Conservation Strategy Fund | Technical Report | December 2025

Ecosystem Service Valuation report for the Amathole Strategic Water Source Area in South Africa

Produced by Conservation Strategy Fund for The Nature Conservancy

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with support from The Nature Conservancy

Conservation Strategy Fund (CSF) was founded in 1998 on the conviction that economics can play a critical role in transforming conservation efforts around the world. By revealing the true tradeoffs of development, demonstrating the inherent value of nature, and generating financially viable environmental solutions, CSF used economic tools and insights to identify and inform others of the best possible development outcomes.

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List of Abbreviations

ADM – Amathole District Municipality

IAP – Invasive Alien Plants

CO_2 – Carbon Dioxide

CSF - Conservation Strategy Fund

DFFE – Department of Forestry, Fisheries and the Environment (South Africa)

ES – Ecosystem Services

ESVD – Ecosystem Services Valuation Database

GVA – Gross Value Added

IPCC – Intergovernmental Panel on Climate Change

LSU – Livestock Unit

MAR – Mean Annual Runoff

NbS – Nature-based Solutions

NBSAP – National Biodiversity Strategy and Action Plan

NDC – Nationally Determined Contribution

NPV – Net Present Value

PES – Payments for Ecosystem Services

SWSA / SWSAs – Strategic Water Source Area(s)

Stats SA – Statistics South Africa

tCO_2e – tonnes of CO_2 equivalent

TNC – The Nature Conservancy

USD – United States Dollar

WfW – Working for Water (South Africa's public works programme for invasive clearing)

WTP – Willingness to Pay

ZAR – South African Rand

1. Introduction

South Africa's Strategic Water Source Areas (SWSAs) play a fundamental role in sustaining the country's economy, society, and biodiversity. These areas are the ecological "engines" that secure water supplies for downstream municipalities, agriculture, and industry. Yet, unlike South Africa's iconic game reserves and national parks, many SWSAs remain under-protected and weakly managed, despite the essential services they deliver (Le Maitre *et al.*, 2018). To justify increased protection and investment in South Africa's SWSAs, The Nature Conservancy (TNC) and the Conservation Strategy Fund (CSF) launched a collaborative effort to assess and demonstrate the economic value of SWSAs, with the Amathole SWSA selected as a focal case study. Unlocking predictable and sufficient funding, resources, and capacity for conservation depends on demonstrating the economic significance of the ecosystem services these areas provide to society.

The Amathole SWSA was selected due to its ecological richness, hydrological significance, socio-economic importance as well as its status as one of the least protected of the country's SWSAs. It supplies water to major urban centers such as East London, King William's Town, and Bhisho, while also sustaining critical dams (supplying 93% of the water to dams in the area) that secure water for local communities and industries (Le Maitre *et al.*, 2018). Ecologically, the Amathole mountain range is among the richest in biodiversity across all SWSAs, with nearly three-quarters of its landscape still in a natural state (Adams *et al*., 2023). This intactness provides immense potential for ecosystem services (ES) such as water supply, carbon sequestration, and food provision, making it a strategic area for nature-based solutions. At the same time, the region faces pressing socio-economic challenges, including high unemployment, poverty, and environmental pressures from land degradation and invasive species, which heighten the urgency of leveraging ecosystem services for development and conservation. Assessing the economic value of ES is therefore essential to inform restoration and conservation efforts. A targeted valuation of these services can provide compelling evidence to support the area's rehabilitation, long-term protection, and effective management.

In the first phase of this project, CSF carried out a structured process to identify and prioritize the most relevant ecosystem services for valuation in Amathole. This included in-depth discussions with TNC as well as a targeted literature review to balance two key elements:

1. The strategic needs of TNC in advancing conservation and policy objectives, and
2. The feasibility of applying robust valuation methods based on available data.

Through this process, three ecosystem services were jointly selected as priorities: **food provision, carbon storage, and water supply**. These services represent both the ecological strengths of Amathole and the socio-economic benefits most relevant to local communities, downstream users, and national conservation priorities.

In the second phase, we present an economic valuation of the three prioritized ecosystem services in the Amathole SWSA. The objective is to quantify their contribution in monetary terms, providing a clear and evidence-based argument for investing in the protection and sustainable management of this critical area. By demonstrating the economic value of these ecosystem services, the study supports policy decisions, strengthens communication strategies, and contributes to national and local initiatives such as South Africa's 30x30 draft implementation plan.

The report is structured as follows; Section 2 outlines the methodology used to identify and analyze existing ecosystem service valuation studies that informed the valuation of the prioritised ecosystem services. This is followed by a detailed analysis of the economic valuation of carbon storage in Section 3, water supply in Section 4, and food provision in Section 5. The results of the valuation and literature review are integrated into each of these sections describing the economic valuation of each of the ES. In Section 6, the document concludes with a set of general recommendations designed to inform conservation strategies, financing mechanisms, and policy dialogue for Amathole and other SWSAs across South Africa.

2. Methodology Overview: Benefit Transfer and Targeted Literature Review

In this study, the benefit transfer method[1] was universally applied to all the selected ecosystem services in combination with other methods due to the absence of primary data. This method is a commonly used approach in ecosystem service valuation when there is insufficient time or resources to conduct new primary studies (such as surveys, field experiments, or detailed models). Instead of collecting new data, existing economic values are "transferred" from other studies — usually from similar ecosystems, regions, or contexts — to the study area. As there are various forms of benefit transfer methodologies available, details of the specific approaches for each of the ES are explained in detail in Sections 3 to 5.

To inform the benefit transfer method, the CSF team conducted a targeted review of the Ecosystem Services Valuation Database (ESVD)[2] to assess the availability of relevant studies and monetary values that could support a benefit transfer approach. The review was carried out using two main filters:

Country: South Africa

Biomes, Ecozones and Ecosystem types: including grasslands, savannas, inland wetlands, and rivers and lakes, reflecting the biophysical characteristics of the Amathole SWSA.

The filters "Country" and "Biomes, Ecozones and Ecosystems" together seek to ensure that the identified valuation studies have social-ecological characteristics as close as possible to Amathole SWSA, so that they can be adjusted and transferred to the region.

[1] Benefit transfer method is an economic valuation approach that applies monetary estimates from existing studies, typically conducted in similar ecological and socio-economic contexts, to a new study area. Rather than collecting primary data, the method "transfers" values (e.g., USD/ha/year or USD/m^3) and adjusts them using local biophysical or socio-economic information. It is widely used when time, data, or resources limit the feasibility of conducting original field research.

[2] Ecosystem Services Valuation Database (ESVD) is a global database that compiles peer-reviewed economic valuation studies of ecosystem services. It provides standardized monetary estimates (e.g., USD/ha/year, USD/m^3) across ecosystem types and regions, enabling comparisons and supporting methods such as benefit transfer when primary valuation data are not available.

This process aimed to identify existing economic valuation studies that could provide transfer-ready unit values (e.g., USD/ha/year, USD/m³, or USD/person/year) for the selected ecosystem services. The ESVD database has two different ES classifications, both of which were analyzed. A total of 21 valuations (Appendix 1) were identified based on the System of integrated Environmental and Economic Accounts (SEEA[3]) classification, with 13 relating to food supply and 3 focused on water supply. Ecosystem services such as carbon sequestration, water regulation, and recreation are represented by only a single valuation each, resulting in limited data availability to support robust benefit transfer analysis. In the case of the The Economics of Ecosystems and Biodiversity (TEEB[4]) classification, 31 valuations were identified, of which 25 are food provision and 3 are water supply. As with SEEA, the ES of carbon sequestration, water regulation, and recreation also have only 1 valuation each, which limits the amount of data available for benefit transfer.

The number of records found in the ESVD by ecosystem service, valuation method, and unit of measurement was summarised in Deliverable 1. This information helped to confirm the availability of data and feasibility for applying benefit transfer to certain ES, while also indicating where primary data gaps remain. Based on this analysis, the CSF team identified that the ESVD could support the following ecosystem services valuation: water provisioning and food provision. The next three sections describe how the economic valuation for each of these ES was conducted.

For all calculations, the currency conversion from United States Dollars (USD) to South African Rand (ZAR) was performed using the USD/ZAR spot exchange rate prevailing on 21 July 2025 of 1USD = ZAR 17.69 to ensure the transaction reflects the accurate economic context of that period.

3. Carbon Sequestration Ecosystem Service Valuation

Based on a review of multiple ecosystem service valuation studies drawn from the ESVD and complementary literature, this section guides how to apply benefit transfer techniques, which variables are required, and how to distinguish between carbon sequestration and carbon storage when valuing natural systems. The objective is to enable an evidence-based and context-sensitive estimation of the monetary value of this key regulatory ecosystem service[5].

In the literature, two main concepts are commonly discussed:

- **Carbon storage** refers to the total amount of carbon currently held in vegetation and soils. It represents the carbon stock accumulated over decades or centuries.

[3] The SEEA is an internationally standardized statistical framework that integrates economic and environmental data to assess environmental conditions, economic contributions, and impacts across countries.

[4] The TEEB study is a global initiative that emphasizes the economic value of biodiversity, the rising costs of its loss, and promotes actionable solutions through collaboration across science, economics, and policy.

[5] Regulatory ecosystem services are ecological functions that regulate environmental conditions, such as climate regulation, water flow regulation, erosion control, carbon sequestration, and pollination, which maintain ecosystem stability and support human wellbeing.

- **Carbon sequestration** refers to the **annual rate** at which ecosystems absorb carbon dioxide from the atmosphere, expressed as **tCO_2e/ha/year** (tons of carbon dioxide equivalent per hectare per year). This flow-based measure is preferred when calculating the economic benefit of ongoing conservation or restoration actions that continue to remove CO_2 from the atmosphere.

Valuation efforts focused on long-term projects (e.g., 30-year conservation plans) may calculate the net present value (NPV) of a stream of annual sequestration, while others may estimate the avoided emissions or opportunity cost associated with maintaining existing carbon stocks.

3.1.Summary of Relevant Studies and Carbon Values

The ESVD database and related documents reviewed contain several studies reporting carbon sequestration or storage estimates. While the monetary valuation per ton of CO_2 is not always explicit, sequestration rates (in tCO_2e/ha/year) or total stored carbon (tCO_2e/ha) are often provided. These values serve as the scientific basis for benefit transfer:

- **Forest ecosystems**: Sequestration rates range from 3 to 6 tCO_2e/ha/year.
- **Thicket ecosystems**: Annual sequestration values vary between 1 and 4 tCO_2e/ha/year.
- **Grasslands**: Generally lower sequestration rates, between 0.5 and 1.5 tCO_2e/ha/year, though values can vary significantly depending on management.
- **Wetlands**: Depending on organic matter accumulation and hydrology, peatlands or saturated wetlands may sequester >5 tCO_2e/ha/year.

For example, Farrel et al. (2011) reference thicket restoration in the Eastern Cape with values around 3.5 tCO_2e/ha/year. Other ecosystem assessments range from 2.6 to 6.5 tCO_2e/ha/year for forested areas in southern Africa, depending on biomass and management.

These data points confirm that reliable and contextually relevant carbon values exist for application to Amathole, particularly if disaggregated by vegetation type.

3.2. Recommended Approach for Amathole

The following steps were undertaken to conduct a benefit transfer-based carbon valuation in Amathole:

Step 1: Define Vegetation Types and Areas

We obtained data spatial data from Stats SA (2023) and adjusted values using DFFE Land Cover 2022 spatial data on current and potential vegetation types, including:

- Natural forest
- Thicket
- Grassland

- Wetlands
- Plantation/woodlot
- Cultivated (subsistence and commercial)
- Woodland

Each vegetation type may have distinct carbon dynamics and should be valued separately.

Step 2: Obtain or Estimate Sequestration Rates
Sequestration rates were drawn from literature or national carbon assessments. As seen above:

- Forest: ~3–12 tCO_2e/ha/year (Mills & Cowling, 2006; Thornley et al., 2021; IPCC, 2006)
- Thicket: ~1–4 tCO_2e/ha/year (Farrel et al., 2011)
- Grassland: ~0.5–1.5 tCO_2e/ha/year (IPCC, 2006; Conant et al, 2001)
- Wetlands: >5 tCO_2e/ha/year (Thornley et al., 2021; IPCC, 2014)
- Plantation/woodlot:~2–6 tCO_2e/ha/year (IPCC, 2006; Scholes & Van der Merwe, 1996)
- Cultivated (subs+comm):~0.1–0,3 tCO_2e/ha/year (IPCC, 2006; Lal, 2004)
- Woodland:~2–7 tCO_2e/ha/year (Due to lack of regional data on woodland sequestration rates, we used an intermediate of forest and thicket biomes)

Step 3: Apply Shadow Price of Carbon
The shadow price[6] reflects either the social cost of carbon or prevailing carbon market rates. We identified the following per-unit values based on a review of existing literature:

- Social cost[7]: USD 50–100/tCO_2e
- Market-based: USD 10–30/tCO_2e (if focusing on the voluntary carbon market) (Nurhayati e tal, 2024; Yan e tal, 2023; Forest Trends, 2025)

Step 4: Calculate Economic Value
Economic Value = Sequestration Rate (tCO_2e/ha/year) × Area (ha) × Carbon Price (USD/tCO_2e)

For multi-year projections, a Net Present Value (NPV) can be calculated over 30 years using a discount rate (e.g., 5–8%). (HM Treasury - Green Book, UK, 2021; US EPA, 2016; Kenneth Arrow et al., 2013)

[6] Shadow price is an economic value assigned to a unit of carbon that reflects its true societal cost or benefit, even if no formal market price exists. The shadow price typically represents either (i) the social cost of carbon, the estimated economic damage from emitting one additional ton of CO_2 or (ii) a benchmark value based on prevailing carbon market prices used for planning, policy analysis, and investment decisions.

[7] SCC (Social Carbon Cost) is a key metric that estimates the economic costs an additional tonne of CO2 released into the atmosphere would produce in terms of impacts on natural and human systems, from *Estrada, F., Lupi, V., Botzen, W.J.W. et al. Urban and non-urban contributions to the social cost of carbon. Nat Commun 16, 4193 (2025). https://doi.org/10.1038/s41467-025-59466-y*

3.3. Spatial and Land-Use Data

To complete this valuation, spatial and land use data were sourced from literature and personal communication with TNC staff:

- Spatial extent (in ha) of vegetation types (mapped by class) (Le Maitre et al., 2018; Stats SA., 2023)
- Historical land use and land cover change data (to assess restoration or degradation scenarios) (DFFE., 2023)

3.4. Final Remarks and Results Regarding Carbon Sequestration Economic Valuation

The valuation of carbon sequestration in Amathole was conducted using benefit transfer, using the key spatial and biophysical variables obtained. Shadow pricing using per-ton values combined with local estimates of sequestration rates per vegetation type provided a defensible valuation. Where possible, values should be disaggregated by ecosystem type, and the results should clearly distinguish between stored carbon and newly sequestered carbon flows. This clarity is critical for accurate reporting and alignment with international carbon finance mechanisms.

A final valuation table (Table 2) was produced once vegetation areas and carbon stock/sequestration rates were confirmed. Based on the reviewed literature the sequestration rates values of 3–6 tCO_2e/ha/year for forests, 1–4 for thickets, and 0.5 -- 1.5 for grasslands are considered reliable starting points for benefit transfer to the Amathole region.

Building on this methodological foundation, we estimated the aggregated economic values of carbon sequestration for Amathole under three scenarios. Results range from US$ 2 million/year (ZAR 35.5 million/year) in the conservative scenario, to US$ 19.6 million/year (ZAR 347.6 million/year) in the intermediate scenario, and up to US$ 80.6 million/year (ZAR 1.4 billion/year) in the optimistic scenario (Table 1). These scenario-based results illustrate the wide potential range of economic benefits depending on assumptions about sequestration rates and carbon pricing.

Table 1. Carbon sequestration valuation results by scenario

Scenario	US$/year	ZAR/year
Conservative	$ 2,007,133.00	R 35,506,182.77
Intermediate	$ 19,647,439.74	R 347,563,209.04
Optimistic	$ 80,648,194.43	R 1,426,666,559.43

When disaggregated by ecosystem type, natural areas emerge as the largest contributors, with an estimated value of US$ 8.2 million/year (ZAR 144.9 million/year). Plantations contribute US$

4.39 million/year (ZAR 77.7 million/year), however this needs to be taken in the context of a regularly harvested crop, the ultimate use of which affects the permanence of the carbon removal. Wetlands add approximately US$ 260,760/year (ZAR 4.61 million/year) while cultivated areas contribute the smallest share, estimated at US$ 152,864/year (ZAR 2.7 million/year). This breakdown confirms the central importance of intact natural ecosystems in driving carbon sequestration benefits in Amathole, while also underscoring the additional but smaller role of transformed landscapes such as plantations and cultivated land (Table 2).

Table 2. Carbon sequestration valuation results by ecosystem type

Ecosystem	US$/year	ZAR/year
Natural	$ 8,190,717.44	R 144,893,791.51
Wetlands	$ 260,760.24	R 4,612,848.65
Thicket	$ 1,910,805.95	R 33,802,157.26
Woodland	$ 3,592,315.19	R 63,548,055.64
Grassland	$ 1,146,483.57	R 20,281,294.35
Plantation/woodlot (unnatural area)	$ 4,393,492.88	R 77,720,889.05
Cultivated (subs+comm) (unnatural area)	$ 152,864.48	R 2,704,172.58
Total	$ 19,647,439.75	R 344,859,036.46
Total (natural areas)	$ 15,101,082.39	R 267.138.147,41
Total (unnatural areas)	$ 4,546,357.36	R 77,720,889.05

Together, these results demonstrate both the scale and distribution of carbon sequestration values across Amathole. The combination of scenario-based and ecosystem-specific estimates provides a robust evidence base to inform conservation priorities, guide restoration efforts, and strengthen the case for integrating Amathole into climate finance mechanisms such as carbon markets, payments for ecosystem services, or ecological fiscal transfers.

4. Water Supply Ecosystem Service Valuation

Water supply is a critical ecosystem service, particularly in the context of the Amathole Strategic Water Source Area (SWSA), where both urban centers and rural communities depend on the consistent provision of clean water. This section synthesizes findings from multiple ecosystem service valuation studies that address water supply and proposes a single, practical approach for applying benefit transfer in Amathole. The objective is to provide a clear and implementable valuation method, based on existing studies and compatible with available data sources.

4.1. Conceptual Framework: Water Supply as an Ecosystem Service

Water supply as an ecosystem service refers to the natural provision of surface and groundwater for human consumption, agricultural irrigation, and other productive uses. In the Amathole region, this service supports smallholder farmers and rural communities as well as urban populations such as East London and King William's Town both situated within the Buffalo City Municipality, which has an estimated population of 975 255 (Census 2022 Municipal fact sheet). s. Natural ecosystems, including forests, wetlands, and grasslands, play a key role in capturing, storing, and delivering water.

This section of the report focuses on quantifying the economic value of water provision by these ecosystems through a benefit transfer methodology, using values expressed in USD per cubic meter (USD/m³). This method aligned with the evidence base available from ESVD studies and was consistent with the time and data constraints of the project.

4.2. Review of Relevant Studies and Value Transfer Potential

Among the reviewed studies, Adekola et al. (2008), Lannas & Turpie (2009), and Mudavanhu et al. (2017) provide relevant valuation data for water provisioning services in southern African contexts. These studies present monetary values either directly linked to the volume of water supplied or indirectly through land-use categories.

- **Adekola et al. (2008)**: Estimated water provisioning services in Ga-Mampa wetland - located in the Ga-Mampa Valley in the Limpopo Province of South Africa, within the Mafefe tribal area of the Lepelle-Nkumpi Local Municipality, in the Olifants River catchment. - at a value equivalent to approximately USD 0.13/m³ (adjusted for inflation to 2024).
- **Lannas & Turpie (2009)**: Found water provisioning services valued at approximately USD 0.14–0.23/m³, with differentiation between rural and peri-urban settings in Letseng-la-Letsie wetland in southern Lesotho, a high-altitude rural area where local communities depend heavily on natural resources for grazing, crop production, wild plants, and other livelihood needs.
- **Mudavanhu et al. (2017)**: Provided higher-end estimates between USD 0.20–0.30/m³ based on avoided cost and market replacement values.

Based on this evidence, we applied a range of USD 0.13–0.30 per m³ as the reference value for benefit transfer to Amathole, with adjustments depending on local ecosystem type and population served.

4.3. Proposed Methodological Approach for Amathole

The recommended methodology consists of estimating the economic value of the water supplied by ecosystems in Amathole based on:

1. **Estimated volume of water supplied** (in m^3/year) by the ecosystem, disaggregated by catchment or subregion.
2. **Unit value of water provisioning**, based on benefit transfer from relevant ESVD studies (expressed in USD/m^3).

The economic value is calculated using the following formula:

Economic Value = Volume of Water Supplied (m^3/year) × Unit Value (USD/m^3)

To improve accuracy, values can be differentiated according to land cover type or ecosystem (e.g., forests vs. wetlands), if available in the literature. Unit values should be drawn from studies conducted in South Africa or comparable African regions and adjusted, if necessary, for inflation and currency conversion.

4.4. Water yield, Ecosystem Condition and Land Cover Data

To complete this valuation, the following data was sourced from literature:

- **Annual water yield or supply volume** per catchment or subregion in Amathole (m^3/year), as modeled or estimated in hydrological assessments (Le Maitre et al., 2018; Stats SA., 2023).
- **Information on ecosystem condition**, especially if degradation or invasive species affect water flow Le Maitre et al., 2018.

These inputs allowed for the application of transferred unit values and ensured that estimates reflect the ecological reality of the region.

4.5. Final Remarks and Results Regarding Water Supply Economic Valuation

The economic valuation of water provisioning in Amathole was conducted through a benefit transfer approach using monetary values per cubic meter (USD/m^3), based on literature from Southern Africa. From the Ecosystem Services Valuation Database (ESVD) and complementary studies, unit values were identified as USD 0.13/m^3 in rural contexts (Adekola et al., 2008), USD 0.23/m^3 for peri-urban settings (Lannas & Turpie, 2009), and USD 0.30/m^3 for avoided cost/market replacement estimates (Mudavanhu et al., 2017). These values were compared with local Amathole District Municipality tariffs of ZAR 28–66/m^3 (USD 1.58-3.73/m^3) to provide a sensitivity analysis and contextual benchmark.

Hydrological inputs were derived primarily from Le Maitre et al. (2018), which estimated the impacts of invasive alien plants on water flows in South Africa, including annual water yield per dam, river systems, and the reduction of Mean Annual Runoff (MAR) due to invasives. The Amathole SWSA is particularly critical as it supplies approximately 93% of the water captured in dams, with the main reservoirs being Gubu, Wriggleswade, Rooikrantz, Laing, Nahoon, Maden, and Bridledrift. Table 3 shows details of the dam capacity, its firm yield annually, estimated annual water usage, respective river system, areas served and water uses.

Table 3. Amathole SWSA dam yields and water uses (Amatola water corporate plan, 2024/25 -2028/9)

Dam name	Capacity in Mm3	Total firm yield (Mm3/a)	Urban/ Domestic Mm3/a	Irrigation Mm3/a	Raw water uses in 2024/25 Mm3/a	River System	Supply area/nature of area served	Uses
Rooikrantz/Maden Dam	4,8	7,5	4.5	1.2	5,3	Buffalo River	King Williams (Qonce), Bisho	Domestic and industrial uses e.g Da Gama textiles
Laing Dam	19,8	18,3	8,4	1,9	10,0		Rural	Domestic, agriculture
Bridledrift Dam	Data unavailable (DU)	29,41	DU	DU	DU		Mdantsane, East London	Domestic, agroprocessing, agriculture and industrial uses (e.g. automotive manufacturing Mercedes-Benz South Africa)
Gubu Dam	8,8	6,7	1,1	0,8	2,2	Gubu River	Stutterheim-Amahlati local municipality	Domestic, agriculture, forestry (e.g Amathole Forest Company (Rance Timber)
Wriggleswade Dam	91,2	31,2	14,6	3	0	Kubusi River	Stutterheim	This dam was built to supplement the shortfall for industrial and domestic use in the East London area.
Nahoon Dam + Wriggleswade Allocation	19,9	24,3	8,4	1,3	12,1	Nahoon River	Pakamisa, Potsdam, Mount Coke, (63% urban, 17% peri-urban and 20% rural)	Domestic, agriculture

Nahoon Dam Yield = Nahoon yield + Wriggleswade registered allocation

Mm3/a = million cubic metres per annum

The valuation applied the following formula to both baseline and degraded scenarios:

Value = Yield (million m^3/year) × 1,000,000 × Unit Value (USD/m^3).

Incorporating ecosystem degradation caused by Invasive Alien Plant (IAP) encroachment results in an estimated reduction in Mean Annual Runoff (MAR) of 6.02% (Le Maitre et al., 2018), directly affecting the monetary value of water provisioning. This resulted in a range of outcomes that vary according to both scenario assumptions and the presence of invasive alien species.

Table 4. Water supply valuation results under different scenarios and invasive species conditions

Scenario	No Invasive Species (US$/year)	No Invasive Species (ZAR/year)	With Invasive Species (US$/year)	With Invasive Species (ZAR/year)
Conservative (0.13/m3)	$ 10,693,800	R 189,173,322	$ 10,050,033	R 177,785,088
Intermediate (0.23/m3)	$ 18,919,800	R 334,691,262	$ 17,780,828	R 314,542,848
Optimistic (0.3/m3)	$ 24,678,000	R 436,553,820	$ 23,192,384	R 410,273,280

These results confirm that annual water provisioning values range from USD 10.0 -- 24.7 million (ZAR 177–437 million) depending on scenario and invasive species pressure. The differences between the "with" and "without invasives" conditions illustrate the direct economic impact of ecological degradation on water services, particularly through reduced runoff and altered hydrological functioning.

Beyond the numerical estimates, several policy and management insights emerge. First, the results provide a baseline for watershed investment and restoration in Amathole, particularly in relation to invasive species control and wetland rehabilitation. Second, they highlight the importance of engaging municipalities and utilities to refine local valuation through willingness-to-pay (WTP) studies or replacement cost analyses, ensuring tariffs better reflect ecosystem sustainability. Third, the findings support the design of payments for ecosystem services (PES) and ecosystem-based financing mechanisms that link water users with upstream conservation actions.

WTP studies from South Africa and other African watersheds highlight the economic value that communities and urban consumers place on a reliable water supply and watershed conservation. In Cape Town, Turpie and Letley (2023) found that residents were willing to pay an additional ZAR 116 per month to safeguard the condition of rivers and estuaries. South Africa's Working for Water (WfW) programme exemplifies a model for financing water-related ecosystem services. Administered by the Department of Forestry, Fisheries and the Environment, WfW is the country's largest poverty relief and public works initiative, operating across all nine provinces to control invasive alien plants, enhance water resources, and create employment. While WfW does not fit the traditional definition of a PES scheme, since the government funds restoration on public lands, it has encouraged voluntary contributions from municipalities, utilities, and private companies to clear invasive species from their catchments using WfW's institutional framework (Turpie et al., 2008; Markets for Watershed Services, 2006). In Tanzania, Swai and Kessy (2024) found that 71% of domestic water users and 82% of non-domestic users in Babati District were willing to pay for improved watershed services, with annual contributions of TAS 1,261 (ZAR 8.94) and TAS 112,322 (ZAR 796) respectively. Similarly, a study in Kenya by Van de Sand et al. (2014) revealed that 80% of community water users were willing to pay an additional US$3 (ZAR 52) per month to support watershed conservation efforts.

Water Funds also represent an effective and increasingly adopted PES model for water security in Africa and globally. These mechanisms create long-term, co-financed partnerships in which downstream water users—such as cities, utilities, and private companies—invest in upstream conservation to secure water supply. For example, the Upper Tana–Nairobi Water Fund in Kenya demonstrates how Water Funds can generate substantial benefits by reducing sedimentation, lowering water treatment costs, and improving water reliability for downstream users (TNC, 2015). Similarly, the Greater Cape Town Water Fund, led by The Nature Conservancy and partners, channels public and private resources into clearing invasive alien plants in priority catchments to improve water yield for the metropolitan area. These Water Fund models illustrate how PES-like arrangements can be formalized to finance watershed protection at scale, complementing government-led programmes such as Working for Water.

Various studies offer valuable insights into how WTP can inform the design of financing mechanisms, including potential PES schemes. These approaches are critical for ensuring long-term water security, conserving biodiversity, and advancing socio-economic development. However, WTP is highly context-specific, influenced by factors such as users' income and education levels, proximity to water sources, trust and confidence in service providers and governance systems. While a precise valuation of WTP for water services in the Amathole SWSA would require tailored economic studies, this economic valuation suggests that the water supply ecosystem service delivers substantial benefits to users in the area, including industries such as agriculture, agro-processing, automotive manufacturing (e.g. Mercedes-Benz South Africa), manufacturing (e.g. Da Gama Textiles, Amathole Forest Company (Rance Timber)), and tourism, as well as to urban and rural communities. In addition, it demonstrates the significant monetary contribution of Amathole's ecosystems to regional water security, while also quantifying the costs of inaction in terms of invasive species spread and ecosystem degradation. This evidence strengthens the case for embedding ecosystem service values into conservation planning, water resource management, and long-term financing strategies.

5. Food Provision Ecosystem Service Valuation

This section synthesizes the findings from several key studies selected from the ESVD database, all addressing the ecosystem service of food provision. The objective is to guide the benefit transfer process and support the economic valuation of this service in the Amathole Strategic Water Source Area (SWSA), South Africa. The first part of this section focuses on food provisioning through commercial and subsistence agriculture followed by an outline of the valuation approach used for livestock production, which applies a direct market valuation method. By analyzing methodologies, data inputs, and valuation results, we define how best to adapt and combine the findings of existing studies into a consistent valuation framework relevant to the Amathole context.

5.1 Commercial and Subsistence Agriculture

5.1.1 Synthesis of Selected Studies

Adekola et al. (2008) conducted an in-depth valuation of provisioning services in the Ga-Mampa wetland using direct-use values based on household-level data. The services evaluated included crop production, collection of wild plants, reeds, fuelwood, and fishing. The study found a total net annual value of USD 83,263 for 100 hectares, equivalent to USD 832.63/ha/year in 2005, which adjusts to approximately USD 1,374/ha/year for 2024. This study is highly transferable to wetland and mixed subsistence-agriculture systems and remains the most detailed among those reviewed.

Hassan (2003) estimated the economic value of forest and woodland resources in South Africa by modeling asset values and flow benefits, presenting aggregated value-added figures. Woodland ecosystem services, for instance, were valued at ZAR 2,613 million across 41.76 million hectares, resulting in a conservative estimate of approximately ZAR 62.5/ha/year in 1998, or roughly USD 8.3/ha/year today. While less detailed than Adekola's work, Hassan's results provide a useful lower-bound benchmark for large-scale assessments.

Shackleton et al. (2002) and Dovie et al. (2002, 2005) contributed studies focused on rural villages and community-level extraction of ecosystem goods. These studies used interviews and field surveys to quantify annual household-level use and valuation of products such as wild fruits, vegetables, insects, fuelwood, and construction materials. Though not always expressed on a per-hectare basis, they offer valuable support for understanding patterns of dependence and can be used to cross-validate area-based estimates.

Lannas & Turpie (2009) compared provisioning values in a rural wetland in Lesotho and a peri-urban wetland in South Africa, estimating values of USD 220/ha/year and USD 1,765/ha/year, respectively. These values reflect significant variation in ecosystem use intensity and demonstrate the importance of socio-economic and ecological context. Mudavanhu et al. (2017) also contributed useful estimates from direct-use services, although their focus on ecosystem goods as part of a broader protected area limits transferability.

5.1.2 Land Cover Data

To operationalize this valuation framework, specific landcover data were sourced from literature and from personal communication with TNC staff.:

1. **Land cover map of Amathole**, identifying and quantifying (in hectares) the extent of:
    - Wetlands and riparian zones (Le Maitre et al., 2018)
    - Subsistence or smallholder agricultural zones (Stats SA, 2023)
    - Woodland and forest areas (Stats SA, 2023)
    - Communal use zones or un-cultivated lands (Le Maitre et al., 2018; Stats SA, 2023)

These inputs are crucial to validate the relevance of high or low-end values and may help refine the final estimates through adjustments for local dependence and market integration.

5.1.3 Application to Amathole: Recommended Approach

Informed by this body of literature, we applied a benefit transfer approach using a range of per-hectare values for different ecosystem types. To account for the value of ecosystem support to agriculture in Amathole SWSA, two valuation approaches were employed. These methods represent different levels of data availability and theoretical grounding, and are designed to be complementary.

- Pathway A applies values from published literature, expressed in monetary units per hectare per year (US$/ha/year), to known land use categories.
- Pathway B estimates the contribution of ecosystem services by applying coefficients of ecological dependence to the gross production value of agricultural systems, requiring local data on yields, prices, and household engagement.

The two pathways respond to different informational realities. Pathway A is useful when spatial land cover data is available, but local production data is scarce. Pathway B is more analytically detailed but also more data-intensive, relying on context-specific information.

5.1.3.1 Pathway A: Direct Valuation Using Unit Values (US$/ha/year)

This approach estimated the economic value of food provisioning services by applying average monetary values per hectare, derived from previous valuation studies. These studies typically estimate the total benefits derived from agriculture in ecologically dependent contexts, incorporating services such as soil regulation, pollination, water supply, and pest control. The area of subsistence agriculture in Amathole SWSA is estimated at 3,569 hectares according to land cover data from 2020 (Statistics South Africa (Stats SA) (2023). Two scenarios are developed to reflect a lower-bound and upper-bound estimate based on empirical references.

Scenario A – Lower Bound (Lesotho Study)

The study by Lannas & Turpie (2009) focused on the Letseng-la-Letsie wetland in Lesotho, where livestock grazing and subsistence farming are critical components of rural livelihoods. Through household interviews and analysis of local market values, the authors estimated a value of USD 220 (ZAR 3,891.80) per hectare per year derived from ecosystem support. Given the rural nature and socio-ecological conditions in Amathole, this value is considered a conservative but relevant proxy.

Calculation: 8,734 ha × USD 220/ha/year **= USD 1.921.480,00/year (ZAR 33.990.981,20/year)**

Scenario B – Upper Bound (Limpopo Study)

The second scenario is based on Musetsho et al. (2022), who applied the Co$ting Nature V3 tool to the Mphaphuli area in Limpopo. This model integrates land cover and ecosystem service flows with global economic proxies to estimate the value of nature's contributions to human wellbeing. Their findings suggest an average value of USD 3,150 (ZAR 55,723.50) per hectare per year for subsistence agriculture, reflecting a setting with high natural dependence and low external input. While model-based and sensitive to input assumptions, this estimate provides an important upper bound for contexts of ecosystem-intensive production.

Calculation: 8,734 ha × USD 3,150/ha/year = **USD 27.512.100,00/year (ZAR 486.689.049,00/year)**

5.1.3.2. Pathway B: Indirect Valuation Using Ecological Dependence Coefficients

The second valuation approach adopted in this study estimated the value of ecosystem services indirectly, by attributing a portion of the gross agricultural production value to ecological support functions. This method, referred to here as *Pathway B*, goes beyond the application of generic per-hectare monetary values and seeks to anchor the valuation in the local economic and agroecological reality of Amathole SWSA. It is particularly relevant in rural and subsistence-oriented contexts, where farming systems rely significantly on natural fertility, rainfall, pollination, and other regulating and supporting services.

To operationalize this pathway, three key data components must be integrated: (i) crop productivity data (tons per hectare), ideally differentiated by farming system or input level; (ii) current market prices for each crop, expressed in local currency; and (iii) ecological dependence coefficients, which estimate the share of agricultural output that can be attributed to ecosystem services. These coefficients are derived from existing literature and tend to vary between 15% and 40%, depending on the crop type, the intensity of external inputs, and the quality of the surrounding environment. For the South African context, this study will use the reference of 16% by Gallai et al (2009).

In the case of Amathole SWSA, maize was selected as a representative crop due to its prevalence in both subsistence and commercial systems. Empirical data from Dumani et al. (2024) provided localized productivity figures for maize in Amahlathi Local Municipality, situated within the Amathole district. Their findings indicate that maize yield varies from 2.71 tons/ha under farmer-based traditional practices to 3.63 tons/ha when recommended agronomic practices are adopted. These figures reflect real-world performance in dryland systems and offer a grounded basis for economic valuation.

Market prices for maize were drawn from the Abstract of Agricultural Statistics (2025). The 2023/2024 gross producer prices indicate R 3,430/ton for yellow maize—typically associated with subsistence use—and R 4,695/ton for white maize, which is more prevalent in commercial production systems. Land cover data for the Amathole SWSA Land Account (1990–2020) was used together with verification from TNC support staff to determine the spatial extent of subsistence (8,734 ha) and commercial (9,099 ha) cropping areas (Personal communication, 2025; Stats SA, 2023).

Assuming a moderate ecological dependence coefficient of 16%—in line with similar valuation exercises in rainfed systems—we estimated the annual value of ecosystem services to maize production as follows:

- **Subsistence Scenario**:
  8,734 ha × 2.71 t/ha × R 3,430/t × 16% = **R12.941.691,84/year**
- **Commercial Scenario**:
  9,099 ha × 3.63 t/ha × R 4,695/t × 16% = **R24.606.607,68/year**

These figures represent conservative but meaningful estimates of how much natural ecosystem functions contribute to agricultural productivity in monetary terms. By linking ecological processes to real production and income data, this pathway enables decision-makers to more clearly perceive the invisible yet essential role of nature in local food systems.

5.1.4. Comparative Analysis and Policy Relevance

The application of both valuation pathways reveals not only the quantitative magnitude of ecosystem support to food production in Amathole SWSA, but also the trade-offs between methodological simplicity and contextual depth. While the results produced by the two approaches differ in format and structure, they are complementary and together offer a more nuanced understanding of the ecosystem–agriculture interface.

Pathway A applies unit values per hectare from peer-reviewed studies in comparable socio-ecological contexts for the subsistence scenario, providing a quick and transparent method of estimation. The resulting values, ranging from **USD 1,9 million (ZAR 33,9 million) to USD 27,5 million (ZAR 486 million)** annually, capture a wide range of assumptions about ecosystem dependence, from more conservative low-input systems (e.g., Lesotho case) to more integrated and intensive ecological settings (e.g., Limpopo). This approach is useful for initial scoping, policy advocacy, or when spatial land cover data is available but local production data is lacking.

Pathway B, by contrast, requires more detailed local data and assumptions, but delivers greater analytical insight. Connecting yield, price, land use, and ecological contribution, it makes explicit how different agricultural systems benefit from environmental support. It also enables more precise disaggregation by crop type, production intensity, and land tenure systems. For instance, the valuation conducted here for maize alone suggests an annual ecosystem contribution of **over R 37 million**, demonstrating that the value of nature is not abstract—it is reflected in local livelihoods and food availability. Irrigated and dryland maize production is a vital crop for the Amathole District Municipality (ADM), supporting many households with staple food and contributing significantly to food security, especially in the district's rural areas. Additionally, the maize industry plays a key role as an employer and foreign currency earner, due to its wide-ranging economic multiplier effects.

From a policy perspective, these findings have several important implications. First, they offer a strong economic rationale for mainstreaming nature-based solutions in agricultural development planning, particularly in areas with high poverty, environmental degradation, and food insecurity. Second, the estimates can be used to justify investments in sustainable land management, soil health programs, or agroecological transitions. Third, they provide an evidence base for designing or scaling Payments for Ecosystem Services (PES) schemes or ecological fiscal transfers, ensuring that communities and farmers are compensated for maintaining ecosystems that sustain food production. Maize production in the ADM is already constrained by the district's low rainfall and shallow, erosion-prone soils. Therefore, the introduction of innovative environmental sustainability programs is especially welcome.

Finally, the results underscore the need for better integration between environmental and agricultural data systems. Regularly updated and spatially explicit data on crop yields, farming practices, and ecological conditions would allow the expansion of indirect valuation to multiple crops and regions. Ultimately, both valuation pathways remind us that ecological functions are not free inputs to agriculture—they are vital assets that underpin food security and rural resilience in South Africa and beyond.

5.2 Livestock Production

The direct market valuation approach estimates the value of ecosystem goods or services based on actual market prices. It involves using observable prices from relevant markets to assign monetary value to products or services provided by the environment. In the context of livestock and grassland ecosystems, this means linking livestock prices to measures such as stocking rates and total grazing area to quantify the economic benefits derived from these natural resources. This approach is practical and grounded in real market data, providing clear monetary estimates of the provisioning service offered by ecosystems.

5.2.1 Data description

5.2.1.1 Grazing area

Assuming that grassland and the thicket ecosystems are the primary source of forage, we gathered spatial data for these ecosystems from TNC.

Table 5. Total hectarage for grassland and thicket ecosystems

Category	Área (ha)
Grassland	37 491
Thicket	59 573

5.2.1.2 Livestock stocking rates

A **livestock stocking rate** is the number of animals grazed on a specific area of land over a defined period, usually expressed as animal units per hectare. It indicates how intensely the land is being used by livestock and helps managers balance forage availability with animal demand to ensure sustainable grazing. A **livestock unit**[8] **(LSU)** is a standardized measure used to compare different types and sizes of animals based on their feed requirements, with one LSU commonly representing the forage needs of an average adult dairy cow (Benoit and Veysett. 2021). Although stocking rates are influenced by rangeland conditions and the quality of management practices employed by landowners, the figures used provide useful reference points as they are from areas similar to the study site. The LSU/ha identified from literature for regions similar to the Amathole SWSA is summarised in the table below. These data informed the classification of stocking rate scenarios into low, medium, and high categories.

Table 6. Livestock stocking rate values and source of data

LSU/ha	Source	Location of study
0,78-1,18	Talore et al. 2015	Arid Eastern Cape, South Africa
0,17	Dean and Mac Donald 1992	Cape Province South Africa

[8] In Africa,an LU is a cow (female over 4 years old) of 250 kg, and the equivalence coefficients of the different types of cattle are calculated according to the metabolic weight of the animals (1 heifer from 1 to 4 years old weighing 100 kg = 0.50 LU; 1 whole or castrated adult male of 320 kg= 1.20 LU (Benoit and Veysett (2021)

0,07-0,28	Mokhesengoane et al. 2021	Bloemfontein, South Africa

5.2.1.3 Livestock market prices

Livestock market prices represent the prevailing monetary value at which animals are traded within a given market. To inform our valuation, we reviewed auction reports from the Eastern Cape province, which offer practical insights into livestock pricing trends in areas similar to the Amathole SWSA. These auctions serve as key platforms where both commercial and communal farmers sell their animals, with prices reflecting local supply and demand dynamics. Influencing factors include animal quality, weight, breed, and buyer interest. While auction prices provide a useful benchmark, they can vary due to market events and participation levels, so they should be interpreted within a broader pricing context. For this analysis, prices were grouped into low, medium, and high categories to support scenario-based valuation.

Table 7. Approximate low, medium and high livestock prices for the Eastern Cape Province

Livestock price category	**US$/head**	**ZAR/head**
Low	$330,70	R 5,850.00
Medium	$707,69	R 12,519.00
High	$1,243.64	R 22,000.00

5.2.1.4 *Calculation*

Grasslands low stocking rate scenario

37,491 ha × 0,1 LSU/ha x USD 330,70/ head = **USD 1,239,809.78 (ZAR 21,932,235)**

Thicket low stocking rate scenario

59,573 ha × 0,1 LSU/ha x USD 330,70/ head **= USD 1,970,051.16 (ZAR 1,572,727,200)**

Calculations for the medium, high scenario stocking rates and livestock prices were done using the same approach indicated above. However, it is worth noting a limitation that there were no current numbers available for the number of cattle in the area.

5.2.3. Final Remarks and Results Regarding Food Provision Economic Valuation

The reviewed studies offer a robust foundation for valuing food provision in Amathole, but it is important to stress that this valuation focuses on ecosystem services that support food production, rather than total agricultural output. The functions considered include nutrient cycling, soil fertility, pollination, and water regulation — all of which underpin the productivity of agricultural systems but are not always captured in market prices. For grassland and thicket ecosystems, we focus on their contribution to livestock production, especially through the provision of forage resources. This focus is particularly relevant in the rural context of the Amathole SWSA, where subsistence and low-input production systems remain highly dependent on natural ecosystem functions. The purpose of this valuation is to provide evidence for integrating ecosystem support into policy, planning, and financing decisions related to agriculture and rural development.

5.2.3.1 Commercial and subsistence agriculture

To assess food provision through commercial and subsistence agriculture we applied two complementary valuation pathways, each reflecting a different methodological angle.

Pathway A – Direct valuation: uses per-hectare values from the literature (USD/ha/year) applied to subsistence agriculture areas (8,739 ha). This approach is suitable when reliable local production data is scarce but land cover data is available.

Pathway B – Indirect valuation: applies ecological dependence coefficients to the gross value of agricultural production, using local yields and prices. This pathway is more data-intensive and allows disaggregation by crop type and production system.

Table 8. Pathway A – Direct valuation results for food provision (subsistence agriculture area: 8,739 ha)

Scenario (study source)	Value per ha (USD/ha/year)	Total Value (US$/year)	Total Value (ZAR/year)
Scenario I – Lannas & Turpie (2009, Lesotho)	$220	$ 1.92 M	R 33.9 M
Scenario II – Musetsho et al. (2022, Limpopo)	$3,150	$ 27.51 M	R 486.7 M

This pathway captures a wide range of assumptions, from conservative to high natural dependence, providing useful benchmarks for scoping and advocacy.

Table 9. Pathway B – Indirect valuation results for maize production in Amathole

Production system	Area (ha)	Yield (t/ha)	Price (R/t)	Dependence coefficient	Ecosystem contribution (R/year)
Subsistence	8,739	2.71	3,430	16%	R 12.94 M
Commercial	9,099	3.63	4,695	16%	R 24.60 M
Total					R 37.54 M (≈ US$2.12 M)

This pathway demonstrates how ecosystem support contributes directly to agricultural output, with maize alone showing an annual ecosystem-related contribution of around R 37 million. Unlike Pathway A, which relies on external unit values, Pathway B is anchored in local data, allowing disaggregation by crop type and production system.

Taken together, the two approaches provide a richer and more nuanced picture of the ecosystem–agriculture relationship. Pathway A offers a quick estimation approach useful for scoping, external communication, and advocacy. Pathway B, by contrast, allows for more grounded and locally specific analysis, which is particularly valuable for policy design and agricultural planning.

The comparative analysis shows that, under both approaches, food provision delivers substantial economic value from ecosystem support to agricultural production. This evidence justifies investments in sustainable land management, soil health, and agroecological practices, while also supporting the design of payments for ecosystem services (PES) schemes and ecological fiscal transfers. It further highlights the need for integrated environmental–agricultural data systems, so that ecosystem contributions to food security and livelihoods are consistently recognized and factored into decision-making.

5.2.3.2 Livestock production

Table 10 below shows three stocking rate scenarios (low, medium, and high) combined with three livestock price scenarios (low, medium and high) for each ecosystem type. These scenarios collectively illustrate a range of potential economic outcomes, capturing variability in grazing intensity and market conditions.

Table 10. Direct valuation results for livestock production in the Amathole SWSA

Ecosystem	Area (ha)	Scenario	Stocking rate LSU/ha	Value (USD/total area)	Value (ZAR/total area)
Grassland	37491	Low	0.1	1.2M	22M
		Medium	0.78	20.7M	366.1M
		High	1.2	23.6M	989.7M
Thicket	59573	Low	0.1	2M	34.9M
		Medium	0.78	32.9M	581.7M
		High	1.2	88.9M	1.57B

The valuation results for livestock production from grassland ecosystems range from approximately ZAR 22 million to ZAR 989.7 million while thicket ranges from ZAR 34.9 million to ZAR 1.57 billion. The combined total contribution for both grassland and thickets to the local economy range from R56.9 million(for the low stocking rate scenario) - 2.56 billion (for the hush stocking rate scenario). These figures represent the highest potential value achievable with effective grazing management practices that maintain ecosystem health and productivity. The quality and extent of grazing is however influenced by a number of factors including herd management, topography, proximity to water sources, and the composition of plant species.

Despite possible differences in value arising from the factors outlined above, the results provide clear, evidence-based benchmarks for informing policymakers and investors about the economic benefits derived from sustainably managed grassland and thicket ecosystems. By showcasing the potential financial returns under different scenarios, the results can support the justification and design of targeted financing solutions, incentives, or subsidy programs aimed at promoting sustainable grazing practices. This economic evidence is critical for mobilizing resources and securing commitments to ecosystem conservation and livestock productivity interventions, ultimately contributing to long-term rural livelihoods and environmental sustainability.

6. Conclusion and Final Recommendations

The valuation of ecosystem services in the Amathole Strategic Water Source Area (SWSA) demonstrates that maintaining healthy ecosystems is not only an environmental necessity but also a sound economic strategy. The combined annual value of carbon sequestration, water supply, and food provision reaches hundreds of millions to billions of Rands, illustrating the magnitude of nature's contribution to livelihoods, industries, and public welfare.

However, the cost of inaction is equally striking. Continued degradation, through deforestation, invasive alien species, and soil erosion, would directly translate into water scarcity, declining food productivity, increased flood and fire risks, and the erosion of rural incomes. In contrast, investing in restoration and sustainable land management can secure these services for future generations, ensuring a steady flow of benefits that underpin local development and national climate resilience.

The valuation of carbon sequestration in the Amathole SWSA reveals a significant potential for climate regulation services. Depending on the assumptions applied, annual economic values range from US$ 2 million/year (ZAR 35.5 million/year) in the conservative scenario, to as high as US$ 80.6 million/year (ZAR 1.4 billion/year) in the optimistic scenario. These estimates reflect the combination of sequestration rates from different vegetation types and the application of both shadow prices and market-based carbon values. They underline the considerable contribution of Amathole's ecosystems to both local and global climate strategies. The results also highlight the importance of differentiating between carbon storage and carbon sequestration flows, which can be strategically aligned with either long-term conservation planning or participation in carbon markets.

For water supply, the analysis combined data from the Ecosystem Services Valuation Database (ESVD) and hydrological assessments of the Amathole catchments. Unit values per cubic meter were drawn from Southern African case studies: US$ 0.13/m³ in rural contexts (Adekola et al., 2008), US$ 0.23/m³ for peri-urban settings (Lannas & Turpie, 2009), and US$ 0.30/m³ for avoided cost estimates (Mudavanhu et al., 2017). These were compared with local Amathole District Municipality tariffs (ZAR 28–66/m³) for sensitivity analysis. Using these values and data from Le Maitre et al. (2018) on invasive species impacts, the conservative scenario without invasive species was valued at US$ 10.6 million/year (ZAR 189 million), dropping to US$ 10.0 million/year (ZAR 177 million) when invasive species are included. Under the optimistic scenario, values reach US$ 24.6 million/year (ZAR 436 million) without invasives and US$ 23.1 million/year (ZAR 410 million) with invasives. These results underscore the tangible cost of ecological degradation, particularly from invasive alien plants, on the water economy of Amathole.

The valuation of food provision confirms the substantial role of ecosystems in supporting both subsistence and commercial agriculture including crop and livestock production. A direct benefit transfer approach applied per-hectare values from key studies—ranging from USD 1.9 million (ZAR 33,9 million) in conservative assumptions to USD 27.5 million (ZAR 486 million) under higher-use contexts. Complementing this, an indirect valuation pathway was applied using crop yields, prices, and ecological dependence coefficients (16% from Gallai et al., 2009). For maize, the analysis estimated R 12.94 million/year from subsistence agriculture and R 24.60 million/year from commercial systems, for a total contribution of R 37.54 million/year (≈ US$ 2.12 million). The economic valuation for livestock production demonstrates a potential contribution ranging from R 22 million/total area to R 989.7 million/ total area for grassland ecosystems and R 34.9 million to R 1.57 billion for thicket ecosystems. Together, these approaches provide a multi-dimensional picture of how natural ecosystems underpin food production, from household food security to market-based agriculture.

Taken as a whole, the three ecosystem services (carbon sequestration, water supply, and food provision) demonstrate that the Amathole SWSA provides hundreds of millions to billions of Rands in annual economic value, depending on the scenario. These values emphasize that conservation is not merely a matter of biodiversity protection, but a strategic economic investment. They also reveal how different threats, particularly invasive species, directly erode economic returns from ecosystem services, reinforcing the urgency of restoration and management interventions.

The valuation results also reveal critical policy and financing implications. For carbon sequestration, the quantified values strengthen the case for leveraging carbon markets and integrating Amathole into South Africa's broader climate mitigation framework. For water supply, the results provide a robust baseline for watershed investment programs and restoration efforts, particularly those targeting invasive alien species and degraded wetlands. For food provision, the findings highlight the importance of investing in sustainable land management, soil fertility, and agroecological practices to maintain and enhance ecosystem support to agriculture.

Beyond monetary values, improved land management creates jobs and socio-economic opportunities. Implementing nature-based solutions (NbS), such as wetland restoration, thicket rehabilitation, and invasive species control, can generate local employment through public works or PES mechanisms, particularly in rural and marginalized communities. These interventions also reduce fire and flood risks, improve tourism potential, and strengthen resilience of commercial sectors dependent on natural resources. Securing land tenure and integrating Vision 2040 for Amathole, in partnership with SANParks and local authorities, would provide an investment platform for long-term rural revitalization, anchored in the delivery of essential ecosystem services: water, food, and climate regulation.

To maximize these benefits, stronger alignment with national policy frameworks is essential. Integrating Amathole's ecosystem service valuation into the implementation of the National Biodiversity Strategy and Action Plan (NBSAP), the National Water Act (NWA), and South Africa's Nationally Determined Contribution (NDC) will demonstrate how ecosystem protection contributes directly to national targets on biodiversity, water security, and climate resilience.

It also calls for the establishment of innovative financing mechanisms such as Payments for Ecosystem Services (PES), ecological fiscal transfers, and carbon or watershed investment programs, to ensure the long-term sustainability of restoration efforts, community livelihoods, and biodiversity protection. In parallel, it highlights the need to promote sustainable land management and secure land tenure as essential foundations for rural development, linking conservation initiatives with job creation, agroecological transitions, and the growth of nature-based tourism opportunities.

Finally, it underlines the urgency of addressing data and knowledge gaps by developing integrated monitoring systems that combine environmental, agricultural, and socio-economic indicators, enabling adaptive management and evidence-based decision-making. By acting on these recommendations, Amathole can become a model for nature-based development in South Africa, demonstrating how ecological restoration, climate action, and inclusive growth can reinforce one another to build a resilient and sustainable rural economy.

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8. Appendix

ESVD database for South Africa

<u>Overview South Africa</u>

<u>1. Biomes categories</u>

Biomes

Desert and semi desert

Inland wetlands

Inland wetlands; Rivers and lakes

Intensive land use

Marine

Rangelands and natural grasslands

Shrubland and shrubby woodland

Shrubland and shrubby woodland; Rangelands and natural grasslands

Temperate forest and woodland

Tropical and subtropical forests; Shrubland and shrubby woodland

<u>2. Ecozones categories</u>

Ecozones

Annual cropland

Dry temperate shrubs and heath

Dry tropical shrublands

Dry tropical shrublands; Tropical and subtropical savannas

Perennial monoculture

Seasonal floodplain marshes

Seasonal floodplain marshes; Rivers and streams

Semi desert

Shelf sea

Shelf sea; Pelagic zone

Temperate deciduous forest

Tropical and subtropical rainforest; Tropical and subtropical mountain forest; Dry temperate shrubs and heath

Tropical and subtropical savannas

Tropical and subtropical savannas; Grassy woodlands and grasslands

True desert

3. Ecosystems categories

Ecosystems

Coral reefs

Dry temperate shrubs and heath

Dry tropical shrublands

Dry tropical shrublands; Tropical and subtropical savannas

Extensive annual cropland

Hyper and arid desert

Intensive annual cropland; Extensive annual cropland

Kelp forests

Plantations

Seasonal floodplain marshes

Seasonal floodplain marshes; Seasonal lowland rivers

Tropical and subtropical savannas

Tropical rainforest; Subtropical mountain forest; Dry temperate shrubs and heath

NA

SEEA classification South Africa

4. Number of observations per SEEA category, filter by Biome, Ecozones and Ecosystems

Ecosystem Service

Number of Observations

Baseline flow maintenance services 1

Crop provisioning services 13

Global climate regulation services	1
Grazed biomass provisioning services	2
Recreation-related services	1
Water supply	3
Total	21

5. Number of valuation methods per SEEA category, filter by Biome, Ecozones and Ecosystems

Valuation Methods	Number of Observations
Market Prices	18
Opportunity Cost	1
Production Function	1
Social Cost of Carbon	1
Total	21

6. Number of valuation methods per SEEA category, filter by Biome, Ecozones and Ecosystems

Ecosystem Service / Valuation Methods	Number of Observations
Baseline flow maintenance services/ Market Prices	1
Crop provisioning services/ Market Prices	13
Global climate regulation services/ Social Cost of Carbon	1
Grazed biomass provisioning services/ Market Prices	1
Grazed biomass provisioning services / Production Function	1
Recreation-related services/ Market Prices	1
Water supply/ Market Prices	2
Water supply/ Opportunity Cost	1

TEEB classification South Africa

7. Number of observations per TEEB category, filter by Biome, Ecozones and Ecosystems

Ecosystem Service	
Climate regulation	1
Food	25
Opportunities for recreation and tourism	1
Regulation of water flows	1
Water	3
Total	31

8. Number of valuation methods per TEEB category, filter by Biome, Ecozones and Ecosystems

Valuation Methods	
Market Prices	29
Opportunity Cost	1
Social Cost of Carbon	1
Total	31

9. Number of valuation methods per TEEB category, filter by Biome, Ecozones and Ecosystems

Valuation Methods	
Climate regulation/ Social Cost of Carbon	1
Food/ Market Prices/	25
Opportunities for recreation and tourism/ Market Prices	1
Regulation of water flows/ Market Prices	1
Water/ Market Prices	2
Water/ Opportunity Cost	1

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Conservation Strategy Fund (CSF), in collaboration with The Nature Conservancy (TNC)