Gross Ecosystem Product (GEP) for the Cook Islands

A Case Study for an Island Economy

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1 Introduction

The environment provides considerable value to human economies. But this value is often undervalued due to the non-market medium that ecosystem services enter into economic benefits. Natural capital accounting has begun to attempt to quantify the quantity of these services, and to a degree translate them into monetary terms. Gross ecosystem product (GEP) is emerging as a useful corralary to gross domestic product (GDP) for the value of ecosystem services. This value of the flow of ecosystem services into economy from environmental factors is summarized by a simple accounting identity.

$$GEP = \sum_{e \in E} \lambda_e \times P_e \times Q_e$$

This equation states that the gross production value of ecosystem services in equivilent to the unit price of the service (P), the quantity supplied (used) of the service (Q), and a weight for the percentage contribution of the ecosystem service dervied from nature's contribtuion (λ). For each ecosystem service e in the set of ecoystem services considered E, simply aggregate the total production value across all services to estimate a national GEP. A simple panel could be estimated by adding a time script if desired. The quantity of services provided are estimated using biophysical models. Then prices are determined using either the market value of those services or non-market evaluation techniques to determine a williness-to-pay for the services. And finally, the contribution of nature for the service partials out human contributions such as labor or capital inputs that increase the value of the ecosystem service.

GEP creates a money metric for the current value of ecosystem services at any given time. This identity can be applied to any type of ecosystem service, allowing for both a comparision between the value of services in the same units as well as allow for the aggregation of ecosystem services across several different envrionmental contributors to the economy.

We propose to estimate GEP for the Cook Islands as a case study in natural capital accounting for island economies. While GEP has been estimated for parts of China [Ouyang et al., 2020, Zheng et al. [2023], Lin et al. [2024]] and there is a current endeavour to globally estimate national GEP [Polasky and et al., 2025], noone has yet estimated a panel of national GEP recognized at the federal level. We would like to partner with the Cook Islands in producing this world first, and hopefully incorporate it into the ongoing statistics by the federal government alongside the GDP estimates reported by the Cook Islands Stastics Office. Because the Cook Islands has a large oceanic terretory, this allows lends to an estimation of important marine-based natural capital accounting.

While annual GDP for the Cook Islands trends around $500 million USD, the large potential for ecosystem services generated by these Pacific islands may equal or eclipise this valuation. Given the environmental focus of the Cook Islands, this would be provide a valueable metric for highlighting the wealth of this nation beyond the traditional scope of economic production.

Below, we discuss a potential avenue for estimating ecosystem services valuable for the Cook Islands.

2 GEP for the Cook Islands

We aim to focus on the following sectors: Our scope is not limited to the following ecosystem services and we are open to expanding the list to the ecosystem services or environmental contributions that may generate value for the Islanders. For each service, we define the human benefit derived from the ecosystem and determine the methodology for determine the quantity, price, and nature's contribution values to estimate GEP for that service. Finally, we identify the data we would require to make these estimations.

Need to cite here prior work on estimating natural capital for cook islands. Then citations for natural capital for other island economies.

2.1 Agriculture

For commerical agriculture, we can use modification of GDP statistics from the agricultural sector. This may come from the statistical office of the Cook Islands or from what is reported by the Food and Agriculture Organization (FAO). Using the marketed consumption value of commerical agriculture, we have an annual monetary value which already encapsulates both price and quantity. The adjustment that needs to be made is to modify this value by the contribution of nature (as opposed to farm labor or processing) which is the source of that value. The technique proposed is to use a resource rent. This is the difference between the marketed value and production cost of producing the commodity. By removing production costs, we are able to extract the market value minus labor and capital inputs. The Changing Wealth of Nation's (CWON) report provides a measure of resource rents at the national level

for 2021 and 2024 in the agircultural sector. We can use is as the modification for nature's contribution.

So, to estimate commerical agriculture GEP we simply need:

$$GEP_{Agr} = (GDP_{Agr}) \times (ResourceRentalRate)$$

There is promise to estimating substience agriculture. While agricultural production for own consumption does not permiate through the market, we can use market prices to estimate the implicit value of that production. To estimate quantity, we would a measure of farmer production which is used for own consumption as opposed for commerical use. This could be obtained through a representative survey of farmers. This survey would need to follow the FAO own consumption toolkit to assess the portion of agricultural production which is used for consumption as home. This provides the quantity of own consumption as aggregated monetary value per hectare of farmable land. Using this estimate, we need to estimate the number of small-holder farmers in the country and the size of their plots. Multiplying the number of hectares by this average value estimates the total value of non-commerical agricultural production. Some capital investments (i.e., shovels, plows, etc.) and farm labor, a similar resource rental rate adjustment is necessary. It is unclear that nature's contribution from agriculture will be higher for subsistence vs commerical production. But, supposing that subsistence agriculture relies more heavily on natural inputs, using the same CWON rental rates will produce a lower bound estimate of GEP for subsistence agriculture.

We can estimate subsistence agriculture GEP through the following:

$$GEP_{AgrOwn} = (HectaresFarmland) \times (OwnConsumptionValue) \times (ResourceRentalRate)$$

If it is possible to disaggregate production by the type of crop produced, then these two GEP values can provide a rich sense of ecosystem service value for both cash crops and household staples. Combining both commercial and subsistence agriculture, the total GEP for agriculture is:

$$GEP_{Agriculture} = GEP_{Agr} + GEP_{AgrOwn}$$

2.2 Crop Pollination

Wild pollinators support the production of several agricultural products in the Cook Islands. In particular, papaya, taro, bananas, coconuts, mango, and guava. Using InVEST's crop pollination model, we can use land use land cover (LULC) data with high spatial resolution to determine pollinator abundance. Further, if we have access to polygons for agricutlural plots

we can estimate the contribution of pollinators to these plots. This provides the estimate of nature's contribtuion through pollination to agricultural products. But to determine the monetary value of this service, we need to match market prices for agricultural commodities with the crops produced. This requires a raster layer of what crops are produced where. Combined with the raster of pollination inputs to agriculture, we have a quantity measure of crop pollination adjusted for the nature contribution from pollinators to crop production. Multiplying this quantity with annual crop prices estimates the GEP value of crop production.

This is summarized in the following formula summarizing over crops (c) and plots (p):

$$GEP_{Poll} = \sum_{c} \sum_{p} (PollAbundance)_p \times (CropProd)_{cp} \times (CropPrice)_c$$

2.3 Fisheries

For commerical fisheries, we can use a similar method as commerical agriculture and rely on GDP values of fisheries with an adjustement for resource rents. CWON estimates of national resource rents for fisheries can be used for the adjustment factor.

$$GEP_{Fish} = (GDP_{Fish}) \times (ResourceRentalRate)$$

Subsistence fisheries is a more novel concept to estimate. The USGS has recently estimated the nutritional value of inland fisheries and translated that into monetary value using replacement cost model (https://www.nature.com/articles/s43016-024-00961-8/tables/2). We could attempt to replicate this method with an adjustment for the size of subsistence fishing in the Cook Islands and shifting to marine fisheries.

Combining both commercial and subsistence agriculture, the total GEP for agriculture is:

$$GEP_{Fisheries} = GEP_{Fish} + GEP_{SubFish}$$

2.4 Non-fish Aquaculture

- perals and trochus
- sand and coral aggregate

2.5 Forestry Products

- timber products
- non-timber products
- fuelwood

2.6 Nature-based Tourism and Recreation

- Ecotourism
- Beach tourism
- Recreational fishing and water activities

There is past work for cook islands. So should look at those methods first. INCA method, or gdp values with resource rents.

2.7 Mining

- Straight from GDP values with CWON resource rents

2.8 Water Use

- Water demand/use
- Waste water disposal
- Water quality (COD, NH-N, TP)
- Most difficulty thinking about prices. Maybe something with VSL from pollution. Or loss to fisheries.

2.9 Coastal Erosion Protection

- InVEST for coastal protection
- Avoided cost of property damages

2.10 Carbon Storage and Sequestration

- Forest cover for CO2 emissions
- InVEST carbon storage model
- Social cost of carbon with national adjustment: https://www.rff.org/publications/data-tools/scc-explorer/

3 Outputs

The final outputs of this project are two fold. The first is an accounting table of GEP values by sector and year. This accounting table is aimed at incorporation into the existing reports of the Statistics Office. The second is a technical white paper. This documents the methdology and data requirements necessary to replicate our work and continue to document GEP nationally beyond the scope of this project. Given the estimates generated, we may also be able to provide some descriptive statistics on the evolution of GEP over a period of time for the Cook Islands. This may identify trends to inform policy makers in sectors of growth and decline for GEP. Further, since GEP is measured in monetary terms it can be directly compared to the corresponding GDP generated by the Cook Islands at any given time.

4 References

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