The Importance of Climate Information Services in OACPS Countries

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Abstract:

The Organization of African, Caribbean, and Pacific States (OACPS) has chartered a system dynamics (SD) project to model the socio-economic benefits (SEB) of Climate Information Services (CIS) in its constituent countries. The SEB model is intended to show how the CIS value chain builds capacity for responding to the impacts of climate change. This paper describes Phases 1 and 2 of the project and objectives for Phase 3.

Keywords: *climate services, climate change abatement / adaptation, socio-economic benefit, system dynamics, OACPS, ClimSA*

1. Introduction

The Climate Services and Related Applications Programme (ClimSA[1]) initiative of the OACPS[2] has chartered a SD project with the overall objective of modeling the SEB of the climate services value chain in each of its constituent countries. The SEB model is intended to show the importance of building climate services capacity in the OACPS countries and how to make effective use of those services in managing the impacts of climate change. This paper describes the results obtained from Phases 1 and 2 and the objectives for Phase 3.

The overall objective of the ClimSA programme is to strengthen the CIS through building the capacities of decision-makers at all levels to make effective use of climate information and services. To help achieve this objective, the programme identified the goal of contributing to the strengthened production, availability, delivery and application of science-based climate prediction and services. Improving the timeliness and quality of science-based climate information services offered by the Regional Climate Centres (RCCs) and hydro meteorological organizations of the OACPS countries will demonstrate achievement of the goal by increasing value-added climate knowledge and information services in each RCC.

To attain this programme goal, a project was initiated in 2022 to build an integration framework to demonstrate the SEB of CIS to the economic output, measured by gross domestic product (GDP), of each OACPS country. ClimSA contracted with Ventana Systems, Inc. (‘Ventana’) to develop and deliver a system dynamics model to realize the desired framework in an SEB model.

A subset of OACPS countries participated in Phases 1 and 2 to build the SEB exploratory[3] models, with Phase 3 planning now underway to build the explanatory models for each participant country.

The project is organized as a group modeling effort. During the exploratory model phases, Ventana facilitated SD training to enable the delegates from participating countries to fully engage as subject matter experts for collaborative model building.

1.1 Dynamic Hypothesis

Many examples use SD for climate modeling, e.g. En-ROADS and FREE[4,5]. The SEB model is unique in incorporating the SEB of CIS – i.e., meteorological capacity as defined by the World Meteorological Organization[6] – for improving the response to climate change impacts.

The project's dynamic hypothesis is that improving the capacity of CIS will help address "the availability of timely and accurate climate information to guide decision-making" [7] to support effective 'climate-smart' planning in the OACPS countries.

This dynamic hypothesis, or problem behaviour, is illustrated in Figure 1.

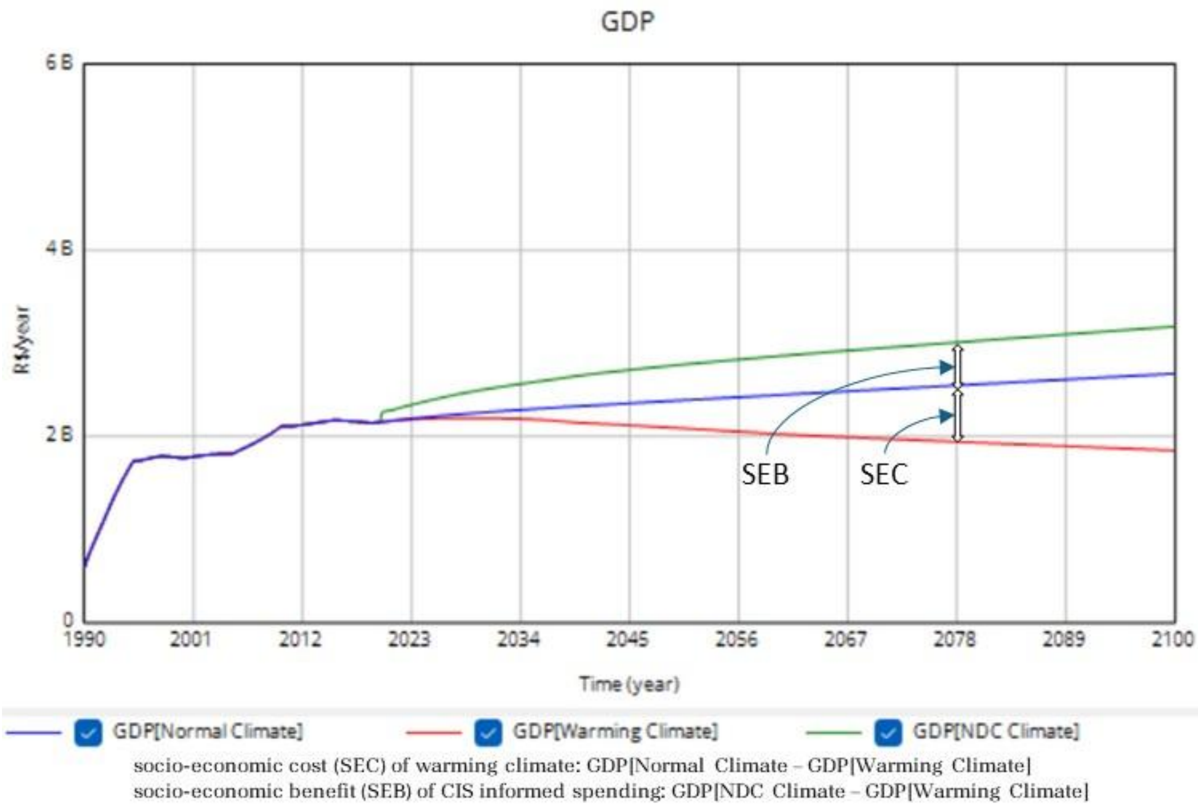

Figure 1. Dynamic hypothesis based on three climate scenarios - Normal Climate (blue), Warming Climate (red), and NDC Climate (green).

Figure 1 shows the expected country GDP for the century 2000 to 2100 for three scenarios.

- The Normal Climate (blue line) scenario creates a reference baseline for SEB and socio-economic cost (SEC) measurement by fixing climate change factors at 2020 levels but allowing population and population-related changes, including net migration, fertility, morbidity, and mortality.
- The Warming Climate (red line) scenario considers the impact of two climate change drivers – the rates of temperature rise and sea level rise – based on Intergovernmental Panel on Climate Change (IPCC) data[8(p. 571)].
- The Nationally Determined Contributions (NDC) Climate (green line) scenario is active climate management, considering abatement and adaptation actions. This scenario considers the two IPCC climate change drivers and further assumes the country's CIS value chain is informing decision-making regarding adaptation and abatement[i] actions. This scenario is thus characterized as CIS-informed.

The SEC of no climate action and SEB of CIS-informed climate action are defined as follows:

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[i] Abatement is used here, without prejudice, to mean either mitigation or abatement.

$$SEC = \text{GDP[Normal Climate]} - \text{GDP[Warming Climate]}$$

$$SEB = \text{GDP[NDC Climate]} - \text{GDP[Warming Climate]}$$

The problem behaviour is that, without interventions, the Warming Climate scenario results in climate-induced impacts to the country, as measured by the rate of decline of GDP relative to the Normal Climate reference scenario.

The dynamic hypothesis is that in the NDC Climate scenario, with CIS-informed active climate management, the climate-induced impacts on country performance are reduced. Further, as shown later, results for the NDC Climate scenario are potentially improved by strengthening the CIS value chain by increasing the level of the country's CIS[ii] . GDP can potentially perform better than the reference scenario due to improved population dynamics and economic output associated with NDC action.

The causal loop diagram (CLD) shown in Figure 2 illustrates how the dynamic hypothesis is modeled. Starting on the left is the current state for the level of CIS in the country. This qualitative assessment, using integer values from 1 (Basic CIS) to 4 (Advanced CIS) indicates the capacity for producing increasingly sophisticated CIS information and forecasts. Following the loop clockwise, an increased level of CIS increases the quality of the analytics and forecasts, which improves the quality of climate management funding submissions by decision-makers, leading to increased funding for abatement and adaptation. This increased funding then increases the number of abatement and adaptation actions (projects and initiatives) initiated by the country.

Increased funding increases GDP by 1) increased abatement and adaptation actions generating increased economic activity in the country; and, more importantly, by 2) these actions contributing to increased economic sector-specific production, which in turn increases GDP. The resulting GDP increase is due, in part, to the improved level of CIS-informed services, which then increases the SEB from CIS-informed actions when measured against the GDP (Normal Climate) baseline. The increase in SEB reinforces the value and need for advanced CIS service capacity, which increases the funding to build that CIS capacity, thereby closing the loop by increasing the level of CIS. This reinforcing loop is labelled the CIS Value Chain.

[ii] The World Meteorological Organization has developed a checklist of climate service category levels comprised of basic, essential, full and advanced service levels, according to the nature and socio-economic values.

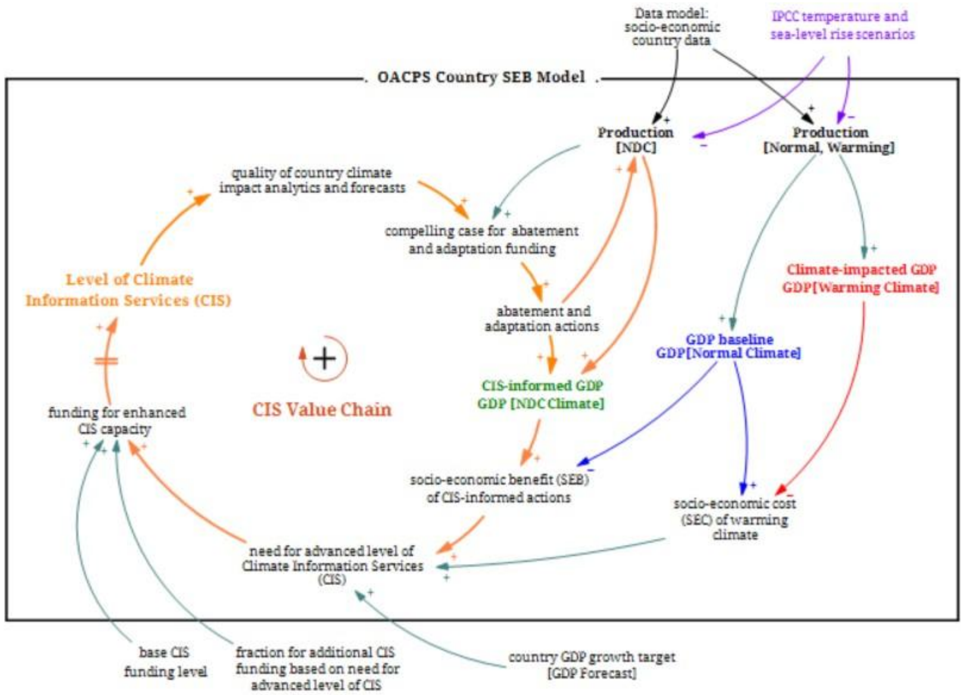

Figure 2. Causal Loop Diagram (CLD) for determining the socio-economic benefits (SEB of Climate Information Services (CIS).

The variable GDP is an example of the use of subscripted variables in the DSS version of Vensim, where the subscript 'scenario' is defined with three elements [Normal Climate], [Warming Climate], and [NDC Climate][iii]. By using a single subscripted variable for GDP, three equations are defined within that variable using the general form:

$$GDP[Scenario] = SUM(value\ added\ in\ producing\ sector[[scenario], producing\ sector!])$$

which results in GDP being calculated, for each climate scenario, as the sum of the value-add in each of the producing sectors; summation is denoted by the exclamation symbol. This structure simplifies the model structure by avoiding the need to replicate model structure for three separate GDP variables.

Figure 2 shows, above and below the box, key exogenous variables and data used in the model. The CLD is focused on describing the CIS value chain and therefore simplifies the model structure.

1.2 Project Scope

The scope of the project is to build an SD model to explain the complex feedback, show the CIS value chain, and quantify country improvements from CIS in SEB in the face of climate change.

ClimSA describes the main modelling steps[7] as shown in Figure 3.

iii Square brackets are used in Vensim DSS to denote elements of a subscripted variable.

Figure 3. ClimSA SEB Model Development Main Steps ([Figure 51, from 1]

To date Phases 1 and 2 have completed a first iteration of all five steps, resulting in an exploratory model. Phase 3 is proposed to complete a second iteration of Steps 3 through 5 to strengthen the model and engage a broader spectrum of external stakeholders to gain acceptance for extending the use of the model into mainstream climate policy decision-making (Step 5.1).

The remainder of the paper is organized as follows:

- Methodology: the modeling approach and progress to date
- Results: CIS value chain information
- Findings: high-level analysis of the results
- Conclusions and Future Work: path forward to completing the model.

2. Methodology

As noted in a recent ClimSA document[7] "timely and actionable weather and climate services are fundamental to progress on key global and regional national policy agendas." A lengthy section entitled 'System Dynamics Models of Environment, Energy, and Climate Change in Dangerfield[9, Section III] emphasizes the role of SD models for this purpose. In this section we describe the model constructed to quantify the benefits of CIS.

2.1 Model Overview

The SEB model is constructed using Ventana's Vensim® version Decision Support Software (DSS). Information about the DSS version is available via the web [10]; a book covering DSS features with sample models is also available [11].

While making the SD modeling learning curve steeper for OACPS delegates, Vensim DSS, e.g., enables use of subscripted variables to simplify model construction (as described in 1.1 in discussion of the variable 'GDP').

The SEB model allows IPCC temperature and sea-level rise scenarios to influence the macroeconomic performance of key economic sectors of the model country over time. Using a qualitative scale of CIS capacity, the model predicts the value of increased CIS capacity for policy making and climate-related investment initiatives. Given that collectively, and certainly individually, OACPS climate initiatives can have little mitigation impact due to their small contribution to global climate impacts[12], the model focuses on country-level abatement (reducing infrastructure impacts) and adaptation (reducing population health impacts) scenarios using a set of feedback loops and stock-flow structures.

Other deliverables from Phases 1 and 2 are not discussed here.

2.2 Model Development

A collaborative modeling process was used in Phases 1 and 2 of the project. OACPS participants received training in SD modeling and SEB model building. While the aspirational objective is that the participants will ultimately maintain and enhance their country model, the short-term goal is for them to gain confidence in model design and model calibration.

Phases 1 and 2 developed a template exploratory model comprised of two parts – a data model and a country model. The data model was designed to be country-specific from the outset, while the country model started with a template model that would become country specific in two stages:

- After construction of a template country model connecting climate to a multi-sector economic model and a data model, country data was imported from the data model to the SEB country model and initial calibration was performed.
- Validation, optimization, and verification of each country model.

Phases 1 and 2 completed the first stage; Phase 3 will complete the second stage.

2.3 Model Structure

Each SEB model is comprised of a data model and a country model. The country model is the main user interface to the model and provides decision-making information.

2.3.1 Data Model

The data model imports data from six spreadsheets containing historical data, which is then consolidated for use by the country model. Macroeconomic data from IO tables is reformatted into the Vensim change file (constants) .cin format. Figure 4 shows the data processing flow for the models.

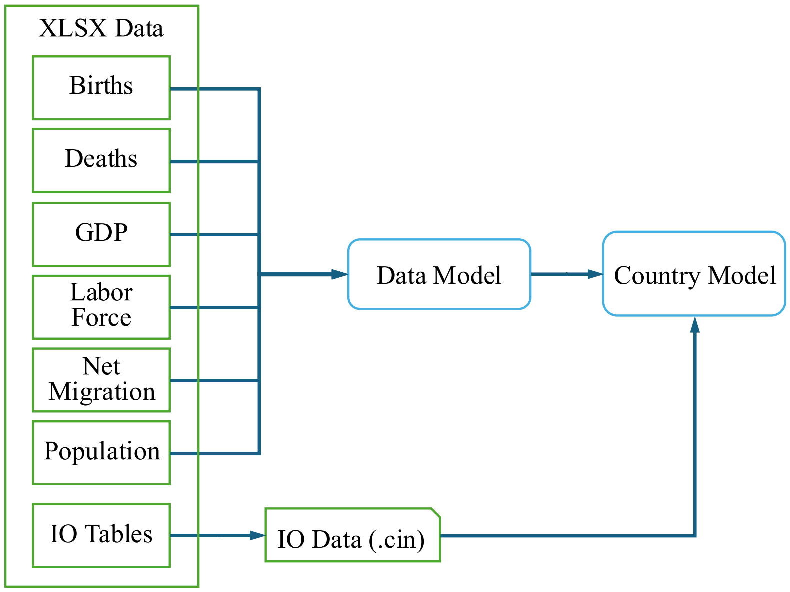

Figure 4. Data processing flow for the SEB models.

2.3.2 Country Model

As the country model realizes the CIS value chain, we will limit our discussion to that model for the remainder of the paper. Figure 5 shows the Home view of the country model. The Home view shows the sectoral structure of the model and serves as the main menu, with hyperlinks for navigating to the functional views (green shaded boxes).

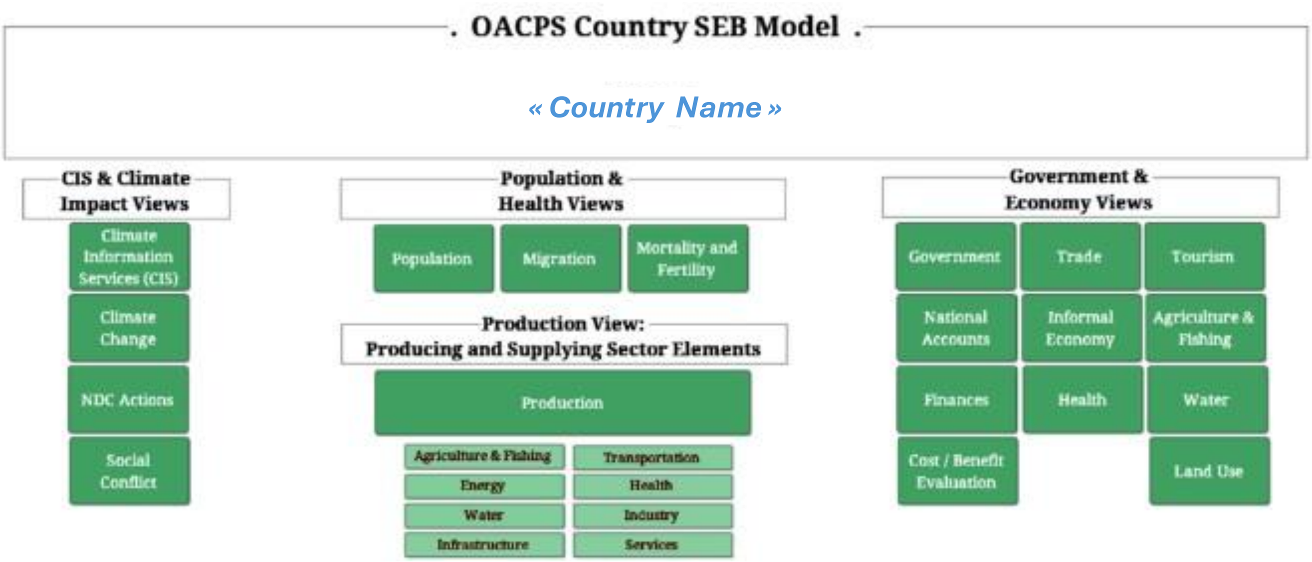

Figure 5. Sector map displayed on the Home (main) view of the model. Hyperlinks enable navigation to the sub-models (green-shaded boxes).

The SEB model has twenty sub-models (views), of which four are key: Population, Production, Climate Change, and Climate Information Services. Population uses a three-stage aging cohort structure (young, working age, old), with links to the Mortality & Fertility and Migration sub-models to determine the population in each cohort. The working age cohort is used to determine the country's labour force.

Production contains most of the model structure used to calculate the annual production in each of the eight economic sectors used in the model. The subscript feature of DSS defines the sector subscript elements, one for each of the eight economic sectors described above. As with scenarios, the use of sector subscripts greatly simplifies the model.

The Climate Change sub-model defines the variables 'temperature degrees above 1990 level' and sea level meters above 1990 level'. IPCC AR6 WG1 data is used for the temperature change and sea level rise for each of these variables according to one of three user-selected IPCC projections for model:

- SSP 1-1.9 (approximately 1.4 degrees of warming and 0.0375 meters of sea level rise by 2100)
- SSP 1-2.6 (approximately 2.0 degrees of warming and 0.045 meters of sea level rise by 2100)
- SSP 1-1.9 (approximately 2.9 degrees of warming and 0.055 meters of sea level rise by 2100)

The model uses lookup tables based on these projections to determine the effect on the economy, productivity, population, health, land, tourism, inventory, mortality and morbidity. It is understood that other effects are left to future phases.

The Climate Information Services sub-model defines the variable 'Level of CIS' (Figure 6, lower left). Level of CIS becomes the input parameter to the model structure and is used to forecast the benefit of an increased level of CIS on variables in production, health, and other sub-models. As an example, for exploratory purposes, the model returns 2% for CIS Level 1 and 20% for CIS Level 4 as the value for the variable 'fraction of vulnerable infrastructure protected by CIS'. This becomes a shadow variable (purple oval) in the Production sub-model, where the equation (1- fraction of vulnerable infrastructure protected by CIS) is used in the calculation of 'sea level destruction of fixed capital'. In the future explanatory model these tables will be calibrated for each OACPS country. Figure 6 shows this example.

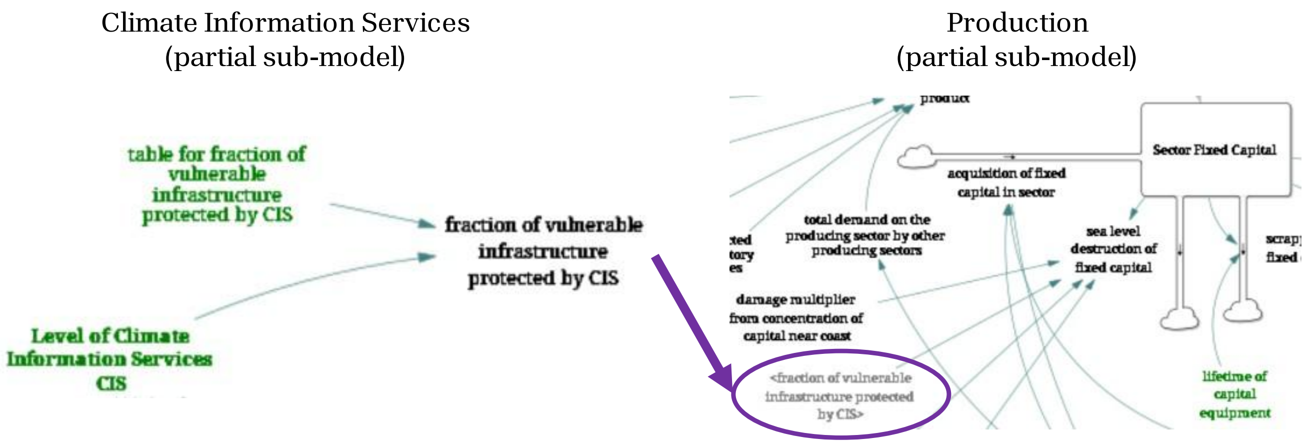

Figure 6. Example showing Level of CIS (bottom, right) influencing the fraction of fixed capital protected from sea level destruction.

The NDC Actions sub-model quantifies the part of the CIS value chain where the activity to implement NDC adaptation and abatement actions results in economic output because of these activities. As the CIS value chain showed, an increased level of CIS leads to increased funding which can then be directed to abatement and adaptation actions in specific economic sub-sectors (health, tourism) or aggregated and applied to multiple sectors (infrastructure, transportation, energy, etc.) to counter climate change impacts.

Figure 7 shows a section of the NDC sub-model and how the level of CIS is used to determine the fractions of external and country (internal) funding are used to determine the amount of population health adaptation funding required to address the loss of economic value-add (va) in the health sector.

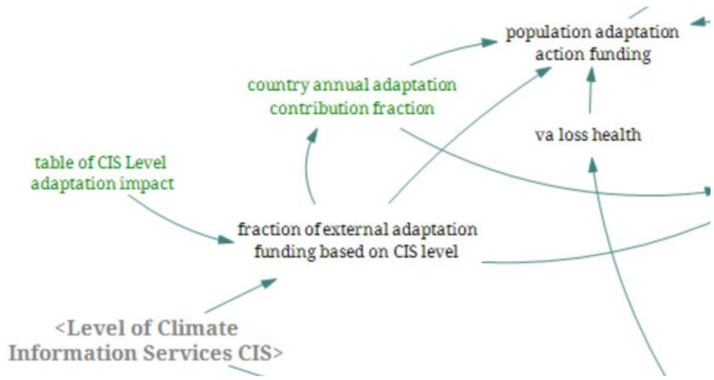

Figure 7. Use of Level of CIS to calcualte the external and country funding requirement to address population health adaptation.

2.4 Web User Interface

Key charts and parameters of interest to OACPS stakeholders are being made available via a web user interface (web UI). The initial web UI is limited in scope and complexity, meant to be illustrative to the stakeholders of the potential for the SEB model to assist in decision-making and demonstrate the value of CIS. Figure 8 shows the work in progress web UI with CIS set to level 1 (basic) on the left and level 2 (essential) on the right.

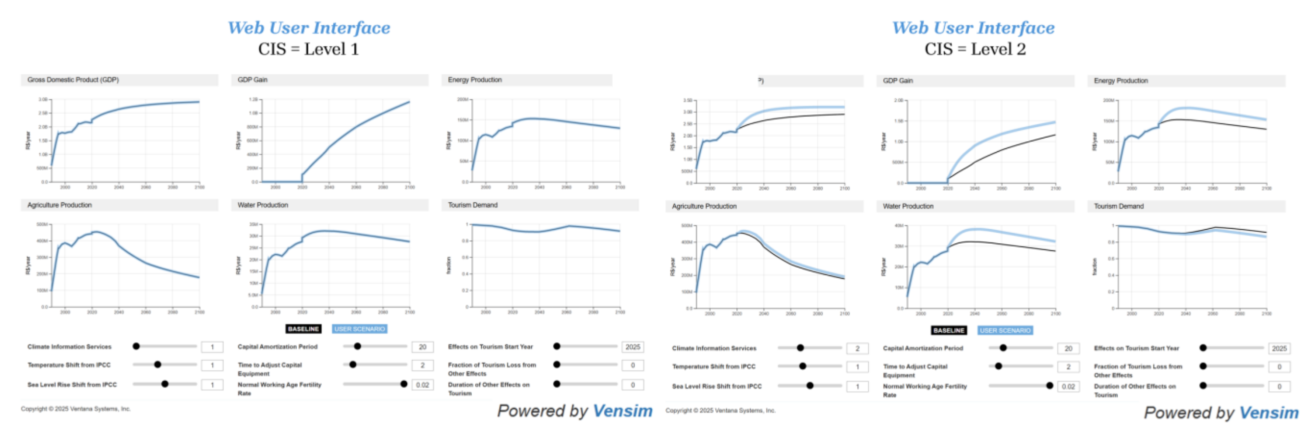

Figure 8. SEB Web User Interface (work in progress). The left side shows CIS set to Level 1 and on the right with CIS set to Level 2.

3. Results

For each scenario (Normal Climate, Warming Climate, NDC Climate), the model first calculates the value added in each producing sector, net of supplies usage and consumption of capital per sector. GDP is then calculated as the sum of the value added in all producing sectors, with the value add from abatement and adaptation actions included in the GDP calculation for the [NDC Climate] scenario.

As shown earlier in Figure 1, the model quantifies the SEB of CIS-informed climate impact management actions and compares it to the SEC of no climate impact management for smaller economies such as those found in OACPS countries. The initial exploratory and explanatory data and country models are for six OACPS countries: Angola, Burkina Faso, Fiji, Guyana, Jamaica, Kenya.

Figure 9 shows the changes in GDP[scenario] and net SEB (SEB – SEC) for CIS levels 1 to 4 (Basic, Essential, Comprehensive, and Advanced, respectively).

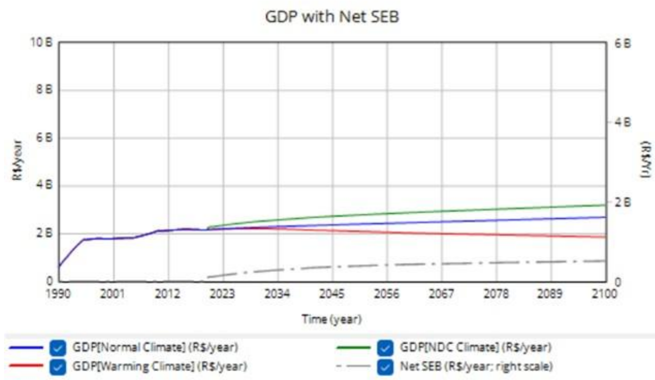

Fig. 9a) CIS = 1

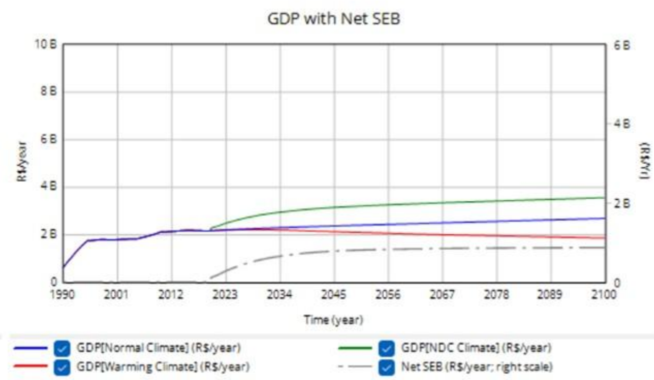

Fig. 9b) CIS = 2

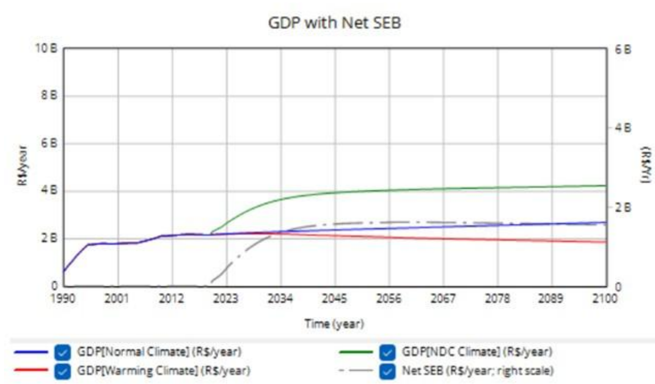

Fig. 9c) CIS = 3

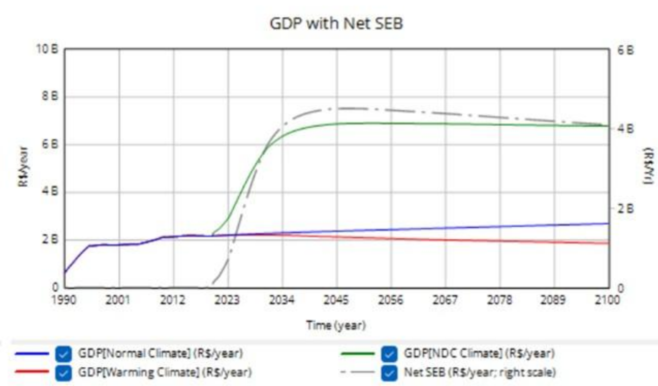

Fig. 9d) CIS = 4

Figure 9. GDP[scenario] for CIS levels 1 to 4, showing Net SEB.

This set of graphs quantifies the CIS value chain using the metric Net SEB:

$$Net\ SEB = SEB - SEC$$

GDP[NDC Climate] increases due to both increases in population growth (not shown) and the economic value-add of NDC actions, which increase with increasing levels of CIS as discussed previously. Net SEB rises rapidly at year 2020, reflecting the default value of the 'normal climate reference year'. This variable determines the start date for implementing NDC actions, and thus the resulting economic improvements. Earlier NDC actions can be shown by adjusting the reference year.

These results are for the climate management policies reflected in the set of parameters chosen for the NDC Actions sub-model.

4. Findings

The results show the positive effect the CIS value chain can have on an OACPS country's response to climate change. Increasing the level of CIS contributes in two ways:

- by providing improved climate information to the production sectors, thereby increasing output and raising the country's GDP, and
- by increasing the level of economic activity to deploy infrastructure and services for abatement and adaptation actions.

The combined effects of these value-add components can be seen in the increasing net SEB for increasing levels of CIS (Figure 9).

A leverage point not tested in the model is the funding available for NDC actions. The model currently assumes that the value-add lost in the production sectors due to climate change (the SEC) will be used to determine funding for NDC actions. Further, the fraction of funding provided by external sources is based on the level of CIS, with the remainder contributed by the country. This exploratory model structure, which should be viewed as a starting point, is shown in Figure 10.

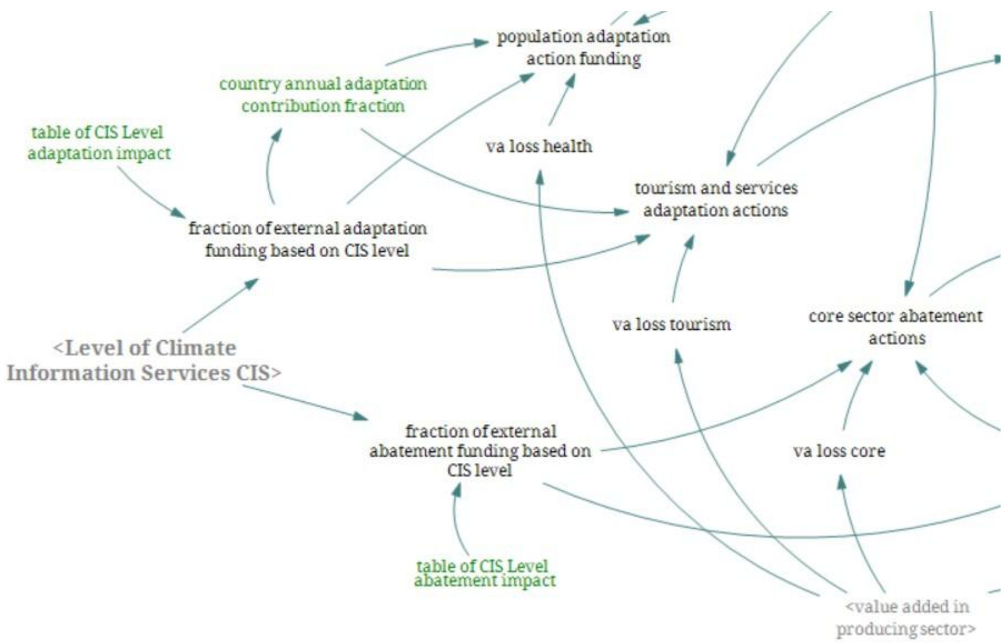

Figure 10. Model structure showing the amount and sources of NDC actions funding.

At the bottom right, the subscripted variable 'value added' (va) in producing sector[scenario, producing sector] creates the matrix of economic value add for each of the eight producing sectors, for each of the three scenarios. Using the previous equation for SEC the value added that is lost in the health sector (va loss health), tourism sector (va loss tourism), and remaining sectors (va loss core, which includes agriculture, energy, water, infrastructure, transportation, and industry). At the lower left, the fraction of external funding is determined using a lookup table based on the level of CIS. The fraction not funded by external sources is used as the country funding fraction. While simplistic, it does provide insight into the level of GDP recovery that might be possible (Figure 9, net SEB) if recovery from climate impacts is fully funded.

5. Conclusions and Future Work

The current SEB model provides useful insights for stakeholders who have been oriented to the methodology. It remains a work in progress to become the influential decision-making tool envisioned by the project champions.

The next phase of work proposes creating cross-functional expert panels in each country. These panels would comprise a broad range of stakeholder experts – SD modelers, climate scientists, policy analysts, decision-makers, and others with the goal of consolidating country expertise. In so doing, a holistic approach to integrating the insights generated from the climate services value chain can be more rapidly integrated into climate management policy.

Future work to be initiated in Phase 3 envisions continuing the collaborative approach and expanding the collaboration team to include subject matter experts in population, health, macroeconomics at the country and production sector level, as well as a broader cohort of policy analysts and decision-makers. Subject to funding, the next Phase 3 would focus on the specific items listed below:

- Validate key macroeconomic leverage points influenced by the Level of CIS.
- Validate the determination of key leverage points for external and country funding of climate management actions.
- Validate data sources: data sources are reviewed and approved by country stakeholders and domain experts including macroeconomics, population, climate, health, water, and other supply & production sector experts (agriculture, energy, infrastructure, transportation, industry, services (which includes tourism). Policy experts on social unrest and informal economy should also validate data sources for their specialties.
- Optimized country model: optimize the model using the normative reference data and expert input from the preceding step.
- Verify results: re-engage the expanded collaboration of country subject matter experts to verify the results of the optimized model.
- Show CIS value chain impacts on Net SEB from stepwise investments in CIS level.
- Web User Interface refresh: enhance the web user interface to better serve various use cases such as displaying a richer set of model outputs, viewing graphs larger, displaying graph descriptions and exposing all model assumptions to users.

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