**Preliminary Economic Assessment of Climate Change**

**Impacts for Vanuatu**

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***Report prepared for CSIRO within the context of the Socio-Economic Benefit Analysis of the Green Climate Fund-funded Van KIRAP Vanuatu Climate Information Services for Resilient Development project.***

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**Summary**

This study is focussed on preliminary evaluation of the economic impact of climate change at a macro-economic and more detailed sectoral level for Vanuatu. This report is prepared for CSIRO Climate Intelligence Program, as a designated Delivery Partner for the Green Climate Fund supported Van KIRAP *Vanuatu Climate Information Services for Resilient Development* Project, led by the Secretariat of the Pacific Regional Environment Programme and the Vanuatu Meteorological and Geohazard Department (Government of Vanuatu).

We evaluate the economic effects of two global climate change scenarios for the western tropical Pacific by 2050:

* Scenario #1: an average increase of 1.7° C, and
* Scenario #2: an average increase of 2.4° C.

These scenarios correspond to standardised global emissions scenarios, climate model output and associated large-scale climate processes, as specified by CSIRO for the Van KIRAP project:

* Scenario #1: RCP2.6, low warming, SPCZ moves south, and
* Scenario #2: RCP8.5, high warming, SPCZ moves north.

Our methodology involves the translation of physical impacts of changes in the mean condition of relevant climate hazards and associated scenarios, in terms of economic variables inside a Computable General Equilibrium modelling framework. We make use of a recently developed Input-Output data for Vanuatu as part of the CSIRO scope of work for the Van KIRAP project. We use CSIRO-derived damage estimates to represent five climate hazard-based impacts: mean sea level rise impacting coastal infrastructure, future changes in mean temperature and rainfall impacting variation in agricultural crop yields, and projected change in mean temperature impacting labour productivity, human health, and household energy demand; all across varying (national/sub-national spatial scales).

We find that increases in global average temperature as a consequence of climate change will greatly affect Vanuatu’s economy. We estimate value-added (aggregated) losses of US$ 130.5 million (about 14% of annual GDP) for the modelled Scenario #1, and US$ 276.4 million (about 30% of annual GDP) for Scenario #2.

These effects are largely driven by the sea level rise effect. We use Van KIRAP’s modelling of sea level rise defined by the increase in the replacement value of assets included in area inundated by the highest astronomical tide plus 0.2 m and 0.4 m for Scenario #1 and #2 correspondingly. The loss in labour productivity due to heat stress and changes in mortality and morbidity incidence of some diseases represent about 9 percent of the total effect. By contracts, based on CSIRO Van KIRAP project estimates of agricultural suitability hazard assessments for four crops, we find that agricultural income potentially increases by US$ 13.6 million for Scenario #1, and US$ 45.8 million for Scenario #2 in the event that climate change potentially provides an opportunity for enhanced production of some crops in some locations of Vanuatu (i.e., over and above the potential reduction in productivity for some crops in some locations).

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**Introduction**

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Our methodology involves the translation of physical impacts of changes in the mean condition of relevant climate hazards and associated scenarios, in terms of economic variables inside a Computable General Equilibrium modelling framework. We make use of a recently developed Input-Output data for Vanuatu (Valenzuela and Vallecilla 2023a) produced as part of the CSIRO scope of work for the Van KIRAP project. We use CSIRO-derived damage estimates and a World Bank study (Roson and Sartori 2019) to represent five climate hazard-based impacts: mean sea level rise impacting coastal infrastructure, changes in mean temperature and rainfall impacting variation in agricultural crop yields, change in mean temperature impacting labour productivity, human health, and household energy demand; all across varying (national/sub-national spatial scales).

The next section outlines the methodology and data to be used. The following section presents estimates of the economic-wide effects of five climate change impacts. The final section draws out implications of the results and future research.

**Methodology**

Our methodology utilises damage function estimates corresponding to Scenarios #1 and 2 as ‘economic shock’ inputs into a combination of a general equilibrium modelling framework contextualised by the Input-Output model of Vanuatu’s economy.

We use the latest version of the comparative static general equilibrium GTAP model (Version 7, see Corong et al. 2017). Our choice of a comparative static modelling allows us to concentrate on the economic effects of the damage function parameters under Scenarios #1 and 2, without forcing additional assumptions on economic trajectories over an extended period of time. The GTAP model is a comparative static computable general equilibrium model, with detailed economic theory and producer and consumer behaviour (Hertel 1997). The model assumes perfect competition and constant returns to scale in production. The functional forms are nested constant elasticities of substitution production functions. Land is specific to agriculture in the GTAP database and is mobile amongst alternative agricultural uses according to a Constant Elasticity of Transformation which, through a revenue function, transforms land from one use to another. In the model closure adopted here, labour and produced capital are assumed to be mobile across all uses. On the demand side there is a ‘national representative household’ whose expenditure is governed by a Cobb-Douglas aggregate utility function which allocates net national expenditures across private, government and saving activities. That household distinguishes between domestic and imported versions of a product and between different countries of origin in the case of imported goods. We use the standard GTAP Model’s default values of all these and other elasticities, making replication by other modelers easy (Valenzuela et al. 2008).

We use a recently developed database for the Pacific region (Hanslow and Newth 2021) providing preliminary detailed estimates of production, consumption, and trade for 14 Pacific Island countries. We supplement this database with newly developed Input-Output table estimates tailored specifically for Vanuatu (Valenzuela and Vallecilla 2023a, b).

**Climate Change Impacts and Damage Functions**

The damage functions for each of the specified Scenarios (#1 and2) and associated climate change impacts are derived from an interdisciplinary assessment of published sources including a World Bank study (Roson and Sartori 2016), and CSIRO Van KIRAP project modelling computations and estimates. These are considered central values projections of climate change impacts, without consideration of uncertainty or risk (i.e., no provision of standard errors of the parameters).

The translation of the physical impacts and economic shocks for both scenario is shown in Table 1. These estimates are used as exogenous shocks into the economic modelling framework for the present study.

The climate hazard-based impacts and associated damage functions under consideration are further defined as:

1. Mean sea level rise impacting coastal infrastructure: CSIRO estimates of the replacement value of inundated coastal assets across Vanuatu (included in area inundated by the highest astronomical tide plus 0.2 m and 0.4 m for scenario 1 and 2 correspondingly) of 22% for a 0.2m increase and 52% for a 0.4 m increase. These estimates are translated into the economic modelling framework as a loss of land and capital productivity.
2. Changes in mean temperature and rainfall impacting variation in agricultural crop yields: higher temperatures, higher concentration of carbon dioxide in the atmosphere, and different precipitation patterns will affect crop yields and agricultural productivity; CSIRO estimates of change in agricultural land suitability for four distinct crops across Vanuatu are +22% for cocoa, +30% for taro, -44% for coffee, -40% for kava.
3. Change in mean temperature impacting heat stress and labour productivity: determined by high temperature and humidity levels, implies more frequent pauses, interruptions, lower speed and higher probability of injury. Therefore, changes in working atmospheric conditions will affect labour productivity across Vanuatu, depending on the degree of heat exposure and physical labour intensity. Table 1 shows estimates of the loss of labour productivity for Pacific Island countries aggregated according to physical intensity. We use estimates of reduction of labour productivity as a linear function of temperature based on Roson and Sartori (2016).
4. Change in mean temperature impacting human health: Increases in temperature and changes in precipitation patterns imply changes in mortality and morbidity incidence of some vector-borne diseases (malaria, dengue, and other parasitic infections), heat and cold related diseases, and diarrhea. We use estimates of human health impacts in the form of labour productivity reduction as a linear function of temperature, based on Roson and Sartori (2019).
5. Change in mean temperature impacting household energy demand: household energy demand is correlated to variations in temperature. For Pacific Island countries, increases in temperature will likely cause an increase of electricity consumed for cooling purposes. We use CSIRO estimates of increases in the cost of electricity production (for urban/peri-urban populations of Port Vila) of 0.2% for the 1.7° C scenario, and 6.6% for the 2.4° C scenario.

**Table 1: Economic effects translation of climate change physical impacts and economic shocks by specified increases in mean annual temperature (Scenario #1 and 2) for Vanuatu.**

|  |  |  |  |
| --- | --- | --- | --- |
| Physical impacts | Economic shocks | Scenario 1:1.7° C increaseRCP2.6, low warming, SPCZ moves south | Scenario 2: 2.4° CRCP8.5, high warming, SPCZ moves north |
| Sea level rise-Mean sea level rise causing inundation. | Replacement value of inundated coastal assets included in area inundated by the highest astronomical tide plus 0.2 and 0.4 mCapital and land productivity (%) | +22%-22% | +52%-52% |
| Changes in agricultural land suitability  | Agricultural productivity (%) | Coffee -44%Kava -40%Cocoa 22%Taro 30% | Coffee -93%Kava -97%Cocoa 103%Taro 85% |
| Heat effects  | Loss of labour productivity (%) | High physical intensity | -11 | -15.5 |
| Medium physical intensity | -3.7 | -6.6 |
| Low physical intensity | -0.1 | -2.0 |
| Human health (mortality and morbidity) | Loss of labour productivity (%) | -0.4 | -0.5 |
| Energy cost increase | Increase in cost of electricity production (%) | 0.2 | 6.6 |

Source: Based on CSIRO Van KIRAP project, and Roson and Sartori (2016).

**Results**

The results are presented for the two climate change scenarios with attribution to specific climate impacts, at an aggregate national income and at a detailed sectoral production and income levels.

**Scenario 1: 1.7° C increase, RCP2.6, low warming, SPCZ moves south**

Our findings indicate that a 1.7° C increase in global mean annual temperature would decline Vanuatu GDP by US$ -130.5 million (about 14% of annual GDP) (Table 2). A decomposition of the climate effects reveals that sea level rise is the most dominant effect with a decline of US$ -133.4 million, followed by the heat-related impacts on labour productivity with US$ -8.2 million and on health with US$ -2.4 million, and the increased cost of electricity production with US$ -0.1 million. Our results indicate that there is a positive effect of $US 13.6 million due to the change in agricultural suitability for the four crops considered (coffee, kava, cocoa, and taro); these crops account for almost one third of the agricultural value of production.

**Table 2: Scenario #1 - Economic impact on Vanuatu GDP (US$ million) of a 1.7° C increase in global average temperature by climate change impact.**

|  |  |
| --- | --- |
|  | Economic impact (US$ million) due to: |
|  | Sea level rise impacts on coastal infrastructure | Temp and rainfall impacts on agricultural suitability | Temp impacts on labour productivity | Temp impacts on human health | Temp impacts on energy demand | **Total** |
| Vanuatu | -133.4 | +13.6 | -8.2 | -2.4 | -0.1 | **-130.5** |

In this study the modelling of the increase in the mean sea level rise causing inundation considers a treatment of the replacement value of inundated coastal assets as a proxy of capital and land productivity in all economic activities. Previous studies have consistently reported a low impact of the sea level rise effect as they consider only a loss of land stock through erosion, inundation or salt intrusion along the coastline. We believe that treatment is insufficient as land is only utilised in agricultural activities in computable general equilibrium modelling databases, and a projected increase in the mean sea level rise causing inundation would have a marked impact of physical capital in addition to land loss.

The estimated heat-related impacts are consistent with previous climate change studies that have identified that heat stress on labour productivity is a key economic impact of climate change (Roson and Sartori 2016; Day *et al*. 2018; Valenzuela and Newth 2022).

***Changes in production***

An increase in global average temperature of 1.7° C (Scenario #1) will decrease output values of all activities, with the sole exception of ‘roots and vegetables’ driven by increase in potential agricultural suitability (Figure 1). The value of output in the food sector decreases by US$ 22 million. Infrastructure is the most affected sector, with construction output value declining by US$ 48 million; and transport, accommodation, trade and real estate activities all impacted in a range of –3 to -15 percent of the value of production.

***Changes in Value added***

An increase in global average temperature of 1.7° C (Scenario #1) will result in a decrease of value added in all sectors of the Vanuatu’s economy, except for ‘roots and vegetables’ (again as Taro gains significantly in potential agricultural suitability). Table 3 shows the change in value added for all 26 categories of the economy as depicted in the Vanuatu Input-Output table produced for Van KIRAP.

We use this detailed sectoral value-added analysis to produce aggregate measures for five priority sectors (Table 4): agricultural production, fishing, production, tourism, infrastructure, and water services. Following convention, these measures are based on the following aggregation of individual sectors depicted in the Vanuatu Input-Output table.

|  |  |
| --- | --- |
| **Sectoral aggregates** | **Individual sectors as depicted in Vanuatu’s Input-Output Table.** |
| Agriculture | Coconut, roots and vegetables, kava, cocoa, coffee, other crops, cattle, chicken, and pork. |
| Fishing | fishing |
| Infrastructure | Construction; wholesale, retail trade and repair of motor vehicles; other wholesale trade; real estate; transport; and accommodation and food services. |
| Tourism | Accommodation and food services; transport; and retail trade. |
| Water | Water supply (Input-Output Table also includes electricity supply) |



**Figure 1: Climate change impact on Vanuatu’s production (US$ million) of a 1.7° C increase in global mean temperature for selected categories of the economy (Scenario #1).**

**Table 3: Breakdown of value-added changes (US$ million) across the Vanuatu economy (as per Input-Output table) of a 1.7° C increase in global average temperature by climate change impact (Scenario #1).**

(US$ million)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Sea Level Rise | Agricultural suitability | Heat effects on | Energy cost | **Total** |
|  | Labour productivity | Human health |
| Coconut | -3.3 | -0.1 | -0.2 | 0.0 | 0.0 | -3.7 |
| Roots, vegetables | -10.9 | 26.2 | -0.8 | -0.1 | 0.0 | 14.5 |
| Kava | -3.8 | -12.5 | -0.3 | 0.0 | 0.0 | -16.6 |
| Cocoa | -0.3 | 0.3 | 0.0 | 0.0 | 0.0 | -0.1 |
| Coffee | 0.0 | -0.1 | 0.0 | 0.0 | 0.0 | -0.1 |
| Others crops | -8.9 | -0.3 | -0.9 | 0.0 | 0.0 | -10.1 |
| Cattle | -0.4 | 0.0 | 0.0 | 0.0 | 0.0 | -0.4 |
| Other livestock | -0.4 | 0.0 | -0.1 | 0.0 | 0.0 | -0.5 |
| Forestry | -3.3 | 0.0 | -0.2 | 0.0 | 0.0 | -3.6 |
| Fishing | -2.1 | 0.0 | -0.1 | 0.0 | 0.0 | -2.2 |
| Mining and Quarrying | -0.1 | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 |
| Food, bev. and tobacco | -10.7 | -0.1 | -1.0 | -0.2 | 0.0 | -11.9 |
| Other manufacturing | -3.0 | 0.0 | -0.3 | -0.1 | 0.0 | -3.3 |
| Electricity and Water supply | -1.9 | 0.0 | -0.6 | -0.1 | 0.0 | -2.5 |
| Construction | -24.9 | 0.0 | -2.8 | -0.3 | -0.2 | -28.2 |
| Wholesale, Retail Trade and repair of vehicles | -1.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.9 |
| Other Wholesale Trade  | -2.1 | 0.0 | 0.1 | -0.1 | 0.0 | -2.0 |
| Retail Trade | -10.2 | 0.0 | 0.4 | -0.3 | 0.0 | -10.0 |
| Transport | -0.8 | 0.0 | 0.1 | 0.0 | 0.0 | -0.8 |
| Accommodation and Food Services | -11.1 | 0.0 | 0.3 | -0.4 | 0.0 | -11.3 |
| Information and Communication | -3.7 | 0.0 | -0.1 | -0.1 | 0.0 | -3.9 |
| Finance and Insurance | -6.5 | 0.0 | -0.2 | -0.1 | 0.0 | -6.8 |
| Real Estate | -3.6 | 0.0 | -0.1 | -0.1 | 0.0 | -3.8 |
| Professional, Services | -0.6 | 0.0 | 0.0 | 0.0 | 0.0 | -0.7 |
| Government services | -12.6 | 0.0 | -0.7 | -0.3 | 0.0 | -13.7 |
| Education, Health, Rec other Services | -7.3 | 0.0 | -0.4 | -0.2 | 0.0 | -7.9 |
| **Total** | -133.4 | 13.6 | -8.2 | -2.4 | -0.1 | -130.5 |

The impacts of an increase of 1.7° C in global average temperature for the five priority sectors (Scenario #1) are shown in Table 4, by individual climate impact. Agriculture income is affected by US$ -16.9 million (a reduction of about 8.6 percent in total agricultural value-added). Fishing activities are reduced by US$ -2.2 million. Tourism income is reduced by US$ -22 million. Infrastructure value-added is reduced by US$ -47.1 million. Water supply activities value-added is reduced by US$ -2.5 million.

**Table 4: Value added changes by aggregated Van KIRAP priority sectors (US$ million) of a 1.7° C increase in global average temperature** **for each of the selected hazard-based impacts/economic shocks (Scenario #1); NA, not applicable.**

(US$ million)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Sea Level Rise | Agricultural suitability | Heat effects on | Energy cost | **Total** |
|  | Labour productivity | Human health |
| **Agriculture** | -27.9 | 13.6 | -2.5 | -0.2 | 0.01 | **-16.9** |
| **Fishing** | -2.1 | NA | -0.1 | 0.0 | 0.0 | **-2.2** |
| **Tourism** | -22.1 | NA | 0.7 | -0.7 | 0.0 | **-22.0** |
| **Infrastructure** | -43.5 | NA | -2.5 | -0.9 | -0.1 | **-47.1** |
| **Water** | -1.9 | NA | -0.6 | -0.1 | 0.0 | **-2.5** |

**Scenario 2: 2.4° C, RCP8.5, high warming, SPCZ moves north**

The results for Scenario #2 are summarised in Table 5. These indicate that a 2.4° C increase in global annual temperature would decline Vanuatu’s GDP by US$ -276.4 million (about 30% of annual GDP). A decomposition of the climate effects reveals that sea level rise is the most dominant effect with a decline of US$ -295 million, followed by the heat-related impacts on labour productivity with US$ -20.2 million and on health with US$ -4.8 million, and the increased cost of electricity production with US$ -2.4 million. Our results indicate that there is a positive effect of $US 45.8 million due to the change in agricultural suitability for the four crops considered (coffee, kava, cocoa, and Taro); these crops account for almost one third of the agricultural value of production.

We find a large effect of the sea level rise impact, as previously mentioned this is due to the large exogenous shock of the simulation and the modelled loss of productivity in physical capital and land endowments.

In line with the analysis of the first scenario, our heat-related impacts estimate is consistent with previous climate change studies identifying that labour productivity reductions are a key factor of climate change impacts (Roson and Sartori 2016; Day *et al*. 2018; Valenzuela and Newth 2022).

**Table 5: Economic impacts on Vanuatu GDP (US$ million) of a 2.4° C increase in global average temperature by climate change impact (Scenario #2).**

|  |  |
| --- | --- |
|  | Economic impact (US$ million) due to: |
|  | Sea level rise impacts on coastal infrastructure | Temp and rainfall impacts on agricultural suitability | Temp impacts on labour productivity | Heat impacts on human health | Temp impacts on energy demand | **Total** |
| Vanuatu | -294.8 | 45.8 | -20.2 | -4.8 | -2.4 | **-276.4** |

***Changes in production***

An increase in global average temperature of 2.4° C (Scenario #2) will decrease output values of all activities, with the sole exception of ‘roots and vegetables’ driven by Taro’s increase in potential agricultural suitability (Figure 2). The value of output in the food sector decreases by US$ -44 million. Construction is the most affected sector with a reduction of $US -105 million in output value.



**Figure 2: Climate change impact on Vanuatu’s production (US$ million) of a 2.4° C increase in global average temperature for selected categories of the economy (Scenario #2).**

***Changes in Value added***

An increase in global average temperature of 2.4° C (Scenario #2) will result in a decrease of value added in all sectors of the Vanuatu’s economy, except for ‘roots and vegetables’ (as Taro gains significantly in potential agricultural suitability). Table 6 shows the change in value added for all 26 categories of the economy as depicted in the Vanuatu Input-Output table.

We use these data to evaluate income changes in the Van KIRAP’s five priority sectors (Table 7). Agriculture income is affected by US$-19.6 million (a reduction of about 10 percent in total agricultural value-added). Fishing activities are reduced by US$ -4.4 million. Tourism income is reduced by US$ -55 million. Infrastructure value-added is reduced by US$ -108.2 million. Water supply activities value-added is reduced by -5.4 US$ million.

**Table 6: Breakdown of value-added changes (US$ million) across the Vanuatu economy (as per Input-Output table) of a 2.4° C increase in global average temperature by climate change impact (Scenario #2).**

(US$ million)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Sea Level Rise | Agricultural suitability | Heat effects on | Energy cost | **Total** |
|  | Labour productivity | Human health |
| Coconut | -7.1 | -0.1 | -0.4 | 0.0 | 0.0 | -7.7 |
| Roots, vegetables | -23.4 | 75.1 | -1.4 | -0.1 | 0.1 | 50.3 |
| Kava | -8.1 | -30.1 | -0.5 | 0.0 | 0.0 | -38.7 |
| Cocoa | -0.8 | 1.5 | 0.0 | 0.0 | 0.0 | 0.7 |
| Coffee | -0.1 | -0.1 | 0.0 | 0.0 | 0.0 | -0.2 |
| Others crops | -21.1 | -0.3 | -1.3 | 0.0 | 0.1 | -22.7 |
| Cattle | 0.0 | 0.0 | -0.1 | 0.0 | 0.0 | -0.1 |
| Other livestock | -0.9 | 0.0 | -0.2 | 0.0 | 0.0 | -1.1 |
| Forestry | -7.5 | 0.0 | -0.3 | 0.0 | 0.1 | -7.7 |
| Fishing | -4.3 | 0.0 | -0.1 | 0.0 | 0.0 | -4.4 |
| Mining and Quarrying | -0.1 | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 |
| Food, bev. and tobacco | -21.9 | -0.1 | -2.0 | -0.2 | 0.2 | -23.9 |
| Other manufacturing | -6.8 | 0.0 | -0.7 | -0.1 | 0.2 | -7.4 |
| Electricity and Water supply | -4.2 | 0.0 | -1.0 | -0.1 | -0.2 | -5.4 |
| Construction | -51.3 | 0.0 | -4.8 | -0.3 | -5.3 | -61.7 |
| Wholesale, Retail Trade and repair of vehicles | -2.3 | 0.0 | -0.1 | 0.0 | 0.0 | -2.3 |
| Other Wholesale Trade  | -4.9 | 0.0 | -0.1 | -0.1 | 0.2 | -4.9 |
| Retail Trade | -24.2 | 0.0 | -0.6 | -0.3 | 0.3 | -24.7 |
| Transport | -2.1 | 0.0 | 0.0 | 0.0 | 0.1 | -2.0 |
| Accommodation and Food Services | -26.7 | 0.0 | -1.4 | -0.4 | 0.3 | -28.3 |
| Information and Communication | -8.2 | 0.0 | -0.4 | -0.1 | -0.1 | -8.8 |
| Finance and Insurance | -14.9 | 0.0 | -0.7 | -0.1 | 0.0 | -15.8 |
| Real Estate | -8.3 | 0.0 | -0.4 | -0.1 | -0.1 | -8.8 |
| Professional, Services | -1.4 | 0.0 | -0.1 | 0.0 | 0.0 | -1.5 |
| Government services | -27.9 | 0.0 | -2.2 | -0.3 | -0.5 | -30.9 |
| Education, Health, Rec other Services | -16.3 | 0.0 | -1.3 | -0.2 | -0.3 | -18.1 |
| **Total** | -294.8 | 45.8 | -20.2 | -2.4 | -4.8 | -276.4 |

**Table 7: Value added changes by aggregated Van KIRAP priority sectors (US$ million) of a 2.4° C increase in global average temperature for each of the selected hazard-based impacts/economic shocks (Scenario #2); NA, not applicable.**

(US$ million)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Sea Level Rise | Agricultural suitability | Heat effects on | Energy cost | **Total** |
|  | Labour productivity | Human health |
| **Agriculture** | -61.6 | 45.9 | -3.9 | -0.1 | 0.3 | -19.5 |
| **Fishing** | -4.3 | NA | -0.1 | 0.0 | 0.0 | -4.4 |
| **Tourism** | -53.0 | NA | -2.0 | -0.7 | 0.7 | -55.0 |
| **Infrastructure** | -95.5 | NA | -6.9 | -1.0 | -4.8 | -108.2 |
| **Water** | -4.2 | NA | -1.0 | -0.1 | -0.2 | -5.4 |

**Discussion**

We have modelled a translation of the physical impacts of two global climate change scenarios by 2050 into a general equilibrium modelling framework supplemented by a newly developed Input-Output table for Vanuatu. These physical climate change hazard-based impact estimates are the result of a combination of new CSIRO Van KIRAP estimates for sea level rise, agricultural yields and energy cost for Vanuatu and World Bank (Roson and Sartori 2016) estimates of heat impacts on labour productivity and health.

Our main methodological contribution is to show a decomposition of the GDP effects by individual climate change impact and changes in income and production, at a national; (GDP) and more detailed sectoral level for Vanuatu’s economy. In terms of empirical results, this study presents novel detailed estimates of climate change impacts for Vanuatu relying on a recently developed production and trade database for the Pacific Island countries (Hanslow and Newth 2021), a newly developed Input-Output database for Vanuatu (Valenzuela and Vallecilla 2023a, b).

The study confirms and improves first-order regional approximations that the negative effects of climate change will be significantly borne by the Pacific Island economies (Roson and Sartori 2016). The study is in alignment with previous computable general equilibrium modelling of climate change economic impacts for the Pacific Island nations showing significant negative effects (Newth, Gunasekera, and Gooley 2017; Newth and Hanslow 2021; Valenzuela and Newth 2022). In particular, we find that heat-related impacts are a key economic impact of climate change in alignment with previous climate change studies (Roson and Sartori 2016; Day *et al*. 2018; Valenzuela and Newth 2022).

Based on the specified scenarios and CSIRO estimates of the impact of sea level rise on the value of Vanuatu’s replacement value of infrastructure, we find that the sea level rise is the most dominant effect of climate change on Vanuatu’s economy. Previous studies have consistently reported a low impact of the sea level rise effect as they consider only a loss of land stock through erosion, inundation or salt intrusion along the coastline (Roson and Sartori 2016). We believe that treatment is insufficient as land is only utilised in agricultural activities in computable general equilibrium modelling databases, and a projected increase in the mean sea level rise causing inundation would have a marked impact of physical capital in addition to land loss.

Our findings indicate that a 1.7° C global average temperature increase would decline Vanuatu’s GDP by US$ -130.5 million, and a 2.4° C global average temperature increase would decline Vanuatu’s GDP by US$ -276.4 million. This economic evaluation is dependent on the accuracy of the projected physical climate change hazard-based impacts and associated economic shocks. It is also the case that these results are to be considered conservative as they relate to projected ‘average’ change in the climate for sea level, temperature and rainfall, without consideration of increases in intensity and frequency of extreme climate events (e.g. extreme temperature and rainfall, drought and flooding, tropical cyclones, marine heatwaves, coral bleaching etc), and climate variability from large-scale natural processes such as the El Nino Southern Oscillation. Likewise, the analysis does not include the impacts of possible ‘step changes’ in projected climate due to exceedance of tipping points in the cryosphere such as rapid loss of Greenland and/or Antarctic ice sheets.

**Concluding comments**

Pacific Island countries are considered highly vulnerable to the physical impacts of climate change. These potential impacts include significant changes in climatic conditions resulting for Vanuatu potentially (among other impacts) in loss of infrastructure and agricultural land, alteration of crops cycles and coastal fisheries, higher incidence of certain diseases, and marked loss of labour productivity due to heat.

We have modelled a translation of the physical impacts on Vanuatu of two specific global climate change scenario by 2050 into a general equilibrium modelling framework, supplemented by a newly developed Input-Output table for Vanuatu. These physical impact estimates are the result of a wide scientific consensus based on construction of climate change damage functions considered relevant for selected climate change hazard-based impact assessments.

Our main methodological contribution is to show both: (a) a decomposition of the GDP effects by individual climate change impact within a Computable General Equilibrium modelling framework, and (b) changes in income and production at both national (GDP) and a more detailed sectoral level for Vanuatu’s economy using the latest available economic data for Vanuatu. Our analysis shows that the mean sea level rise causing inundation effect has potentially a large damaging impact on the Vanuatu’s economy. These impacts are compounded by the loss in labour productivity, due to heat stress and changes in mortality and morbidity incidence of some diseases.

Our framework, methods and analytics lend themselves to improvement as new data on climate change physical impacts and more detailed household expenditure, and geospatial mapping information of the Pacific nations become available, including for Vanuatu. For instance, it could be inferred that the impact of sea level rise and extreme weather events on health, infrastructure and tourism activities is considerably more significant based on episodic extreme weather and climate variability driven by combined impacts of climate change and ENSO than on average time-extended trends. Thus, in order to formulate economic uncertainty assessments of climate change impacts it is required to undertake such assessments with inventories of infrastructure at risk, health population dynamics, and concerted scientific efforts to provide new physical evidence based on scientifically robust analysis of climate extremes over multi-decadal timescales.

Our findings contribute significantly to the discussion of climate change impacts in the Pacific, and Vanuatu in particular, as they confirm the potential large differentiated negative effects to the Pacific Island countries region. Our macroeconomic effects relate exclusively to projected ‘average’ trends, so they serve as lower-bound estimates of the likely (expected) climate change impact in the region. As new evidence become available and development of interdisciplinary modelling platforms is supported, more detailed appraisal of the impacts of climate change will be possible.

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