RWANDA
ENVIRONMENTALLY ADJUSTED MACROECONOMIC INDICATORS
Draft

18 January 2024

FOREWORD

This is a first attempt to estimate environmentally adjusted macroeconomic indicators for Rwanda. The estimation follows the framework of the Changing Wealth of Nations (CWON) project of the World Bank, which adjusts standard economic indicators from national accounts—such national income and savings—for environmental depletion and degradation. CWON also computes *total wealth*, which includes wealth from produced capital, subsoil assets, natural capital, and human capital. The CWON reports, which provide estimates for 146 countries, use global datasets, of which many, but not all, include country-specific data. Using national data makes the indicators both more accurate and more reliable for in-country use. This report computes two flow indicators—adjusted net national income and adjusted net savings—using national data as far as possible. We do not attempt to compute wealth, and instead report wealth estimates for Rwanda from the CWON database.

The National Institute for Statistics Rwanda has provided most of the national data, including economic macroindicators, education expenditure, and mineral depletion. Other data sources include the Rwanda Environment Management Authority's National Greenhouse Gas Emission Inventory and the Rwanda Forestry Agency, which provided information on forest cover.

This report is part of the *Natural Capital Accounting and Valuation of Ecosystem Services to Inform Decision-Making in Rwanda* technical assistance funded by the World Bank's Global Program for Sustainability, and was prepared by Baba Ali Mwango and Sofia Ahlroth, consultants to the World Bank.

EXECUTIVE SUMMARY

Traditional economic indicators, such as gross domestic product, are instrumental in tracking economic growth. But they often fall short in capturing the full scope of a nation's environmental wealth and the repercussions of its depletion. Inspired by its Vision 2020 forestry blueprint, Rwanda has developed accounts for land, water, and ecosystems (Government of Rwanda 2018a, 2018b, 2019) to bridge this gap, proactively exploring more encompassing metrics to provide a holistic view of its wealth that encompasses its rich natural endowments and its human capital.

This report is a first attempt to estimate environmentally adjusted macroindicators, incorporating an array of costs and benefits into its economic assessments. It follows the World Bank's Changing Wealth of Nations (CWON) project methodology, and focuses on the following flow indicators:

- *Adjusted Net national Income (ANNI),* defined as net national income [gross national income[1] minus consumption of fixed capital] minus natural capital depletion [net forest depletion plus mineral depletion plus energy depletion]
- *Adjusted Net Savings (ANS),* defined as net national savings [gross national savings minus consumption of fixed capital] minus natural capital depletion [net forest depletion plus mineral depletion plus energy depletion] minus pollution damage [carbon dioxide damage plus air pollution damage].

It is important to note that the *natural capital depletion* component in this report include only the value of forest depletion, and only the value of timber. We do not include significant ecosystem services such as soil retention, water retention, habitat for biodiversity, or nontimber forest products. In addition, provisioning and regulating ecosystem services from other ecosystems such as lakes and wetlands are missing.

Table S1 shows the data sources for each of the ANS and ANNI components. Our ambition is to use national data as much as possible, but where these are not available—such as for forest depletion and air pollution—we use Rwanda estimates from the CWON database. While the National Institute for Statistics Rwanda compiles data on *timber production*, these do not specify whether some of this production was in excess of natural growth and so might represent forest depletion. CWON *forest depletion* data are based on the Global Forest Resources Assessment database at the Food and Agriculture Organization of the United Nations' food and agriculture statistics (FAOSTAT). Replacing these with national data could change the picture dramatically (see the appendix for a more details). For *air pollution*, national data on ambient air quality data are available, but we were unable to compile other data needed to compute the health damages within the project timeframe.

The CWON's computation of *total wealth* emphasizes the conservation of both natural resources and human capital. As we were not able to estimate Rwanda's wealth within the scope of this project, we use the results for Rwanda from the CWON report. Using more granular national data would result in better estimates of Rwanda's wealth and the sustainability of economic growth. In particular, the value of protected areas would likely change considerably, as these gather significant income in Rwanda and are probably quite undervalued with the proxy method used in the CWON estimates.

[1] Gross national income = GDP plus net primary income from abroad

Table S1. Data sources for ANS and ANNI for Rwanda

	Source
Gross Domestic Product (GDP)	National Institute of Statistics of Rwanda/GDP publication
Plus: net primary income from abroad	National Bank of Rwanda/Balance of Payment
Gross National Income (GNI)	
Plus: net current transfers from abroad	National Bank of Rwanda/Balance of Payment
Gross National Disposable Income (GNDI)	
Deduct: household final consumption	National Institute of Statistics of Rwanda/GDP publication
Deduct: government final consumption	National Institute of Statistics of Rwanda/GDP publication
Gross National Savings (GNS)	
Deduct: consumption of fixed capital (depreciation)	National Institute of Statistics of Rwanda/GDP publication
Net National Saving (NNS)	
Plus: Education expenditure	National Institute of Statistics of Rwanda
NNS + Education expenditure	
Deduct: Forestry depletion	World Bank
Deduct: Mineral depletion	National Institute of Statistics of Rwanda
Deduct: Energy depletion	N/A
Deduct: CO2 damage	Rwanda National Greenhouse Gas Inventory (GHG emissions); World Bank (CO2 price)
Deduct: Air pollution damage	World Bank
Adjusted Net National Saving (NNS)	
Net National Income	
Adjusted Net National Income	

Table S2 shows that ANS fluctuates over the period, roughly following gross national savings. As *education expenditure* is counted as investment in human capital, we add it to the savings, while we deduct *natural capital depletion* and *pollution damage*. *Net forest depletion,* which falls under natural capital depletion, is by far the largest adjustment item, and *damage to human health from air pollution*, which falls under *pollution damage*, is the second largest. However, these two figures are from the CWON database, which would preferable be replaced with national data. *Carbon dioxide damage,* included in *pollution damage*, is small, mirroring Rwanda's low greenhouse gas emissions per capita. *Energy depletion* is also very small, since Rwanda does not have any subsoil assets besides peat and is omitted in the table. *Mineral depletion* is 0 up to 2016, which is an effect of low productivity in the sector during the period, yielding negative resource rents. This situation changes from 2017 onward, which may be due to improved equipment and expertise.

Table S2. ANS at constant 2017 price (RF, millions) 2014–21

	2014	2015	2016	2017	2018	2019	2020	2021
Gross savings	780,636	551,909	609,522	1,117,000	902,515	1,062,588	1,114,651	1,528,821
Consumption of fixed capital	-116,448	-114,705	-115,927	-114,843	-121,571	-124,573	-126,640	-132,640
Net savings	664,189	437,204	493,595	1,002,157	780,944	938,015	988,012	1,396,181
Education expenditure	362,626	353,273	366,111	367,456	374,618	410,846	276,718	454,311
Natural capital depletion	-372,744	-379,972	-412,231	-420,693	-358,151	-329,561	-344,771	-369,573
Pollution damage	-128,877	-135,062	-146,306	-160,370	-169,952	-186,501	-204,457	-218,703
Adjusted net savings	525,193	275,444	301,169	788,551	627,458	832,799	715,501	1,262,217

Note: RF = Rwanda francs.

It is informative to look at ANS as a percentage of gross national income (GNI). As GNI shows steady growth over the study period, investment in human capital (*education expenditures*) and *forest depletion* both decrease in relation to GNI, despite themselves increasing or staying stable (figure S1). ANNI (table S3) follows the trend of GNI quite closely. This is because natural capital depletion as captured here as less than one percent of GNI. To get a true picture of ANNI and ANS, we would need a more encompassing depiction of natural capital depletion.

Table S3. ANNI at constant 2017 price (RF, billions) 2014–21

Constant price 2017 RWF, billions	2014	2015	2016	2017	2018	2019	2020	2021
Gross National Income	6,270	6,853	7,199	7,452	8,049	8,835	8,628	9,594
Consumption of fixed capital	116	115	116	115	122	125	127	133
Net forest depletion	10	12	11	9	-17	15	9	14
Energy depletion	0	0	0	0	0	0	0	0
Mineral depletion	6	3	3	3	3	2	4	1
Adjusted net national income	**6,138**	**6,723**	**7,069**	**7,325**	**7,941**	**8,693**	**8,489**	**9,446**

A comparison between ANS estimated with national and CWON data reveals differences in both the environment adjustments and the national accounts data. As shown in figures S1 and S2, the largest difference is not for environment variables but for consumption of fixed capital (CFC) from the national accounts. CFC is much larger in the CWON database than in the Rwandan national accounts, making net savings hover around 0. When we make environment adjustments, the values become negative.

With the national data, ANS stays positive during the study period, primarily because CFC is much smaller than in the CWON dataset, making net savings only slightly lower than gross savings. Another, albeit smaller, cause for the difference is that national data show higher education expenditure. Both mineral depletion and carbon dioxide damage, while small, differ significantly between the datasets. CWON estimates mineral depletion to be around 0.02 percent of GNI in 2014, and 0 in 2021, while national data estimate it at 0 in 2014 and 0.5 percent from 2017 onward. Carbon dioxide damage is very small (around 0.5 percent) in CWON and almost negligible (0.001 percent) in national estimates.

Figure S1. ANS using national data, aggregated adjustment variables (% of GNI) 2014–21

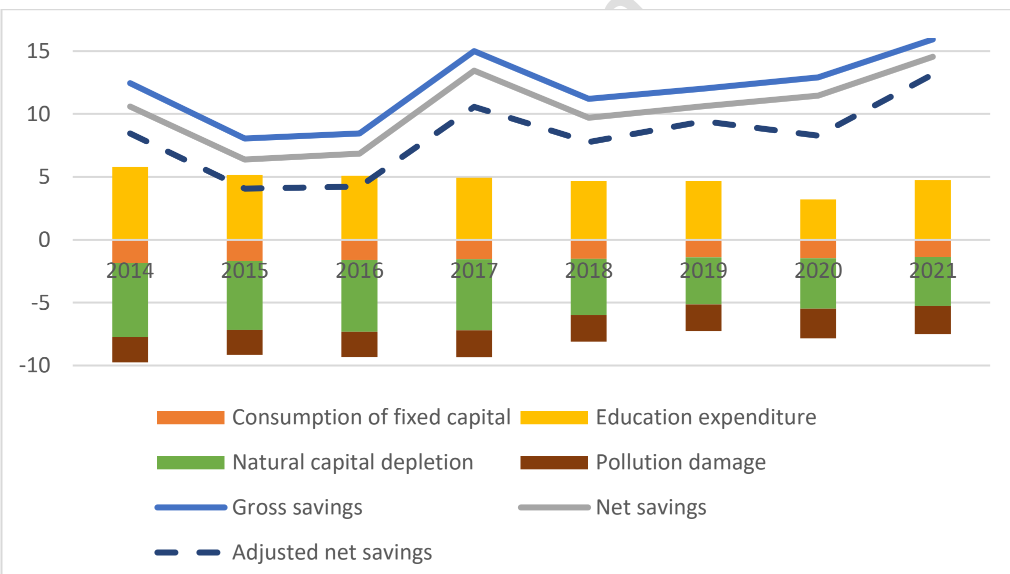
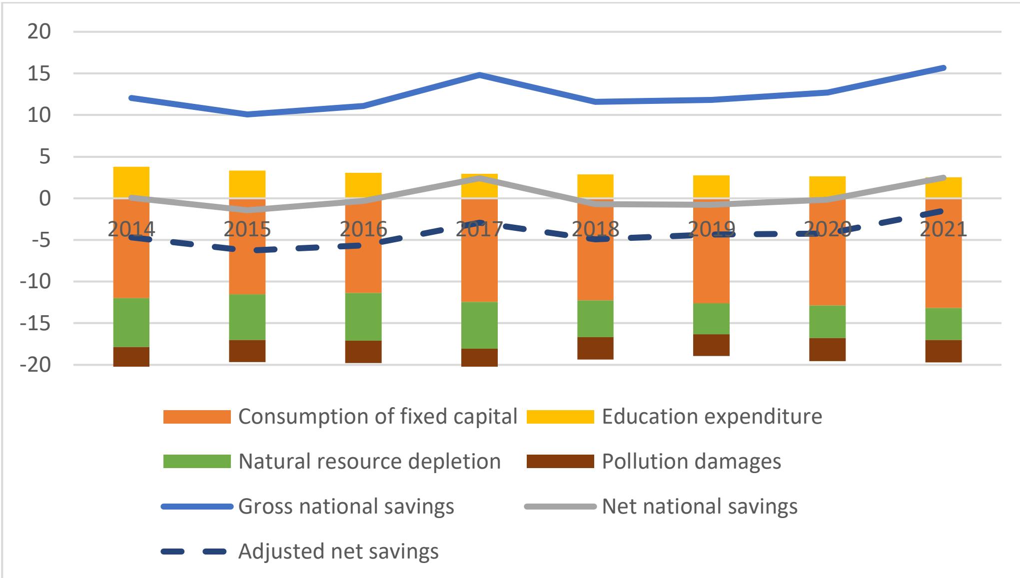


Figure S2. ANS using CWON estimates for Rwanda (% of GNI) 2014–21



WAY FORWARD

This report is a pilot for compiling adjusted macroindicators for Rwanda and should be viewed as work in progress. More work is needed to arrive at national forest depletion and air pollution estimates.

Although there are good data on forest production, there are discrepancies between different national data sources on forest depletion. It will be important to gather experts from the relevant agencies to go through the classifications and agree a common nomenclature and an estimate of net forest depletion. For the longer run, it might be useful to compile forest accounts, including not only timber but also nontimber products, to serve as the official source for forest-related data.

Including provisioning and regulating ecosystem services from forests, lakes, cropland and wetlands would be an important step forward. Rwanda has developed physical ecosystem accounts for 1990 – 2016 for some important ecosystem services related to water and soil (Government of Rwanda 2018b). Updating and building on these to develop monetary ecosystem accounts would enable Rwanda to incorporate a wider set of ecosystem services in the adjusted macroindicators. As many of these services, such as soil retention, water retention, and flood prevention, are crucial, this would provide vital information not only for the adjusted indicators but also for analyzing land use planning and policies that impact the way land is used.

Developing national data on wealth would be a considerable improvement on global estimates. Using more accurate methodologies for valuing natural capital and more granular data, these data would provide better estimates of Rwanda's wealth and the sustainability of economic growth. National data would be particularly useful for estimating the value of protected areas, which gather significant income in Rwanda and are therefore likely to be underestimated in CWON estimates.

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ACRONYMS

ANNI	adjusted net national income
ANS	adjusted net savings
CFC	consumption of fixed capital
CWON	Changing Wealth of Nations
FAO	Food and Agriculture Organization of the United Nations
FRA	Global Forest Resources Assessment
GDP	gross domestic product
GHG	greenhouse gas
GNI	gross national income
GNS	gross national savings
GO	gross output
IBES	Integrated Business Enterprise Survey
IC	intermediate consumption
MoFPED	Ministry of Finance, Planning and Economic Development
NISR	National Institute for Statistics Rwanda
NNI	net national income
NNS	net national savings
PM2.5	very fine particulate matter
RCMRD	Regional Centre for Mapping of Resources for Development
RF	Rwanda francs
SNA	System of National Accounts
SUT	supply and use tables
tCO2e	tons of CO2 equivalent

All dollar ($) amounts are US dollars

1 Introduction

1.1 Background and Rationale

Over the past decade, Rwanda, known as the Land of a Thousand Hills, has embarked on a transformative journey toward environmental conservation and efficient natural resource management. The nation's rich biodiversity—which includes national parks, forests, wetlands, and lakes—is a testament to its dedication to preserving its natural heritage. Environmental and natural resource conservation have been well integrated in country's development blueprints, such as Vision 2020 Economic Development and Poverty Reduction Strategy, Vision 2050, and the National Strategy for Transformation (2018–24). Rwanda's commitment to protect nature was further cemented in 2011 when it pledged, through the Bonn Challenge, to restore 2 million hectares (almost 8 percent of total land area) by 2030 (Government of Rwanda 2019b).

While traditional economic indicators, such as the Gross Domestic Product (GDP), have been instrumental in tracking Rwanda's developmental trajectory, they fall short of capturing the full scope of its environmental wealth and the repercussions of its depletion. To bridge this gap, Rwanda has been proactively exploring more encompassing metrics that provide a more holistic view of the nation's wealth, encompassing both its rich natural endowments and human capital.

GDP growth is the most widely used macroeconomic indicator for measuring broad economic progress. But this is typically examined without reference to the evolution and composition of underlying economic variables, such as a nation's asset portfolio or wealth. The latter is formed by assets that turn into income (Net National Income, or NNI), which is partly consumed and partly saved. But in low-income countries, empirical evidence suggests that the consumption of these assets—often natural resources—can comprise a large share of NNI, sometimes as high as 50 percent. This deteriorates the country's genuine savings, indicating that growth is neither economically nor environmentally sustainable. It is therefore vital to track both a comprehensive measure of both *savings*, adjusted for the depletion of capital, and *wealth*, including both natural and human capital. Natural capital accounting aims to provide such comprehensive measures. Using the System of Economic-Environmental Accounts (SEEA) framework,[2] adopted as a statistical standard by the United Nations Statistical Commission, *natural capital accounting* integrates environment and natural resources into standard national accounts, facilitating the development of environmentally adjusted macroindicators to complement standard economic metrics, such as GDP, gross national income (GNI), and gross national savings (GNS).

In line with the System of Economic-Environmental Accounts framework, World Bank's Changing Wealth of Nations (CWON) project, publishes adjusted macroeconomic indicators biannually for 146 countries.[3] The indicators include Adjusted Net National Income (ANNI), Adjusted Net Savings (ANS) and total wealth.

Uganda and Ghana are among the African countries that have committed to developing measures for environmentally adjusted macroindicators. Uganda has been regularly reporting on these indicators since 2019, releasing its third edition in 2023. Indicating the usefulness of such information, its Ministry of

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[2] https://seea.un.org/.

[3] www.worldbank.org/en/publication/changing-wealth-of-nations

Finance, Planning and Economic Development (MoFPED) has created a budget line for the adjusted macroeconomic indicators to ensure regular publication. The government has also used the indicators to highlight specific policy issues—for example, the Macroeconomic Policy Department used the macroeconomic indicator framework to present MoFPED senior management with options for potential taxes and subsidies, to meet the target of raising tax levels from 12 to 16 percent while also contributing to sustainable development. MoFPED is also planning to set targets for the adjusted macroindicators. Ghana recently prepared its first draft report and has started the process to integrate natural capital accounting when computing its GDP to promote holistic and inclusive growth and development.

As the 2030 milestone year approaches, having comprehensive adjusted macroindicators would provide important insights into Rwanda's environmental accomplishments. The government of Rwanda has developed accounts for land, minerals, water, and ecosystems[4]. By continuously updating the environmental accounts, the nation would ensure that every aspect of its natural capital is duly represented, shaping both immediate fiscal decisions and long-term visionary plans.

This report is a first attempt to estimate environmentally adjusted macroindicators that incorporate natural capital depletion and pollution damage into standard economic metrics. Focusing on the ANNI and ANS flow indicators, our ambition is to use national data as much as possible. Where these are not available, we use data from the CWON database to give a comprehensive picture. We also include CWON's estimates of total wealth, emphasizing both natural resource conservation and the contribution of human capital. This report has been prepared in collaboration with the National Institute of Statistics of Rwanda (NISR), Rwanda Forestry Authority, and the International Union in Conservation of Nature (IUCN).

1.2 Framework

The adjusted macroeconomic indicators take GDP as a starting point and make adjustments to income, investments in natural capital, and environmental impact from emissions. *GDP* refers to the monetary worth of all the goods and services that are produced inside an economic region within a particular time period; often a year. It is based the System of National Accounts (SNA),[5] which includes both flows (annual production and consumption) and stocks (assets) of an economy, and covers both income and wealth (assets). But not all countries compile asset accounts, as these data are more difficult to obtain than production and consumption data.

The primary environmentally adjusted macroeconomic and wealth metrics include:

- ANNI and ANS (flow indicators)
- Total wealth (stock indicator)

ANNI and ANS include natural capital depletion and pollution damage. It should be noted that the measures in this report include only a few components of natural capital depletion: depletion of minerals, energy, and forests. Furthermore, the forest depletion estimates only include the value of

[4] Wealth Accounting and the <span>Valuation of Ecosystem Services (wavespartnership.org)

[5] https://unstats.un.org/unsd/nationalaccount/sna.asp.

timber products; significant ecosystem services such as soil retention, water retention, habitat for biodiversity, and nontimber forest products are not included.

Flow indicators: ANNI and ANS

Figure 1. Adjustments made to arrive at ANNI and ANS

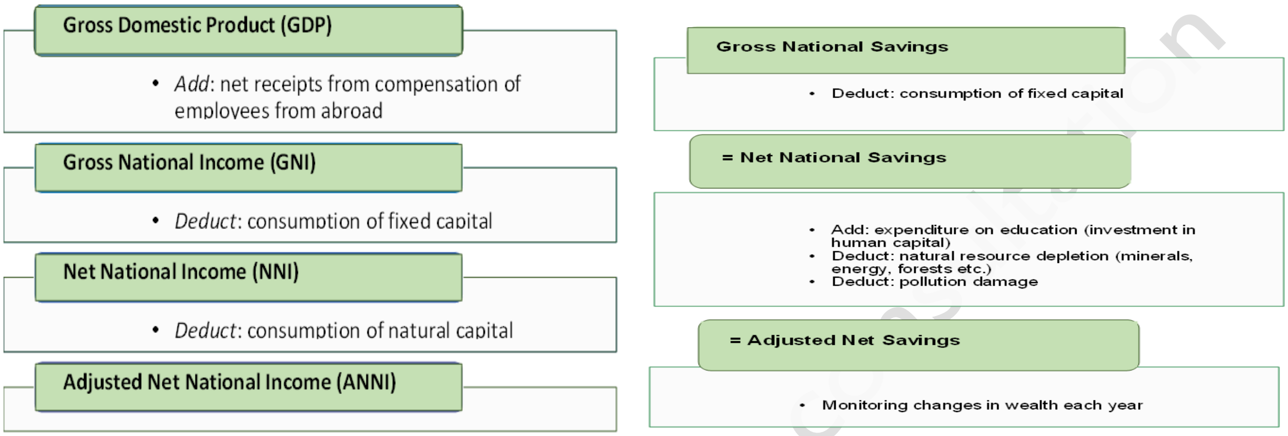


Figure 1 outlines the adjustments made to GDP and GNS to arrive at ANNI and ANS. For non-renewable natural assets, such as minerals and fossil energy, all of the production (extraction) is counted as depletion. For renewable natural capital (such as forests and fisheries), depletion is measured by the excess of production over the natural rate of regrowth. Sustainable consumption of renewable resources ensures that their use does not surpass their natural replenishment rate.

In the ANS calculations, we also consider the environmental impact of economic activities, specifically air pollution damage, as this is equal to negative savings. We break this environmental cost into two main components: the cost (damage) associated with greenhouse gas emissions (measured as carbon dioxide equivalents) and the impact of fine particulate matter (PM2.5) emissions, which have direct health implications.

A negative ANS indicates a concerning trend, suggesting that economic activities might be decreasing the nation's wealth and might not be sustainable in the long run.

The World Bank's World Development Indicators database[6] provides annual updates on ANNI and ANS. The data provides a general overview of the situation across the globe but is less well suited to be used in-country. Using national data to derive the indicators will likely provide a more accurate representation of a country's unique context and challenges. Where possible, the CWON database includes country-reported data, but all variables are not always available for all countries. In these cases, it uses proxies, such as an average from countries in the same region.

Stock indicator: total wealth

A country's wealth is composed of a varied set of assets that collectively establish the foundation of its economic structure. The SNA only considers produced capital and subsoil assets. Total wealth includes all types of natural capital as well as human capital. It can be noted total wealth not necessarily indicative

[6] https://datacatalog.worldbank.org/search?q=Adjusted%20Net%20Savings.

of overall human welfare, as it does not include social and institutional assets. Just as GDP sometimes faces criticism for not truly reflecting societal well-being, wealth accounts can also be perceived as lacking in this regard.

2 RESULTS

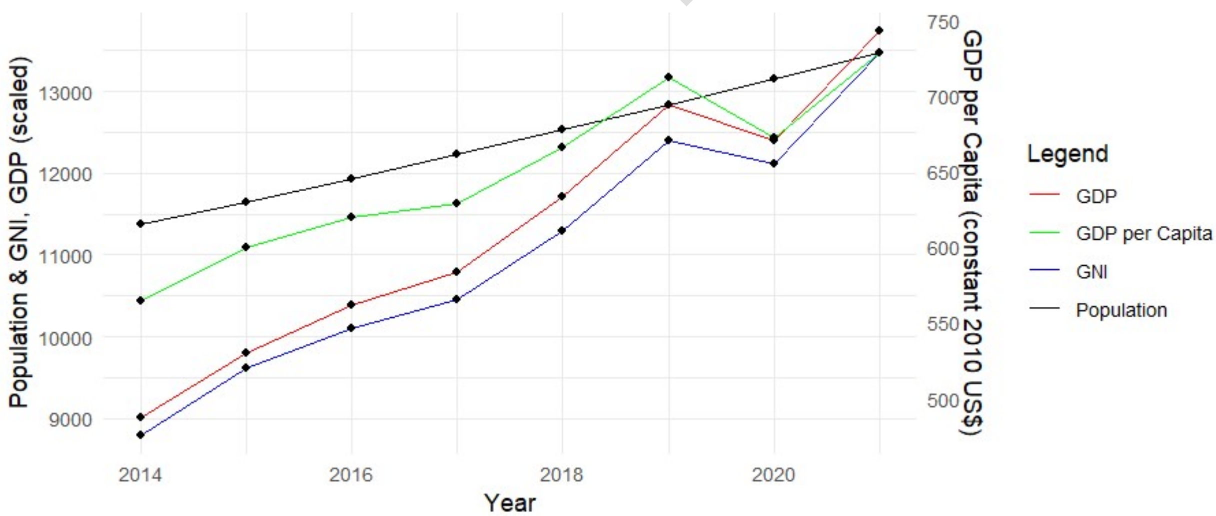
Over the eight-year study period, there was an upward trend in both GDP and GNI, so it is useful to compare the adjustments made with this growth. Rwanda's population also increased gradually, from 11.4 million to 13.5 million over the same period. But, as the increase in GDP per capita to 2019 shows, GDP grew faster than the population, though this dipped in 2020, emphasizing the broader challenges faced that year (table 1, figure 2).

This chapter briefly discusses results and data sources for ANS, ANNI, and total wealth. For a more in-depth explanation of how we derives these figures, see the appendix.

Table 1. Macroeconomic indicators for Rwanda, 2014–21

Macroeconomic Indicator	2014	2015	2016	2017	2018	2019	2020	2021
Population, total (1000 persons)	11,368	11,643	11,931	12,230	12,532	12,835	13,146	13,462
GNI (constant 2017 rwf, billions)	6,270	6,853	7,199	7,452	8,049	8,835	8,628	9,594
GDP (constant 2017 rwf, billions)	6,417	6,986	7,403	7,694	8,351	9,142	8,833	9,794
GDP per capita (constant 2017 rwf)	564	600	620	629	666	712	672	728

Figure 2. Macroeconomic indicators, 2014–21



2.1 ADJUSTED NET SAVINGS

Table 2 shows the ANS components at constant 2017 price in millions of Rwandan francs, and table 3 shows them as a percentage of GNI. ANS fluctuates across the study period, roughly following GNS. *Net forest depletion* is by far the largest adjustment item, and *air pollution damage* the second largest. *Carbon dioxide damage* – part of air pollution damage - is small, mirroring Rwanda's low per capita GHG emissions. *Energy depletion* is very small, as Rwanda does not have any subsoil assets besides peat.

Mineral depletion is 0 up to 2016; this is an effect of low productivity in this sector yielding negative resource rents, a situation that changed in 2017.

Table 2. ANS at constant 2017 price (RF, millions), 2014–21

Component	2014	2015	2016	2017	2018	2019	2020	2021
Gross national savings	780,636	551,909	609,522	1,117,000	902,515	1,062,588	1,114,651	1,528,821
Consumption of fixed capital	-116,448	-114,705	-115,927	-114,843	-121,571	-124,573	-126,640	-132,640
Education expenditure	362,626	353,273	366,111	367,456	374,618	410,846	276,718	454,311
Net forest depletion	-367,083	-376,516	-409,559	-417,855	-354,737	-327,131	-341,001	-367,973
Energy depletion	-1	-15	-34	-44	-89	-84	-61	-126
Mineral depletion	0	0	0	-4,066	-4,629	-3,222	-5,190	-2,021
Carbon dioxide damage	-47	-54	-49	-70	-87	-102	-115	-133
Air pollution damage	-128,830	-135,008	-146,257	-160,300	-169,865	-186,399	-204,342	-218,570
ANS	**525,193**	**275,444**	**301,169**	**788,551**	**627,458**	**832,799**	**715,501**	**1,262,217**

Note: RF = Rwanda francs.

Table 3. ANS as percent of GNI, 2014–21 (%)

Component	2014	2015	2016	2017	2018	2019	2020	2021
Gross national savings	12.45	8.05	8.47	14.99	11.21	12.03	12.92	15.94
Consumption of fixed capital	-1.86	-1.67	-1.61	-1.54	-1.51	-1.41	-1.47	-1.38
Education expenditure	5.78	5.15	5.09	4.93	4.65	4.65	3.21	4.74
Net forest depletion	-5.85	-5.49	-5.69	-5.61	-4.41	-3.70	-3.95	-3.84
Energy depletion	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mineral depletion	0.00	0.00	0.00	-0.05	-0.06	-0.04	-0.06	-0.02
Carbon dioxide damage	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Air pollution damage	-2.05	-1.97	-2.03	-2.15	-2.11	-2.11	-2.37	-2.28
ANS	**8.38**	**4.02**	**4.18**	**10.58**	**7.80**	**9.43**	**8.29**	**13.16**

Data sources and results

GNS: All macroeconomic indicators—GDP, GNI, and GNS—are from the national accounts produced by NISR. Starting at RF 781 billion in 2014, there is a noticeable dip in 2015. But subsequent years see an upward trend, culminating in 2021 with a significant rise to RF 1,529 billion. Although fluctuating over the time period, GNS keeps pace with GNI on average, growing from 12 to almost 16 percent of GNI.

CFC: Indicating the depreciation or wear and tear of the country's capital goods, CFC increases slightly during the period. But it decreases relative to GNI, despite starting at a very low level compared to other countries, where CFC generally lies around 10–20 percent of GDP (OECD 2011).

Net forest depletion: The data suggest fairly stable levels of forest depletion, peaking in 2017. But as a percentage of GNI, forest depletion is decreasing. These estimates are from the CWON database, which in turn are based on the Global Forest Resources Assessment (FRA) database at the Food and Agriculture Organization of the United Nations (FAO) food and agriculture statistics (FAOSTAT). Due to inconsistencies between different national data sources that we could not resolve within the project timeframe, the results are not based on data reported to the FRA; rather, they are based on an analysis of available sources and as such, should be interpreted with care (see the appendix for more detail). Replacing these with national data could change the picture dramatically.

Energy depletion: This is very low, reflecting that Rwanda has some peat bogs, but no subsoil assets such as oil, coal, and gas. We use data from the global CWON database for these calculations.

Mineral depletion: Rwanda's mineral assets primarily consists of wolfram, cassiterite, and cobalt. From 2012 to 2016, resource rents from minerals were negative, meaning that the net gain was lower than the normal rate of return, most likely due to low prices and systemwide production inefficiencies (Government of Rwanda 2019a). From 2017 onward, resource rents are positive, possibly due to the introduction of advanced extraction equipment and the availability of skilled professionals, such as engineers, enhancing profitability.[7] From 2017 onward, the value of mineral depletion varies between RF 2 and 5 million.

Air pollution damage: This has steadily increased over the years, signaling growing environmental or industrial activities that contribute to pollution. These estimates are taken from CWON, as it was not possible to do estimations with national data within the project timeframe. Although ambient air quality data are available, computing the damage would require data on exposure of the population, age composition, and so on. CWON air pollution damage estimates include illnesses caused by exposure to ambient concentrations of PM2.5, ambient ozone, and indoor PM2.5 concentrations in households that cook with solid fuels (Forouzanfar et al. 2016). Monetary losses associated with premature mortality due to air pollution exposure are valued under a forgone labor output approach (see the appendix for more details).

Carbon dioxide damage: This almost triples over the study period, albeit from a very low initial level, mirroring Rwanda's low GHG emission levels of 0.76 tons of carbon dioxide equivalent (tCO_2e) per capita, compared to the global and African averages of 6.90 and 3.39 tCO2e, respectively. GHG emissions data are from Rwanda's GHG Inventory 2006–18, reported to the United Nations Framework Convention on Climate Change in 2021 (Republic of Rwanda 2021). The damage value of carbon dioxide, $40 per tCO2e, represents a lower bound of the global social cost of carbon and follows the value used by the World Bank (2023).

2.2 ADJUSTED NET NATIONAL INCOME

As for ANS, the largest adjustment for ANNI comes from *forest depletion*, followed by *mineral depletion* (table 4). However, as noted above, these results should be interpreted with care as we used CWON data for these calculations. Using national data could change the picture dramatically.

Table 4. ANNI at constant 2017 price (RF, millions) 2014–21

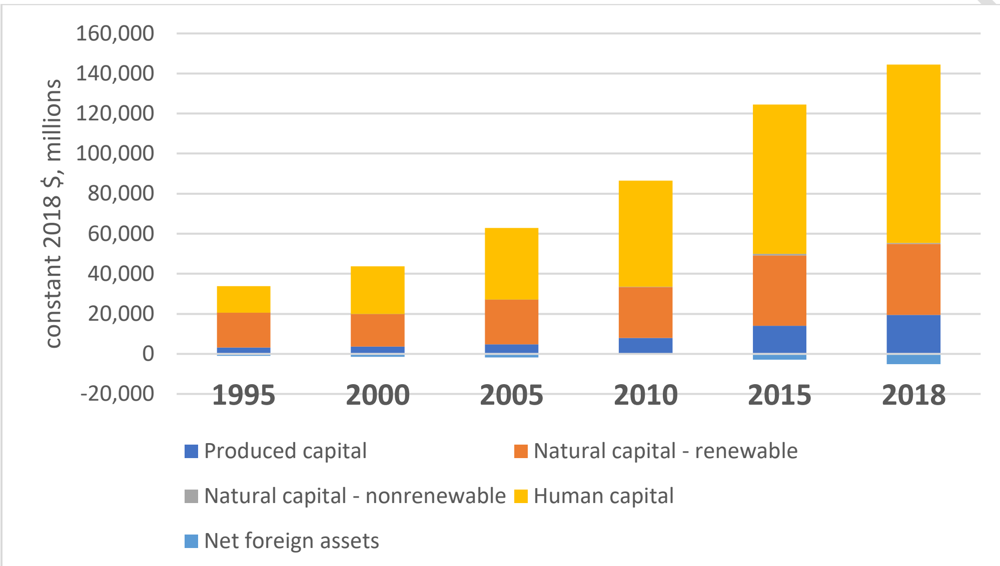
Component	2014	2015	2016	2017	2018	2019	2020	2021
Gross national income	6,270	6,853	7,199	7,452	8,049	8,835	8,628	9,594
Consumption of fixed capital	-116	-115	-116	-115	-122	-125	-127	-133
Net forest depletion	-367	-377	-410	-418	-355	-327	-341	-368
Energy depletion	0	0	0	0	0	0	0	0
Mineral depletion	0	0	0	-4	-5	-3	-5	-2
ANNI	**5,787**	**6,362**	**6,673**	**6,915**	**7,568**	**8,380**	**8,156**	**9,091**

[7] NISR, personal communication.

2.3 TOTAL WEALTH

As noted above, the total wealth estimates are based on CWON data[8]. As shown in figure 3, Rwanda's wealth has grown significantly over the last 20 years. *Human capital* represents the country's largest wealth category and has increased the most. *Nonrenewable natural capital* is the second largest. Produced capital has grown from around 3,000 million US$ in 1995 to 19,400 in 2018, but it is still little more than 50 % of the value of natural capital.

Figure 3. Rwanda: total wealth, 1995–2018



Source: World Bank staff calculations, based on CWON data

Looking at natural capital, Rwanda's cropland has the highest value, dwarfing all the other categories (figure 4). *Forests and ecosystem services* includes timber as well as several ecosystem services, such as recreation, hunting, fishing, nonwood forest products, and watershed protection. Annual per-hectare values for each service category are based on a spatially explicit meta-regression model (Siikamäki et al. 2021).

To estimate the asset value of protected areas, CWON uses a simplified approach that estimates the quasi-opportunity cost of protection per unit area of land contained in terrestrial protected areas as the lower of cropland and pastureland's per hectare wealth. This value per hectare is then multiplied by the country's total terrestrial protected area, to arrive at the asset value of protected areas. This is a lower bound on the true value of protected areas; an estimate based on national data would likely be much higher.

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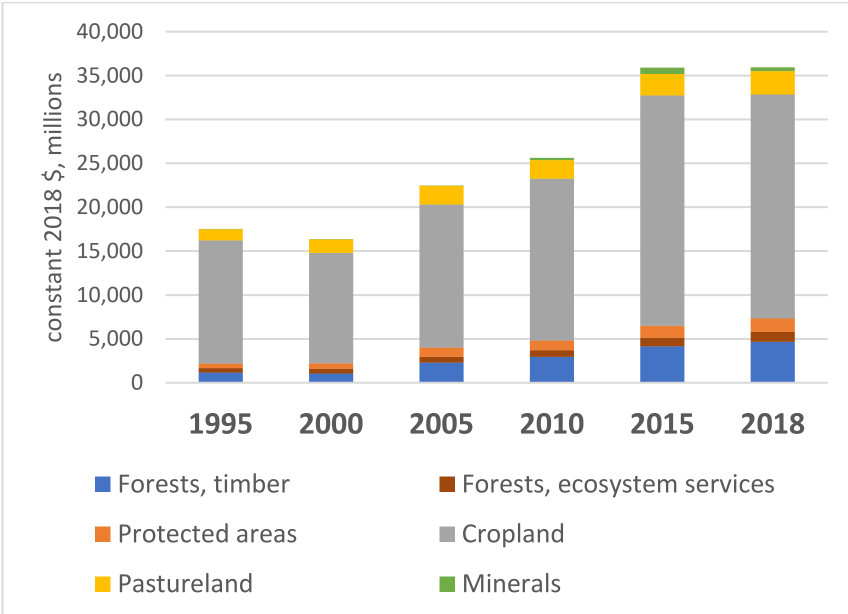
[8] www.worldbank.org/en/publication/changing-wealth-of-nations/data

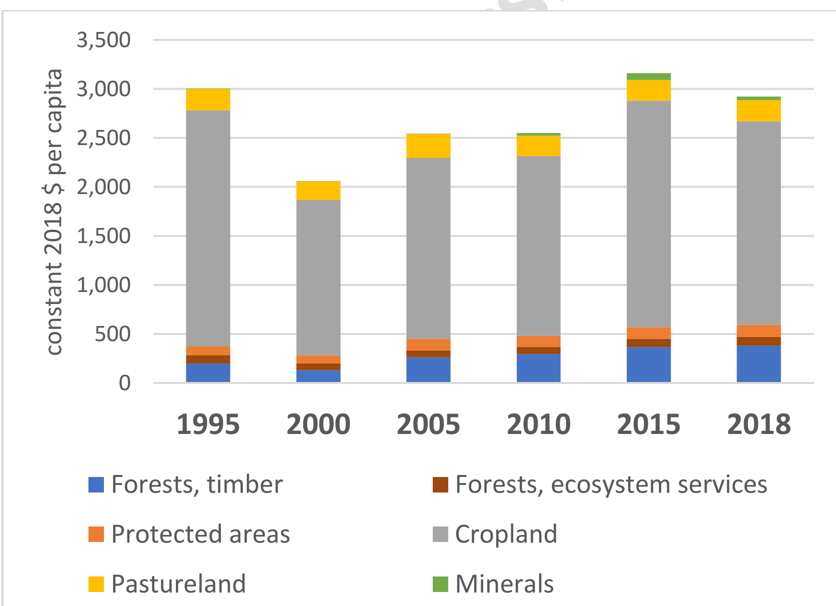
Figure 4. Composition of Rwanda's natural capital, 1995–2018



Source: World Bank staff calculations, based on CWON data

While the value of natural capital increases in total value across the study period, this picture changes somewhat when we look at natural capital wealth per capita (figure 5). The level of natural capital wealth per person in 2018 is very similar to 1995, despite the population more than doubling in that time.

Figure 5. Rwanda's per capita natural capital wealth, 1995–2018

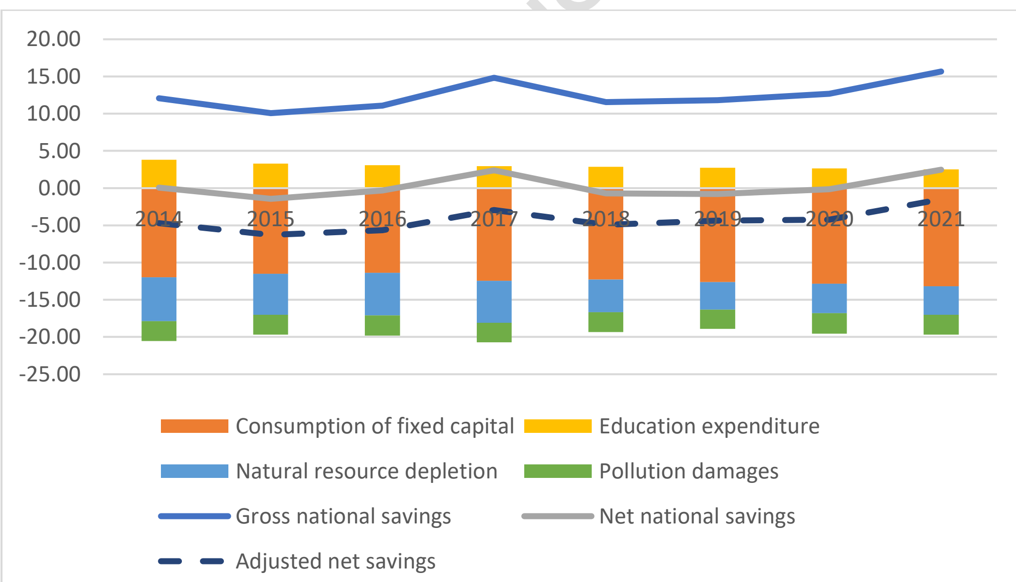


3 COMPARISON WITH GLOBAL ANS ESTIMATES FOR RWANDA

A comparison between national and CWON ANS reveals various differences in environment adjustments and national accounts data, particularly for CFC (figures 6 and 7). In the CWON database, CFC is around 12 percent of GNI, while in the Rwandan national accounts, it is less than 2 percent. This makes net national savings (NNS) hover around 0 in the CWON estimate, turning negative after environment adjustments. ANS lies around -5 percent of GNI, and CFC is much larger than the adjustment for natural capital depletion and pollution damage combined (figure 6).

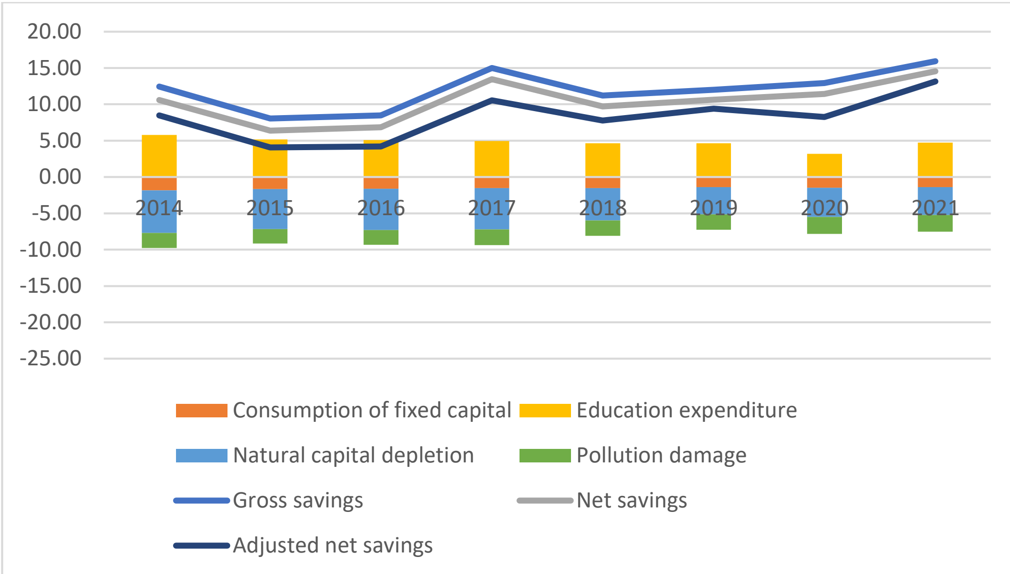
Using national data, ANS stays positive throughout the study period (figure 7), primarily because CFC is much smaller than in the CWON dataset, making net savings only slightly lower than gross savings. Another, albeit smaller, cause of this difference is that national data show higher education expenditures. We use CWON data for *natural capital depletion* and *air pollution damage*, so these are the same magnitude as in the global dataset, and they are by far the largest of each aggregate. *Mineral depletion* and *carbon dioxide damage* differ between the datasets. CWON estimates mineral depletion at around 0.02 percent in 2014 and 0 in 2021, while the national data estimate it at 0 in 2014 and, due to resource rents becoming positive, around 0.5 percent of GNI from 2017 onward. Carbon dioxide damage, while also very small (around 0.5 percent of GNI) in CWON, is almost negligible (0.001 percent of GNI) in national estimates.

Figure 6. ANS as percent of GNI, using CWON estimates for Rwanda, 2014–21



Source: World Bank staff calculations, based on CWON data

Figure 7. ANS as percent of GNI, based on national data, 2014–21



Source: World Bank staff calculations, based on national data

4 CONCLUSIONS

This report is a pilot for compiling adjusted macroindicators for Rwanda and should be viewed as work in progress. More work is needed to arrive at national estimates for forest depletion and air pollution, provisioning and regulating ecosystem services from forests, lakes, and wetlands, and wealth. Here, we set out some conclusions and possible ways forward.

CFC: Our comparison of the national and CWON Rwanda estimates shows a large discrepancy for CFC, which is part of the standard national accounts. CFC is typically approximated with the Perpetual Inventory Method rather than based on direct information, which is rarely available. While for most countries, CFC lies around 10–20 percent of GDP (OECD 2011), our estimates for Rwanda for 2014–20 lie between 1.5 and 2 percent of GDP. It would be useful to investigate these numbers further and specify the methodology, to arrive at correct NNI and NNS, which are the basis for ANNI and ANS.

Forest depletion: Although there are good data on forest production, the information on how much of this production is depletion is inconclusive. Gathering experts from the relevant agencies to review the classifications and agree on a common nomenclature and an estimate of net forest depletion would be useful, and using these to compile forest accounts, including timber but nontimber products, could create an official source for forest-related data moving forward.

Ecosystem services: Including ecosystem services in the indicators would be a significant improvement. Rwanda has compiled partial ecosystem accounts for some important ecosystem services related to water and soil (Government of Rwanda 2018b). These are however only in physical terms, and measures the potential supply, regardless of how much they are used. To arrive at full ecosystem accounts, it is necessary to estimate how much of the services are actually used, and then value the services to get to the monetary accounts. As many of these are critical services—such as soil retention, water retention, and flood prevention—understanding demand would provide vital information not only for the adjusted indicators but also for analyzing land use planning and policies that impact the way land is used.

Wealth: Using national data to estimate total wealth would be a considerable improvement on the global estimates. By enabling the use of more precise methodologies for valuing natural capital, and more granular data, it would result in better estimates of Rwanda's wealth and the sustainability of economic growth. One of the components likely to change most is the value of protected areas, as these gather significant income in Rwanda and are likely quite undervalued with the proxy method used in the CWON estimates.

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APPENDIX. METHODOLOGY AND DATA SOURCES

This appendix provides an overview of the methodology and sources we use for the computations in this report.

A1. FRAMEWORK

Considered one of the most essential metrics in the System of National Accounts (SNA), *gross domestic product (GDP)* is a useful indicator of how well an economy is doing. It can be quantified in three ways: through production, expenditure, or income (presented at current and constant prices).

The National Institute of Statistics of Rwanda (NISR) creates supply and use tables (SUTs) which provide detailed data for the GDP. These give an in-depth view of the supply of goods and services and how they are used, whether for final consumption, capital formation, creating further commodities and services, or for export to other countries. SUTs provide a comprehensive framework that demonstrates how a country uses commodities and services for ultimate use or intermediate consumption, depending on whether they produce them domestically or import them. Table A1 provides an up-to-date structure of the Rwanda economy using the production approach.

Table A1. Rwanda GDP estimates at constant 2017 price (RF, billions)[9]

Activity description	ISIC4	2014	2015	2016	2017	2018	2019	2020	2021	2022
GROSS DOMESTIC PRODUCT (GDP)		**6,417**	**6,986**	**7,403**	**7,694**	**8,351**	**9,142**	**8,833**	**9,794**	**10,593**
AGRICULTURE, FORESTRY & FISHING	**A**	**1,775**	**1,863**	**1,935**	**2,027**	**2,151**	**2,259**	**2,278**	**2,424**	**2,461**
Food crops	AA	1,157	1,199	1,235	1,297	1,373	1,428	1,433	1,529	1,516
Export crops	AB	116	132	136	138	147	154	140	139	144
Livestock & livestock products	AC	142	155	170	186	206	229	247	268	291
Forestry	AD	341	354	367	378	395	417	432	455	477
Fishing	AE	26	26	27	29	30	31	26	33	34
INDUSTRY	**B-F**	**1,127**	**1,228**	**1,310**	**1,330**	**1,446**	**1,686**	**1,614**	**1,831**	**1,922**
Mining & quarrying	B	131	124	137	165	170	170	117	148	169
TOTAL MANUFACTURING	**C**	**480**	**520**	**555**	**591**	**671**	**746**	**762**	**842**	**935**
Of which: Food	*CA*	*172*	*174*	*188*	*210*	*237*	*248*	*265*	*284*	*322*
Beverages & tobacco	*CB*	*159*	*168*	*174*	*159*	*166*	*184*	*186*	*197*	*214*
Textiles, clothing & leather goods	*CC*	*21*	*22*	*24*	*34*	*54*	*64*	*61*	*71*	*85*
Wood & paper; printing	*CD*	*23*	*26*	*28*	*26*	*29*	*37*	*34*	*40*	*47*
Chemicals, rubber & plastic products	*CE*	*21*	*24*	*26*	*34*	*40*	*53*	*54*	*66*	*75*
Non-metallic mineral products	*CF*	*22*	*26*	*31*	*34*	*37*	*44*	*44*	*49*	*53*
Metal products, machinery & equipment	*CG*	*18*	*25*	*29*	*32*	*39*	*47*	*51*	*53*	*57*
Furniture & other manufacturing	*CH*	*52*	*61*	*55*	*61*	*68*	*69*	*67*	*83*	*82*
Electricity	D	63	68	77	84	92	98	100	112	128
Water & waste management	E	30	30	32	32	33	33	34	36	37
Construction	F	420	485	509	458	480	638	602	693	653
SERVICES	**G-T**	**2,948**	**3,256**	**3,488**	**3,684**	**4,041**	**4,376**	**4,134**	**4,625**	**5,188**
TRADE &TRANSPORT	**G-H**	**782**	**871**	**930**	**992**	**1,172**	**1,338**	**1,196**	**1,357**	**1,573**
Maintenance and repair of motor vehicles	GA	34	36	38	40	43	46	45	60	63
Wholesale & retail trade	GB	488	550	584	597	705	815	788	880	1,002
Transport services	H	260	285	308	355	424	477	364	417	508
OTHER SERVICES	**I-T**	**2,166**	**2,385**	**2,558**	**2,692**	**2,869**	**3,039**	**2,938**	**3,268**	**3,615**
Hotels & restaurants	I	107	117	130	140	150	165	98	118	221
Information & communication	J	95	112	121	134	153	167	216	257	307
Financial services	K	154	173	179	191	210	228	222	262	289
Real estate activities	L	471	493	523	560	586	609	611	636	646
Professional, scientific and technical activities	M	125	143	151	163	179	197	195	221	223
Administrative and support service activities	N	208	242	266	277	288	302	281	297	301
Public administration and defence; compulsory social security	O	373	393	437	446	477	500	514	527	577
Education	P	214	218	226	231	239	244	153	242	284
Human health and social work activities	Q	131	144	153	160	160	165	192	209	225
Cultural, domestic & other services	R-T	292	348	372	391	427	462	456	499	540
TAXES LESS SUBSIDIES ON PRODUCTS		**562**	**641**	**669**	**654**	**713**	**820**	**806**	**914**	**1,022**

Source: National Institute of Statistics of Rwanda

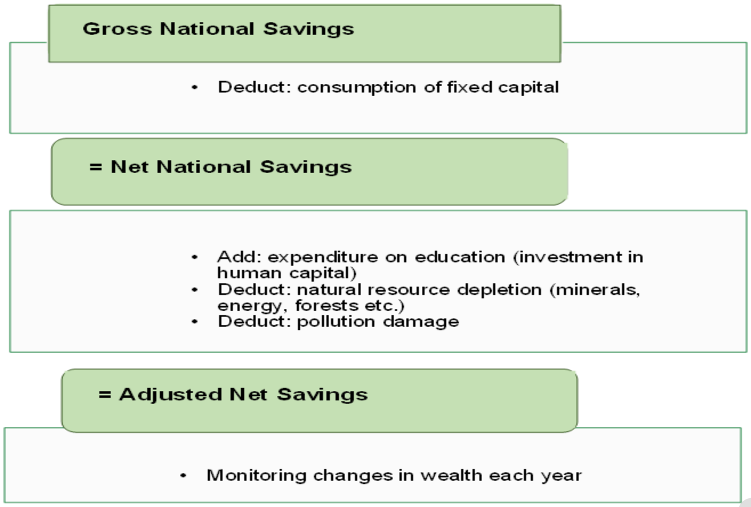
To calculate *adjusted net savings (ANS),* we start with traditional *gross national savings* (GNS), which represent the savings and investments a country has accrued during the fiscal year. The measure of interest here is net of depreciation, so first, we deduct *consumption of fixed capital* (CFC) from GNS to arrive at *net national savings* (NNS). The SNA defines CFC as the decline, in an accounting period, in the current value of the stock of fixed assets owned and used by a producer as a result of physical deterioration, normal obsolescence, or normal accidental damage. Essentially, it views asset depreciation as a form of negative saving. We use CFC data from NISR.

To include changes in as many types of capital as possible, we add investments in human capital, represented by the country's *education expenditures*, and subtract values associated with *natural capital depletion* and *environmental degradation* (figure A1).

[9] ISIC = International Standard Industry Classification

In this report, *natural capital depletion* includes forest and mineral depletion. Because *air pollution* entails harmful impacts on human and natural capital, it represents negative savings, and as such we factor it into the calculation. *Pollution damage* includes both global (climate change) and local (health effects from ambient air pollution) impacts.

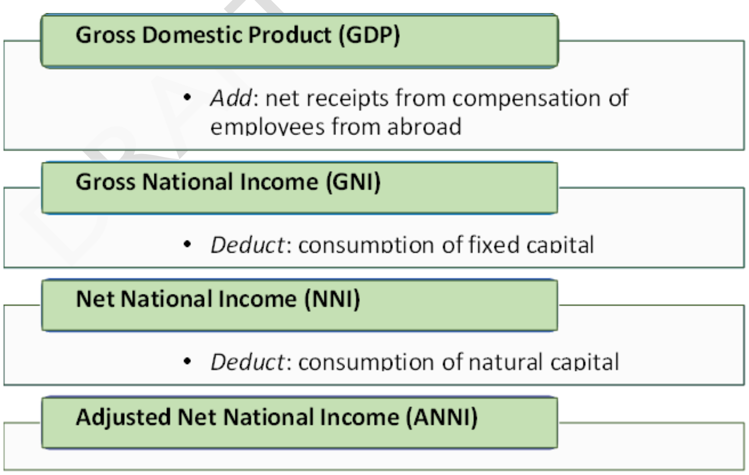
Figure A1. Adjusted net savings



We get *adjusted net national income (ANNI)* from *gross national income (GNI)* which is the country's total income, generated at home or abroad. GNI is thus GDP plus net receipts from compensation of employees from abroad. To get to *net national income (NNI),* we deduct depreciation of produced capital (or CFC) from GNI. These data come from the national accounts, produced by NISR. Next, we deduct *natural resource depletion*, which encompasses both renewable and nonrenewable resources (figure A1), which gives us ANNI.

Compared to GDP or GNI, ANNI (figure A2) offers a more precise representation of Rwanda's sustainable income, since it factors in whether a portion of its income arises from asset depletion. The natural capital we consider in this report is *depletion of forest* (timber harvest in excess of natural growth) and *minerals*, which we derive in the same way as for ANS.

Figure A2. Adjusted net national income



A2. ENVIRONMENTAL ADJUSTMENTS: METHODS AND DATA SOURCES

Table A2 outlines the data sources we use to compute ANS and ANNI. Where possible, we use national data from NISR. Where these data are not available—net forest depletion, carbon dioxide value and air pollution—we use World Bank CWOM data to fill the gaps in national data, as described in sections A2.2 and A2.3.

Table A2. Data sources for ANS and ANNI for Rwanda

	Source
Gross Domestic Product (GDP)	National Institute of Statistics of Rwanda/GDP publication
Plus: net primary income from abroad	National Bank of Rwanda/Balance of Payment
Gross National Income (GNI)	
Plus: net current transfers from abroad	National Bank of Rwanda/Balance of Payment
Gross National Disposable Income (GNDI)	
Deduct: household final consumption	National Institute of Statistics of Rwanda/GDP publication
Deduct: government final consumption	National Institute of Statistics of Rwanda/GDP publication
Gross National Savings (GNS)	
Deduct: consumption of fixed capital (depreciation)	National Institute of Statistics of Rwanda/GDP publication
Net National Saving (NNS)	
Plus: Education expenditure	National Institute of Statistics of Rwanda
NNS + Education expenditure	
Deduct: Forestry depletion	World Bank
Deduct: Mineral depletion	National Institute of Statistics of Rwanda
Deduct: Energy depletion	N/A
Deduct: CO2 damage	Rwanda National Greenhouse Gas Inventory (GHG emissions); World Bank (CO2 price)
Deduct: Air pollution damage	World Bank
Adjusted Net National Saving (NNS)	
Net National Income	
Adjusted Net National Income	

A2.1 Education expenditure: investing in human capital

The rationale for adding *education expenditure* is that spending on education equates to investing in the nation's human capital, a valuable asset. Therefore, it should be added as a positive. We only consider recurrent education expenditure because expenses on fixed assets, such as school construction, are already included in the GNS tally. *Educational spending* encompasses both public (government and its benefactors) and private (household) contributions.

To estimate public education gross output (GO), intermediate consumption (IC), and gross value added by level of education, we use the government finance statistics for preprimary, primary, secondary, technical, higher, and other education. We also use pay-as-you-earn (PAYE) data to extrapolate the education component of nonprofit institutions serving households (NPISH). We then use these same data, and the Ministry of Education framework, to calculate the cost of goods and services, gross fixed capital formation, and CFC.

We generate estimates for private education according to educational attainment, calculating value indices from income data, turnover data, and other administrative sources to extrapolate GO benchmark estimates. By deflating the current prices with the appropriate education consumer price index we can arrive at constant prices. We create constant price IC by adding fixed IC/GO ratios from the SUT to constant price GO. Using a weighted IC pricing index, we then determine the current price IC. The residuals are used to produce the gross value added estimations. For both current and fixed prices, we determine the value added by the difference between output and IC.

A2.2 Natural capital depletion

In the World Bank-compiled ANS indicator, *natural capital depletion* includes depletion of forests, minerals, and energy. For Rwanda *natural capital* covers forest depletion (timber harvest in excess of natural growth) and mineral depletion.

Forest depletion

Because forests can regrow, extracting wood is not necessarily a disinvestment in the future and needs not be counted against ANS, unless this extraction is unsustainable and beyond the natural rates of forest growth and resource replacement. Producing roundwood, fuelwood, and other timber is different from deforestation, which represents a permanent change in land use. Our correction to saving rates is therefore not simply the value of wood extraction; rather, it is the value of the portion of wood extraction that exceeds natural increment in the country in any particular year. Where increment exceeds wood extraction, there is no need to make adjustments to national savings.

The measure of net forest depletion in this report is limited to timber values, thus omitting other valuable goods and services from forests like the supply of nontimber forest products and ecological services such as preventing soil erosion and waterway silting, harboring biological diversity, and providing recreational opportunities.

For the purpose of this report, we investigated the availability of national data to estimate forest depletion. The NISR collects data on household consumption of forestry products such as charcoal, firewood, and logs used in dwelling construction through its household budget survey, which is conducted every three years. The national accounts team uses the results of this and business surveys to construct the SUT for compiling Rwanda's GDP. The business survey provides information on the quantity of wood used by the wood and construction industries.

These data, together with imports and export statistics, help to estimate the annual harvest of national forests. The model is based on the 2011, 2014, and 2017 household budget surveys, annual business surveys, and quarterly trade statistics.

We estimate *forestry production* by considering the quantities of woodfuel, including firewood, charcoal logs, and timbers, used by households and industry and multiplying those by the corresponding prices.

Table A3. Forestry production values (RF, billions) 2014–22

	2014	2015	2016	2017	2018	2019	2020	2021	2022
In current prices	339	352	365	379	499	538	569	637	795
In constant prices	314	321	329	336	346	364	378	396	412
Price index	108	109	111	113	144	148	151	161	193

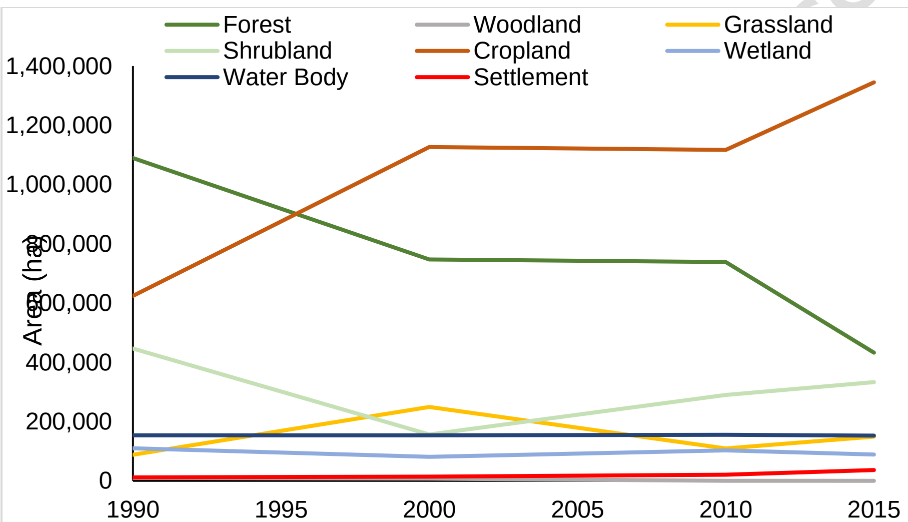
Source: World Bank staff calculations, based on data from NISR

Table A3 shows a high variation in current prices for forestry production. This is linked to price changes as a result of high inflation in the second half of 2017 and the whole of 2018 and then again in 2022. Constant price estimates, on the other hand, show a moderate variation of 3.5 percent per annum.

We were unable to find data on regrowth for the relevant forest areas—which is needed to estimate whether part of forestry production represents depletion—within the project timeframe. There are some estimates of deforestation/afforestation in Rwanda, including the Rwanda Forest Cover Mapping report (Republic of Rwanda 2019), which was compared with the 2009 forest cover map, detecting deforested areas by overlaying the two maps. Countrywide, about 105,713 hectares have been deforested (a15.7 percent decrease in forest cover), while new 139,674 hectares have been planted, representing a 20.7 percent increase in forest cover between 2009 and 2019. The net balance is thus about 5 percent afforestation over 10 years; meaning that, on average, Rwanda adds around 0.5 percent of forested areas each year. According to these data, Rwanda's forest increased between 2009 and 2019, making its net forest depletion 0.

However, results from the Rwanda land cover and ecosystem accounts for 2012–16 show a different picture. The accounts are based on land use and land cover maps that Rwanda created together with the Regional Centre for Mapping of Resources for Development (RCMRD) for 1990, 2000, 2010, and 2015. As shown in figure A3, forests decline significantly between 1990 and 2015, a decrease that is perfectly mirrored by the increase in cropland.

Figure A3. Changes in land cover, 1990–2015



Source: Government of Rwanda 2018a

The classes used are slightly different from that in the 2019 Rwanda Forest Cover Mapping report. In the data from the Regional Centre for Mapping of Resources for Development (RCMRD) that the accounts used, the category "forest" includes dense, moderate and sparse forest, with a total of 432 thousand hectares in 2015. Shrubland is at a total of 332 thousand hectares. In the 2019 forest cover report, 'forest' encompasses plantations, natural forests, wooded savannah, and shrubs, which together covers a total of 725 thousand hectares, of which 76 percent have medium (40-70 %) or high (> 70 %) density. Adding up forest and shrubland in the land cover accounts would make up a similar figure as in the 2019 report. However, as can be seen from Figure 6, this does not explain the whole discrepancy, as the increase in shrublands does not fully compensate for the loss of forest lands. It would also be necessary to determine how much of the shrubland area that could qualify as forested according to the IPCC classification, which was adopted by Rwanda(RCMRD/SERVIR 2012).

The Food and Agriculture Organization (FAO) regularly compiles data from countries on forests in the Global Forest Resources Assessment (FRA), such as growing stock and forest area. The data were not officially reported by Rwanda, but FAO have used a number of reports and data sources from Rwanda to estimate changes in forest. The results show a decrease in forests (including natural forest, plantations, woodlands and trees on other lands) of 14 % between 1990 and 2019.

Moving forward, it will be important to disentangle the differences between the various sources and determine the correct number for net forest depletion. For the purpose of this report, we have used CWON estimates fro Rwanda, which are based . CWON uses the FRA and FAOSTAT data.

Mineral depletion

Rwanda's mineral assets primarily consists of wolfram, cassiterite and cobalt. From 2012 to 2016, the resource rents from minerals were negative, meaning that the net gain from minerals was lower than the normal rate of return. The source for these figures is the Rwanda Minerals Accounts from 2019 [10]. An analysis of the reasons behind the negative rents in Rwanda is provided in the mineral accounts report, which concluded that the dominant factors contributing to the negative resource rents were likely the low prices and the system-wide production inefficiencies. From 2017 onward, resource rents are positive, possibly due to the introduction of advanced extraction equipment and the availability of skilled professionals, such as engineers, enhancing profitability.[11] So, from 2017, we have a value for the depletion, which varies between RF 2 and 5 million.

The calculations adhere to the following foundational principles and data sources:

1. **Volumetric data:**
   The foundation for volumetric production and trade data, including exports, comes from the physical accounts.

2. **Assessing revenue:**
   - Mining operators: The unit price multiplies production data from the physical accounts to determine revenue.
   - Mining traders: Revenue for traders is sourced from published export values. Their sales' unit price is inferred by dividing the export value by the export volume, as indicated in the physical accounts.

3. **Determining production costs:**
   - Both operators and traders derive their production costs from an amalgamation of revenue data and the sector-wide expenditure data. This information is sourced from the 2019-2021 Integrated Business Enterprise Survey (IBES) conducted by the NISR.
   - The relative expenditure-to-income ratio from the IBES determines the allocation of extraction, production, and operating costs for both mining operators and traders
   - The proportion determined above is applied to the real production value, providing an estimation of the sector-wide extraction, production, and operational costs.
   - A customary industry-wide profit margin is then incorporated into this cost as a stand-in for the cost of capital.

[11] NISR, personal communication

4. **Estimating resource rent:**
   The resource rent is calculated by subtracting the total costs (including a standard profit) from the turnover value.

Negative resource rents either implies resource abundance (absence of resource scarcity) or is a clear indicator of an illiquid or cash-strapped and lossmaking sector that operates at suboptimal levels. They can be the result of:

- unit prices that are too low to ensure profitability;
- high system-wide inefficiencies leading to too low production;
- production costs that are too high with respect to the level of production;
- low quality or accessibility of the resource; or
- a combination of the above.

For Rwanda, it was concluded that dominant factors behind the negative resource rents were likely the low prices and the system-wide production inefficiencies, which were improved upon in the later part of the time period.[12]

A2.3 Pollution damage

Damage from pollution include climate change impacts from greenhouse gas (GHG) emissions and health impacts from air pollution.

Carbon dioxide damage

The accounting of damage from GHG emissions in ANS follows the Polluter Pays principle. Under this principle, global damage from GHG emissions is charged to the emitting countries. The Polluter Pays principle is a cornerstone of international environmental law and flows from the assumption that countries suffering from the effects of climate change have a property right to a clean and healthy environment, and as such, each country's emissions are treated as a notional deduction from savings.

As climate change impacts from GHG are global, the value of the damage is estimated on a global basis, and calculated by multiplying emissions by a cost per ton of carbon dioxide equivalent (tCO2e). According to the High-Level Commission on Carbon Prices, a range of $40–80/tCO2e in 2020, rising to $50–100/t CO2e by 2030 is concluded in line with achieving the core objective of the Paris Agreement of keeping temperature rise below 2 degrees (World Bank, 2017). In this report, we use the lower value ($40/tCO2e in 2020) and assume the historic increase of the social cost of carbon to 2.25 percent per year. Table A4 provides the values from 2000 to 2021.

[12] NISR, personal communication.

Table A4. Social cost of carbon applied 2000–21

US$/tCO2eq	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
SCC (constant 2017 US$)	26	26	27	27	28	29	29	30	31	31	32
SCC (current US$)	19	19	20	21	22	23	25	26	27	28	29

US$/tCO2eq	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
SCC (constant 2017 US$)	33	33	34	35	36	37	37	38	39	40	41
SCC (current US$)	30	31	32	34	35	36	37	39	41	42	45

Data on GHG emissions—including emissions and removals from agriculture, forestry, and other land use, waste, energy, and industrial processes and product use—are from Rwanda's GHG Inventory 2006–2018, reported to United Nations Framework Convention on Climate Change in 2021 (Republic of Rwanda 2021).

Air pollution damage

To arrive at ANS, we deduct damage from air pollution, since the harmful effects of pollution represent negative savings and should be factored into the adjustment. We take local air pollution damage estimates from the World Bank database, and estimates of the number of premature deaths per age group due to exposure to air pollution from the *Global Burden of Disease Study* 2020 (GBD 2020), an international scientific effort led by the Institute for Health Metrics and Evaluation at the University of Washington. The damages include illnesses caused by exposure to ambient concentrations of very fine particulate matter (PM2.5), ambient ozone, and indoor concentrations of PM2.5 in households cooking with solid fuels (Forouzanfar et al. 2016).

Monetary losses associated with premature mortality due to air pollution exposure are valued under a forgone labor output approach, which equates the financial cost of air pollution with the labor income that people would have earned over their remaining working life, discounted to the present year, had they not died prematurely from an illness caused by exposure to air pollution. Under this approach, losses are estimated per five-year age group for premature mortality suffered among individuals up to the age of 79, after which it is assumed that no one is working (World Bank 2023).

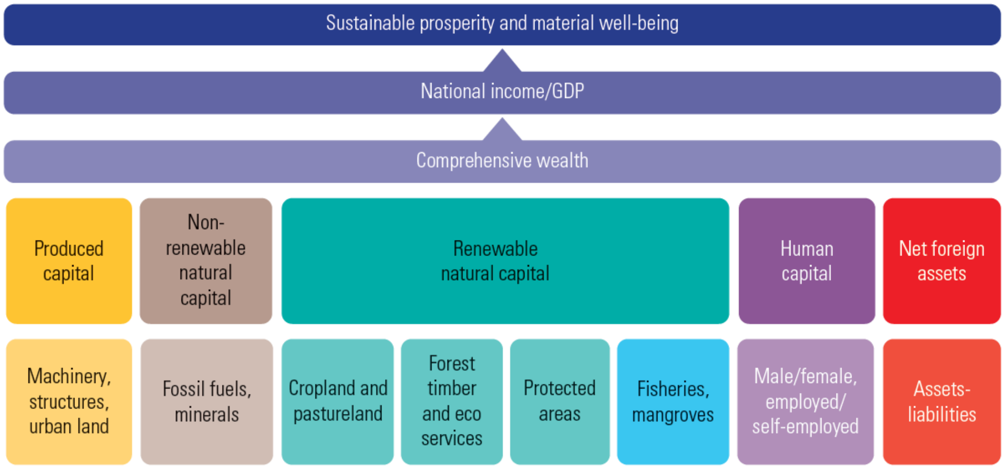
A2.4 Total wealth

A country's wealth is composed of a varied set of assets that collectively establish the foundation of its economic structure. The SNA currently only includes produced capital and subsoil assets. As illustrated in figure A4, *total wealth* includes:

- **Produced capital**, which includes machinery, infrastructure, equipment, and urbanized land
- **Renewable natural capital**, such as forests (timber and ecosystem services), mangroves, fisheries, agricultural land (cropland and pastureland), and protected areas
- **Nonrenewable natural capital**, including energy sources such as oil, coal, and natural gas, and a selection of 10 metals and minerals
- **Human capital**, including the expertise, abilities, and collective experiences of the working population
- **Net foreign assets**, which consist of equity portfolios, debt instruments, direct foreign investments, and other fiscal assets located abroad

As noted previously, this project made no attempt to estimate total wealth with national data.

Figure A4. Structure of total wealth and income accounts



Source: World Bank.

Several elements influence the fluctuations, both upward and downward, in wealth per capita, a key gauge of sustainability (as depicted in table A5). While some of these factors are apparent, others might exert a more subtle impact by affecting value indirectly.

Table A4. Factors that influence wealth over time

	Wealth per capita, beginning of period	
Factor	**Minus**	**Plus**
Produced capital	Normal depreciation Not included: catastrophic losses from natural disasters or civil conflicts, obsolescence	Investment in produced capital: buildings, structures, machinery, intellectual property
Nonrenewable natural capital	Extraction Other reductions in proven reserves and production volume Decrease in unit rent due to • Lower market price • Higher production costs Extended extraction path Not included: the impact of changes in future prices and policies, because these are unknown	Increase in proven reserves and production; increase in unit rent due to • Higher price • Lower production costs Accelerated extraction path Not included: the impact of changes in future prices and policies, because these are unknown
Renewable natural capital	Extraction greater than natural regeneration Degradation Decrease in unit rent due to • Lower market price • Higher production costs Not included: the impact of changes in future prices and policies, because these are unknown	Increase in harvestable extent, improved condition, increase in unit rent due to • Higher price and/or unit value • Lower production costs and/or improved efficiency Not included: the impact of changes in future prices and policies, because these are unknown
Human capital	Decline and/or aging of the labor force, declining wage rates, decline in education Changing wage growth trajectory due to economic shocks such as COVID-19 Not included: loss of human capital from missed schooling and health damages from COVID-19 Loss of human capital via migration	Growth of the labor force through growth of the domestic population, increased labor force participation, or migration (gain to one country, loss to another) Increasing wage rates; increasing education
Net foreign assets	Foreign liabilities	Foreign assets
Population change	Mortality Out-migration	Births Immigration
	Wealth per capita, end of period	

Source: World Bank.