Challenges and sensitivities in assessing total ecosystem service values: Lessons from Vanuatu for the Pacific

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Abstract

Ecosystem service valuation (ESV) can inform land-use change policy and adaptation responses to climate change in Pacific Small Island Developing States. Despite SIDS communities relying acutely and directly on ecosystem service (ES) flows, methodologies must contend with limited valuation data and challenges. We undertake ESV to generate coefficients we then apply to mapped habitat extents for Vanuatu. We find the contribution of ESs to the people of Vanuatu is considerable and significantly larger than its gross domestic product. Therefore, policies that support ecologically sustainable exploitation of ESs are paramount in promoting community well-being. We also identify and discuss context-specific methodological challenges, which, if not addressed, risk distorting valuations, supporting perverse policy responses and eroding confidence in ESV. We make recommendations to address the challenges of accounting for ecosystem condition, data gaps, consideration of customary benefits, provide context to the interpretation of our results, and suggest where further research can ameliorate risks.

Keywords

Ecosystem services, Economic valuation, Subsistence farming, Land use change, Cultural ecosystem services

1. Introduction

Environmental economics has built robust methods and a strong case for the economic valuation of the contributions of nature to human well-being (Boyd & Banzhaf, 2007; Braat & de Groot, 2012; Costanza et al., 2017). This has been conceptualised through ecosystem service (ES) classification, originally developed by the Millennium Ecosystem Assessment (MEA) (2005), and further developed by de Groot, et al. (2012) and the Common International Classification for Ecosystem Services (CICES) (Haines-Young & Potschin-Young, 2018). From the original MEA conceptualisation, ESs are classified into three broad categories: (i) *provisioning* – biological products used by humans obtained directly from ecosystems; (ii) *regulating* – benefits obtained through natural regulation of ecosystem processes; and (iii) *cultural* – the non-material benefits people receive from ecosystems. The importance of ecosystems to human welfare has numerous dimensions (ecological, socio-cultural and economic), however, expressing value in monetary terms has proven useful in helping to consistently frame trade-offs between options that have to address multiple assessment criteria (Costanza et al., 2017; Díaz et al., 2018; Georgiou, Whittington, Pearce, & Moran, 1997). Within this context, ecosystem service valuation (ESV) has three broad purposes (Laurans, Rankovic, Billé, Pirard, & Mermet, 2013): to be (i) *informative*, such as raising awareness of the value of biodiversity (Costanza et al., 1997, 2017; Kumar, 2010) and providing data for ecosystem accounting for integration into green GDP (Andrade & Garcia, 2015; Secretariat of the Convention on Biological Diversity, 2010) and for full-cost corporate accounting (Capitals Coalition, 2016; Epstein et al., 2011); (ii) *technical*, such as setting compensation rates for loss of environmental amenity (Aultman et al., 1993); and (iii) *decisive*, such as informing policy-making in land-use using benefit cost analysis (Barbier, 2012; Gashaw et al., 2018; Heal et al., 2005; Sinner, Bell, Phillips, Yap, & Batstone, 2016; Sumarga & Hein, 2016). Unlike normal market goods, most ESs do not lend themselves to “spatial arbitrage”, to take advantage of higher willingness to pay elsewhere (the exception to this rule is carbon sequestration services, which provide benefits at a global scale as a public good, or a private good if traded as a permit) (Boyd & Banzhaf, 2007, p. 622; UN Statistical Division, 2014), therefore many ESV applications involve integrating a spatial element, enabling analysts to estimate the ES benefits for a spatially-defined unit.

Spatial aspects of ESV are codified in the UN Statistical Commission’s System of Environmental Economic Accounting – Experimental Ecosystem Accounting (SEEA-EEA) (UN Statistical Division, 2014). SEEA-EEA integrates environmental assessment with the human economy through the quantification of ecosystem assets and measurement of the flows of ESs into and out of human society. SEEA-EEA takes a landscape view – assessing ecosystem assets in terms of *type, extent, condition*, and the *services* they provide. The links between ecosystem flows and society are assessed in terms of both ES benefits and the impacts of human activities on ecosystems that can influence their future capacity to continue to deliver benefit flows (externalities) (Hein, van Koppen, de Groot, & van Ierland, 2006). Ecosystem assets generate a specific, quantifiable combination, or “basket”, of potential environmental material and non-material flows (Obst, Hein, & Edens, 2016, p. 12), analogous to (but not completely overlapping with) the MEA/CICES conception of ES. SEEA-EEA incorporates spatial units that are both natural/unmodified or influenced by human activity (urban areas, subsistence gardens and tree plantations, for example).

SEEA-EEA is designed to be compatible with the UN system of national accounts (SNA), which, amongst other measures, standardises estimations of national gross domestic product (GDP). SEEA-EEA resolves to deploy only exchange values for ESs – the price at which an ES is, or would be,

exchanged if a market for the same, or similar, service existed. It therefore determines the contribution of ecosystem assets by the product of its quantity of service provided and derived exchange value, or price. Importantly, this excludes valuations that estimate a consumer surplus – the difference between what someone would be willing to pay and its price in a market. Since most ES, particularly regulating and cultural services, are non-excludable and thus ‘free’ at point of use (they are public goods, or common pool resources), people can enjoy an increase in welfare without any notional exchange. The ESV literature, more broadly, incorporates both exchange- and surplus value-based approaches, from the full gamut of economic valuation methods, including those reliant on respondent stated preferences in hypothetical scenarios. The inclusion of the broader set of ESVs allows valuations of spatial units to be greater than GDP and SEEA-EEA based ecosystem accounting.

To date, with some exceptions (Chen & Zhang, 2000; Costanza et al., 1997; de Groot et al., 2012; Deloitte Access Economics, 2017; Kubiszewski, Costanza, Anderson, & Sutton, 2017; Sannigrahi, Bhatt, Rahmat, Paul, & Sen, 2018), most ESV focusses on marginal changes in the value of a narrow suite of ES flows, commonly from a single, locally-important habitat (Baskara, Hendarto, & Susilowati, 2017; Matthew et al., 2018; Pascal et al., 2016). In application, these values are typically used in *social* benefit cost analysis of specific proposals (Georgiou et al., 1997; van der Ploeg & de Groot, 2010). However, from a policymaker’s or programme funder’s perspective, what is often required is an ESV of *aggregated* flows from a particular habitat, or an estimate of the value of all ESs within a particular biophysically- or politically-defined landscape, known as total ecosystem service value (TESV) (Gashaw et al., 2018; Mackey, Ware, Nalau, et al., 2017; Tolessa, Gessese, Tolera, & Kidane, 2018).

The context of this paper is one such study, undertaken for the Republic of Vanuatu and one of its islands, Tanna, to reveal the TESV of its habitats (Buckwell, Ware, Fleming, Smart, & Mackey, 2019a; Mackey, Ware, Nalau, et al., 2017). The study formed part of the Pacific Ecosystems-based Adaptation to Climate Change Project (PEBACC) – a programme that advocates for ecosystem-based adaptation to be integrated into national adaptation and planning processes (SPREP, 2018). TESV is applicable to a range of scenarios, including: (i) assessing trends in the value of ESs over time as a result of external factors, such as climate change (Buckwell, Ware, Fleming, Smart, & Mackey, 2019b); (ii) assessing the cost-effectiveness of ecosystem-based climate change adaptation options (Buckwell et al., 2018); (iii) assessing benefit trade-offs involved in macro land-use trends (Gashaw et al., 2018; Troy & Wilson, 2006); (iv) determining appropriate price envelopes for payments for ecosystem service (PES) schemes (Bishop & Hill, 2014); and (v) identifying community dependencies and vulnerabilities to economic and social change, especially where reliance on ESs for immediate provisioning needs, such as food and *materiale*, is direct, immediate, and significant (Buckwell et al., 2018; Mackey, Ware, Buckwell, et al., 2017). Isolated from global trade flows, rural communities in Vanuatu, outside the major centres, are dynamic and complex socio-ecological systems, where market-based exchange is limited, and well-being and natural resource management are arbitrated through customary institutions and relations.

Estimating TESV requires making judgements as to what constitutes *intermediate* ESs and *final* ESs – those that are directly “enjoyed, consumed, or used to yield human well-being” (Boyd & Banzhaf, 2007, p. 619). If both intermediate and final ES values are totalised, contributions are double counted. For example, pollination services are intermediate inputs into the final food production value provided by agriculture, forests, and plantations. Therefore, the value of pollination services is embedded in the provisioning ES value for food. Ecosystem accounting reconciles inputs and outputs so that the value of final services is the sum of value-added through intermediate components. However, as we also

included ESVs that estimate a consumer surplus, accounting principles cannot be adhered to. In general, regulating ESs are intermediate services to final benefits enjoyed locally and therefore not totalled in a TESV (though nevertheless present useful information for decision-making). The exceptions to this are (i) air quality regulation (an ends in itself), (ii) climate regulation, which, although this provides a measure of an intermediate service (a stable climate) that contributes to local food production for example, it also provides a final service to global society as a public good, or a private good if emissions reductions are converted into a carbon permit; and (iii) the moderation of disturbance functions of coral reefs and mangroves, providing coastal protection.

Undertaking *primary* ESV research is cost prohibitive to many non-governmental organisations and Pacific SIDS. Accordingly, these communities have been subject of few studies, despite the apparent importance of ecosystem services. Therefore, practitioners are resigned to draw on secondary, often methodologically heterogeneous data, or accept gaps, risking misleading valuation that may provide misguided support for perverse policy responses and may erode confidence in ESV. Furthermore, as development funding is often determined on the basis of GDP per capita, the missing contribution of ESs to welfare via the ‘non-observed economy’, which may considerably outweigh the conventional measures of wellbeing (OECD, 2002; van Heemst, 1984), may misguide contributions towards rural communities at the expense of the urban poor, for example. Consequently, to provide more representative or meaningful measures of economic and environmental disadvantage, there is a pressing need to obtain and improve broad-spectrum TESV.

The purpose of our study is to report on our findings from two economic valuation case studies (Vanuatu and Tanna), which use prior-generated spatial and land cover data (see Supplementary Information) and economic valuation to produce landscape-level valuations of ESs. While providing useful data in and of themselves, these case studies also provided insights into data sensitivities and methodological challenges and we discuss how these can be either mitigated, accounted for, or acknowledged in the presentation of such findings to policy- and decision-makers. Section 2 describes our case study locations in some detail, so as to properly inform our subsequent discussion; Section 3 describes our ESV method (the original mapping component is contained in Supplementary Information); Section 4 reports the results for our case study sites; Section 5 examines sensitivities and challenges; and Section 6 concludes our discussion.

2. Case study context

The Republic of Vanuatu is an island nation in the south-western Pacific Ocean. It has a land area of 1.22 million hectares (ha) (see Figure 1). Many of the islands are steep, with fertile, but unstable, soils of volcanic origin with little permanent freshwater. Shorelines are mostly rocky, with some fringing coral reefs. Vanuatu’s population is estimated to be 272,459, with an annual growth rate of around 2.3% (double the global mean) and a relatively young median age of 20 years (UN DESA / Population Division, 2017; Vanuatu National Statistics Office, 2016). In terms of GDP per capita, Vanuatu is seemingly poor, ranked 126th from 192 listed countries by the UN (UN Statistics Division, 2017). Vanuatu has a history of European colonial interference, dating back to the 1880s; one that has included transport of indentured labour to Australia (Hunt, 2007), a base for war operations, and the imposition of tax haven status in service of colonial currency manipulation interests (Rawlings, 2019); all which have had an enduring legacy on the country’s political institutions, religious life, society and economy. Historic colonial and contemporary development of export-based agricultural industries, such

as beef, copra and sandalwood have also disrupted subsistence livelihoods. Vanuatu regained its independence from France and the United Kingdom in 1980.

Figure 1: Location of Tanna and the Republic of Vanuatu

Broader economic opportunities and employment specialisation outside the main centres (Port Vila and Luganville) are limited. The majority of the population engages in small-scale traditional (and generally subsistence) farming and coastal fishing. Approximately 75% of the population live in rural areas and more than 98% of households nationwide undertake *some* form of food production (Vanuatu National Statistics Office, 2009). Rural farming systems typically comprise three components: (i) shifting cultivation; (ii) perennial plantation; and (iii) an aboricultural system (Blanco, Pascal, Ramon, Vandenbroucke, & Carrière, 2013; Clarke & Thaman, 1993; Thaman, Clarke, Manner, Decker, & Ali, 1993). The shifting cultivation component, that which most closely relates to traditional subsistence agriculture, is a rotational system of slash and burn of secondary forest to grow root vegetables and, after depletion of the soil's fertility, a fallow period of forest regrowth (Mackey, Ware, Nalau, et al., 2017). Perennial cultivation constitutes the main source of any cash income, mostly grazing cattle in amongst coconut plantation, growing coffee and cacao, and harvesting sandalwood (Lamanda, Malézieux, & Martin, 2006). Lastly, large trees, such as breadfruit, nuts, and fig, are often kept standing amongst the garden plots, for their productive and cultural value. This inter-dependent, cyclical relationship between rotational subsistence agriculture, perennial planting, secondary forest regrowth, and use of forest products is part of an intricate and complex pattern of land-use that supports community well-being throughout much of rural Vanuatu.

Tanna is in the southern Vanuatu province of Tafea. It covers 58,793 ha and has a recorded population of 32,280 (Vanuatu National Statistics Office, 2016). Many of the tribes on the island live

in traditional housing in village-based systems. Tanna is a stronghold of *Kastom*¹ – a place where people still know traditional songs, can trace their lineage, and participate in rituals, community decision-making processes and ceremonies (Lindstrom, 2011). However, common to many Pacific islands, customary practices are eroding under the influence of ‘Western’ economic systems and philosophical traditions² (Brosi et al., 2007; Nalau, Becken, & Mackey, 2018). Currently, virtually all of the population of Tanna depend on a combination of traditional farming, fishing, and wild food and non-food harvesting (for housing and ceremonial dress) for their livelihoods (Vanuatu National Statistics Office, 2016).

Vanuatu, typical of Pacific SIDS, have economic development pathways, in part due to being isolated from global trade flows and variable levels of poverty linked to increasing environmental and resource pressures, climate change (Klöck & Nunn, 2019), and a shift towards urban living, based on cash incomes, away from *Kastom* land, which limits capacity for food production (Carter, Little, Mogues, & Negatu, 2007; Fafchamps, 2003). However, the rural Ni-Vanuatu have remained relatively shielded from destitution, hunger, and food insecurity due to continuation of widespread subsistence farming and fishing, and their legally-recognised control of *Kastom* lands, prohibiting involuntary alienation (Asian Development Bank, 2003; Farran & Corrin, 2017; Gerbeaux, Kami, Clarke, & Gillespie, 2007). Resource-based conflict exists but arises more from competing uses of ecosystem assets and supply of different, or competing ES, rather than from control of the ecosystem *per se*. Tribal boundaries are defined but can be contested and are porous to incursion and manipulation by extractive industries as regulation of uses is poor. Communities across the archipelago face pressure from local and global ecological, geological, and socio-economic factors, including: climate change, which has the potential to increase the incidence of destructive weather and alter local climates and optimal traditional crop-growing envelopes (Roy & Connell, 1991); population growth; land use change away from traditional, subsistence gardens, which puts pressure on forests and fringing reefs (Siméoni & Lebot, 2012); and falling yields from gardens, driving demand for cash incomes to purchase alternative imported commodities, such as rice and canned meat (Fleming, 2007; IPCC, 2014; Mackey, Ware, Nalau, et al., 2017; Siméoni & Lebot, 2012). The combination of these risks commonly place Vanuatu at the top of World Risk Reports (United Nations University, 2019). At the same time, there is potential for rapid cultural and socio-economic dislocation, as communities transforms from village-based agrarian subsistence to an economy based on exchange and specialisation (Boydell & Holzknecht, 2003; World Travel & Tourism Council, 2017). Vanuatu’s National Sustainable Development Plan (Republic of Vanuatu, 2016) seeks to address these risks to well-being and to harness the country’s natural resources in service of home-grown food and national development, but also in the conservation of the range of ES³.

3. Valuation methodology

We determine the TESV provided by key habitats of the Republic of Vanuatu and Tanna. Our method is based on a spatial component, to determine habitat type and extent, and an economic valuation component, to determine the value of ESs. The spatial component, which identifies and

¹ *Kastom* – pronounced ‘custom’ and loosely translating as such, but further encompassing a broader range of meanings that include the arrangement of private relations, social and economic systems, ways of being and activities and practices associated with managing the landscape.

² The role of *Kastom* in arbitrating community outcomes is not universally positive, particularly for women. Hierarchy persists, particularly in terms of gender roles and which activities and resources are traditionally men’s and women’s entitlements.

³ It should be noted that the term ‘ecosystem services’ is not explicitly used in the plan.

classifies ecosystem types is in Mackey et al. (2017) and summarised in Supplementary Information (SI), Table S1. For the economic component we determined ES coefficients for per hectare per year contributions to well-being and calculated the TESV by calculating the product of the two. We employed two valuation methods, namely, benefit transfer (Richardson, Loomis, Kroeger, & Casey, 2015) and the residual method (Young, 2010). Benefit transfer estimates the economic value of ESs at a *target* site by employing data from an existing study (or studies) conducted at an alternative *source* site, or sites. Undertaking benefit transfer typically involves searching the published literature to identify existing studies in relevant contexts of socio-economic and biophysical characteristics to the target site, in terms of the population density, property rights regimes, and ecosystem exploitation patterns (Cordes, 2017; Georgiou et al., 1997). Although benefit transfer has been referred to as a “second-best strategy” (Troy & Wilson, 2006, p. 436), in the absence of alternative, primary data, it is nonetheless widely, but not uncritically, accepted as providing reasonable ESV estimates (Johnston & Rosenberger, 2010). We also used the residual method, which quantifies the value attributable to non-priced inputs to agricultural production (Young, 2010). For example, plantation cropping demands a combination of human and natural inputs to provide the final ES (food). Human inputs (labour, fuel) generally have clear exchange values already priced-in to the cost of production. The residual method subtracts the costs of human inputs from the gross revenue obtained from agricultural production and then assigns the resulting margin as the return attributable to relevant non-market, un-priced inputs, such as ESs.

Our strategy for determining ES coefficients followed the hierarchy below (see also Table 1 and Figure 2).

- 1) We undertook a literature search for Vanuatu-specific ESV studies (n=2) to apply in the first instance. Studies identified were Pascal and Bulu’s economic valuation of mangroves (2013) and Pascal et al.’s (2016) estimate of the economic contribution of coral reefs to coastal protection.
- 2) For plantation cropping, we used the residual method for determining an ESV based on data from the Queensland Government Department of Agriculture and Fisheries (Queensland Government, 2016) and the Food and Agriculture Organisation (McGregor, 1999).
- 3) To obtain the majority of our ES coefficients, we queried the database constructed by van der Ploeg et al. (van der Ploeg & de Groot, 2010; van der Ploeg, de Groot, & Wang, 2010). In this work, the authors collated and assessed 1,310 studies for The Economics of Ecosystems and Biodiversity (TEEB) study (TEEB, 2010). This database provides monetary values for 12 ‘biomes’ (that contain 38 more granular categories of ‘ecosystems’), which we aligned with the ecosystem types from Mackey et al. (2017) (Table S1 in Supplementary Materials). The database includes 29 categories of ‘ecosystem services’, further-granulized into 78 ‘sub-services’, which we rationalised into 22 ESs across *provisioning*, *regulating*, and *cultural* categories. To ensure the most appropriate studies were used for benefit transfer, we filtered the TEEB database as follows (also summarised in Figure 2):
 - a) excluded values for ‘Total Economic Value’ (TEV) (i.e. already aggregated ES values);
 - b) excluded ‘Habitat Services’ to avoid double counting of final ES value (Boyd & Banzhaf, 2007);
 - c) excluded ‘High Income’ and ‘Upper Middle Income’ countries from ‘Country Income Group’, on the basis that the primary benefits derived from ESs in these countries bear little resemblance to the primary benefits derived from the same ES flows in developing nations, such as Vanuatu;
 - d) excluded the more generalised criterion of ‘World’ from the column ‘Country’ to exclude valuations being inflated by developed world values (a single continent-wide value in the ‘Country’ column, for ‘Africa’, was included in our study);

- e) included only studies that were valued on a currency unit, per hectare, per year basis;
- f) excluded valuations considered highly specific to the context of the source site, or inappropriate for the Vanuatu context (n=1) ⁴.

Where the filters returned more than one ES value for an ecosystem type, we determined the median, mean, maximum, and minimum values.

- 4) Neither the Vanuatu-specific literature, nor the TEEB database contained a valuation for subsistence gardens. Therefore, to obtain this value we used Anderson's (2006) estimates of the value of customary-managed land for subsistence food production in Papua New Guinea (culturally also Melanesian). This study estimates a maximum and minimum value, from which we determined a median and mean ⁵.

Thaman and Thaman et al. (1995; 2006) describe the likely and growing contribution of urban agriculture to food security in Pacific SIDS and to urbanising Ni-Vanuatu (temporary or permanent). Though we could map the extent of urban areas (see Supplementary Information), and to do so is consistent with the SEEA-EEA framework, we could not ascertain any ESV from the literature ⁶.

Figure 2: Summary of our economic valuation methodology

⁴ Rosales et al. (2005) estimate an ecosystem service value for tropical forests based on large-scale hydro-electricity potential. No large-scale hydroelectric power is scheduled for Vanuatu; the geography of the islands dictates there are few permanent streams. Note Rosales et al. (2005) also estimated a value for small-scale hydroelectric power, which is included in our coefficient.)

⁵ No value for human-modified environments, such as subsistence gardens are available in the TEEB database. Anderson's (2006) estimate was the only appropriate value we found.

⁶ The ES value of urban agriculture is, however, likely to be non-trivial.

A range of treatments were required to standardise valuations from items 1-to-4 above. These are summarised in Table 1. Finally, we transformed all ES coefficients into US dollar values and further adjusted them using the US dollar deflator as appropriate (World Bank, 2018a). The final output was a directly comparable 2016 US dollar per hectare per year value for each ecosystem type.

Table 1: Treatments to determine ecosystem service coefficients

Ecosystem asset type	Ecosystem service(s)	Study and reference	Treatment applied
Subsistence gardens	Food	Anderson (2006)	Estimates of the economic valuation of customary-managed land for food production in Papua New Guinea.
Plantation forest	Food	McGregor (1999) and the Queensland Government (2016)	We use an area-weighted average of the reported gross margins per hectare from coconut and cocoa production to represent the value attributable to ecosystem service inputs in the Cultivated Plantation category. Gross margin per hectare from copra-focused coconut production is obtained from a whole of farm budget spreadsheet for copra production in the Pacific, developed by the Queensland Government Department of Agriculture and Fisheries (Queensland Government, 2016). Gross margin per hectare from cocoa production (assuming the cocoa beans are sold direct from the grower to an intermediary trader), is obtained from a budget spreadsheet for cocoa production in Vanuatu in an FAO publication (McGregor, 1999).
Mangroves	Food, coastal protection, recreation, climate regulation	Pascal and Bulu (2013)	The authors provide an economic valuation of mangroves as part of the IUCN Oceania Mangrove EcoSystems for Climate Change Adaptation and Livelihoods (MESCAL) project. In this study, the authors use a combination of desktop research and field studies to determine the cultural and commercial uses of mangrove resources at Crab Bay (Malekula Island) and Eratap (Efate Island). The authors present economic valuations for nine ES (subsistence fishing, commercial fishing, recreational fishing, coastal protection, tourism, wood extraction and carbon sequestration), which were adapted and inserted into the classification scheme set out in Supplementary Information Table S1.
Coastal coral reef	Erosion prevention	Pascal et al. (2016)	The authors report on the Economic Assessment and Valuation of Marine Ecosystems: Vanuatu provides an estimate of the contribution of coral reefs to erosion prevention, from which we derive a per hectare valuation. The authors evaluated coral reefs' contribution to erosion prevention for the islands of Efate (separate east and west coast values were determined), Espiritu Santo and Malekula, using the avoided damage cost method. As Vanuatu's emerging tourism sector is concentrated on Efate and (to a lesser extent) Espiritu Santo, these islands host high value property and infrastructure, such as hotels and airports, in contrast to Malekula. Malekula's settlement pattern was judged to be similar to that of the majority of coastal Vanuatu, thus the Malekula-derived value for coral reefs' contribution to erosion prevention was considered the most appropriate for Vanuatu at the national scale

4. Results

To derive our final TESH results we use the product of our 2016 US dollar per hectare per year ES coefficients from Table 2 for each of the nine ecosystem types for Vanuatu and the ecosystem extents generated by Mackey et al. (2017) (Supplementary Information, Table S1). This output is the median total final ES value per year for Vanuatu and Tanna and is detailed in Tables 3 and 4. Using the median values for our ES coefficients safeguarded against the value being unduly influenced by outlier ES values.

Table 2: Ecosystem service value coefficient and median calculated ecosystem service value for ecosystem types for Vanuatu (2016 US\$ha⁻¹ yr⁻¹)

Ecosystem type	Coastal coral	Coastal mangrove ^a	Coastal seagrass	Tropical forest	Grassland	Freshwater waterbodies	Freshwater wetlands	Subsistence gardens	Plantation cropping
Provisioning ecosystem services									
1 Food	64	1,085	21	7	39	21	71	12,552	56
2 Water supply (drinking and irrigation)		2,206		214	138	1,377	76		
3 Raw materials and energy	1	335		34	7	1	28		
4 Genetic resources				6					
5 Medicinal resources		3		53			15		
6 Ornamental resources	3								
Regulating ecosystem services									
7 Air quality regulation		236		458	105				
8 Climate regulation	213	3,064	45	129	312	60			
9 Moderation of disturbance	188	316		48			1,359		
10 Water flow regulation				1					
11 Waste treatment	3								
12 Erosion prevention		102		110					
13 Soil fertility maintenance		224		15	255	1	3		
14 Pollination				43					
15 Biological control ^φ	0.3								
Cultural ecosystem services									
18 Aesthetic	3								

19	Cognitive	2					
20	Inspiration ^Φ	0.1					
21	Spiritual	1					
22	Recreation	351	282	16	5	397	15

^Φ Ecosystem service coefficients calculated to be less than 1 (2016 US\$ ha⁻¹ yr⁻¹) are shown with decimal places, to demonstrate value was generated and therefore still greater than zero.

4.1. Total ecosystem service value for Vanuatu

The value of Vanuatu's ESs to human society is considerable, delivering a median value of more than \$ 2,901 m per year (min.: \$ 1,963 m; max.: \$ 11,537 m) (Table 3). On a per capita basis, this is \$ 10,423 per annum (min.: \$ 7,054; max.: \$ 41,452). By comparison, Vanuatu's GDP for 2016 was \$ 804 million (m) (World Bank, 2018b) – smaller by a factor of 3.6 – and Vanuatu's GDP per capita is \$ 2,890 per annum. This reflects the relative importance of ESs to the people of Vanuatu, when compared to goods and services traded through formal markets. Food provision, predominantly originating from the system of subsistence agriculture and agroforestry, is the most important ES by a considerable factor, representing 67.8% (median: \$ 1,957 m yr⁻¹) of final ES value to Vanuatu. Air quality regulation (15%; median: \$ 433 m yr⁻¹), water provision (7.3%; median: \$ 210 m yr⁻¹), and climate regulation (5.5%; median: \$ 158 m yr⁻¹) comprise the majority of the remainder. Provisioning ES provide \$ 2,255 m yr⁻¹ (78.1% of total), regulating services provide \$ 591 m yr⁻¹ (20.5%), and cultural services (mainly tourism) provide \$ 40.7 m yr⁻¹ (1.4%). 87.6% of Vanuatu's TESV derives from just two ecosystem types: subsistence gardens and tropical forests (Table 3).

Table 3: Total median, mean, minimum and maximum final ecosystem service value for Vanuatu (2016 US\$ yr⁻¹)

Habitat type	Extent (Ha)	Gross value				Variance from median (median=1)		
		Median	Mean	Minimum	Maximum	Mean	Minimum	Maximum
Coastal coral	70,238	58,050	461,357	12,081	2,742,716	7.9	0.2	47.2
Coastal mangrove	1,665	12,529	12,545	9,634	15,473	1.0	0.8	1.2
Coastal seagrass	124,038	8,185	8,185	4,072	12,298	1.0	0.5	1.5
Tropical forest	934,831	857,523	1,758,854	560,825	6,173,858	2.1	0.7	7.2
Grassland	39,776	24,094	37,193	14,801	72,677	1.5	0.6	3.0
Freshwater waterbodies	539	1,001	991	168	1,795	1.0	0.2	1.8
Freshwater wetlands	406	83	319	8	1,320	3.8	0.1	15.9
Subsistence gardens	154,186	1,935,300	1,935,300	1,357,598	2,513,001	1.0	0.7	1.3
Plantation cropping	73,940	4,141	4,141	4,141	4,141	1.0	1.0	1.0
Total final ecosystem service value		2,900,906	4,218,885	1,963,327	11,537,280	1.5	0.7	4.1
<i>Total intermediate</i>		<i>213,943</i>	<i>633,226</i>	<i>66,953</i>	<i>1,992,709</i>			

4.2. Total ecosystem service value for Tanna

Similarly, the value of final ES to the people of Tanna is considerable, providing \$ 325 m yr⁻¹ (min.: \$ 368 m; max.: \$ 681 m) (Table 4). On a per capita basis, this is \$ 10,053 per annum (min.: \$ 6,973; max.: \$ 21,100). Comparisons with Tanna's gross island product are not possible, due

to lack of data. For Tanna, \$ 304 m yr⁻¹ (93.6%) of final ES value is delivered through provisioning services, \$ 19 m yr⁻¹ (6.0%) is delivered through regulating services, and \$ 1.4 m yr⁻¹ (0.4%) is delivered through cultural services. Approximately 99.0% of Tanna's ES value derives from just two ecosystem asset types: subsistence gardens and tropical forests.

Table 4: Total median, mean, minimum and maximum ecosystem service value for Tanna (2016 US\$ yr⁻¹)

Habitat type	Extent (Ha)	Median	Mean	Minimum	Maximum
Coastal coral	2,493	2,060	16,375	429	97,349
Coastal mangrove	0	-	-	-	-
Coastal seagrass	0	-	-	-	-
Tropical forest	30,165	27,670	56,754	18,097	199,217
Grassland	1,598	968	1,494	595	2,920
Freshwater waterbodies	138	256	254	43	460
Freshwater wetlands	0	-	-	-	-
Subsistence gardens	23,387	293,547	293,547	205,921	381,173
Plantation cropping	93	5	-	-	-
Total final services		324,506	368,429	205,921	681,124
<i>Total intermediate services</i>		<i>6,949</i>	<i>20,473</i>	<i>2,208</i>	<i>64,329</i>

5. Discussion

In our case studies, we applied a typical economic valuation methodology for estimating the TESV of two defined landscapes (Vanuatu and Tanna), where primary data are scarce and analysts must rely predominantly on benefit transfer. Our assessment provides a snapshot of ES benefits at a point-in-time. Repeated application, holding ESs values (or 'prices') steady, enables an understanding of longitudinal trends in ES flows as a result of land-use changes (Boyd & Banzhaf, 2007), such as those carried out by Tolessa et al. (2018) in Ethiopia and Kreuter et al. (2001) in the USA. Our approach can also inform scenario-based planning, which is relevant in light of projected increases in risk from a rapidly changing climate, for example, by assessing ecosystem-based adaptation to both meet the challenges of climate change and provide social benefits as positive externalities (Buckwell et al., 2019b; Morris, Konlechner, Ghisalberti, & Swearer, 2018). Such ESVs can play a role in the global, cross-sector drive towards achievement of the Sustainable Development Goals, specifically target 15.9, which aims to integrate ecosystem and biodiversity values into local planning processes and national accounts. Finally, this methodology can be used to demonstrate the monetary values of ESs that have the potential to attract revenue through PES schemes (Bishop & Hill, 2014). To date the majority of PES schemes have focused on incentivising carbon sequestration through forest and mangrove protection and/or rehabilitation through frameworks such as REDD+ (Venter & Koh, 2012). Our approach demonstrates to program sponsors the value of a range of co-benefits associated with habitat conservation, some of which could be potentially monetised in the future (Brown et al., 2017; Webb &

Martin, 2016). Our valuations should help Pacific SIDS assist communities to co-design schemes to capture greater value from natural capital stocks under their management, which may otherwise become degraded either through over-exploitation, or in the pursuit of economic development pathways incompatible with local sustainable development. Overall, our study, by demonstrating the value of the full gamut of ESs and, in particular, including non-market and climate regulation values, reveals the considerable contribution that Vanuatu's natural capital assets deliver to human society, locally (food and provisioning services, for example), nationally, and globally (climate regulation, for example).

Our valuations immediately telegraph the need for discussion about comparisons between the contribution of ESs to well-being and Vanuatu's GDP. In 2016 GDP (current prices) was reported to be US\$ 804.3 m (World Bank, 2018b). Our valuation estimates the contribution of ESs to well-being is between US\$ 2,901 m – US\$ 11,537 m – larger by a factor of between $\sim 2\frac{1}{2}$ and ~ 17 . The gulf between GDP and TESV might, in part, explain the disparity between Vanuatu's global ranking in terms of GDP per capita (126th out of 192) (UN Statistics Division, 2017) and its position of fourth in the Happy Planet Index (Happy Planet Index, 2016). Published Vanuatu national accounts for 2013 (the latest publication of this data) include assessment of the contribution of 'subsistence custom/traditional' agriculture of US\$ 112.29 m (2013 prices). As a proportion of GDP, between 2004 and 2013, the reported contribution of subsistence gardens fluctuates slightly but we estimate a mean contribution in 2016 to be 14.9%. From this, we estimate the 2016 contribution of subsistence gardening to be US\$ 119.8 m, or US\$ 430 per capita. In contrast, our ecosystem assessment estimates a contribution of between \$ 4,878 and \$ 9,029 per capita per year – larger by a factor of between ~ 11 and ~ 21 . From a theoretical standpoint, our estimate (derived from Anderson's value of subsistence agriculture) is compatible with SNA estimations, as it uses an exchange value (prices from a local market) and includes no consumer surplus from non-market cultural values, nor any external costs, that may have emanated from any environmental damages from the production of the food. Therefore, the values are directly comparable and the discrepancy suggests there is a potential under-valuation of the contribution of subsistence agriculture to Vanuatu, which warrants further *in situ* research to calibrate.

Critiques of GDP as a proxy measure for human well-being are well-developed (Giannetti, Agostinho, Almeida, & Huisingh, 2015; Philipsen, 2015; Saunders & Dalziel, 2017; Stiglitz, Sen, & Fitoussi, 2010), encompassing environmental, distributional, and feminist critiques particularly pertinent to SIDS. More sophisticated alternatives are being adopted by national and state governments, including in Vanuatu itself (Malvatumauri National Council of Chiefs, 2012). However, progress in developing, codifying and embedding these alternatives into policy is slow and GDP remains a pervasive measure in driving policy decisions, perhaps because alternative outputs tend not to support political imperatives. As our case studies have shown, in Vanuatu, estimating the level of individual and community well-being via GDP alone potentially underestimates the important contribution of ecosystem assets to human well-being, perhaps leading to misdiagnoses of community threats and pursuit of maladaptive land-use policy. Whilst further development of ecosystem accounting through the SEEA Central Framework (UN Statistical Division, 2012) and the incorporation of ecosystem flows into 'green GDP' will start to close this gap, it remains imperative to also consider locally-specific consumer surplus values associated with non-market spill-overs when designing policy and programmes in Pacific SIDS contexts. Not considering the full gamut of ES values will also likely have distributional consequences, favouring policy that promotes monetary exchange of what would otherwise be Kastom goods and services, outside the production boundary, such as housing, food and materials.

In undertaking our TESV estimation a number of context-specific sensitivities and challenges were evident, which, if not adequately addressed, or at least acknowledged, may result in misleading valuations, provide misguided support for perverse policy responses and erode confidence in valuations.

5.1. *Sensitivity and data gaps*

In data-poor environments, analysis risks significant sensitivity in valuation. Analysts must trade-off between “specificity, reliability and applicability” to provide justifiable and replicable valuations (Troy & Wilson, 2006, p. 445). Our results show reasonable spread in the median, minimum and maximum values. For example, on a \$ ha⁻¹ yr⁻¹ basis, for Vanuatu, coastal coral exhibits the greatest spread, with minimum and maximum values varying from the median (1.0) by 0.2 and 47.2 respectively (Table 3). The largest spread in value for individual ESs was for ornamental services (1.0, 0.1, 105.1). In general—and unsurprisingly—the greater the number of observations abstracted through our economic valuation strategy, the greater the spread in ES values. However, this relationship was a poor fit (R^2 of 0.0016). For example, the variance for food, which had the greatest number of observations, was relatively modest (1.0, 0.7, 1.4), though this is strongly influenced by the value attributed to food for subsistence gardens (Table 3). Overall, the variance across all ESs was between 0.7 (min.) and 4.1 (max.).

Variation in valuation estimates are undoubtedly a reflection of the heterogeneity in the socio-economic-ecological environments of the original studies and the valuation methods employed, rather than a systemic weakness in benefit transfer. However, the reasonable variances from the limited number of studies indicates that incorporation of datasets from new studies could significantly change our coefficients. The work completed for the TEEB valuation database by van der Ploeg & de Groot (2010), though highly cited, is now more than 10 years old and based on studies going back much further. Encouraging funding for more primary studies is the obvious answer, however, continually supported and curated valuation databases of existing studies would also improve this situation. More broadly, our study identified there is a lack of ES valuation data from research conducted in Vanuatu and Pacific SIDS, more generally. For example, our search revealed just two valuations for Vanuatu and relied on a single source for subsistence gardens in a Melanesian context (see Section 3).

Our method also highlighted gaps in key data. For example, our case studies lack an important estimate for biological control for tropical forests and climate regulation for subsistence gardens. Such gaps result in an underestimation of the ES values for these habitats. These gaps also extend to spatial data. Our method’s data source for seagrass estimated zero extent for Tanna, yet from fieldwork conducted by the authors in 2018, we discovered and measured seagrass beds on Tanna’s south coast.

Table 5: Variances in ecosystem service values for Vanuatu and Tanna by ecosystem type (2016 US\$ ha⁻¹ yr⁻¹)

Ecosystem service type	Ecosystem service	Median	Mean	Min	Max	Median	Mean	Min	Max
Provisioning	Food	1,956,787	1,970,990	1,377,965	2,675,476	1	1.0	0.7	1.4
	Water supply (drinking & irrigation)	210,457	249,244	132,882	404,645	1	1.2	0.6	1.9
	Raw materials and energy	32,467	301,752	400	2,519,180	1	9.3	0.0	77.6
	Genetic resources	5,415	28,859	4,770	76,393	1	5.3	0.9	14.1
	Medicinal resources	49,808	481,905	274	2,096,438	1	9.7	0.0	42.1
	Ornamental resources	224	7,921	16	23,522	1	35.4	0.1	105.1
Regulating	Air quality regulation	433,079	433,079	433,079	433,079	1	1.0	1.0	1.0
	Climate regulation	158,254	334,689	12,022	1,091,625	1	2.1	0.1	6.9
	Moderation of disturbance	59,083	293,205	16,568	1,460,170	1	5.0	0.3	24.7
	Water flow regulation	1,184	1,184	1,184	1,184,292	1	1.0	1.0	1.0
	Waste treatment	221	1,038	207	2,687,396	1	4.7	0.9	12.1
	Erosion prevention	102,747	371,182	2,534	1,382,190	1	3.6	0.0	13.5
	Soil fertility maintenance	24,600	174,631	11,260	488,034	1	7.1	0.5	19.8
	Pollination	39,815	39,815	35,581	44,049	1	1.0	0.9	1.1
	Biological control	18	18	18	18	1	1.0	1.0	1.0
Cultural	Aesthetic	232	232	232	232	1	1.0	1.0	1.0
	Cognitive	126	1,136	3	3,278	1	9.0	0.0	25.9
	Inspiration	5	5	5	10	1	1.0	1.0	2.0
	Spiritual	71	71	71	71	1	1.0	1.0	1.0
	Recreation	40,253	161,153	1,207	827,705	1	4.0	0.0	20.6

5.2. Ecosystem integrity

It is not contentious to assert that the quality and thus quantity of ES flows reduce with declining ecosystem integrity. For example, ten fragmented 10 ha blocks of tropical forest, when compared to a single, intact 100 ha block will have a lesser potential for the provision of a number of ESs, including as a carbon stock, refuge for wildlife, and regulation of sediment and microclimates (Briant, Gond, & Laurance, 2010; Broadbent et al., 2008; Forman & Alexander, 1998; Hamilton et al., 2017; Kindu, Schneider, Döllner, Teketay, & Knoke, 2018). Benefit transfer valuations commonly lack the local data needed to match the condition of ecosystems with either the potential, or realised, flow of benefits. We know from field transects carried out in 2017 and 2018 that, while Tanna's coral reefs are generally in adequate condition (localised pressure in proximity to the main town, notwithstanding), there is wide variation in the condition of Tanna's tropical forests, which range from young secondary re-growth to intact primary forest. The converse can be said for the condition of coral reefs across Vanuatu, which are not consistent with the relatively good condition of those around Tanna (Naviti & Aston, 2002). Whilst it is probable that the values on which our ES coefficients are derived are from habitats that span

a range of conditions, site-specific survey data are needed in order for these relationships to be quantified and appropriate adjustments made to the coefficient values of relevant ESs. This is an ongoing subject of further research, recognised in the SEEA-EEA framework (UN Statistical Division, 2014). SEEA-EEA tackles this challenge from two directions; firstly by including only those ESs for which there is a measurable local demand, thus ensuring that the demonstrated demand can never exceed supply; and secondly, by reporting indicators of ecosystem asset condition that can be used to scale the ability of specific assets to deliver particular ES flows (Keith et al., 2019). In our case study, reflecting only services for which there is a local demand would ensure more robust final ESV for subsistence gardens and plantation forests, but would come at very significant cost in terms of demanding detailed primary research.

5.3. *Application of data*

Our inclusion of subsistence gardens and plantation cropping as ‘ecosystem types’ (consistent with the SEEA-EEA framework) lends to results being interpreted in a way that suggest land-uses can be traded-off to increase the TESV generated by a landscape. In our case studies, the trade-off between tropical forests, plantation forests, and subsistence gardens presents a pertinent tension. Across much of Vanuatu (mountainous areas, aside), each of these ecosystem types are interchangeable and are in competition. A forest, for example, provides different and often incompatible services to distinctive user groups who might wish to utilise it in competing ways – using a forest for timber extraction impacts on others who harvest non-timber forest products, yet both groups may have legitimate access to the habitat. The potential conflicts between incompatible land uses highlight the need to understand the role of synergies amongst and between regulating ESs that arise from the connectivity between ecosystems, such as the role of tropical forests in protecting coral reefs by reducing sediment run-off (Brown et al., 2017) and the role of secondary tropical forest regrowth in providing soil fertility. Ostensibly, at a per hectare per year level, the contribution of subsistence gardens to food is US\$ 12,552, whereas tropical forest contributes US\$ 917 in final services. This suggests conversion of tropical forest to subsistence gardens represents optimal policy for increasing well-being. It also, perhaps, explains the reality on-the-ground: on Tanna, conversion of tropical forest to subsistence gardens is occurring at a significant rate (~60 ha per year) (Mackey, Ware, Nalau, et al., 2017). Simplistically, the greater the rate of conversion of tropical forest to subsistence gardens, the greater the level of welfare that can be obtained from the land.

Our data assumes a linear relationship between ecosystem asset area and ES delivery. Despite an overall increase in the area of cultivated land, population growth (2.3% per annum) has reduced the cultivated area per capita (however, it is possible urbanisation might have offset the per capita loss of cultivated area for rural subsistence households). This trend suggests that increasing demand for food is resulting in the over-exploitation of current agricultural land, leading to encroachment on forests in the search for new, more fertile soil for subsistence agriculture (Reardon et al., 1996). While tropical forests provide important ESs, subsistence gardens provide the most pressing of human needs: food. Reported reductions in agricultural yields, most likely from root crop diseases and falling soil fertility from insufficient fallow periods, coupled with population growth that increases the demand for food, will likely lead to further deforestation pressures, until forest scarcity equalises the opportunity cost of more clearing. This trend has implications for the ongoing protection of tropical forests on Tanna and their associated ESs, including the regulating services they in-turn provide to subsistence gardens, as apparent, observed ecological state and thus, the signal of scarcity, might not be in equilibrium.

On Tanna, external pressures, such as climate change impacts and the increased demand for food from population growth, will undoubtedly heighten pressures on habitats, increase the likelihood of

degradation in their condition, and potentially invoke irreversible changes. Experience elsewhere across a range of ecosystems highlight that the risk of reductions in future yields of ESs (particularly provisioning and regulating) may not become evident before thresholds have already been breached and state change has become inevitable (Koch et al., 2009). Current ES flow is thus not necessarily the final equilibrium outcome of present drivers and current state. For example, it is unclear if current fishing effort on Tanna is within long term sustainable thresholds, or the “safe operating space” for coastal coral reefs (Hughes et al., 2017). Community consultations on Tanna reveal the shore-based reef fishery is both important to local food supply and has been subject to significant changes in catch, in terms of quantity and fish species. Time series data collection should be a priority to detect any changes in ES delivery. However, we currently lack the information to identify thresholds in ecosystem asset areas below which specific ESs begin to degrade non-linearly.

5.4. *Incorporating Kastom conceptions of ecosystem services*

Governing services are those “co-produced by humans using societal institutions and nature's components and processes” (Spangenberg, Görg, & Settele, 2015, p. 202). In this instance, the authors were discussing developed world governance structures—laws, policies, governments that protect private property—but similarly, Mackey, et al. (2017) introduced the concept of ‘Kastom services’ to articulate the close coupled socio-ecological systems, such as how Kastom land and reef resource management is an enabler for people and communities to harvest and benefit from ESs. Estimates of these contributions to aspects of Kastom in the Pacific SIDS context have been attempted (Kenter, Hyde, Christie, & Fazey, 2011; Paudyal, Baral, & Keenan, 2016). Though Ni-Vanuatu communities undoubtedly experience significant benefits from habitats and landscapes providing ESs to culture, including sense of communal identity, sacred sites for ceremonies, and other aspects of traditional knowledge (Nalau, Becken, Schliephack, et al., 2018), there are very few studies from which benefit estimates could be transferred. Furthermore, benefit transfer is likely not an appropriate method for Kastom services as, by their nature, they are highly situation-specific (Kenter et al., 2011). We, therefore, did not attempt to derive a monetised valuation of one of the most important benefits of tropical forest ecosystems in the Vanuatu context, namely, their Kastom use. Kastom use is largely of a non-extractive nature, including cultural practices and harvesting of some non-timber-based products. The cloud forest on Tanna, in particular, has both high biodiversity and Kastom values, as have numerous places across Vanuatu and Pacific nations. Whilst it is not essential to obtain *monetised* valuations for cultural ES, it is worthwhile investigating whether there are feasible approaches to *qualifying* Kastom values in a way that can integrate with ESV through multi-criteria assessment, particularly as, in our case studies, these forests are under pressure from poorly-regulated timber extraction and expansion of subsistence agriculture.

Whilst the demand for food, raw materials, and water is direct, immediate and well-understood in the community, regulating and cultural services, which undoubtedly contribute essential elements of value, are more difficult to evaluate (Fischer & Eastwood, 2016; Rasmussen, Watkins, & Agrawal, 2017). This has implications for data capture methods in future research into the ESV in SIDS and Least Development Countries, and perhaps suggests that discursive elicitation techniques should be used in parallel to traditional valuation methods, to better capture social and shared benefits provided by the different ES types (Jacobs et al., 2016; Kenter et al., 2016, 2011). For example, the value of the Tanna reef fishery is not simply a function of the catch rate, but also an outcome of an understanding of the role of cultural relations within and between tribes and their relationship with Kastom natural resource management (Foale, Cohen, Januchowski-Hartley, Wenger, & Macintyre, 2011; Lindstrom, 2011; Stoeckl et al., 2018).

However, the very concept of ‘cultural services’ is critiqued. For example, Satz et al. (2013) argue cultural benefits are more conceptual, rather than material, which has tended to lead the category being used as a miscellaneous basket into which unallocated, non-material services get placed when no better basket can be determined. Instead, the authors suggest cultural ESs be revised and the term intangible / immaterial ESs be used to clarify boundaries. Further critiques have looked at the relational aspects of cultural services, arguing cultural services are co-produced by nature and society (Díaz et al., 2018) or the value lays in the state of the ‘stock’ of relational strength between people and nature (Jackson & Palmer, 2015).

5.5. *Willingness to pay as a measure of value*

Economic valuations of ES in low-income contexts, such as those from low-income countries in the TEEB database, will typically yield very low willingness to pay values. In predominantly cashless, subsistence communities, where land is majority customarily owned, there is often lower values associated with the utility of money (as there is often little to buy with cash) when compared to communities for whom exchange via cash is dominant (Bush, Kitts, Fleming, & Taye, 2020; Kenter et al., 2011). Kastom communities in the Pacific also have a tendency to accumulate and share common wealth (Lindstrom, 1982; Nalau, Becken, Schliephack, et al., 2018), rather than retain it only at the individual or household level – the standard unit of neo-classical economic analysis. From initial fieldwork on Tanna, it is evident common ownership principles do not extend to the full gamut of material goods (fishing gear, boats and household items are exclusively ‘owned’ by households or families), but clearly land and coral reefs and the provisioning goods from these habitats are customarily-owned and therefore do not lend to individualistic notions of willingness to pay estimation of value.

Monetary values of ESs elicited through economic valuation methods assume that demand curves are derived from opportunity costs in efficiently functioning markets, not one where the price is opaque or the market is distorted, which is often the *prima facie* case for undertaking the economic study in the first place. For example, basing the marginal ES value of a subsistence garden on the cost of goods purchased at a nearby market (in this instance, the value from Anderson (2006)), assumes the prices at those markets have already accounted for any externalities (positive and negative) in their production, such as forest loss and depletion of localised regulating ESs to grow cash crops. This is *never* likely to be the case. Vinde Folkersen (2018) suggests a range of value-indicators, such as time, labour, geographical distance and collective community efforts be explored in the evolution of social and non-monetary valuation of ecosystems in Pacific SIDS contexts, which reflect complex, social norms and cultural value systems, such as kastom (Costanza et al., 2017; Kenter et al., 2016; Stoeckl et al., 2018; Vinde Folkersen, 2018). Further research that reveals more locally-explicit exchange values for the contribution of subsistence agriculture (based on replacement cost, for example), would fill an important research gap at the national or regional scale, however, overlaying these values with complex, social values at the local scale should also be included where budgets allow.

Lastly, non-market valuation methods assume that social welfare (or the total value of a good, or the net social benefit of a project) is the sum of individual willingness to pay values. There is growing recognition that benefits associated with the environment are frequently inter-dependent (i.e. ‘complex’) (Stoeckl et al., 2018). Researchers who aggregate partial values to estimate TESV risk both double counting overlapping values or precluding inter-dependent values that may be synergistic; that is, the whole may comprise more than the sum of its parts. Furthermore, simple aggregation of individual estimates of ‘value’ may be inappropriate in some contexts; particularly when both the ecosystem asset and their values are held at the community level (Adamowicz, Boxall, Williams, &

Louviere, 1998). This suggests that ‘integrated valuation’ or ‘participatory valuation’ methods could be both fruitful and useful (Costanza et al., 2017, p. 8).

5.6. The political realm

Finally, ESV as a decision support tool should be placed in a political context. Vanuatu has international commitments to the Convention on Biological Diversity and the Aichi Targets, which binds its Government to achieving biodiversity protection outcomes. These targets provide impetus to policy from the top down to the community-level to support sustainable management of ecosystems and Kastom resources through its own *National Biodiversity Strategy and Action Plan* (Republic of Vanuatu, 2018), which includes nationally appropriate interpretations of the Aichi Targets by referencing sustainable management of natural resources, protection of biodiversity for future generations and protection of the legal rights of Ni-Vanuatu as resource custodians and users. ES value estimates should be used as merely one type of evidence amongst many (e.g. habitat assessments, ecological field studies, biological inventories, socio-economic research, etc.) in supporting natural resource allocation and management decisions (Troy & Wilson, 2006), particularly to avoid risks of commodifying nature (Gómez-Baggethun & Ruiz-Pérez, 2011).

6. Conclusion

Our study estimated final TESH provided by the habitats of Vanuatu and Tanna to their people. This value is substantial, far outweighing measures of economic activity recorded in GDP. However, in undertaking our work a number of sensitivities and challenges were identified, which, if not accounted for, or acknowledged, can encourage misinterpretation or maladaptive responses to environmental pressures. Our assessment of these sensitivities and challenges can guide analysts to improve methods and the communication of results to stakeholders, so that the original purpose of the study – often to highlight market failures and to incorporate non-priced goods and services – do not serve to support perverse outcomes and continued over-exploitation of natural resources. We have pointed to a number of ways of improving ESV in Pacific SIDS contexts, such as hastening new primary research, maintaining serviceable valuation databases, augmenting ecosystem accounting with stated preference valuations to incorporate complex, social values, such as Kastom value, incorporating data on ecosystem condition into benefit transfer approaches, and supplementing survey methods with more participatory methods of value elicitation.

Despite decades of defensible and replicable ESV and incorporation of these values into policy evaluation and benefit cost analysis in the developed and developing world, it could be argued there has been little improvement in environmental outcomes. Information alone is a necessary but insufficient condition, as economic development pathways have tended towards running down natural capital. Pacific SIDS communities, which, as we have demonstrated, rely heavily and directly on nature for the provisioning of their immediate needs, such as food, water and shelter, and who experience close spiritual and cultural connections to their traditional land and ocean resources, are reliant on the continuation of ecosystem functions and processes. The extent of this reliance is missing from prosaic measures of well-being. ESV can provide a vital role in highlighting trade-offs inherent in economic development and continues to evolve in response to experience in valuation exercises in the field and in new contexts, including Pacific SIDS.

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