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An ecosystem values framework to support decision makers in the Coral Triangle

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1 Introduction and background

Marine and coastal ecosystems are among the most productive systems in the world, providing more benefits to human wellbeing per unit area than most other systems. This is due to their highly diverse and productive nature, and because over half the Earth's population lives within 200 kilometres of the coast (Brown and Hausner, 2017); and is projected to substantially increase.

Coasts and oceans provide a range of vital goods and services to humans such as food, transport, recreation, waste disposal and cultural inspiration. These "ecosystem goods and services" (EGS) are under increasing pressure from the growing demands of increasing human populations and economic activity which include over-exploitation of natural resources, pollution, and climate change. The consequences of this are unprecedented declines in quantity and quality of natural resources (trees, water, soils), habitats, species, and ecosystem functioning. This is especially true in developing-country settings such as in the Coral Triangle where rapid population growth and unfettered development are placing enormous pressures on marine and coastal ecosystems to meet the growing demands of economic activities and human needs (Skewes et al., 2011, 2015a, Tulloch et al., 2016).

Sustainable development, integrated spatial planning, ecosystem-based natural resource management, and disaster and incident response all endeavour to protect and enhance human wellbeing while promoting ecosystem sustainability. A key requirement for these processes and activities is comprehensive, accessible, trustworthy information on the characteristics of ecosystems (specifically their value to people and distribution over space and time) and the relationships people have with nature (i.e., cultural, recreational and spiritual). This information, however, is often lacking, inaccessible to decision makers, not credible, or incompatible with decision-making processes; making it difficult for effective (legitimate, efficient and just) decisions to be made. This is especially true for "seascapes[1]" management and governance (Atkinson et al., 2011) within the CTI (CTI, 2012) where the values of local stakeholders are often not well understood, mechanisms to fairly represent and account for plural values in trade-off analyses are weak, the required networks and capacities of actors to deliberate and negotiate solutions to conflicts about values are under-developed (Jacobs et al., 2016, Fazey et al., 2011), and where the rules (institutions) governing decision-making processes themselves are not designed or unfit for the purpose of fairly accounting for plural values. And this is especially problematic where there are strong market and political forces to exploit natural resources for private (individual or corporate) interests in the guise of economic growth for jobs and income creation) (McDonnell et al., 2017).

There are many approaches to valuing ecosystems due to the complexity of the elements and the relationships between these elements and because they span ecological (e.g. biodiversity,

[1] Seascapes are defined as: "Large, multiple-use marine areas, defined scientifically and strategically, in which government authorities, private organizations, and other stakeholders cooperate to conserve the diversity and abundance of marine life and to promote human well-being." (Atkinson et al., 2011)

productivity), economic (e.g. economic benefits from harvesting and regulation) and socio-cultural domains (e.g. spiritual fulfilment, aesthetic enjoyment, cultural heritage). Valuing ecosystems has been the focus of dedicated research for many decades. The concepts of Total Economic Valuation (TEV) and Ecosystem Services (ES) were developed as approaches to recognise the full range of benefits that ecosystems provide to humans and have played influential roles in raising the profile of the importance of nature for human wellbeing, including its role as a fundamental, irreplaceable building block of social and economic systems. The approaches to valuing and communicating the plural values that diverse stakeholders have for, and derive from, ecosystems are many and have developed to be consistent with the rules and objectives of the decision-making process within which the values need to be considered. For example, the economic valuation approach has been developed to elicit and quantify values information for market-based economic decisions. In market settings, the approaches to valuation can and should only be applied to things that meet the requirements of economic valuation, namely that the thing can be commodified and exchanged in a market. Economic valuation done in breach of these requirements provides value estimates that are not credible or legitimate (McCauley, 2006; Sandel, 2012).

While it is important that the information about the benefits that individuals and communities derive from their relationships with ecosystems (as direct or indirect users and non-users) reflects the full range of benefits and types of relationships at different scales, it is equivalently important that this values information is credible and salient and can be legitimately used by decision makers in their decision-making processes to achieve their mandated goals/objectives. This is especially important and difficult in the Melanesian context where both federal governance arrangements and local traditional informal cultural norms and practices are constitutionally recognised and where traditional barter systems and formal market systems operate in parallel (May, 2004; McDonnell et al., 2017; Skewes et al., 2011; Butler et al., 2012a, 2012b; Wise et al., 2014).

Recent developments in the application of approaches to valuing ecosystems has shown that combining multiple disciplines and methods to represent the diverse set of values of nature, informed by understanding of the requirements of the rules and the actors of the relevant decision-making processes, is a good strategy for achieving salient, credible (comprehensive and representative) and legitimate understandings of the values at stake in any resource-use dilemma (Gómez-Baggethun and Martín-López, 2015; Jacobs et al., 2016; Vatn, 2009; Gorddard et al., 2016). It is becoming increasingly acknowledged that to achieve efficient and just outcomes towards people and nature, today and in the future, requires that the diversity of values that stakeholders have or derive from their relationships with nature are acknowledged and accommodated in decision procedures and outcomes. These 'relational values' might consider and reflect: 1) the values to people from the direct and indirect use of the ecosystem (recreational, consumptive, etc) and 2) the benefits people derive from just knowing the thing exists or that others are benefiting from it, from the cultural and spiritual fulfilment realised, or from the future-use options it provides (Chan et al., 2016; Diaz et al., 2015).

The comprehensive valuation of ecosystems and the services they provide can be defined as the process of eliciting, synthesizing, interpreting and communicating knowledge and data about the ways in which people relate to and derive meaning, fulfilment and wellbeing from ecosystems (Gómez-Baggethun and Martín-López, 2015). This information needs to be readily accessible to decision makers and stakeholders and the content must be transparent, relevant, replicable and credible to justify choices and actions especially in highly contested spaces (e.g., where interests and values are ambiguous or in conflict).

This leads to approaches to the comprehensive, inclusive, and legitimate valuing of ecosystems that provides disaggregated/granular information on a range of value types so that decision-makers can integrate the information and make decisions with due consideration for the suite of values at stake. This reflects four premises of integrated valuation of ecosystem services (Gómez-Baggethun and Martín-López, 2015): (1) consistent combination of different valuation languages; (2) interdisciplinarity and methodological pluralism; (3) integration of different forms of knowledge (e.g. formal scientific knowledge; traditional ecological knowledge); and (4) consideration of values across various levels of societal organization (scale) (Reid et al., 2016).

It is important to understand what it is about ecosystems that humans value, and how these values can be more effectively elicited, captured and articulated (quantitatively or qualitatively) in assessments of the costs and benefits (trade-offs) of developmental, conservation and adaptation options/choices. Discussions with stakeholders in PNG and the Solomon Islands indicated that, currently, decision-makers have little information on ecosystem values to make decisions (Skewes and Wise, 2015b; Meharg et al., 2016). Since most decisions have a strong spatial component (sites for industrial development, protected areas, local human use), reliable and accessible spatial information is critical (maps and computer based spatial data inventory (SDI) for enabling effective decision making.

The primary focus of this project has been the adaptive co-design and co-development of a comprehensive and effective values framework (Figure 1-1) with key stakeholders to inform and support decisions about the allocation and use of resources (terrestrial and ocean) that have impacts on marine and coastal ecosystems in the Coral Triangle. These efforts have initially focused on the “Seascape” of the Bismarck Sea in Papua New Guinea (PNG). The values framework will be designed to capture a full range of values for stakeholders at different spatial scales, and show connectivity to dependent ecosystem features. The values data will be designed for immediate use by relevant stakeholders, but also for future deployment of additional pressure-asset interaction analysis and improved decision support tools.

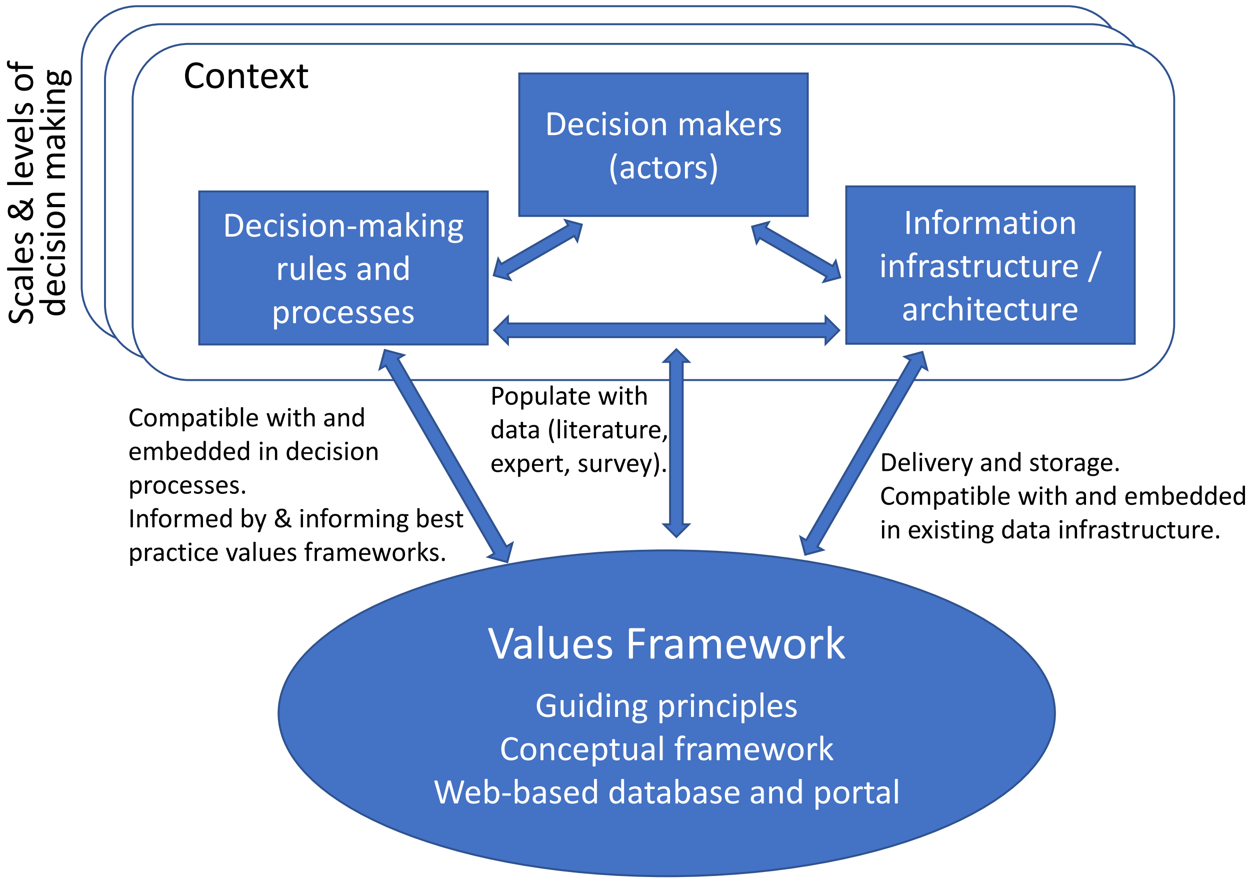

Figure 1-1. Approach to supporting the consideration of reliable measures of plural ecosystem values in decision making

1.1 Value concepts

The word 'value' has several related meanings. It can be: the worth, importance, or usefulness of something; or about moral principles and one's judgment of what is important in life; or simply a measure of a variable (Oxford dictionary; Hirons et al., 2016). These meanings of value are often linked; however, it is important that they are not conflated (Pascual et al., 2017). Valuation, therefore, is the act of assessing, appraising or measuring value or importance. The many concepts of value are listed and defined in Table 1-1.

A way of framing values to help identify and inform their consideration in decision making involves recognising that the articulation and assessment of values are intimately linked to the personal and shared relationships that people have with nature. And, these human-nature relationships are determined by the complex interactions between the *knowledge* that people have about the ecosystems and their dynamics, the *held values* that determine the motivational behaviours and interactions of people with nature, and the *rules* governing how people are allowed to interact with, express their values for, and manage ecosystems (Gorddard *et al.*, 2016; 2017). This has a number of consequences for the ways of eliciting values or incorporating plural types of values into assessments or decision-making processes. Furthermore, the values of an ecosystem depend not only the benefits derived from the ecosystem, they also depend on the biophysical characteristics of the ecosystem (i.e. its health, its scarcity) and on peoples' preferences for *how* ecosystems should be allocated.

Therefore, being clear about these different concepts of value and how they relate to each other is important in order to reduce ambiguity and confusion and to provide a consistent and structured way of thinking about and evaluating values in assessments of the costs and benefits to society from different choices about the allocation, use and impacts on ecosystems (Abson and Termansen, 2011; Gómez-Baggethun and Martín-López, 2015; Kenter et al., 2015). For example, understanding whether conflicts and contestations about how resources are being allocated is due to differences in deeply held values, misunderstandings about the different value relationships that diverse stakeholders have with ecosystems, or how value is being assigned and articulated in decision processes can help diverse stakeholders build shared understanding and work out ways of overcoming the conflict.

It is therefore critical that the approaches to ecosystem valuation are sensitive to the type of ecosystem, its socio-cultural context, procedural issues regarding its management, and the institutional arrangements governing how ecosystem values are expressed and accounted for in decision-making. Gorddard et al. (2016) for example discuss these dimensions when exploring the difficult trade-offs between public and private values in the context of adapting coastal ecosystems to the changing inundation risks from sea level rise.

Valuation approaches often will reflect a way of thinking and a form of relationship with the environment, in particular, collective worldviews and belief systems. However, considering different value contexts can also help people of various socio-cultural groups rethink their own values in relation to the natural environment and increase their knowledge about the consequences of pressures and threats, and the value of interventions.

Because of the context-specific (diverse) social, cultural and biophysical factors that influence values, the outputs of any valuation approach will be relative to a given individual or group of people in their specific location. In the context of multi-cultural and socially diverse settings, this makes the question of choosing a defensible valuation approach more important than finding a correct value (Brondízio et al., 2010). We present a valuation approach capable of doing this in Section 2. The following sub-sections in this Section 1 provide explanations of the various values concepts and approaches as background information to ensure shared understanding before the values framework is presented.

Table 1-2. Different concepts of values and their definitions, which can be shared/social values or individual values

Type of value	Definition
Ecological/ Functional values	Non-preference-based values derived from a quantification of the biological or physical relation of one entity to another, for example, the value of nesting habitats for birds. Such values are free from human preferences and as such are outside the realm of valuation (Brown, 1984).
Inherent values	Non-preference-based values derived from a quantification of the biological or physical attributes of an entity. These includes Ecosystem Services values (including direct and indirect use cultural services such as recreation and aesthetics - but not non-use values such as existence or bequest), and Ecological/Functional values such as biodiversity or rarity.
Intrinsic values	These reflect the ethical stance that an object has value for its own sake, expressed as "culturally embedded moral truths" (Zimmerman, 2001; Sandel, M.J., 2012)
Held values	These are deeply held first-order values that influence subsequent, second-order (ascribed) values. Examples of held values are ideas of justice, identity, sustainability and freedom. These form the conceptual basis for decision making (Schwartz, 2012).
Motivational values	These are ethical precepts or beliefs that determine the way people select actions and evaluate events. Schwartz (2012) identified ten universal values according to the motivation or goal that underlies each: power, achievement, hedonism, stimulation, self-direction, universalism, benevolence, tradition, conformity, and security. These are related in conflicting or congruent ways and are assigned different priorities according to the individual and the context (Gorddard et al., 2016)
Assigned values	Assigned values are second-order preferences, generally associated with ecosystem goods or services that individuals are prepared to ascribe relative values to and make trade-offs between (Brown, 1984). Assigned values are the stories or measures (indicators) used to describe, quantify, or articulate the value relationships and held values that people have for things, so these can be legitimately considered in particular decision-making process (Gorddard et al., 2017)
Shared / social values	Shared values, also known as social values, are often used to refer to guiding principles and normative values that are shared by groups or communities or to refer to cultural values more generally (Kenter et al., 2015).
Value relationship	The value or importance of a thing derives from how people relate to and experience the thing. The relationship between people and the thing determines and reveals the values that people have for, and assign to, the thing and the benefits they derive from the thing. Value relationships often take the form of formal and informal rules about how individuals or groups are allowed or expected to interact with the thing and how the values are articulated (Gorddard et al., 2017)

1.1.1 Ecosystem Services

The benefits that humans derive from ecosystems can be characterised as "ecosystem services" (Figure 1-2) (see https://www.gov.uk/guidance/ecosystems-services for a thorough overview and associated advice on how to value and consider ecosystem services in decision making). In this approach, ecosystems are valued for their importance in sustaining human well-being. The concept of ecosystem services arose during the 1970s to increase public interest in biodiversity conservation and highlight the lack of appreciation of societies' dependence on natural ecosystems (Gómez-Baggethun et al., 2010). The Millennium Ecosystem Assessment (MA) in 2005 did much to advance the concept as a tool for comprehensive socio-ecological assessments in policy agendas.

The ecosystem service framework is becoming increasingly central to how human-environment relations are conceptualized and approached by policy-makers. Much of the focus of the ecosystem services concept has been on the benefits nature provides in concrete, measurable and quantifiable ways, linked to a shift in the concept to one increasingly focused on monetary valuation and potential inclusion in markets (Hirons et al., 2016).

In this approach, ecosystems are valued for their importance in sustaining human well-being, however, the link between the environment and well-being is complex. These values comprise economic values, ecological values, and socio-cultural values, each of which is explored below (Figure 1-3). Global drivers of change including climate change, population growth, economic development, and human responses to these changes, will impact on ecosystems and the benefits that people experience from them. It is therefore important to understand what it is about ecosystems humans value, and how these values can be quantified and more effectively included in assessments of the costs and benefits (trade-offs) of developmental, conservation and adaptation decision making.

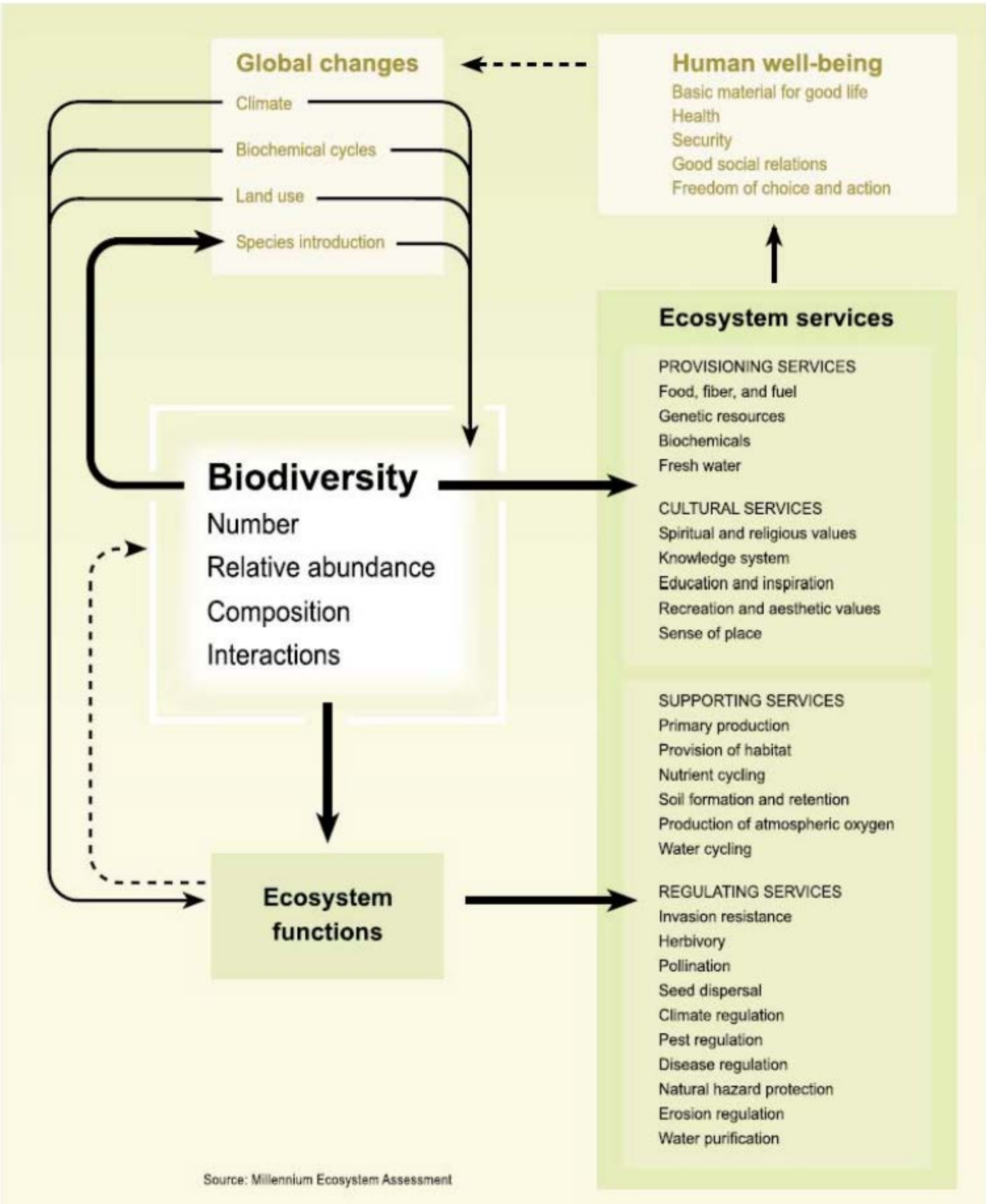

Figure 1-2. Ecosystem services foundational concepts (MA, 2005).

Since most ecosystem services have plural values associated with them (Figure 1-3), it is important that decision makers are aware of whether the assessment and appraisal processes that utilise ecosystem values allow for these plural values to be accounted for in decision making. Valuing ecosystem services for the purpose of decision-making requires understanding of the different types of values derived from ecosystems, criteria for measuring these values, and methods for qualitatively or quantitatively estimating their absolute or relative sizes. These aspects are addressed sequentially for ecological values, socio-cultural values and economic values.

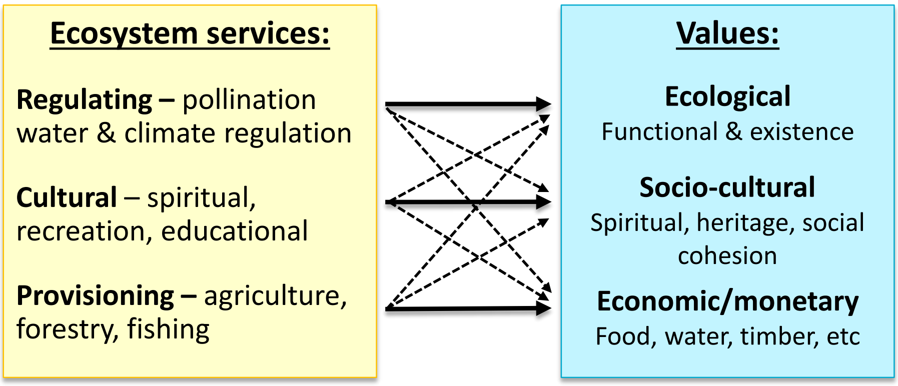

Figure 1-3. Associations between major categories of ecosystem services (i.e., provisioning, regulating and cultural services) and major categories of values (i.e., ecological, socio-cultural and monetary values) (adapted from Gómez-Baggethun and Martín-López, 2015). The width of arrows represents the level of association.

1.1.2 Economic (monetary) values

The assignment of monetary values requires three key assumptions to be met regarding the meaning of value:

1. Value can be ascribed,

   Economic values are based on utilitarian perspective where something only has value if it leads to an improvement in utility (i.e., not functional values – in other words, non-preference based derived from the biophysical relation of one entity to another and not held values, which are the deeply-held first-order preferences including things like sustainability, justice, freedom that underpin second-order preferences (action and choice realm of consumption).
2. Value should be measured at the margin

   Critical due to the effect of scarcity on value – marginality requires that ecosystem services (ES) can be split into discrete units of consumption which is not possible for ES such as cultural services providing spiritual value, and many other aspects of ES that provide social or shared values or contribute to meeting first-order preferences.
3. Value can be expressed in terms of exchange.

The exchange value provides a common unit to express the trade-offs between different factors that contribute to human welfare, and many aspects of value provided by ecosystems cannot be captured by such a single metric). Requires private ownership (i.e., for something to be exchanged requires that someone has the 'right' to exchange units of the good for other goods.

These three assumptions are generally well founded in the context of market goods but do not necessarily hold true when applied to non-market goods and services such as most ecosystem services (Abson and Termansen, 2010). Only provisioning services and a subset of regulating services (such as carbon sequestration and water provision, for example) meet all three assumptions of economic valuation. The remaining services do not, but can be articulated and evaluated alongside economic values using other metrics, provided the decision-making processes allow this (see Section 1.1.6 for a description of the characteristics of decision processes that facilitate the valuing and evaluation of plural values).

Where monetary values for ecosystem services can be legitimately and credibly quantified (i.e., when the above three assumptions are fulfilled), the Total Economic Value (TEV) framework (Krutilla, 1967) is a useful structured approach to ensuring all relevant dimensions of these economic values are identified and accounted for (Figure 1-4). Extensive lists have been developed of the ‘use’ values, ‘non-use’ values and ‘option’ values associated with different ecosystems in many locations in the Pacific and globally.

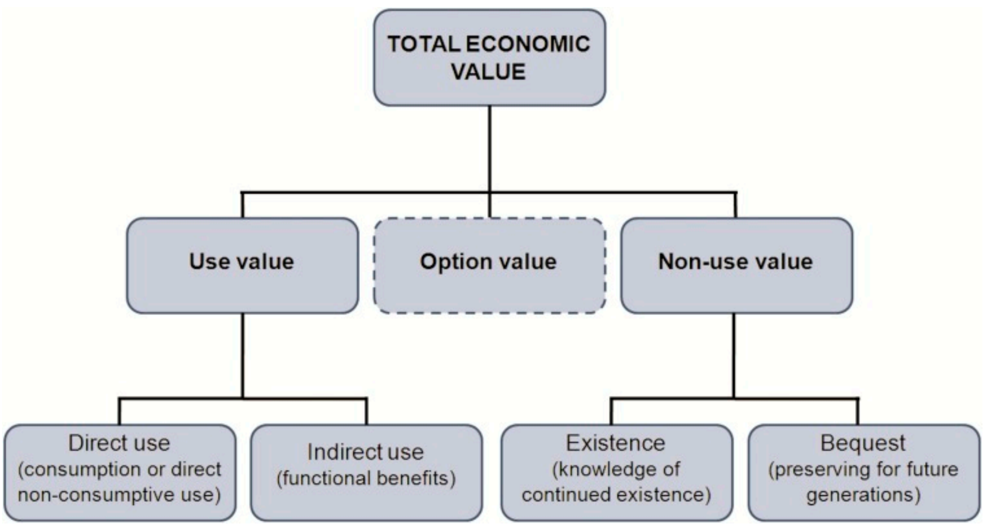

Figure 1-4. The Total Economic Value framework, accounting for use values, non-use values and option values (adapted from Krutilla, 1967)

Estimating economic values of the ecosystem goods and services that cannot be exchanged in markets is not possible. In such cases alternative approaches involve:

1. Estimating the monetary/economic value of the (potential or actual) economic costs of replacing or restoring the ecosystem goods and services in the event of their being used. Such approaches draw on the costs of activities and inputs to restore or replace the ecosystem goods and services, for which market prices do exist;

2. Techniques such as hedonic pricing and travel cost methods that draw upon 'parallel markets' or contingency valuation and choice modelling based on 'hypothetical markets' (see for e.g., De Groot et al., 2002, Gómez-Baggethun and Muradian, 2015); and

3. Discourse-based and stakeholder-oriented methods such as deliberative monetary valuation (Spash, 2007; Wilson and Howarth, 2002) or 'deliberative multi-criteria evaluation' (Proctor and Dreschler, 2006). These methods encourage stakeholders to express their values through dialogue and scientific information and other expert input can be added to the process. Many of these methods integrate stakeholder valuation into a particular decision-making process, so it may be difficult to separate the valuation elements from the outcome of the decision-making process (Gómez-Baggethun and Martín-López, 2015).

There have been concerns for some time about some moral and technical shortcomings of economic valuation approaches. Exclusively monetary valuations can embed and legitimize an approach to environmental decision-making that marginalizes the poor and erodes the very values that underpin cultural ecosystem services (Hirons et al., 2016). It is recognised that with increasing system complexity and value plurality, monetary valuations become less useful for input into management and policy processes (Brondizio et al., 2010).

1.1.3 Ecological values

Ecological (or Functional) values are what gives ecosystems capacity to sustain ecosystem services over time. These relate to the ecosystem structure, processes and functions on which ecosystem service delivery depends and are typically measured by criteria that reflect an ecosystem's *biodiversity, productivity, stability, and connectivity*. Methods for measuring these include: material flow analysis, land-cover flows, and embodied energy analysis to name only three. Further information on these methods and an assessment of their suitability for different purposes is provided by Gómez-Baggethun and Martín-López (2015).

Ecological values are sometimes termed as insurance value in ecological economics, such that it represents an ecosystem's capacity to maintain a sustained flow of benefits (**Error! Reference source not found.**, Pascual et al., 2010). This includes most regulatory functions that provide a positive service to the ecosystem itself (as opposed to humans).

A simple and effective way of to summarise information about ecological values is through the use of values constructs – sets of criteria that describe broadly agreed characteristics of the environment that are considered to be ecologically important. The values constructs synthesise scientific/technical information and traditional/local knowledge and transform it into easily used information based on the criteria. This approach can be used to manage systems faced with increasing demands on the marine environments from diverse sectors that may have conflicting objectives. Areas that have high ecological value are most often described through expert or stakeholder workshops where the values are described and mapped spatially. At national and global scales this is often with scientists, industry and government experts who can contribute information at those scales and can make use of analysis done prior to the workshops that inform the identification of areas. However, at subnational and local scales, these discussions should include local representatives who will have detailed knowledge of local areas. Within the CTI, such values constructs could be used to identify what areas Member countries would see as priorities for the development of seascapes, whether national or transboundary.

Multiple governments and international organisations have adopted an approach based on ecological value constructs consisting of sets of criteria that can be used to describe the components of important or significant parts of marine ecosystems. These have been arrived at through a series of independent global and national process and represent a consensus on what characterises areas in the marine environment that are of high environmental value. Three different sets have been described for use by UN organisations, Ecologically or Biologically Significant Areas (EBSA) by the Convention on Biological Diversity (CBD) (Bax et al., 2015), Particularly Sensitive Sea Areas (PSSA) by the International Maritime Organisation (IMO) (Olsen, 2008) and Vulnerable Marine Ecosystems (VME) by the Food and Agriculture Organisation (FAO). The criterion sets share common concepts (Figure 1-5) and can be used to describe most areas that have high ecological value.

The primary difference between these different sets is that PSSA and VME both relate to specific industries (Shipping and Deep Sea Fishing respectively) and have very specific management responses associated with each area, whereas EBSA are not associated with specific sectors. While they share similar values, areas given the status of PSSA and VME require interactions with shipping or deep sea fisheries respectively. Because they do not have a sectoral component, EBSA potentially encompass a much broader set of areas that are inclusive enough to inform the designation of PSSA or VME. Given the overlap with other criteria sets and the universal acceptance of the CBD criteria by all countries party to the CBD, the EBSA criteria provide a sector independent set of criteria that can be used and adapted to other purposes, and feed other international processes where appropriate. The criteria that are used to identify EBSA are:

1. Uniqueness or rarity – areas that contain unique or rare species, communities or features;
2. Special importance for life history of species – areas that are required for a population to survive and thrive;
3. Importance for threatened, endangered or declining species and/or habitats – areas that support threatened species;
4. Vulnerability, fragility, sensitivity, slow recovery – areas that contain a relatively high proportion of sensitive habitats, biotopes or species that are functionally fragile;
5. Biological productivity – areas with higher productivity;
6. Biological diversity – areas with higher biological diversity;
7. Naturalness – areas that are comparatively in a more undisturbed state.

The EBSA criteria are designed to identify geographically or oceanographically discrete areas that provide important services to one or more species/populations of an ecosystem or to the ecosystem as a whole, compared to other surrounding areas or areas of similar ecological characteristics, as areas that are to be the focus future conservation and management efforts (Dunstan et al., 2016).

Experience shows that the use of value systems identified within national frameworks have been useful prioritisation tools, focusing effort and attention onto the areas where most caution is needed to ensure sustainable use. In all cases, the areas identified using the national criteria sets are treated with increased caution when considering development proposals. Importantly, such areas are not necessarily precursors to Marine Protected Areas.

EBSA (CBD)	PSSA (IMO)	VME (FAO)
Uniqueness or Rarity	X	X
Special Importance for life history stages of species	X	X
Importance for threatened, endangered or declining species and/or habitats	X	X
Vulnerability, Fragility, Sensitivity or Slow Recovery	X	X
Biological Productivity	X	
Biological Diversity	X	X
Naturalness	X	

Figure 1-5. Comparison of EBSA (CBD) ecological criteria and those considered by other International, National and NGO criteria sets for Environmental values. (EBSA (CBD) = Ecologically or Biologically Significant Areas by the Convention on Biological Diversity; PSSA = Particularly Sensitive Sea Areas by the International Maritime Organisation (IMO); Vulnerable Marine Ecosystems (VME) by the Food and Agriculture Organisation (FAO).

1.1.4 Socio-cultural values

Socio-cultural values associated with ecosystems have been relatively neglected compared to provisioning and regulating services (Hirons et al., 2016). A significant proportion of cultural value research has been focused on direct use values such as tourism and recreation, and the importance of these values is expected to grow and even be a viable solution to local economic development. Cultural values defined as non-use values (e.g. existence and bequest values), have been particularly difficult to quantify. However, they are of great importance because of the linkages between cultural values and the collective decision-making that influence human well-being, especially of indigenous communities that have a close connection to nature. Socio-cultural values contribute to social cohesion and sense of community, to name a few. Research has also shown that cultural values are essential for cultural identity and even survival among many traditional communities (Kenter et al., 2015). They are among the most highly recognized ecological values and on readily perceived by people, and they may have the most direct links with human well-being (Hirons et al., 2016).

While cultural services are difficult to quantify and even conceptualise, meaning they are often underestimated, they are a powerful way to communicate the importance of protecting ecosystems as they are often directly experienced and intuitive. The most persuasive arguments for conservation often involve a community's (from local to global) emotional connection with a place (Hirons et al., 2016). At local and personal levels, cultural services are influential motivators of local land management decisions, and they are often more important than traditional commodity production drivers (Hirons et al., 2016). In Melanesia, spiritual and cultural beliefs that relate to the ecosystem often direct sustainable or conservation-based behaviour at the community level. Protection comes in the form of rules established by local communities (Cinner et al., 2005).

Cultural services are distinct from provisioning and regulating services; however, they are also intertwined and overlap with them. Many cultural services cannot be replaced or substituted even by replicating the particular place that is valued, let alone by a different (cultural) ecosystem service. They are also, due to their largely subjective nature, nongeneralizable (Hirons et al., 2016).

The values for cultural ecosystem services are difficult to quantify because they usually lack any obvious biophysical or monetary counterpart. In some cases, tools have been developed to quantify cultural services and related values using scores and constructed scales as in the cases of place values and aesthetic values. In other cases, however, quantifying cultural services may be too difficult and demands holistic approaches that may include qualitative measures or even narration (Gómez-Baggethun and Martín-López, 2015; Kenter et al., 2015). Even the direct-use values of cultural heritage and spiritual fulfillment (and to a lesser degree aesthetics) are created in the minds of the beneficiaries and therefore can vary depending on the individual. They are also influenced by the formal and informal rules that govern the behaviours, norms, taboos and cultural practices of societies/communities (Kenter et al., 2015). The value of various socio-cultural assets for indigenous communities have been assessed by applying various indirect methods, namely basic value transfer (BVT) (de Groot et al., 2012) and other methods such as deriving substitute values using Government Indigenous welfare expenditures (Sangha et al., 2017).

To make them comparable with other ecosystem services in trade-offs and management plans, there have been many attempts to develop ways of assigning monetary values to cultural services. Although this has been reasonably successful for recreational and educational values, generally, cultural services are poorly reflected in economic indicators and rarely marketable (Hernández-Morcillo et al., 2013; Hirons et al., 2016). As a result, their integration into ecosystem assessment and decision-making is comparatively neglected (Chan et al., 2012).

While there is a range of approaches to valuing and assessing socio-cultural values their use in decision-making processes is often compromised and manipulated within the political and power dynamics amongst stakeholders, which can marginalize some values and prioritise others in support of the interests of incumbent players (Hirons et al., 2016; McDonnell et al., 2017).

It is vital to consider the context of valuations, especially questions concerning who is doing the valuing, whose values are being considered, and for what purpose? These issues and perspectives are important because of the often unavoidable trade-offs in the benefits and dis-benefits generated, and unevenly distributed across many diverse stakeholders, from different ecosystem services. For example, some ecological and tourism benefits from wilderness areas and wild animals experienced by some stakeholders will also provide dis-benefits to others who fear wilderness and wild animals or who have to give up (or lose) benefits that would be provided from other uses of the resources such as conversion to home gardens.

1.1.5 Plural values and approaches to valuation

Numerous studies have highlighted the shortcomings of single rod economic valuation of environmental values (value monism) or comprehensive cost-benefit analysis and decision-making (Martín-López et al., 2014, Wegner and Pascual, 2011). This is especially true for socio-cultural values (Hirons et al., 2016). Recent studies recommend that monistic approaches to ecosystem valuation should be replaced by pluralist approaches composed of heterogeneous value-articulating methods that are appropriate to the specific context. Traditional analysis approaches such as cost-benefit analysis, may become an appropriate tool to examine trade-offs if applied to plural values in a negotiated weighting to reflect impacts on ecosystems and their services (Wegner and Pascual, 2011).

Plural values recognises that there is value in reflecting a broad range of value types when considering the value of ecosystems across ecological, socio-cultural and economic values. Complex systems and value plurality (including non-use values) requires methods which are able to capture value plurality, ecosystem complexity and biodiversity (Brondizio et al., 2010).

From an applied perspective, the need for combining multiple disciplines and methods to represent the diverse set of values of nature is increasingly recognized (Jacobs et al., 2016). The primary point of all valuing approaches is that there are a multiplicity of values that humans derive from the environment and that any valuing frame needs to take this into account to be successful.

1.1.6 Value articulating institutions

Institutions (rules) that allow individuals and groups to express their values and promote their consideration in decision-making are referred to as 'value-articulating institutions' (Vatn, 2009). Examples of well-known value-articulating institutions include: markets and cost-benefit analysis procedures, which are effective at articulating economic or monetary values of private goods and services; and regulations for environmental protection, which are reasonably effective at ensuring the intrinsic, aesthetic and functional values of ecosystems are accounted for in decisions.

The suitability of decision processes, or the institutions that enable or constrain decision-making, for accommodating diverse values (social, cultural, economic, and ecological) in integrated assessments of costs and benefits of adaptation depends on the degree to which they:

1. build or access the expertise required to undertake integrated valuations of diverse values using inter-disciplinary and specialised (quantitative and qualitative) methodologies;
2. draw upon different types of knowledge relevant for ecosystem valuation including scientific knowledge, lay knowledge and local, traditional ecological knowledge; and
3. consider values across levels of decision making (local, regional, national and sometimes global) which requires recognising diverse value-articulating institutions.

Where the decision-making process is found to be wanting in any one of these criteria, it is unlikely the decision-making process will effectively account for how different values stand in relation to each other (i.e., conflicting or complementary) when assessing the costs and benefits of development or adaptation interventions.

2 Ecosystem Values Framework

We have developed a framework for collating and presenting information on the values of terrestrial, marine and coastal ecosystems to relevant stakeholders for planning and decision-making tasks in rural developing country settings. Our approach is built on contemporary approaches to understanding plural values and the need for plural approaches to valuation of ecosystem features that are important to people. The framework draws predominantly on the 'relational' perspective on values that emphasises the importance of the relationships that people have with nature which are underpinned/determined by the deeply held values of people and communities and the values assigned to nature to inform what ecosystems are managed for (e.g., Gorddard et al., 2017, Chan et al., 2016, Gómez-Baggethun and Martín-López, 2015, Abson & Termansen, 2010, Chan et al., 2016; Gorddard et al., 2017)

The framework presents the links between ecosystems, ecosystem services and the types/forms of values that underpin these and the benefits derived from these. The approach/framework presents an all-encompassing framing of the key factors and concepts that inform and influence understandings of values, their valuation, and their consideration in decision making. The approach is designed to aid decision makers identify the important dimensions of the system to focus on and understand the "what" people value about ecosystems and "why". The schematic highlights the important components of ecosystems and the social systems to focus on, and the links between these components. For example, it highlights the links between the key components of ecosystems and ecosystem services and the important dimensions of the relationships between people and nature that determine the benefits received or generated from the direct or indirect use and non-use of ecosystems. The three important dimensions that influence the values assigned to ecosystems are: the **fundamental values** (held values and functional values) that underpin/determine the types of **value relationships** that people (as individuals or as groups) have with ecosystems, and the **assigned values** that allow the benefits or dis-benefits to be articulated and accounted for in decision-making processes. Importantly, the framework is designed to help reveal the many factors that influence the diverse values of ecosystem services to inform the key considerations and trade-offs involved in the allocation and use of ecosystems for the benefit of people and nature.

The framework has also been informed by the following key principles and design criteria:

- It is entirely transparent and makes all assumptions and components explicit
- It is flexible and can be readily modified and updated in response to feedback
- It is cheap to access and easy to use
- It is informed by the latest thinking and developments in ecosystem values, valuation approaches, and decision-making processes
- It includes the range of value concepts (held values, value relationships, assigned values) and assigned value types (including socio-cultural, economic and ecosystem values), along with making explicit how these values concepts relate to ecosystem services (provisioning, regulating, cultural) and the benefits/dis-benefits derived from them.

- The multiple values within each value type are explicitly recognised and can be accommodated in representative ways that reflect the relative importance and contribution of each of these values to meeting the livelihoods needs (food security, social cohesion, income, health) of the individual or community.
- Is spatially comprehensive and fully representative of the many, diverse values derived from the ecosystems services and ecosystem features in all habitats and land-use activities/types. In other words, the approach ensures all assigned values can be spatially represented for all types of ecosystem, habitat or land-use type and for specific geographical features.
- The underpinning database (data storage infrastructure) is sufficiently flexible to be able to capture, store and spatially map different types of data about different types of values that has been collected in different ways.
- Has the ability to reflect the different scales (local, provincial, national).

There are four categories of benefits from ecosystems represented in the framework:

- Benefits from ecosystem structure and processes;
- Benefits from ecosystem regulatory functions;
- Benefits from natural resources (ecosystem goods and services supply); and
- Benefits from socio-cultural interactions and relationships with nature.

This represents a comprehensive range of types of benefits as defined by a range of frames, including ecosystem services (MA, 2005), total economic valuation (TEEB, 2010; de Groot et al., 2010) and socio-cultural or relational valuing approaches (Kenter *et al.*, 2015, Hirons et al., 2016).

A fundamental basis of our framework is that it is feature based – including both ecosystem and man-made features (Figure 3-1). The full range of socio-cultural, economic and ecological values can then be associated with that feature, and these can then be overlain in spatial systems to produce a comprehensive spatial valuation. In addition, the socio-cultural values associated with man-made features (such historical wrecks, buildings etc.) can be captured in the spatial values system.

The metrics and estimating approaches for each of the values are listed in Table 2-1, and include a range of information gathering approaches from literature reviews, expert opinion and participatory elicitation (Gómez-Baggethun and Martín-López, 2015; Kenter et al., 2015; Skewes et al., 2015a; Richardson et al., 2014). These approaches are all well established and have a high feasibility. However, two information streams require dedicated forums for eliciting values information — a natural resource importance elicitation workshop and an expert scientific workshop for ecosystem structure and process values. Much of the scientific knowledge pertaining to ecosystem feature and process in particular will not be accessible through established scientific literature.

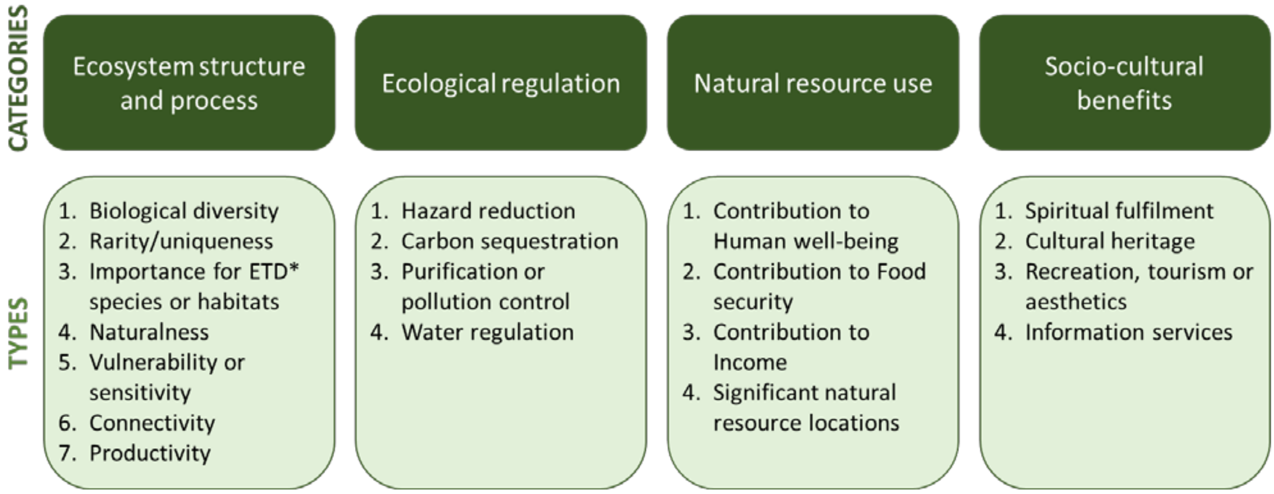

Figure 2-1. Value categories (attributes and benefits) expressed within the Marine and Coastal Values Framework. *ETD = endangered, threatened or declining

The values framework represents the suite of ecosystem services, benefits and dis-benefits from ecosystems, and value types using existing legislated and legitimate value metrics that reflect the diverse socio-cultural value frames (principals and preferences) for all stakeholders and the rules/mechanisms (e.g., regulations, norms, markets) within which values are assigned and accounted for. In this way, the framework does not weight each value type but provides the absolute metric where possible so that it can be used in pluralistic and deliberative approaches and processes (e.g. deliberative multi-criteria analysis) to inform and support negotiations in policy and development decision making processes.

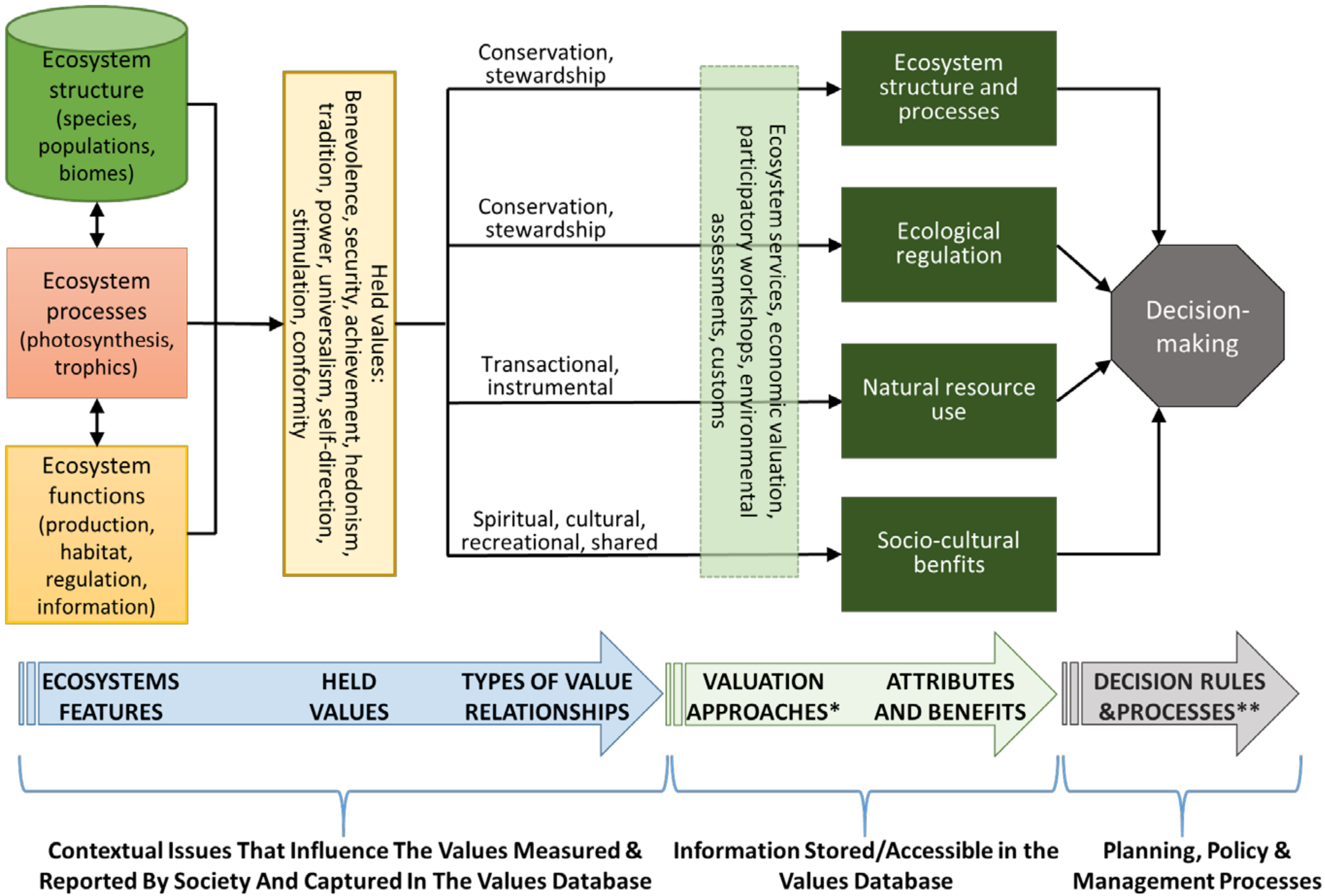

Figure 2-2. Framework for valuing ecosystems for decision-making. *The approaches, processes, frameworks, methods and tools for identifying, quantifying, capturing and reporting ecosystem attributes and benefits. **Regulations and processes for decision makers to evaluate trade-offs and make choices between different resource use/allocations.

Table 2-1. Descriptions of value (attributes and benefits) categories and types contained within the Spatial Values System for application to decision-making in PNG.

Value category	Value type	Metric	Estimation approach	Ancillary metrics	Scales and stakeholders	Rationale
1. Ecosystem structure and process	1.1 Biological diversity	Relative diversity level (Baseline (0), High (1), Very high (2))	Expert knowledge, literature review	Number of species per unit area; standard biodiversity indices.	Not scalar	Underpins ecosystem function and resilience. Intrinsic and non-use cultural services (existence, bequest) values.
	1.2 Rarity (species) or Uniqueness (communities, habitats)	Relative rarity or uniqueness (Baseline (0), High (1), Very high (2))	Expert knowledge, literature review	Species or habitat total range.	Provincial, National, Global	Risk of permanent loss of species or habitats. Intrinsic and non-use cultural services (existence, bequest) values.
	1.3 Importance for endangered, threatened or declining (ETD) species or habitats	Relative importance of area for ETD species or habitats (Baseline (0), High (1), Very high (2))	Expert knowledge, literature review (local legislation; IUCN Redbook)	Number or type of rules and conventions.	Not scalar	Risk of permanent loss of species or habitats. Intrinsic and non-use cultural services (existence, bequest) values.
	1.4 Naturalness (level of disturbance)	Relative level of naturalness (Baseline (0), High (1), Very high (2))	Expert knowledge, literature review	Estimates of degradation.	Not scalar	Important to maintain these areas as reference sites to safeguard and enhance ecosystem resilience.
	1.5 Vulnerability or sensitivity	Relative vulnerability or sensitivity (Baseline (0), High (1), Very high (2)).	Expert knowledge, literature review	Area of habitat or number of species that are functionally fragile to disturbance.	Not scalar	Risk of permanent loss of species or habitats if human activities and impacts are not managed effectively.
	1.6 Connectivity	Relative degree of connectivity with adjacent areas (Baseline (0), High (1), Very high (2)).	Expert knowledge, literature review (current modelling, migration routes)	Connectivity metrics.	Provincial, National, Global	Underpins ecosystem function and resilience. Risk of habitat/species loss from disturbance (can incur benefit for sink and detriment for source areas).
	1.7 Productivity	Relative productivity of system or habitat (Baseline (0), High (1), Very high (2)).	Expert knowledge, literature review, remote sensing	Quantity of biota or habitat that are active primary producers.	Not scalar	Underpins ecosystems productivity and functions which affects Natural resource provision.
2. Ecological regulation	2.1 Hazard reduction (e.g. coastal protection, erosion protection)	Hazard impact mitigation potential (Baseline (0), High (1), Very high (2))	Targeted research, risk analysis, benefit transfer	Economic valuation (value of protected infrastructure, agric.)	Not scalar	Provides economic and life benefits to humans through reduced impacts from hazards.
	2.2 Carbon sequestration	Carbon sequestration potential (Baseline (0), High (1), Very high (2))	Targeted research, benefit transfer	CO_2e stock and flow; Economic benefit valuation	Not scalar	Reduces climate change impacts on human societies.
	2.3 Purification or pollution control	Purification potential (Baseline (0), High (1), Very high (2))	Targeted research, benefit transfer	Denitrification (kg/ha/yr); Economic benefit valuation	Not scalar	Reduces pollution impacts on human societies.

Value category	Value type	Metric	Estimation approach	Ancillary metrics	Scales and stakeholders	Rationale
	2.4 Water regulation	Water retention capacity (Baseline (0), High (1), Very high (2))	Targeted research, benefit transfer	Water retention capacity in soils or at surface; Economic benefit valuation	Not scalar	Infiltration and gradual release of water underpins healthy ecosystems, agriculture and human use.
3. Natural resource use	3.1 Contribution to human well-being	Importance for human well-being (% of overall human well-being (per unit area)	Elicitation workshop, literature, expert knowledge, TEK	Economic valuation	Local, Provincial	The well-being of local communities is highly reliant on local natural resources in the PNG. Takes wellbeing from external sources into account.
	3.2 Contribution to food security	Importance for food security (% of overall food security (per unit area))	Elicitation workshop, literature, expert knowledge, TEK	Economic valuation	Local, Provincial	Food security of local communities is highly reliant on local natural resources in PNG. Takes food security from external sources into account.
	3.3 Contribution to income	Importance for income (% of overall income (per unit area))	Elicitation workshop, literature, expert knowledge, TEK	Economic valuation	Local, Provincial	Income of local communities is highly reliant on local natural resources in PNG. Takes income from external sources into account.
	3.4 Significant natural resource locations	Has significant natural resource importance (1)	Elicitation workshop, literature, expert knowledge, TEK	Size of user group, Number or type of rules and conventions	Local, Provincial, National	Some locations will have higher than average importance for the provision of natural resources, due to accessibility or natural resource abundance.
4. Socio-cultural benefits	4.1 Spiritual fulfilment	Has significant spiritual importance (1)	Local elicitation	Size of user group, Number or type of rules and conventions	Local, Provincial, National	Benefits people through spiritual fulfilment gained from sacred natural sites.
	4.2 Cultural heritage	Has significant cultural heritage importance (1)	Elicitation, Government legislation	Size of user group, Number or type of rules and conventions	Local, Provincial, National	Benefits people through cultural heritage information attached to natural and man-made sites.
	4.3 Recreational, tourism or aesthetic importance	Has significant recreational or tourism importance (1)	Elicitation, Industry and government data	Size of user group, economic valuation, rules and conventions.	Local, Provincial, National	Benefits people through recreational activities and income from tourism.
	4.4 Information services	Has significant information services importance (1)	Elicitation, Industry and government data	User group, rules and conventions.	Local, Provincial, National	Benefits people through production of knowledge.

Each value also has a narrative that includes: General description of area, feature, habitat or species; Status and trends; Rules, regulations and conventions; Pressures; Confidence; Information sources (literature, study date, workshop date, information location, links).

2.1 Ecosystem structure and process

Ecosystem structure and process values are mostly inherent attributes of ecosystem features (species, populations, biomes) that underpin ecosystem functions and can be used to reflect intrinsic ecosystem values and cultural non-use values (existence and bequest). In this sense, they do not reflect human preferences (held values) in their valuation. They can take on ascribed values when they are assessed for their importance (usually be the application of held values (preferences, regulations, norms) during the appraisal phase of the decision-making process. For example, the presence of rare species or importance for threatened, endangered or protected species, can be valued for maintaining biodiversity (and subsequently ecosystem resilience and productivity) but can also encapsulate the existence value as the benefit people receive from knowing that a species exists.

This valuing frame is common to many national and international valuing approaches applied to ecosystems, mostly for identifying areas of higher conservation value for management and protection (e.g. EBSA, VME, PSSA, KEFS etc.; Dunn et al., 2014; Bax et al., 2016; Ardron et al., 2013).

Much of the information to populate this value category it will be formulated through the production of scientific knowledge; however, some local non-scientific elicitation is also possible. It can be sourced from available scientific literature but as much of it will be in the grey literature or even unpublished data, the use of expert workshops if often required. Elicitation of local traditional and layman knowledge can be done through structured interviews and during participatory planning workshops.

The metrics for these values are semi-quantitative and ordinal scale, where a score is applied to identify areas that have a high (1) or very high (2) level of the value/criteria (CBD, 2009). Guidance on each of the value types (assessment criteria in EBSA parlance) are available on the EBSA website (https://www.cbd.int/ebsa/). The narrative, supported by references where possible, are critical to the usability and transparency of the information in this category of values.

2.2 Ecological regulation

This value category is focused on ecosystem functions that supply regulating services, particularly those that have indirect use value, such as water purification, carbon sequestration and hazard reduction. It has a broad valuation approach by recognising those habitats that have a significantly higher importance of each of the value types.

The metrics for these values are on an ordinal scale, where a score is applied to identify areas that have relatively high (1) or very high (2) level of the regulatory service compared to its surrounds, and can be based on first order stocks and flows information that describe ecological regulatory values of ecosystem features, and potentially economic benefits to humans (as regulatory services or hazard mitigation).

Stocks and flows information that underpins regulatory values usually needs to be collected locally, and can be sourced from the literature or expert knowledge, and can be augmented by remote sensing data. Monetary benefits can be estimating using spatial characterisation of ecosystem features and benefit transfer approaches using established valuations (Richardson et al., 2014).

This information to populate the value framework can be gained from local ecosystem valuation studies or by using the benefit transfer method. Examples of recent studies that can provide information on the regulatory values of habitats in Melanesia include the MACBIO Marine Ecosystem Service Valuation project (http://macbio-pacific.info/marine-ecosystem-service-valuation/, Jungwiwattanaporn and Pendleton, 2015).

2.3 Natural resource use

This valuing category provides a measure of the value of natural resources (equivalent to direct use provisioning ecosystem goods and services - EGS) that are utilised form local ecosystems by designated communities. This is a particularly pertinent valuation category for coastal rural communities in developing countries (including the CTI and throughout Melanesia) that have a high reliance on local natural resources for food, fibre and fuel (Skewes et al., 2016).

While it is quite feasible to estimate the monetary benefit of provisioning EGS, we have developed approaches to estimating the value of natural resources for overall human well-being of a community (Skewes et al., 2015a, Butler et al., 2012a, b) through four constituents of well-being (CoWBe). This is a holistic approach to valuing natural resources and is information that can be elicited at the local level reliably. The production of spatial natural resource well-being valuations is done using an established elicitation approach (ADWIM; Skewes et al., 2015) using participatory workshops containing local and regional stakeholders (Butler et al., 2012a). It includes the following steps (Figure 2-3):

1. List all local natural resources (Ecosystem goods and services - EGS)

A preliminary list of all the local EGS utilised by communities is formulated from interviews with local resource scientists and community stakeholders. This list is then reviewed by local stakeholders and any missing EGS added. The resolution of EGS (i.e. individual species; species groups; resource type) will depend on the relative importance of the EGS, its identity and the tractability of the valuation process.

For each EGS, the underpinning ecosystem features (EF) are identified for later mapping. This is a description of the area/habitat that contain and/or supported the EGS. Other information can be gathered such as the current status, approximate area, location, and relationships to other EAs and system drivers and stressors.

2. Determining EGS well-being importance

The relative importance of all EGS to a community's well-being, or at least that component of well-being that relies on local EGS, is estimated at participatory workshops. The calculation is based on the following steps:

A) Workshop participants, individually or in small groups, scored each EGS's relative volume on a semi-quantitative scale of 0 (none) to 5 (greatest volume). To facilitate the scoring, participants were asked to consider the highest volume EGS first and to score this 5, and then to score all other EGS relative to this.

B) Workshop participants then scored each EGS' relative value against the four indicators of well-being (income, health, food security and culture) using a scale from 0 (no value) to 5 (highest value). Participants were asked to consider the value of each EGS as if they had the same quantity of each EGS (e.g. 1 tonne) and then to score the highest value EGS first and to score this 5, and then to score all other EGS relative to this. The overall value of an EGS was the addition of the four separate indicator scores.

C) The well-being importance for each EGS was calculated as the product of the volume score and the sum of the indicator values scores. The raw importance scores were then standardised such that the importance of each EGS was relative to the total EGS importance scores, and represented as a percentage of the overall EGS-based well-being importance. This scaled the importance of each EGS relative to the overall EGS-derived well-being for the community (Figure 2-4).

3. Assign and map ecosystem features (EF).

Each ecosystem feature (EF – habitats, populations, geographical locations) that underpin each EGS was described and mapped. During this assignment exercise, it was important to include all ontogenetic habitats and populations that directly support the EGS. If multiple EF underpin an EGS, then the relative importance to each EF for supporting EGS was also assigned. This can default to being distributed evenly among the EF for each EGS (Figure 2-5).

4. Calculate relative EGS well-being value using EF area

Relative well-being value of EGS per unit area (usually Ha) was calculated using the EGS well-being value (importance) assigned to each EGS and the aerial extent of the assigned EF, so that area standardised values were considered when assessing the potential impacts of planning decisions (Figure 2-6).

5. Estimate relative contribution of natural resources and external income to overall well-being

Relative contribution of natural resources and external income to overall community well-being was estimated by comparing the relative importance of each component to three indicators of well-being independent of income (health, food security and culture). This produced a relative importance of natural resources to overall community well-being that was used to scale the relative EGS well-being values calculated in step 4. This value was used in subsequent spatial allocation of natural resource values.

6. Spatial join

The relative overall well-being importance table was joined to the spatial maps of EF to produce a spatial well-being importance map. This included a separate join for each of the economic and food security CoWBe components of natural resource importance. The assignment of well-being importance to an EF polygon was done on the per area basis. This resulted in each feature having a series of EGS well-being importance scores assigned to them. The addition of relative spatial values on a spatial basis formed the basis of the spatial natural resource relative overall well-being values (See Chapter 3).

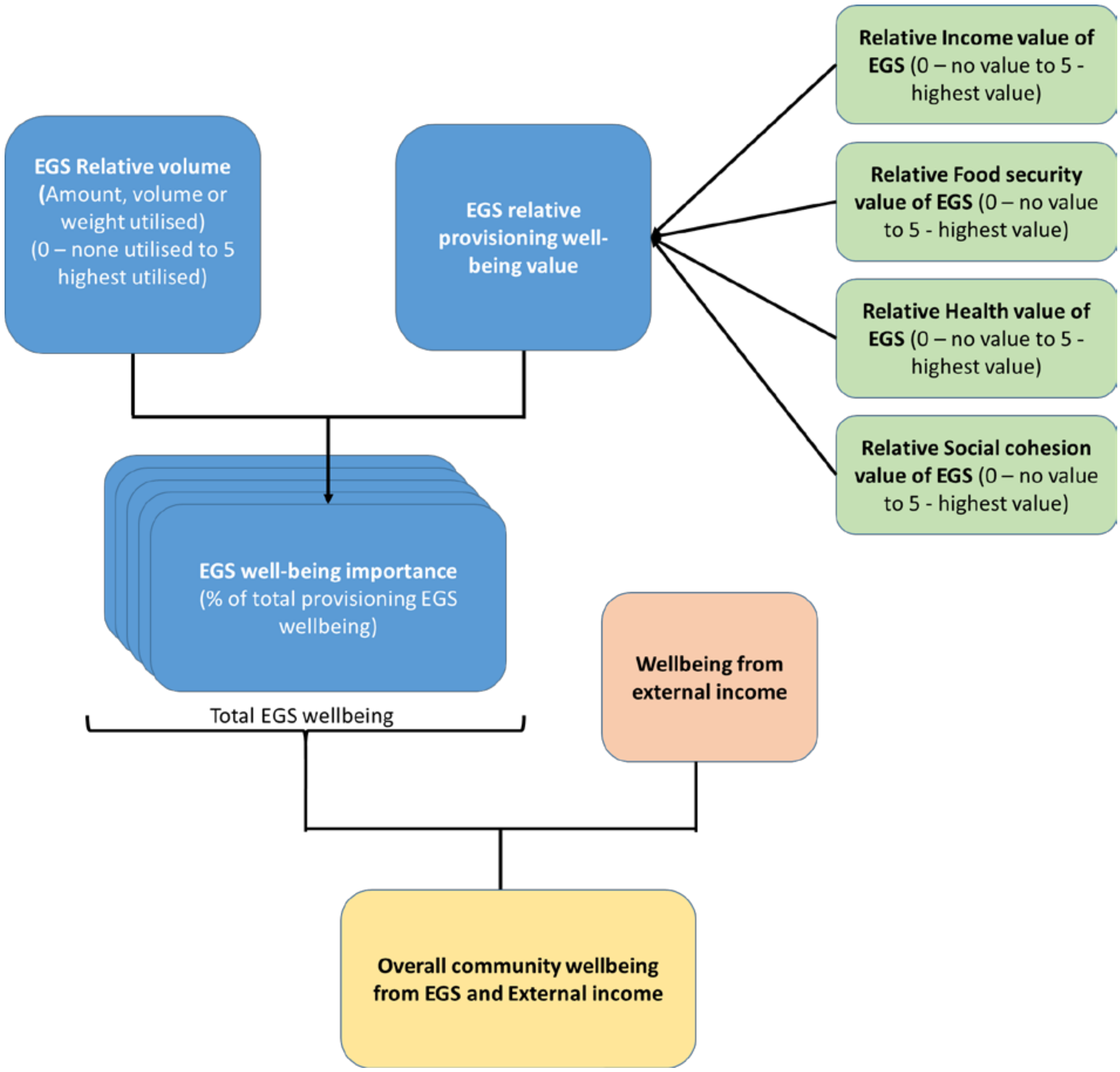

Figure 2-3. Scoring of natural resource (EGS) well-being importance.

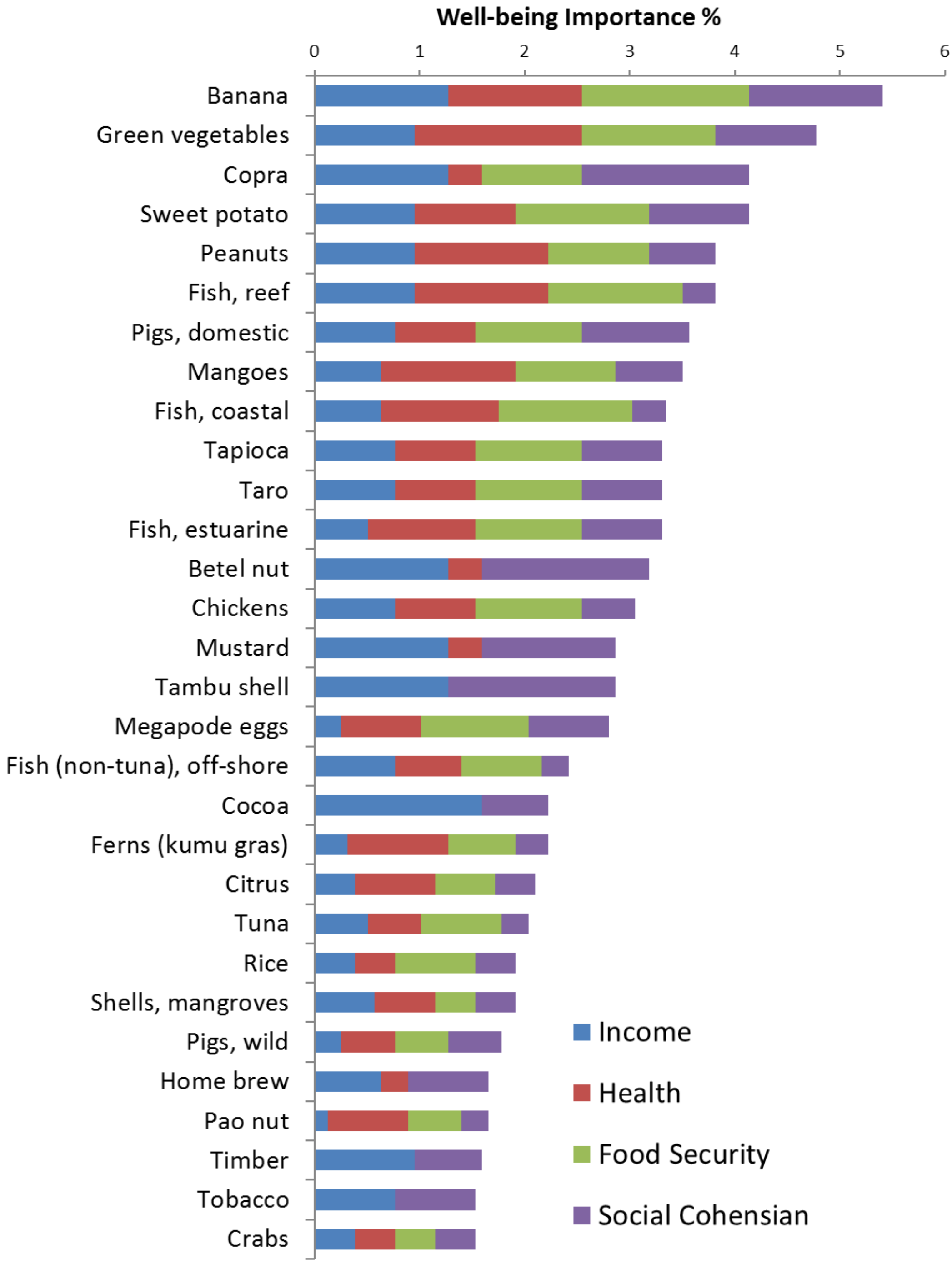

Figure 2-4. Gazelle district EGS Well-being Importance.

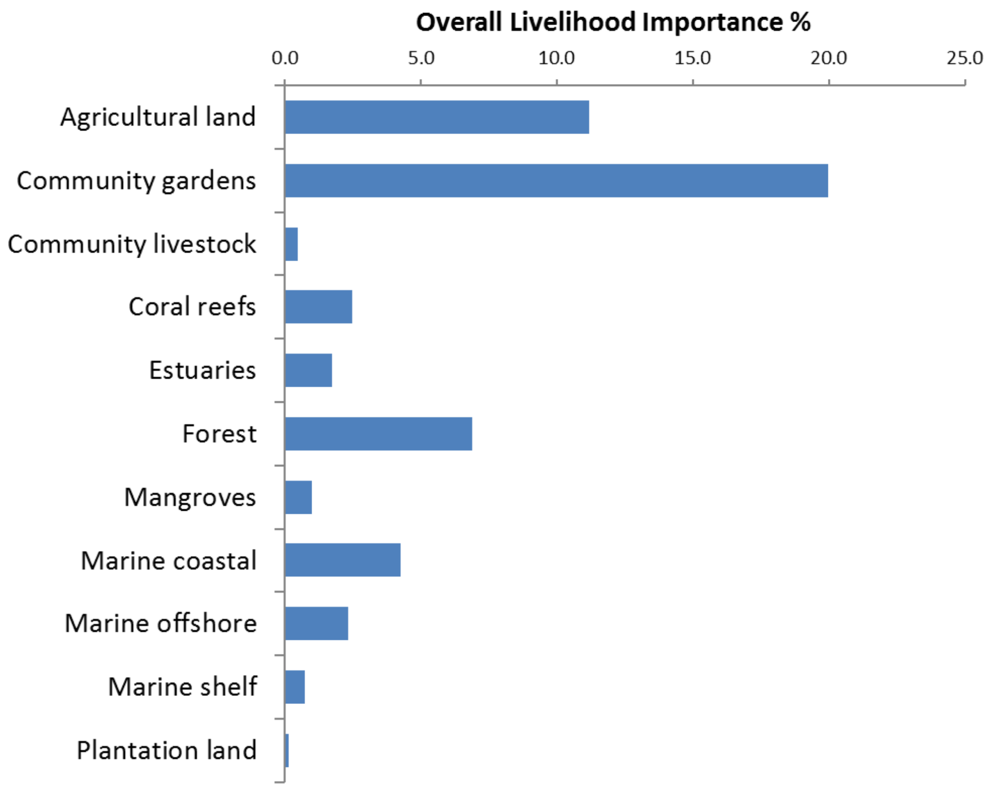

Figure 2-5. Gazelle District EGS Livelihood Importance.

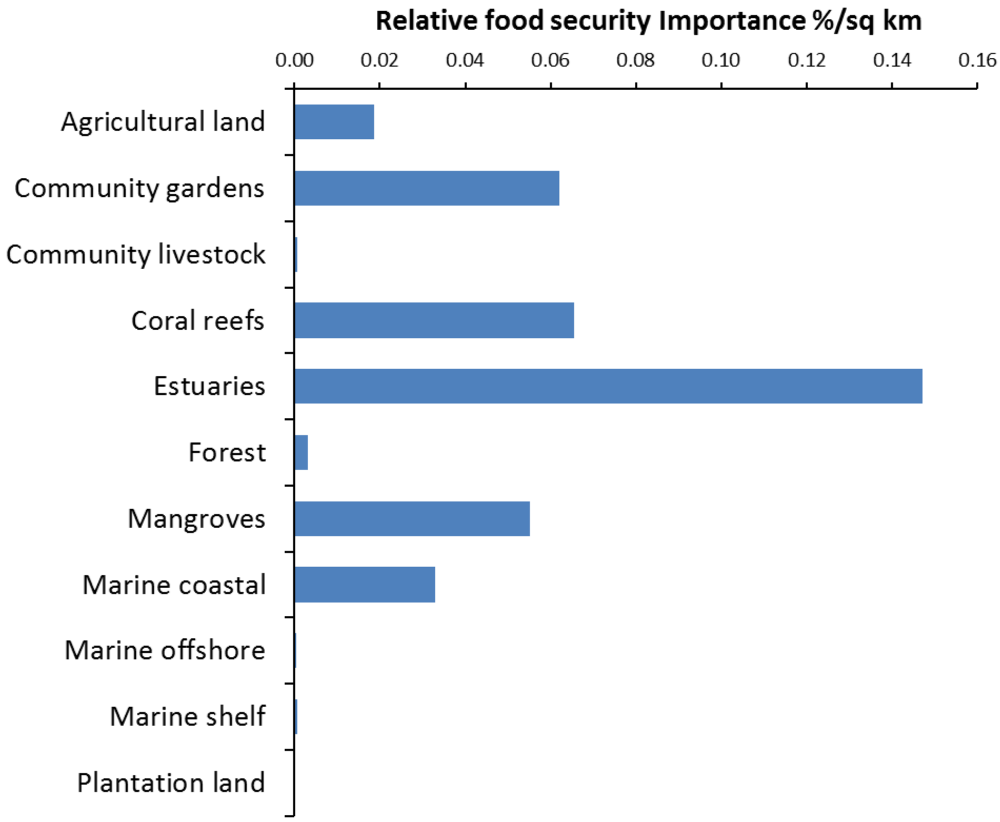

Figure 2-6. Gazelle District relative food security importance.

2.4 Socio-cultural benefits

These values include all direct use (cultural heritage, spiritual, recreation, tourism, aesthetic, knowledge) cultural values attached to natural features (but not the non-use values for existence and bequest values - these are applied to ecosystem structure value types by the application of held values in the appraisal and assessment process of decision-making). Cultural heritage can apply to some human built structures as well, and these are usually place based and also need to be considered during spatial developmental planning. For this reason, socio-cultural values also extend to human built (anthropogenic) features.

It can also include some elements of human well-being from other ecosystem services (e.g. provisioning services) that reflects the socio-cultural benefits of provisioning EGS and harvesting activities, for example.

Many of these values are not marginal or exchangeable, and therefore are very difficult to quantify (e.g. by monetary valuation), therefore the metrics associated with socio-cultural values are measured as a binary “has value” metric. The narrative (to whom and why) is therefore critical information when assessing the assigned values of socio-cultural assets.

Socio-cultural values are gathered using existing established spatial information about socio-cultural values and can be elicited from local stakeholders using participatory GIS during participatory planning workshops where location and narratives of the community’s interactions with nature can be expressed directly by stakeholders (Brown and Hausner, 2017).

3 Environmental and Livelihood Values Interrogation System - ELVIS

We have developed a database-linked GIS based system for connecting values in the marine and coastal values framework with spatial ecosystem features for display, interrogation and the production of electronic and hardcopy maps. The system is based on open-source software solutions that can be freely disseminated (SQLite, QGIS and Python).

All values are assigned to ecosystem (and human built) features in ELVIS (Figure 3-1). Some ecosystem features (EF) were available as spatial layers previously mapped by ecosystem mapping projects but others needed to be constructed from descriptions given by local stakeholders (Table 3-1). EF definition can be done using various sources of information, from existing digital maps of habitats (e.g. Millennium reef mapping coral reef maps) and areas of interest to participatory mapping exercises at participatory planning workshops such as TNCs Ridge to Reef mapping approach (TNC, 2013).

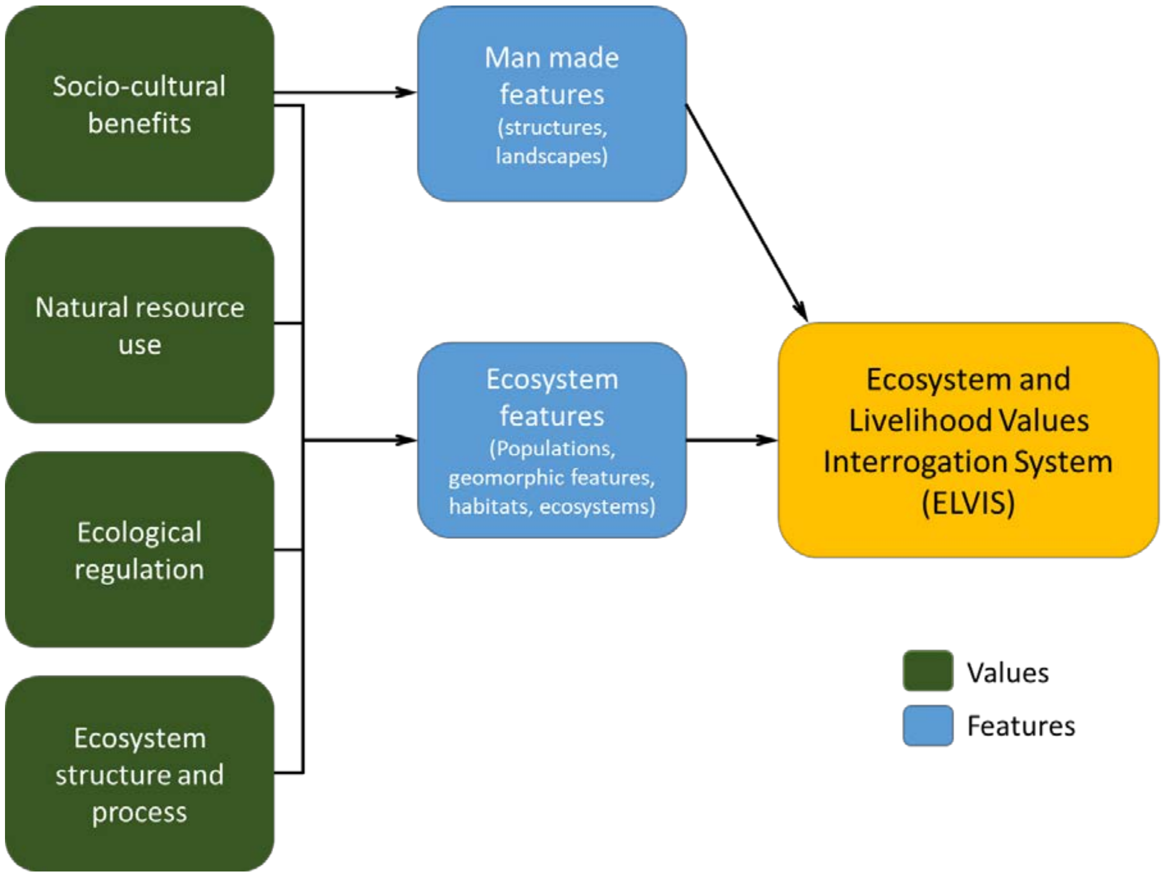

Figure 3-1 Information streams for Environmental and Livelihood Values Interrogation System (ELVIS).

Table 3-1. Spatial ecosystem features required for joining to Natural resource values.

Layer No.	Layer name	Layer description
1	Agricultural land	All land excluding Forest, Urban, Rivers, Community gardens, Plantation land.
2	Marine shelf	Marine habitat shallower than 200m.
3	Marine coastal	500m buffer along coast.
4	Community gardens	1 km buffer around communities excluding forest.
5	Community livestock	3 km buffer around communities excluding forest.
6	Coral reefs	Coral reefs shallower than 30 m. Millennium Coral Reef Mapping Project (2009). Sourced from UNEP-WCMC.
7	Estuaries	500 m buffer 500 m either side of river mouths.
8	Forest	Uncleared or regrowth forest. (FIMS vegetation cover database (Hammermaster E.T. and Saunders J.C. 1995 and PNG Forest Authority)
9	Marine inshore	2 km buffer along coast.
10	Mangroves	All mangrove forests (Global Mangrove Distribution (UNEP-WCMC 2011))
11	Mining areas	Active mining areas or Area of active mining leases (PNG Mineral Resource Authority).
12	Marine offshore	All marine areas excluding 2 km buffer along coast.
13	Plantation land	Designated plantation land (New Britain Palm Oil Limited)
14	River	Rivers and 50 m buffer.

ELVIS enables a user to easily visualise and query spatial layers containing various marine values objects in the regions of interest (Figure 3-2). It will replace QGIS functionality as described below and offer a single, easy to use interface to complete all commonly used tasks required by the QGIS component of the Marine Values project.

The tool is auto-loaded on start of QGIS or loaded via a menu point (if it unintentionally terminates). The tool uses a single, un-intrusive window for all tasks. Main QGIS functionality (working with layers, zooming, interrogation) can be performed in the tool. Comprehensive error handling is performed on user inputs where possible and if errors are raised the function stops and an error message is displayed.

Within the tool the user can load existing projects and all their shapefiles, view feature attributes, spatially query point and polygon data about their values and end QGIS. Area of interest polygons can be defined using a points list or from shapefile polygon, stored in the database and retrieved to allow different evaluations to run on the same area. Export functionality provides creation of a CSV file that contains all selections (including the polygon definition) and the resulting marine value output.

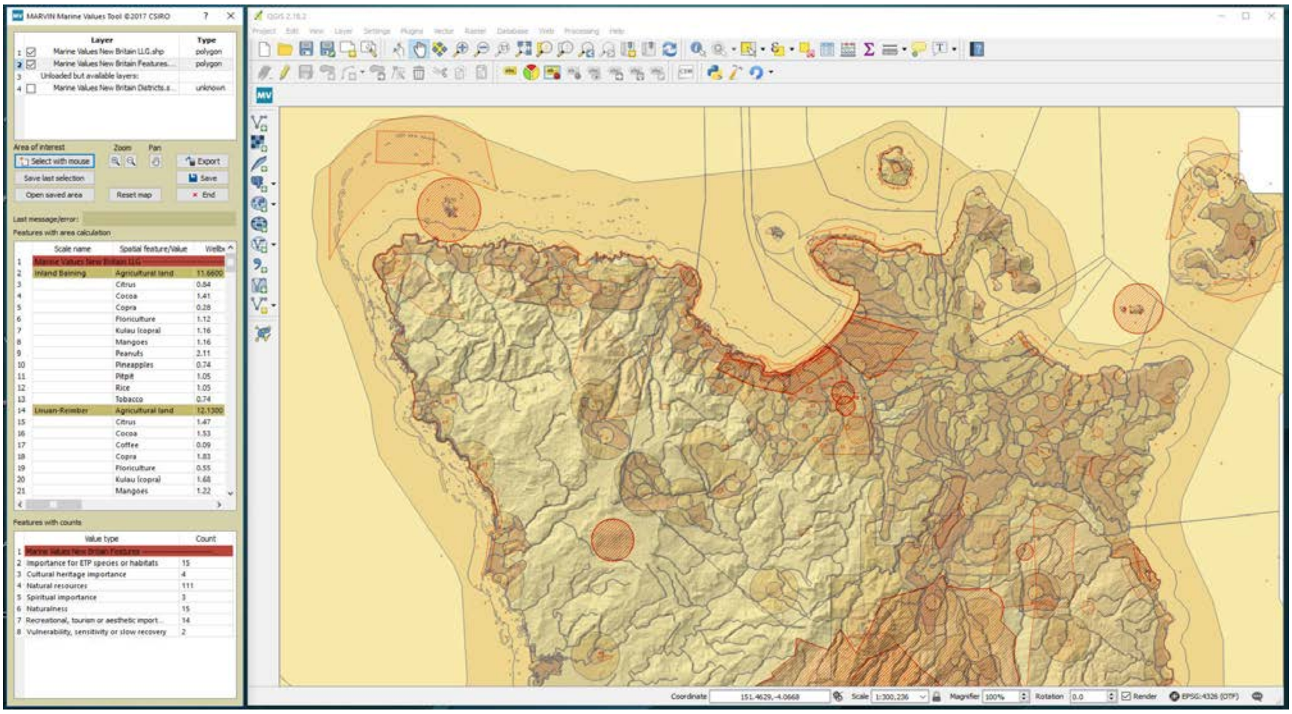

Figure 3-2 QGIS based values spatial system and interrogation tool - ELVIS.

ELVIS is capable of selected area queries that provide a summary of well-being importance of natural resources in the area of interest, regulatory value scores, socio-cultural sites and size of areas important for ecosystem structure and processes.

4 Discussion

The purpose of valuation, as discussed here, is to provide knowledge about the value of ecosystems and their services as a contribution to environmental decision-making, monitoring and management. One of the strengths of our approach is that it employs a pluralist approach to provide a comprehensive and accessible values database that can provide the relevant information necessary for informed decision-making processes. The categories and types of values are designed to cover the full spectrum of use and non-use values that would be represented in the classical ecological economic calculation of Total Economic Value, and to represent all values in the Ecosystem Services framing of values. This is designed to present values that will have relevance to mixed strategies for dealing with developments and negotiated outcomes that provide for best outcome for all parties.

Our approach, with its inclusion of a well-being valuation of natural resources (Provisioning ecosystem goods and services) and locations with socio-cultural and cultural heritage importance, emphasises the importance of improving or at least maintaining human well-being through development, especially at the local scale, and seeks to ensure achievement of this through planning for the sustainable development of ecosystems and societies.

For communities and decision-makers to effectively plan and respond to threats there is a requirement for decision-support tools and information that are relevant and accessible to them and other stakeholders. More broadly information tools must be transparent, credible, and unbiased (Cash et al., 2003; Bagstad et al., 2013). Also, because policies are continually revised as updated data, models and projections become available, information tools must be replicable, affordable and flexible enough to incorporate new knowledge into iterative decision-making (Wise et al., 2014).

The natural resource valuing approach needs to demonstrate the attributes of transparency, credibility, flexibility, affordability and providing unbiased information promotes its utility and usefulness. It is also highly relevant to stakeholders because of the EGS considered, namely the goods and services which are actually and directly valued and consumed by people (Wallace, 2007; Kent and Dorward, 2012).

It is difficult to elicit and communicate ecosystem values in a complex setting such as the CTI area and Melanesia with nested spatial scales of natural resource interactions and divers environments in a comprehensive and compact way that can be easily digested for use by stakeholders and decision-makers. Indeed, the application of more complex valuing approaches, such as monetisation, can have profound affects the outcomes of the valuation exercise, while important values outside the method reach are left unaccounted for (Jacobs et al, 2016), and some stakeholders will have less influence in decision-making because their interests are not represented.

It is important that the choice of values and level of stakeholder inclusion is comprehensive. The effort to collect this data can be daunting, however, our approach is efficient in that natural resource, socio-cultural information can be collected during participatory planning workshops.

We have endeavoured to assemble an array of values that is comprehensive and provides inherent information that can be subsequently used by stakeholders to make trad offs and informed decisions.

The relatively straightforward valuation approach and simple metrics used in the database increase the utility of the database through increased transparency and perceived lack of bias (Table 4-1) – values are reported at the level of "inherent" attributes and are, in the main, free from human preference. Even spiritual and cultural importance are the result of past development of lore and historical event – not something that can be denied. Naturally, the ascribed importance of those values will be subject to the application of held values in subsequent assessment and appraisal processes.

Of course, the presentation of values that are Inherent (not subject to Held values) and also not subject to monetisation or other "abstract" valuing approach, will be more transparent and credible to stakeholders. Our approach is to provide values as generic values that are not subject to modification by worldview contexts (e.g. community level food security importance, descriptions of cultural importance) but that reflect a broad range of value types, including use and non-use, that can be utilised in a diverse array of decision-making frameworks. Our goal is to be comprehensive and transparent.

The pluralistic, comprehensive and transparent nature of the values in the database provides an opportunity to contribute to better approaches to integrated planning and decision-making processes that extends from inshore areas out to the boundaries of the EEZ. The difficulty of some valuation approaches and the complexity of real life settings defy hopes for a methodological common denominator (Jacobs et al., 2016), and the need to consider multiple stakeholders at a range of social positions who articulate different values and use different value languages, as well as different levels of societal organization, from individuals, to communities, to larger societies.

One of the challenges of pluralist approaches that strive to be comprehensive is double counting. While there may appear to be some overlap between values in the database (e.g. between the socio-cultural services from natural resource utilisation and spiritual and cultural heritage values attached to ecosystem features), we have been careful to eliminate them as far as possible. In any case, the simplistic and transparent nature of values in the database will allow for informed decision to be made during the appraisal process.

Another potential error of this valuing approach is that it is assumed that the natural resource values are only derived from within the spatial unit of analysis (local, regional or national scale). This may underestimate the contribution of natural resources from outside the scale of analysis, and therefore overestimate the natural resource value of the local ecosystems. This error is more likely to occur at finer scales of analysis (i.e. subdistricts and villages) (Skewes et al., 2016). In the CTI region and Melanesia, most of natural resources utilized in households are extracted or grown locally.

Table 4-1. Attributes of values information for effective communication of scientific data and ecosystem service assessments (modified form Skewes et al., 2015a).

Criteria	Self-assessment
1. Transparent	Information on source and derivation of values is contained in the database. Values are first order values and are not subject to human preferences. Narratives are included as well as referenced sources, and can be reviewed by peers and other experts.
2. Quantifiable	Value metrics are relatively simple and report on “inherent” attributes of value types. Natural resource values are scored as for contribution to overall well-being.
3. Replicable	Low elicitation and scoring complexity enabling real-time adjustment to updated information on values.
4. Relevant	Natural resources and socio-cultural values utilised by local communities are included. Communities are largely dependent on local Natural resources. Analysis and outputs of direct relevance to the unit of analysis and its stakeholders. Outputs tailored for participatory planning approaches.
5. Credible	Natural resource and socio-cultural values defined by local stakeholders through valuation process in workshops.
6. Flexible	Applicable at multiple spatial scales (e.g. province, subdistrict, village). Can incorporate multiple forms of knowledge (e.g. secondary data, expert opinion, scientific literature).
7. Affordable	Low values metric complexity does not require extensive analysis. Expert elicitation can be undertaken individually or collectively (e.g. workshop).
8. Unbiased	Values data free form human preference. Values data supplied directly by local stakeholders. Natural resource importance defined by participants through valuation process in workshops.

Because our approach is particularly focused on expressing local communities value context, then the well-being values of local natural resources are particularly pertinent as they reflect the benefits that local communities derive from ecosystems. Similarly, the direct use socio-cultural values (spiritual, cultural heritage, recreation etc) also primarily focuses on local community values, though some broader national and international values (e.g. WW2 significant sites). Broader global non-use values (existence and bequest) are not explicitly valued in the framework, as they are very much the result of held values, and will need to be ascribed during the assessment process. Many of the ecosystem structure and function values will be appropriate for ascribing these values.

The lack of comprehensive values data is often acute in developing countries, where even data on primary natural resource values (e.g. agriculture and fisheries production) are often scattered, non-existent or inaccessible. Consequently, it is difficult to determine the potential impact that future development scenarios will have on ecosystem values and human well-being, exacerbating the vulnerability of resource dependent communities. A solution necessitates the integration of disparate data sources, augmented by experts’ and local stakeholders’ knowledge, often elicited relatively rapidly through participatory processes (Butler et al., 2014). While perhaps sub-optimal from a purely scientific perspective, this approach has the benefit of empowering local stakeholders, and considering their knowledge and values through the process (Butler et al. 2012 a,b).

The valuing approaches in this framework builds on growing recognition of the ecosystem services concept as a platform for viewing linked social-ecological systems, and its utility for science and management. This follows from the Millennium Ecosystem Assessment (MA, 2005), which promoted ecosystems as vital assets, and recognised the central role they play in supporting human well-being today and in the future (Daily et al., 2009). This triggered the development of decision-support tools that assess, quantify, model, value, or map multiple ecosystem services in land and seascapes. A comparative assessment of 17 tools by Bagstad et al. (2013) found that the majority were focused on mapping ecosystem services.

The values database can be used as the basis for decision-making by assessing the implications of development and management decisions on the outcome of a comprehensive range of values. This information is commonly used in a deliberative manner to allow decision-makers and interested stakeholders to explore different scenarios and assist them with decisions. Deliberative and scenario approaches can also be used for decision-making, without the need to convert datasets to common units, using weighted or multi-criteria (MCA) approaches. As part of a deliberative process, the best available knowledge and data can be presented and decision-makers, in collaboration with representatives of a broad range of interests surrounding the issue concerned, can collectively agree on the best course of action (Hirons et al.,2016).

The description and assessment of values are intimately linked to decision-making processes affecting the thing being valued (Gorddard et al, CSIRO unpublished report). Having a comprehensive and pluralist values framework can counter to some extent the strongly vested interests in current patterns of resource use and environmental decision-making,

The next steps in the development of the values framework is to test it in case studies of planning and management objectives in New Britain in late 2016. Of course, the “valuation” in itself is in instrument for framing an approach to disseminating the risks and returns of ecosystems and development that changes the value of those ecosystems, by representing a plurality of values pertinent to a broad range of scales. And making this information accessible and usable.

The protection of ecological values is a serious problem with unfettered development and environmental degradation occurring in the developing world in particular driven by inadequate regulation, corruption, poverty and the desire for a better life, lack of information on the value of the ecosystem with which to make informed decisions, and the power imbalance in decision-making. This data will provide comprehensive and locally relevant data on the value of ecosystems.

Glossary

Value: can refer to

1) A principle or core belief,
2) An individual's absolute or relative and ethical value,
3) A preference (for something or for a particular state of the world),
4) The importance (of something for itself or for other things),
5) The contribution of an action or object to user-specified goals, objectives, or conditions,
6) A measure (for example the number of species).

Valuation: The process of expressing a value for a particular good or service in a certain context (e.g., of decision-making) usually in terms of something that can be counted, often money, but also through methods and measures from other disciplines (sociology, ecology, and so on). (MA, 2005a).

Total economic value: The value obtained from the various constituents of utilitarian value, including direct use value, indirect use value, option value, quasi-option value, and existence value.

Ecosystem services: The direct and indirect contributions of ecosystems to human well-being. The concept ‘‘ecosystem goods and services’’ is synonymous with ecosystem services.

Nature: non-anthropocentric or intrinsic values

Ecosystem services: are the direct and indirect contributions of ecosystems to human well-being. They support directly or indirectly our survival and quality of life.

Provisioning services: are the products obtained from ecosystems such as food, fresh water, wood, fibre, genetic resources and medicines.

Regulating services: are defined as the benefits obtained from the regulation of ecosystem processes such as climate regulation, natural hazard regulation, water purification and waste management, pollination or pest control.

Supporting services: highlight the importance of ecosystems to provide habitat for migratory species and to maintain the viability of gene-pools.

Cultural services: include non-material benefits that people obtain from ecosystems such as spiritual enrichment, intellectual development, recreation and aesthetic values.

Human well-being: A context-and situation-dependent state, comprising basic material for a good life, freedom and choice, health and bodily well-being, good social relations, security, peace of mind, and spiritual experience. (MA, 2005a).

Cultural values: generally understood to be the nonmaterial benefits obtained from ecosystems that arise through human-environment relationships. Cultural ecosystem services (CES) are the non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences.

Human well-being: A context-and situation-dependent state, comprising basic material for a good life, freedom and choice, health and bodily well-being, good social relations, security, peace of mind, and spiritual experience. (MA, 2005a)

Ecosystem feature: A point or polygon in a shapefile which was delivered by researchers or created by the user.

Natural resources: The flows of ecosystem goods and services (EGS) provided by ecosystem assets which are directly utilised by people (Wallace, 2007; Kent and Dorward, 2012). This combines the Millennium Ecosystem Assessment's (2005) classification of 'provisioning' ecosystem services (products obtained from ecosystems) and 'cultural' ecosystem services (non-material benefits), but ignores 'regulating' (benefits obtained from the regulation of ecosystem processes) and 'supporting' services (those necessary for the production of all other ecosystem services)

Human well-being: Following the Millennium Ecosystem Assessment (2005), well-being is the fulfilment of peoples' basic need to live a healthy life, including income, health, food security, social cohesion and freedom of choice. We simplified this to four indicators: income, health, food security and culture, of which the first three are core components of the Millennium Development Goals United Nations (2014)

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Appendix A Values database fields

Field name	Description
value_name	Species, natural resource or place name
value_category	Value category
value_type	Value type
scale_type	Scale type
scale_name	Scale name
scale_gender	Scale gender
value_metric_description	Value metric description
value_metric_units	Value metric units
value_metric_score	Value metric score
ancillary_metric_description	Ancillary metric description
ancillary_metric_score	Ancillary metric score
spatial_feature_name	Spatial feature name
spatial_feature_description	Spatial feature description
narrative	Narrative
date_collected	Date data collected
metric_score_source	Source of data
metric_score_contact	Contact for data
spatial_feature_data_source	Source of spatial feature data

scale_type
Global
Regional
Country
Province
District
Local Government
village/community

value_category	value_type	value_metric_description	value_metric_units	Auxillary metrics
Ecosystem structure and process values	Biological diversity	Relative diversity level	Baseline (0), High (1), Very high (2)	Number of species per unit area; standard biodiversity indices.
	Rarity/uniqueness	Relative rarity or uniqueness	Baseline (0), High (1), Very high (2)	Species or habitat total range.
	Importance for ETP species or habitats	Relative importance of area for ETP species or habitats	Baseline (0), High (1), Very high (2)	Number or type of rules and conventions.
	Naturalness	Relative level of naturalness	Baseline (0), High (1), Very high (2)	Estimates of degradation.
	Vulnerability, sensitivity or slow recovery	Relative vulnerability or sensitivity	Baseline (0), High (1), Very high (2)	Area of habitat or number of species that are functionally fragile to disturbance.
	Connectivity	Relative degree of connectivity with adjacent areas	Baseline (0), High (1), Very high (2)	Connectivity metrics.
	Productivity or nutrient cycling	Relative productivity of system or habitat	Baseline (0), High (1), Very high (2)	Quantity of biota or habitat that are active primary producers.
Ecological regulatory values	Hazard reduction	Hazard impact mitigation potential	Baseline (0), High (1), Very high (2)	Economic valuation (value of infrastructure, agric.)
	Carbon sequestration	Carbon sequestration potential	Baseline (0), High (1), Very high (2)	CO_2e stock and flow; Economic benefit valuation
	Purification or pollution control	Purification potential	Baseline (0), High (1), Very high (2)	Denitrification (kg/ha/yr); Economic benefit valuation
	Water regulation	Water retention capacity	Baseline (0), High (1), Very high (2)	Water retention capacity in soils or at surface; Economic benefit valuation
Natural resource values	Contribution to human well-being	Importance for human wellbeing	% of overall human well-being (per unit area)	Economic valuation, Production rates
	Contribution to Food security	Importance for food security	% of overall human well-being for food security (per unit area)	Economic valuation, Production rates
	Contribution to Income	Importance for income	% of overall human well-being for income (per unit area)	Economic valuation, Production rates

	Contribution to Health	Importance for health	% of overall human well-being for health (per unit area)	Economic valuation, Production rates
	Contribution to Social cohesion	Importance for social cohesion	% of overall human well-being for social cohesion (per unit area)	Economic valuation, Production rates
	Natural resources	Has significant natural resource value	Does not (0), does (1)	Economic valuation, Production rates
Socio-cultural values	Spiritual importance	Has significant spiritual importance	Does not (0), does (1)	Size of user group, Number or type of rules and conventions
	Cultural heritage importance	Has significant cultural heritage importance	Does not (0), does (1)	Size of user group, Number or type of rules and conventions
	Recreational, tourism or aesthetic importance	Has significant information service importance	Does not (0), does (1)	Size of user group, economic valuation, rules and conventions.
	Information services	Has significant recreational, tourism or aethetic importance	Does not (0), does (1)	Size of user group, economic valuation, rules and conventions.

Appendix B Entering data into the spatial values system

1. Enter the name of the value [value_name]
    - This is the place, EGS or species name that identifies the value in the system
2. Enter the value Category [value_category]
3. Enter (from list dependant on value Category) value Type [value_type] (Table 2-1).
    - If man-made feature, enter "Anthropogenic" in Sub-type [value_subtype].
    - This will also determine the default value metric used in the values system [value_metric_description] and [value_metric_units] (Table 2-1)
    - Note, the same value name can have different value categories attached to it. Just enter in new row.
4. Enter the scale at which the values are being considered [scale_type] and name of scale [area_name] (some value types will have pre-defined scales; Table 2-1)
    - Some value types are only available at global scales (e.g. carbon sequestration potential)
    - These area name scales will need to be made as polygons in the GIS for viewing, mapping, clipping spatial feature layers etc.
5. Enter the value metric and score for that value [value_metric_score]
    - Use default value metric units [value_metric_units] as a guide (Table 2-1).
6. Enter any ancillary value metrics (free text) and scores (Table 2-1)
    - We will most likely need the capacity to enter multiple values here.
7. Enter spatial feature definition method [spatial_feature_definition]
    - Enter location -> New point. Enter Latitude and longitude of new feature location. This can be entered in a separate table, or just make a new point in a shape file (haven't figured this one out yet but currently linked by OBJECTID_1 to Nates GIS file.)
    - Draw on map -> New polygon or point. So when this is running on the QGIS system, we will (hopefully) have the capability to draw new points or polygons in the GIS directly with the mouse.
    - Use an existing layer -> Enter the name of an existing or made-for-purpose GIS feature layer.
    - Note: The spatial values system will have to apply an area calculation for those values that have a per area representation (e.g. % livelihood scores)
8. Write a narrative for value [narrative]
    - Narrative can include: General description of area, feature, habitat or species; Status and trends; Rules, regulations and conventions; Pressures; Confidence; Information sources (literature, study date, workshop date, information location, links).
9. List metric score information source [metric_score_source]
    - Citation, workshop date, information location, links.
10. List spatial feature data source [spatial_feature_data_source].
    - If spatial layer came from an external source (e.g. Millenium reef mapping project)

- Citation, study date, workshop date, information location, links.

11. Value code
    - This is a CAAB code for the value. Based on Scale, scale_ID, value_ID

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