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A typology of natural resource use for livelihood impact assessments in Nusa Tenggara Barat Province, Indonesia

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ABSTRACT

The vulnerability of less developed regions is exacerbated by a lack of information to inform appropriate adaptation planning. We addressed this challenge in the islands of Lombok and Sumbawa (Nusa Tenggara Barat Province, Indonesia) by combining multiple sources of knowledge to develop a typology of natural resource use by communities of the province. This enabled an assessment of future impacts of drivers of change such as population growth and climate change. The typology was developed by cluster analysis of an inventory of the use of ecosystem goods and services (EGS) by the 105 rural subdistricts in the province. The data were largely elicited from expert knowledge, augmented by a rapid rural appraisal of communities' marine resource use in Sumbawa. Exploratory analysis of existing secondary data on livelihoods and land use provided context and skeleton data, which were developed further by experts. Overall, 82 EGS were identified from nine terrestrial, coastal, marine and freshwater habitats. EGS included livestock, cropping, forestry, wildlife hunting, fishing, aquaculture, mining, water (for drinking and agriculture) and tourism. The typology comprised seven types that captured 42% of the variation in the data matrix. The types were moderately spatially aggregated and showed some congruence with administrative (district) boundaries. We discuss the implications of the results for planning livelihood adaptation strategies, and out-scaling these among subdistricts of matching types.

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Introduction

The rural poor in developing countries are the most vulnerable to the impacts of climate change, predictions of which are reviewed by the IPCC (2013). Such communities and households are highly dependent on climate-sensitive natural resources and the ecosystem goods and services (EGS) that these provide, and they have limited adaptive capacity in terms of the assets which they can mobilise in response (Adger et al., 2003). The vulnerability of these groups is exacerbated by the

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generally poor quality and quantity of information available to inform decision-makers on appropriate adaptation strategies (Ensor, 2011). Furthermore, in comparison to rural areas of developed countries, livelihood systems tend to be diverse, potentially requiring replicated and therefore resource-intensive planning processes (Butler et al., 2014, 2015).

In such situations methods are required which can draw on multiple sources of quantitative and qualitative data, and simplify complex information across large spatial scales (Butler et al., 2016). One approach is to group system components of a given class into a manageable number of types based on an appropriate typology. This enables analysis of fewer cases and allows scaling out of results to similar types in other systems. Typologies are most effective when variability is maximised between types and minimised within types. Classification methods (particularly analytical methods) usually explicitly aim to optimise this objective. However, there is a trade-off between having highly specific types and having a typology that is practical for a given purpose (e.g. having a manageable number of types) (Ellis, 2000).

Such a typology approach is often applied to group households or communities by livelihood in socioeconomic research and to define bundles of ecosystem services in ecological research. Livelihood typologies are used for such purposes as developing strategies for enhancing the wellbeing of the rural people in developing countries, whereas ecosystem service bundles were developed for use in natural resource management.

A livelihood comprises the capabilities, assets and activities required for a means of living (Chambers and Conway, 1992). Livelihoods can be defined at different levels (e.g. individual, household, community), with household being the most common (Chambers and Conway, 1992). Livelihood typologies are similarly often defined with household as the classification unit (e.g. Yuerlita et al., 2013; Tittonell et al., 2010; Perret and Kirsten, 2000), but they may also be defined using broader units such as communities or towns (e.g. Stimson et al., 2001). Livelihood typologies are used for such purposes as reducing the number of cases that must be considered for research or policy development (Ellis, 2000). The kind of typology (e.g. the livelihood attributes considered) and the classification method (e.g. analytical versus descriptive) depend on the objectives and resources available (Perret and Kirsten, 2000), but typologies have been used in both developing (e.g. O'Brien et al., 2004) and developed countries (e.g. Nelson et al., 2010) to estimate the relative impacts of climate change and vulnerability, and to prioritise adaptation investments.

Ecosystem services are benefits people obtain from ecosystems (Millennium Ecosystem Assessment, 2005). Ecosystem service bundles are sets of services that appear together repeatedly (Raudsepp-Hearne et al., 2010). If functional relationships among ecosystem services within a bundle are understood, then strategies for managing ecosystems can account for synergies or trade-offs among ecosystem services, for example when they involve promoting one service at the expense of another (Bennett et al., 2009; Kareiva et al., 2007). In practice, however, ecosystem bundles are often identified empirically by analysis of correlations in ecosystem service production data (Raudsepp-Hearne et al., 2010; Queiroz et al., 2015) or in social data on perceived ecosystem service importance (Martin-Lopez et al., 2012). For climate adaptation, ecosystem service bundles can be used to predict and manage changes in covarying ecosystem services under predicted climate change (Dunford et al., 2015) and to identify and manage climate adaptation services, defined as ecosystem services that support climate adaptation (Lavorel et al., 2014).

Livelihoods and ecosystem services are connected because the diverse livelihoods of households in a community determine the aggregate use of many ecosystem services by the community (particularly of provisioning services). Although livelihoods depend on the ownership or availability of resources, ultimately they are also determined by factors such as cultural preferences, education, inheritance and gender (Chambers and Conway, 1992).

Although livelihood typologies and ecosystem service bundles group related livelihood attributes and ecosystem services respectively, they can in turn be used to group the households or communities on which they are based. This is necessary if we are to know the people or land area to which a strategy developed for a livelihood type or ecosystem bundle applies. This step can be simplified by the fact that analytical methods for defining livelihood typologies and ecosystem service bundles are in practice often based on clustering of households or communities by livelihood attributes or ecosystem services (Yuerlita et al., 2013; Raudsepp-Hearne et al., 2010; Queiroz et al., 2015).

Household livelihood strategies do not necessarily align with geographical regions or existing zones (e.g. political boundaries) because livelihoods can be diverse even within local communities (Yuerlita et al., 2013; Tittonell et al., 2010). However, aggregate ecosystem service use of communities or administrative units might be more spatially aggregated if important drivers of livelihoods tend to be shared by neighbouring units. In that case, a livelihood typology based on administrative units might be developed using a zoning approach or spatial aggregation might be included as a classification objective.

In this paper we develop a typology of natural resource use based on an inventory of ecosystem goods and services utilised by communities in Nusa Tenggara Barat Province (NTB), Indonesia. The typology is developed using the methodology for classifying ecosystem service bundles. Although our focus is on grouping communities by resource use rather than on identifying ecosystem services that are functionally related to one another, empirical relationships identified among ecosystem services may later be applicable to adaptation strategy development (Dunford et al., 2015; Lavorel et al., 2014). The primary purpose of the typology was to support an NTB-scale assessment of climate change and human population growth impacts on communities' natural resource base using the Assets-Drivers-Wellbeing-Impact-Matrix (ADWIM), which is presented separately in this special issue (Skewes et al., this 2016).

In presenting the typology we highlight how mixed sources of information can be integrated in a data-poor context to support adaptation planning, and discuss how limitations of the data can affect how directly the data can be included in quantitative analysis. We compare the typology with an administrative grouping (subdistricts within districts), and discuss the relative merits of each for adaptation strategies. Finally, we explore considerations that should be taken into account when such a tool is to be applied for scaling out planning decisions for livelihood adaptation to climate and other change.

Methods

Study site

NTB is located in the island archipelago of eastern Indonesia (Fig. 1). NTB consists of two principal islands, Lombok (4725 km^2) and Sumbawa (15,448 km^2), which feature the volcanoes of Mount Rinjani and Mount Tambora. As a result the topography is steep and highly variable (Fig. 1). NTB has a tropical climate with a monsoon season of December–April, and is affected by the El Nino Southern Oscillation, which can generate drought periods or wetter than average years (Kirono et al., 2016). Soils are generally volcanic and rich on both islands, but rainfall is lower on Sumbawa. Due to the orographic effects of the volcanoes, steep climate gradients exist across the islands (McGregor et al., 2015). Combined with variations in soil type, these micro-climates support diverse agricultural systems (Yasin et al., 2007). Due to the heterogeneity of cultures, human development status, micro-climates and soil types, rural livelihoods' characteristics vary over short distances (Butler et al., 2014).

In 2010 the province was divided into eight districts (kabupaten) and two urban municipalities (Mataram on Lombok and Bima on Sumbawa) (Fig. 1). The rural districts were divided into 105 subdistricts (kecamatan). All were on the two main islands, but parts of some included smaller off-shore islands. In 2010 the NTB population was 4.5 million. Lombok had the higher population (70% of the total) and a much higher population density (671/km^2 versus 86/km^2 on Sumbawa). The majority of the province's population (58%) was rural (Fachry et al., 2011).

Units of analysis

To develop the typology, administrative units (subdistricts) were clustered according to use of ecosystem goods and services (EGS) by communities within them. EGS were defined as those goods and services which are provided by ecosystems and actually and directly valued and consumed by people (Wallace, 2007; Fisher et al., 2009; Kent and Dorward, 2012). This combines the Millennium Ecosystem Assessment (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 necessary for the production of all other ecosystem services) services. The justification for this approach was to enable the modelling of potential impacts on the natural resource base under current production and harvesting systems for different future scenarios of climate change and population growth, using ADWIM (Skewes et al., 2016).

Subdistricts were chosen as the units of classification because this was the focal administrative level for adaptation planning (Butler et al., 2016), and this was also the finest scale of resolution at which data collection across the whole of

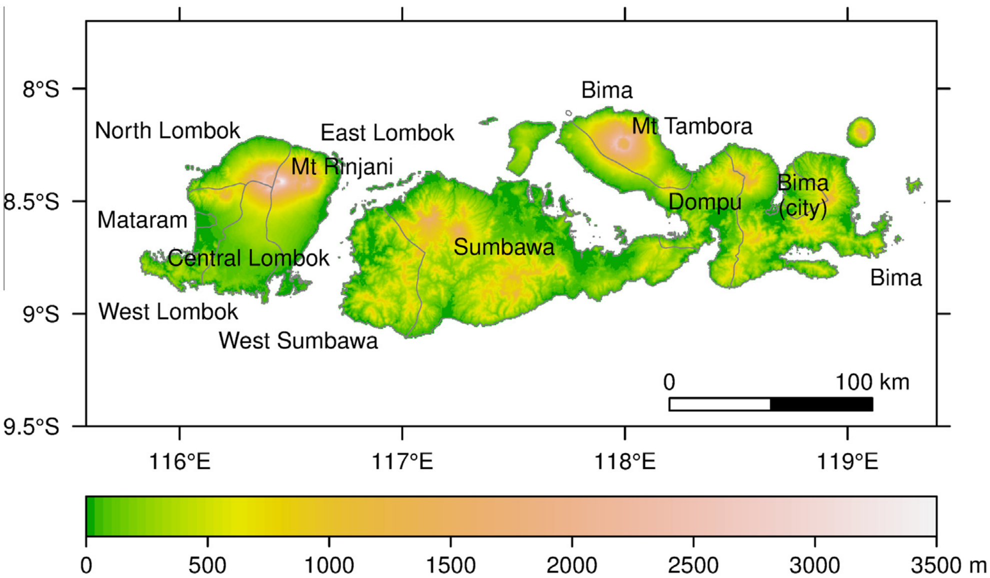

Fig. 1. Nusa Tenggara Barat Province, showing the eight rural districts, plus the two city districts (Mataram and Bima), Mount Rinjani and Mount Tambora.

NTB was practical. Our analysis therefore assumes that aggregate resource use by a subdistrict is reasonably representative of resource use by communities within the subdistrict.

Data sources

The following sources of data were available and collated for the 105 rural subdistricts and eight rural districts:

- *Habitat and land use:* GIS layers of topography (SRTM, Version 2.1, 2009; Farr and Kobrick, 2000), habitat types (e.g. forest; Department of Forestry, 2003) and land use (e.g. irrigated agriculture; National Land Agency, 2007).
- *Village livelihood statistics:* Village Potential Statistics (PODES), which is based on village-level surveys conducted alongside the periodic censuses (Statistics Indonesia, 2006, 2008). It includes information on economic activities, trade, industry, agriculture and land use of villages.
- *Community surveys:* In some cases there were data gaps in the available information and expert knowledge. Community surveys were conducted to fill these gaps (see below).
- *Fishery data:* Management of the fisheries zone (3 km off-shore) is the responsibility of district governments in NTB. Fishery records were sourced from the eight rural district governments and assumed to be representative of fishing activities for the coastal subdistricts within each district.

To address gaps in data on marine resources in Sumbawa, Indonesian members of the research team conducted rapid rural appraisal and key informant interviews to assess resource use patterns (Karnan et al., 2011). Interviews with local fishers, fish traders, fish landing place heads, fish cage owners and seaweed farmers were performed in Sumbawa, Dompu and Lima (mainly in and around Saleh Bay and Sape Bay) from December 2010 to March 2011, In addition, site visits were performed to validate the data.

The process for compiling information on EGS use by each subdistrict comprised the following four stage approach: (a) a data and literature review to provide a 'skeleton' of resource use characteristics within rural subdistricts; (b) preliminary listing of EGS used throughout NTB based on the skeleton, and refined with expert opinion, (c) semi-quantitative importance scoring of EGS (i.e. in terms of relative volume and value) by experts, and (d) additional community scale rapid surveys to fill data gaps and resolve uncertainties. This general approach follows that of Skewes et al., 2011.

A variety of datasets were used to provide context for the team and experts (e.g. Suadnya et al., 2011) and to provide a 'skeleton' of resource use for experts to further develop. Key datasets included PODES and topography, land use maps and forestry maps (see above). Although we initially attempted to derive information directly from data using analytical methods, this proved impractical because the available data did not sufficiently resolve EGS, subdistricts and/or their interactions. Also, some relevant datasets were biased because they represented only a subset of the use of an EGS (e.g. only commercial fish species rather than all species). In general, the available data contributed most to defining the 'stocks' of EGS (i.e. the capacity of an ecosystem to provide a service; Layke, 2009) in each subdistrict, whereas the flows of EGS (i.e. the benefits people receive from the stock; Layke, 2009) and the relative importance of EGS were mostly derived from expert knowledge.

Based on the data and literature review, a draft list of EGS used throughout NTB was developed by the Australian and Indonesian authors. The Indonesian members of the team then worked with local experts (mainly local researchers and government agency officers) to finalise the EGS list and assign a score (1–3) for the importance of each EGS within each subdistrict. Note that in some cases EGS scored as being used in a subdistrict were located outside that subdistrict (e.g. marine resources). The most significant gap in the data was for fisheries and other marine resources in Sumbawa. This gap was addressed by Indonesian members of the team through a literature review and a program of rapid rural appraisal and key informant interviews in the subdistricts concerned (Karnan et al., 2011), and data were integrated with the EGS listing and scoring for those subdistricts.

Classification process

We then classified each subdistrict based on the binary use or non-use of EGS by communities within its area. We reduced the ordinal scores (1–3) to a binary score because the scoring had not been adequately standardised across the dataset or by subdistrict. The classification method was partitioning around medoids (PAM), which is a non-hierarchical method similar to *k*-means. The distance measure used for the cluster analysis was the Hellinger distance. PAM with the Hellinger distance provides a clustering method that is basic, but robust, and relatively insensitive to noise in data. PAM requires the number of clusters to be specified in advance. We chose seven, which was small enough to simplify provincial-scale ADWIM modelling and resulted in clusters that were relatively well separated from one another. Cluster separation was examined with silhouette plots. To characterise the clusters after clustering, we examined the importance ranks of the EGS in the subdistricts of each cluster.

Congruence with districts

To assess the congruence between the typology and other established administrative boundaries, we compared the distribution of subdistrict types with rural district boundaries. We partly selected seven types for the typology in order to approximately match the number of rural districts (eight). We measured congruence as the information shared by the typology and district memberships, with information defined as Shannon information and partitioned as described by Legendre and Legendre (2012).

Results

Ecosystem goods and services

Overall, we identified 82 EGS derived from nine habitats, which included terrestrial, coastal, marine and freshwater examples (Table 1). EGS included livestock, cropping, forestry, hunting wildlife, fishing, aquaculture, mining, water and tourism. Note that we used habitat only in the definitions of the EGS (i.e. EGS were nested within habitats), and not as a spatial unit of analysis.

EGS subdistrict typology

We clustered the subdistricts into seven types (Table 2 and Fig. 2). This number of types resulted in clusters that were well separated from one another relative to clusters based on different but similar numbers of types. Types 1 and 2 were generally coastal, were located in eastern Sumbawa and Lombok, and had an emphasis on fishing. Type 3 was located on inland/slope areas of Lombok and eastern Sumbawa and had an emphasis on rice and bandeng ponds (milkfish aquaculture). Type 4 was located on coastal to highland areas around Mount Rinjani (mostly the eastern side) on Lombok and featured diverse agriculture and forest use. Type 5 was mostly found in the southern inland of Lombok and had an emphasis on dryland rice and tobacco. Type 6 covered all of western Sumbawa, plus most of west Lombok, and featured diverse livestock and cropping. Type 7 was located on coastal and highland areas around the west of Mount Rinjani on Lombok and featured diverse cropping and coastal activities.

The seven types captured 42% of the variation in the data matrix. The cophenetic correlation, which for non-hierarchical clusters is simply a measure of the similarity of a pair of sites from the same cluster relative to that of a pair from different

Table 1
The 82 EGS identified from the nine habitat types in NTB.

Forest		*Dryland*		*Coastal*	
1	Timber	1	Padi gogo production	1	Mangrove for timber
2	Honey bee	2	Soya bean	2	Mangrove for crab fishery
3	Palm sugar	3	Mung bean	3	Salt pond
4	Rattan, bamboo	4	Maize	4	Ecotourism
5	Durian	5	Cassava	*Coral reef*	
6	Mango	6	Peanut	1	Building material
7	Banana	7	Vegetables	2	Fishery
8	Coffee	8	Garlic	3	Ecotourism
9	Cacao	9	Onion	*Inshore*	
10	Candle nut	10	Durian	1	Fishing
11	Tamarind	11	Mango	2	Pearl farm
12	Cashew nut	12	Banana	3	Seaweed
13	Coconut	13	Pineapple	4	Brown algae (*Sargassum*)
14	Wildlife hunting	14	Coffee	*Offshore*	
15	Ecotourism	15	Cacao	1	Fishing
Wetland		16	Cashew	*River, spring water*	
1	Rice production	17	Avocado	1	Drinking water
2	Soya bean	18	Coconut	2	Agricultural irrigation
3	Mung bean	19	Jatropha	3	Ecotourism
4	Maize	20	Tamarind	*Ground water*	
5	Cassava	21	Tobacco	1	Drinking water
6	Peanut	22	Bandeng pond	2	Agricultural irrigation
7	Vegetables	23	Salt pond		
8	Onion	24	Buffalo		
9	Sweet potato	25	Cattle		
10	Rambutan	26	Goat		
11	Tobacco	27	Chicken		
12	Bandeng pond	28	Custard apple		
13	Prawn pond	29	Sand mining		
14	Salt pond	30	Pumice mining		
15	Buffalo	31	Strawberry		
16	Cattle				
17	Goat				
18	Chicken				
19	Red rice				

Table 2
Subdistrict types and their attributes.

Type	Area (km^2)	Population (2012)	Key features
1. Fishing	4135	509034	Inshore and offshore fishing Also buffaloes, cattle, ecotourism, seaweed, honey bees, rice
2. Fishing and seaweed	1791	156105	Fishing, seaweed Also buffaloes, salt ponds, mangos, bananas, durian, padi gogo, rice, mangroves
3. Rice and bandeng ponds	863	426938	Rice, bandeng ponds Also peanuts, vegetables
4. Diverse agriculture and forest use	1172	543731	Rice, irrigation, tobacco Also cattle, goats, vegetables, timber, drinking water, cassava, peanuts, mung beans, coffee, cacao, garlic, onions, bandeng ponds, ecotourism
5. Rice and tobacco	1198	1048565	Rice, tobacco Also padi gogo, cattle, goats, vegetables
6. Diverse livestock and cropping	9087	958412	Cattle, goats, irrigation, drinking water Also rice, buffaloes, coconuts, cashews, chickens, soya beans, mung beans, bananas, peanuts, maize, coffee, jatropha
7. Diverse cropping and coastal activity	967	253685	Irrigation, rice, ecotourism, fishing Also coconuts, maize, cacao, coffee, drinking water, cassava, cashews

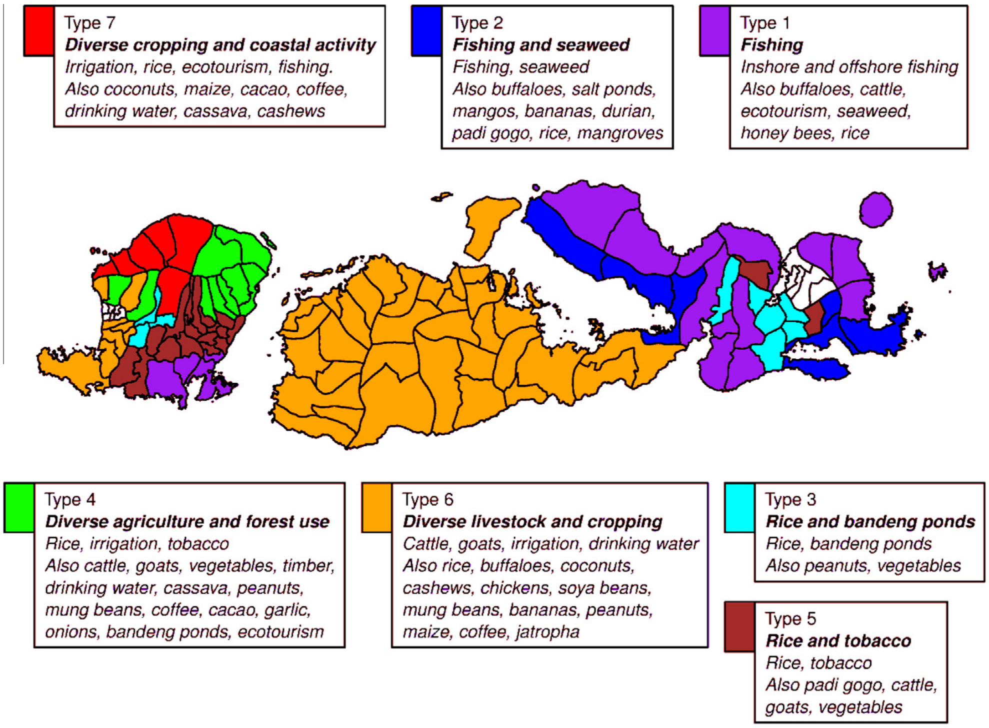

Fig. 2. Subdistrict types and the ecosystem goods and services that characterise them.

clusters, was 0.54 (as R^2). These statistics indicate that although the typology captured a substantial proportion of the variation in EGS use, subdistrict types were not homogeneous in that there was residual variation in EGS among subdistricts of a given type (Fig. 3). For example, although subdistrict type 6 was characterised by use of terrestrial EGS such as livestock and cropping, some coastal subdistricts of that type, such as Sekatong on Lombok and Sape on Sumbawa, also depended upon coastal and marine EGS such as fishing, mangrove timber and seaweed harvesting.

Subdistricts of a given type were generally spatially aggregated, but not completely in that there was often more than one 'clump' of subdistricts per type (Fig. 2). The 105 subdistricts were arranged into 21 clumps. On average there were three clumps per type and five subdistricts per clump. Clumps of a given type were often separated by relatively large distances. For example, the majority of types (five of seven) included subdistricts on both Lombok and Sumbawa.

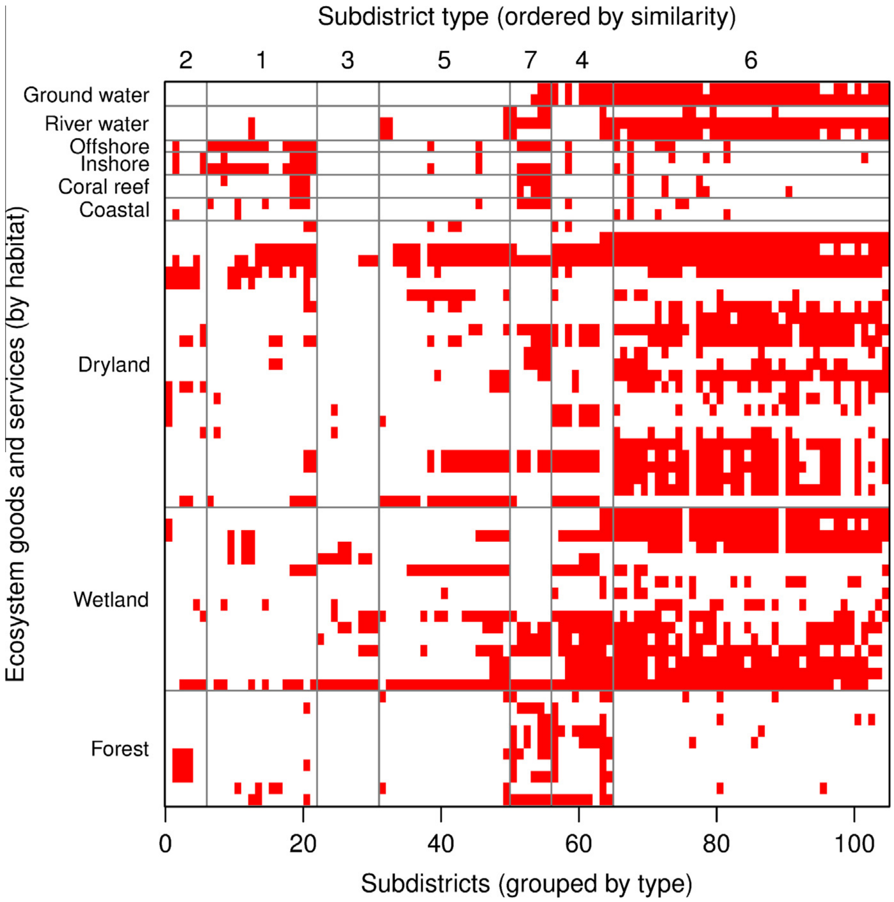

Fig. 3. Variation of EGS use within and among subdistrict types. The figure presents a re-ordered version of the EGS by subdistrict data matrix that was used in the cluster analysis. The subdistricts are grouped by type. The types and subdistricts are ordered by similarity of EGS use. (The *x* axis scale is the re-ordered subdistrict number.) The figure provides a visual representation of how EGS use (columns of data) is more similar among subdistricts of the same type than among those of different types.

Congruence with districts

There was some association between subdistrict types and districts (Fig. 4). The information shared by the subdistrict typology and district memberships was 41% of the total information of the subdistrict type by district contingency table. The district memberships contained 62% of the information in the subdistrict typology. Using the best association between districts and subdistrict types (one type assigned to each district), districts correctly predicted 54% of subdistrict types. North Lombok, Sumbawa and West Sumbawa each contained subdistricts of only one type. In contrast, Bima and Central Lombok each contained subdistricts of four types. Subdistricts of a given type were distributed among two to four districts and each district contained subdistricts from one to four types (average 2.4). For example, subdistrict type 1 (associated with fishing) was represented in four districts—two each on Lombok and Sumbawa.

Using districts in place of the typology, the eight districts captured almost as much variation in the data matrix as the seven types of the typology (40%), but the cophenetic correlation was lower ($R^2 = 0.24$), indicating that the clusters defined by the districts were less well separated than those of the typology. Reduced separation can be due to a mix of EGS within a district or a few atypical subdistricts in a district. For example, Bima included subdistricts of four of the typology subdistrict types. The majority were of fishing types (types 1 and 2), but others were from types characterised by wetland or upland rice production (types 3 and 5, respectively). In West Lombok, where subdistricts were mostly of type 6, Narmada and Gunungsari were of type 4, reflecting the emphasis on forestry EGS rather than dryland EGS in these two subdistricts.

Discussion

We developed a typology of the use of EGS by communities in NTB by numerical cluster analysis of a table of the use/non-use of each EGS by each of the 105 rural subdistricts. The typology comprised seven subdistrict types that explained

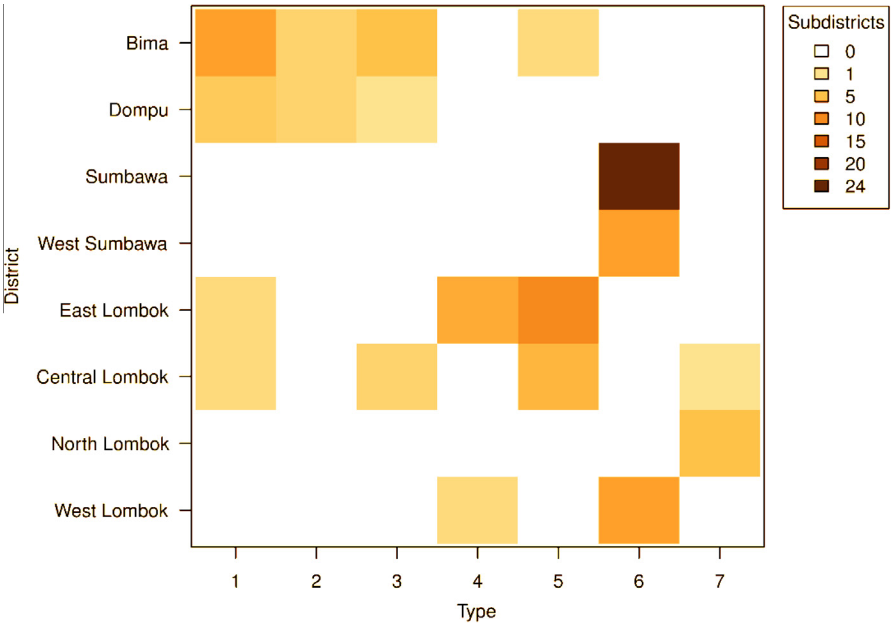

Fig. 4. Association between districts and subdistrict types. The graph shows the number of subdistricts in each district and type. For example, all Sumbawa subdistricts were of type 6, and all type 7 subdistricts were in Central Lombok and North Lombok.

a substantial proportion of the variation in the data table (42%). Residual variation of EGS use among subdistricts of a given type was potentially due to a variety of factors such as geographical variation in EGS availability and factors affecting the use of EGS in livelihood strategies, such as cultural preferences, education and the availability of infrastructure (Chambers and Conway, 1992). Some will also have been due to noise (from uncertainty) and possibly errors in the data.

Subdistricts of a given type tended to be spatially aggregated into clumps, but the aggregation was not complete and there was an average of three clumps of subdistricts of each type, and the majority of types occurred on both Lombok and Sumbawa. Because we did not encourage or constrain the cluster analysis to create spatially aggregated types, this aggregation is entirely due to the geographical pattern of the data: neighbouring subdistricts often made similar use of EGS.

We considered whether districts provide an alternative to the typology for grouping subdistricts for future impact assessment and development of adaptation strategies. The number of districts (eight) was in the target range for the typology, which ultimately had seven types. Compared with the typology, districts aggregate subdistricts into fewer, tighter clumps (usually just one). Districts also represent administrative units, which may be an advantage if development and implementation of adaptation strategies depends heavily on district administrators. Districts generally grouped subdistricts with similar EGS use together almost as well as the typology. However, on average they were less well separated due to exceptions such as districts with relatively mixed EGS use (e.g. Bima, Dompu and Central Lombok) and atypical subdistricts within otherwise uniform districts (e.g. West Lombok).

Livelihood typologies are typically defined with household as the classification unit using data specifically collected for the purpose with questionnaires and interviews (e.g. Yuerlita et al., 2013; Tittonell et al., 2010; Perret and Kirsten, 2000). In contrast, ecosystem service bundles are more often based on classification of broader units such as regions or communities using secondary (aggregate) data (e.g. Raudsepp-Hearne et al., 2010; Queiroz et al., 2015). Because we were classifying subdistricts for which existing data were available (e.g. government census data and land use maps), we made use of those data where possible. Exploratory analysis of the data provided context information for the research team, experts and stakeholders and enabled drafting of some skeleton data. However, these datasets were broad in scope and did not sufficiently resolve the EGS that were the focus of this study. The specific data used for the cluster analysis (EGS use by subdistricts) were therefore largely new data elicited from experts or rapid rural appraisal surveys (Karnan et al., 2011).

Although grouping subdistricts by natural resource use simplifies impact assessment and development of adaptation strategies, a potential issue arises when impact assessment is based on nominal values of driver impacts for subdistrict types (e.g. average values, typical values or values of a particular subdistrict declared to be representative). Nominal values of impacts may be less representative of subdistricts of a given type than nominal values of resource use because subdistrict types were defined by clustering resource use, and not impacts. For example, subdistricts of the same type but in different regions (e.g. type 1 in south-east Lombok and east Sumbawa) may experience different changes in climate, in which case the average change in climate for the subdistrict type will not be representative of the changes in one or both regions. Also, averaging over subdistricts from different locations will smooth climate variation because variation among subdistrict types will be less than variation among subdistricts.

Hence adaptation strategies developed at the scale of subdistrict types risk being too generic and targeted at impacts of drivers on the most prevalent EGS within each type. For our study, this problem justified the further development of strategies at the community scale, through a process which considered other subdistrict attributes including communities' adaptive capacity and stakeholders specific to the administrative unit concerned (Butler et al., 2015, 2016).

Having identified more specific strategies at the subdistrict level, there may be an intention to scale out strategies to other subdistricts within the same type. However, as shown or suggested above, other subdistricts of the same type may vary in the attributes upon which the strategy depends, such as EGS use, driver impacts, adaptive capacity or administration. Scaling out would therefore require testing of strategy assumptions and modifying the strategy to accommodate differences. The same issues would apply when scaling out a strategy to subdistricts within the same district (rather than type), although in this case we would expect differences to be greater for EGS use and less for attributes such as administration.

The vulnerability of less developed regions is exacerbated by a lack of information to inform appropriate adaptation planning. This is clearly the case in NTB, and the challenge is accentuated by the steep climate (Kirono et al., 2016; McGregor et al., 2015) and agro-ecological gradients across the islands (Butler et al., 2014), which requires data to be aggregated at a relatively fine scale. We were faced with multiple sources of secondary data, some of which was incomplete. To address this shortcoming we applied a four stage approach: (a) a data and literature review to provide a 'skeleton' of resource use characteristics within rural subdistricts; (b) preliminary listing of EGS used throughout NTB based on the skeleton, refined with expert opinion, (c) semi-quantitative importance scoring of EGS by experts, and (d) additional community scale rapid surveys to fill data gaps and resolve uncertainties. The resulting typology of natural resource use was intended for the participatory modelling of potential future climate and population growth impacts on the natural resource base, through ADWIM (Skewes et al., 2016). However, we suggest that this approach could be useful in other similar situations where rural community resource use is diverse, and information is incomplete or inadequate, to inform adaptation planning.

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