Ecosystem contributions to the growth of trees and other woody biomass in both cultivated (plantation) and uncultivated production contexts	Total output in terms of m^3 per ha per year
	Wild fish and other natural aquatic biomass provisioning services	Ecosystem contributions to the growth of fish and other aquatic biomass harvested in uncultivated production contexts	
	Wild animals, plants and other biomass provisioning services	Contributions to growth of wild animals, plants and other biomass harvested in uncultivated production context (other than wood and aquatic resources).	Wild natural resources harvested from ecosystems for subsistence or small-scale production, in terms of kg or m^3
	Genetic material services*	Genes and varieties obtained and their influence on pharmaceutical sales and crop and livestock production.	Not included due to lack of information. Largely intermediate to cultivated outputs
	Water supply	Combined ecosystem contributions of water flow regulation, water purification, and other ecosystem services to the supply of water of appropriate quality to users for various uses including household consumption	Total water extracted for consumption, in Mm^3
Regulating services	**Global climate regulation** services	Ecosystem contributions to reducing concentrations of GHG in the atmosphere	Stocks of carbon in each time period, expressed as tonnes of carbon per ha; annual additions and subtractions are not estimated but net changes are tabulated between two time periods
	Rainfall pattern regulation (at sub-continental scale) services *	Ecosystem contributions of vegetation, in particular forests, in maintaining rainfall patterns through evapotranspiration at the sub-continental scale.	Not included
	Local (micro and meso) climate regulation services *	Regulation of ambient atmospheric conditions (including micro and mesoscale climates) through the presence of vegetation that improves the living conditions for people and supports economic production	Not included
	Air filtration services*	Ecosystem contributions to the filtering of air-borne pollutants through the deposition, uptake, fixing and storage of pollutants by ecosystem components, particularly plants, that mitigates the harmful effects of the pollutants.	Not included

Broad category	Ecosystem service	Description	Physical measure (all per ha and per year)
	Soil quality regulation services*	Ecosystem contributions to the decomposition of organic and inorganic materials and to the fertility and characteristics of soils, an intermediate service.	Not included
	Soil and sediment retention services	Reducing soil loss and sediment transportation to downstream environments (including mudslides) through holding soils in situ (by vegetative cover) or through trapping eroded sediments (by slowing down movement of water through the landscape, e.g. in a wetland).	Measured in terms of the difference in amount of sediment retained (m^3 per year) at key points between the observed land cover and a situation of bare and degraded landscape (for wetlands this means loss of holding capacity).
	Solid waste remediation services*	Ecosystem contributions to transformation of organic or inorganic substances, through the action of micro-organisms, algae, plants and animals that mitigates their harmful effects. Final or intermediate service.	Not included
	Water purification services: retention and breakdown of **nutrients** and other pollutants	Ecosystem contributions to the restoration and maintenance of the chemical condition of surface water and groundwater bodies through the breakdown or removal of nutrients and other pollutants by ecosystem components that mitigate the harmful effects of the pollutants on human use or health.	(Nutrients only) Measured in terms of the difference in the nutrient loads (kg per year) delivered at key points between the observed land cover situation and a situation of intensively modified and degraded landscape (for wetlands this means loss of holding capacity).
	Water flow regulation services: base flow maintenance and peak flow mitigation	Smoothing of flow over the longer duration through infiltration and storage, reducing need for storage to achieve a given yield.	Average quantity of infiltration that is demanded for groundwater use, measured in m^3 per year. Cost savings in terms of surface water supply infrastructure is expected to be small due to dependence on lakes and was not measured.
	Flood control services: river and coastal*	Smoothing of fluvial flows during storm events through interception, infiltration, storage and landscape roughness, reducing the flood peak volume, velocity and flood height in the receiving area.	Not included
	Storm mitigation*	Ecosystem contributions of vegetation including linear elements, in mitigating the impacts of wind, sand and other storms (other than water related events) on local communities. A final ecosystem service.	
	Noise attenuation*	Ecosystem contributions to the reduction in the impact of noise on people that mitigates its harmful or stressful effects. Usually a final ecosystem service.	
	Pollination services*	Pollination of crops by animals living in surrounding environments, thus contributing to productivity.	Not included separately, since farmland is too broadly delineated (being a complex landscape of cultivated and semi-natural vegetation) and much of the service is therefore internal to the ecosystem. The service is thus accounted for within the crop production inputs.
	Biological control services: pest control and disease control*	Control of crop pests by animals living in surrounding environments, thus contributing to productivity.	

Broad category	Ecosystem service	Description	Physical measure (all per ha and per year)
	Nursery population and habitat maintenance services*	Provision of critical habitat for populations that are utilised in other locations, such as fish nursery areas; wildlife breeding areas or migratory staging areas. As for the above service, this requires attributing some of the ecosystem inputs to these activities to the critical habitat areas rather than the areas in which the activities take place.	Not included
Cultural services	**Experiential-related services**[9]	Experiential fulfilment associated with active or passive use, through any type of or purpose including recreation, education, scientific research, spiritual, artistic or other cultural activities (typically some combination of these).	No appropriate physical measure. Therefore, expressed only in monetary terms, as the sum of: • contribution to property value (not included) • simulated exchange value of local use (not included) • contribution to **tourism value**
Flows related to non-use values	Ecosystem and species appreciation *	Ecosystem and species appreciation concerns the wellbeing that people derive from the existence and preservation of the environment for current and future generations, irrespective of any direct or indirect use. e.g. donations	Not included, and not accommodated in the SEEA EA methods as yet.

[9] Note that the SEEA EA reference list separates these into (i) recreation related services, (ii) visual amenity services, (iii) education, scientific and research services and (iii) spiritual, artistic and symbolic services. The authors feel that this separation is artificial as experiences and motivations for use often comprise a mixture of these, and that the breakdown should be based on user types which involve different valuation methods (Turpie et al. 2022, Turpie et al. in prep.). Therefore, we use the term "Experiential-related services" to encompass the full suite. This is only partially valued in these accounts, and the aspect valued could be classified as "recreation-related services" if the reference list is strictly followed.

VALUATION

VALUING ECOSYSTEM SERVICE FLOWS IN TERMS OF EXCHANGE VALUES

In order to be compatible with the measures used in the SNA, the ecosystem accounts express the value of ecosystem service flows in terms of "exchange values", which is the amount that is paid by the users of ecosystem services to the owners of those services, or that would be paid if a market existed (UN 2017). Note that this differs from, and is lower than, the welfare measures used in conventional valuation of ecosystem services, e.g. for use in project or policy appraisal methods such as cost-benefit analysis. In the latter, the economic value used is the sum of producer and consumer surplus, where producer surplus is the producer's net income (turnover minus all costs of production) and consumer surplus is the difference between aggregate willingness to pay and the aggregate expenditure, for a given good or service. The SNA is concerned with income, but not consumer surplus.

The SNA measures the gross output (= turnover or expenditure generated), and the direct value added (= turnover minus intermediate costs) for each sector in the economy. The latter is the net income generated to all economic actors and includes net income to the owners of the factors of production (= producer surplus), to employees (= salaries and wages) and to government (= taxes minus subsidies).

In the SNA, environment is not recognised as a sector, and many environmental inputs are not paid for, and thus not accounted for. In some cases, the benefit to which the environmental input contributes is accounted for (e.g. tourism), but in others it is not (e.g. recreation in open access green space areas). The latter production value is said to be outside of the SNA production boundary. Because it is outside the production boundary, the SNA does not impute values for transactions between ecosystems and their users. In the monetary ecosystem service accounts, ecosystem services that are used in the generation of benefits are valued as if such a transaction occurred. In some cases, this would be the equivalent of an intermediate expenditure for a sector whose output (SNA products as categorized in the Central Product Classification or CPC) is already within the SNA production boundary (e.g. inputs to agriculture). In other cases, it would be the equivalent of a final expenditure for a benefit that is outside of the SNA production boundary (e.g. use of public green open space).

It is important to note that for the cases where ecosystem services contribute to outputs that are measured in the SNA, the value assigned to ecosystems is the residual value after all costs are subtracted. Basic prices are used as far as possible, which are market prices adjusted to remove tax and subsidy distortions. Note that many goods and services used in crop and livestock production in Uganda are VAT[10] exempt (URA, 2014, 2022; Kasirye, 2015), and there is little subsidisation within the primary sectors. A key limitation of this approach is that the proportion of the residual value to the overall gross output of the activity does not necessarily reflect the relative importance of ecosystem services in the generation of those outputs. It is a lower bound value. Indeed, a much larger proportion of the gross output of that sector (possibly all of it) could be lost if the environmental

[10] The Value Added Tax rate in Uganda is 18%.

input were lost. These effects can only be determined through analysis of an accounting time series or by doing a scenario analysis for varying levels of ecosystem services.

Not all ecosystem services are valued in this way. Some ecosystem services are consumed purposely, such as provisioning and cultural services, while others are used inadvertently, such as most of the regulating services. The first group are usually consumed through the joint contribution of ecosystem services and some form of man-made capital and labour inputs. For these services, the benefits derived from ecosystem services are valued in terms of the residual value (or resource rent) after all human inputs are accounted for, as described above. The second group are generally ecosystem services that could (at least in theory) be replaced by technology or infrastructure, or if lost could result in damages, and are valued in terms of net costs saved.

Based on general advice of the SNA (chapter 3), the SEEA EA (para 9.23) recommends that valuation methods are applied in the following order of preference:

i. Methods where the price for the ecosystem service is directly observable;

ii. Methods where the price for the ecosystem service is obtained from markets for similar goods and services;

iii. Methods where the price for the ecosystem service is embodied in a market transaction;

iv. Methods where the price for the ecosystem services is based on revealed expenditures (costs) for related goods and services;

v. Methods where the price for the ecosystem service is based on expected expenditures or markets."

DETERMINING CONSTANT VALUES AND VOLUME AND PRICE EFFECTS

National accounts are compiled using both "current" and "constant" prices. Current prices are the prices that applied at the time of the transaction or balance sheet entry. These are difficult to compare across years because of inflation, especially when there is a large span of time between accounting years. In Uganda, what was purchased for a shilling in 1990 would have cost approximately 5.44 shillings in 2015.

Constant prices are expressed in terms of the prices prevailing in a specified "base year" so that one can assess the "real changes" in output after correcting for price changes. This is usually done using the Consumer Price Index or a GDP deflator. In the SNA, changes in volumes of production can therefore be estimated based on monetary data alone. Thus, the SNA separates volume and price effects to show the extent to which changes in total output value are due to changes in the amount of production versus effects of input costs and demand on prices. Note that both the volume and price effects are expressed in monetary terms.

In ecosystem services accounting, services are measured in terms of physical flows as well as monetary flows, so the changes in volume do not have to be estimated *post hoc* as is done in national accounting. Indeed, because there are some services for which markets do not exist, it tends to be more challenging to estimate changes in current prices. For example, one might estimate the replacement cost value of a regulating service in terms of an engineering construction based on some recent data on construction costs, but it is difficult to know what that cost might have been at the start of the accounting period, other than assuming that it only changed by inflation. Thus, for all ecosystem services, it is possible to assess volume changes, but price effects cannot be computed for most non-market services. In these accounts, volume changes are described in physical terms, but we also disaggregate overall changes in value into volume and price effects to align with SNA accounting practices.

To convert the values to constant prices, we used the same base year as the most recent national accounts in Uganda. This is updated approximately every seven years to reflect a new base year and simultaneously benchmark estimates against new datasets. The most recent benchmark and rebasing[11] was done in October 2019, in which the base year was updated to 2017. All values in this report are therefore adjusted to constant UGX 2017 prices using an economy wide price change indicator, national inflation rates (NEMA, 2021a). Any values that were initially in USD were first converted to UGX at the prevailing exchange rate for that year, before being adjusted to the 2017 base year price[12]. Changes in the UGX / USD exchange rate are expected to have had an impact on the resource prices; however, multiple sources were used for the calculation of resource prices and an average was used. It is therefore unlikely that the exchange rate would have affected the valuation substantially.

ESTIMATING ECOSYSTEM ASSET VALUES

The **asset value of ecosystems** was calculated as the net present value (NPV) of the discounted sum of expected future flows of all ecosystem services that are generated by a particular ecosystem asset over a given period of time. Some of the future flows were adjusted based on sustainability of current use (see section on sustainability adjustment).

The calculation of NPV was made using a social discount rate for Uganda of 4.04% (based on Kotchen *et al.* 2019), and an asset life of 100 years (UN et al., 2021). The SEEA EA suggests using an asset life of 100 years[13] when expecting the ecosystem to be used long into the future (UN et al., 2021). In mathematical terms, the value of a single ecosystem asset *V* is written as:

$$V_\tau(EA) = \sum_{i=1}^{i=S} \sum_{j=\tau}^{j=N} \frac{ES_\tau^{ij}(EA_\tau)}{(1+r_j)^{(j+1-\tau)}}$$

where ES_τ^{ij} is the value of ecosystem service i in year j as expected in base year τ generated by a specific ecosystem asset EA; S is the total number ecosystem services, r is the discount rate and N is the lifetime of the asset.

[11] Rebasing is the replacement of the national accounts existing constant prices with new constant prices from a new reference year.

[12] The exchange rate was 3692 Ugandan shillings to the US Dollar in 2017.

[13] This is far longer than the 25 years used by Turpie et al. in South Africa's pilot monetary accounts, for reasons of uncertainty of longer projections. As a matter of interest, if the projected future stream of benefits were constant, then the asset value over 25 years would be 64.09% of the asset value over 100 years.

SUSTAINABILITY ADJUSTMENT

For provisioning services, the projection of future value flows included consideration of the level of sustainability of resource use. In the case of crop provisioning services, it was based on trends in productivity per unit area. In the case of harvested resources, this was based on the ratio of harvests to sustainable yields[14] at the level of each pixel of the underlying BSU. If harvesting was done at a rate that was higher than the sustainable yield, then stocks were depleted over time, with corresponding effects on future harvests. Sustainability adjustments were made for the resources likely to be most sensitive to rates of exploitation: wood, fish, grass and bushmeat. Sustainable yields for each resource were based on the literature or Uganda's existing ecosystem accounts and are summarised in Table 3.3. Details are provided in the corresponding sections.

Table 3.3 Sustainable yields (as a percentage of stocks) used for each resource

Resource	Sustainable yield assumption
Roundwood (Forest)	0.5%
Roundwood (Plantations)	10%
Fuelwood (Wetland, Grassland, Bushland)	10%
Fuelwood (Woodland, Forest)	5%
Fuelwood (Plantation)	8%
Fuelwood (Farmland)	15%
Fish	26%
Grass	30%
Bushmeat	30%

No sustainability adjustment was made for calculating the contribution of regulating or cultural services to asset value. This would require incorporation of ecosystem condition trends into the analysis, whereas at this stage ecosystem condition has not been properly measured or accounted for. It should therefore be noted that the contributions of these values to asset value implicitly and optimistically assume no further degradation or loss of extent and condition of ecosystems in future.

DECOMPOSITION OF CHANGES IN ASSET VALUE

Changes in asset value at national scale were decomposed into changes that were due to ecosystem conversions (area effects), changes in the real price of services (price effects) and changes in the volume of services used (volume effects). Volume effects were then further decomposed as being the result of changes in ecosystem capacity (enhancement of degradation) or changes in demand. The area, volume and price effects were computed as follows:[15]

$$Area\ effect: \left[\frac{1}{3}\overline{p_0^i}q_0^i + \frac{1}{6}\overline{p_0^i}q_1^i + \frac{1}{6}\overline{p_1^i}q_0^i + \frac{1}{3}\overline{p_1^i}q_1^i\right] * \left(a_1^i - a_0^i\right);$$

$$Volume\ effect: \left[\frac{1}{3}\overline{p_0^i}a_0^i + \frac{1}{6}\overline{p_0^i}a_1^i + \frac{1}{6}\overline{p_1^i}a_0^i + \frac{1}{3}\overline{p_1^i}a_1^i\right] * \left(\overline{q_1^i} - \overline{q_0^i}\right);$$

$$Price\ effect: \left[\frac{1}{3}a_0^i\overline{q_0^i} + \frac{1}{6}a_0^i\overline{q_1^i} + \frac{1}{6}a_1^i\overline{q_0^i} + \frac{1}{3}a_1^i\overline{q_1^i}\right] * \left(\overline{p_1^i} - \overline{p_0^i}\right).$$

[14] The amount of the resource that can be extracted annually without reducing the stock over time.
[15] Note that these equations have been corrected from the mistyped version presented in the SEEA EA (UN et al. 2021).

Where $\overline{p_t^i}$ is the average (discounted) unit price of the i_{th} ecosystem service over the asset life, $\overline{q_t^i}$ is the average volume per unit area of the i_{th} ecosystem service supplied, a_t^i is the area of the ecosystem supplying the service, t = 0 is the opening time period (1990) and t = 1 is the closing time period (2015). For the subnational accounting areas, the changes in asset value were decomposed into area versus price or volume effects.

SPATIAL FRAMEWORK

The process of constructing ecosystem accounts involves compiling and organising data on land cover, land use and ecosystem extent into a spatial framework that allows for comparison of several different spatial datasets over the accounting period. This spatial framework is supported through defining a basic spatial unit (BSU) that is internally homogenous in terms of its biophysical properties and provides a consistent fine-level data framework within which data about various characteristics can be incorporated (UN et al., 2021). For these accounts, the basic spatial unit is a100x100 m cell, aligned and snapped to the country's national land cover datasets.

Ecosystem assets can be defined as distinct, contiguous areas covered by a specific ecosystem type (e.g. grassland, wetland, estuary, forest). Ecosystem types, on the other hand, are aggregations of individual ecosystem assets representing a specific type of ecosystem, including non-contiguous areas (e.g. the total area of grassland). The difference between ecosystem assets and types is represented in Figure 3.1.

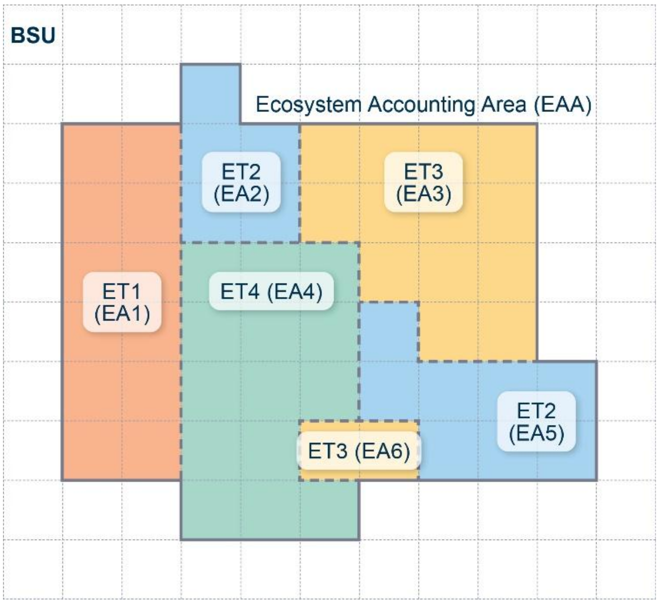

Figure 3.1. Diagram representing the relationship between the basic spatial unit (BSU – underlying grid), ecosystem assets (EAs – contiguous areas, e.g. EA1), ecosystem types (ETs – collection of EAs of similar ecosystem type, e.g. ET3) and the ecosystem accounting area (EAA – area of interest in bold outline). Source: Based on UN (2017)

ECOSYSTEM ACCOUNTING AREAS

These ecosystem service and asset accounts were conducted at three scales of ecosystem accounting areas:

- National (1 EAA)
- Drainage basins (9 EAAs – 8 major basins plus the remaining areas)

- Districts (including cities) (146 EAAs)

In order to summarise the service flows for each of these areas, it was necessary to map the ecosystem services at a relatively high level of resolution. This meant that all data needed to be disaggregated to at least the District scale. As far as possible, all ecosystem service flows were mapped to the BSU (1 ha resolution) so that they could be summarised at district scale.

ACCOUNTING TABLES

For each of the above EAAs, the supply and use of each major category of ecosystem services is summarised per biome in physical and monetary terms for 1990 and 2015, and the asset account records the change in asset value of each ecosystem type within that EAA.

The supply and use tables ideally only account for ecosystem services which are used. In the case of some regulating services, accounting only for the service used is easier to achieve in monetary than physical terms because of the spatio-dynamic complexity of the service, and thus for certain services the physical accounts have reported on the service *capacity*, irrespective of whether it is demanded. For certain cultural services, only the monetary accounts are provided, since physical measures were not available. These deviations are explained in more detail under the relevant sections of Chapter 4.

The supply of each type of ecosystem service is summarised for each broad ecosystem type (biome), and the use is summarised for different economic actors (agriculture, forestry and fisheries, water supply, trade, catering & accommodation, other industries, government, households). As required in accounting tables, the sum of supply must equal the sum of use. The supply tables denote origin of the utilised services and should not be confused with ecosystem capacity to supply a particular service (which may be different from the utilised amount). For wild biomass, the amount used would also include illegal use and amounts exceeding sustainable yield. The supply and use tables also have the ability to account for intermediate ecosystem services (i.e. ecosystem service flows from one ecosystem type to another that help support the functioning of that ecosystem type), but intermediate flows are not developed in this report.

The ecosystem monetary asset account records the monetary value of opening and closing stocks of all ecosystem assets within an ecosystem accounting area and any additions or reductions in these stocks. These values can be thought of as comparable with the value of produced assets.

According to the SEEA EA (UN et al., 2021) ecosystem services which are not used by economic units that are resident in the ecosystem accounting area are defined as exports. Exports of biomass and related products are recorded in the standard economic accounting tables, not as exports in the ecosystem service flow account. Transactions which involve processing, transportation or sale of biomass and their products are not the focus of ecosystem accounting.

4. ECOSYSTEM SERVICES AND BENEFITS

CROP PROVISIONING SERVICES

OVERVIEW

Crop provisioning services are the ecosystem contributions to the growth of cultivated plants. In these accounts, crop production takes place in human-modified ecosystems termed "farmland", which comprises the areas classified in the land cover as commercial farmland and small-scale farmland. The ecosystem contribution includes the substrate and provision and retention of nutrients and soil moisture. Because this complex contribution is difficult to quantify in a single physical measure, the tonnage of crops produced is used as the physical measure.

The service is valued as the gross output less the man-made capital and labour inputs, and less inputs from surrounding ecosystems, such as pollination services and biological control services, for which the service values should accrue to those ecosystems (Turpie et al. 2022). However, in this study, because farmland as delineated includes both planted areas and the natural or semi-natural areas in between, pollination and pest control services, which typically are supplied from natural ecosystems within about 2 km of vegetable and fruit crops, are likely to be supplied largely from within what has been delineated as the farmland ecosystem type and were not calculated separately. Future studies could investigate this further, using a higher-resolution delineation of farmland.

DATA AND METHODS

DATA SOURCES

In order to generate district-level estimates of production for each crop for 1990 and 2015, the study drew on the following data sources:

- 1990 production statistics at national scale from FAOSTAT (FAO, 2022a)
- 2008/2009 Agricultural Census (UBOS, 2010) at district level
- 2018 Annual Agriculture Survey (UBOS, 2020a) at the scale of Zonal Agricultural Research and Development Institute (ZARDI) areas.
- National-level crop production figures for 2015 in the Statistical Abstract (UBOS, 2020b)

The UBOS reports generally have limited information on cash crops. Both the UBOS Agricultural Census (UBOS, 2010) and Agriculture Survey (UBOS, 2020a) did not include tea, sugar, tobacco and cotton, while coffee was only included in the latter report.. These crops (aside from coffee) were also excluded from the Land and Soil Improvement Accounts (giving crop production in 2009, 2018; NEMA, 2021b). National-level production for some of these cash crops in 2015 (tea, cotton, tobacco) is provided in the Statistical Abstract (UBOS, 2020b). Finally, for cash crops excluded from the Statistical Abstract (tobacco and sugar), production data was obtained from FAOSTAT for both 2015 and 1990 (FAO, 2022a). Downscaling national production of these crops required information on which districts each crop is grown in. Information on tea growing districts was obtained from (CIAT, 2011) and the National Agriculture Advisory Services (NAADS) website. The latter lists several districts to which tea growing has expanded recently. It was thus assumed that these districts produced tea in 2015 but not 1990. Sugar growing districts were obtained from an assessment of all sugar manufacturing companies in Uganda and the areas from which they harvest. Tobacco growing districts were identified based on the overlap with tobacco growing livelihood zones in the map of Ugandan livelihood zones produced by the Famine Early Warning System Network (FEWS NET, 2010), as well as information from the African Tobacco Industry Monitoring report (Wanyonyi *et al*., 2020). Districts growing cotton were estimated from the map produced by the Cotton Development Organisation (CDO, n.d.)

ESTIMATING PRODUCTION IN 1990 AND 2015 AND DOWNSCALING TO DISTRICT LEVEL

To estimate district-level production in 1990 for crops included in the 2008/2009 census (UBOS, 2010), the 2008/2009 production was adjusted based on the difference in farmland area from 1990 to 2010 (the closest year for which land cover data were available). This was done at district level, using the district boundaries as at 2008/9. Finally, a uniform correction factor was applied to the district-level data to align the total estimated production of each crop with 1990 production reported by FAOSTAT (FAO, 2022a). Yield per hectare of farmland for each crop was then calculated and mapped at district level by dividing estimated production by total farmland area[16] of each district in 1990.

For commercial crops not included in the agricultural census (tea, sugar, cotton, tobacco), a simpler method had to be used as only national-level production data was obtained. Various sources of information were used to identify districts where each of these crops are grown. The total area of farmland within these districts was summed to obtain a total potential growing area for these crops. It was assumed that sugar and tea are grown largely or exclusively in areas classified as commercial farmland in the land cover data. The 1990 national production estimates for each crop were then disaggregated by multiplying the proportional contribution of each district by the total potential area over which each crop could be grown. Yield per hectare of farmland for each crop could then calculated and mapped at district level by dividing estimated production by total farmland area (cotton and tobacco) or total commercial farmland area (tea and sugar) of each district in 1990.

To estimate district-level crop production in 2015 of crops included in the UBOS surveys, subregional production reported in the 2018 Agricultural Survey (UBOS, 2020a) was first adjusted back to 2015 based on the change in farmland area between 2015 and 2017 (the closest land cover data to 2018). To downscale subregional production to district level, the proportional contribution of each district to subregional production of each crop was calculated from the 2008/2009 agricultural census data. This was then multiplied by the 2015 subregional production estimates to obtain district-level production estimates of each crop. Lastly, a uniform correction factor then applied to align the total national production of each crop with national production for 2015 reported in the Statistical Abstract (UBOS, 2020b). Yield per hectare of farmland for each crop was then calculated and mapped at district level by dividing estimated production by total farmland area of each district in 2015.

For commercial crops not included in the UBOS surveys, the same method was used as for 1990 based on estimating the total farmland area in the districts in which each crop is grown, with tea and sugar again limited to commercial farmland. This was then used to downscale the national-scale production estimates for 2015 from either the Statistical Abstract (UBOS, 2020b) (tea and cotton) or FAOSTAT (sugar and tobacco).

[16] In the absence of a breakdown of production between commercial and small-scale farmland in the source data, production was spread evenly across total farmland area (i.e. commercial plus small-scale farmland in the land cover).

ESTIMATION OF USE

Use was allocated to households or industry, where household use refers to production for subsistence use including some informal trade, and where industry refers to commercial production by farming enterprises. The proportion of production allocate to household use was obtained from the Land and Soil Improvement Accounts for Uganda (NEMA, 2021a) for most crops. For crops which were not included in the Land and Soil Improvement Accounts, such as sugar, tea, coffee, tobacco, and cotton, it was assumed that all use was commercial.

VALUATION

Crop prices for 2009 and 2018 were taken from the Land and Soil Improvement Accounts (NEMA, 2021a). These were coarse estimates, with the same price per unit across all users and districts in each time period. When expressed in constant UGX 2017, this suggested an annual increase for all crops of 0.89%. This trend was used to estimate crop prices for 1990 and 2015.

Resource rents were calculated based on the value of output and the total production costs for the different crop types according to Kraybill and Kidoido (2009). Average costs of labour include the costs of hired labour as well as the costs of material input, including seeds, fertilizers, chemicals, mechanized and draft power. A resource rent was calculated for and applied to each crop type for the country average farmer and for enterprise production with higher input technologies (Kraybill & Kidoido, 2009). Resource rents were higher for larger scale producers than smaller scale farmers and varied across crops. Average resource rent for small-scale farmers was 0.48 and 0.56 for larger scale producers.

RESULTS

In 2015, roughly 44% of Uganda's surface area comprised farmland (small-scale and commercial), up from 35% of national area in 1990. Spatial variation in the total production of crops in 2015, expressed in terms of tonnes per hectare of farmland, is shown in Figure 4.1.

It should be noted that not all farmland is under active crop production in any given year, as the land cover type includes fallow areas, pastures and unutilised areas between fields. In other words, the planted area is often significantly lower than the farmland area as per the land cover. In 2015, it was estimated that total planted area (based on agricultural census data) was around 80% of the total farmland area in Uganda. Since detailed spatial data on planted area are not available, the service was attributed to all farmland area as per the land cover. This means that the average output per hectare of farmland will often be lower than the average output of areas under production in that year. Notably, this is not the case in parts of Uganda where land is intensively used and two crops are grown per year (e.g. around Mount Elgon), as the planted area exceeded farmland area in some districts. In sum, the value of the crop production service thus varies markedly within the farmland land cover type, and the spatial locations of areas generating the most output might change from year to year depending on the intensity of land use.

Estimates of the total supply of crop provisioning services (expressed in terms of tonnes of crop output supported) and value for 1990 and 2015 are provided in Table 4.1, by crop. During the accounting period, there was a notable increase in the production of tobacco, tea and sugar. This is mostly the effect of Uganda's opening up for trade over this period. Maize and rice production also increased markedly, by over 5-fold. Overall, the aggregate value of crop provisioning services increased by 85% from 1990 to 2015. However, both monetary and physical supply of crops per capita decreased between 1990 and 2015. Average per capita physical supply of crop provisioning services declined by 42% and average per capita monetary value of the crop provisioning services declined by 14% between 1990 and 2015.

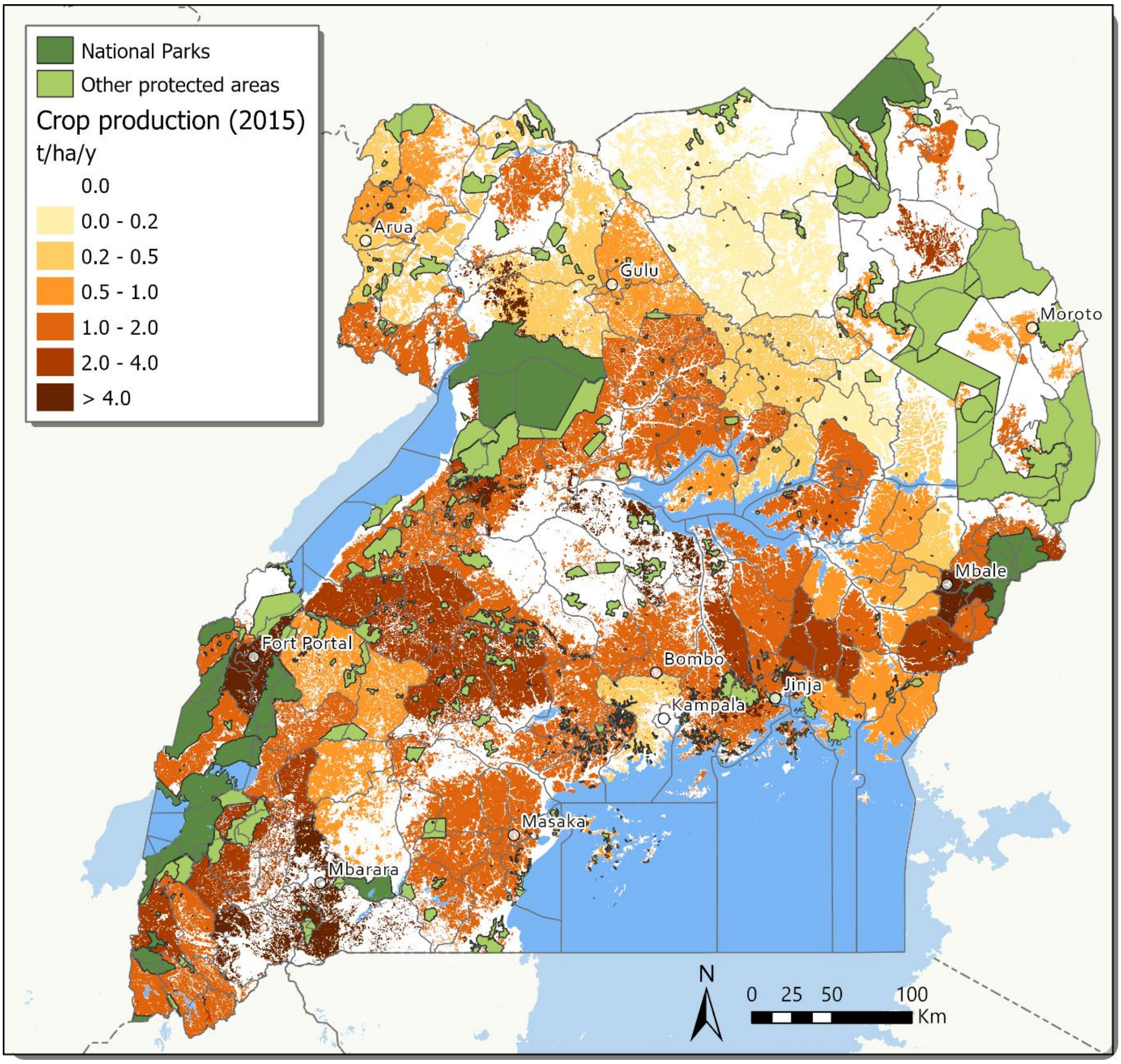

Figure 4.1. Variation in crop production across Uganda in 2015, in total tonnes/ha/year.

Table 4.1 Physical supply and use of crop provisioning services in 1990, in thousands of tonnes per year.

	Economic units				Ecosystems										
Physical supply 1990	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Maize (kt/y)	-	-	-	-	0	0	0	0	0	0	0	602	0	0	602
Finger millet (kt/y)	-	-	-	-	0	0	0	0	0	0	0	560	0	0	560
Sorghum (kt/y)	-	-	-	-	0	0	0	0	0	0	0	360	0	0	360
Rice (kt/y)	-	-	-	-	0	0	0	0	0	0	0	54	0	0	54
Beans (kt/y)	-	-	-	-	0	0	0	0	0	0	0	396	0	0	396
Field peas (kt/y)	-	-	-	-	0	0	0	0	0	0	0	14	0	0	14
Cow peas (kt/y)	-	-	-	-	0	0	0	0	0	0	0	39	0	0	39
Pigeon peas (kt/y)	-	-	-	-	0	0	0	0	0	0	0	51	0	0	51
Groundnuts (kt/y)	-	-	-	-	0	0	0	0	0	0	0	158	0	0	158
Sim sim (kt/y)	-	-	-	-	0	0	0	0	0	0	0	62	0	0	62
Soybean (kt/y)	-	-	-	-	0	0	0	0	0	0	0	37	0	0	37
All bananas (kt/y)	-	-	-	-	0	0	0	0	0	0	0	7 842	0	0	7 842
Cassava (kt/y)	-	-	-	-	0	0	0	0	0	0	0	3 420	0	0	3 420
Sweet potato (kt/y)	-	-	-	-	0	0	0	0	0	0	0	1 693	0	0	1 693
Irish potato (kt/y)	-	-	-	-	0	0	0	0	0	0	0	224	0	0	224
Sugar (kt/y)	-	-	-	-	0	0	0	0	0	0	0	610	0	0	610
Tea (kt/y)	-	-	-	-	0	0	0	0	0	0	0	7	0	0	7
Coffee (kt/y)	-	-	-	-	0	0	0	0	0	0	0	129	0	0	129
Tobacco (kt/y)	-	-	-	-	0	0	0	0	0	0	0	3	0	0	3
Cotton (kt/y)	-	-	-	-	0	0	0	0	0	0	0	8	0	0	8
Total	**-**	**-**	**-**	**-**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**16 269**	**0**	**0**	**16 269**
Physical use 1990															
Maize (kt/y)	424	0	178	602	-	-	-	-	-	-	-	-	-	-	-
Finger millet (kt/y)	135	0	425	560	-	-	-	-	-	-	-	-	-	-	-
Sorghum (kt/y)	13	0	347	360	-	-	-	-	-	-	-	-	-	-	-
Rice (kt/y)	51	0	3	54	-	-	-	-	-	-	-	-	-	-	-
Beans (kt/y)	81	0	315	396	-	-	-	-	-	-	-	-	-	-	-
Field peas (kt/y)	0	0	14	14	-	-	-	-	-	-	-	-	-	-	-
Cow peas (kt/y)	0	0	39	39	-	-	-	-	-	-	-	-	-	-	-
Pigeon peas (kt/y)	0	0	51	51	-	-	-	-	-	-	-	-	-	-	-
Groundnuts (kt/y)	61	0	97	158	-	-	-	-	-	-	-	-	-	-	-
Sim sim (kt/y)	1	0	61	62	-	-	-	-	-	-	-	-	-	-	-
Soybean (kt/y)	0	0	37	37	-	-	-	-	-	-	-	-	-	-	-
All bananas (kt/y)	539	0	7 303	7 842	-	-	-	-	-	-	-	-	-	-	-
Cassava (kt/y)	277	0	3 143	3 420	-	-	-	-	-	-	-	-	-	-	-
Sweet potato (kt/y)	181	0	1 512	1 693	-	-	-	-	-	-	-	-	-	-	-
Irish potato (kt/y)	78	0	146	224	-	-	-	-	-	-	-	-	-	-	-
Sugar (kt/y)	610	0	0	610	-	-	-	-	-	-	-	-	-	-	-
Tea (kt/y)	7	0	0	7	-	-	-	-	-	-	-	-	-	-	-
Coffee (kt/y)	129	0	0	129	-	-	-	-	-	-	-	-	-	-	-
Tobacco (kt/y)	3	0	0	3	-	-	-	-	-	-	-	-	-	-	-
Cotton (kt/y)	8	0	0	8	-	-	-	-	-	-	-	-	-	-	-
Total	**1 302**	**0**	**14 967**	**16 269**	-	-	-	-	-	-	-	-	-	-	-

Table 4.2 Physical supply and use of crop provisioning services in 2015, in thousands of tonnes per year.

	Economic units				**Ecosystems**										
Physical supply 2015	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Maize (kt/y)	-	-	-	-	0	0	0	0	0	0	0	2 813	0	0	2 813
Finger millet (kt/y)	-	-	-	-	0	0	0	0	0	0	0	236	0	0	236
Sorghum (kt/y)	-	-	-	-	0	0	0	0	0	0	0	411	0	0	411
Rice (kt/y)	-	-	-	-	0	0	0	0	0	0	0	238	0	0	238
Beans (kt/y)	-	-	-	-	0	0	0	0	0	0	0	1 080	0	0	1 080
Field peas (kt/y)	-	-	-	-	0	0	0	0	0	0	0	13	0	0	13
Cow peas (kt/y)	-	-	-	-	0	0	0	0	0	0	0	13	0	0	13
Pigeon peas (kt/y)	-	-	-	-	0	0	0	0	0	0	0	13	0	0	13
Groundnuts (kt/y)	-	-	-	-	0	0	0	0	0	0	0	296	0	0	296
Sim sim (kt/y)	-	-	-	-	0	0	0	0	0	0	0	44	0	0	44
Soybean (kt/y)	-	-	-	-	0	0	0	0	0	0	0	28	0	0	28
All bananas (kt/y)	-	-	-	-	0	0	0	0	0	0	0	4 623	0	0	4 623
Cassava (kt/y)	-	-	-	-	0	0	0	0	0	0	0	2 727	0	0	2 727
Sweet potato (kt/y)	-	-	-	-	0	0	0	0	0	0	0	2 045	0	0	2 045
Irish potato (kt/y)	-	-	-	-	0	0	0	0	0	0	0	173	0	0	173
Sugar (kt/y)	-	-	-	-	0	0	0	0	0	0	0	5 225	0	0	5 225
Tea (kt/y)	-	-	-	-	0	0	0	0	0	0	0	59	0	0	59
Coffee (kt/y)	-	-	-	-	0	0	0	0	0	0	0	229	0	0	229
Tobacco (kt/y)	-	-	-	-	0	0	0	0	0	0	0	32	0	0	32
Cotton (kt/y)	-	-	-	-	0	0	0	0	0	0	0	17	0	0	17
Total	-	-	-	-	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**20 316**	**0**	**0**	**20 316**
Physical use 2015															
Maize (kt/y)	1 980	0	833	2 813	-	-	-	-	-	-	-	-	-	-	-
Finger millet (kt/y)	57	0	180	236	-	-	-	-	-	-	-	-	-	-	-
Sorghum (kt/y)	15	0	396	411	-	-	-	-	-	-	-	-	-	-	-
Rice (kt/y)	225	0	13	238	-	-	-	-	-	-	-	-	-	-	-
Beans (kt/y)	221	0	858	1 080	-	-	-	-	-	-	-	-	-	-	-
Field peas (kt/y)	0	0	13	13	-	-	-	-	-	-	-	-	-	-	-
Cow peas (kt/y)	0	0	13	13	-	-	-	-	-	-	-	-	-	-	-
Pigeon peas (kt/y)	0	0	13	13	-	-	-	-	-	-	-	-	-	-	-
Groundnuts (kt/y)	115	0	181	296	-	-	-	-	-	-	-	-	-	-	-
Sim sim (kt/y)	1	0	43	44	-	-	-	-	-	-	-	-	-	-	-
Soybean (kt/y)	0	0	28	28	-	-	-	-	-	-	-	-	-	-	-
All bananas (kt/y)	318	0	4 306	4 623	-	-	-	-	-	-	-	-	-	-	-
Cassava (kt/y)	221	0	2 506	2 727	-	-	-	-	-	-	-	-	-	-	-
Sweet potato (kt/y)	218	0	1 827	2 045	-	-	-	-	-	-	-	-	-	-	-
Irish potato (kt/y)	60	0	113	173	-	-	-	-	-	-	-	-	-	-	-
Sugar (kt/y)	5 225	0	0	5 225	-	-	-	-	-	-	-	-	-	-	-
Tea (kt/y)	59	0	0	59	-	-	-	-	-	-	-	-	-	-	-
Coffee (kt/y)	229	0	0	229	-	-	-	-	-	-	-	-	-	-	-
Tobacco (kt/y)	32	0	0	32	-	-	-	-	-	-	-	-	-	-	-
Cotton (kt/y)	17	0	0	17	-	-	-	-	-	-	-	-	-	-	-
Total	**1 625**	**0**	**18 691**	**20 316**	-	-	-	-	-	-	-	-	-	-	-

Table 4.3 Monetary supply and use of crop provisioning services in 1990. Values are in constant 2017 UGX (billions).

	Economic units				Ecosystems										
Monetary supply 1990	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Maize	-	-	-	-	0	0	0	0	0	0	0	141	0	0	141
Finger millet	-	-	-	-	0	0	0	0	0	0	0	96	0	0	96
Sorghum	-	-	-	-	0	0	0	0	0	0	0	41	0	0	41
Rice	-	-	-	-	0	0	0	0	0	0	0	33	0	0	33
Beans	-	-	-	-	0	0	0	0	0	0	0	175	0	0	175
Field peas	-	-	-	-	0	0	0	0	0	0	0	5	0	0	5
Cow peas	-	-	-	-	0	0	0	0	0	0	0	14	0	0	14
Pigeon peas	-	-	-	-	0	0	0	0	0	0	0	17	0	0	17
Groundnuts	-	-	-	-	0	0	0	0	0	0	0	5	0	0	5
Sim sim	-	-	-	-	0	0	0	0	0	0	0	31	0	0	31
Soybean	-	-	-	-	0	0	0	0	0	0	0	12	0	0	12
All bananas	-	-	-	-	0	0	0	0	0	0	0	1 691	0	0	1 691
Cassava	-	-	-	-	0	0	0	0	0	0	0	1 287	0	0	1 287
Sweet potato	-	-	-	-	0	0	0	0	0	0	0	218	0	0	218
Irish potato	-	-	-	-	0	0	0	0	0	0	0	79	0	0	79
Sugar	-	-	-	-	0	0	0	0	0	0	0	323	0	0	323
Tea	-	-	-	-	0	0	0	0	0	0	0	1	0	0	1
Coffee	-	-	-	-	0	0	0	0	0	0	0	64	0	0	64
Tobacco	-	-	-	-	0	0	0	0	0	0	0	4	0	0	4
Cotton	-	-	-	-	0	0	0	0	0	0	0	1	0	0	1
Total	-	-	-	-	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**4 240**	**0**	**0**	**4 240**
Monetary use 1990															
Maize	99	0	42	141	-	-	-	-	-	-	-	-	-	-	-
Finger millet	23	0	73	96	-	-	-	-	-	-	-	-	-	-	-
Sorghum	2	0	40	41	-	-	-	-	-	-	-	-	-	-	-
Rice	31	0	2	33	-	-	-	-	-	-	-	-	-	-	-
Beans	36	0	139	175	-	-	-	-	-	-	-	-	-	-	-
Field peas	0	0	5	5	-	-	-	-	-	-	-	-	-	-	-
Cow peas	0	0	14	14	-	-	-	-	-	-	-	-	-	-	-
Pigeon peas	0	0	17	17	-	-	-	-	-	-	-	-	-	-	-
Groundnuts	2	0	3	5	-	-	-	-	-	-	-	-	-	-	-
Sim sim	0	0	30	31	-	-	-	-	-	-	-	-	-	-	-
Soybean	0	0	12	12	-	-	-	-	-	-	-	-	-	-	-
All bananas	116	0	1 575	1 691	-	-	-	-	-	-	-	-	-	-	-
Cassava	104	0	1 183	1 287	-	-	-	-	-	-	-	-	-	-	-
Sweet potato	23	0	195	218	-	-	-	-	-	-	-	-	-	-	-
Irish potato	28	0	52	79	-	-	-	-	-	-	-	-	-	-	-
Sugar	323	0	0	323	-	-	-	-	-	-	-	-	-	-	-
Tea	1	0	0	1	-	-	-	-	-	-	-	-	-	-	-
Coffee	64	0	0	64	-	-	-	-	-	-	-	-	-	-	-
Tobacco	4	0	0	4	-	-	-	-	-	-	-	-	-	-	-
Cotton	1	0	0	1	-	-	-	-	-	-	-	-	-	-	-
Total	**859**	**0**	**3 381**	**4 240**	-	-	-	-	-	-	-	-	-	-	-

Table 4.4 Monetary supply and use of crop provisioning services in 2015, values in constant 2017 UGX (billions)

	Economic units				Ecosystems										
Monetary supply 2015	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Maize	-	-	-	-	0	0	0	0	0	0	0	821	0	0	821
Finger millet	-	-	-	-	0	0	0	0	0	0	0	50	0	0	50
Sorghum	-	-	-	-	0	0	0	0	0	0	0	58	0	0	58
Rice	-	-	-	-	0	0	0	0	0	0	0	180	0	0	180
Beans	-	-	-	-	0	0	0	0	0	0	0	595	0	0	595
Field peas	-	-	-	-	0	0	0	0	0	0	0	6	0	0	6
Cow peas	-	-	-	-	0	0	0	0	0	0	0	6	0	0	6
Pigeon peas	-	-	-	-	0	0	0	0	0	0	0	6	0	0	6
Groundnuts	-	-	-	-	0	0	0	0	0	0	0	12	0	0	12
Sim sim	-	-	-	-	0	0	0	0	0	0	0	27	0	0	27
Soybean	-	-	-	-	0	0	0	0	0	0	0	11	0	0	11
All bananas	-	-	-	-	0	0	0	0	0	0	0	1 243	0	0	1 243
Cassava	-	-	-	-	0	0	0	0	0	0	0	1 281	0	0	1 281
Sweet potato	-	-	-	-	0	0	0	0	0	0	0	329	0	0	329
Irish potato	-	-	-	-	0	0	0	0	0	0	0	76	0	0	76
Sugar	-	-	-	-	0	0	0	0	0	0	0	2 921	0	0	2 921
Tea	-	-	-	-	0	0	0	0	0	0	0	10	0	0	10
Coffee	-	-	-	-	0	0	0	0	0	0	0	143	0	0	143
Tobacco	-	-	-	-	0	0	0	0	0	0	0	49	0	0	49
Cotton	-	-	-	-	0	0	0	0	0	0	0	3	0	0	3
Total	-	-	-	-	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**7 829**	**0**	**0**	**7 829**
Monetary use 2015															
Maize	578	0	243	821	-	-	-	-	-	-	-	-	-	-	-
Finger millet	12	0	38	50	-	-	-	-	-	-	-	-	-	-	-
Sorghum	2	0	56	58	-	-	-	-	-	-	-	-	-	-	-
Rice	171	0	10	180	-	-	-	-	-	-	-	-	-	-	-
Beans	122	0	473	595	-	-	-	-	-	-	-	-	-	-	-
Field peas	0	0	6	6	-	-	-	-	-	-	-	-	-	-	-
Cow peas	0	0	6	6	-	-	-	-	-	-	-	-	-	-	-
Pigeon peas	0	0	6	6	-	-	-	-	-	-	-	-	-	-	-
Groundnuts	5	0	8	12	-	-	-	-	-	-	-	-	-	-	-
Sim sim	0	0	27	27	-	-	-	-	-	-	-	-	-	-	-
Soybean	0	0	11	11	-	-	-	-	-	-	-	-	-	-	-
All bananas	85	0	1 158	1 243	-	-	-	-	-	-	-	-	-	-	-
Cassava	104	0	1 177	1 281	-	-	-	-	-	-	-	-	-	-	-
Sweet potato	35	0	294	329	-	-	-	-	-	-	-	-	-	-	-
Irish potato	27	0	50	76	-	-	-	-	-	-	-	-	-	-	-
Sugar	2 921	0	0	2 921	-	-	-	-	-	-	-	-	-	-	-
Tea	10	0	0	10	-	-	-	-	-	-	-	-	-	-	-
Coffee	143	0	0	143	-	-	-	-	-	-	-	-	-	-	-
Tobacco	49	0	0	49	-	-	-	-	-	-	-	-	-	-	-
Cotton	3	0	0	3	-	-	-	-	-	-	-	-	-	-	-
Total	**4 267**	**0**	**3 562**	**7 829**	-	-	-	-	-	-	-	-	-	-	-

GRAZED BIOMASS/LIVESTOCK PROVISIONING SERVICES[17]

OVERVIEW

The ecosystem contribution to reared animal production is mainly in the form of natural fodder production and natural water sources, but may also include factors such as shade, etc. As for crops, the reduction of a complex set of services to a single physical measure is difficult. Some authors use the biomass of fodder consumed (termed "grazed biomass" in the SEEA EA) as a means to quantify the service in physical terms. However, this may be overly simplistic, as it is the combination of water availability and grazing resources as well as other factors that determine use and the value of the service. It is also possible to use livestock production as a proxy (much in the same way as done for crops, above), but this does not capture the variety of livestock products sold, such as milk and hides as well as meat, which all form part of the value of livestock production in the SNA. A better proxy, and one that is readily understood by policy makers, might be to quantify the service as the amount of livestock supported by the ecosystem. However, but this is a stock, so it is difficult to reconcile with a flow account.

In this study, the stocks of animals supported are estimated and mapped for information purposes, but for the accounts, the service flow was quantified in physical terms as tonnes of biomass consumed per year, although noting that this is not the only aspect of the service. The monetary value is estimated as the resource rent of livestock production and does encapsulate all of the ecosystem inputs, including fodder, water, shade, etc.

DATA AND METHODS

DATA SOURCES

No comprehensive livestock data exist for the two accounting years. The most recent district-level livestock population data were from the 2008 Livestock Census (MAAIF and UBOS, 2009). The 2018 Annual Agricultural Survey (UBOS, 2020a) provided the closest available estimates livestock production to 2015 at subnational (ZARDI) level. These were then aligned to the national livestock population totals in 2015 as reported by the Statistical Abstract (UBOS, 2020b). Only national-level livestock population estimates could be obtained for 1990, based on 1991 estimates in the 2008 census (MAAIF and UBOS, 2009) for goats and sheep. No 1991 estimate was given for cattle, hence FAO data was used instead. Livestock numbers from the Soil and Land Improvement Accounts (NEMA, 2021a) were not used due an inexplicably high reported increase in sheep numbers between 2009 and 2018 (1188%) and the fact that livestock numbers in the accounts were generally much lower than numbers reported in the original survey source data (MAAIF and UBOS, 2009; UBOS, 2020a).

[17] Note that the SEEA EA currently gives two options to describe the ecosystem contributions to livestock production. The first is "grazed biomass" and the second is "livestock provisioning services". The difference is subtle, and the guidance for this service needs revision. The term "grazed" is a poor choice, since many livestock are browsers. Although we use the biomass consumed as a physical measure in the absence of a better measure that combines all the aspects of the services, we use the term "livestock provisioning services", since the full contribution of ecosystems is valued (including substrate, shade etc).

ESTIMATION AND MAPPING OF REARED ANIMALS AND GRAZED BIOMASS

As with crops, data from the 2008 census data (MAAIF and UBOS, 2009) was the only data point providing livestock numbers at a district level. To estimate livestock numbers in 1990, the 2008 district-level population estimates were projected backwards, based on trends in the national population size of cattle, goats and sheep between1990 and 2008. Since no subnational breakdown of livestock numbers between 1990 and 2008 could be obtained, a uniform back-casting factor was applied across all districts. To estimate 2015 livestock numbers at district-level, livestock numbers per ZARDI were first extracted from the 2018 agricultural survey (UBOS, 2020a) and adjusted by correction factors so that the national population of each livestock type matched the 2015 total population (UBOS, 2020b). The estimated 2015 livestock population per ZARDI was then divided by the total population per ZARDI from the 2008 census, to obtain projection factors for each ZARDI. Finally, these factors were then applied to the 2008 district-level livestock numbers, based on which ZARDI each district fell into.

Livestock numbers were converted to tropical livestock units (TLU; 1 TLU = live weight of 250 kg), which have been a standard measure of livestock biomass in tropical countries since the 1950s (Rothman-Ostrow et al 2020). Cattle are assumed to be 0.7 TLU/head while sheep and goats are 0.1 TLU/head. Annual grazed biomass consumption was then estimated using a standard conversion factor of 2.28 t of biomass per TLU per year, equivalent to a daily consumption of 0.025% of animal mass (Amsalu & Addisu, 2014; FAO, 2018a). This assumes that all fodder is grazed directly from ecosystems, which in this case includes farmland. Indeed, livestock may make some use of cultivated fodder, but the latter is not accounted for under crops. Given that the cost of fodder production has not been accounted for as input, this may lead to a slight overestimation of value for the service.

To map the district-level livestock estimates back to ecosystems, several rules were used. Firstly, it was assumed that only certain land cover types are suitable for livestock, namely woodland, bushland, grassland, farmland and wetland. For wetland, it was assumed that only 10% of wetland area is used for grazing, as wetlands in the land cover are mostly papyrus swamps where grazing would only be possible on the margins. In addition to being limited to certain land cover types, it was also conservatively assumed that livestock are excluded from protected areas, although some encroachment is likely. For mapping purposes, livestock numbers per district were divided by suitable area per district, producing a map of livestock density/ha, which was then converted to TLUs/ha and grazed biomass/ha.

VALUATION

The service was valued in terms of resource rents from the offtake of livestock. Farm gate prices for 1990 and 2015 were estimated based on the values and quantities provided in the Land and Soil Improvement Accounts 2009-2018 and are reported in UGX 2017 constant prices. According to the Land and Soil Improvement Accounts, the real price of livestock decreased by 1.3% yearly between 2009 and 2018. Resource rents were calculated by adjusting the market price for the costs of input for livestock production, including practicing controlled mating, paying for feed and water, using vaccines, using anti-parasites, and applying curative treatments. Average annual costs for inputs for livestock production paid by agricultural households was given in the Annual Agricultural Survey 2018 and used to estimate the resource rent on a national level. Cost of inputs are differentiated for cattle farming and small ruminants but not between sheep and goats. The same resource rent proportion (0.439) is applied for both sheep and goats. The resource rent proportion for cattle farming is 0.907.

RESULTS

A map of the grazed biomass production service in 2015 is shown in Figure 4.2, showing estimated quantity of grazed biomass per hectare. The highest quantities used are generally found in Karamoja in the northeast of the country. This is the driest part of Uganda where crop cultivation remains limited and pastoralism is still a dominant livelihood activity (FAO, 2018b). Grazed biomass per hectare was also estimated to be high in some wetter parts of the country, such as around Mount Elgon and Rwenzori. Even though households typically own small numbers of livestock in such areas, the higher absolute numbers of people here result in higher numbers of livestock (Benson & Mugarura, 2010). There were also some notable differences in livestock populations between the 2009 and 2018 datasets, which underlie some of the spatial patterns seen in Figure 4.2. For example, the cattle population in Serere ZARDI reported in the 2018 survey (UBOS, 2020a) is just 34% of the population in the 2008 census (MAAIF and UBOS, 2009), resulting in relatively low estimated grazed biomass values for 2015 in this ZARDI (Figure 4.2). Grazed biomass per ecosystem type is summarised in Table 4.6 and Table 4.7.

The estimated offtake of livestock from different ecosystems is summarised in Table 4.5. The total value of livestock provisioning services was estimated to be UGX 2866 billion in 1990 (Table 4.8) and UGX 5743 billion in 2015 (Table 4.9; all expressed in constant 2017 UGX).

Table 4.5. Livestock offtake by ecosystem type for 1990 and 2015, in terms of actual numbers of cattle, goats and sheep, and total numbers in standardised tropical livestock units.

	Wetland	Grassland	Bushland	Woodland	Farmland	TOTAL
1990						
Cattle (1000s)	16.9	1 483.8	513.1	587.4	2 402.1	5 003.4
Goats (1000s)	13.0	1 027.7	340.2	463.1	2 161.4	4 005.3
Sheep (1000s)	1.3	270.6	129.6	78.5	265.5	745.5
Total TLUs (1000s)	13.3	1 168.5	406.1	465.3	1 924.2	3 977.5
2015						
Cattle (1000s)	53.0	4 401.1	1 670.5	609.1	7 297.1	14 030.8
Goats (1000s)	60.2	4 448.6	1 710.5	605.3	8 487.1	15 311.8
Sheep (1000s)	5.7	1 791.8	581.4	159.1	1 304.0	3 841.9
Total TLUs (1000s)	43.7	3 704.8	1 398.5	502.8	6 087.1	11 736.9

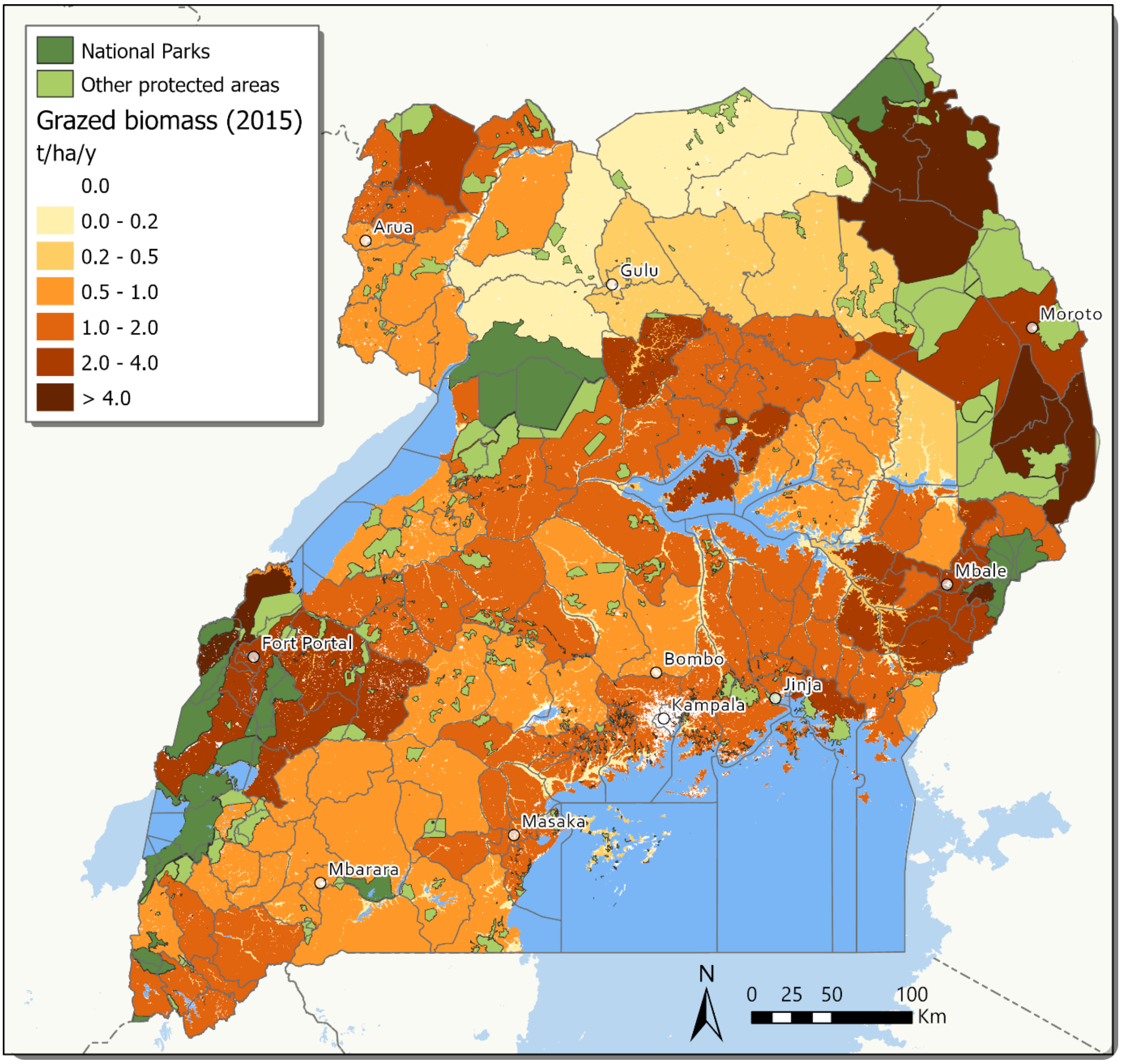

Figure 4.2. Variation in the amount of natural biomass consumed by livestock across Uganda in 2015, in t/ha/year.

Table 4.6 Physical supply and use of grazed biomass provisioning services in 1990

	Economy				Ecosystem										
Physical supply 1990	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Grazed biomass (cattle)	-	-	-	-	0	27	2 368	819	937	0	0	3 834	0	0	7 985
Grazed biomass (goats)	-	-	-	-	0	3	234	78	106	0	0	493	0	0	913
Grazed biomass (sheep)	-	-	-	-	0	0	62	30	18	0	0	61	0	0	170
Total	-	-	-	-	**0**	**30**	**2 664**	**926**	**1 061**	**0**	**0**	**4 387**	**0**	**0**	**9 069**
Physical use 1990															
Grazed biomass (cattle)	639	0	7 347	7 985	-	-	-	-	-	-	-	-	-	-	-
Grazed biomass (goats)	73	0	840	913	-	-	-	-	-	-	-	-	-	-	-
Grazed biomass (sheep)	14	0	156	170	-	-	-	-	-	-	-	-	-	-	-
Total	**725**	**0**	**8 343**	**9 069**	-	-	-	-	-	-	-	-	-	-	-

Table 4.7 Physical supply and use of grazed biomass provisioning services in 2015

	Economy				Ecosystem										
Physical supply 2015	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Grazed biomass (cattle)	-	-	-	-	0	85	7 024	2 666	972	0	0	11 646	0	0	22 393
Grazed biomass (goats)	-	-	-	-	0	14	1 014	390	138	0	0	1 935	0	0	3 491
Grazed biomass (sheep)	-	-	-	-	0	1	409	133	36	0	0	297	0	0	876
Total	-	-	-	-	**0**	**100**	**8 447**	**3 189**	**1 146**	**0**	**0**	**13 879**	**0**	**0**	**26 760**
Physical use 2015															
Grazed biomass (cattle)	1 791	0	20 602	22 393	-	-	-	-	-	-	-	-	-	-	-
Grazed biomass (goats)	279	0	3 212	3 491	-	-	-	-	-	-	-	-	-	-	-
Grazed biomass (sheep)	70	0	806	876	-	-	-	-	-	-	-	-	-	-	-
Total	**2 141**	**0**	**24 619**	**26 760**	-	-	-	-	-	-	-	-	-	-	-

Table 4.8 Monetary supply and use of grazed biomass provisioning services in 1990, values in constant 2017 UGX (billions)

	Economy				Ecosystem										
Monetary supply 1990	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Cattle	-	-	-	-	0	10	849	294	336	0	0	1 375	0	0	2 863
Goats	-	-	-	-	0	0	0	0	0	0	0	1	0	0	2
Sheep	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0
Total	-	-	-	-	**0**	**10**	**850**	**294**	**336**	**0**	**0**	**1 376**	**0**	**0**	**2 866**
Monetary use 1990															
Cattle	229	0	2 634	2 863	-	-	-	-	-	-	-	-	-	-	-
Goats	0	0	2	2	-	-	-	-	-	-	-	-	-	-	-
Sheep	0	0	0	0	-	-	-	-	-	-	-	-	-	-	-
Total	**229**	**0**	**2 636**	**2 866**	-	-	-	-	-	-	-	-	-	-	-

Table 4.9 Monetary supply and use of grazed biomass provisioning services in 2015, values in constant 2017 UGX (billions)

	Economy				Ecosystem										
Monetary supply 2015	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Cattle	-	-	-	-	0	22	1 799	683	249	0	0	2 983	0	0	5 736
Goats	-	-	-	-	0	0	1	1	0	0	0	3	0	0	5
Sheep	-	-	-	-	0	0	1	0	0	0	0	0	0	0	1
Total	-	-	-	-	**0**	**22**	**1 801**	**684**	**249**	**0**	**0**	**2 987**	**0**	**0**	**5 743**
Monetary use 2015															
Cattle	459	0	5 277	5 736	-	-	-	-	-	-	-	-	-	-	-
Goats	0	0	5	5	-	-	-	-	-	-	-	-	-	-	-
Sheep	0	0	1	1	-	-	-	-	-	-	-	-	-	-	-
Total	**459**	**0**	**5 283**	**5 743**	-	-	-	-	-	-	-	-	-	-	-

AQUACULTURE PROVISIONING SERVICES

OVERVIEW OF THE SERVICE

Aquaculture provisioning services are the ecosystem contributions to the growth of animals and plants in aquaculture facilities (UN et al., 2021). Uganda has a growing aquaculture sector, which includes both pond and floating cage production systems (NEMA, 2021b). For the purposes of ecosystem service accounting, the focus here is limited to cage production systems in waterbodies, as it was unclear how values would be assigned to ecosystems for pond aquaculture since the ponds are generally too small to show up as water in the land cover data and are thus subsumed within terrestrial ecosystem types. In contrast, cage aquaculture operations are largely confined to a smaller number of locations within large waterbodies. The lack of spatial information on aquaculture pond locations does not present a problem for accounting at national level, as the value of all aquaculture could simply be added to the overall value of open water. However, it is an issue for accounting at basin and district-level, as the absence of any map of aquaculture ponds means that there is no way of spreading the value across basins or districts. For the purposes of this report, pond aquaculture could have been accounted for at national-level only. However, this would result in an undesirable discrepancy between the value of the service in the national-level accounts and the total value of the service across the basin and district-level accounts. Improved information on the location of aquaculture ponds would thus be needed to facilitate sub-national accounting for this service.

DATA AND METHODS

Cage aquaculture is still a relatively nascent industry in Uganda, with the first cages only being installed in 2006 (Adeleke *et al.*, 2020). The main operations are on Lake Victoria, according to the Fishery Accounts (NEMA, 2021b). However, there are also some cage operations on Lake Kyoga (Mbowa, Odokonyero & Munyaho, 2017) which are not mapped in the Fishery Accounts . Unfortunately, the Fishery Accounts do not indicate the breakdown of aquaculture production between cage and pond systems, only giving an overall production estimate for all aquaculture production. Since no breakdown of production was given in the Fishery Accounts, information on the contribution of cage systems to total aquaculture production was sought from other sources, as described below.

RESULTS

Total aquaculture production in 2015 was estimated to be 117 600 t in 2015 (NEMA, 2021b), up from just 52 t in 1990 (FAO, 2022b). Since no breakdown of production into pond and cage systems was given in the accounts, an attempt was made to gather this infromation from other sources. However, data on the contribution of cage aquaculture to overall production was limited and even contradictory, which may be a reflection of the emerging status of the industry. For example, one report gives an annual production figure for cage aquauculture of just 1349 t (Mbowa *et al.*, 2017), only 1% of overall annual aquaculutre production as reported in the Fishery Accounts (NEMA, 2021b). However, another study of the aquaculture sector stated that farmed fish production in Uganda is almost exclusively from cages (Larive International and Asigma, 2022), suggesting a much higher contribution of cage systems to overall aquaculture prodcution. In general, there seems to be a high level of uncertainty in aquaculture production statistics as a whole in Uganda, with many experts stating the production figures are grossly-overestimated while others argue figures are under-estimated (Bolman, van Duijn & Rutaisire, 2018). Given the scarcity of reliable information on the size of the cage aquaculture industry in Uganda, a final value for the aquauculture provisioning service was not estimated in this study.

WOOD PROVISIONING SERVICES

OVERVIEW

Wood provisioning services are the ecosystem contributions to the growth of woody biomass harvested from natural and cultivated (plantation) areas for various uses including timber and energy. The wood provisioning service used was quantified in physical terms as the amount of wood harvested for timber, poles, firewood and charcoal by households or businesses, inclusive of any discarded biomass. The service was valued in terms of the resource rent. All monetary values were calculated using producer prices, as stipulated in the SNA, and thus do not include any transport costs or margins added by wholesalers or retailers.

DATA AND METHODS

Data for this account were taken from the Wood Accounts (GoU, 2020a), the Statistical Abstracts (UBOS, 2018), the national censuses, and the National Charcoal Survey (Mugo *et al*., 2016). While the Wood Accounts provide aggregate estimates of the production of timber, poles, firewood and charcoal at national scale, additional information was used to provide spatially disaggregated estimates to account for ecosystem services down to the district level. A literature review was first undertaken to source information as well as to help with interpretation of results.

Mapping the wood provisioning service was done by overlaying mapped estimates of commercial and household use. Commercial use was estimated by spreading the reported production figures in proportion to estimated stocks in areas available for commercial exploitation. Household use was estimated by first mapping the demand for resources, and then estimating use with a model that considered spatial variation in both demand and available stocks. Commercial and household use was mapped separately for firewood, charcoal (in terms of wood inputs), poles and timber, and the eight physical layers and eight monetary layers were then combined to estimate the total wood volumes used and their value, respectively.

LITERATURE REVIEW ON WOOD RESOURCES USE IN UGANDA

To model the wood provisioning service, a review of published literature, census data, Uganda's wood and forest resource accounts (GoU, 2020a) and other government reports relating to the use of woody resources in Uganda was conducted (e.g., MoWE, 2016). This information was then used to design and parametrise the models used to estimate and map the wood provisioning service. Some of the key information gathered from these studies is summarised below.

A major component of the wood provisioning service in Uganda is still used for subsistence purposes, thus making a crucial contribution to livelihoods. Most Ugandan households (rural and urban) still rely on wood fuel as their main source of energy, while most rural households still rely on locally-sourced poles and timber for construction (UBOS, 2018). Additionally, there is some commercial use of the wood provisioning service to produce poles and timber by industry. Overall, it was previously estimated by UBOS that some 48.581 million tonnes of woody biomass, was produced in 2015[18], with a value of UGX876.789 billion (UBOS, 2016b). Of this, the vast majority (92.4%) of harvested woody biomass was used for fuel (Figure 4.3).

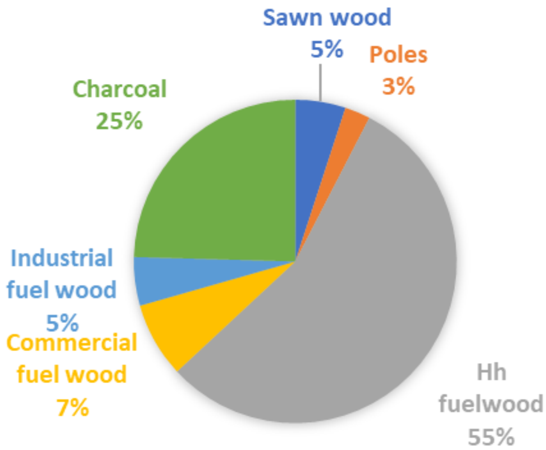

Figure 4.3. Final wood products, expressed as a percentage of total harvested woody biomass in 2016/17 (Source: UBOS 2018).

Both rural and urban households also use sawn timber for door and window frames and furniture. For example, around Mount Elgon, a study in the 1990s found that 86.5% of households used timber for construction, but this was mainly bought, with only 3% of households being involved in harvesting the timber (Scott, 1998). Hence, wood provisioning services to create and supply timber is used by industry, not households. The source of wood has gradually shifted from indigenous species harvested from natural forests, to wood grown in plantations and woodlots. Hardwoods have become scarce, and this is now largely imported from neighbouring countries such as the DRC. Some 80% of timber harvested in 2015 was illegal (i.e. cut without a licence, use of banned chain saws, and tax evasion (MWE, 2016).

Uganda has a timber deficit, with demand exceeding supply. The most common species for timber in Uganda are *Maesopsis eminii, Melicia excelsa, Albizia coriaria, Chrysophyllum albidum, Lovoa trichiliodes, Funtumia elastica, Entandophragma angolense,* and *Podocarpus latifolius*. Demand for pine (*Pinus caribaea, Pinus patula*) has also increased in recent years. The sawn wood market was estimated to be 369 000m^3 in 2015 (Turyahabwe et al., 2016). Most timber used domestically is for construction (80%) and furniture (10%). In the past, the main sources were government-owned forest plantations and natural forests in the Central Forest Reserves (CFRs) and Local Forest Reserves (LFRs). However, due to overexploitation, the trade relies increasingly on supply from private lands, which is poorly regulated. Timber supply is derived from woodland, forest and plantations. While the extent of plantations increased by 234% between 1990 and 2015, forest extent decreased by 35% and woodland extent by 66%. Tonnes per hectare derived from woodland increased by 2008% between 1990 and 2015, while

[18] Note that the Wood Accounts (GoU, 2020a) used the same source data, but multiplied the charcoal value by 8 to estimate wood weight. However, that adjustment had already been made. This was verified through reference to the 2015 National Charcoal Survey, which estimated a dry weight of 2.1 million tonnes of charcoal was produced in 2015 (Mugo *et al.*, 2016). This corresponds well to the Statistical Abstracts which report a roundwood weight of about 12 million tonnes (UBOS, 2020b). Thus, it was concluded that multiplying the latter by 8 again was in error.

it increased by 937% for forests and 2923% for plantations. The increase in supply of timber per hectare of woodland and forest is concerning given the decline in the extent of these ecosystems.

By 2005, the supply of timber from natural forests was already declining, with more than 30% of tropical high forest being degraded. Pit sawing provided 90% of the sawn timber on the local market. The local timber market was estimated to be 240 000m^3 (equivalent to 800 000 m^3 of logs per year), which was twice the national sustainable allowable cut (Odokonyero, 2005). Despite a ban on timber exports, Kenya was the main market for Ugandan hardwoods, with exports dominated by mvule and mahogany.

Poles are widely used as a construction material, for building houses and for uses like fencing. In 2016/17, 28% of households in Uganda lived in dwellings with walls constructed from poles and mud, ranging from 1.6% in Kampala to 78.3% in Karamoja subregion (UBOS, 2018). In another Karamoja study, all respondents reported using wood for fencing (Egadu, Mucunguzi & Obua, 2007).

Uganda's high dependence on fuelwood is a result of the low level of electrification as well as the higher price of alternative energy sources like paraffin, kerosene, and electricity (where available). Firewood is the main energy source in rural areas, but due to scarcity in urban areas and higher incomes, most urban households depend on charcoal. In 2016/17, some 80.8% of rural households used firewood for cooking and 15.5% used charcoal, whereas in urban areas, 22.3% used firewood and 66.4% used charcoal (UBOS, 2018). Indeed, the State of Uganda's Forestry Report states that approximately 70% of charcoal is consumed in urban centres, with only 30% being consumed in rural areas (MWE, 2016). The supply and use tables show that the majority of wood provisioning services are used by households, with most of the use (66%) coming from firewood. Wood provisioning services are also used by industries to produce charcoal (16% of wood provisioning services) (Table 4.12; Table 4.13). Estimates for annual per capita fuelwood demand vary from 409 kg/year to 675 kg/year (Kayanja & Byarugaba, 2001; Walter, 2001; Drigo et al., 2013; Egeru, 2014; Gianvenuti & Vyamana, 2018). According to the Uganda National Household Surveys, households spent a total of UGX 13.967 billion and UGX 4.076 billion on firewood and charcoal, respectively, in 1996/7, and a total of UGX 310.44 billion and UGX 98.699 billion on firewood and charcoal, respectively, in 2009/10.

While rural households tend to source their own firewood, charcoal is a lucrative industry and is produced commercially for transport and sale to urban areas (MWE, 2016). This may be undertaken by local rural people, with some of the charcoal produced for their own accounts and some of it supplied to others, or by commercial harvesters travelling from other regions. In the ecosystem accounts use tables, charcoal production is therefore assigned to industry, not households. According to the National Charcoal Survey, of the over 100 tree and shrub species used, the major species are *Acacia hockii, Ficus natalensis, Albizia coriaria, Eucalyptus grandis, Combretum molle, Maesopsis eminii, Mangifera indica* and *Milicia excels* (Mugo *et al*., 2016). There have been serious concerns about the sustainability of fuelwood harvesting since the 1980s. By then, firewood had already become scarce around a number of urban centres, with peri-urban households starting to resort to the use of crop residues. With growing urbanisation, the amount of wood provisioning services used for charcoal production has also increased, with detrimental impacts on forest and woodland ecosystems, including on slow-growing, indigenous hardwood trees (Naughton-Treves, Kammen & Chapman, 2007). For example, forest extent declined from 970 372 ha in 1990 to 631 005 ha in 2015 – a decline of 35% over 25 years.

ESTIMATION AND MAPPING OF USE BY COMMERCIAL BUSINESSES

Commercial harvests of timber, poles, charcoal and firewood in 2015 were estimated using the quantities reported in the Statistical Abstracts, expressed in terms of tonnes of roundwood. It is not explicitly stated whether these estimates include any illegal harvesting, and if so what proportion of the production figure this is thought to account for. In the case of charcoal, the breakdown of charcoal production per subregion was obtained from the National Charcoal Survey (Mugo *et al.*, 2016). The national or subregional production was then mapped to the landscape in proportion to the availability of stocks (again taking land tenure into account). In the case of charcoal, the subregions used by Mugo *et al.* (2016) for reporting production had been modified somewhat from the normal subregion boundaries (for example, Acholi and Lango were reported together as Mid-Northern subregion). This required a custom subregion GIS layer to be produced for mapping charcoal use, based on the list of districts reported to be in each subregion as per Mugo *et al.* (2016). The 1990 national harvested quantities were estimated based on the Wood Accounts (with calculation errors corrected). In the absence of further information, it was assumed that the proportional breakdown of national charcoal production by subregion did not change between 1990 and 2015.

ESTIMATION AND MAPPING OF USE BY HOUSEHOLDS

Household harvests of woody resources were estimated in two steps: the mapping of woody resource stocks, and estimation of the level of use of these stocks. The stocks of woody resources were mapped based on estimates from the National Biomass Surveys. Biomass in small scale farmland, plantations, forests, woodland, bush and grassland habitats for each district was taken from the 2005 National Biomass Survey (NFA, 2009). Estimates for wetlands, built-up areas and commercial farmland were based on national averages from the 2002 National Biomass Survey (Drichi, 2002), as biomass estimates for these land cover types were not given in the 2005 survey.

The ecosystems to which stocks were mapped varied by resource. Firewood was mapped to all habitat types with woody biomass values in the Biomass Surveys, except for built-up areas and commercial farmland. Even though there may be woody plants present, it was assumed that biomass is not harvested for firewood from these land cover types. Charcoal stocks were limited to broad-leaved plantations, forest, woodland, bushland and small-scale farmland. It was assumed that grassland lacked sufficient tree cover for charcoal harvesting while coniferous (softwood) plantations were assumed to be unsuitable due to the preference for hardwood species in charcoal production (Naughton-Treves *et al.*, 2007). This is supported by the National Charcoal Survey, which reported that *Eucalyptus* are used for charcoal production, but no pine or other coniferous species were reported (Mugo *et al.*, 2016). Timber and *commercial* pole stocks were limited to habitats dominated by large trees (*i.e.* plantations, forests and woodland), as it was assumed other land cover types do not have sufficiently large trees for timber and commercial pole production. However, it was assumed that poles for rural household use can also be harvested from bushland and woody vegetation on small-scale farmland. This was firstly because smaller trees can be utilised to supply poles for household use. Secondly, if it was assumed that bushland and small-scale farmland contain no harvestable stocks for rural pole use, then a large portion of rural households would have no pole stocks within their harvesting radius, particularly in areas dominated by farmland and bushland. However, census data indicates that there is still a level of pole use by rural households in such areas.

Stock estimates for each resource were overlaid by land tenure, which was used to moderate the availability of wood resources for harvest. For example, woody resources in national parks were not considered accessible, while only a percentage of stocks in forest reserves were available for harvesting. The use of the resources was then mapped to the most likely source areas at a spatial scale that could be summarised by ecosystem for each of the EEAs (national, basins and districts). This was done separately for commercial and household use, as described below.

Rural household demand for firewood and poles was estimated at district level based on the proportion of households using these resources from census data, and the average demands per household from the Statistical Abstracts (UBOS, 2018). The demand was mapped to 100 m resolution based on spatial population data. The source areas of these resources were then mapped based using the spatial model developed by Turpie et al. (2021). The model assumes that households collect resources from their surrounds, based on distance and availability of the resource.

VALUATION OF SERVICE FLOWS

Unit prices for timber and poles were calculated from the Wood Accounts and Statistical Abstracts. However, in the case of firewood and charcoal, these were very different from the prices in the literature, including in the comprehensive study by Mugo *et al.* (2016). The latter study also provided detailed cost estimates which were used to derive the resource rent as 73% of market price for commercial actors. Resource rents for household use were assumed to be 95% of market price.

SUSTAINABILITY ADJUSTMENT FOR ASSET VALUATION

Limited information was found on sustainable wood yields. For timber harvesting, which is limited to trees with a large diameter at breast height (around 50 cm or more), a sustainable yield of 1 m^3/ha/year is quoted in studies of natural forests in Uganda (Odokonyero, 2005; Nabonga, Namaalwa & Sssenyonjo, 2010). This amounts to around 0.5% of standing biomass. This figure was thus used as the sustainable yield for timber and commercially harvested poles from forest and woodland (Table 4.10). The sustainable timber yield from plantations was substantially higher, since plantation species have much faster growth rates. Based on local information, a timber rotation of around 15 years was assumed for Ugandan plantations (World Bank, 2020a, 2022; FAO, 2021). Additionally, it was estimated by World Bank (2020b) that transmission poles could be harvested after around eight years of growth, equivalent to 45% of the final timber harvest. Based on these assumptions, it was estimated that the sustainable annual yield of timber and commercial poles from plantations was around 10% of standing stocks.

Table 4.10. Sustainable yields (as a percentage of stocks) used for each resource.

Resource	Sustainable yield percentage of stocks
Roundwood (Forest)	0.5%
Roundwood (Plantations)	10%
Fuelwood (Wetland, Grassland, Bushland)	10%
Fuelwood (Woodland, Forest)	5%
Fuelwood (Plantation)	8%
Fuelwood (Farmland)	15%

Different sustainable yields were used for the harvesting of fuelwood (which includes commercial and household firewood as well as charcoal) and household (*i.e.* smaller) poles, as these can utilise a much broader range of size classes than commercially viable timber, including small trees and bushes which tend to have higher growth rates than very large mature trees. For natural ecosystems and farmland, sustainable yields for fuelwood and household pole harvesting were based on the mean annual increment (MAI) measurements for these ecosystems in Uganda's National Biomass Studies, ranging from 5% of standing stock in forest and woodland to 15% in farmland (Table 4.10). Even though plantations have higher MAIs, it was assumed they were managed largely for timber production. According to World Bank (2020b), 2% of stocks can be harvested each year without compromising the final timber harvest. Additional firewood can be harvested during thinning every three years, while poles for household construction can be harvested after five years. These thinning events yield wood equivalent to 61% of the final timber harvest (World Bank, 2020a). Based on these assumptions, it was estimated that the sustainable harvest of fuelwood and household poles from plantations is around 8% of standing biomass. In 1990, timber harvesting was sustainable across all harvested areas. However, by 2015 timber harvesting was sustainable in only 27% of the timber producing area. Fuelwood was sustainably harvested in 78% of the harvested area in 1990, while it was sustainable in only 26% in 2015.

RESULTS

WOOD FOR TIMBER

Wood harvested for commercial timber production increased dramatically from 0.3 million tonnes in 1990 to 2.5 million tonnes in 2015 (GoU, 2020a; UBOS, 2020b). Over the same period, the available standing stock in land cover types suitable for timber harvesting declined by 74% due to significant conversion of forest and woodland, and to a lesser extent the formal gazettement of additional protected areas in the forested regions of Uganda. By 2015, most contiguous blocks of vegetation which could still support timber harvesting were limited to the intact larger forest reserves, due to the patchy distribution of forests, woodlands and plantations elsewhere (Figure 4.4). These include Budongo, Bugoma, Kasyoha-Kitomi and Mabira Central Forest Reserves. Outside of protected areas, the most notable regions that retain some timber stocks include woodland patches between Arua and Gulu and the Kafu River Valley southwest of Lake Kyoga. Notably, both these areas were also estimated to be experiencing severe charcoal harvesting pressures (Figure 4.7).

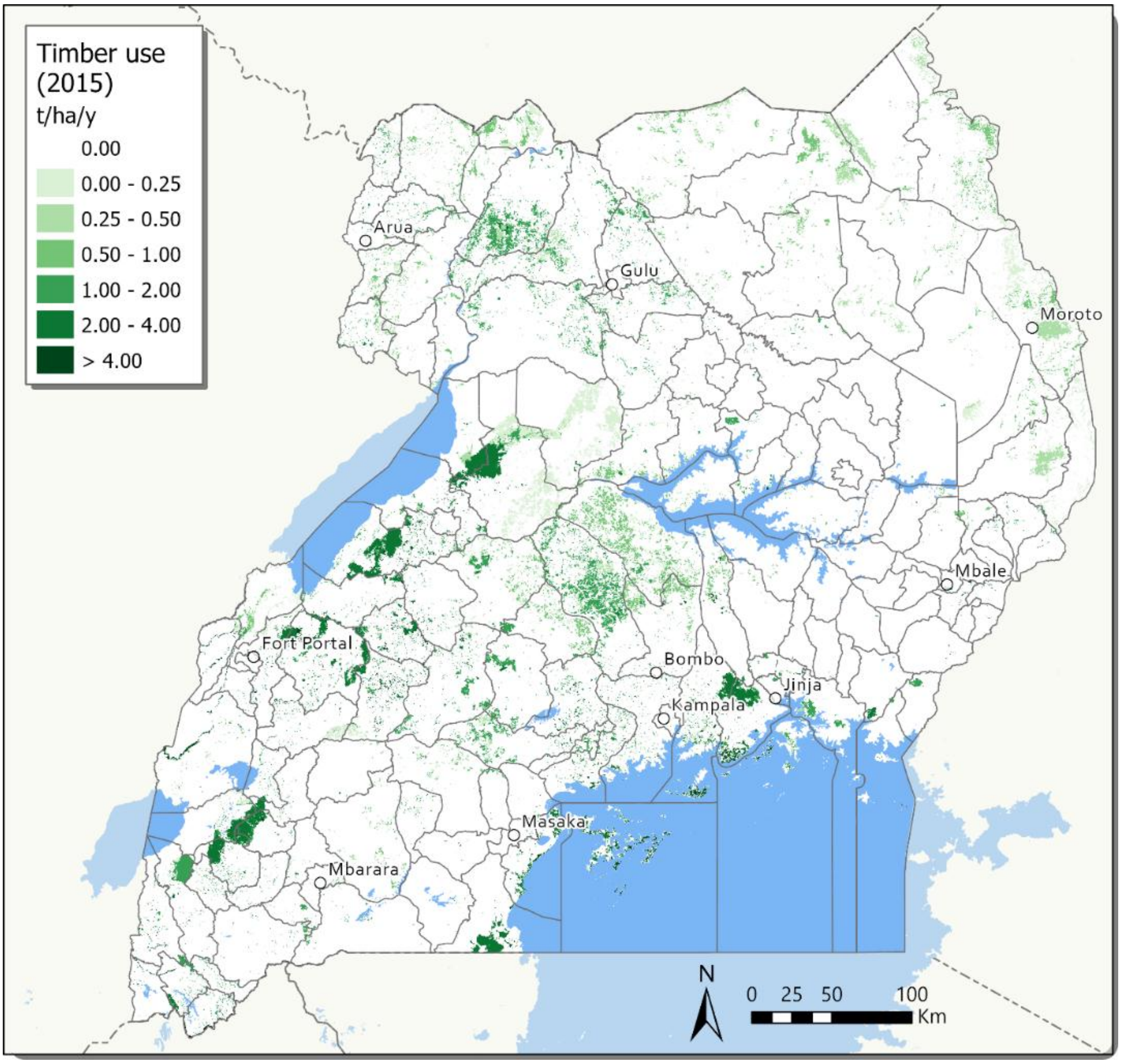

Figure 4.4. Estimated variation in the annual harvest of timber across Uganda in 2015, in tonnes/ha/year.

POLES

Harvesting of poles by rural households was estimated to increase from 614 000 t in 1990 to 842 000 t in 2015 (Table 4.12; Table 4.13). While the 1990 estimate may seem high given that the rural population was much lower, it can be explained by the fact that the proportion of rural households using traditional construction materials was estimated to be much higher in 1990, based on the extrapolation of available census data. In contrast, commercial harvesting of poles increased significantly from 108 000 t in 1990 to 439 000 t in 2015 (Table 4.12; Table 4.13). The combined total harvesting of poles is shown in Figure 4.5. Harvesting was estimated to be particularly high around Mount Elgon, due to a combination of high rural population densities and relatively high proportions of households using traditional construction materials. Harvesting was also estimated to be high for Mabira and several other forest reserves in the west of the country, due to a combination of high rural population demand and high utilisable stocks of timber. The latter means that these forest reserves also had high estimates for commercial pole harvesting, given the national-level commercial demand was spread in proportion to available biomass stocks.

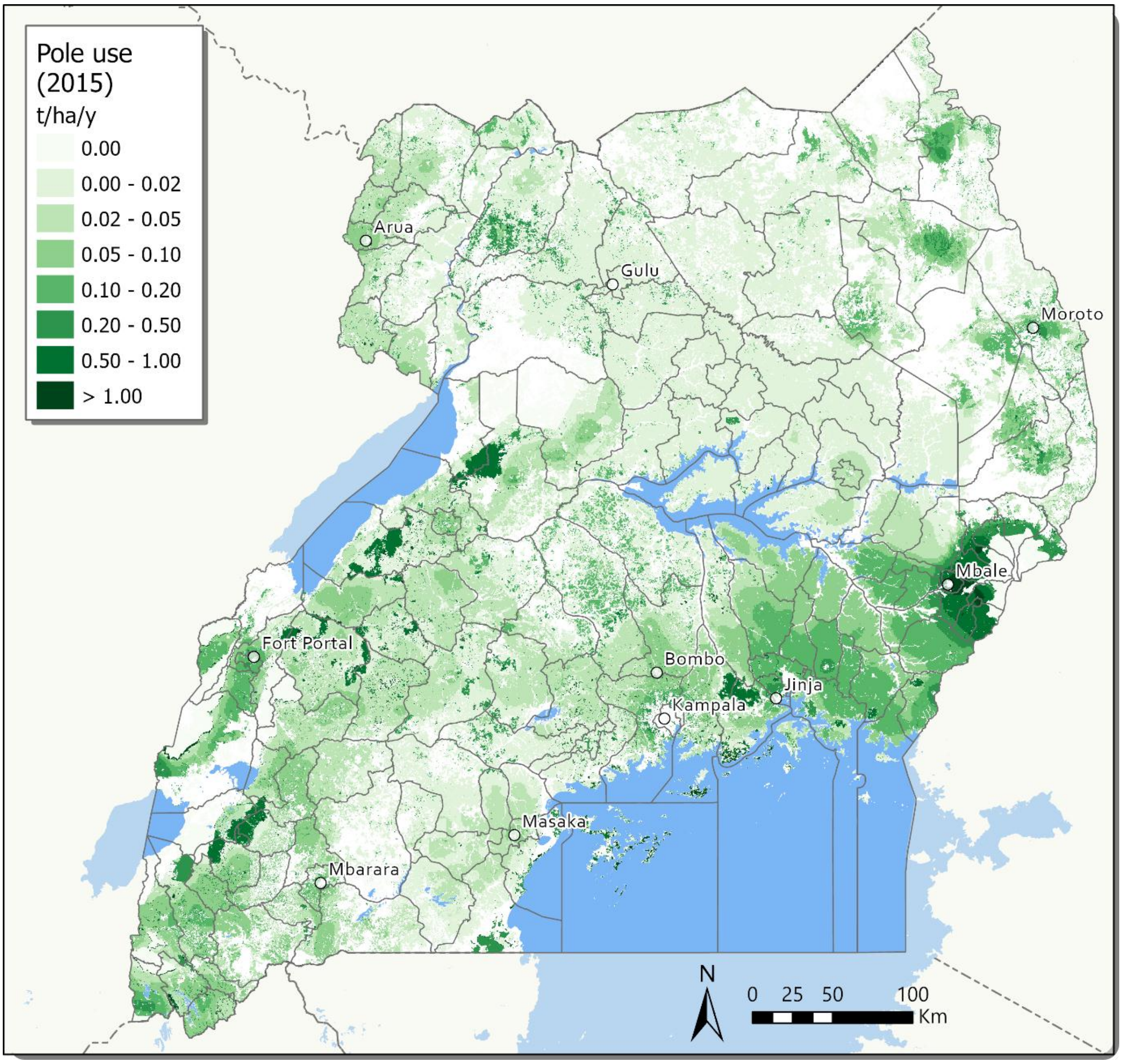

Figure 4.5. Estimated variation in the annual harvesting of wood resources for pole production for household and commercial use across Uganda in 2015, in tonnes/ha/year.

FIREWOOD

Some 1.8 million tonnes of woody biomass were harvested for commercial firewoood sales in 1990, increasing to 6.0 million tonnes in 2015 (Table 4.12; Table 4.13). In addition, rural households collected an estimated 10 million tonnes of firewood in 1990, increasing to 17 million tonnes in 2015 (Table 4.12; Table 4.13). The latter figure is significantly lower than the 25.6 million tonnes of household firewood consumption in 2015 reported in the Statistical Abstract (UBOS, 2020b), but slightly higher than the 14.8 million tonnes of firewood consumption estimated from the surveys conducted by Mugo *et al.*, (2016). Meanwhile, the 1990 estimate is relatively close to the reported firewood consumption of 11.7 million tonnes in the Wood Accounts (GoU, 2020a).

Total harvesting of firewood (household and commercial) in 2015 is shown spatially in Figure 4.6, and largely reflects rural population density. Values are mostly high in the east of Uganda between Kampala and Mount Elgon, and in the southwest. Harvesting of firewood is in the more sparsely populated north and northeast of Uganda. Notably, harvesting is high in the immediate surroundings of several protected areas, including Mount Elgon, Rwenzori and Bwindi Impenentrable National Parks, indicating signficant pressure on wood resources in these regions.

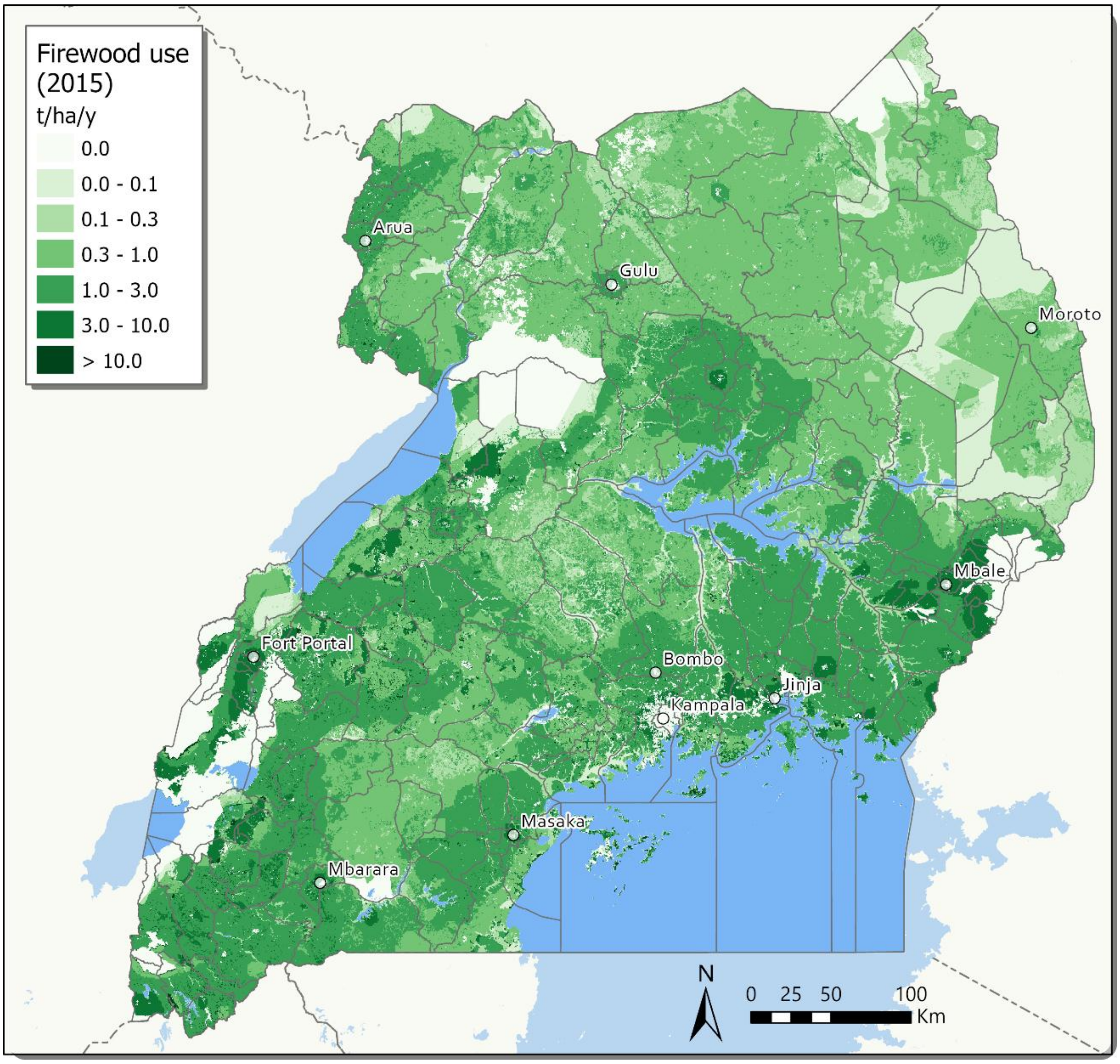

Figure 4.6. Estimated variation in the annual harvesting of firewood for household and commercial use across Uganda in 2015, in tonnes/ha/year.

WOOD USED FOR CHARCOAL PRODUCTION

Data in the Wood Accounts and the Statistical Abstracts indicate a fivefold increase in the amount of woody biomass harvested to produce charcoal, from 2.4 million tin 1990 to 12.0 million t in 2015 (GoU, 2020a; UBOS, 2020b). This large increase reflects both overall population growth and increasing urbanisation. Given widespread concern that charcoal harvesting is contributing significantly to deforestation, a comparison between charcoal demand at subregion level (Mugo *et al.*, 2016; UBOS, 2020b) and the wood stocks estimated to be available, after adjustment for land tenure, was made Table 4.11. This shows that while charcoal use increased fivefold between 1990 and 2015, wood stocks available for charcoal harvesting declined by 55%. This is due to the conversion of high biomass woody habitats to cultivation and built-up areas, and to a smaller extent by the formal designation of additional protected areas between 1990 and 2015. As a result of the increase in demand and decline in supply, use of wood for charcoal increased from 0.8% of available stocks in 1990 to 8.7% of available stocks in 2015. Harvesting levels are particularly concerning for Central II (North Buganda) subregion, where wood consumption for charcoal was estimated to be 22.4% of available standing stocks. This well exceeds the annual biomass increments estimated in the 2002 Biomass Survey (Drichi, 2002), which found that annual biomass growth is generally less than 10% of standing stock for natural vegetation types. This highlights that charcoal demand alone is significantly depleting wood stocks in parts of Uganda, before accounting for firewood harvesting and other pressures on woody resources.

Table 4.11. Comparison of wood used for charcoal production (Mugo *et al.*, 2016; GoU, 2020a; UBOS, 2020b) and available wood stocks in suitable land cover types, after adjusting for land tenure

Subregion	Wood use 1990 ('000 t)	Wood use 2015 ('000 t)	Available stock 1990 ('000 t)	Available stock 2015 ('000 t)	% of available stock used 1990	% of available stock used 2015
Central I	109	546	24 856	13 618	0.4%	4.0%
Central II	1 059	5 285	44 820	23 586	2.4%	22.4%
East-Central	4	20	8 704	6 265	0.0%	0.3%
Eastern	31	157	7 913	8 045	0.4%	1.9%
Mid-Northern	601	3 000	43 746	20 332	1.4%	14.8%
North-East	23	114	9 858	6 552	0.2%	1.7%
West-Nile	254	1 267	20 561	10 708	1.2%	11.8%
Mid-Western	271	1 354	123 563	35 337	0.2%	3.8%
South-Western	44	219	23 712	13 806	0.2%	1.6%
Total	2 396	11 962	307 733	138 249	8.7%	0.8%

A map showing estimated wood harvesting for charcoal is shown in Figure 4.7. Harvesting was estimated to be highest in Centeral II (North Buganda) subregion (north of Kampala), which is where harvesting as a proprotion of available stocks was estimated to be very high (Table 4.11). This region includes several of the districts which make the greatest contribution to Kampala's charcaol supply, including Nakasongola and Nakaseke which alone are estimated to provide 32% of the charcoal supplied to Kampala (Mugo *et al.*, 2016). Harvesting of wood for charcoal was also estimated to be relatively high over the north and northwest of Uganda. Savanna vegetation in these areas also contributes to to charcoal use in Kampala, as well as supplying charcoal to local urban centres such as Gulu (Mugo *et al.*, 2016).

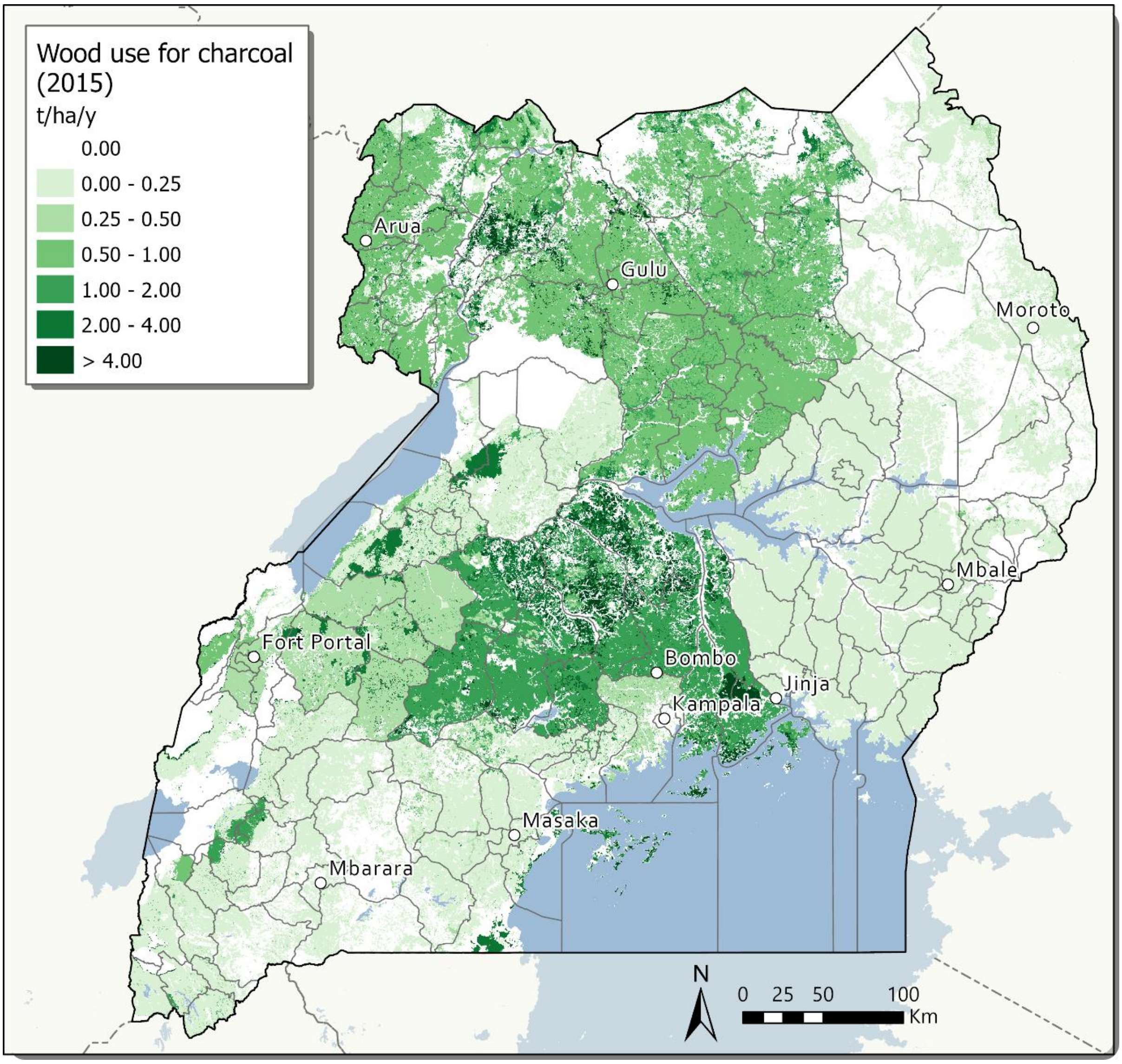

Figure 4.7. Estimated variation in the annual use of wood resources for charcoal production across Uganda in 2015, in tonnes/ha/year.

OVERALL USE OF WOODY BIOMASS PROVISIONING SERVICES

In total, it was estimated that 15.3 million tonnes of woody biomass were harvested across Uganda in 1990, increasing to 38.8 million tonnes in 2015, representing a 154% increase in wood harvesting. A map of the total amount of wood harvested for both commercial and subsistence purposes is shown in Figure 4.8. This represents the sum of all harvested wood inputs to the various major wood products in Uganda (firewood, charcoal, poles and timber). The supply and use of woody biomass provisioning services is summarised in Table 4.12 to Table 4.15.

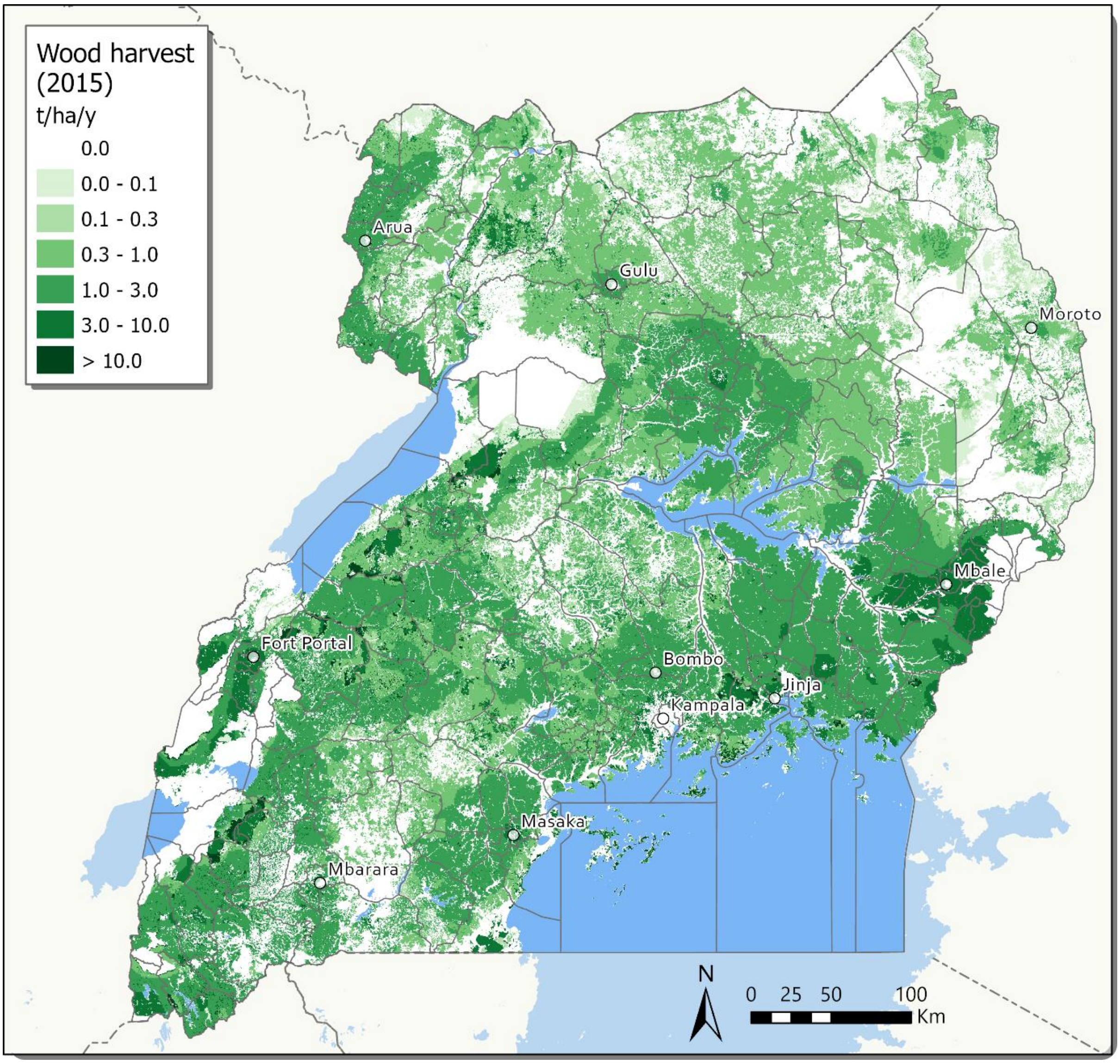

Figure 4.8. Total biomass of wood harvested across Uganda in 2015

Table 4.12. Physical supply and use table for wood resources (in kilo tonnes (kt) = 1000 tonnes) for 1990.

	Economy				Ecosystem										
Physical supply 1990	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Wood for timber (kt/y)	-	-	-	-	0	0	0	0	106	215	2	0	0	0	324
Poles (kt/y)	-	-	-	-	0	0	0	28	111	160	23	400	0	0	722
Wood for charcoal (kt/y)	-	-	-	-	0	0	0	64	1 029	883	7	413	0	0	2 396
Firewood (kt/y)	-	-	-	-	0	24	1 434	364	1 821	2 577	307	5 346	0	0	11 873
Total	**-**	**-**	**-**	**-**	**0**	**24**	**1 434**	**455**	**3 067**	**3 835**	**339**	**6 160**	**0**	**0**	**15 315**
Physical use 1990															
Wood for timber (kt/y)	324	0	0	324	-	-	-	-	-	-	-	-	-	-	-
Poles (kt/y)	108	0	614	722	-	-	-	-	-	-	-	-	-	-	-
Wood for charcoal (kt/y)	2 396	0	0	2 396	-	-	-	-	-	-	-	-	-	-	-
Firewood (kt/y)	1 787	0	10 086	11 873	-	-	-	-	-	-	-	-	-	-	-
Total	**4 615**	**0**	**10 700**	**15 315**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

Table 4.13. Physical supply and use table for wood resources (in kilo tonnes (kt) = 1000 tonnes) for 2015.

	Economy				Ecosystem										
Physical supply 2015	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Wood for timber (kt/y)	-	-	-	-	0	0	0	0	768	1 451	233	0	0	0	2 453
Poles (kt/y)	-	-	-	-	0	0	0	88	205	339	91	560	0	0	1 282
Wood for charcoal (kt/y)	-	-	-	-	0	0	0	1 367	2 575	2 602	245	5 172	0	0	11 962
Firewood (kt/y)	-	-	-	-	0	81	2 678	1 689	1 733	3 000	1 185	12 698	0	0	23 063
Total	**-**	**-**	**-**	**-**	**0**	**81**	**2 678**	**3 144**	**5 281**	**7 392**	**1 755**	**18 429**	**0**	**0**	**38 760**
Physical use 2015															
Wood for timber (kt/y)	2 453	0	0	2 453	-	-	-	-	-	-	-	-	-	-	-
Poles (kt/y)	439	0	843	1 282	-	-	-	-	-	-	-	-	-	-	-
Wood for charcoal (kt/y)	11 962	0	0	11 962	-	-	-	-	-	-	-	-	-	-	-
Firewood (kt/y)	6 020	0	17 043	23 063	-	-	-	-	-	-	-	-	-	-	-
Total	**20 874**	**0**	**17 887**	**38 760**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

Table 4.14. Monetary supply and use table for wood resources for 1990; values in constant 2017 UGX (billions).

	Economy				**Ecosystem**										
Monetary supply 1990	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Wood for timber	-	-	-	-	0	0	0	0	11	22	0	0	0	0	34
Poles	-	-	-	-	0	0	0	2	7	10	1	24	0	0	44
Wood for charcoal	-	-	-	-	0	0	0	1	16	13	0	6	0	0	37
Firewood	-	-	-	-	0	0	8	2	11	15	2	31	0	0	69
Total	-	-	-	-	**0**	**0**	**8**	**5**	**44**	**61**	**4**	**62**	**0**	**0**	**184**
Monetary use 1990															
Wood for timber	34	0	0	34	-	-	-	-	-	-	-	-	-	-	-
Poles	7	0	37	44	-	-	-	-	-	-	-	-	-	-	-
Wood for charcoal	37	0	0	37	-	-	-	-	-	-	-	-	-	-	-
Firewood	10	0	59	69	-	-	-	-	-	-	-	-	-	-	-
Total	**87**	**0**	**96**	**184**	-	-	-	-	-	-	-	-	-	-	-

Table 4.15. Monetary supply and use table for wood resources for 2015; values in constant 2017 UGX (billions)

	Economy				Ecosystem										
Monetary supply 2015	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Wood for timber	-	-	-	-	0	0	0	0	403	760	122	0	0	0	1 285
Poles	-	-	-	-	0	0	0	27	63	104	28	172	0	0	393
Wood for charcoal	-	-	-	-	0	0	0	105	198	200	19	397	0	0	918
Firewood	-	-	-	-	0	2	78	49	51	88	35	372	0	0	676
Total	-	-	-	-	**0**	**2**	**78**	**181**	**714**	**1 152**	**204**	**941**	**0**	**0**	**3 272**
Monetary use 2015															
Wood for timber	1 285	0	0	1 285	-	-	-	-	-	-	-	-	-	-	-
Poles	135	0	259	393	-	-	-	-	-	-	-	-	-	-	-
Wood for charcoal	918	0	0	918	-	-	-	-	-	-	-	-	-	-	-
Firewood	176	0	499	676	-	-	-	-	-	-	-	-	-	-	-
Total	**2 514**	**0**	**758**	**3 272**	-	-	-	-	-	-	-	-	-	-	-

WILD FISH AND OTHER NATURAL AQUATIC BIOMASS PROVISIONING SERVICES

OVERVIEW

Wild fish and other natural aquatic biomass provisioning services are the ecosystem contributions to the growth of these organisms that are captured in uncultivated production contexts. Fish make an important contribution to domestic protein consumption in Uganda, while the fishery sub-sector is the second largest foreign exchange earner for Uganda's economy, after coffee (Mbowa *et al.*, 2017). Uganda's extensive waterbody, wetland and perennial river systems support a significant wild capture fishery production industry.

DATA AND METHODS

ESTIMATION OF FISH CATCHES

Information on fish catches by waterbody are available from 2001 to 2018 in the Fishery Accounts (NEMA, 2021b). These present total fish catch across six lake and river systems with a seventh category for "other waterbodies". An estimate of fish catches for 1990 was obtained from FAO data (FAO, 2022b). The FAO estimates were generally similar to or identical to the catch estimates in the Fishery Accounts, suggesting that the two datasets are comparable. However, no breakdown of catches by waterbody is provided in the FAO data. It was also noted that for several years summation of the catch values by waterbody did not align with the reported catch total in the Fishery Accounts (NEMA, 2021b). In such cases, it was assumed that the catches per waterbody were correct, and that the error occurred with the summation step.

To estimate catch per waterbody in 1990, the mean proportional contribution of each waterbody to total fish catches between 2001 and 2015 was estimated from the data in the Fishery Accounts (NEMA, 2021b). These proportions were then applied to the total catch figure for 1990 from the FAO data to disaggregate national production down to the various waterbodies. To map 2015 and 1990 fish catches back to the landscape, the extent of each of the six lake and river systems was delineated in ArcGIS, based on the maps in the Fishery Accounts, and the total catch in each spread across total open water area as per the land cover. To spatialise catches in the "other waterbodies" grouping, the total area of open water outside of the six named lake and river systems was estimated, and catches then spread across this total area.

VALUATION OF SERVICE FLOWS

Fish prices were calculated from the physical and monetary supply and use tables in the Fishery Accounts (NEMA, 2021b). Resource rents were assumed to be 43% of market price based on revenue and cost data published for all waterbodies in 2015 in the Fishery Accounts (NEMA, 2021b).

SUSTAINABILITY ADJUSTMENT FOR ASSET VALUATION

In order to account for sustainability in the calculation of asset value, information about sustainable fish yields was taken from the 2021 Fisheries Resources Accounts for Uganda which show fish assets accounts for Lake Victoria in 2015/2016, including the opening stock (1 116 905 tonnes) for 2015 and the total additions to stock in 2015 and 2016 (a total addition of 289 132 tonnes over two years or 144 566 annually), which suggests a sustainable yield of roughly 13%. In the absence of further information it was assumed that the level sustainability was similar for all the lakes and across time.

RESULTS

Total capture fish production almost doubled from 245 000 t in 1990 to 455 000 t in 2015 (Table 4.16). Most of this was ascribed to industry (around 80%) while households accounted for around 20% of the catch (NEMA, 2021b). Lake Victoria contributed the largest share of capture fishery production. However, in terms of fish catches per open water area, Lake Albert and Lake Wamala were estimated to be the most productive lake systems.

Total monetary value of the service (in constant 2017 UGX billions) was estimated to be 0.1 and increased to 0.59 constant 2017 UGX billions in 2015 (Table 4.19 and Table 4.20).

The reported fish catch from Lake Victoria in 2015 (238 630 tonnes) was much higher than the estimated sustainable yield (ca. 145 000 tonnes).

Table 4.16. Wild capture fish production across the seven lake and river systems used in the fishery accounts

Waterbody/river system	1990 (t)	2015 (t)
Lake Edward, George and Kazinga Channel	3 303	6 350
Lake Victoria	122 122	238 630
Lake Albert	78 037	149 040
Lake Kyoga	24 751	41 770
Lake Wamala	8 004	4 190
Albert Nile	2 972	5 120
Other waterbodies	6 035	9 770
Total	**245 223**	**454 870**

Table 4.17. Physical supply and use table for wild fish provisioning services, for 1990

	Economy				Ecosystem										
Physical supply 1990	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Fish (kt/y)	-	-	-	-	245	0	0	0	0	0	0	0	0	0	245
Physical use 1990															
Fish (kt/y)	197	0	48	245	-	-	-	-	-	-	-	-	-	-	-

Table 4.18. Physical supply and use table for wild fish provisioning services, for 2015

	Economy				Ecosystem										
Physical supply 2015	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Fish (kt/y)	-	-	-	-	455	0	0	0	0	0	0	0	0	0	455
Physical use 2015															
Fish (kt/y)	365	0	90	455	-	-	-	-	-	-	-	-	-	-	-

Table 4.19. Monetary supply and use table for wild fish provisioning services, for 1990; values in constant 2017 UGX (millions)

	Economy				Ecosystem										
Monetary supply 1990	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Fish	-	-	-	-	98.3	0	0	0	0	0	0	0	0	0	98.3
Monetary use 1990															
Fish	79.0	0	19.4	98.3	-	-	-	-	-	-	-	-	-	-	-

Table 4.20. Monetary supply and use table for wild fish provisioning services, for 2015; values in constant 2017 UGX (millions)

	Economy				Ecosystem										
Monetary supply 2015	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Fish	-	-	-	-	593	0	0	0	0	0	0	0	0	0	593
Monetary use 2015															
Fish	476	0	117	593	-	-	-	-	-	-	-	-	-	-	-

WILD ANIMALS, PLANTS AND OTHER BIOMASS PROVISIONING SERVICES

OVERVIEW

This service is the ecosystem contributions to the growth of wild animals, plants and other biomass captured and harvested in uncultivated production contexts (UN *et al.,* 2021). This account focuses on use by households who harvest wild plant and animal resources (other than wood and fish) for own consumption or informal trade and does not include sport hunting or bioprospecting. The use is quantified based on spatial estimates of the availability of resources across the landscape, coupled with spatial estimates of the aggregate household demand for resources. The supply of these harvested resources is a final ecosystem service and is valued as the equivalent market value of the harvest, less the costs of harvesting.

The capacity of the landscape to supply different types of wild resources is related to vegetation type and condition, availability of water and other factors. However, a number of other factors determine their use and value, and these vary in space and time. The accessibility of wild resources is determined by regulations such as land tenure and harvesting rights, by social norms and informal agreements, by geographic features such as topography and rivers, and man-made features such as roads. The demand for wild resources is influenced by the socio-economic circumstances of households and the prices of alternatives (MWE, 2016). Due to data constraints, few, if any, studies have modelled these factors comprehensively. For these accounts, estimates of capacity, accessibility, demand and use are made for seven groups of resources, as follows (Table 4.21).

Table 4.21. Groupings of wild resources (other than woody and fishery resources)

Purpose	Group
Nutrition and health	Wild medicines
	Wild fruits and vegetables
	Mushrooms
	Wild honey
	Bushmeat (birds, reptiles and mammals)
Raw materials	Thatching grass/materials
	Reeds and sedges
	Bamboo

Note that these accounts estimate the use of wild plant and animal resources for subsistence purposes or small-scale trade. The illegal commercial trade of high-value endangered or other species and products, which carry high social costs that counter the illicit gains, is not accounted for.

DATA AND METHODS

DATA SOURCES

Data were collated on the demand for different resources by households, the stocks and yields of these resources in the different habitat types of the study area, and the spatial distribution and characteristics of households in the study area. Very little of the harvesting of wild natural resources is monitored in Uganda. Therefore, this estimation was based on ecological and socio-economic studies that have taken place in Uganda and in other areas with similar contexts. Available information on system yields, quantities harvested, harvesting costs and market prices for different resource types were obtained from the literature, using information from the study area as far as possible. Where data for Uganda were limited, then information from comparable socio-ecological systems in the broader region was used.

ESTIMATION OF RESOURCE STOCKS AVAILABLE FOR HARVEST

Spatial variation in resource stocks and yields per unit area were estimated based on information from the literature for ecosystem types corresponding to the different natural land cover classes of the Ugandan Land Cover series, in conjunction with information on vegetation types or species distributions, where appropriate. The land cover provides the most suitable primary data for the assessment, since it is based on satellite imagery of vegetation structure at the time of the account, whereas the vegetation map is a static description of the distribution of floral communities before the influence of man and in some areas bears little relationship to the vegetation present at the time period under study. However, combining land cover and vegetation map data (van Breugel *et al.*, 2015) helped to give an indication of the remaining area of different vegetation types in 1990 and 2015 while adding further detail to the land cover categories. For example, bamboo stocks were mapped based on where forest and woodland land cover types overlapped with areas classified as bamboo in the vegetation map.

Numerous literature estimates were used for estimating natural resource stocks for different land cover/vegetation types as follows: wild medicines (Turpie *et al.*, 2007); wild plant foods (Campbell, 1987; Chapman, Wrangham & Chapman, 1994; Nkuutu *et al.*, 2000; Okia *et al.*, 2008; Buyinza, Senjonga & Lusiba, 2010; Assefa & Abebe, 2011; Lovett, 2013; Naughton, Lovett & Mihelcic, 2015); mushrooms (Engola *et al.*, 2007; de-Miguel *et al.*, 2014; Degreef *et al.*, 2016), wild honey (Schneider & Blyther, 1988; Jaffé *et al.*, 2010; Vaudo *et al.*, 2012; Ribeiro *et al.*, 2019) ; bushmeat (Coe, Cumming & Phillipson, 1976; Barnes & Lahm, 1997; Monadjem, 1997; Chapman & Lambert, 2000; Plumptre & Cox, 2006; Kaschula & Shackleton, 2009; Treves *et al.*, 2009; Plumptre *et al.*, 2010; Wanyama *et al.*, 2014), thatching grass (Bourlière & Hadley, 1970; Shackleton, 1990; Wronski, 2003; Mworia, Kinyamario & John, 2008; Verdoodt *et al.*, 2009; Kyoshabire, Kizza & Rollanda, 2018); reeds and sedges (Thompson, Shewry & Woolhouse, 1979; Jones MB & Muthuri FM, 1997; Saunders, Jones & Kansiime, 2007) and bamboo (Bitariho & Mosango, 2005; Shiferaw, Kelbessa & Soromessa, 2011; Bitariho & Ssali, 2013). In the case of bushmeat, stock estimates per habitat also varied by protected area status, reflecting the fact that large wildlife are mostly limited to protected areas. Stock estimates for bushmeat in national parks drew on estimates for animal biomass conducted in strict protected areas. Stock estimates in other protected areas were lowered somewhat, drawing on the aerial surveys of Kidepo Valley (Wanyama *et al.*, 2014) which compared wildlife densities in the national park and the surrounding Karenga Community Wildlife Area. Outside of protected areas, bushmeat stock estimates drew on estimates of small mammal and bird biomass in unprotected environments (Monadjem, 1997; Kaschula & Shackleton, 2009).

ESTIMATION AND MAPPING OF USE

All of the harvestable resources were considered fully available outside of protected areas. The assumed availability was reduced to 10% of standing stocks in national parks, 20% in other UWA protected area categories (game reserves and wildlife sanctuaries) and 50% in forest reserves. While the national parks have historically had a no-take policy for resources, most have experienced some level of unsanctioned resource extraction. Over time, various protected areas have introduced arrangements to allow controlled access to certain resources, particularly where parks are adjacent to rural communities. More recently, resource harvesting agreements have also been introduced. However, there is no systematic data collection on legal or illegal resource harvesting in protected areas. Slightly higher availability was assumed for game reserves and wildlife sanctuaries than for national parks, based on the assumption that enforcement of harvesting restrictions is weaker. Finally, forest reserves were estimated to have the highest stock availability of the various PA categories, since a portion of forest reserves is formally set aside as buffer zones for resource harvesting (Howard *et al.*, 2000; Jjagwe, Kakembo & Bernard, 2021).

The quantities of resources harvested by subsistence and small-scale users from terrestrial and freshwater habitats was estimated based on the estimated household demand and available stocks in the landscape. Quantities demanded were estimated at the census district level, based on household survey data and census data on numbers and characteristics of households. Percentages of households using different types of resources was taken from the literature. Average demand for resources per household was estimated by multiplying the percentage of households per district using a resource with the average harvest of a resource per year per household per district.

Population data, urbanisation levels, household sizes and the proportion of houses with thatched roofs were available at district level from the 2014 census data and were used to estimate demand for resources in 2015. Population data for 1991 was taken from the 2014 census which broke population down from 1991 to 2014 by new districts. However, the 1991 census data were less detailed, providing only population numbers by district, and so the 2014 data were adjusted to estimate household numbers and characteristics in 1990 at the district level. Subregional data on urbanisation levels for 2014 and 1991 and on average household size for 2002 and 2014 were used to estimate the 1990 district level estimates, based on an extrapolation of trends.

The quantity of wild resources harvested for subsistence use was estimated based on the minimum of the estimated demand and the estimated available stocks of resources within approximately 6 km of the demand source, using the GIS-based method of Turpie et al. (2021*a,b*, 2022 in prep).

VALUATION OF SERVICE FLOWS

As per SEEA-EA guidelines, the estimated total amount of resources extracted was valued, irrespective of whether the estimated level of harvesting was sustainable or permitted. Total revenue was taken to be the market value of the resources harvested, irrespective of whether they were consumed or sold, using average prices obtained from the literature (Table 4.22). Based on estimations from Turpie et al. (1999), the resource rent of harvesting bush meat and honey was assumed to be 65%; resource rents for collected raw materials was 85%, and wild foods and medicines were assumed to have a resource rent of 95%.

Table 4.22. Values used for natural resources harvested for 2015 resources, values are constant 2017 UGX

Resource	Unit	Value per unit, 2017 UGX
Wild medicines	kg	7 282
Wild fruits and vegetables	kg	684
Mushrooms	kg	3 706
Wild honey	litre	3 891
Bushmeat	kg	4 705
Thatching grass	kg	178
Reeds and sedges	kg	178
Bamboo	stem	2 165

SUSTAINABLITY ADJUSTMENT IN ASSET VALUATION

Sustainability of the estimated harvest levels was estimated for bush meat and thatching grass only. The sustainable yield of bush meat was estimated to be 30% of the stock, based on studies from Ling & Milner-Gulland (2006) and Barychka *et al.* (2020). The sustainable yield of thatching grass was also estimated to be 30% (McKean, 2003). The sustainable yields of medicinal and food plants and honey were unknown and should be considered in future editions of the accounts. In the case of mushrooms and reeds and sedges, the sustainable yields were not known but harvests were expected to be relatively sustainable due to the growth patterns of these resources.

RESULTS

Brief descriptions of the use of the different types of resources are provided below, along with maps of the estimated harvested quantities in 2015 (Figure 4.9-Figure 4.16). Only the maps for 2015 are shown. The estimated harvests of wild plant foods, medicines, and bushmeat were high across most of the country, while those of thatching grass, bamboo, reeds and sedges were more localised because of limited ranges and habitats in which they are found.

WILD MEDICINES

At the national level, it is estimated that about 80% of Uganda's population uses traditional plant-based medicines (Kanabahita, 2001). This is particularly important in areas where access to modern medicine is generally lacking. Nevertheless, many people regard traditional plant medicines to be more effective than modern ones (Twinamatsiko *et al.,* 2014). While some medicines are mainly collected by traditional healers, there are other medicines that are commonly collected by households. This may underlie high variability in estimates of proportions of households harvesting medicinal plants across the region, from as low as 16% around Bwindi National Park (Harrison *et al.*, 2015) to 33% around Volcanoes (Nahayo, Ekise & Niyigena, 2013) and 49% around Kibale (Hartter, 2010) National Parks. In Nkasongola District, 54% of households indicated they obtain medicines from savanna woodlands (Kalema, 2010). Around Mount Elgon, 88% of households adjacent to the forest edge used plant medicines, while 78% of households further away from the forest were users (Scott, 1998). Based on available information, the estimated quantities of wild medicines used from different parts of the landscape are shown in Figure 4.9.

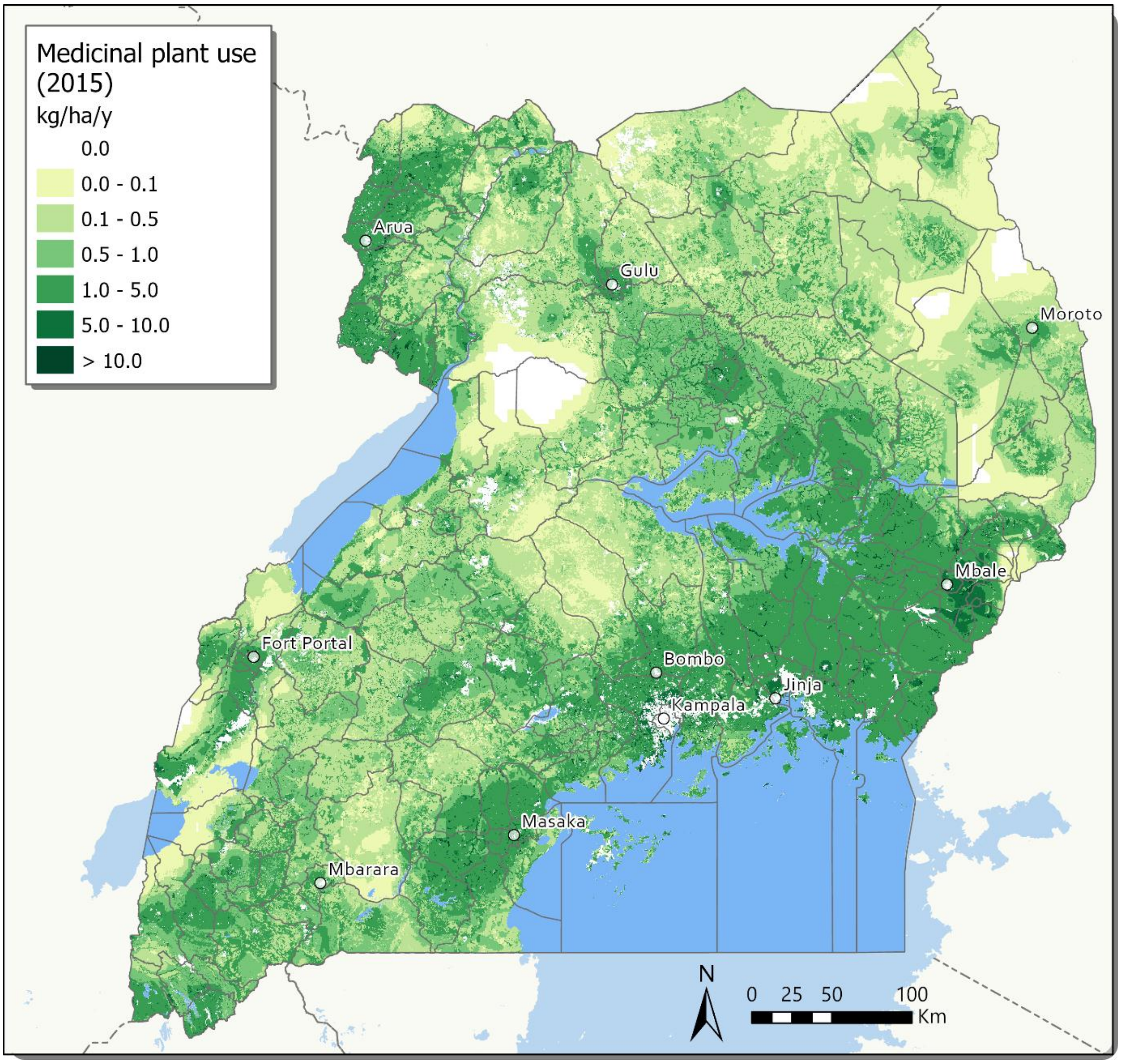

Figure 4.9. Estimated variation in the annual medicinal plant use across Uganda in 2015, in kg/ha/year.

WILD PLANT FOODS AND MUSHROOMS

Collection of wild fruits, vegetables, and mushrooms is a commonly mentioned activity for rural households across Uganda. This is particularly important for poorer households, and during periods of famine and drought, when they may provide an emergency food source, particularly in the drier parts of the country (Stites et al., 2007; Arensen, 2015). Important food species in the savanna areas of the country include the widely distributed desert date *Balanites aegyptiaca* and tamarind *Tamarindus indica*. As it bears both edible leaves and fruits and tolerates annual rainfall as low as 400 mm, *B. aegyptiaca* is a particularly important species to communities in the more arid parts of the country (Hall, 1992; Egeru, Okia & de Leeuw, 2014; Arensen, 2015). The African shea tree *Vitellaria paradoxica* is another important species in some parts of Uganda (Naughton *et al.*, 2015). Shea fruits can be eaten directly, while the kernels are dried to make shea butter, which is prized as an edible oil, cooking fat, soap, cosmetics, and medicine (Booth & Wickens, 1988; Naughton et al., 2015). A substantial global demand for shea products in the cosmetic, pharmaceutical, and confectionary industries has also emerged, indicating the commercial potential of the species (Elias & Carney, 2007; Lovett, 2013). Mushrooms are also reportedly widely consumed where they are available. Based on reported availability and rates of household consumption, the estimated quantities of wild plant foods and mushrooms obtained across the landscape are shown in Figure 4.10 and Figure 4.11 respectively.

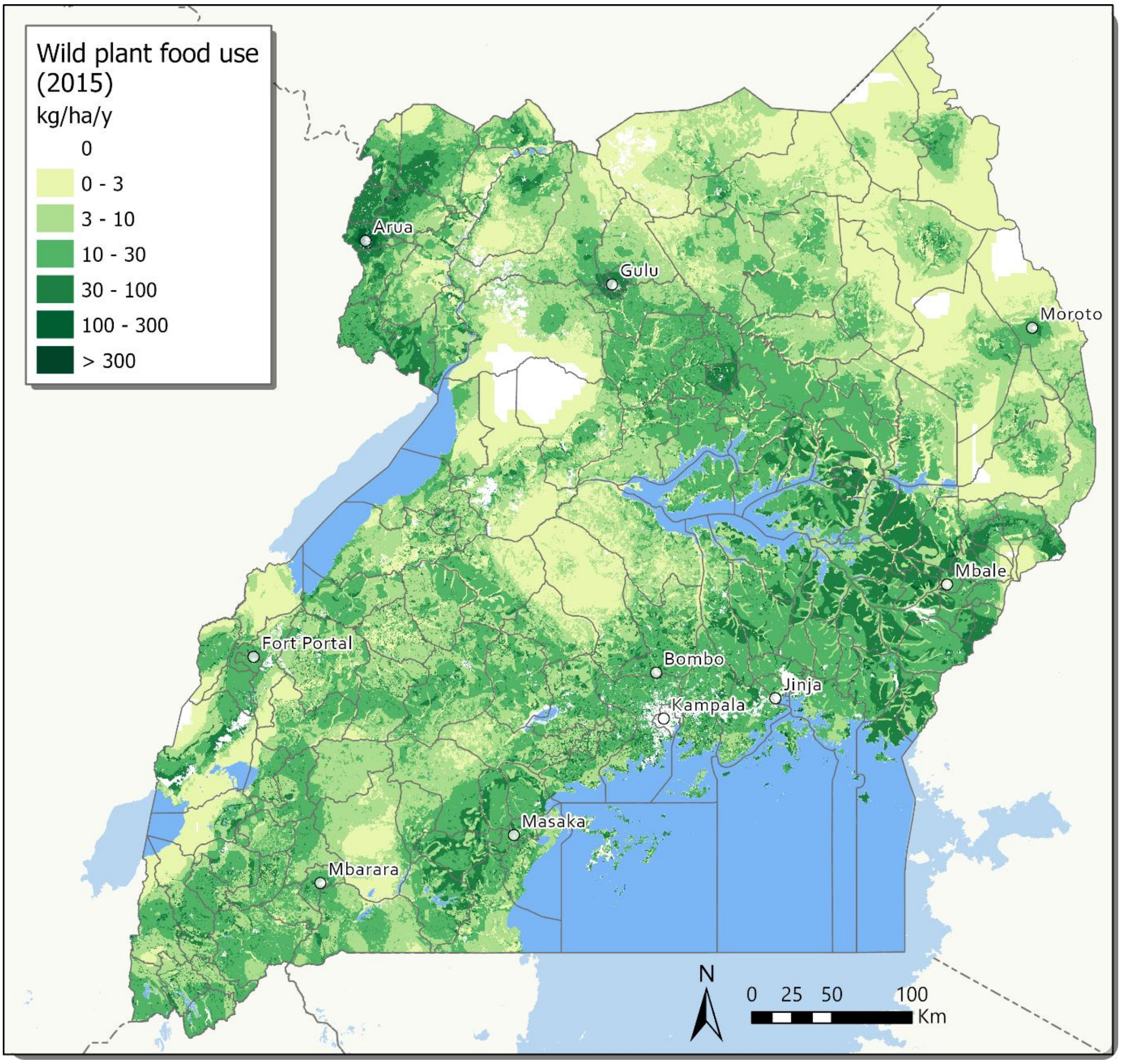

Figure 4.10. Estimated variation in the annual wild plant food use across Uganda in 2015, in kg/ha/year.

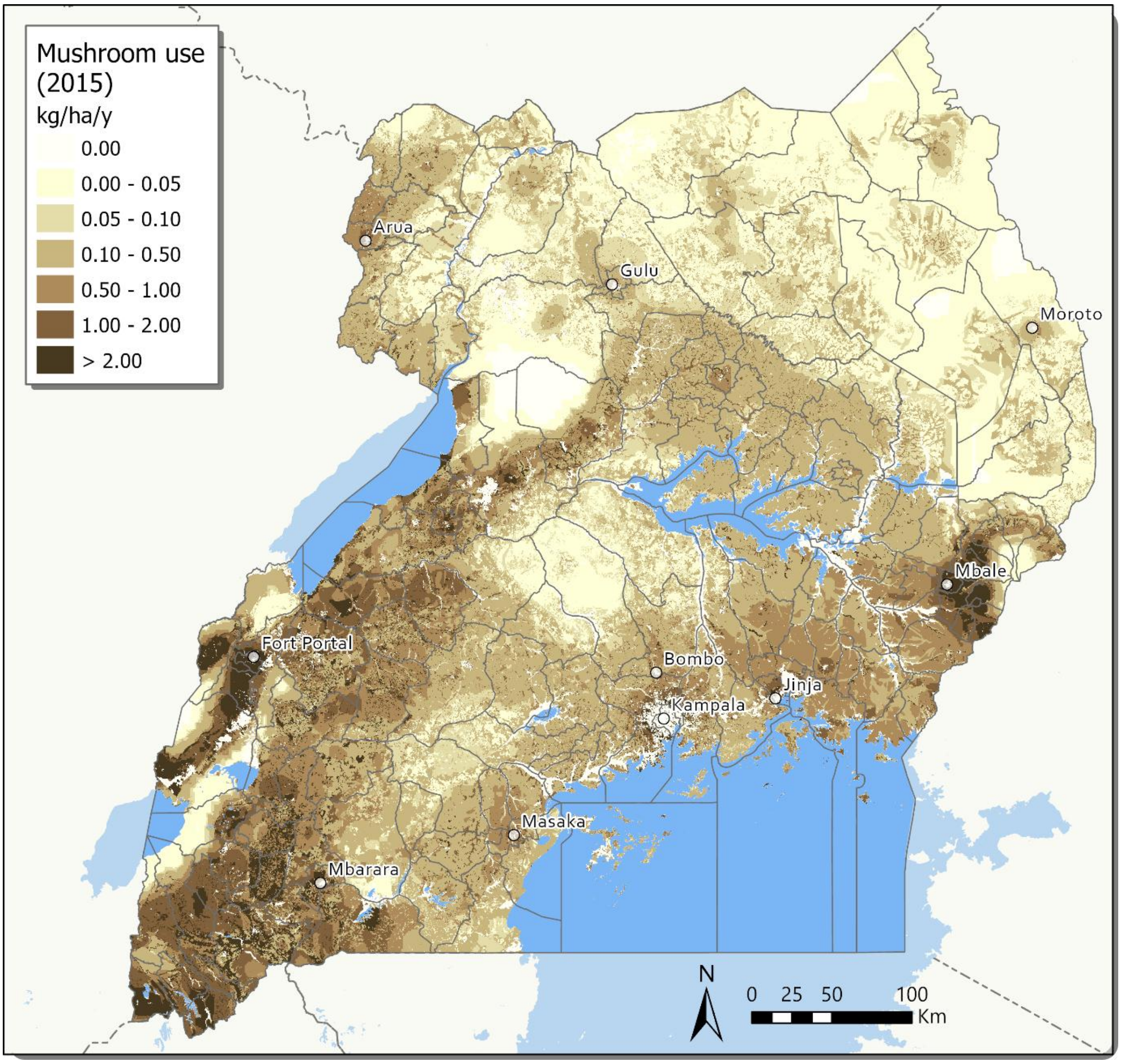

Figure 4.11. Estimated variation in the annual mushroom use across Uganda in 2015, in kg/ha/year.

WILD HONEY

Honey harvesting is a commonly reported activity across the country (e.g. Ayoo, Opio & Kakisa, 2013; Burns, Bekele & Akabwai, 2013; Egeru *et al.*, 2014; Visser *et al.*, 2017), with estimates of household participation ranging from 5-25% (Ndayambaje, 2002; Hatfield & Malleret-King, 2007; Rwamahe, 2008; Harrison *et al.*, 2015). Some protected areas in western areas of the country permit beekeeping, such as Bwindi and Mgahinga National Parks, where individuals with permits are legally allowed to harvest honey from designated multi-use zones (Harrison *et al.*, 2015; Bitariho, Sheil & Eilu, 2016). Honey sales have been found to provide significant supplementary income to beekeeping households around Bwindi National Park (Bitariho *et al.*, 2016). Based on available information, the estimated quantities of wild honey used from different parts of the landscape are shown in Figure 4.12.

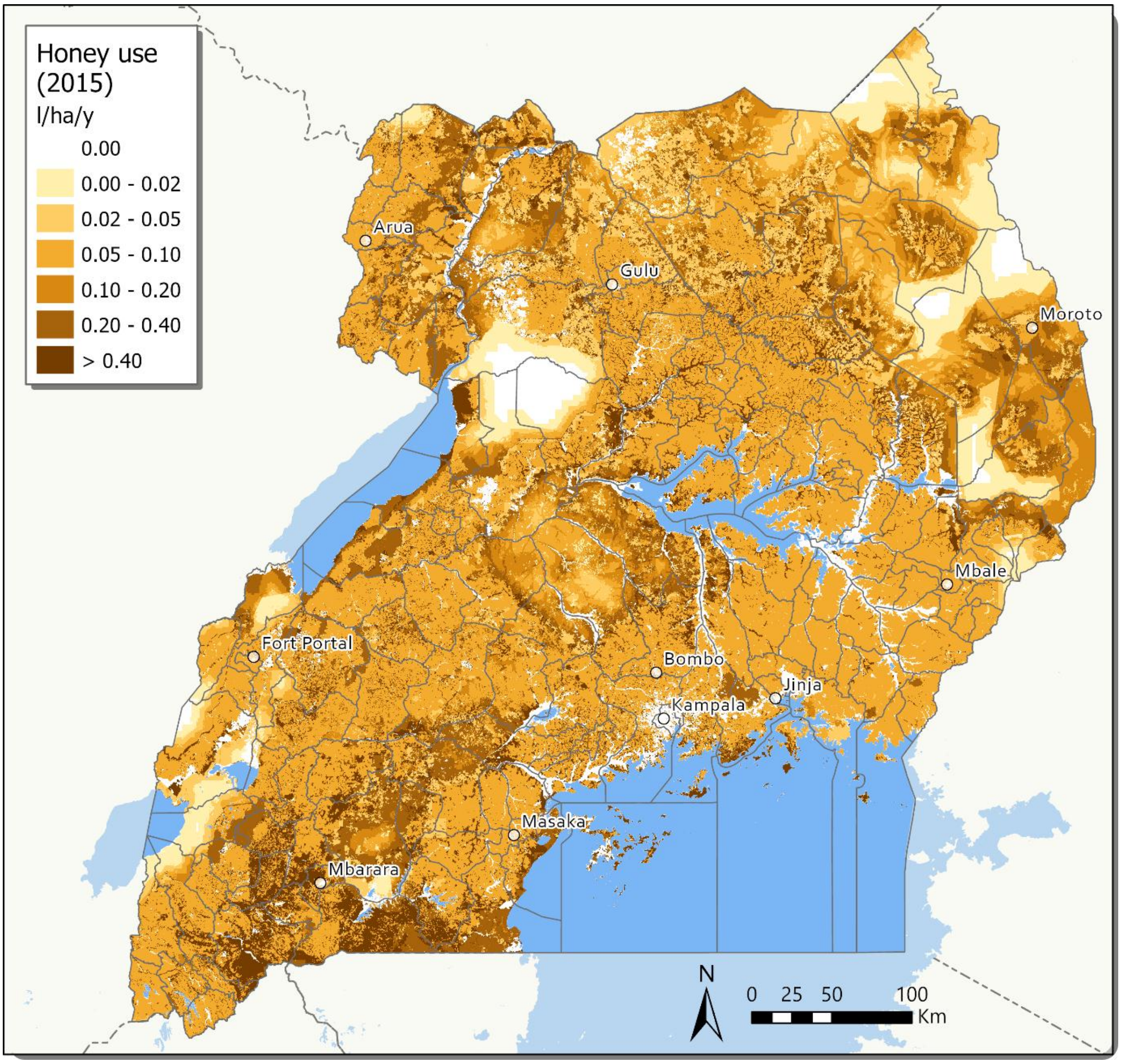

Figure 4.12. Estimated variation in the annual wild honey use across Uganda in 2015, in litres/ha/year.

BUSHMEAT

Bushmeat hunting is also a common livelihood activity, providing an important source of protein to poor rural households who cannot afford meat from domestic animals, and a potentially valuable income source to households that sell it (Tumusiime *et al.,* 2010; Harrison, 2013; Twinamatsiko *et al.,* 2014). Kayanja & Byarugaba (2001) noted that bushmeat harvesting in Uganda is "significant, but largely unrecorded," which remains generally true today. Estimates of household involvement in bushmeat consumption are highly variable. The illegal nature of bushmeat is likely a contributing factor of this variability, leading to under-reporting of consumption and hunting. Cultural differences, varying availability of bushmeat species, and different levels of law enforcement effectiveness are likely to also underlie the variation in bushmeat consumption estimates. Around Murchison Falls National Park and Kafu Basin areas of western Uganda the proportion of households using bushmeat was fairly low, at 32% and 12% respectively, and it was generally not consumed often by these households (Olupot, McNeilage & Plumptre, 2009). About two-thirds of meat caught in these areas was sold by hunters. Around Mount Elgon in Uganda, similarly moderate consumption of bushmeat was reported by Scott

(1998), where 33% of households adjacent to the forest and 22% of households further away from the forest, consumed bushmeat. About 26% of households around Bwindi National Park (Harrison et al., 2015) reported consuming bushmeat. While data on consumption levels are scarce, some studies report declines in availability of bushmeat due to excessive hunting (Stites *et al.*, 2007). Based on available information, the estimated quantities of wild medicines used from different parts of the landscape are shown in Figure 4.13.

Total bushmeat stock (not including endangered species) was estimated to be 64 035 tonnes in 1990 and 58 787 tonnes in 2015. The harvesting of bushmeat was estimated to be sustainable in only 36% of harvested areas in 1990 and 32% of harvested areas in 2015.

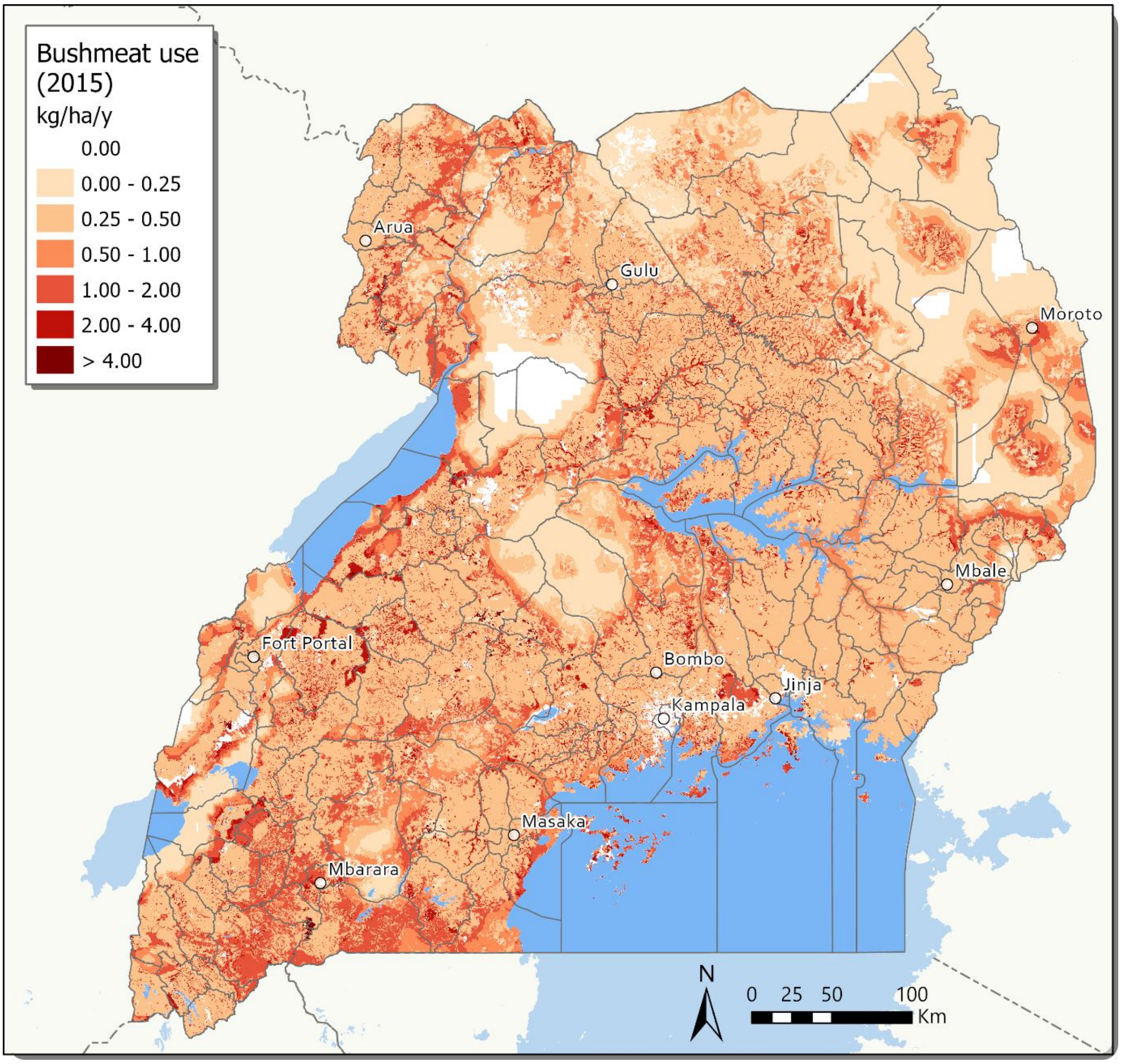

Figure 4.13. Estimated variation in the annual bushmeat use across Uganda in 2015, in kg/ha/year.

THATCHING GRASS

The use of thatch varies depending on access to the resource. For example, it is not widely used in some forested districts (UBOS, 2018). The use of grass thatch is higher in the northern and eastern parts of the country, where usage of grass thatch is upwards of 80% of households (UBOS, 2018). The use of thatch is lower in the southern and western parts of the country (UBOS, 2018). Based on available information, the estimated quantities of thatching grass used from different parts of the landscape are shown in Figure 4.14.

The total stock of thatching grass was estimated to be 2 954 850 tonnes in 1990 and 2 446 484 tonnes in 2015. Harvesting of thatching grass was estimated to be sustainable in almost all harvested areas (99% in 1990 and 98% in 2015).

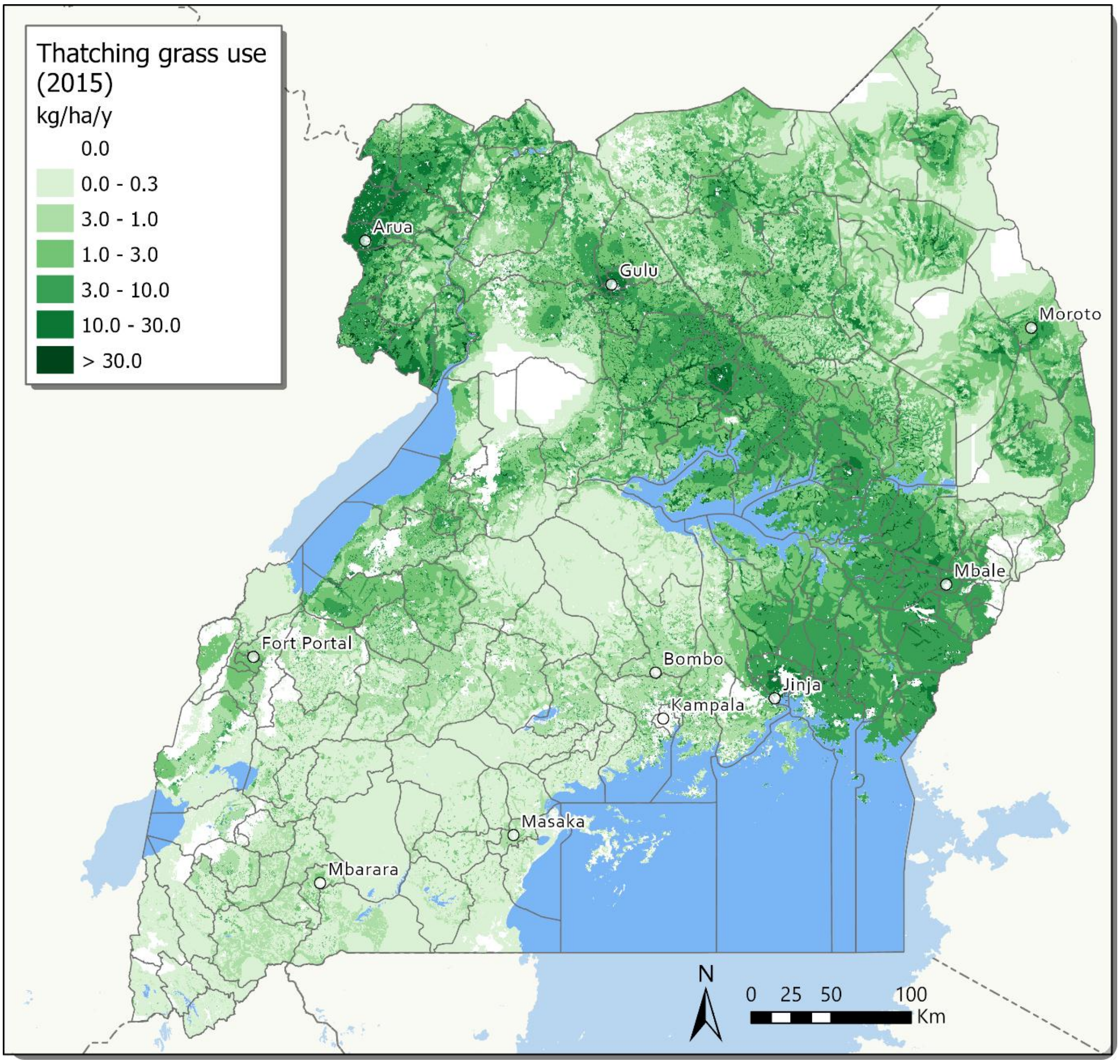

Figure 4.14. Estimated variation in the annual thatching grass use across Uganda in 2015, in kg/ha/year.

REEDS & SEDGES

As with thatching grass, the use of reeds and sedges (e.g., papyrus) varies depending on access to the resource. Where it is available, reeds and sedges are harvested for use in making sleeping mats and in constructing temporary fencing, walls or doors. This is an important resource along the shores of Lake Victoria, Lake Kyogo and in the northwest parts of the country along the Albert Nile. Based on available information, the estimated quantities of reeds and sedges used from different parts of the landscape are shown in Figure 4.15.

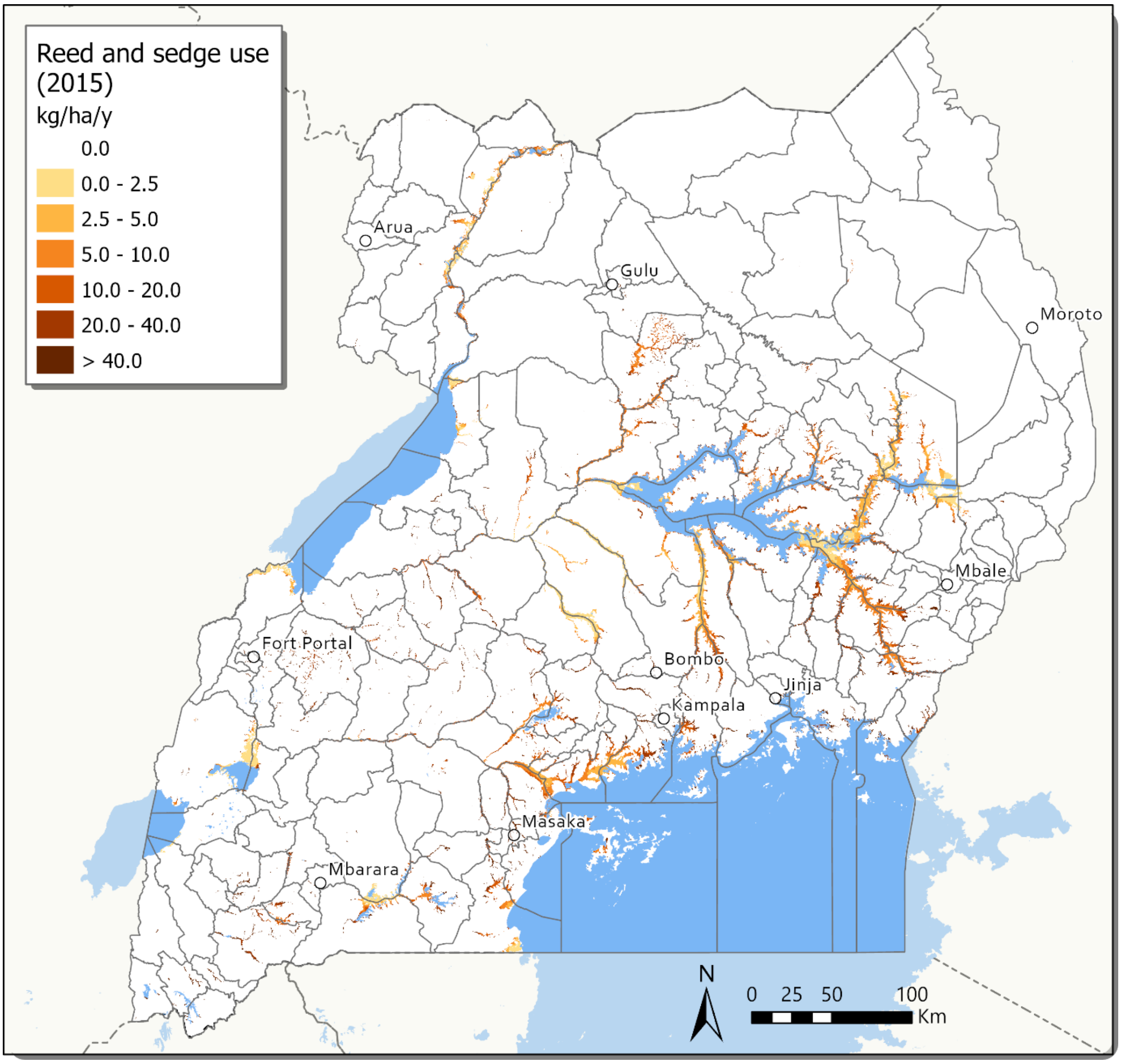

Figure 4.15. Estimated variation in the annual reed and sedges use across Uganda in 2015, in kg/ha/year.

BAMBOO

Localized populations of African mountain bamboo *Yushania alpina* occur in high-altitude forest areas of Uganda (Nzigidahera, 2006; van der Hoek et al., 2019). The species is prized for a range of uses including handicrafts, furniture, rope, poles, and firewood (Bitariho & Mosango, 2005; Zhao et al., 2018). Sale of bamboo products is a primary livelihood for some individuals, with an average annual income of about US$30 reported for bamboo harvesters using Echuya Forest Reserve in Uganda (Kalanzi et al., 2017). Stocks of bamboo in protected areas like Bwindi and Mgahinga National Parks provide a source of rhizomes, which can be legally collected for on-farm planting by authorized community members (Bitariho & Mosango, 2005). Bamboo is of localized but high importance in the Mount Elgon region. Stems are harvested for a range of purposes, including construction, stakes for growing crops like beans and bananas, and for weaving into granaries and baskets (Scott, 1998). The shoots are also eaten, but the area's Bagisu are the only known ethnic group in Africa that regularly consumes bamboo. Bamboo on Mount Elgon is used to meet a large demand for shoots across Mbale District in Uganda (Scott, 1998). The importance of bamboo is reflected by the fact that 95% of households near the forest edge harvest shoots for eating and stems for construction. Due to the large demand for bamboo in the region, selling of shoots and stems also provides an important income source to many households living close to the Mount Elgon forests (Scott, 1998). Based on available information, the estimated quantities of bamboo used from different parts of the landscape are shown in Figure 4.16.

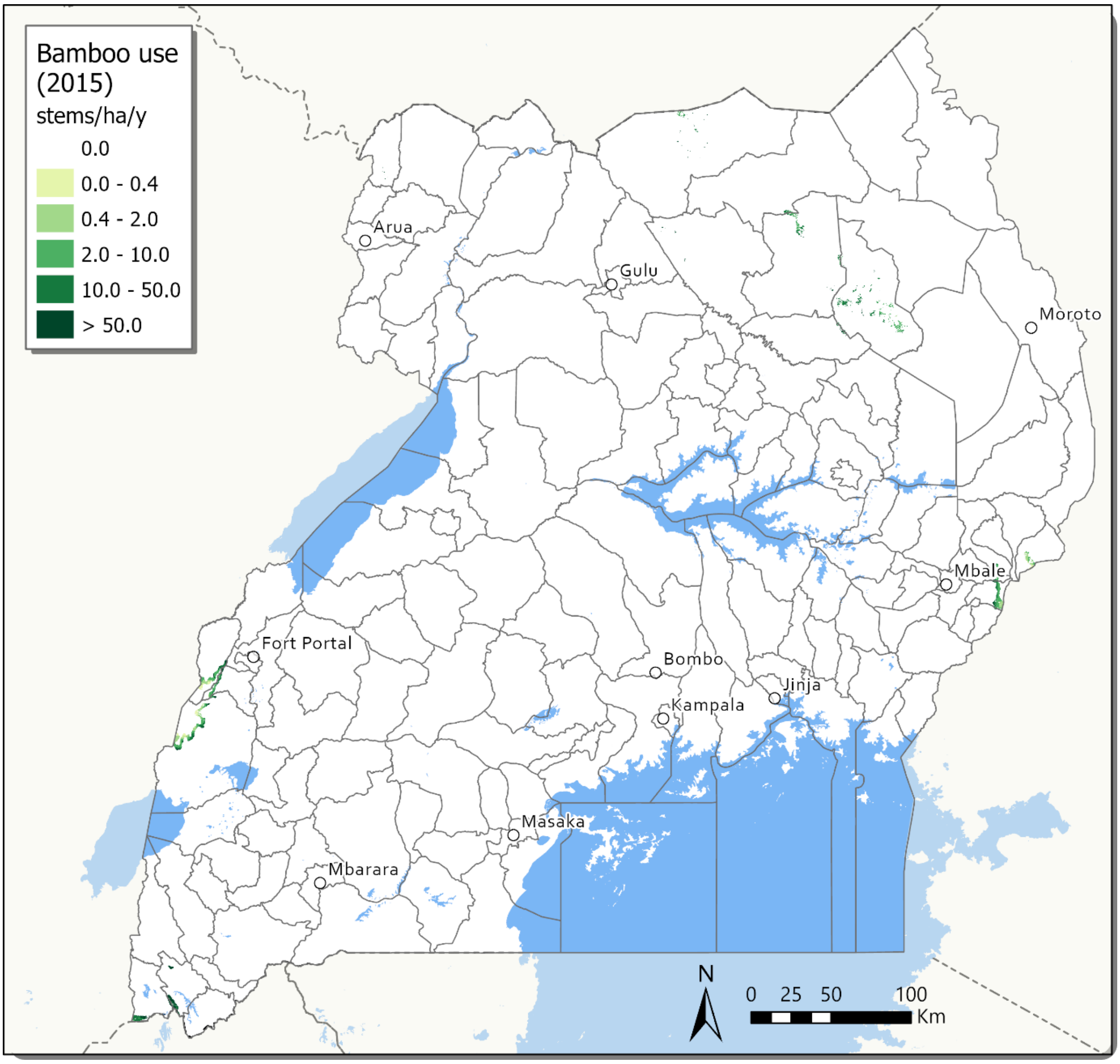

Figure 4.16. Estimated variation in the annual bamboo use across Uganda in 2015, in kg/ha/year.

OVERALL SUMMARY OF HARVESTS AND VALUE

The overall estimated use and value for 1990 and 2015 are summarised in Table 4.23 to Table 4.26. Provisioning of wild resources was estimated to be worth some UGX 147 393 million in 1990 and UGX 414 934 million in 2015 (in constant 2017 UGX; Table 4.25; Table 4.26). The value of provisioning of wild resources from forests and woodlands aligns well with an earlier estimate of the national value of NTFPs from woodlands and forests at UGX69 144 million/y (Bush, Nampindo & Aguti, 2004), as reported in the 2015 State of Uganda's Forestry Report (see MoWE, 2016). Note that the Bush *et al.* (2004) estimate was limited to forest and woodland only, and it also considered a narrower suite of NTFPs than those shown above. It is thus not surprising that a significantly value was estimated for NTFP harvesting in the present study. The increase in value of constant 2017 UGX 267 541 million over the 25-year period suggests an annual rate of increase of 4% per year from 1990 to 2015. Wild plant foods were found to be the most valuable resource harvested across the country followed by wild medicines and bushmeat. While wild plant foods were the most valuable, the increase in the value of these resources was lower than for thatching grass, reeds and sedges, and mushrooms, suggesting that these resources have become more valuable over time. This is as a result of increased numbers of people demanding these resources, as well as their increasing scarcity, which leads to real increases in price.

Table 4.23. Physical supply and use table for wild resources for 1990.

	Economy				Ecosystem										
Physical supply 1990	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Medicinal plants (t/y)	-	-	-	-	0	483	4 160	1 278	3 991	2 319	0	6 891	0	0	19 122
Wild plant foods (t/y)	-	-	-	-	0	2 437	47 630	18 131	49 316	20 826	251	113 163	0	0	251 755
Mushrooms (t/y)	-	-	-	-	0	0	2 390	378	1 355	843	69	3 261	0	0	8 296
Honey (kl/y)	-	-	-	-	0	0	920	227	698	373	7	384	0	0	2 609
Bushmeat (t/y)	-	-	-	-	0	347	4 256	930	2 694	1 285	14	3 499	0	0	13 026
Grass (t/y)	-	-	-	-	0	579	13 265	2 145	6 293	0	0	10 563	0	0	32 844
Reeds (t/y)	-	-	-	-	0	18 359	0	0	0	0	0	0	0	0	18 359
Bamboo ('000 stems/y)	-	-	-	-	0	0	0	0	506	970	0	0	0	0	1 476
Physical use 1990															
Medicinal plants (t/y)	0	0	19 122	19 122	-	-	-	-	-	-	-	-	-	-	-
Wild plant foods (t/y)	0	0	251 755	251 755	-	-	-	-	-	-	-	-	-	-	-
Mushrooms (t/y)	0	0	8 296	8 296	-	-	-	-	-	-	-	-	-	-	-
Honey (kl/y)	0	0	2 609	2 609	-	-	-	-	-	-	-	-	-	-	-
Bushmeat (t/y)	0	0	13 026	13 026	-	-	-	-	-	-	-	-	-	-	-
Grass (t/y)	0	0	32 844	32 844	-	-	-	-	-	-	-	-	-	-	-
Reeds (t/y)	0	0	18 359	18 359	-	-	-	-	-	-	-	-	-	-	-
Bamboo ('000 stems/y)	0	0	1 476	1 476	-	-	-	-	-	-	-	-	-	-	-

Table 4.24. Physical supply and use table for wild resources for 2015.

	Economy				Ecosystem										
Physical supply 2015	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Medicinal plants (t/y)	-	-	-	-	0	1 150	3 234	3 599	2 012	1 254	0	10 568	0	0	21 816
Wild plant foods (t/y)	-	-	-	-	0	4 879	35 266	41 289	22 396	9 796	713	156 272	0	0	270 611
Mushrooms (t/y)	-	-	-	-	0	0	1 807	1 297	761	514	165	4 563	0	0	9 108
Honey (kl/y)	-	-	-	-	0	0	921	546	263	146	26	491	0	0	2 393
Bushmeat (t/y)	-	-	-	-	0	600	3 489	2 210	920	618	50	4 436	0	0	12 324
Grass (t/y)	-	-	-	-	0	1 475	13 415	8 297	3 050	0	0	20 129	0	0	46 366
Reeds (t/y)	-	-	-	-	0	20 526	0	0	0	0	0	0	0	0	20 526
Bamboo ('000 stems/y)	-	-	-	-	0	0	0	0	391	778	0	0	0	0	1 169
Physical use 2015															
Medicinal plants (t/y)	0	0	21 816	21 816	-	-	-	-	-	-	-	-	-	-	-
Wild plant foods (t/y)	0	0	270 611	270 611	-	-	-	-	-	-	-	-	-	-	-
Mushrooms (t/y)	0	0	9 108	9 108	-	-	-	-	-	-	-	-	-	-	-
Honey (kl/y)	0	0	2 393	2 393	-	-	-	-	-	-	-	-	-	-	-
Bushmeat (t/y)	0	0	12 324	12 324	-	-	-	-	-	-	-	-	-	-	-
Grass (t/y)	0	0	46 366	46 366	-	-	-	-	-	-	-	-	-	-	-
Reeds (t/y)	0	0	20 526	20 526	-	-	-	-	-	-	-	-	-	-	-
Bamboo ('000 stems/y)	0	0	1 169	1 169	-	-	-	-	-	-	-	-	-	-	-

Table 4.25. Monetary supply and use table for wild resources for 1990; values in constant 2017 UGX (millions)

	Economy				Ecosystem										
Monetary supply 1990	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Medicinal plants	-	-	-	-	0	1 288	11 103	3 412	10 653	6 188	0	18 391	0	0	51 035
Wild plant foods	-	-	-	-	0	611	11 945	4 547	12 368	5 223	63	28 379	0	0	63 136
Mushrooms	-	-	-	-	0	0	3 247	513	1 840	1 145	93	4 429	0	0	11 268
Honey	-	-	-	-	0	0	898	221	681	364	7	375	0	0	2 546
Bushmeat	-	-	-	-	0	410	5 021	1 097	3 179	1 516	17	4 128	0	0	15 367
Grass	-	-	-	-	0	34	775	125	368	0	0	618	0	0	1 920
Reeds	-	-	-	-	0	1 073	0	0	0	0	0	0	0	0	1 073
Bamboo	-	-	-	-	0	0	0	0	359	688	0	0	0	0	1 047
Total	-	-	-	-	**0**	**3 417**	**32 989**	**9 915**	**29 447**	**15 124**	**180**	**56 321**	**0**	**0**	**147 393**
Monetary use 1990															
Medicinal plants	0	0	51 035	51 035	-	-	-	-	-	-	-	-	-	-	-
Wild plant foods	0	0	63 136	63 136	-	-	-	-	-	-	-	-	-	-	-
Mushrooms	0	0	11 268	11 268	-	-	-	-	-	-	-	-	-	-	-
Honey	0	0	2 546	2 546	-	-	-	-	-	-	-	-	-	-	-
Bushmeat	0	0	15 367	15 367	-	-	-	-	-	-	-	-	-	-	-
Grass	0	0	1 920	1 920	-	-	-	-	-	-	-	-	-	-	-
Reeds	0	0	1 073	1 073	-	-	-	-	-	-	-	-	-	-	-
Bamboo	0	0	1 047	1 047	-	-	-	-	-	-	-	-	-	-	-
Total	**0**	**0**	**147 393**	**147 393**	-	-	-	-	-	-	-	-	-	-	-

Table 4.26. Monetary supply and use table for wild resources for 2015; values in constant 2017 UGX (millions)

	Economy				Ecosystem										
Monetary supply 2015	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Medicinal plants	-	-	-	-	0	7 954	22 377	24 897	13 922	8 672	0	73 108	0	0	150 929
Wild plant foods	-	-	-	-	0	3 172	22 925	26 840	14 558	6 368	463	101 586	0	0	175 912
Mushrooms	-	-	-	-	0	0	6 362	4 568	2 680	1 810	580	16 065	0	0	32 065
Honey	-	-	-	-	0	0	2 328	1 381	666	369	66	1 241	0	0	6 052
Bushmeat	-	-	-	-	0	1 833	10 671	6 760	2 815	1 891	153	13 565	0	0	37 688
Grass	-	-	-	-	0	224	2 033	1 257	462	0	0	3 050	0	0	7 026
Reeds	-	-	-	-	0	3 110	0	0	0	0	0	0	0	0	3 110
Bamboo	-	-	-	-	0	0	0	0	719	1 431	0	0	0	0	2 151
Total	-	-	-	-	**0**	**16 293**	**66 695**	**65 703**	**35 824**	**20 542**	**1 262**	**208 616**	**0**	**0**	**414 934**
Monetary use 2015															
Medicinal plants	0	0	150 929	150 929	-	-	-	-	-	-	-	-	-	-	-
Wild plant foods	0	0	175 912	175 912	-	-	-	-	-	-	-	-	-	-	-
Mushrooms	0	0	32 065	32 065	-	-	-	-	-	-	-	-	-	-	-
Honey	0	0	6 052	6 052	-	-	-	-	-	-	-	-	-	-	-
Bushmeat	0	0	37 688	37 688	-	-	-	-	-	-	-	-	-	-	-
Grass	0	0	7 026	7 026	-	-	-	-	-	-	-	-	-	-	-
Reeds	0	0	3 110	3 110	-	-	-	-	-	-	-	-	-	-	-
Bamboo	0	0	2 151	2 151	-	-	-	-	-	-	-	-	-	-	-
Total	**0**	**0**	**414 934**	**414 934**	-	-	-	-	-	-	-	-	-	-	-

WATER SUPPLY

OVERVIEW

The water supply service reflects the combined ecosystem contributions of water flow regulation, water purification and other ecosystem services to the supply of water of appropriate quality to various users (UN et al., 2021). The SEEA EA allows for the supply of water *per se* to be recorded as a provisioning service. In this case, the water itself is valued, rather than the cost-savings in its provision due to moderation of the timing of flows, for example. In line with the SEEA, the contributions of ecosystems to water purification (through removal of excess nutrients) and to the regulation of groundwater recharge are valued separately as regulating services. In this section, the focus is on the provision of surface water to various users in Uganda. The final service is thus attributed solely to open water ecosystems.

DATA AND METHODS

Data on surface water use by different actors was obtained from the Water Accounts (UBOS, 2019) for 2015-2018. This was used in conjunction with census and land use data to estimate surface water abstraction in 1990 and 2015 within each drainage basin. In doing so, some modifications were made to the drainage basins layer used for accounting. For example, Kampala District straddles the Lake Victoria, Victoria Nile and Lake Kyoga basins. However, Lake Victoria is the main source of water for the city. For the purposes of estimating water use per drainage basin, the boundary of the Like Victoria basin was thus adjusted to include all of Kampala District. Modification was also made to the so-called "balancing area" basin, *i.e.* the boundary areas of Uganda which do not fall within the eight major drainage basins mapped by MWE. Since the balancing area extends across several disparate border regions of the country, it would be unrealistic to treat it as a single unit for estimating water demand. Hence, the balancing area was split into four different segments for mapping demand, one in the north-west corner of Uganda, two along the eastern boundary of Uganda, and one in the southeast corner of Uganda.

The Water Accounts include precipitation falling directly on to the landscape in their estimates of water use by the various sectors, based on summation of meteorological rainfall data. Direct use of precipitation in fact accounts for 99.97% of estimated water use in the accounts. However, only surface water abstraction is considered here since rainfall inputs to crop production are incorporated in crop provisioning services. Unfortunately, numerous errors were encountered in the physical use tables in UBOS (2019), including the table for 2015. This necessitated comparison with the 2017 physical use table (UBOS, 2021) to obtain water use estimates for certain sectors, which were projected back to 2015 as data allowed.

Estimates of water use by the various sectors are only given at national scale in the Water Accounts, requiring the use of various proxies to disaggregate use to the drainage basin level. The assumptions used for spatial disaggregation and projection back to 1990 are outlined in Table 4.27.

Table 4.27. Methods used for spatial assignment of national-level water use data to drainage basins and adjustment of values from 2015 to 1990

User group	Estimating 2015 use	Estimating 1990 use
Agriculture (Irrigation)	Spread across total area of commercial farmland in 2015	Total use estimated as a proportion of 2015 use based on the change in commercial farmland area between 1990 and 2015. Total use then spread across commercial farmland in 1990.
Agriculture (Livestock)	Spread in proportion to the numbers of TLUs in each basin as a percentage of the total 2015 population	Spread in proportion to the numbers of TLUs in each basin as a percentage of the total 1990 population
Agriculture (Forestry)	Spread in proportion to the total plantation area in each basin as a percentage of the national plantation area in 2015	Spread in proportion to the total plantation area in each basin as a percentage of the national plantation area in 1990
Agriculture (Fisheries)	Spread in proportion to the number of functional dams/ponds per basin in 2015, assuming that at least some of these are used for aquaculture production	Total water abstraction reduced in proportion to the difference in aquaculture production in 2015 and 1990. Abstraction then spread in proportion to the number of functional dams/ponds per basin in 1990
Crude oil and mining	Spread in proportion to the number of active mining leases per drainage basin as of 2015	Assumed to be 10% of 2015 use based on the near tenfold increase in number of mining licenses issued between 1999 and 2010 Based on MEMD data reported in the Uganda Mining Sector Profile)
Manufacturing, construction, accommodation, public administration, education, health and "other"	Assumed these largely take place in built-up areas, so use was spread across total built-up area in 2015	Total use estimated as a proportion of 2015 use based on the change in built-up area between 1990 and 2015. Total use then spread across built-up area in 1990
Households receiving distributed water from NWSC or other suppliers of distributed water	Assumed households receiving distributed water are largely urban. Urban population in 2014 estimated from census (UBOS, 2016a). Overlay of WorldPop population density and built-up area used to estimate proportion of Uganda's urban population in each basin. These proportions were then applied to the total use of distributed water by households, to estimate use per basin.	Total demand for 1990 estimated based on the change in Uganda's urban population between 1991 and 2014 from census data. Overlay of WorldPop population density data for 2000 (no earlier data available) and built-up area in 1990 used to estimate proportion of total 1990 urban population in each basin. As for 2015, these proportions were then applied to estimate basin-level demand from total estimated distributed household water use for 1990.
Household water abstracted for own use	Assumed households abstracting their own water are largely non-urban. Non-urban population estimated by subtracting the estimated urban population (as above) from the total population per basin in 2015. This was then used to calculate the proportional contribution of each basin to Uganda's non-urban population in 2015. These proportions were applied to the total abstraction for own use in Uganda to estimate use per basin.	Total household abstraction for own use in 1990 estimated from the change in population size between 1990 and 2015. Non-urban population in 1990 estimated by subtracting the estimated urban population (as above) from the total population per basin in 2015. As for 2015, these proportions were then applied to estimate basin-level demand from total estimated household abstraction for own use in 1990.
Water for sewerage and waste management	Assumed that demand for water in sewerage and waste management comes largely from urban areas, so use was spread across total built-up area in 2015	Total use estimated as a proportion of 2015 use based on the change in built-up area between 1990 and 2015. Total use then spread across built-up area in 1990

The physical use tables divide water abstracted for "own use" in each sector by source *i.e.* surface water or groundwater. This refers to water abstracted directly by users in each industry or sector, as opposed to water that is distributed to the sector by water service providers. The latter is also reported, split into groundwater and surface water based on the proportional contributions of groundwater and surface water to water used in "supply and distribution". The amount of water distributed to sectors is lower than the amount of water abstracted by the "Water Supply; Sewerage and Waste Management Activities Sector". It was thus assumed that the remaining portion of water, after subtracting the amount distributed for supply, corresponds to the amount of water abstracted for sewerage and waste management. Notably, water used by households is not split by source in the accounts. For households abstracting water for own use, it was assumed that 12.5% of this comes from surface water and the remainder from groundwater. This is based on UBOS household survey data, which reported that 25% of rural households used unimproved drinking water sources in 2016/2017, which includes unprotected wells and springs, rivers and lakes, vendors and water tankers. In the absence of additional information, it was assumed that half of the water in the "unimproved" source category comes from surface water sources.

MAPPING THE SOURCE AREAS OF WATER USED

It was assumed that the final ecosystem service of surface water supply is provided only by open water ecosystems. The total area of open water for each drainage basin in 1990 and 2015 was thus obtained from the land cover data. To allow surface water supply to be downscaled to district level, total surface water abstraction in each drainage basin was divided by total surface water area, in order to estimate abstraction/ha of open water. This approach is relatively simplistic, as it assumes all areas of open water contribute equally to meeting the basin-level demand. More detailed sub-national information on water abstraction would be required to achieve a more nuanced method. The resolution of the land cover data is another major limitation, as small dams/ponds and most rivers are not picked up as open water. This means that value excess is attributed to the larger waterbodies and few rivers that are actually mapped in the land cover data. More detailed information on both the use and supply (land cover) side of the water supply service would be required to improve the spatial accuracy of the mapping.

VALUATION

Water supply services to water service providers was valued in terms of resource rents, taking into account the variation in revenues accruing from different user types. Water prices for the different user types (apart from agriculture) were available from the National Water & Sewerage Corporation (NWSC)'s tariff guide for 2022 and converted to UGX 2017 values. Prices were available for domestic water users, institutions, and commercial and industrial entities. To price agricultural water, the average price for domestic and industrial water users was applied. Prices used are shown below (Table 4.28). In 2020, a technical and financial review of the NWSC by the Public-Private Infrastructure Advisory Facility (PPIAF) which is administered by the World Bank showed that NWSC's operating margin is around 20% on average (PPIAF, 2022). We used this percentage for the resource rent calculations. Water supply to households that collected their own water was valued in terms of the price of distributed water, as a replacement cost.

Table 4.28. Water prices (per m^3) per water user group in constant UGX 2017.

Water user	Price per m^3 (UGX)
Domestic	3102
Institutions	3139
Commercial	3350
Agriculture	3002
Industrial	2902

RESULTS

Total surface water abstraction by relevant sectors was estimated to be 560 585 thousand m^3 in 2015 (UBOS, 2019, 2021). Using the back-projection approaches described above, surface water abstraction in 1990 was estimated to be 140 023 thousand m^3, or a quarter of the 2015 estimate. The major reasons for the much lower estimated surface water abstraction in 1990 include the much smaller commercial farmland area (resulting in lower demand for water in irrigation), the negligible size of the aquaculture industry at the time (resulting in very low abstraction by fisheries) and the much smaller number of domestic urban consumers (resulting in lower demand from urban households).

Table 4.29. Surface water abstraction (in thousands of m^3) by various sectors based on Uganda's Water Accounts (UBOS, 2019; 2021), with back-projection to 1990.

Sector	1990 (m^3 000's)	2015 (m^3 000's)
Agriculture (Irrigation)	104 263	390 559
Agriculture (Livestock)	3 970	11 714
Agriculture (Forestry)	986	3 295
Agriculture (Fisheries)	36 629	16
Crude oil and Mining	180	1 804
Manufacturing (Food and Beverages)	2 622	9 858
Manufacturing (Other)	2 216	8 332
Construction	1 993	7 494
Accommodation	321	1 207
Public Administration	4 446	16 719
Education	201	757
Health	367	1 380
Other	1 189	4 470
Urban households	11 756	52 287
Other households	4 209	9 238
Sewage and waste management	1 287	4 841
Total	**140 023**	**560 585**

Table 4.30. Physical supply and use table of the water supply ecosystem service, for 1990

	Economy				Ecosystem										
Physical supply 1990	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Water (ML)	-	-	-	-	140 021	0	0	0	0	0	0	0	0	0	140 021
Physical use 1990															
Water (ML)	117 754	6 302	15 965	140 021	-	-	-	-	-	-	-	-	-	-	-

Table 4.31. Physical supply and use table of the water supply ecosystem service, for 2015

	Economy				Ecosystem										
Physical supply 2015	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Water (ML)	-	-	-	-	560 577	0	0	0	0	0	0	0	0	0	560 577
Physical use 2015															
Water (ML)	475 358	23 696	61 524	560 577	-	-	-	-	-	-	-	-	-	-	-

Table 4.32. Monetary supply and use table of the water supply ecosystem service, for 1990; values in constant 2017 UGX billions

	Economy				Ecosystem										
Monetary supply 1990	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Water	-	-	-	-	84.5	0	0	0	0	0	0	0	0	0	84.5
Monetary use 1990															
Water	70.7	4.0	9.9	84.5	-	-	-	-	-	-	-	-	-	-	-

Table 4.33. Monetary supply and use table of the water supply ecosystem service, for 2015; values in constant 2017 UGX billions

	Economy				Ecosystem										
Monetary supply 2015	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Water	-	-	-	-	338	0	0	0	0	0	0	0	0	0	338
Monetary use 2015															
Water	285	14.9	38.2	338	-	-	-	-	-	-	-	-	-	-	-

GLOBAL CLIMATE REGULATION: CARBON RETENTION

OVERVIEW

Global climate regulation services are ecosystem contributions to reducing concentrations of greenhouse gases in the atmosphere through the removal (sequestration) from the atmosphere and retention (storage) of carbon in biomass and soils (UN *et al.,* 2021). Carbon accumulates in vegetation biomass through plant growth, and also accumulates in soils and peat as a result of the production of leaf litter and partially decayed biomass. Certain ecosystem types, such as forests and wetlands, can hold very high quantities of carbon. Conversely, when vegetation is disturbed or removed, CO_2 is released into the atmosphere, contributing to global climate change. Indeed, the loss of forests is responsible for about 12–17% of the world's greenhouse gas emissions (Nakakaawa, Vedeld & Aune, 2011). It has been estimated that the carbon stocks in Uganda decreased by some 850 million tons between 2006 and 2010 as a result of the conversion of forested land to other land uses (Zhang et al., 2017). Where ecosystems are in decline, such as is the case in Uganda, the SEEA EA advises that the focus of the measurement should be placed on carbon retention. Carbon retention is valued in terms of the global social cost of carbon.

DATA AND METHODS

QUANTIFICATION IN PHYSICAL TERMS

This account draws on the physical carbon accounts that were compiled for 1990 – 2015 by GoU (2020b), while adding additional spatial detail to the carbon stock estimates as well as using supplementary data sources. These were based on changes in land cover, and the data collected in the Ugandan National Biomass Surveys (Drichi, 2002; NFA, 2009; GoU, 2021b), and values given in Willcock *et al.* (2012).

The total carbon retention was calculated using estimates of aboveground, belowground, soil and dead organic matter stocks. Aboveground carbon estimates were based on aboveground woody biomass (eg. stems and branches). Estimates of mean aboveground biomass (AGB) in small scale farmland, plantations, forests, woodland, bushland and grassland ecosystem types were calculated at district level, using information taken from the 2005 National Biomass Survey, which contains comprehensive information on the biomass of different land cover types across Uganda. (NFA, 2009). In the absence of such detailed national-level data for 1990 and 2015, this approach assumes that *average* biomass per hectare of each ecosystem type is comparable across years. Changes in carbon stocks between years thus result from changes in the extent of each ecosystem at district level. Aboveground biomass estimates for wetlands, built-up areas and large-scale farmland were based on national averages from the 2002 National Biomass Survey (Drichi, 2002), as these were excluded from the 2005 survey. This still represents a more detailed approach than previous ecosystem accounting in Uganda, which used a single national mean for average biomass in all land cover types (GoU, 2020b).

Belowground biomass (BGB) (eg. Roots) was calculated from AGB according to the root-shoot ratios for comparable ecosystem types as reported in the IPCC guidelines (IPCC, 2006, 2019), ranging from 0.27 for farmland to 1.58 in grassland. This is again more detailed than earlier accounting work, which simply used a relatively low root-shoot ratio of 0.24 for all land cover types (GoU, 2020b). Above and belowground biomass were converted to tonnes of carbon using a 50% conversion factor (IPCC, 2006).

Estimates of carbon stored in dead organic matter (e.g. leaf litter) for each habitat were based on the values used in GoU (2020b), which were originally derived from Willcock *et al*. (2012). Lacking further information, the same national level averages for each land cover type as reported in GoU (2020b) were used in the current study.

Soil organic carbon (SOC) stocks were derived from the Global Soil Organic Carbon (GSOC) Map (FAO & ITPS, 2018), which provides SOC estimates for the topsoil layer (0 – 30 cm depth). Mean SOC for each land cover type were calculated at district level in ArcGIS. This approach was considered to provide more accurate and spatially disaggregated estimates than the single estimates per land cover class used by GoU (2020b), again derived from Willcock *et al* 2012). For example, small-scale farmland was estimated to have one of the highest values for SOC/ha in GoU (2020b), second only to THF well stocked. In contrast, the GSOC map showed high variation in SOC stocks in farmland, ranging from moderately high values in certain wetter parts of the country to low SOC stocks in dry regions, with SOC in farmland generally lower than in neighbouring natural habitats. An exception was made for wetlands, which were estimated to have very high SOC stocks in previous work (Willcock *et al.*, 2012; GoU, 2020b), based on case studies of papyrus swamps in East Africa (Jones MB & Muthuri FM, 1997). This localised phenomenon was not fully captured in the GSOC map, hence the use of the alternative estimate.

Mean carbon stocks per land cover were then mapped down to district-level in ArcGIS, based on the stock estimates for the four different carbon pools (AGB, BGB, SOC and dead organic matter) which were calculated as described above. Estimated carbon storage by ecosystem type is shown in Table 4.34. Forest was estimated to have the highest carbon storage per hectare, followed by wetlands, due to organic rich wetland soils. Excluding water and bare areas (mostly bare rock hence no soil carbon estimate), farmland was estimated to have the lowest carbon storage per hectare. Built-up areas had comparatively higher carbon storage values due to the presence of urban trees.

Table 4.34. Mean carbon storage per hectare in aboveground biomass (AGB), belowground biomass (BGB), deadwood and litter, and Soil Organic Carbon (SOC) by ecosystem type. Sources: Drichi, 2002; IPCC, 2006; NFA, 2009; FAO & ITPS, 2018; GoU, 2020b.

Ecosystem	Mean AGB (tC/ha)	Mean BGB (tC/ha)	Deadwood and litter (tC/ha)	Mean SOC (tC/ha)	Total Carbon (tC/ha)
Open Water	0.0	0.0	0.0	0.0	0.0
Wetland	0.2	0.3	5.7	148.2	154.5
Grassland	3.2	5.1	0.8	55.8	65.0
Bushland	4.6	1.8	15.0	54.4	75.8
Woodland	*16.1*	4.5	21.1	59.7	101.4
Forest	111.6	59.4	12.8	73.6	257.3
Plantation	49.3	18.2	5.3	57.0	129.9
Farmland	2.1	0.6	0.3	54.7	57.6
Built-up	11.8	4.6	0.0	50.3	66.7
Bare	0.0	0.0	0.0	0.0	0.0

VALUATION IN MONETARY TERMS

There are at least three possible ways of estimating the value of carbon sequestered or retained:

i. the market value of that carbon revealed in the trade of carbon credits;
ii. the marginal abatement cost of carbon, which is the avoided costs incurred in meeting carbon reduction targets through changes in technology; or
iii. the avoided damages by the contribution of that carbon to climate change, termed the "social cost of carbon" (SCC).

Market prices can be used in the accounts, where carbon credits have been sold in return for adopting cleaner technologies or securing carbon in ecosystems. However, since carbon storage and sequestration is still largely a public good and markets are not fully developed, this will result in an undervaluation of the ecosystem services.

The marginal cost of abatement (the cost of implementing technology changes to reduce emissions from industry and other sources) is an estimate of the costs avoided for countries that have to meet emissions reductions targets. This is one of the preferred methods for valuing carbon in project and policy analysis in the North. For example, one might want to compare the value of restoring a degraded forest in terms of carbon gains with what would otherwise have to be spent to reduce carbon emissions by the same amount. The value is calculated by estimating the value of each next most affordable means of reducing carbon up to the point at which the target is met. The cost per unit reduction at that point is the marginal abatement cost used. For example, in the United Kingdom, this value is between £124 and £373 per tonne of CO_2 emitted in 2022 (and rising over time).[19].

The social cost of carbon is based on estimates of the total cost to society of each extra tonne of CO_2 emitted, based on estimates of the total cost of climate change impacts. The SCC is the discounted present value of the cumulative impact of one additional ton of carbon dioxide emitted into the atmosphere today over its residence time in the atmosphere (Watkiss *et al.* 2005). The calculation is typically done over a time frame of 100 years. The value is typically estimated in terms of reductions in GDP, which is a directly compatible measure for ecosystem accounting. Estimates of SCC vary depending on the choice of climate models, the approach to valuing damages and the discount rate used and range from about US$10 to over US$1000/tCO_2. By 2008, there were at least 232 published estimates of SCC, the average of which was about US$33/t$CO_2$ (Tol 2008). In an effort to refine these estimates, the more recent literature has also tended to broaden the types of damage costs considered, increasing the estimates of SCC.

It should be noted that the damage costs per tCO_2 also increase in real terms over time, as populations and per capita incomes grow, and thus it is strictly correct to see the estimate being specified in terms of the year of emission. For example, using the Dynamic Integrated model of Climate and the Economy (DICE) model, Nordhaus (2017) provided updated estimates of the SCC for a ton of CO_2 emitted in 2015 (US$31.25/t$CO_2$ in 2010 US$) and also for CO_2 emissions in a range of future years. These values increased at a real growth rate of 3% per year. The SCC estimate should therefore correspond to the year of the account, as carbon retained in the environment will increase in real value over time.

More recent studies have also attempted to disaggregate these global SCC estimates to regional or country level. For example, Nordhaus (2017) provided an updated estimate of global SCC as

[19] Valuation of greenhouse gas emissions: for policy appraisal and evaluation - GOV.UK (www.gov.uk)

US$31/t$CO_2$ and estimated that 3% of this would be borne in Africa. Ricke *et al.* (2018) estimated the global SCC as US$417/t$CO_2$, and disaggregated this to country-level, with the estimated cost to Uganda being US$0.84/t$CO_2$.

For this account, carbon retention was valued in terms of the annualised global SCC, based on the modest estimates of Nordhaus (2017). The SCC estimates were adjusted at a rate of 3% per year to derive prices for 1990 and 2015, which in 2010 US$ were 2015 = 31.25, 1990 = 14.93. However, for the supply and use tables, values must be determined for the year in question. Thus, the annualised social cost of carbon (ASCC) was then estimated as:

$$ASCC = \frac{(\delta * SCC)}{(1-(1+\delta)^{-t}}$$

where δ is the discount rate, and t is the time period of the SCC calculation in years. For this study, it was assumed t = 100 years, and a social rate of discount of 4.06% was used.

RESULTS

After making the adjustment to the 1990 land cover described above, it was estimated that total carbon retention in Uganda decreased from 2171 Megatonnes (Mt) in 1990 to 1943 Mt in 2015 (Table 4.35; Table 4.36), representing a loss of 10.5% of the carbon stored in the country over this period. Given the reported trends in the extent of high biomass habitats in Uganda (such as forest, woodland and wetlands), this appears to be a much more credible result than the initial estimate of a 0.2% decline in carbon storage before the adjustment to the wetland area in 1990 had been made. The carbon estimates need to be further improved by incorporating measures of ecosystem health, particularly for wetlands, which could have a major effect on how much carbon is actually stored.

The spatial variation in ecosystem carbon is shown in Figure 4.17. Areas with the highest carbon retention values correspond with forest and wetland ecosystems. In many areas, there is a visible blockiness to the map associated with district boundaries. This is due to the different biomass per hectare estimates at district level derived from the National Biomass Survey (Drichi, 2002; NFA, 2009)

The value of carbon retention is estimated to have increased from UGX 4.8 trillion in 1990 to 9.1 trillion in 2015 (constant 2017 UGX; Table 4.37; Table 4.38). This increase is partly due to the slight overall increase in carbon stocks, but is largely as a result of the real increase in value of carbon over time. The value of this service is recorded as accruing to government, as they can participate voluntarily in the international carbon markets and sell carbon credits.

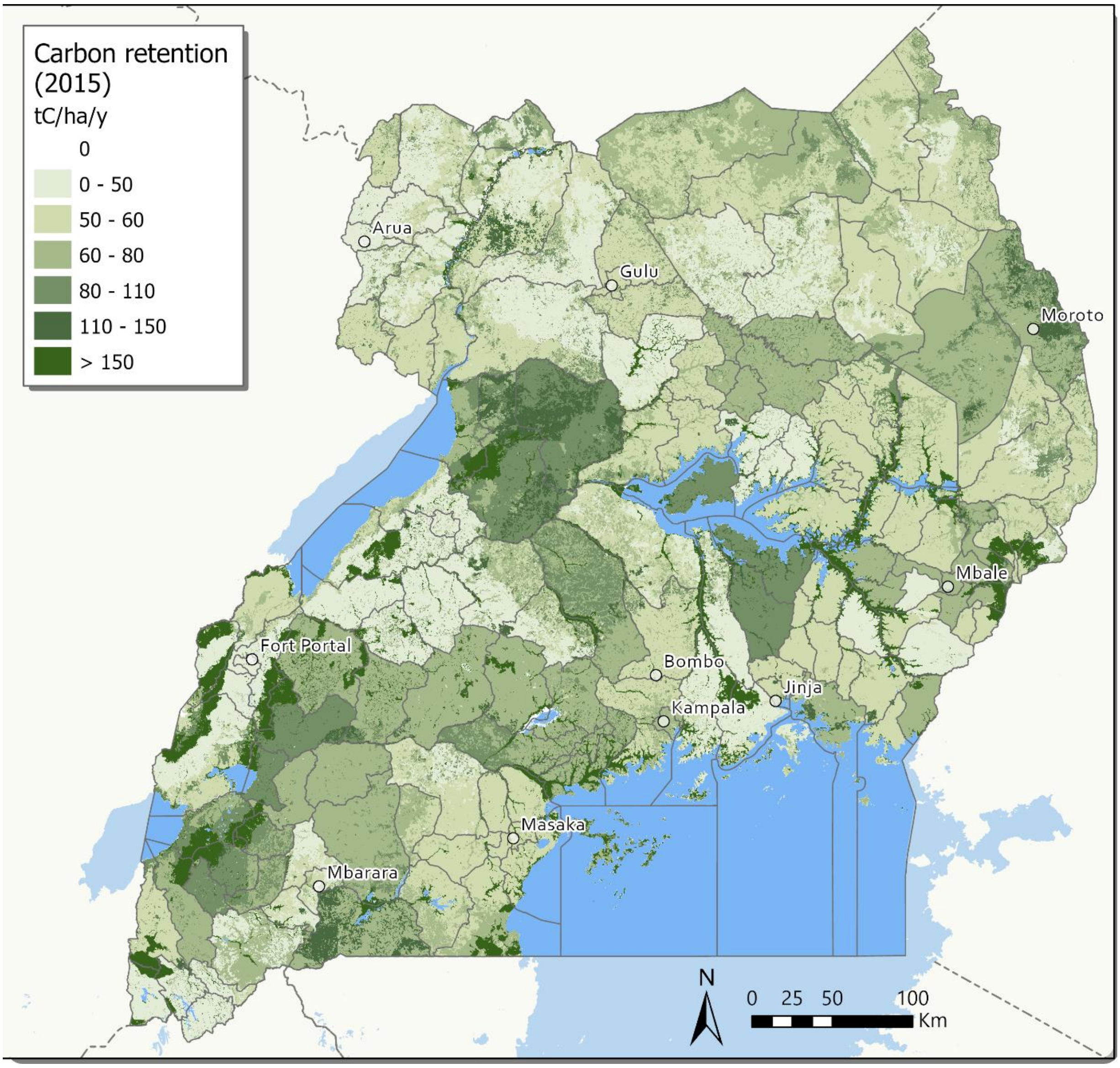

Figure 4.17. Carbon stored in above ground biomass, below ground biomass, soil and dead organic matter across Uganda in 2015, in tonnes/ha/year.

Table 4.35. Physical supply and use table of carbon retention, for 1990

	Economy				Ecosystem										
Physical supply 1990	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Carbon retention (Mt)	-	-	-	-	0	346	505	124	369	293	4	527	2	0	2 171
Physical use 1990															
Carbon retention (Mt)	0	2 171	0	2 171	-	-	-	-	-	-	-	-	-	-	-

Table 4.36. Physical supply and use table of carbon retention, for 2015

	Economy				Ecosystem										
Physical supply 2015	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Carbon retention (Mt)	-	-	-	-	0	524	321	147	122	195	15	611	9	0	1 943
Physical use 2015															
Carbon retention (Mt)	0	1 943	0	1 943	-	-	-	-	-	-	-	-	-	-	-

Table 4.37. Monetary supply and use table for carbon retention, for 1990; values in constant 2017 UGX billions

	Economy				Ecosystem										
Monetary supply 1990	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Carbon retention	-	-	-	-	0	772	1 126	276	824	653	10	1 175	5	0	4 840
Monetary use 1990															
Carbon retention	0	4 840	0	4 840	-	-	-	-	-	-	-	-	-	-	-

Table 4.38. Monetary supply and use table for carbon retention, for 2015; values in constant 2017 UGX billions

	Economy				Ecosystem										
Monetary supply 2015	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Carbon retention	-	-	-	-	0	2 445	1 499	686	567	908	68	2 850	41	0	9 064
Monetary use 2015															
Carbon retention	0	9 064	0	9 064	-	-	-	-	-	-	-	-	-	-	-

SOIL AND SEDIMENT RETENTION SERVICES: SOIL EROSION CONTROL

OVERVIEW

Soil erosion control services are "the ecosystem contributions, particularly the stabilising effects of vegetation, that reduce the loss of soil (and sediment) and support use of the environment (e.g. agricultural activity, water supply)" (UN et al. 2021).

Agricultural expansion, encroachment into natural wetlands and the removal of natural vegetation result in elevated levels of erosion and subsequent increases in sediment loads being carried downstream. These sediments are then deposited in downstream rivers, lakes and reservoirs, reducing their depth and storage capacity. Elevated loads of suspended sediments also contribute to water quality problems and increase wear and tear on hydropower generation structures (Pimentel *et al.*, 1995). The extent to which sediments end up in river systems is determined by several factors including soils, rainfall patterns (amount and intensity), slope and the type and amount of vegetative cover. Vegetative cover prevents erosion by stabilizing soil and by intercepting rainfall, thereby reducing its erosivity. This is particularly valuable where soils are highly erodible. Vegetated areas, especially wetlands, 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 (Gathagu, Sang & Maina, 2018). While some level of sedimentation of reservoirs is expected under natural conditions and planned for, elevated catchment erosion either incurs dredging costs or shortens the projected lifespan of reservoirs and related infrastructure. Globally, anthropogenic sedimentation has been estimated to account for about 37% of the annual costs of reservoirs (i.e. $21 billion) in terms of replacement costs (Basson, 2010). In urban contexts, elevated sediment loads also have to be removed from sewerage systems, storm water drainage systems and harbours.

In this account, sediment retention services are measured in terms of the avoided export of sediment to rivers and lakes relative to a no-service scenario, measured in cubic metres of sediment. The service is usually valued using the avoided costs or replacement cost approach. In this account, sediment retention services are valued in terms of the avoided costs of constructing measures to prevent damaging sediments from reaching waterbodies where the service would be demanded.

DATA AND METHODS

PHYSICAL MODELLING OF SEDIMENT RETENTION

Sediment outputs were modelled using the InVEST Sediment Delivery Ratio (SDR) model. The model first estimates potential annual soil loss from each 100 m pixel using the Universal Soil Loss Equation (USLE) (Wischmeier & Smith, 1978), which requires information on topography, rainfall erosivity, soil erodibility and land cover. Rainfall erosivity was mapped using the global layer produced by Panagos *et al.* (2017). Soil property data (sand, silt, clay and organic matter content obtained from the Africa Soil Information Service (AfSIS) (Hengl *et al.*, 2015). Soil erodibility was calculated from these various soil properties through the same equations used in the soil erosion risk assessment of Uganda by Karamage *et al.* (2017). Cover management and support practice factors for the different land cover classes were based on prior InVEST modelling work (GoU, 2020b) with some modifications. Potential soil loss from each pixel is then multiplied by the SDR which has a value between 0 and 1. The SDR estimates the proportion of eroded soil from each pixel which actually ends up reaching a watercourse, after accounting for downslope deposition. The SDR is also calculated on a per pixel level and varies as a function of the intervening topography and land cover between a given pixel and the nearest watercourse. The model thus incorporates both the ability of vegetation cover to reduce erosion in the first place, as well as the ability of vegetation to capture and retain sediment eroded upslope.

Sediment export was firstly modelled for existing land cover in 1990 and 2015. To estimate the sediment retention service provided by ecosystems, sediment export from a bare landscape was then modelled by adjusting the cover management factors for all land cover classes (excluding built-up areas) to reflect the total absence of vegetation cover. Built-up areas were not modified in the bare scenario, as the change in sediment export with the removal of built infrastructure was not considered relevant for ecosystem accounting purposes. The amount of sediment retained by ecosystems was then calculated by subtracting modelled sediment export in 1990 and 2015 from sediment export in the bare landscape scenario.

MAPPING OF THE DEMANDED SERVICE

To identify where the service was demanded, dam locations were obtained from the MWE. Since some dams appeared to be missing from the dataset, additional dam locations were added through reference to satellite imagery, WWF HydroLAKES and GIS data on the location of hydropower stations in Uganda. In addition to dams, it was considered that sedimentation could present a threat to smaller and/or shallower lakes. Avoided sedimentation was thus also valued for most natural waterbodies. Lakes Victoria, Albert and Edward were excluded, as it was assumed that the greater size and depth of these lakes would result in a negligible influence of sedimentation on storage capacity. The catchment areas for dams and selected lakes were delineated using the InVEST DelineateIT tool.

VALUATION

The value of the soil and sediment retention service within the dam and lake catchment areas was estimated using the replacement cost of lost storage capacity through measures such as raising the dam wall, constructing a substitute dam at a new site to recover the lost capacity or constructing check dams to prevent sediment entering the dam or lake. This was done by estimating the amount of storage that would have to be constructed to prevent a similar amount of sediment from reaching downstream aquatic environments, using an average capital replacement cost of UGX 4532 per m^3 (UGX 2017, Mekonnen *et al.*, 2015). The modelled mass of sediment was converted to volume using a sediment bulk density of 1.35 t/m^3 (Rooseboom 1992, Haarhoff & Cassa 2009). The sediment retention service of each pixel was then valued based on the amount of avoided sediment export on each pixel.

Soil retained in farmland is also of value to farmers, as the loss of soil would lead to reduced production. However, the value of this soil is already captured in the ecosystem contribution to crop production, so is not valued here to avoid double counting.

RESULTS AND DISCUSSION

It was estimated that mean sediment export across Uganda increased from 10.0 t/ha/year in 1990 to 11.8 t/ha/year in 2015, reflecting the expansion of agriculture at the expense of less erosion-prone natural land cover classes. Conversely, the amount of sediment retained relative to a bare landscape declined from 201.6 t/ha/year in 1990 to 198.6 t/h/year in 2015. In other words, sediment export would have been around 20.1 times higher in 1990 and 16.8 times higher in 2015, in the total absence of vegetation cover. A map of sediment retention (tons/ha/y) in 2015 is shown in Figure 4.18. Sediment retention is generally highest in steep and/or high rainfall areas which have the highest potential soil erosion risk, meaning sediment export would be very high in the absence of vegetation cover.

Within dam and selected lake catchment areas specifically, it was estimated that the presence of vegetation reduced sediment export by some 1254 million tonnes in 1990 and 1477 million tonnes in 2015. The increase in avoided sediment export from 1990 to 2015 reflects an increase in the use of the service, not the change in overall service capacity, which would have decreased. Over this period, the number of dams in Uganda increased, resulting in a 10.6% increase in the area over which the sediment retention service was demanded. Interestingly, the average amount of sediment retained by vegetation within dam and lake catchments also increased from 180.6 t/ha in 1990 to 192.2 t/ha in 2015, even though average sediment retention across Uganda overall decreased with the conversion of natural habitats to cultivation. This increase in sediment retention/ha can be explained by the construction of dams between 1990 and 2015 in areas with high erosion potential (e.g. western Uganda), resulting in high sediment retention values in these new dam catchment areas.

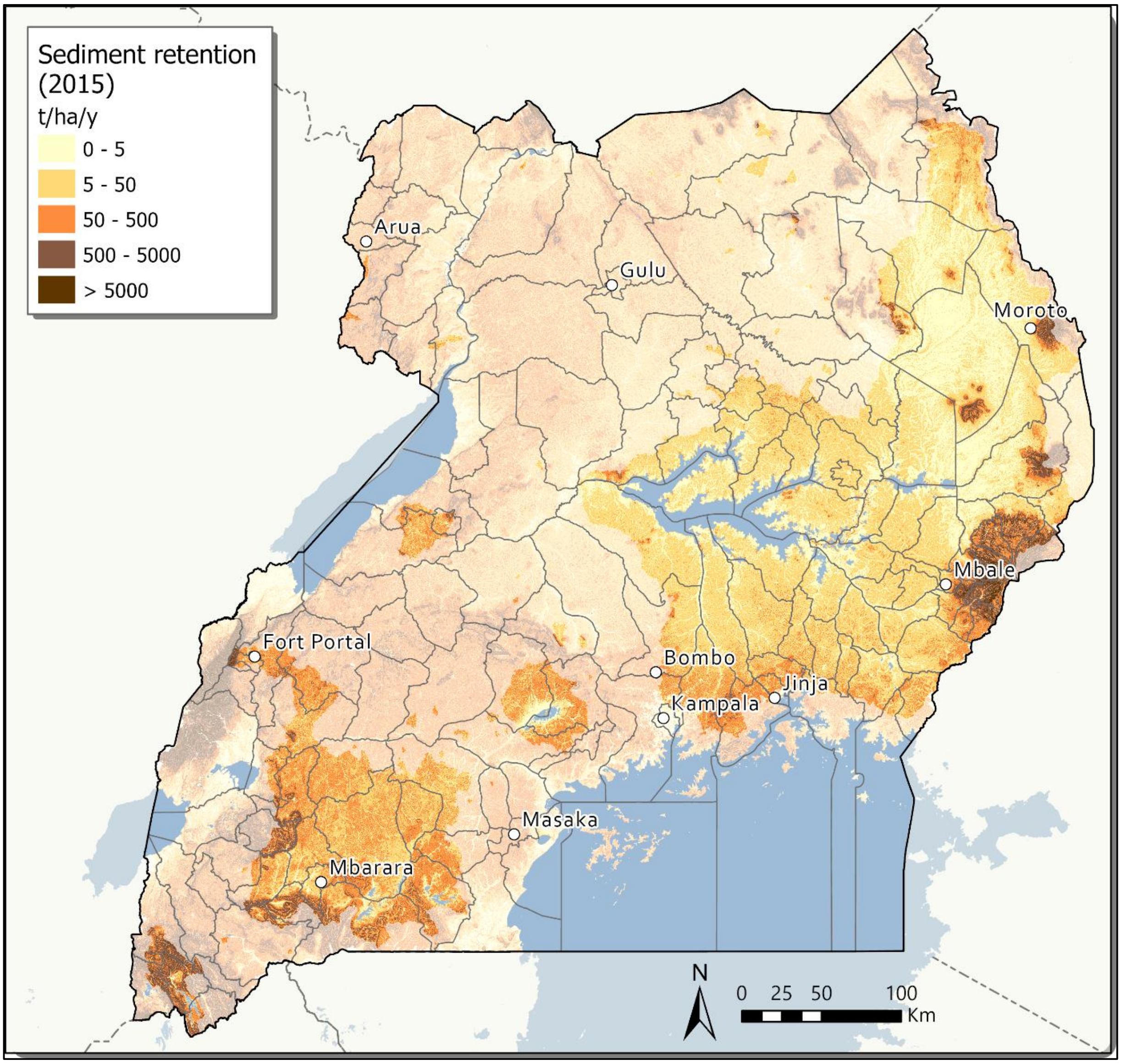

Figure 4.18. Estimated average sediment retention across Uganda in 2015, relative to a barren catchment, in tonnes/ha/year.

The value of sediment retention by natural vegetation and cultivated land was estimated to be UGX 4.21 billion in 1990 and UGX 4.96 billion in 2015 (constant 2017 UGX; Table 4.41; Table 4.42). The increase in the value of the service is largely due to the higher number of dams in 2015, which increased the area over which the sediment retention service was demanded.

Table 4.39. Physical supply and use table of sediment retention services, for 1990

	Economy				Ecosystem										
Physical supply 1990	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Sediment retention (million m^3/y)	-	-	-	-	0	5	143	62	113	210	2	395	0	0	929
Physical use 1990															
Sediment retention (million m^3/y)	929	0	0	929	-	-	-	-	-	-	-	-	-	-	-

Table 4.40. Physical supply and use table of sediment retention services, for 2015

	Economy				Ecosystem										
Physical supply 2015	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Sediment retention (million m^3/y)	-	-	-	-	0	8	175	78	87	214	9	522	0	0	1 094
Physical use 2015															
Sediment retention (million m^3/y)	1 094	0	0	1 094	-	-	-	-	-	-	-	-	-	-	-

Table 4.41. Monetary supply and use table of sediment retention services, for 1990; values in constant 2017 UGX (billions)

	Economy				Ecosystem										
Monetary supply 1990	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Sediment retention	-	-	-	-	0	22	648	280	514	951	9	1 789	0	0	4 212
Monetary use 1990															
Sediment retention	4 212	0	0	4 212	-	-	-	-	-	-	-	-	-	-	-

Table 4.42. Monetary supply and use table of sediment retention services, for 2015; values in constant 2017 UGX (billions)

	Economy				Ecosystem										
Monetary supply 2015	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Sediment retention	-	-	-	-	0	37	794	355	396	968	43	2 366	0	0	4 959
Monetary use 2015															
Sediment retention	4 959	0	0	4 959	-	-	-	-	-	-	-	-	-	-	-

WATER QUALITY REGULATION: NUTRIENT RETENTION

OVERVIEW

Water quality regulation services are "the ecosystem contributions to the restoration and maintenance of the chemical condition of surface water and groundwater bodies through the breakdown or removal of nutrients and other pollutants by ecosystem components that mitigate the harmful effects of the pollutants on human use or health" (UN et al., 2021). As a final service to raw water users, it can be measured in terms of the quantity of anthropogenically introduced pollutants removed, and is valued in terms of avoided costs, such as costs to human health or increased water treatment costs. It can also be valued as an intermediate service to the supply of other ecosystem services (e.g. fish) from downstream aquatic ecosystems. In these accounts, we estimate the final ecosystem service value of nutrient removal to raw water users.

Water purification is closely related to the sediment retention service, in that suspended sediments are an element of water quality, and nutrients such as phosphorous which attach to sediments can be prevented from reaching downstream ecosystems as a result of sediment retention. This section focuses on the retention of nutrients.

While there is a natural level of nutrient deposition and transport (e.g. from the atmosphere and nitrogen fixation - Nkonya et al., 2004; Zhou et al., 2014) that helps to sustain healthy ecosystems, it is the anthropogenic increase in this level that can lead to damages. These anthropogenic additions, typically from waste water and the application of manure and fertilizers to farmland (Odada et al., 2004), result in the eutrophication of downstream water bodies. Increased phosphorus is typically the problem in freshwater systems, where this nutrient is naturally limiting. The increase in nutrients leads to higher abundance of phytoplankton, and ultimately the development of toxic algal blooms. This reduces the ecological value and productivity of river, wetland and lake systems. Where this occurs in raw water sources for water treatment works, it requires increased use of chemical flocculants such as aluminium phosphate ("alum"), dredging of settlement ponds and backwashing of filters with treated water, all of which also increase labour and energy requirements.

Natural ecosystems can intercept and remove some of the additional nutrients in the landscape introduced by human activities before they enter downstream water bodies, limiting the damages caused. Wetlands are generally regarded as the most efficient natural system for removing pollutants (Turpie et al., 2016), but forests and other terrestrial vegetation types also have the capacity for water quality amelioration, particularly in the buffer zones between agricultural landscapes and river systems, removing a high percentage of sediments and nutrients from surface and subsurface flows (Mayer et al., 2007; Liu et al., 2008; Zhang et al., 2010; Sweeney & Newbold, 2014).

DATA AND METHODS

PHYSICAL MODELLING

The water quality amelioration service was estimated using the InVEST Nutrient Delivery Ratio (NDR) model. This combines measures of nutrient input across the landscape, retention capacities for the various land cover classes and the characteristics of downslope pathways to determine the mass of nutrients that is eventually exported into watercourses. In addition to the basic inputs for the seasonal water yield model, the model also required inputs on the nutrient (phosphorous) additions to each pixel in kg/ha/year. Only cropland and urban ecosystems were attributed phosphorus inputs to emulate anthropogenic additions to the landscape. Atmospheric deposition and other natural additions that might occur were omitted. Nutrient loads for farmlands were estimated using fertilizer application data from the Annual Agricultural Survey (UBOS, 2020c) and MAAIF report on fertilizer consumption and fertilizer use by crop in Uganda (Godfrey & Dickens, 2015), and crop residue data from the Land and Soil Improvement Accounts for Uganda (NEMA, 2021a). The use of fertilizer varies both between commercial and small-scale agriculture and across Uganda, thus farmland was reclassified by farmland type (commercial or small-scale) and ZARDI and allocated a specific nutrient load value in line with the available data. Nutrient loads for urban areas were estimated based on available literature relevant to Uganda or areas with conditions that most closely matched those in Uganda (Bagstad *et al.*, 2020; Sharp *et al.*, 2020; Turpie *et al.*, 2021). In contrast to farmland, these load values were kept constant across the country, in the absence of sufficient local data to justify variation by area (Leh et al., 2013; Bagstad et al., 2020). Each pixel's land cover specific nutrient load value was then modified to account for local runoff potential. A runoff proxy raster was acquired from the seasonal water yield module of InVEST.

Estimation of nutrient retention capacities required a nutrient retention coefficient to be assigned to each landcover class, which varied between 0 (no retention) and 1 (complete nutrient retention). Natural vegetation types generally have higher nutrient retention efficiencies than cultivated land, while urban areas have very low nutrient retention. These values were estimated based on literature relevant to Uganda or areas with conditions that most closely matched those in Uganda (Bagstad *et al.*, 2020; Sharp *et al.*, 2020; Turpie *et al.*, 2021) The next step in the model incorporated characteristics of the downslope pathway for each pixel to emulate the movement of the nutrients across the landscape to determine the final annual export, or nutrient delivery, into watercourses. This involved calculation of the nutrient delivery ratio (NDR), which is a function of a) the phosphorous retention efficiency of downslope pixels and b) an index of hydrological connectivity based on topography.

The total phosphorus retained by the natural landscape was calculated as the difference between the load of phosphorus that was exported from each cropland and urban pixel, and the load that was eventually exported to a watercourse. Three measures were applied to ensure this retention service was attributed to the appropriate pixels of natural landcover. Firstly, all retention calculations were performed at the level of each of the 2016 level-12 hydrobasins across Uganda (Lehner & Grill, 2013). Secondly, only natural pixels at elevations below the maximum cropland and urban pixels were considered. These conditions ensured natural pixels could only retain phosphorous loads from urban and cropland pixels that were upslope within the same watercourse. Thirdly, the total retained phosphorus was spread across the natural pixels according to the retention efficiency of their respective landcover class. The total annual retained phosphorous was limited to 77 kg per ha, based on studies of the removal rate of papyrus-dominate wetlands around Lake Victoria (Kansiime & Nalubega, 1999).

ESTIMATED DEMAND AND VALUATION

It was assumed that demand for the service is limited to the catchment areas of lakes and dams as the main sources of water supply. Catchment areas for lakes and dams in 1990 and 2015 were thus delineated using the InVEST DelineateIT tool. The nutrient retention rasters for 1990 and 2015 were then clipped to the extent of these catchment areas.

Water quality purification in dam and lake catchment areas was valued by estimating the cost of treatment wetlands, which provides an approximation of the replacement cost if no purification were being performed by natural ecosystems. For this study, the costs were based on a recent study which investigated the feasibility of constructing a treatment wetland on the former Nakivubo wetland area, among other investments (Turpie *et al.*, 2016), which used estimates of costs and nutrient uptake rates from a review other such projects. This suggested that using treatment wetlands to address nutrient pollution would cost approximately USD 15.68 per kgP/y.

RESULTS

The spatial variation in nutrient retention by natural ecosystems is shown in Figure 4.19 Areas performing the water quality purification service (*i.e.* with a phosphorous retention value greater than zero) represent natural ecosystems located downstream of farmland and/or built-up areas. High nutrient retention is associated with natural habitats situated in areas otherwise dominated by cultivation with high levels of fertiliser use, such as natural habitats fringing Lake Victoria and wetlands in the western part of the Lake Kyoga system. Nutrient retention by these ecosystems has a direct impact on reducing nutrient pollution of these key surface water sources.

The total amount of phosphorous removed by natural ecosystem in dam and lake catchment areas increased slightly from 3.37 million t in 1990 to 3.50 million t in 2015 (Table 4.43; Table 4.44). Even though the extent of natural ecosystems declined over this period, this was outweighed by the increase in the amount of phosphorous removed per hectare of remaining natural area, since the expansion of cultivated and built-up areas significantly increased the overall export of phosphorous in 2015.

The service was estimated to be worth UGX 201 billion in 1990 and UGX 209 billion in 2015 (Table 4.45; Table 4.46. Wetlands accounted for the highest share of this value in 2015. Their lower share in 1990 is likely an artefact of the fact that wetlands were underrepresented in the 1990 land cover.

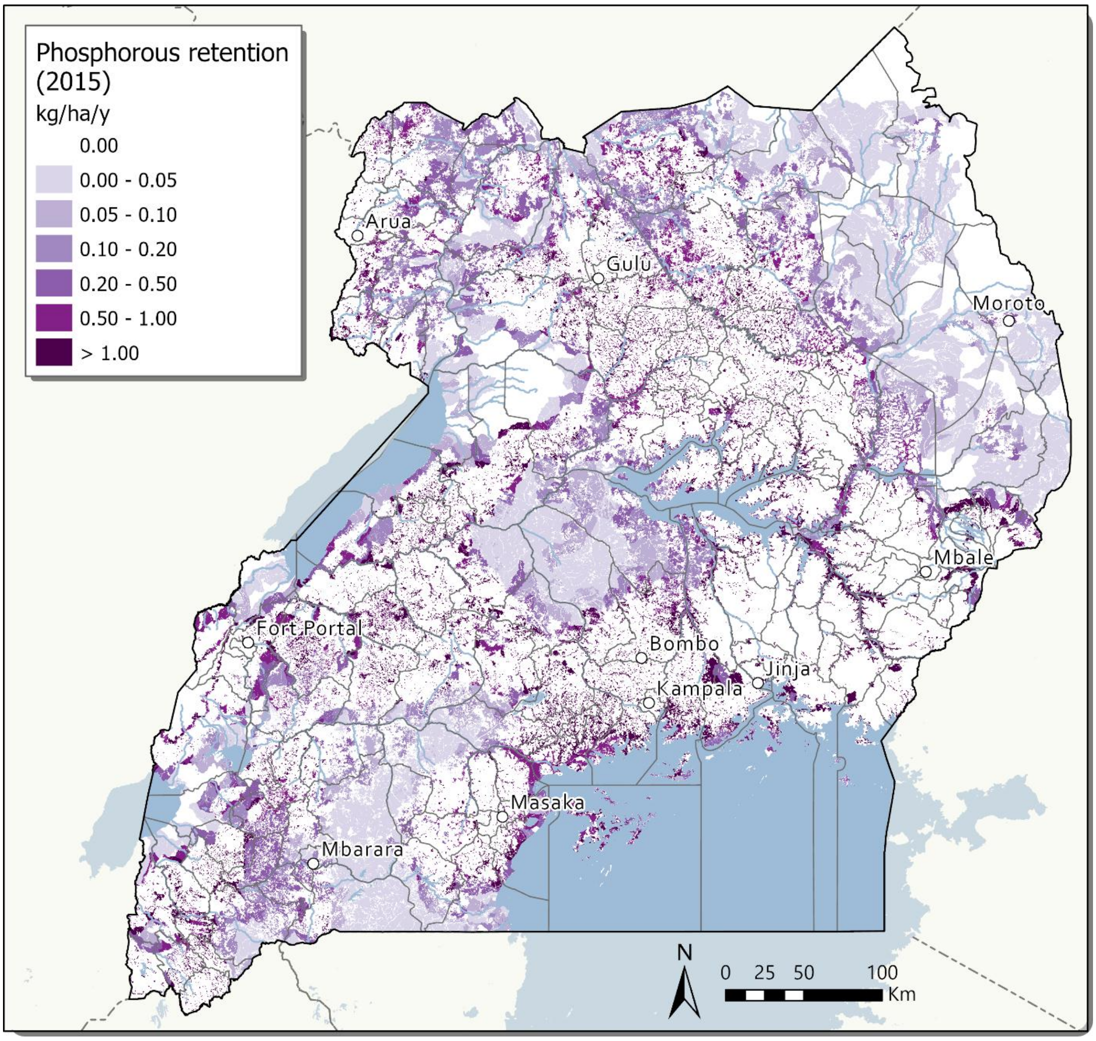

Figure 4.19. Estimated spatial variation in the uptake of anthropogenically-generated phosphorous by ecosystems in 2015, in kg/ha/year.

Table 4.43. Physical supply and use table of phosphorus retention, for 1990

	Economy				Ecosystem										
Physical supply 1990	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Phosphorus (kt/y)	-	-	-	-	0	543	1 110	381	663	582	87	0	0	0	3 366
Physical use 1990															
Phosphorus (kt/y)	3 366	0	0	3 366	-	-	-	-	-	-	-	-	-	-	-

Table 4.44. Physical supply and use table of phosphorus retention, for 2015

	Economy				Ecosystem										
Physical supply 2015	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Phosphorus (kt/y)	-	-	-	-	0	1 103	557	864	258	468	254	0	0	0	3 504
Physical use 2015															
Phosphorus (kt/y)	3 504	0	0	3 504	-	-	-	-	-	-	-	-	-	-	-

Table 4.45. Monetary supply and use table of phosphorus retention, for 1990; values in constant 2017 UGX (billions)

	Economy				Ecosystem										
Monetary supply 1990	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Water quality	-	-	-	-	0	32	66	23	40	35	5	0	0	0	201
Monetary use 1990															
Water quality	201	0	0	201	-	-	-	-	-	-	-	-	-	-	-

Table 4.46. Monetary supply and use table of phosphorus retention, for 2015; values in constant 2017 UGX (billions)

	Economy				Ecosystem										
Monetary supply 2015	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Water quality	-	-	-	-	0	66	33	52	15	28	15	0	0	0	209
Monetary use 2015															
Water quality	209	0	0	209	-	-	-	-	-	-	-	-	-	-	-

WATER FLOW REGULATION SERVICES

OVERVIEW

Water flow regulation services are defined here as the ecosystem contributions to the regulation of the timing of surface, subsurface and groundwater flows into rivers and lakes through mediating the infiltration of rainwater, affecting the seasonal variation in flows and water levels, and hence the accessibility of water to users[20]. Note that while the underlying processes for this service may also contribute to flood control, the latter is recorded as a separate service. The service is usually best quantified in physical terms as the amount of rainfall infiltrating into the ground. It is typically valued in terms of the cost savings in obtaining water for use, such as reduced infrastructure costs and/or reducing the necessity to purchase water during the dry season, relative to a scenario without this service. This is a final ecosystem service to water service providers and water users that obtain their water directly from ecosystems.

During rainfall events, some water soaks into the ground, while the balance runs off the surface ('quickflow'). Some of the former is lost due to evaporation from the soil or evapotranspiration by plants. Of the remainder (the 'net infiltration'), some emerges at springs to join streams and rivers ('baseflows'), while some replenishes groundwater or aquifers ('groundwater recharge'). The balance between quickflow and infiltration varies considerably across the landscape and is mediated to some extent by ecosystems. Vegetation slows down surface flows and facilitates the infiltration of rainfall into the ground, reducing the proportion of rainfall that runs off the surface during rainfall events. In this way, ecosystems can reduce seasonal variation in flows relative to the seasonal variation in rainfall. This can affect the cost of surface or groundwater supply by water utilities and/or the cost of collecting water (for households not supplied by infrastructure). In general, the more variable the runoff, the larger the built storage capacity required to meet water demands during low flow seasons (for small dams) or drier years (for large dams, Guswa et al. 2017; Vogel et al. 1999, 2007). Small dams and run-of-river users are particularly sensitive to seasonal variation in flow. The ecosystem capacity for the service depends on a range of contextual factors such as slope, geology, rainfall pattern, evaporation, evapotranspiration, groundwater depth, etc.

Water supply systems are engineered to the way in which surface and groundwater flows vary across the landscape, as can be seen from the variation in how water is collected. However, if land use or climate changes lead to a decrease in infiltration, this can result in increased quickflow, leading to a reduction in dry season flows, and/or the availability of groundwater and increased costs of storing and extracting water (in addition to increased risk of flood damages). Given that groundwater is the main source of water for rural households in Uganda, as well as the fact that built water storage infrastructure is very limited, the focus here is on the regulation of groundwater recharge by ecosystems, rather than the seasonal moderation of river flows.

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[20] Note that the rest of the SEEA EA definition "They are derived from the ability of ecosystems to absorb and store water, and gradually release water during dry seasons or periods through evapotranspiration (sic) and hence secure a regular flow of water" is incorrect WHY?. Table 6.3 also inappropriately includes peak flow mitigation as a flow regulation service as well as having a separate service called flood control services. Personally I agree with this point. We attempt a better definition of flow regulation in the text that is about the regulation of the timing of water flows affecting their availability for use, and note that while the underlying processes contribute to both, flood control is a separate service.

The landscape capacity to regulate annual groundwater recharge was mapped using the InVEST Seasonal Water Yield (SWY) model, which takes land cover into account. To estimate the ecosystem contribution to enhancing groundwater recharge, groundwater recharge was modelled for a bare land scenario. The difference in groundwater recharge between the bare ground scenario relative to under 1990 and 2015 land cover, was then used to value the contribution of ecosystems to enhancing groundwater recharge in the two accounting years. Only the ecosystem contribution to demanded groundwater recharge was valued, based on the groundwater abstraction estimates provided in the Water Accounts (UBOS, 2019, 2021). The final service flow mapped in physical terms was thus the ecosystem contribution to demanded groundwater recharge. This was valued using a replacement cost, based on the cost of construction dams to store an equivalent amount of water to the additional recharge facilitated by ecosystems.

DATA AND METHODS

The mapping of the contribution of ecosystems to groundwater recharge within each drainage basin was done using the InVEST SWY model, as capacity to supply the service. Demand for the service was based on data on groundwater use by different actors obtained from the Water Accounts (UBOS, 2019) for 2015-2018. This was used in conjunction with census and land use data to estimate groundwater abstraction in 1990 and 2015 within each drainage basin.

PHYSICAL QUANTIFICATION OF THE SERVICE CAPACITY

The InVEST Seasonal Water Yield (SWY) model was selected because it is suited to modelling hydrological processes at large-scale in data-poor environments, with relatively simple parameter requirements. The SWY model is nevertheless somewhat more complex and nuanced than the InVEST Annual Water Yield model which was used in previous ecosystem accounting work in Uganda (GoU, 2020b). An advantage of the SWY model is that it partitions flows into quickflow and “baseflow”. Quickflow refers to rainfall which runs off during or immediately after rainfall events, without infiltrating into the soil. In contrast, “baseflow” refers to the remaining amount of precipitation that infiltrates as soil or groundwater, after accounting for quickflow runoff and evapotranspiration losses. The baseflow component thus captures the contribution of the landscape to groundwater recharge and dry season streamflow, and is the measure of interest for estimation of the groundwater recharge regulation service. The SWY model outputs the annual contribution of each 100 m pixel to baseflow in mm, which can then be converted to m^3 of water per pixel and summed to give total m^3 per basin.

The SWY model calculates quickflow using a Curve Number (CN)-based approach, which estimates runoff potential based on the land cover and soil characteristics of each pixel. Local recharge on each pixel is then calculated as precipitation minus quickflow and evapotranspiration.. Evapotranspiration is calculated on a monthly basis and is limited either by the potential evapotranspiration of each pixel (*i.e.* water demand by soil and vegetation) or the available water generated on the pixel and from upslope areas (where applicable). Potential evapotranspiration is calculated by multiplying the crop evapotranspiration coefficient (Kc) by reference evapotranspiration (ET_0). Kc values express the ratio of actual evapotranspiration to reference evapotranspiration (Liu *et al.*, 2017). Pixels with positive local recharge values are included in the estimation of baseflow, while pixels where local recharge is zero or negative are assigned baseflow value of zero. Zero values for local recharge occur where all water runs off without infiltrating (*e.g.* over bare rock) or where evapotranspiration is very high. Negative values for local recharge can occur where evapotranspiration is greater than precipitation on a cell. This can occur for waterbodies as well as in vegetation types with high evapotranspiration rates where supplementary subsurface water is received from upslope areas.

Given the diversity of climatic and hydrological conditions in Uganda, the land cover map was firstly divided into more detailed classes through combination with the potential natural vegetation map (PNV) of East Africa (van Breugel *et al.*, 2015). To do so, the PNV map was generalised into the five biomes used by Langdale-Brown, Osmaston & Wilson (1964), namely forest, moist savanna, dry savanna, wetland and other (waterbodies). This allowed for woodland, bushland and grassland to be split into moist and dry types, while farmland was split into forest, moist and dry savanna and wetland types. Different curve number and evapotranspiration coefficients could then be assigned to the more disaggregated land cover classes.

Curve numbers were estimated based on those used for comparable vegetation types in other studies (USDA, 2004; Asante *et al.*, 2008; Baker & Miller, 2013; Uribe, Quintero & Valenica, 2013). In the absence of local information, a global layer of hydrological soil groupings (Ross *et al.*, 2018) was used to assign soils into the four soil categories used for curve number estimation. Crop evapotranspiration coefficient (Kc) values for different land cover classes were calculated by dividing monthly reference evapotranspiration data (Trabucco & Zomer, 2018) by monthly actual evapotranspiration measured by remote sensing products (Elnashar *et al.*, 2021), and obtaining an average value per 2015 land cover class in ArcGIS. To account for inter-annual variability, monthly evapotranspiration data were first downloaded for 2014-2016 and an average value per month obtained for this period.

Some validation and refinement of the model estimates was performed. Modelled evapotranspiration results were compared with measured evapotranspiration and further adjustments to evapotranspiration coefficients made where necessary. Some flow gauging station data were also obtained from the Uganda Hydrological Yearbook (MWE, 2014). To compare modelled streamflow with this gauging station data, the InVEST DelineateIT tool was used to delineate the catchment areas draining into selected flow gauging stations described in MWE (2014). Some adjustments were made to improve alignment between modelled and measured streamflow in these catchments. Notably, normal antecedent moisture conditions (AMC II) curve numbers of land cover within the dry savanna biome were lowered to reflect dry antecedent moisture conditions (AMC 1), as initial modelled streamflow was generally too high. In contrast, curve numbers for forest and farmland within the forest biome were increased to better match wet antecedent moisture conditions (AMC III), as initial modelled streamflow was often too low in catchments within the forest biome.

The SWY model was then run for a scenario where all ecosystems were converted to bare ground. The ecosystem contribution to regulation of groundwater recharge in the two accounting years was then estimated by subtracting groundwater recharge in the bare ground scenario from groundwater recharge under 2015 and 1990 land cover. In some areas, recharge at pixel-level was estimated to be higher under bare ground than with extant ecosystems. This was due to evapotranspiration losses from vegetation exceeding the higher runoff losses resulting from the conversion to bare ground (not uncommon; see the metanalysis by Owuor *et al.*, 2016). These areas were considered to have zero capacity to supply flow regulation services.

ESTIMATION OF DEMAND FOR THE SERVICE

For accounting purposes, it was necessary to estimate the contribution of ecosystems to regulation of groundwater flows water that are actually used in Uganda. To estimate groundwater use, the study drew on estimates of groundwater abstraction for different purposes from Uganda's Water Accounts (UBOS, 2019, 2021), and used various ways to downscale these to estimate water use at a drainage basin level. The procedure used was the same as the method used to estimate surface water abstraction per drainage basin for the water supply service.

The estimated groundwater abstraction in each basin was then divided by the annual recharge estimate for 1990 and 2015, to give the proportion of annual recharge abstracted or demanded by groundwater users at drainage basin level. The proportion of annual recharge provided by ecosystems relative to a bare ground scenario was then estimated. The proportion was then applied to the groundwater abstracted and mapped to the ecosystems providing the service.[21]

VALUATION

Flow regulation improves water availability to households and reduces the need for larger dams to supply enough water. Flow regulation was valued using the cost of storage infrastructure that would need to be constructed if the ecosystem service was absent. The replacement cost was valued at UGX966 (constant 2017 UGX) per m^3 based on previous estimates used in the region in (Turpie *et al.*, 2021).

RESULTS

Total groundwater recharge across Uganda in 1990 was estimated to be 12.5 billion m^3. This declined to 12.0 billion m^3 in 2015. In contrast, quickflow was estimated to increase from 19.6 billion m^3 to 21.4 million m^3. This increase in quickflow at the expense of groundwater recharge reflects the replacement of natural habitats with farmland and built-up areas, which generally results in an increase in runoff at the expense of infiltration. The total water yield estimates for 1990 and 2015 are comparable to (albeit slightly lower than) the total runoff estimate for Uganda of 37.4 billion m^3, which was generated from data collected between 1953 and 1978 (MWE, 2022). The comparison of modelled flows with flow data sourced from MWE (2014) also indicated reasonable agreement of measured and modelled annual flows in most catchments, particularly following the adjustments described in the methods section above.

Estimated groundwater abstraction by various sectors estimated from data in the water accounts is shown in Table 4.47. Total groundwater use was estimated to have increased by 2.6 times between 1990 and 2015, with households the major user of groundwater. Overall, total groundwater abstraction from the selected sectors was estimated to be 0.3% of total modelled annual recharge in 1990. This increased to 0.8% of annual recharge in 2015, reflecting the increase in groundwater abstraction and the overall decline in annual recharge resulting from land cover changes.

The ecosystem contribution to groundwater recharge regulation was estimated to be 2.86 billion m^3 in 1990 and 2.33 billion m^3 in 2015. However, the ecosystem contribution to the regulation of abstracted groundwater flows was estimated to be much smaller, since only a small portion of recharge is demanded. Overall, the ecosystem contribution to regulation of abstracted groundwater recharge was estimated to be 5.87 Mm^3 in 1990, increasing to 12.05 Mm^3 in 2015 (Table 4.48)

Figure 4.20 shows the contribution of each pixel to the regulation of groundwater recharge in 2015. Areas with no value reflect pixels where recharge was not estimated to be higher than bare ground, thus resulting in no ecosystem contribution. after multiplying each pixel's total contribution to

[21] For example, take a basin where groundwater abstraction is 3% of total recharge, and 60% of recharge is attributed to pixels GOOD TO HAVE THIS FOOTNOTE – I DID NOT UNDERSTAND WHY YOU INCLUDE ONLY 60 % which make a positive contribution to the groundwater regulation service. If annual recharge for a given pixel in this basin was 100 mm higher than it would be with bare ground, then the contribution of the pixel to the regulation of abstracted groundwater flows would be 100 mm*3%*60%, which amounts to 1.8 mm/year.

baseflow by the estimated percentage of total baseflow demanded per drainage basin. Unsurprisingly, the highest values are associated with some of the wettest parts of the country, including the forested slopes of Mount Rwenzori and Mount Elgon as well as grassland areas higher up on these mountains. Even though forests have high evapotranspiration rates, the large reduction in runoff losses relative to bare ground is enough to compensate for this, resulting in highly positive groundwater recharge values relative to bare ground.

Table 4.47. Estimated water use by sector based on data from UBOS (2019; 2021)

Sector	1990		2015	
	Surface water	Groundwater	Surface water	Groundwater
Agriculture (Irrigation)	104 263	182	390 559	681
Crude oil and Mining	180	363	1 804	3 626
Manufacturing (Food and Beverages)	2 622	462	9 858	1 736
Manufacturing (Other)	2 216	384	8 332	1 443
Construction	1 993	2 437	7 494	9 163
Accommodation	321	51	1 207	193
Public Administration	4 446	238	16 719	897
Education	201	24	757	89
Health	367	20	1 380	76
Other	1 189	529	4 470	1 991
Urban households	11 756	620	52 287	2 758
Other households	4 209	29 466	9 238	64 668
Sewage and waste management	1 287	3 817	4 841	14 353
Total	**135 052**	**38 593**	**508 947**	**101 673**

The water flow regulation replacement cost was valued at UGX5668 million (constant 2017 UGX) in 1990 and at UGX11 632 million (constant 2017 UGX) in 2015 (Table 4.50; Table 4.51). This does not include cost savings for users of raw surface water, although these are expected to be relatively modest given that most surface water is drawn from large lakes (for which the service is not demanded).

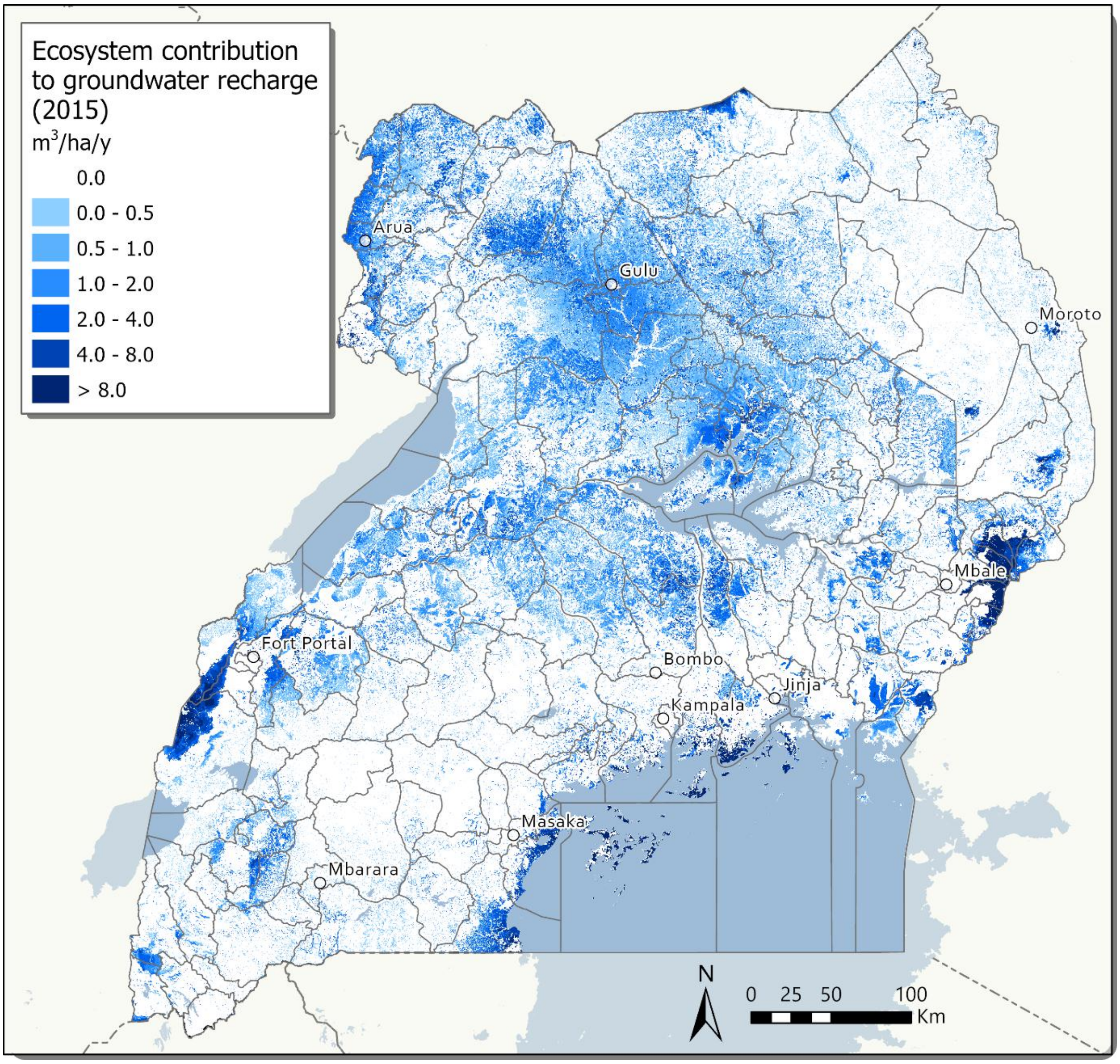

Figure 4.20. Estimated contribution of ecosystems to the regulation of abstracted groundwater recharge, in m^3/ha/year.

Table 4.48. Physical supply and use table for the contribution of ecosystems to the regulation of abstracted groundwater recharge, for 1990

	Economy				Ecosystem										
Physical supply 1990	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Water (ML)	-	-	-	-	0	0	2 009	273	1 361	1 488	3	735	0	0	5 870
Physical use 1990															
Water (ML)	0	5 870	0	5 870	-	-	-	-	-	-	-	-	-	-	-

Table 4.49. Physical supply and use table for the contribution of ecosystems to the regulation of abstracted groundwater recharge, for 2015

	Economy				Ecosystem										
Physical supply 2015	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Water (ML)	-	-	-	-	0	0	3 732	2 054	1 376	2 548	13	2 323	0	0	12 047
Physical use 2015															
Water (ML)	0	12 047	0	12 047	-	-	-	-	-	-	-	-	-	-	-

Table 4.50. Monetary supply and use table for the contribution of ecosystems to the regulation of abstracted groundwater recharge, for 1990; values in constant 2017 UGX millions

	Economy				Ecosystem										
Monetary supply 1990	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Water	-	-	-	-	0	0	1 940	264	1 315	1 436	3	710	0	0	5 668
Monetary use 1990															
Water	0	5 668	0	5 668	-	-	-	-	-	-	-	-	-	-	-

Table 4.51. Monetary supply and use table for the contribution of ecosystems to the regulation of abstracted groundwater recharge, for 2015; values in constant 2017 UGX millions

	Economy				Ecosystem										
Monetary supply 2015	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Water	-	-	-	-	0	0	3 603	1 984	1 328	2 461	13	2 243	0	0	11 632
Monetary use 2015															
Water	0	11 632	0	11 632	-	-	-	-	-	-	-	-	-	-	-

EXPERIENTIAL SERVICES: TOURISM

OVERVIEW

The SEEA reference list includes a range of experiential services: recreation-related services, visual amenity services, education, scientific and research services, spiritual, artistic and symbolic services. These correspond to use values associated with cultural ecosystem services. The service is the ecosystem contribution to these benefits, that are obtained through joint use of ecosystem and human inputs and is a final ecosystem service. They are typically quantified in terms of user days, and valued in terms of resource rents where markets exist, or simulated exchange value where they do not.

Turpie *et al.* (2022) argued that experiencing ecosystems, whether actively or passively, often combines several of these aspects, and that there is no particular need to try and isolate the various motivations or types of benefits obtained. Rather, for accounting purposes it might be more useful to consider recreation by different groups of actors, which influences the type of valuation method used. A logical breakdown is into tourists (who travel significant distances, recorded in tourism satellite accounts), local users (who travel short distances), and property owners (who pay premiums to live near or to have views of ecosystems), since the method for valuing these benefits differs between these groups. This account is limited to estimating the ecosystem contribution to tourism, which is in the SNA.

The ecosystem contribution to tourism relates mainly to nature-based tourism, but also includes tourists' use of farmland and urban natural and semi-natural areas. Thus, the term "ecosystem-based tourism" is used here, since the accounts include natural and semi-natural ecosystems.

Estimation of this service involved estimating the total resource rent of attraction-based tourism expenditure from national statistics, and then disaggregating the value in proportion to the spatial pattern of geotagged photographs uploaded to the internet and their content. We isolate ecosystem attractions from other cultural attractions.

DATA AND METHODS

RATIONALE

Tourism in Uganda includes both domestic and foreign tourism and can be divided into (a) experiencing the country's attractions, or (b) other reasons such as business, visiting friends and family, or shopping. While the first category applies mainly to leisure tourists, business and other tourists may also spend part of their time visiting attractions. Uganda's tourism attractions include both its natural and cultural heritage attractions. Nature-based tourism assets include the national parks and the wildlife that they protect, landscapes for hiking, climbing and trekking, water and adventure activities, as well as urban parks. Cultural attractions include indigenous cultural experiences in rural areas, and attractions such as museums, architecture, monuments and nightlife in urban areas. Nature-based and cultural attractions are often inter-connected, and their relative contribution to attraction-based tourism is difficult to separate. For example, visitors seeking cultural experiences in the form of village visits or homestays are essentially observing how people interact with nature and the role that nature plays in everyday life. Equally, visitors to urban areas may be attracted by the combination of cultural and natural features. In general, attraction-based tourism in natural ecosystems is largely nature-based, whereas tourism focussed on farmland and urban areas is dominated by cultural attractions. For example, nature-based and cultural attractions made up 42.5% and 57.5%, respectively, of attraction-based tourism in the city of Durban (Turpie *et al.*, 2017a).

Quantifying tourism in physical terms is typically approached in terms of visitor statistics, such as numbers of visitors, visitor-days, or bed nights. This is possible for locations for which there are discrete entry points, such as a country or a protected area. However, it is very difficult to map tourism activity in these terms, especially when mapping at fine scale. For these accounts, an index of tourism attraction, based on photographic activity, is used to disaggregate tourism expenditure. However, it cannot be used to disaggregate tourism visitor days, since it cannot be assumed that tourism days are directly proportional to value. For example, a visitor may travel for four days in order to spend one day watching gorillas. Ninety percent of their reason for visiting Uganda might be attributed to that one day. This is reflected in the photographs that they take, but not in where they spend their days. Therefore, the more appropriate physical measure is related to photographic activity, but since it maps identically to value, only the value measure is reported. Where tourism statistics are available at site level (e.g. parks), there does tend to be a strong relationship between photo numbers and visitor numbers (Wood *et al.*, 2013).

DATA AND ESTIMATION OF TOURISM EXPENDITURE FOR 1990 AND 2015

Tourism expenditure and tourism direct contribution to GDP for 2015 was extracted from the 2015/16 tourism performance report and the 2015 tourism statistical abstract (MTWA, 2015a, 2016). Time series data of total annual tourism expenditure (in current USD) and total annual visitor numbers to Uganda for the period 2000-2017 was obtained from the UBOS website, and the best fit trend line was used to estimate total tourism expenditure for 1990 (in current USD). Total expenditure in 1990 was estimated to be 2% of total expenditure in 2017. The estimated expenditure for 1990 was similar to that obtained by estimating the total visitors to Uganda in 1990 and multiplying this by an average spend per visit taken from the economic and statistical analysis of tourism in Uganda for 2012 (World Bank, 2013), converting to current 1990 USD values.

ESTIMATION OF ATTRACTION-BASED TOURISM EXPENDITURE

The proportion of tourism expenditure attributed to visiting attractions, as opposed to activities such as visiting family and friends, attending conferences, religious events, or receiving medical treatment was estimated for different types of tourists based on information collated from the Uganda tourism annual performance reports and tourism statistical abstracts (MTWA, 2015a, 2015b, 2016) and validated using data extracted from the World Bank Tourism Expenditure and Motivation Survey (TEMS; World Bank, 2020). Purpose of visit and spend per tourist type was extracted from the annual tourism performance reports and from time series data downloaded from the UBOS website. For 1990 this was based on the average over the period 2000-2015 and for 2015 was based on reported figures extracted from MTWA, 2015b, 2015a.

ESTIMATION OF RESOURCE RENT

The ecosystem contribution to tourism was valued as the resource rent generated by attraction-based tourism, which is the residual of the total output after intermediate consumption and all costs for capital and labour have been subtracted. Calculating the resource rent was done in two steps. The gross operating surplus was first calculated based on conversion factors extracted from Tourism Satellite Accounts for the Netherlands, South Africa and Zimbabwe. In the absence of a Tourism Satellite Account for Uganda conversion factors from other countries were used where labour costs were proportionally similar. For the Netherlands, South Africa and Zimbabwe, labour costs ranged from 53-57% of value added and gross operating surplus was 43-45% of value added.

Gross operating surplus (GOS) is estimated as follows:

$$GOS = total\ output - (intermediate\ consumption + labour\ costs + taxes\ less\ subsidies\ on\ production)$$

Resource rent was then derived from the gross operating surplus by subtracting user costs of fixed capital, as follows:

$$Resource\ rent = gross\ operating\ surplus - user\ cost\ of\ fixed\ capital$$

Information pertaining to costs of capital were not available for the Ugandan tourism industry and so a factor of 12% of value added (tourism contribution to GDP) was used based on the results of Remme *et al.* (2015) for Limburg Province in the Netherlands for which the estimates of intermediate costs for nature tourism were proportionally similar to those for Uganda. All values were converted to 2017 prices.

MAPPING ATTRACTION-BASED AND ECOSYSTEM-BASED TOURISM VALUE

The spatial distribution of attraction-based tourism value was mapped based on the densities of "photo user days" recorded from geotagged photographic uploads to the website *flickr.com*. This was accessed using the InVEST Visitation: Recreation and Tourism model. This approach provides a means of mapping value to tourism attractions, rather than to the places where tourists spend their money (e.g., at their accommodations), so is more accurate in assigning the tourism value to the actual attractions or assets that caused the expenditure. Geotagged photo data have been found to be a reliable predictor of visitation rates of tourism sites (Wood *et al.*, 2013) and have been used extensively for mapping recreational value (Casalegno *et al.*, 2013; Turpie *et al.*, 2017b; Lee & Tsou, 2018; Barros, Moya-Gómez & Gutiérrez, 2019).

The InVEST visitation model calculates the average annual photo-user-days (PUDs) across an area of interest across the period 2005-2015.[22] The model used the latitude/longitude data from photographs as well as the photographer's username and photo date to calculate PUDs. One PUD is one unique photographer who took at least one photo in a specific location on a single day. This minimises the duplicated counts due to one photographer taking multiple photos at any given site. Across Uganda an annual average of 1699 PUDs were recorded. The tourism value was spatially allocated in proportion to PUD density, after adjusting this to be based solely on the photos that were ecosystem-based, as described below.

Because the photos uploaded to Flickr include social and other content, adjustments were made to the InVEST-generated PUD densities by the percentage of photos that were attraction-based. This was determined for areas classified as water, farmland, natural ecosystems, built-up, or plantations, by categorising the content of 900 photos (30 in each of 30 randomly selected 10x10km cells) in each of these classes. To do so, each 10x10 km sampling area was manually located in the world map viewer directly on the Flickr website, and the contents of the photos taken within that location examined. Photos were categorised as (1) nature, (2) urban green space, (3) agriculture / plantation, (4) built attractions (5) traditional culture, (6) urban life / modern culture / life in Uganda, or (7) social or other non-attractions. All except the last category were taken to represent attractions. The first three categories were considered to be ecosystem-based attractions.

[22] We elected to average over a 10-year period due to the sparseness of georeferenced Flickr photos over much of Uganda. For example, an area with low visitor numbers may have had a few photos added to Flickr over the whole 2005-2015 period, but zero photos uploaded in 2015 specifically. This would have erroneously resulted in no tourism value being assigned to the area.

The approach was validated by comparing the geotagged photographic uploads with recorded national park visitor numbers and revenues. Visitor numbers to the ten national parks were available for the period 2002-2016 from Uganda's Ministry of Tourism, Wildlife and Antiquities (MTWA).

ALLOCATION OF VALUE TO ECONOMIC USERS

Ecosystem contributions to tourism values acrrue to both government and industry, who generate income from the sale of park entry fees and permits, accommodation and other services. The use value accruing to government was based on information in the Biodiversity and Tourism Accounts for Uganda (NEMA, 2021c). The accounts included a breakdown of expenditure by economic unit, with park entrance, vehicle entrance, gorilla tracking, other recreational activities, and hotels, bars and restaurant accruing to government for 2012 and 2019 (UWA run National Parks). It also included a summary of visitor numbers and park entrance fees for each park for the period 2012-2019. These figures were adjusted to 1990 and 2015 based on estimated visitor numbers to National Parks in those years.

RESULTS

OVERALL TOURISM TRENDS

Although tourism has fluctuated year-on-year in Uganda, the sector has experienced significant growth over the past two and a half decades. In 2017, some 1.4 million people visited Uganda, with a total expenditure of UGX 5 247 billion (in 2017 UGX, MTWA, 2018). Based on the trends from 2000 to 2017 (Figure 4.21; Figure 4.22), it was estimated that visitor numbers and expenditure in 1990 were 56 976 and UGX 80 121 million (in 2017 UGX), respectively.

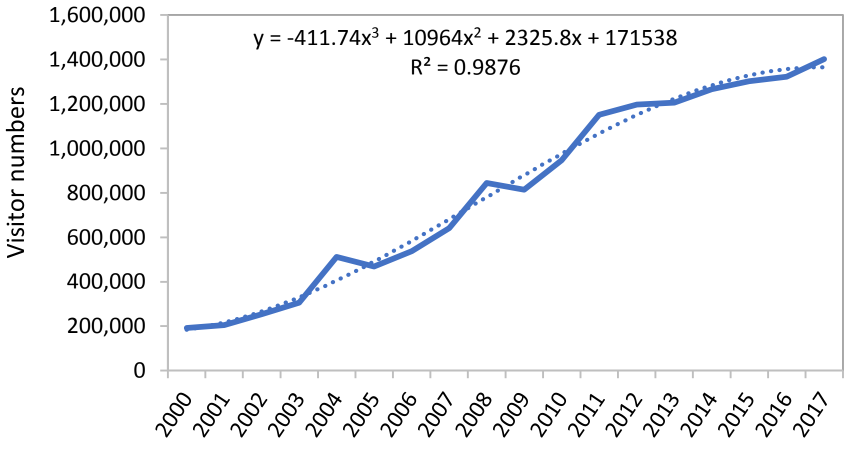

Figure 4.21. Total number of inbound tourists to Uganda over the period 2000-2017. Source: Uganda MTWA.

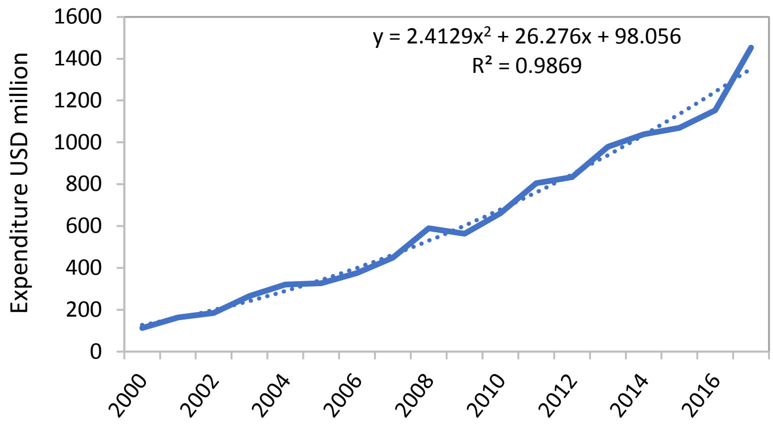

Figure 4.22. Total inbound visitor expenditure in Uganda over the period 2000-2017. Values in current USD millions. Source: Uganda MTWA.

Leisure tourists account for most of the expenditure on visiting tourism assets spending on average 30-100% more than other types of tourists per visit (World Bank, 2020b). Tourists whose main purpose is either visiting friends or family, or business tend to spend much less of their money on visiting attractions. These types of tourists do, however, make up a large proportion of the total tourism spending and so their contributions are not insignificant. Leisure tourists represented about 16% of tourists to Uganda in 1990 and 2015 (Table 4.52 , MTWA, 2015a, 2015b). The total expenditure on all attraction-based tourism was estimated to be UGX 25 057 million in 1990, and UGX 1520 billion in 2015 (in constant 2017 UGX). This represents an average annual growth rate of 239%. The total expenditure on ecosystem-based tourism was estimated to be UGX 16 145 million in 1990, and UGX 979 894 million in 2015 (in constant 2017 UGX). Therefore, about 64% of attraction-based tourism expenditure in Uganda was attributed to ecosystem-based tourism.

The exchange value of the ecosystem contribution to tourism in Uganda was estimated to be UGX 3558 million in 1990 and UGX 215 996 million in 2015 (in constant 2017 UGX millions). The value in 1990 was estimated to be just 2% of the value in 2015.

Table 4.52. Typology of tourists to Uganda in 1990 and 2015. Figures for 1990 are based on the average over the period 2000-2015. Figures for 2015 are reported figures from MTWA, 2015b, 2015a.

Purpose of visit	**Uganda 1990**	**Uganda 2015**
Leisure, recreation, holiday	16%	16%
Business	19%	25%
Visiting friends and relatives (VFR)	29%	35%
Other	38%	25%

SPATIAL DISTRIBUTION OF ATTRACTION-BASED TOURISM VALUE

The spatial distribution of attraction-based tourism value in 2015 is shown in Figure 4.23. Ecosystem-based tourism in Uganda is strongly linked to the country's protected area network. Gorilla trekking is offered in two of the national parks: Bwindi Impenetrable National Park and Mgahinga Gorilla National Park. These two national parks as well as Kibale National Park (and a few forest reserves) also offer chimpanzee trekking. Wildlife safaris are popular in Queen Elizabeth National Park, Murchison Falls National Park, Kidepo Valley National Park and Lake Mburo National Park. The Rwenzori Mountains National Park protects the highest mountain range in Africa with Mount Stanley and the 5100-metre-high Margherita Peak considered some of the most beautiful and challenging mountain trekking in the world. Hosting Africa's largest variety of bird species, birders from around the world are attracted to Uganda's protected areas where over 1000 species of birds can be seen.

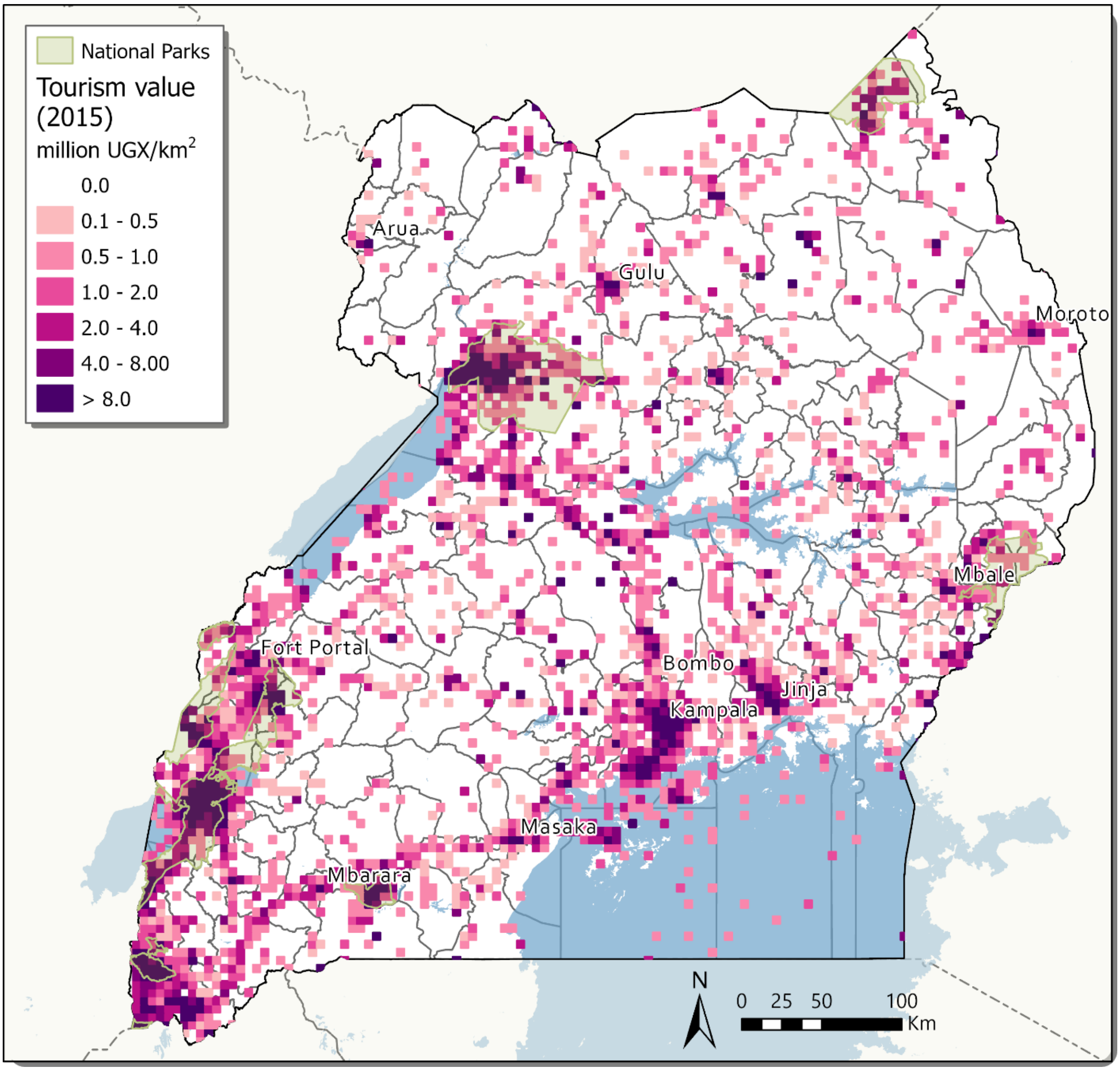

Figure 4.23. Attraction-based tourism value for the year 2015 across Uganda based on the distribution of geo-references photos uploaded to Flickr and their content.

Based on the spatial distribution of photographs and their content, it was estimated that national parks in Uganda contributed UGX 7494 million (19%) and UGX 373 773 million (25%) to the country's total tourism expenditure in 1990 and 2015 (Table 4.53), with the ecosystem contribution (resource rent) amounting to some UGX 1652 million in 1990 and UGX 82 379 million in 2015 (all values in constant 2017 UGX). Total values were highest in Queen Elizabeth and Murchison Falls but per hectare values were highest in Mgahinga Gorilla NP, Lake Mburo NP and Bwindi Impenetrable NP. Note that the expenditure attributed to visiting the national parks is country-wide and shows that the value of parks is orders of magnitude greater than the revenues from entrance fees (NEMA, 2021c). As for all national accounting, this does not include the positive spinoffs for other sectors.

Table 4.53. Total tourism expenditure attributed to national parks, and the ecosystem contribution (resource rent) in 1990 and 2015, values in constant 2017 UGX millions. Source: this study. Note that the expenditure attributed to the park is broader than the expenditure within the park.

National Park	Tourism expenditure		Exchange value of ecosystem contribution		
	1990 UGX mn	2015 UGX mn	1990 UGX mn	2015 UGX mn	2015 UGX/ha
Queen Elizabeth	3 419	114 150	754	25 158	12 055
Murchison Falls	3 114	115 384	686	25 430	6 560
Lake Mburo	757	27 681	167	6 101	16 644
Bwindi Impenetrable	-	33 329	-	7 346	22 458
Kibale	-	28 804	-	6 348	8 039
Rwenzori Mountains	-	23 097	-	5 091	5 154
Kidepo Valley	203	7 815	45	1 722	1 216
Mgahinga Gorilla	-	10 299	-	2 270	62 403
Mount Elgon	-	11 189	-	2 466	2 222
Semuliki	-	2 025	-	446	2 127
Total	**7 494**	**373 773**	**1 652**	**82 379**	**7 351**

The value of the ecosystem service from natural ecosystems was estimated to be UGX 148 466 million in 2015, representing 69% of the total value of the service (Table 4.54). The contribution of rural agricultural land in Uganda to ecosystem-based tourism was estimated to be UGX 48 894 million and urban greenspace areas UGX 16 841 million in 2015, representing 23% and 8% of the total value, respectively. Among natural ecosystem types, grasslands had the highest value in 2015 but forest ecosystems had the highest per hectare value, followed by wetlands and woodlands. Farmland had the lowest per hectare ecosystem-based tourism value of any ecosystem.

Table 4.54. Ecosystem-based tourism expenditure and the ecosystem contribution (resource rent) across different ecosystem types in 1990 and 2015, values in constant 2017 UGX millions.

Ecosystem	Tourism expenditure		Exchange value of ecosystem contribution			
	1990 UGX mn	2015 UGX mn	1990 UGX mn	2015 UGX mn	1990 UGX/ha	2015 UGX/ha
Open water	1 488	90 320	341	19 906	93	5 422
Wetland	1 060	64 311	243	14 174	281	18 647
Grassland	3 408	206 856	763	45 590	150	8 938
Bushland	2 223	134 897	493	29 731	320	15 082
Woodland	1 598	96 957	345	21 369	98	17 614
Forest	1 326	80 487	189	17 696	197	28 044
Plantation	121	7 318	26	1 613	810	14 947
Farmland	3 655	221 843	841	48 894	100	4 643
Built-up area	1 259	76 414	290	16 841	8 044	123 775
Bare	8	490	2	108	399	13 761
Total	**16 145**	**979 894**	**3 530**	**215 923**	**146**	**8 948**

The total value of the service and the per hectare value was highest in The Lake Edward Basin, which is largely attributed to the fact that Mgahinga Gorilla NP and Bwindi Impenetrable NP are situated in this basin (Table 4.55). The Kidepo Basin had the lowest total tourism value because of its size but had a relatively high per hectare value because of the Kidepo Valley NP situated in this basin. The per hectare value was lowest in the Aswa Basin.

Table 4.55. Natural and semi-natural attraction-based tourism expenditure and the ecosystem contribution to tourism (resource rent value) across the eight basins within Uganda in 1990 and 2015, values in constant 2017 UGX millions.

Basin	Tourism expenditure		Ecosystem contribution to tourism			
	1990 UGX mn	2015 UGX mn	1990 UGX mn	2015 UGX mn	1990 UGX/ha	2015 UGX/ha
Albert Nile	613	37 233	141	8 206	68	3 935
Aswa	447	27 140	103	5 982	37	2 180
Kidepo	144	8 755	33	1 929	104	6 070
Lake Albert	810	49 187	178	10 841	97	5 895
Lake Edward	4 947	300 265	988	66 178	529	35 449
Lake Kyoga	1 900	115 294	427	25 367	75	4 442
Lake Victoria	3 719	225 705	848	49 745	137	8 035
Victoria Nile	3 495	212 095	801	46 745	291	16 965
Balancing area	70	4 220	13	930	20	1 499
Total	**16 076**	**975 674**	**3 530**	**215 923**	**146**	**8 948**

The districts with the highest ecosystem-based tourism values are Kasese, Nwoya, Wakiso and Nakasongola (Figure 4.24). These districts are all popular tourist cities or towns that are situated adjacent to popular nature or cultural assets, such as national parks. Kasese District, for example, includes Queen Elizabeth NP and Rwenzori Mountains NP. Wakiso surrounds Kampala and is situated on Lake Victoria and is a popular adventure tourism destination. Per hectare tourism values were highest in Kampala City, Jinja City, and Fort Portal City. Fort Portal is situated centrally between Semuliki NP, Rwenzori NP, and Kibale NP.

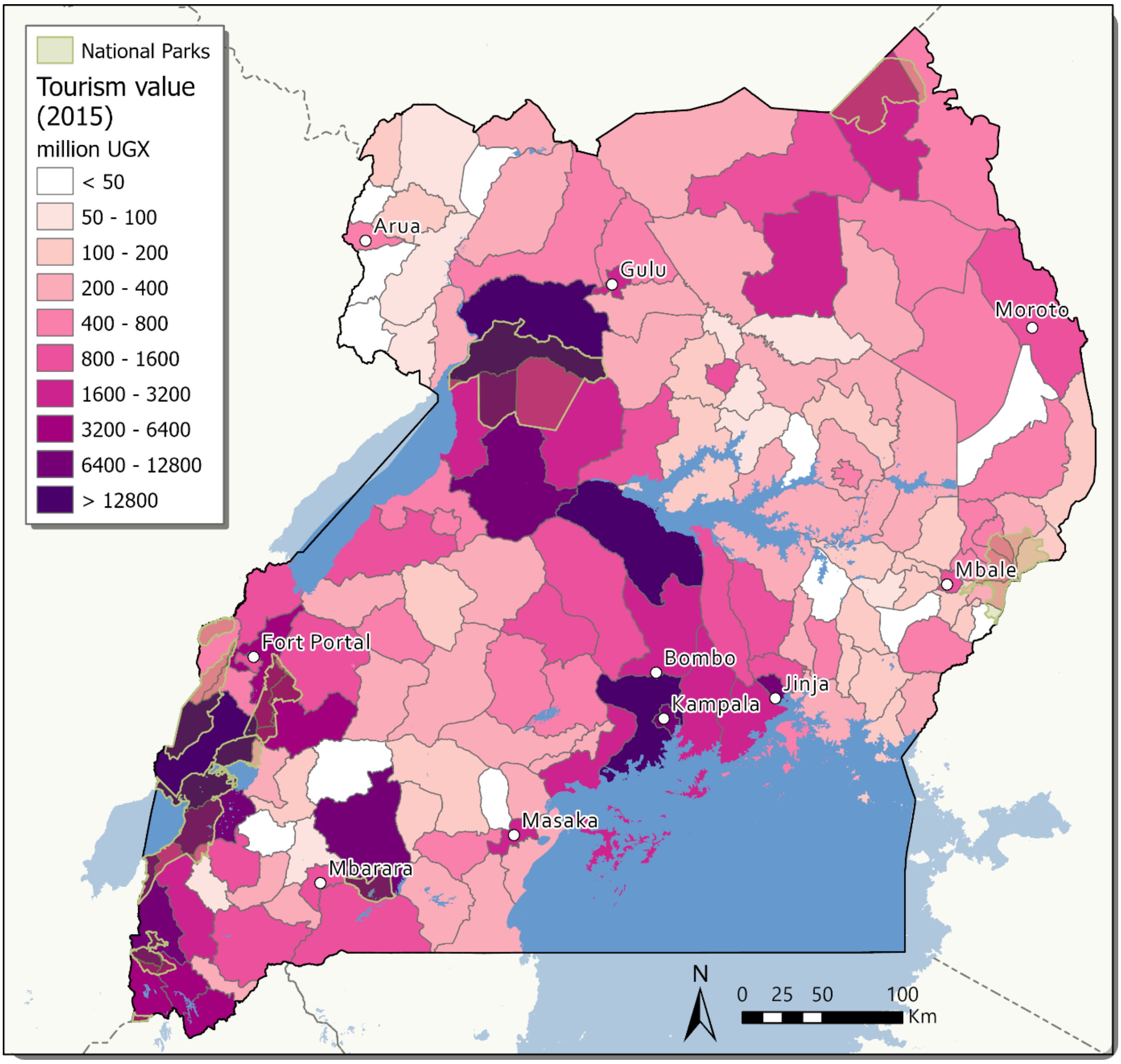

Figure 4.24. The total ecosystem-based tourism value per district for the year 2015.

Table 4.56 Total monetary supply and use of ecosystem tourism services in 1990 (constant 2017 UGX millions)

	Economy				Ecosystem										
Monetary supply 1990	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Tourism	-	-	-	-	341	243	763	493	345	189	26	841	290	2	3 530
Monetary use 1990															
Tourism	3 408	123	0	3 530	-	-	-	-	-	-	-	-	-	-	-

Table 4.57 Total monetary supply and use of ecosystem tourism services in 2015 (constant 2017 UGX millions)

	Economy				Ecosystem										
Monetary supply 2015	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Tourism	-	-	-	-	19 906	14 174	45 590	29 731	21 369	17 696	1 613	48 894	16 841	108	215 923
Monetary use 2015															
Tourism	208 106	7 818	0	215 923	-	-	-	-	-	-	-	-	-	-	-

5. SUMMARY OF THE ACCOUNTS

NATIONAL LEVEL RESULTS

The ecosystem service supply and use tables are presented at national scale in Tables 5.1 to 5.4 below. Tables 5.1 and 5.2 present the flows of ecosystem services accruing to each type of economic user and from each ecosystem type in physical units for 1990 and 2015, respectively. Tables 5.3 and 5.4 present the same, but in monetary units, for 1990 and 2015, respectively.

In physical terms, all but one of the flows of services increased from 1990 to 2015. The flows of all provisioning services increased substantially. This is unsurprising given that the population doubled over this time period. Ecosystem inputs to crop production increased by 25%, but the use of grazed biomass and wood increased by 195% and 153%, respectively. The use of wild fish and other wild resources increased by 86% and 10%, respectively. Water use tripled (300% increase). In comparison, the flows of regulating services did not increase much, apart from the flow regulation service which doubled (105% increase). Sediment and nutrient retention services increased by 18% and 4%, respectively, and carbon retention declined slightly. The most significant increase was that of the ecosystem contribution to tourism value. This could not be mapped in physical terms, but the value increased by 6017% over the 25-year span of the accounts.

In monetary terms, the value flows of all services increased, and generally increased more than the increase in physical terms, though not always. Crop and grazed biomass provisioning services increased by 86% and 100%, respectively. Wood value increased dramatically, by 1683%, while fish and other resources increased by 503% and 182%, respectively. The percentage increases in value for water, flow regulation, sediment and nutrient retention services were the same as for physical flows, since no real price changes were recorded. The value of carbon retention increased by 87% due to the increased price of carbon, and the value of tourism increased by 6016% as mentioned above.

The average monetary value per ha of different ecosystem types is shown graphically in Figure 5.1. All ecosystem types, except for "Bare", increased in value from 1990 to 2015, largely attributable to the increase in numbers of people demanding services from them. The largest value per ha, both in 1990 and 2015 comes from forests and wetlands. The largest percentage increases (per ha) between 1990 and 2015 were recorded in "Open Water", "Plantation", and "Wetland".

Table 5.5 presents the national-level monetary ecosystem asset account for 1990-2015. This account records the monetary value of opening and closing stocks of all ecosystem assets within the country as a whole, and breaks down the changes in values of stocks. The asset value of each ecosystem is the aggregate net present value of the projected annual flows of all ecosystem services over time, taking into account sustainability of use as far as possible. The value of the ecosystem assets, as derived from the value of annual flows, was estimated to be UGX 387.6 trillion in 1990 (USD 105 billion) and UGX 682.9 trillion in 2015 (USD 185 billion; all in constant 2017 prices; Table 5.5).

Some UGX 94.3 trillion was lost as a result of the degradation and loss of ecosystem areas, with most of these losses from woodland and forest areas (Table 5.5, Figure 5.2). Of this, UGX 22.4 trillion was attributed to degradation, and UGX 71.9 trillion was due to the loss of ecosystem area. The value of these losses were offset by the increases in demand for services, and their volume and price effects. The volume effects increased the value of ecosystem assets by UGX 179.1 trillion, while the real increases in prices increased asset values by UGX 116.4 trillion (Table 5.5). As a result, all major ecosystem types increased in value apart from woodland, which decreased in value due to large losses in area. Farmland had the largest overall increase in value, and built-up areas and plantations, which make up less than 1% of Uganda's landcover, showed the largest percentage increases in value between 1990 and 2015 (Table 5.5).

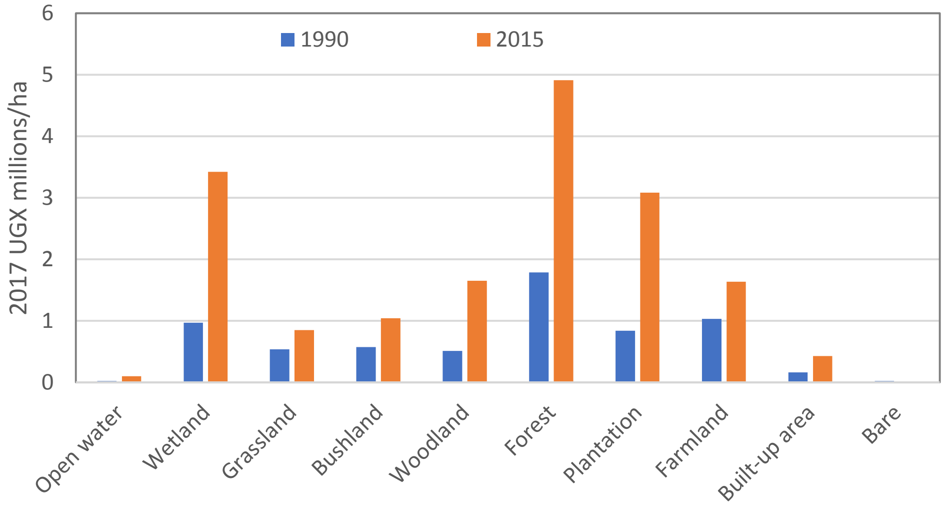

Figure 5.1 Average monetary value of ecosystem service flows per ecosystem type per ha per year in 1990 and 2015. Values expressed in constant 2017 UGX millions per ha per year.

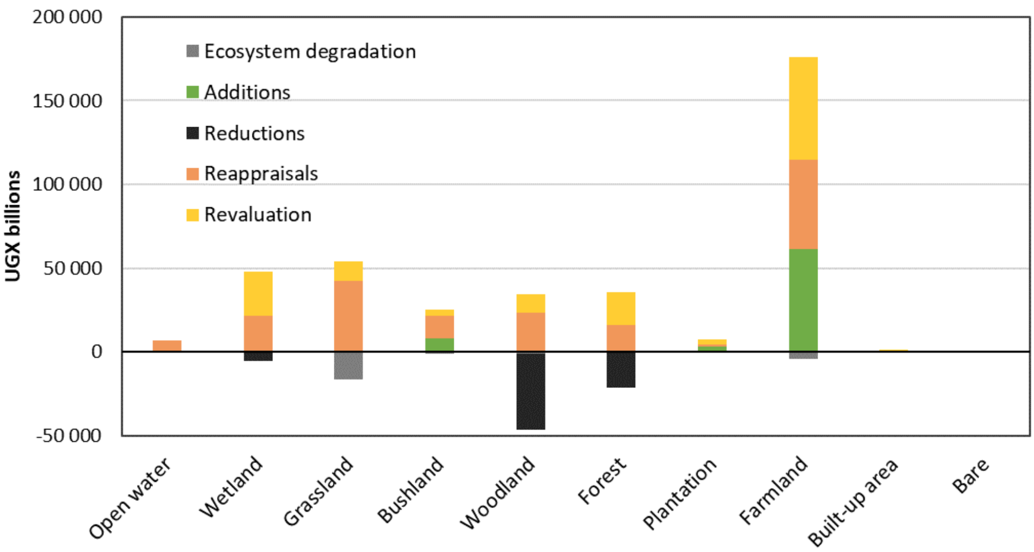

Figure 5.2 Gains and losses in the asset value of ecosystems between 1990 and 2015. Values expressed in constant 2017 UGX billions.

While overall asset values increased between 1990 and 2015, due to increasing demand for resources over time, the total per capita asset value decreased by 17.7% (Figure 5.3). The largest per capita losses occurred in woodlands (65.7%), forests (37.2%) and grassland (26.7%). Farmland also decreased in per capita asset value over time (by 11.3%).

The total asset value of national ecosystem services increased between 1990 and 2015, while it declined on a per capita basis. This suggests that ecosystems have been pushed close to or beyond their tipping points and will not be able to provide each additional Ugandan with the same, or more, services. Uganda needs to ensure that standards of living are increased without further degrading and depleting its natural assets. This will require substantial investments in restoration and increased protection of natural capital, as well as investments in education and measures to reduce population growth.

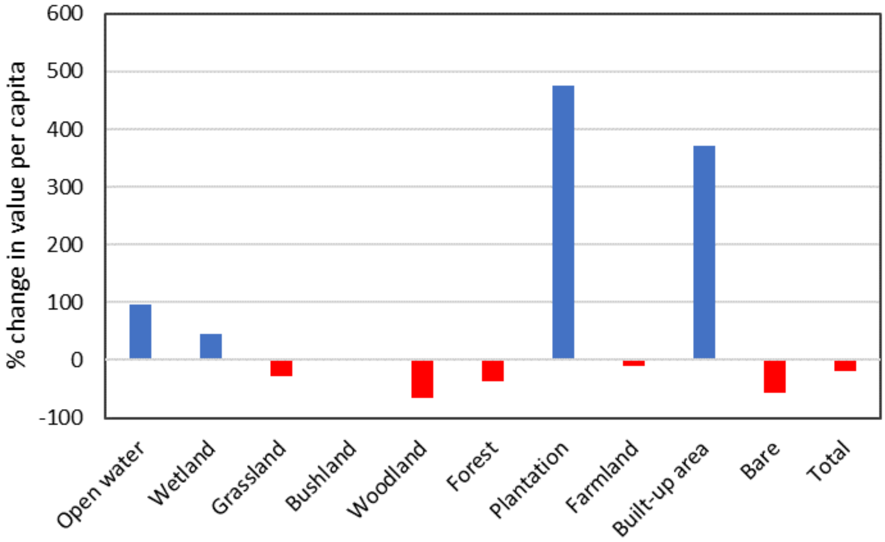

Figure 5.3 Percentage change in the per capita asset value of ecosystems between 1990 and 2015.

Table 5.1. Total supply and use of ecosystem services in 1990, in physical units (apart from tourism, in monetary units). IND = industry, GOV = government and HH = households.

	Economy				Ecosystem										
Physical supply 1990	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Ecosystem Area (km^2)	-	-	-	-	36 767	8 651	50 827	15 419	35 100	9 603	321	84 204	361	50	241 302
Ecosystem service															
Crops (kt/y)	-	-	-	-	0	0	0	0	0	0	0	16 269	0	0	16 269
Grazed biomass (t/y)	-	-	-	-	0	30	2 664	926	1 061	0	0	4 387	0	0	9 069
Wood (kt/y)	-	-	-	-	0	24	1 434	455	3 067	3 835	339	6 160	0	0	15 315
Wild fish (kt/y)	-	-	-	-	245	0	0	0	0	0	0	0	0	0	245
Other wild resources (kt/y)	-	-	-	-	0	22	73	23	66	29	0	138	0	0	352
Water supply (ML/y)					140 021	0	0	0	0	0	0	0	0	0	140 021
Water flow regulation (ML/y)	-	-	-	-	0	0	2 009	273	1 361	1 488	3	735	0	0	5 870
Sediment retention (million m^3/y)	-	-	-	-	0	5	143	62	113	210	2	395	0	0	929
Nutrient retention (ktP/y)	-	-	-	-	0	543	1 110	381	663	582	87	0	0	0	3 366
Carbon retention (MtC)	-	-	-	-	0	346	505	124	369	293	4	527	2	0	2 171
Tourism value (UGX millions/y)	-	-	-	-	341	243	763	493	345	189	26	841	290	2	3 530
Physical use 1990															
Crops (kt/y)	2 598	0	13 671	16 269	-	-	-	-	-	-	-	-	-	-	-
Grazed biomass (t/y)	725	0	8 343	9 069	-	-	-	-	-	-	-	-	-	-	-
Wood (kt/y)	4 615	0	10 700	15 315	-	-	-	-	-	-	-	-	-	-	-
Wild fish (kt/y)	197	0	48	245	-	-	-	-	-	-	-	-	-	-	-
Other wild resources (kt/y)	0	0	352	352											
Water supply (ML/y)	117 754	6 302	15 965	140 021	-	-	-	-	-	-	-	-	-	-	-
Water flow regulation (ML/y)	0	5 870	0	5 870	-	-	-	-	-	-	-	-	-	-	-
Sediment retention (million m^3/y)	929	0	0	929	-	-	-	-	-	-	-	-	-	-	-
Nutrient retention (ktP/y)	3 366	0	0	3 366	-	-	-	-	-	-	-	-	-	-	-
Carbon retention (MtC)	0	2 171	0	2 171	-	-	-	-	-	-	-	-	-	-	-
Tourism value (UGX millions/y)	3 408	123	0	3 530	-	-	-	-	-	-	-	-	-	-	-

Table 5.2. Total supply and use of ecosystem services in 2015, in physical units (apart from tourism, in monetary units). IND = industry, GOV = government and HH = households.

	Economy				Ecosystem										
Physical supply 2015	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Ecosystem Area (km^2)	-	-	-	-	36 716	7 601	51 007	19 713	12 132	6 310	1 079	105 305	1 361	78	241 302
Ecosystem service															
Crops (kt/y)	-	-	-	-	0	0	0	0	0	0	0	20 316	0	0	20 316
Grazed biomass (t/y)	-	-	-	-	0	100	8 447	3 189	1 146	0	0	13 879	0	0	26 760
Wood (kt/y)	-	-	-	-	0	81	2 678	3 144	5 281	7 392	1 755	18 429	0	0	38 760
Wild fish (kt/y)	-	-	-	-	455	0	0	0	0	0	0	0	0	0	455
Other wild resources (kt/y)	-	-	-	-	0	29	59	57	31	15	1	197	0	0	388
Water supply (ML/y)					560 577	0	0	0	0	0	0	0	0	0	560 577
Water flow regulation (ML/y)	-	-	-	-	0	0	3 732	2 054	1 376	2 548	13	2 323	0	0	12 047
Sediment retention (million m^3/y)	-	-	-	-	0	8	175	78	87	214	9	522	0	0	1 094
Nutrient retention (ktP/y)	-	-	-	-	0	1 103	557	864	258	468	254	0	0	0	3 504
Carbon retention (MtC)	-	-	-	-	0	524	321	147	122	195	15	611	9	0	1 943
Tourism value (UGX millions/y)	-	-	-	-	19 906	14 174	45 590	29 731	21 369	17 696	1 613	48 894	16 841	108	215 923
Physical use 2015															
Crops (kt/y)	8 994	0	11 322	20 316	-	-	-	-	-	-	-	-	-	-	-
Grazed biomass (t/y)	2 141	0	24 619	26 760	-	-	-	-	-	-	-	-	-	-	-
Wood (kt/y)	20 874	0	17 887	38 760	-	-	-	-	-	-	-	-	-	-	-
Wild fish (kt/y)	365	0	90	455	-	-	-	-	-	-	-	-	-	-	-
Other wild resources (kt/y)	0	0	388	388	-	-	-	-	-	-	-	-	-	-	-
Water supply (ML/y)	475 358	23 696	61 524	560 577											
Water flow regulation (ML/y)	0	12 047	0	12 047	-	-	-	-	-	-	-	-	-	-	-
Sediment retention (million m^3/y)	1 094	0	0	1 094	-	-	-	-	-	-	-	-	-	-	-
Nutrient retention (ktP/y)	3 504	0	0	3 504	-	-	-	-	-	-	-	-	-	-	-
Carbon retention (MtC)	0	1 943	0	1 943	-	-	-	-	-	-	-	-	-	-	-
Tourism value (UGX millions/y)	208 106	7 818	0	215 923	-	-	-	-	-	-	-	-	-	-	-

Table 5.3. Total supply and use of ecosystem services 1990 in monetary values (constant 2017 UGX billion). IND = industry, GOV = government and HH = households.

	Economy				Ecosystem										
Monetary supply 1990	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Ecosystem area (km^2)	-	-	-	-	36 767	8 651	50 827	15 419	35 100	9 603	321	84 204	361	50	241 302
Ecosystem service															
Crops	-	-	-	-	0	0	0	0	0	0	0	4 240	0	0	4 240
Grazed biomass	-	-	-	-	0	9.7	850	294	336	0	0	1 376	0	0	2 866
Wood	-	-	-	-	0	0	8.4	4.8	44	61	3.5	62	0	0	184
Wild fish	-	-	-	-	0.1	0	0	0	0	0	0	0	0	0	0.1
Other wild resources	-	-	-	-	0	3.4	33	9.9	29	15	0.2	56	0	0	147
Water supply					85	0	0	0	0	0	0	0	0	0	85
Water flow regulation	-	-	-	-	0	0	1.9	0.3	1.3	1.4	0	0.7	0	0	5.7
Sediment retention	-	-	-	-	0	22	648	280	514	951	8.5	1 789	0	0	4 212
Nutrient retention	-	-	-	-	0	32	66	23	40	35	5.2	0	0	0	201
Carbon retention	-	-	-	-	0	772	1 126	276	824	653	9.6	1 175	5.5	0.1	4 840
Tourism value	-	-	-	-	0.3	0.2	0.8	0.5	0.3	0.2	0	0.8	0.3	0	3.5
Total	-	-	-	-	**85**	**840**	**2 734**	**888**	**1 789**	**1 715**	**27**	**8 699**	**5.8**	**0.1**	**16 783**
Monetary use 1990															
Crops	859	0	3 381	4 240	-	-	-	-	-	-	-	-	-	-	-
Grazed biomass	229	0	2 636	2 866	-	-	-	-	-	-	-	-	-	-	-
Wood	87	0	96	184	-	-	-	-	-	-	-	-	-	-	-
Wild fish	0.1	0	0	0.1	-	-	-	-	-	-	-	-	-	-	-
Other wild resources	0	0	147	147	-	-	-	-	-	-	-	-	-	-	-
Water supply	71	4	9.9	85											
Water flow regulation	0	5.7	0	5.7	-	-	-	-	-	-	-	-	-	-	-
Sediment retention	4 212	0	0	4 212	-	-	-	-	-	-	-	-	-	-	-
Nutrient retention	201	0	0	201	-	-	-	-	-	-	-	-	-	-	-
Carbon retention	0	4 840	0	4 840	-	-	-	-	-	-	-	-	-	-	-
Tourism value	3.4	0.1	0	3.5	-	-	-	-	-	-	-	-	-	-	-
Total	**5 662**	**4 850**	**6 271**	**16 783**	-	-	-	-	-	-	-	-	-	-	-

Table 5.4. Total supply and use of ecosystem services 2015 in monetary values (constant 2017 UGX billions). IND = industry, GOV = government and HH = households.

	Economy				Ecosystem										
Monetary supply 2015	**IND**	**GOV**	**HH**	**Total**	**Water**	**Wetland**	**Grass land**	**Bush land**	**Wood land**	**Forest**	**Plantation**	**Farmland**	**Built-up**	**Bare**	**Total**
Ecosystem area (km²)	-	-	-	-	36 716	7 601	51 007	19 713	12 132	6 310	1 079	105 305	1 361	78	241 302
Ecosystem service															
Crops	-	-	-	-	0	0	0	0	0	0	0	7 829	0	0	7 829
Grazed biomass	-	-	-	-	0	22	1 801	684	249	0	0	2 987	0	0	5 743
Wood	-	-	-	-	0	2.4	78	181	714	1 152	204	941	0	0	3 272
Wild fish					0.6	0	0	0	0	0	0	0	0	0	0.6
Other wild resources	-	-	-	-	0	16	67	66	36	21	1.3	209	0	0	415
Water supply	-	-	-	-	338	0	0	0	0	0	0	0	0	0	338
Water flow regulation	-	-	-	-	0	0	3.6	2.0	1.3	2.5	0	2.2	0	0	12
Sediment retention	-	-	-	-	0	37	794	355	396	968	43	2 366	0	0	4 959
Nutrient retention	-	-	-	-	0	66	33	52	15	28	15	0	0	0	209
Carbon retention	-	-	-	-	0	2 445	1 499	686	567	908	68	2 850	41	0	9 064
Tourism value	-	-	-	-	20	14	46	30	21	18	1.6	49	17	0.1	216
Total	-	-	-	-	**359**	**2 601**	**4 322**	**2 055**	**2 000**	**3 097**	**333**	**17 232**	**58**	**0.1**	**32 057**
Monetary use 2015															
Crops	4 267	0	3 562	7 829	-	-	-	-	-	-	-	-	-	-	-
Grazed biomass	459	0	5 283	5 743	-	-	-	-	-	-	-	-	-	-	-
Wood	2 514	0	758	3 272											
Wild fish	0.5	0	0.1	0.6	-	-	-	-	-	-	-	-	-	-	-
Other wild resources	0	0	415	415	-	-	-	-	-	-	-	-	-	-	-
Water supply	285	15	38	338	-	-	-	-	-	-	-	-	-	-	-
Water flow regulation	0	12	0	12	-	-	-	-	-	-	-	-	-	-	-
Sediment retention	4 959	0	0	4 959	-	-	-	-	-	-	-	-	-	-	-
Nutrient retention	209	0	0	209	-	-	-	-	-	-	-	-	-	-	-
Carbon retention	0	9 064	0	9 064	-	-	-	-	-	-	-	-	-	-	-
Tourism value	208	7.8	0	216	-	-	-	-	-	-	-	-	-	-	-
Total	**12 903**	**9 098**	**10 056**	**32 057**	-	-	-	-	-	-	-	-	-	-	-

Table 5.5. Ecosystem monetary asset account 1990-2015. NPV calculated using an asset lifespan of 100 years and a discount rate of 4.04%. All values expressed in constant 2017 UGX billions apart from per capita value in UGX millions.

	Open water	Wetland	Grassland	Bushland	Woodland	Forest	Plantation	Farmland	Built-up	Bare	Total
Opening stock (1990)	**2 064**	**20 403**	**66 270**	**21 544**	**43 297**	**41 580**	**656**	**191 623**	**140**	**3**	**387 580**
Change in ecosystem condition											
Enhancement											
Degradation			-16 580	-919	-935	-113	-40	-3 829	-22	-2	-22 440
Change in ecosystem extent (ecosystems conversions)											
Additions			315	8 218			3 428	61 184	718	1	73 864
Reductions	-7	-5 298			-45 211	-21 373					-71 890
Other changes in volume of ecosystem assets											
Catastrophic losses											
Reappraisals	6 652	21 904	42 186	13 577	23 725	16 055	962	53 777	242	2	179 083
Revaluation	-2	26 114	11 812	3 768	10 942	19 767	3 073	60 897	339	-2	116 441
Net change in value	6 642	42 720	37 733	24 644	-11 479	14 336	7 423	172 030	1 277	0	275 058
Closing stock (2015)	**8 706**	**63 123**	**104 002**	**46 188**	**31 818**	**55 916**	**8 079**	**363 653**	**1 417**	**3**	**682 905**
Closing stock (2015) per capita (in million)	244	1 769	2 915	1 295	892	1 567	226	10 194	40	0	19 143
Net change %	322	209	57	114	-27	34	1 132	90	910	-6	76
Net change % per capita	97	45	-27	0.2	-66	-37	476	-11	372	-56	-18

BASIN LEVEL RESULTS

Ecosystem service and asset accounts were conducted at drainage basins which included eight basins and the remaining area (referred to as "Balancing area"). Lake Kyoga has the highest monetary supply values (constant 2017 UGX), both in 1990 and 2015, in total and per ha (Figure 5.4). The largest percentage increases in total monetary supply and per ha monetary supply between 1990 and 2015 were achieved by the Albert Nile basin.

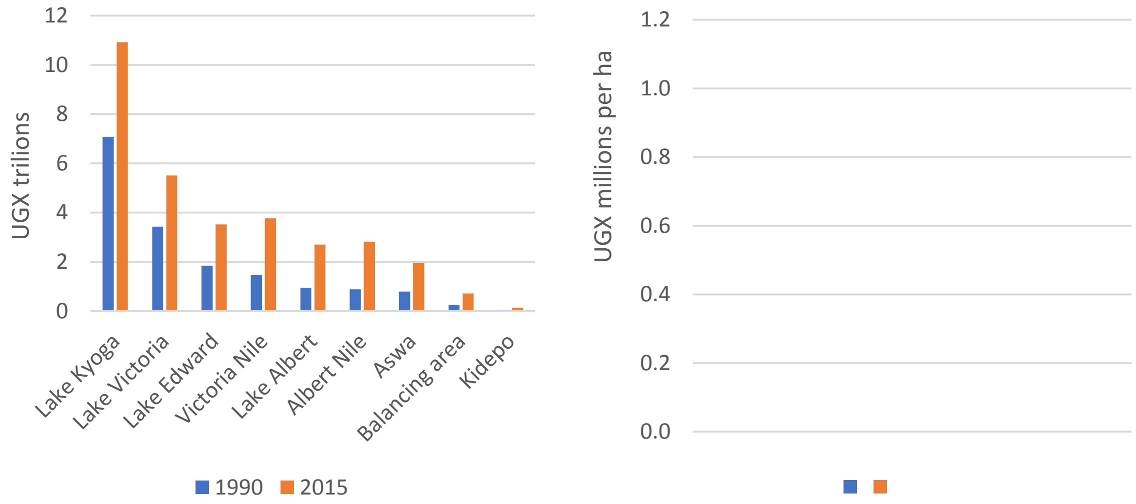

Figure 5.4 Total monetary value of ecosystem service flows (left) and their annual value per ha (right) per basin in 1990 and 2015 (in constant 2017 UGX)

Half of Lake Kyoga's value is derived from farmland. Farmland contributes the majority of asset value in most basins (6% in Kidepo and 71% in Albert Nile) – both Lake Victoria and the Victoria Nile basin also have comparatively large farmland asset values in 2015. Kidepo and the balancing area generate most of their value from grassland. In 2015, over a third of Uganda's total grassland value was derived from Lake Kyoga's grasslands. Lake Kyoga also had the highest value of wetlands in Uganda, making up roughly half of Uganda's total wetland value, followed by Lake Victoria and the Victoria Nile basin. Lake Kyoga also held the highest forest value compared to the other basins, followed by Lake Edward and Lake Albert.

Detailed basin-level results are presented in the accompanying Excel file. Sample tables for the Albert Nile basin are shown in Table 5.6 and Table 5.7.

DISTRICT LEVEL RESULTS

District level ecosystem service and asset accounts are shown in the Excel sheet accompanying this report. Examples of the district-level accounts are shown in Table 5.8 and Table 5.9 for Abim.

Table 5.6 Basin level example table: Albert Nile supply and use of ecosystem services in 1990, in physical units (apart from tourism, in monetary units)

Albert Nile Ecosystem services physical supply and use table 1990	Economic unit							Ecosystem										
	Agric, Forestr	Water supply	Trade, caterin	Other industrie	Government	Households	Total	Open water	Wetland	Grassland	Bushland	Woodland	Forest	Plantation	Farmland	Built-up area	Bare	Total
Ecosystem Area (ha)	-	-	-	-	-	-	-	30 364	42 542	283 113	78 874	789 045	1 438	4 269	854 211	1 494	168	2 085 518
Physical supply 1990																		
Crops (t/y)	-	-	-	-	-	-	-	0	0	0	0	0	0	0	956 174	0	0	956 174
Grazed biomass (t/y)	-	-	-	-	-	-	-	0	1 379	95 323	22 302	258 989	0	0	318 443	0	0	696 436
Wood (t/y)	-	-	-	-	-	-	-	0	486	55 756	24 401	682 161	4 691	39 397	439 912	0	0	1 246 804
WIld fish (t/y)	-	-	-	-	-	-	-	2 987	0	0	0	0	0	0	0	0	0	2 987
Other wild resources (kg/y)	-	-	-	-	-	-	-	0	640 406	5 000 917	1 821 422	12 447 040	7 995	51 488	20 092 206	0	0	40 061 475
Water supply (m^3/y)	-	-	-	-	-	-	-	3 673 325	0	0	0	0	0	0	0	0	0	3 673 325
Water flow regulation (m^3/y)	-	-	-	-	-	-	-	0	0	140 160	18 009	394 111	576	1 838	133 835	0	0	688 528
Sediment retention (m^3/y)	-	-	-	-	-	-	-	0	0	159 373	38 137	23 757	0	0	146 462	0	0	367 729
Nutrient retention (tP/y)	-	-	-	-	-	-	-	0	0	416	104	58,8	0	0	0	0	0	579
Carbon retention (tC)	-	-	-	-	-	-	-	0	26 074 410	16 440 558	5 303 891	73 178 870	440 870	523 623	40 841 064	92 804	0	162 896 090
Tourism value (UGX millions/y)	-	-	-	-	-	-	-	6,9	4,1	55,7	8,9	5,6	0	2,3	48,5	8,9	0	141
Physical use 1990																		
Crops (t/y)	127 256	0	0	0	0	828 918	956 174	-	-	-	-	-	-	-	-	-	-	-
Grazed biomass (t/y)	55 715	0	0	0	0	640 722	696 436	-	-	-	-	-	-	-	-	-	-	-
Wood (t/y)	601 415	0	0	0	0	645 390	1 246 804	-	-	-	-	-	-	-	-	-	-	-
WIld fish (t/y)	2 398	0	0	0	0	588	2 987	-	-	-	-	-	-	-	-	-	-	-
Other wild resources (kg/y)	0	0	0	0	0	40 061 475	40 061 475	-	-	-	-	-	-	-	-	-	-	-
Water supply (m^3/y)	2 242 936	0	64 213	290 517	268 029	807 629	3 673 325	-	-	-	-	-	-	-	-	-	-	-
Water flow regulation (m^3/y)	0	0	0	0	688 528	0	688 528	-	-	-	-	-	-	-	-	-	-	-
Sediment retention (m^3/y)	0	367 729	0	0	0	0	367 729	-	-	-	-	-	-	-	-	-	-	-
Nutrient retention (tP/y)	0	579	0	0	0	0	579	-	-	-	-	-	-	-	-	-	-	-
Carbon retention (tC)	0	0	0	0	162 896 090	0	162 896 090	-	-	-	-	-	-	-	-	-	-	-
Tourism value (UGX millions/y)	0	0	134	0	7,3	0	141	-	-	-	-	-	-	-	-	-	-	-

Table 5.7 Basin level example table: Albert Nile asset value of ecosystems

Albert Nile Summary: Asset value of ecosystems, UGX 2017 millions	Open water	Wetland	Grassland	Bushland	Woodland	Forest	Plantation	Farmland	Built-up area	Bare	Total
Opening stock (1990)	54 306	1 425 213	1 641 839	467 993	6 241 064	25 866	38 715	10 400 596	5 243	-	20 300 833
Change due to change in ecosystem extent	-35 200	-342 609	1 819 424	883 316	-7 678 818	11 280	61 595	7 239 600	57 867	-	2 016 455
Change due to change in service supply or demand	1 384 465	1 796 112	2 114 643	835 588	4 198 624	46 796	387 746	22 661 472	27 775	-	33 453 222
Net change	1 349 266	1 453 503	3 934 068	1 718 904	-3 480 194	58 076	449 340	29 901 072	85 643	-	35 469 676
Closing stock (2015)	1 403 571	2 878 716	5 575 907	2 186 896	2 760 870	83 941	488 055	40 301 667	90 886	-	55 770 510
Net change %	2 485	102	240	367	-55,8	225	1 161	287	1 633	-	175

Table 5.8 District level example table: Abim supply and use of ecosystem services in 2015, in monetary units

ABIM Ecosystem services monetary supply and use table 2015																		
				Economic unit									Ecosystem					
	Agric, Forestr	Water supply	Trade, caterin	Other industries	Government	Households	Total	Open water	Wetland	Grassland	Bushland	Woodland	Forest	Plantation	Farmland	Built-up area	Bare	Total
Ecosystem Area (ha)	-	-	-	-	-	-	-	9,0	293	163 263	49 186	7 901	0	0	52 873	1 467	7,0	274 999
Monetary supply 2015																		
Crops	-	-	-	-	-	-	-	0	0	0	0	0	-	-	12 947	0	0	12 947
Grazed biomass	-	-	-	-	-	-	-	0	2,0	20 572	7 294	65,8	-	-	7 681	0	0	35 615
Wood	-	-	-	-	-	-	-	0	0,2	1 453	2 100	2 408	-	-	2 846	0	0	8 807
Wild fish	-	-	-	-	-	-	-	0,0	0	0	0	0	-	-	0	0	0	0,0
Other wild resources	-	-	-	-	-	-	-	0	2,5	934	435	338	-	-	363	0	0	2 072
Water supply	-	-	-	-	-	-	-	420	0	0	0	0	-	-	0	0	0	420
Water flow regulation	-	-	-	-	-	-	-	0	0	10,9	9,4	1,1	-	-	3,1	0,0	0	24,5
Sediment retention	-	-	-	-	-	-	-	0	0	13 088	10 031	8 558	-	-	5 175	0	0	36 852
Nutrient retention	-	-	-	-	-	-	-	0	0	93,0	15,9	6,0	-	-	0	0	0	115
Carbon retention	-	-	-	-	-	-	-	0	942	41 918	14 188	3 051	-	-	11 280	361	0	71 740
Tourism value	-	-	-	-	-	-	-	0	0	173	21,6	0	-	-	9,9	0	0	204
Total	-	-	-	-	-	-	-	420	947	78 242	34 094	14 427	0	0	40 305	361	0	168 796
Monetary use 2015																		
Crops	4 753	0	0	0	0	8 194	12 947	-	-	-	-	-	-	-	-	-	-	-
Grazed biomass	2 849	0	0	0	0	32 766	35 615	-	-	-	-	-	-	-	-	-	-	-
Wood	4 262	0	0	0	0	4 546	8 807	-	-	-	-	-	-	-	-	-	-	-
Wild fish	0,0	0	0	0	0	0,0	0,0	-	-	-	-	-	-	-	-	-	-	-
Other wild resources	0	0	0	0	0	2 072	2 072	-	-	-	-	-	-	-	-	-	-	-
Water supply	379	0	3,4	13,2	13,1	11,2	420	-	-	-	-	-	-	-	-	-	-	-
Water flow regulation	0	0	0	0	24,5	0	24,5	-	-	-	-	-	-	-	-	-	-	-
Sediment retention	0	36 852	0	0	0	0	36 852	-	-	-	-	-	-	-	-	-	-	-
Nutrient retention	0	115	0	0	0	0	115	-	-	-	-	-	-	-	-	-	-	-
Carbon retention	0	0	0	0	71 740	0	71 740	-	-	-	-	-	-	-	-	-	-	-
Tourism value	0	0	196	0	8,1	0	204	-	-	-	-	-	-	-	-	-	-	-
Total	12 243	36 966	200	13,2	71 786	47 589	168 796	-	-	-	-	-	-	-	-	-	-	-

Table 5.9 District level example table: Abim asset value of ecosystems

ABIM Summary: Asset value of ecosystems, UGX 2017 millions											
	Open water	Wetland	Grassland	Bushland	Woodland	Forest	Plantation	Farmland	Built-up area	Bare	Total
Opening stock (1990)	121	9 035	610 515	213 233	1 173 566	-	-	182 657	28,6	-	2 189 156
Change due to change in ecosystem extent	1 150	0,0	276 402	120 102	-1 691 666	-	-	189 370	6 247	-	-1 098 395
Change due to change in service supply or demand	8 924	13 978	1 014 301	495 131	813 104	-	-	549 169	2 499	-	2 897 105
Net change	10 074	13 978	1 290 703	615 233	-878 562	-	-	738 539	8 746	-	1 798 710
Closing stock (2015)	10 195	23 012	1 901 218	828 466	295 004	-	-	921 196	8 775	-	3 987 866
Net change %	8 295	155	211	289	-74,9	-	-	404	30 581	-	82,2

6. NEXT STEPS

OVERVIEW

The Ecosystem Accounts were compiled over a period of 6 months, from engaging with government on data for the accounts, inspection of the existing data and accounts, to spatial modelling, and compilation of complex accounting tables down to the resolution of 146 districts and cities. As such, the study had to be limited in scope to achieve this. While significant progress was made in extending the previous work, there is still more to be done to complete these, and there are aspects that deserve further consideration, some of which have little precedent globally.

In discussions, the UBOS-led technical working group expressed that achieving complete coverage of ecosystem services should be a priority, even if some of the estimates are very high level or preliminary. This is important to start creating awareness of all these services, as well as what has to be done to refine the estimates. It was also considered important to have some estimate of value, even if preliminary, rather than no estimate at all. Once the coverage is more complete, there will be opportunity to begin refining these estimates over time.

In addition, these accounts are already seven years out of date. It will be important to begin in earnest to bring them closer to the present. This is now possible with the recent completion of the Uganda Land Cover for 2021. The latest land cover data are at much higher resolution (10m) than the previous series (30m), due to the launch of new satellites in 2015.

EXTENDING THE COVERAGE OF ECOSYSTEM SERVICES

The following services were not included due to data or time constraints and should be added to the accounts, as a next step. This list is not exhaustive, and further services included in the SEEA EA Table 6.3 could be considered at a later stage.

<u>Pollination</u>: This service has not been computed in the present version of the accounts due to the broad definition of "agricultural land" in the land cover data. Pollination services come from natural vegetation within 2 m of land under insect, bird or mammal-pollinated fruit and vegetable crops. This can be computed with a landcover dataset that provides a more specific agricultural land cover classification that would have to be combined with the UBOS land cover data. Preliminary estimates can be produced using evidence from other areas. Ultimately, it would be possible to generate evidence from Uganda through extension of its past panel data collection efforts with suitable modifications.

<u>Flood attenuation</u>: Estimation of flood attenuation typically relies on hydrological and hydraulic modelling, as well as detailed spatial data on structures and land use in flood prone areas. Doing this at large scales is a challenge, so must be done using relatively simple methods. InVEST has produced a flood attenuation model which simplifies some of the modelling required.

<u>Recreation services</u>: The current work has focused on tourism. However recreational services also include local use, such as visiting parks and beaches, that is not captured in tourism statistics. This is particularly valuable in urban green space areas, particularly in large urban areas that are more disconnected from surrounding natural environments. The accounts should be extended to include this value, and could make use of earlier work done on the recreational value of green open space in Kampala (Gelo & Turpie 2021).

Air temperature regulation: Also a service that is mainly pertinent to large urban areas, and focussing on trees and wetlands. InVEST has a model for this, which we have applied in Johannesburg. It is not an easy to use model, and again does not do the whole job, but it helps. Setting this up requires detailed mapping of natural habitats and trees, so usually some remote sensing work. The latest land cover will be better suited for this. The modelling also requires a layer of buildings with typology, which takes a bit of time to set up, and can draw on sources such as open street maps. The model generates the temperature amelioration for a specific ambient temperature which needs to be linked to cost savings for air conditioning and/or productivity. We link this to the statistical distribution of ambient temperature.

Air quality regulation. This service is likely to be highly relevant for Kampala. It is typically modelled using software such as iTree. Estimation of the physical service requires (a) data on air quality, and (b) detailed spatial data on trees, including species and canopy type, usually drawing on a combination of satellite data and tree sampling data. Estimation of the value requires linking air quality to illness and death. Such studies have been done using cross sectional statistical analysis of illness and death in relation to air quality across multiple cities, but as far as I know, only in the developed world (USA). We would not be able to take such a study to a refined level, but might be able to generate some preliminary estimates based on the literature.

Regional climate/rainfall regulation: We note that this has not been covered, but it will not be possible to do so within the time frame. Tropical high forests affect cloud cover and rainfall, and through regional/continental scale climate modelling, deforestation of tropical African forests is predicted to have some dramatic impacts on rainfall, which will see drying out of these countries, and concomitant loss of crop and livestock productivity. We are eager to see this tackled eventually with the help of climate modellers, especially as Ugandans are already somewhat sensitised to this service. This is particularly complex as neighbouring country actions affect one another, so the service is both imported and exported.

EXTENDING THE TIME SPAN OF THE ECOSYSTEM ACCOUNTS

The current accounts go to 2015. Meanwhile land cover data have been produced for 2019, and the 2021 cover was in an advanced state of preparation and could be ready. The nature of the land cover data has changed again, so extending the accounts to 2021 will provide the opportunity to demonstrate how to work with this kind of challenge in the time series.

While the next census will only be in 2024, there will be some new data for livestock (following the recent livestock census), and there are likely to be updated statistics for tourism, fisheries, forestry and agriculture.

Extending the accounts to include 2021 (or 2019) will involve rerunning all of the models using the 2019 land cover and updated estimates of demand and prices, using updated data from sources such as the statistical abstracts, or through projection (using similar methods to the projections used in the current study). The table constructions will change and will need to be regenerated. Some additional discussion points would be added, particularly how to interpret the changes given the higher resolution land cover.

INCORPORATING ECOSYSTEM CONDITION

Improving and integrating understanding of ecosystem condition and its effect on ecosystem services is an important next step. These accounts have included estimates of the effects of unstainable resource use in the calculation of asset value. However, these estimates do not extend to agricultural land which in many parts of the world is declining in quality. Furthermore, the estimates of the capacity to supply ecosystem services is linked to ecosystem condition, but there is little information on this in Uganda. Field studies are required to measure and map ecosystem condition, to generate ecosystem condition accounts and link these to the ecosystem services accounts.

IMPROVING ESTIMATES OF ASSET VALUE

Estimates of ecosystem capacity to supply provisioning services are crucial to the computation of ecosystem asset values. More work is needed to estimate the stocks of resources such as fish, bush meat and other harvested resources, as well as the health and production capacity of farmland and rangeland. Methods need to be refined for incorporating this information into the estimates of asset value.

Ideally, there should be eventually there should be a central database of information on resources stocks, sustainable yield and resource demand that is accessible to compilers. Questions pertaining to quantities of resources harvested could be included in the Agricultural Census.

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8. APPENDIX

Uganda's land cover data were the key data input for mapping and estimating the extent of ecosystems in the study. Previous accounting work used land cover classes as a suitable proxy for ecosystem types, as is commonly done in the Ugandan context (GoU, 2020b). However, for the purposes of this study, the 13 national land cover classes were aggregated into 10 ecosystem types, as certain land cover divisions were not considered to meet the definition of distinct ecosystem types based on the SEEA definition. This appendix provides further detail on the overlap between the original land cover classes and the ecosystem types used for accounting, showing the total area of each land cover class and ecosystem type in 1990 (Table 8.1) and 2015 (Table 8.2).

Table 8.1. Cross-walk of the 13 original land cover classes and the 10 final ecosystem types used for accounting. Values give the area of each land cover class and ecosystem type in 1990.

Land cover / Ecosystem	Open water	Wetland	Grassland	Bushland	Woodland	Forest	Plantation	Farmland	Built-up area	Bare	Total
Open water (ha)	3 676 875										**3 676 875**
Wetland		501 765									**501 765**
Grassland			5 338 320								**5 338 320**
Bushland				1 553 473							**1 553 473**
Woodland					3 542 873						**3 542 873**
THF well stocked						742 816					**742 816**
THF low stocked						227 569					**227 569**
Broad leaved plantation							16 574				**16 574**
Coniferous plantation							15 705				**15 705**
Small-scale farmland								8 404 734			**8 404 734**
Commercial farmland								68 571			**68 571**
Built-up									36 185		**36 185**
Impediments										5 088	**5 088**
Total	**3 676 875**	**501 765**	**5 338 320**	**1 553 473**	**3 542 873**	**970 385**	**32 279**	**8 473 305**	**36 185**	**5 088**	

Table 8.2. Cross-walk of the 13 original land cover classes and the 10 final ecosystem types used for accounting. Values give the area of each land cover class and ecosystem type in 1990.

Ecosystem \ Land cover	Open water	Wetland	Grassland	Bushland	Woodland	Forest	Plantation	Farmland	Built-up area	Bare	Total
Open water	3 671 788										**3 671 788**
Wetland		760 109									**760 109**
Grassland			5 100 737								**5 100 737**
Bushland				1 971 363							**1 971 363**
Woodland					1 213 201						**1 213 201**
THF well stocked						529 030					**529 030**
THF low stocked						101 983					**101 983**
Broad leaved plantation							44 359				**44 359**
Coniferous plantation							63 557				**63 557**
Small-scale farmland								10 273 651			**10 273 651**
Commercial farmland								256 860			**256 860**
Built-up									136 062		**136 062**
Impediments										7 848	**7 848**
Total	**3 671 788**	**760 109**	**5 100 737**	**1 971 363**	**1 213 201**	**631 013**	**107 916**	**10 530 511**	**136 062**	**7 848**	**-**