Marine Policy
January 2022, Volume 135 Pages 104848 (9p.)
https://doi.org/10.1016/j.marpol.2021.104848
https://archimer.ifremer.fr/doc/00733/84537/

Indonesia's 13558 islands: A new census from space and a first step towards a One Map for Small Islands Policy

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Abstract :

Indonesia is the largest country made only of islands, with previous census identifying between 13,000 and 25,000 islands. The current official figure puts the number at 17,508 islands. Landsat satellite images were used to provide a documented consistent inventory of the country's islands. A total of 13,558 islands were mapped considering a minimum size of about 0.001 km2-with 87% and 39% of the islands covering less than 1 and 0.01 km2 respectively. These numbers highlight the dominance of small to very small islands. Beyond providing new accurate spatial statistics, we argued that the island census could be the foundation of a One Map for Small Islands Policy. Indonesia launched its One Map Policy in 2017 to mitigate land use conflicts in the largest of the islands, but small islands have their own development, social and conservation issues, and an extension of the One Map Policy vision to Small Islands is warranted.

Keywords : Landsat, Millennium Coral reef Mapping Project, Coral triangle, Island typology, Karst

1. Introduction

Indonesia is a country of islands. From 95°E to 141°E of longitude and spanning three degrees of latitude on both side of the equator, the matrix of small and large pieces of '*land emerging at high tide*' (i.e., islands, *sensu* United Nations Convention on the Law of the Sea) spread in the 4.57 million km^2 Economic Exclusive Zone make Indonesia the world's largest country comprised solely of islands.

From the massive Sumatra to tiny reef islands, the gradient of island sizes and physical diversity is the main driver of the biological and human diversity of this part of the world through the antagonistic effect of both the isolation of the islands and the connectivity given by the sea [1]. The unique biological richnsess in both terrestrial and marine habitats was recognized as a high priority conservation target. For instance, the Coral Triangle Initiative emphasized the coral reef component of this richness [2]. The uniqueness of the Indonesia archipelagic mosaic were first demonstrated following the terrestrial biodiversity work by Wallace (1869) [3]. Alfred Wallace's early natural history findings, explained in terms of island physical isolations, were previews of all the insular processes that shape the archipelago, in ecology and evolution, geodynamics, climate, anthropology and societies, and through the interactions between all these factors [4, 5].

Islands drive the current Indonesian's challenging but opportunity-rich economy. Exploitation of mineral and biological resources, tourism, aquaculture and maritime traffic are Indonesia's major economical assets. Conversely, pollution mitigation, erratic coastal development, deforestation, overfishing and subsequent biodiversity losses are significant issues that the governments, present and future, need to address with adequate data.

In May 2017 Indonesia officially launched its One Map Policy initiative. This initiative was launched to solve conflicts on land and the problems of different representation in, at the time, 19 ministries and institutions in 34 provinces [6, 7, 8]. In practice a series of thematic maps at different scale (1/25000, 1/50000, 1/250000) are assembled to produce 85 different data layers required to describe rainfall, topography, geology, soils , minerals, mining hydrology and water resources, forestry, natural disaster risks, land cover and land use, and infrastructure systems

[6]. The initiative is a strategic pathway for the future of Indonesia to regulate the compilation, improvement, standardization, distribution and unification of geospatial data for policy formulation and problem solving. From this initiative, Martha (2017) [9] advocated also a small island point of entry, which inherently would help focusing on coastal conflicting issues, especially for Indonesian small islands [10]. Such conflicts include those related to fishery, aquaculture, mineral resources and water resources [11, 12, 13], but also transport, health, natural disaster, climate change and pollution management [14, 15, 16]; as well as ecosystem restoration, biodiversity conservation and spatial planning [17, 18, 19], diversification of activities in rural areas with in particular tourism development [13, 14, 20], education planning and training for young population [21]. Not all islands are facing the same problems and many high priority issues can be local, and often include a number of all the issues listed here that interact together [14]. Yet, many issues are shared, and ensuring common data for consistent assessment between islands is a logical step.

The 'One Map Policy', which is on-going and close to its completion [6], and the planning of an extension towards small islands is however impaired by the lack of an accurate island census, nationally but also at many scales of governance [6]. Indeed, previous census of Indonesian islands reported numbers varying from 13,000 to 25,000, depending on the sources [9, 22 and references therein]. The most frequently cited figure today is 17,508 islands, officially listed by the Indonesian Coordinating Ministry for Maritime Affairs, but the exact methodology used to reach this number is unclear. According to an earlier census in 2002 by the National Institute of Aeronautics and Space performed with Landsat satellite images, the Indonesian archipelago has 18,307 islands. According to Indonesia's National Coordinating Agency for Survey and Mapping, and after a geospatial remote sensing based survey conducted between 2007 and 2010, the total number of islands in the archipelago was 13,466. A total of 13,667 islands is reported by Hopper [22], of which 6,044 are named, according to a navy survey completed in 1967. According to recent estimates made by the government of Indonesia 8,844 islands have been named, with 922 of those permanently inhabited [9]. As of 2018, it is reported that 16671 island names (so more than the official number of islands) have been verified by the United Nations Group of Experts on Geographical Names. While there are several published island numbers, statistics of island sizes throughout its full range, or distribution map of island densities are still lacking [9, 23]. These figures would be critical to move ahead for a One Map for Small islands Policy.

The discrepancies between the presently available numbers can be explained by semantic and technical differences. Some censuses could have included ‘tidal islands’ (sandy cays and bars, rocks and reefs that appear during low tide and are submerged during high tide) and others not. Furthermore, unclear methodology, relying on a combination of field surveys, charts, remote sensing and possible import from ancillary global geospatial databases, may have confused the inventories. The two-fold difference between sources in number of named island is also quite puzzling, and it is not clear if duplicate names, in different languages, could explain this discrepancy.

Here, we intend first to set the number of islands straight with a new remote sensing-based census of all Indonesian islands that is conducted independently of all previous databases. Then, we discuss the value of this new census in the context of the One Map policy initiative, and especially towards a small islands extension. We advocate that the new island data set could be the pilot driving-product for such an initiative. Finally, we also discuss how a One Map for Small islands Policy, with additional data complementing the island census provided here, can be critical for a variety of challenging management issues.

2. Material and Methods

To identify islands, we first use the Land mask created by the Millennium Coral Reef Mapping Project (MCRMP, [24, 25]) which was mapped from the Near Infra-Red, Green and Blue bands of Landsat 7 ETM+ images acquired between 1999 and 2003 and included in the MCRMP image database. Indonesian MCRMP images were processed in 2006-2007. The MCRMP Land mask available as a vector GIS shapefile includes land masses, reef islands, some large sand banks, and mangroves, but it carefully avoided, through manual editing, intertidal coral and algal reef flat and crests at low tide that can be easily confused with vegetated land using NIR spectral bands in remote sensing images. Large rivers were truncated upstream and included in the land mask, but the coastal areas kept details of their outlines. Lakes (and islands in lakes) were included in the land masks. Depending on the complexity of the scene and its quality (sometimes, several images were required due to cloud cover), the Land mask for any given image could be produced between few minutes to few days, but the exact time for the land mask production for each Path-Row was not recorded.

Using a GIS software (QGIS® or ArcGis®), a first check of the MCRMP mask considering the focus on islands was performed for complex areas across Indonesia using 36 more recent Landsat 8 OLI images (NIR, Green and Blue bands 5, 3, 2 were also used). Images were acquired between 2014 and 2019 and were available from the United States Geological Survey (USGS)'s Earth Explorer portal (https://earthexplorer.usgs.gov/). Level 2 radiometrically corrected data were downloaded. A first classification of problems emerged, identifying rocky points and promontories, patchy isolated mangroves, mud flats in estuaries, sand banks on reef flats and aquaculture basins bordered by pathways as ambiguous areas to define islands. Although they are intertidal, hence, not compliant with the definition of islands according to the United Nations Convention on the Law of the Sea, decision was taken to consider as Islands individual mangrove islands and rocky promontories clearly separated from main land. Isolated mangrove islands were kept as islands considering their high, emerged canopies and their ecological role for numerous terrestrial and avifauna species.

Because the MCRMP project did not process all Indonesia areas and in particular the turbid areas where coral reefs are absent [26], an extended Indonesia mask land was specifically created for this project using Landsat 8 images. Images were also acquired between 2013 and 2020, available from the USGS Earth Explorer portal, at Level 2 processing levels. Generally, only one image was used for a given Path/Row, as the best one available in term of cloud cover and environmental quality. 53 WR2 path-row and Landsat 8 images were processed for areas not processed by MCRMP or to correct gaps in MCRMP. This represents 23% of the total Indonesia area, which is covered by 226 path/row (Figure 1).

The initial completed vectorized Land mask included about 17,000 polygons, among which 3,915 had a size around 900m^2, which is the size of one Landsat pixel. These 1-pixel polygons were all visually checked against cloud-free Landsat 8 images or Google Earth ® (GE) imagery. GE is considered here as a valid mean to provide pseudo-ground-truthing data when Very High Resolution (VHR) images at few meter spatial resolution are displayed. Not all Indonesia areas are covered by VHR images in GE, and many are actually masked, but it was possible to assess the validity of all these 1-pixel polygons with either GE or Landsat 8 cloud-free data. In their majority they were confirmed to be processing artefacts, generated by the MCRMP raster to vector process, but not all. Eventually, we found, after editing, that 845 of these polygons corresponded to actual islands.

Since this control was manual and visual, any other artefact visible immediately around these 1-pixel polygon was also corrected. This included either removing larger polygons that were not land (e.g., sand banks), or adding pieces of land, generally small, that were missing. This control was spread across the whole of Indonesia. Additional corrections took care of merged islands, sometimes large, and riverine islands. Special care was necessary to refine the areas of high island density, including the east-coast of Sulawesi, the west coast of Halmahera, the Riau Archipelago, the channels around Aru Island in south Maluku provinces, and the karst islands around Misool in West Papua.

Frequent geographic shifts were observed between the contours of the Land shapefile and the features visible on GE background, or between Landsat images di. These are normal errors due to the inherent geodetic precisions of each geospatial product. In some cases the position discrepancy could be as high as 300 meters. Typical imprecision was, however, around 70-100m. Note that a shift against a GE background does not mean the Landsat product is inaccurate. The problem can come from the GE background, or be an accumulation of errors from the different sources of information. Since our focus was to estimate the number of islands and estimate their size distribution at Landsat spatial resolution, we have not attempted to systematically rectify the observed shifts, as the spatial shifts do not impact number and sizes. However, as in any GIS project, this step may be necessary when different layers of data will be combined, should a One Map for Small Island Policy project be launched.

Eventually, all polygons left on the final Land mask were considered as Islands. The count of polygons gave the number of islands. Some islands are smaller than $900m^2$ due to digitization of small missing islands that were not square.

The surface area of each polygon was computed using ArcGIS ®. A map of island densities was also computed using the ArcGIS® tool box. For islands shared with other countries (Borneo, Papua, Timor), only the Indonesia area is provided. Areas were computed using the WGS 1984 Word Mercator projection.

The product is available as a single GIS shapefile, in the WGS 1984 Word Mercator geographic system, with standard metadata.

In summary, the main steps to keep in mind to conduct, or reproduce, the work presented here, are:

1. the type of data sources (existing MCRMP GIS products, new Landsat 8 satellite imagery, and Google Earth © background when available),
2. the selected projection reference (to compute surface areas).

3. the method (i.e., photo-interpretation using the near infra-red spectral band, more effective to identify and discard as islands emerged reefs at low tide, cloud shadows, etc.). This approach can yield variations between practitioners and is time consuming but drastically reduce the time required for quality checking (next).
4. the need for systematic checking and validation of all suspicious, possible false-positive, one-pixel size islands. This is especially necessary if an automatic classification is applied instead of photo-interpretation. The quality-control process for one-pixel polygon can be systematized for all polygons and this is actually recommended, although large false-positive polygons are unlikely if step 3 is followed.
5. A source of errors more difficult to detect are false negative, or omission errors. This occur when (generally small) islands are missing. This implies to return to different satellite imagery, ideally of higher quality than previously used for MCRMP (e.g., Landsat 8 versus Landsat 7). Missing very large islands, or part of an island, is unlikely but clouds and poor quality images can explain these problems.

Other protocols can be applied. If the work is conducted without the import of pre-existing MCRMP data layers, or with other type of data layers that may call for a different quality-control steps.

3. Results

New remote sensing based census

A final total of 13,558 features ultimately qualified as islands, with thus a minimum size of about 900m^2. This is very close to one of the previous figures apparently achieved from geospatial processing, at 13,466 islands [9] and close to the 13,667 islands larger than 800 m^2 reported by [22] from a Navy survey, but far from the current 17,508 official number.

The distribution of island sizes is presented Figure 2 and the spatial distribution is highlighted Figure 3. It becomes in particular apparent that 87% of the islands cover less than one km^2, while 39% cover less than one hectare (Figure 2). Following an arbitrary 1x1° grid, the top-four richest areas, with 600 islands or more, are located around Misool, Aru, Raja Ampat and the western part of the Riau Archipelago (Figure 3). Our estimated total land area represents 1,895,257.5 km^2 (using the WGS 1984 Word Mercator projection) 92% of which is represented by the 13 islands larger than 10,000 km2 (with 86% explained by Borneo, Sumatra, Papua, Sulawesi and Java alone, Figure 2). Another 4% is covered by the 23 islands larger than 2000 km^2. These numbers highlight the dominance of small to very small islands in Indonesia.

4. Discussion

To our knowledge, previous Indonesia island census efforts did not produce user-friendly Geographic Information Systems (GIS) layers, or they were incomplete, which is a common issue for Indonesia [6]. The files previously available online from official governmental offices that we could access displayed less than 10000 islands (polygons), with some obvious gaps. Here, the now available GIS island product can be imported by any interested parties and processed according to relevant administrative and management boundaries, such as national fishing zones, provinces, regencies, marine parks, and any other governance entity.

Hereafter we discuss the limits of the island product, its necessary extension by joining important island attributes (such as their main types), and its potential for a One Map for Small Islands Policy, first as a key reference data layer on its own, and second, as a pillar for the integration of additional specific data sets that could foster applications relevant for small islands.

4.1 Census uncertainty

If the spatial resolution of remote sensing data could be increased, from the Landsat 30m resolution up to the 0.5-5m resolution of commercial satellite sensors, it is likely that the number of islands will increase. For instance, the network of karst islands east of Misool or Raja Ampat in West Papua have numerous emerging features smaller than the minimum discernible unit of Landsat (Figure 4). It is however difficult to state that a new census at very high resolution will converge towards the previous ~17,500 islands, even by assuming island numbers are controlled by fractal laws at the scale of a few meters [23]. Importantly; the exact number will also depend on which feature is eventually included in the definition of an island, and their actual relevance for a variety of applications. For instance, compact clusters of mangrove trees smaller than $1000m^2$ may not be considered as islands anymore. Similarly, if 2-meter resolution imagery allows detecting $\sim 10m^2$ 'islands', it is unlikely that these entities would still be considered as islands if islands are defined by the suitability of their uses by humans.

Mangrove islands in particular posed both semantic and detection problems. Semantically, mangrove islands are not islands according to the UNCLS definition, but they often have local names starting by '*pulau*' (meaning 'island' in bahasa Indonesia). Mangrove islands are included in this census. Technically, many mangrove islands often displayed high level of fragmentation and were the most problematic to resolve at Landsat spatial resolution. Islands forming, or bordering deltas, or high in rivers also posed semantic problems but not identification problems. These riverine island types are frequently also mangrove islands. Finally, sand cays frequently found on coral reef flats were not considered as islands here, as many are likely completely submerged from time to time, and can be transient by nature [27].

Numbers if islands may change in time, but only slightly, due to changes caused by anthropogenic and natural factors, such as aftermath of volcanic eruption (e.g., modifications around Anak Krakatau volcano) or earthquakes. Remarkable massive changes were also visible on rare instances that have occurred since 2003, after the initial MCRMP Land mask was created using 1999-2003 images. Artificial islands have appeared in Jakarta Bay, or in Bali Benoa harbor for instance. Also, large changes from Nias to Mentawai islands, west of Sumatra, were readily visible. These are due to the 26th December 2004 Sumatra-Andaman Earthquake that uplifted vast section of coral reef flats [5], now emerged and vegetated (data not shown here, but visible on Google Earth ®). These areas will be the object of future specific change-detection work.

4.2 Island typology baseline attributes

Indonesia islands morphological and geological diversity is complex [4]. Even without taking into account the full range of geologic, climatic and human factors that have shaped the islands, an island typology, even simple, is useful for their characterization and comparison. For instance, Bunaken National Park includes five islands at short distances (Bunaken, Manado Tua, Naim, Mantehange and Siladen, all separated by less than 20 km). Mantehange is flat and dominated by mangroves, Manado Tua is a high conical dormant volcano, Bunaken is a high remnant volcano, Siladen is a flat, few meter-high, carbonate reef island, and Naim is a high island, probably also from volcanic origin and surrounded by a deep lagoon and a large barrier reef that are absent from the four other islands. All together these five contrasted islands and their surrounding coral reefs could make Bunaken a unique cluster of island types in Indonesia. A first-cut on island typology can be suggested by the identification of the main island, only using the information provided by satellite imagey (Table 1). Further work, in progress, should assign all mapped islands to one or several of the main types listed in Table 1, and detail more each of these broad categories when possible. This is a necessary first step towards a richer thematic product.

4.3 Island census product as a baseline for the One Map for Small Islands Policy

We take advantage of the new GIS island product to promote the view of a *One Map for Small Island Policy* defended first, at least in an academic context, by Martha (2017). This initiative, matching for small islands what was launched for large islands terrestrial areas, would be tremendously useful to help solve coastal issues in Indonesia.

From the new island data set, immediate benefits for Indonesia's marine and small island development, management and conservation policies would be accurate estimation of areal figures, better regional planning and prioritization for both exploitation and conservation programs, adequate funds distribution based on consistent island numbers and sizes, and other decisions presently impaired by lack of consistent data on the number and sizes of targeted islands. Using island size and type statistics also inform on the gaps and priority data layers to fill first, as one can expect medium size islands and their peripheral smaller inhabited islands to receive more management attention in the future. Obviously, allocation of funds for infrastructure, development and conservation cannot be based only on island numbers and sizes. Other criteria are necessary, starting with human population census and density. At this stage, it is not possible to pair each island of the inventory we provide here with human census data, but it is possible to link clusters of islands to a variety of governance scale and entities, such as regencies for instance. Coastal regencies have a number of islands under their authorities.

4.4 Towards a *One Map for Small Islands Policy* and expected value

Obviously, the island census presented here will not be the only required dataset to address small island problems. There are many topics, institutional issues (e.g., fragmentation or overlap of governance offices responsibilities [28]) and socio-cultural diversity and values [29] to recognize, for which multiple data sets are required. Nevertheless, the island census would provide a reliable foundation to link with, compile and create useful information while identifying gaps as said above.

Beyond a first baseline island map product, the value of a One Map for Small Island policy lies in the compilation, homogenization, creation and distribution of ancillary data sets relevant to address management issues at various levels of governance, including indigenous management levels, directly performed by local communities. We list hereafter a number of applications that are relevant at multi-scale (from national to archipelagic) that have emerged in academic papers, requiring data and covering topics in biological, environmental, conservation or human sciences, but there are many more that carry strong weight for the socio-economic wellbeing of the mosaic of Indonesian communities and islands. We can emphasize here:

- Implementation of shoreline monitoring, training, auditing and clean-up to mitigate marine plastic pollution, which is critical for a country previously identified as a major marine polluter [15, 30] can be optimized with better knowledge of island sizes and distributions, and oceanographic currents around them. This is in line and coherent with recent oceanography and remote sensing infrastructure development to enhance the management of Indonesian coasts and seas with spatial data [31].
- Coastal ecosystem and habitat (including coral reefs, mangroves and seagrass) monitoring to assess their resilience to disturbances, should benefit from a consistent and carefully prioritized and representative sampling strategy defined through consistent maps of islands and their habitats. This allows to be more efficiently reactive to disturbances, which can include planed coastal development (for aquaculture or tourism for instance), pollution, natural disasters (tsunamis), coral bleaching and other mortalities during ENSO events, or deforestation [32, 33, 34].
- Related to the point above, the coastal habitats support significant Nature's contribution to Indonesia people (NCP, *sensu* Diaz et al. [35]) including subsistence and commercial fisheries, as well as incomes through collection of species for the marine ornamental trade. Fishery management is a major challenge in Indonesia small islands, with overfishing, illegal fishing, loss of habitats, and necessity to spatially define trade-offs with other activities and conservation restrictions. Although there are many purely local cultural factors and significant heterogeneity between situations [29, 36, 37], consistent spatial data on critical habitats, resources, levels of exploitation, fishing boat density, markets, resource status that

can be itemized per island or clusters of islands should be a priority at the scale of the different fishing grounds to establish coherent assessments and strategies.

- With about 20 million tourists visiting Indonesia before the covid-19 pandemic, the national government was aiming towards a staged tourism development strategy for a number of archipelagoes, including remote ones, to replicate the success of several key sites (e.g., Bali), spread the financial benefits of tourism and lighten the environmental pressure on the most visited islands that are now way beyond their carrying capacity, like Bali or the Gili in Lombok [20, 38, 39]. Although the pandemic may have slowed, and questioned, this strategy, a One Map for Small Island initiative appears necessary to assess in different areas the requirements in infrastructures (transport), resources (water), training, etc. [21], to establish an attractive tourism industry, sometimes virtually from scratch.
- In possible conflict with tourism development and conservation programs, aquaculture and mariculture management sustain many islands, as the main activity or as part of a portfolio of activities. While space-hungry shrimp farming industry is rather developed in large to medium-size islands, seaweed farming is ubiquist and a critical livelihood activity for small communities in all island types [13, 14, 40 and references therein]. Data sets on biomass production, trade networks, habitats, depth, water quality would all be informative to manage seaweed farming development and its market over the long run. Further, restoration of mangroves nearby abandoned ponds, that are common throughout Indonesia, need monitoring and spatial assessment to allocate the efforts [41].
- Finally, Indonesia is very exposed to geophysics risks due to its numerous volcanoes and earthquakes, that regularly strike and brings damages in both urban and rural coastal areas [42]. Recently, Sulawesi (in 2018), Lombok (in 2018) or Sumatra (in 2004) experienced earthquakes and tsunamis that severely impacted the coastlines and their local or visiting populations, but also the myriads of small islands in their vicinity, such as the Mentawai archipelago on the Sumatra west coast. Evacuation plans, urban maps, terrain models, bathymetry are some of the data sets useful to mitigate the risks and inform the island communities on best strategies in case of an event.

These few examples could all require specific developments that will all have local specificities, yet, they all require a number of key data layers common to the majority of the islands, in agreement with a One Map policy vision. The first common layers can be the island census provided here, and its further improvements, if any.

Practically, to go further, we suggest that space technology projects could be the catalyzer of the developments for a One Map for Small Islands Policy framework. One possible way forward could be a follow-up of the INDESO project which has provided marine and coastal remote sensing products to Indonesia [35]. Officially formalizing the idea with a coordinator tied to the Ministry of Marine Affairs and Fishery would be relevant although this scheme would need to include other national ministries and local partners afterwards, for further integration, and dissemination, of relevant data sets.

The implementation of a One Map for Small Islands Policy can also benefit from the lessons of the One Map Policy project that is under completion. Issues are emerging now that includes the choice of some data sources and more importantly some critical gaps, such as how to represent locations critical to indigenous rights. For small islands and their marine and coastal areas, any decisions related to livelihoods, through conservation, closure of fishing areas, coastal developments, planed diversification (if for instance tourism is continued to be developed despite the risk of collapse as seen during the covid-19 pandemic) and other types of actions should ideally require the input from local communities to ensure better compliance and equitable benefits from the taken actions.

4.5 Beyond Indonesia

Obviously, other Asia and Pacific countries could benefit from similar information on their islands, and regional connections and data sharing could be enhanced if the products are consistent. The connection between countries is apparent, among other schemes, in the APEC (Asia-Pacific Economic Cooperation) network which promotes international collaboration and experience-sharing within the Asia-Pacific region, included in the marine realm (https://www.apec.org/Groups/SOM-Steering-Committee-on-Economic-and-Technical-Cooperation/Working-Groups/Ocean-and-Fisheries, accessed October 2021). On-going Indonesian-led projects related to marine management shared within APEC includes the development of marine plastic debris monitoring systems for instance. Similarly, Indonesia could promote One Map for Small Islands Policy at the APEC scale, or for some of its 21 countries which share common boundaries with Indonesia. Consistent and adequate data layers will be useful for transboundary management and decisions.

5. Conclusion

Locally and internationally, the potential, and motivation, for further scientific research, data production and management of Indonesian islands with local stakeholders should be strengthened by new self-consistent and documented island census, such as the one performed in the first part of this study, which can be followed by thematical and geographical enlargement on areas of higher interest for conservation, development, and risk management issues. Better knowledge of Indonesian islands abundance and diversity, and the full realization of the different configurations in the various archipelagoes, should promote more interest and activities in the future for both local, national, and foreign data producers and users, as well as sustained supports from funding agencies.

Acknowledgements

This work is a by-product of the Infrastructure Development of Space Oceanography (INDESO) project (2013–2018), which was funded by a loan from Agence Française De Développement to thsse Indonesian Ministry of Fisheries and Marine Affairs. The Millennium Coral Reef Mapping Project was initially funded by NASA grants NAG5-10908 to SA and Frank Muller- Karger (University of South Florida), and grant CARBON-0000-0257 to Julie Robinson (NASA). The project is now funded by Institut de Recherche pour le Développement for specific application and projects. We are indebted to the PIs, and to Christine Kranenburg, Damaris Torres-Pulliza, Alan Spraggins, Brock Murch and Chuanmin Hu for their time and hard work during the initial phase of project (2002-2007). The Indonesia GIS product is available through the DATASUD repository (https://dataverse.ird.fr/ ; DOI = XXXXXXX). We are grateful to the two reviewers who helped strengthening the message carried by this study.

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Figures

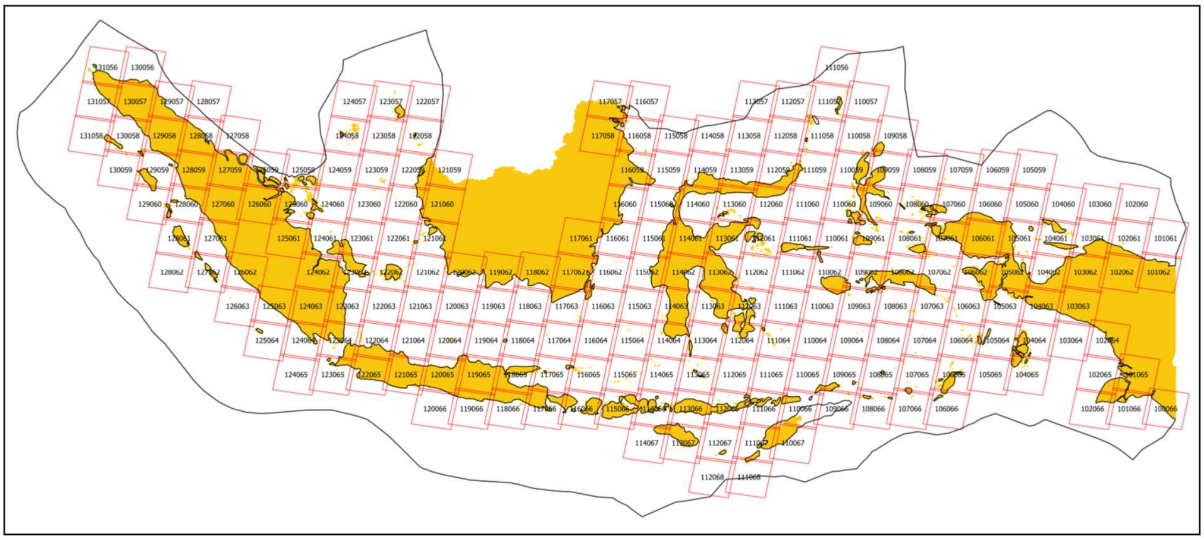

Figure 1: Map of Indonesia with the World Reference System grid of Path-Row (ppprrr number in cells), showing the 226 cells necessary to cover islands and coastlines with Landsat images. The blue outline represent the Indonesia Economic Exclusive Zone in which the island census took place.

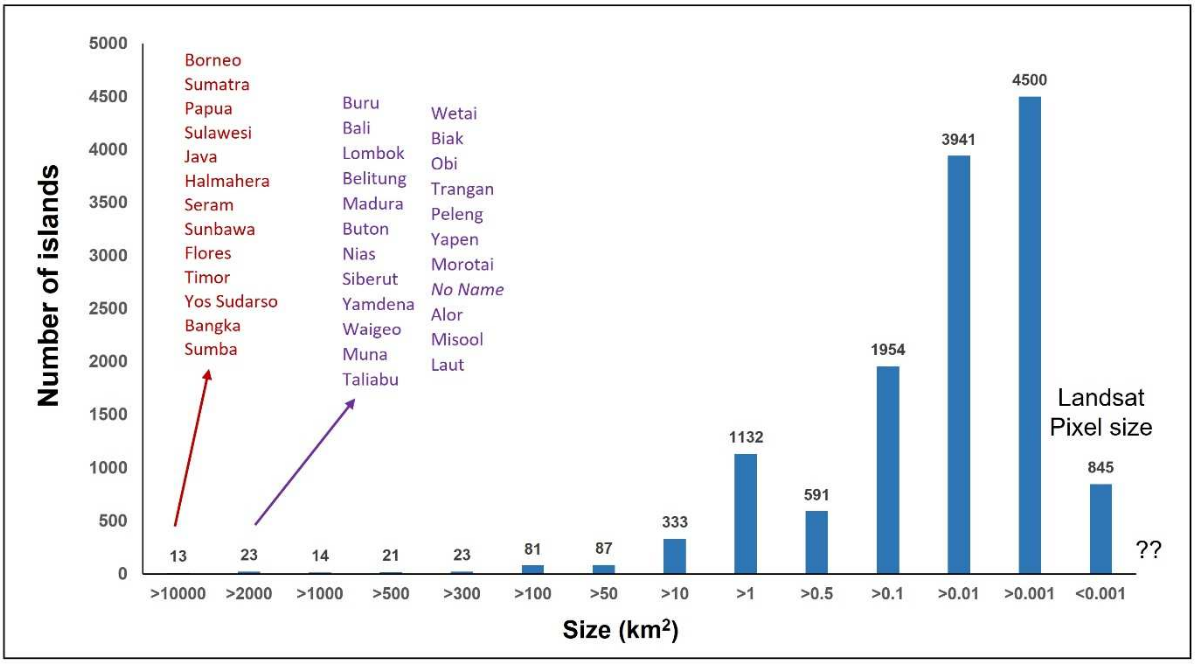

Figure 2: Size distribution of 13,558 Indonesian islands censused from Landsat satellite images (900 m^2 pixel size, or ~0.001 km^2). The name of islands that make the two first classes of sizes are provided. The “??” indicates that the number of islands smaller than the footprint of a Landsat pixel is not known.

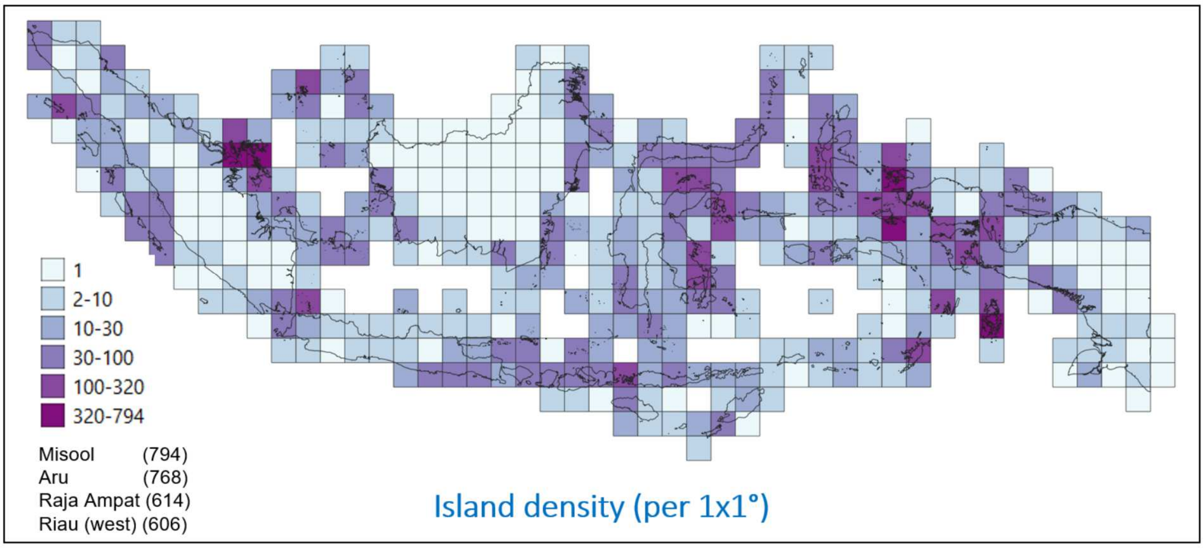

Figure 3: Density of islands across a 1x1° grid. A generic name of the four locations with a score >600 islands are provided on lower left inside.

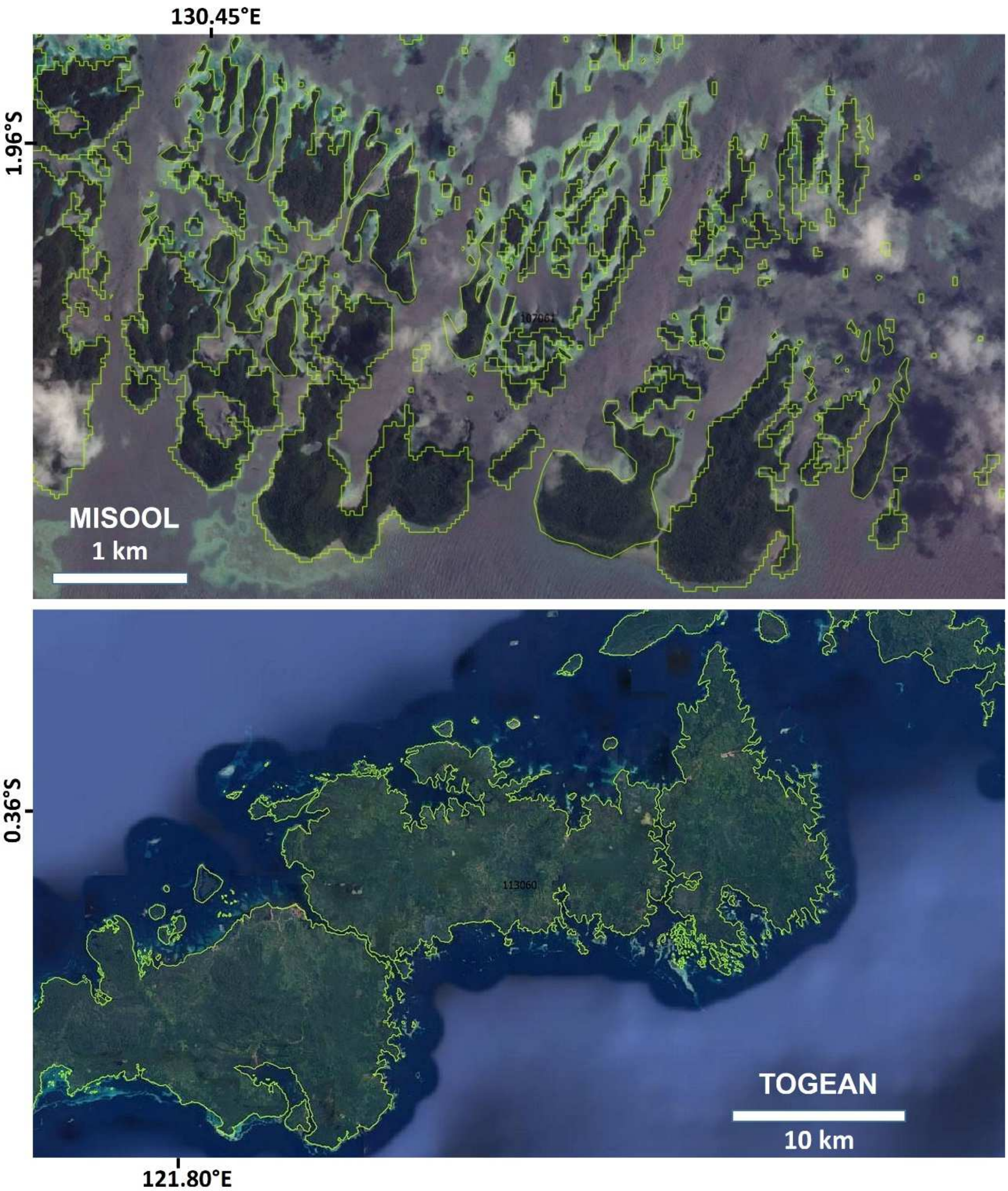

Figure 4: Using a very high resolution Google Earth® background, examples of island delineation for karst islands around Misool Island in West Papua (top) and for the Togean Islands in the Gulf of Bimini in Sulawesi (bottom). The displayed Misool and Togean areas include 193 and 119 islands respectively. Note the different scales. Yellow outlines show the individual islands after import from the Millennium Coral Reef Mapping Project (MCRMP), editing to remove false-positive one-pixel polygons, and editing to add missing polygons that may have been under clouds in MCRMP imagery or missed. Smooth features were manually corrected, while non-smoothed, pixelated polygons directly come from the MCRMP product based on 30 meter resolution Landsat data. Smoothing of these features can be done in post-processing, at users' will. The Misool area is part of the most complex and dense areas, for which further mapping at very high spatial resolution (1-10 m) could affect the number of islands, should very small features still be considered as islands. The Togean area is more typical of medium-complexity Indonesian shores with clusters of small to medium islands that are satellites of larger ones.

Figure 5: Examples of island types found in Indonesia (see Table 1). a) Large 'sub-continent' islands, b) High islands and rocky points, c) High island (here without coral reefs) d) High island (here with coral reefs), e) Carbonate and karst islands, f) Reef island, g) Mangrove island (photos. S. Andréfouët).

Table 1: Main types of islands (examples are provided Figure 5)

Type	UNCLS compliant	Examples	Example (Figure 5)
Large 'sub-continent' islands	Yes	Sumatra, Java, Sulawesi, Borneo, Papua	Photos a, b
High islands and their smaller satellite islands	Yes	Halmahera, Nusa Tenggara, Banda, Mentawai, Riau, Timor, Seram, Sangihe, etc	Photos c, d
Reef islands	Yes	Kepulauan Seribu, etc.	Photo f
Carbonate and karst islands	Yes	Kei Kecil, Wakatobi, Misool, etc.	Photo e
Mangroves islands	No	Frequent in Papua	Photo g
Estuary islands	No	Frequent in Borneo, Sumatra	
Rocky points	Yes	Frequent in Lombok, Java, Sumatra, etc.	Photo b
Artificial islands	Yes	Jakarta Bay	