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Regional Guidelines for the Application of Ridge to Reef (R2R) Spatial Prioritization and Planning Procedures to Identify and Select Priority Coastal Areas and Sites for the Conservation and Sustainable Use of Ecosystem Goods and Services

Summary:

Identification and selection of priority coastal areas for conservation and management is commonly guided by information and observations, which may be qualitative or quantitative. This is a common practice in Pacific Island countries where available information may be lacking and resources supporting resource assessments constrained. The R2R spatial prioritization guidelines set out in this document complement the existing ones in the "tool-box" where their uses and applications may be already widely documented and accepted as best practice. The guidelines are intended for stakeholders and resource managers to use and apply in work up-scaling R2R investments and land-sea integrated planning of ecosystem goods and services.

Recommendations:

The R2R Technical Consultation is invited to:-

(i) Consider and discuss the working draft, reflecting on clarity, relevance and practical application of the guidelines in the context of Pacific Island Countries and Territories; and
(ii) Provide advice and recommendations ,where appropriate, improving the draft guidelines.

Regional Guidelines for the Application of Ridge to Reef (R2R)Spatial Prioritization and Planning Procedures to Identify and Select Priority Coastal Areas and Sites for the Conservation and Sustainable Use of Ecosystem Goods and Services

1. Purpose/ Intent

1. The guidelines provide a simple and user-friendly R2R conceptual frameworks and tools that support the identification and selection of priority coastal areas or selected sites for conservation, protection, and/or sustainable use of natural resources, including future R2R interventions and participatory planning.

2. Rationale

2. Science- and evidence-based approaches to natural resource management and planning is one of the (13) principles of Ridge to Reef. The development of spatial prioritization and planning procedures promote such approaches, which are particularly useful and relevant in high islands where the dynamics of ecosystems from ridge to reef are relatively complex and, in most cases, not readily well known or documented.

3. The implementation of this approach in GIS allows managers to visualize and foresee the potential outcomes of management interventions. This type of approach has the potential to engender collaborative stewardship among agencies, communities, and other stakeholders and inform ecosystem-based, land-sea integrated planning in Pacific Island nations.

3. Scope

4. The scope for the useful application of the guidelines would cover wide range of multiple sectors resource management and planning, stretching from the mountain top or source on land to the reef and seas beyond. Within this stretch of land-sea scapes, which includes land, water, forest and coastal areas, are produced numerous ecological systems goods and services. The R2R concept promotes ecosystem-based management approaches, which effectively links to the holistic conservation and sustainable use of natural resources across sectors.

5. Operationally the guidelines are relevant to the work of scientists and managers, who support and implement multi-sectoral natural resource management. In additional, the guidelines are equally important and relevant to inform policy discussion and decision making at the higher political level.

4. Background

6. There are numerous ways of supporting and informing policy discussion aimed at identifying and selecting priority coastal areas for effective protection and natural resources management. The selection of priority coastal areas to focus such conservation and management efforts is commonly guided by information and observations, which may be qualitative or quantitative. The guidelines set out in this document complement the existing ones in the “tool-box” where their uses and applications may be already widely documented and accepted as best practice.

7. In this vein, and in response to one of the GEF International Waters (IW) R2R project targets and deliverables, the R2R spatial prioritization planning procedures were developedto assist in the identification and selection of priority coastal sites in future R2R interventions andparticipatory planning. The development of spatial prioritization procedures is modelledand implemented at two scales:-

- ***National scale approach*** -Adapt & apply a spatially-explicit framework with scenario planning to identify national priority areas that benefit land & sea; and
- ***Local Scale approach*** - Downscale this application of the planning procedures to test the effect of proposed local R2R management actions in one or several watersheds within or connected to a demonstration site.

8. The land-sea modelling focuses on watershed catchments sediment runoff and export from the source to the shoreline and impacts on adjacent ecosystems and coral reefs habitats based on different land use change scenarios – e.g. deforestation & logging practice codes. The details on the national and local scale approaches are further explained in the sections below.

9. Generally, model results are only as good as the model inputs. Therefore, access to data is extremely important in land-sea modelling and the application of R2R spatial prioritization and planning procedures. While public domain data and information are easily accessible, the non-public domain data require consents and approvals, recognising that the process accessing such information can be lengthy and challenging.

10. It is important that existing processes and requirements are closely followed to access, collect, collate and store the information in databases for processing and analyses. Sometimes, the information and GIS datasets are housed in regional and international organisations and can only be released on consent of countries, entities or individuals who own the data. Where there is no information or the data available is simply inadequate, it can be difficult to proceed with the application of R2R spatial prioritization and planning procedures.

11. In this case, priority areas or sites can be selected based on observations and qualitative assessments. This generally does not demonstrate priority sites selection that is supported by best use of a science- and evidence based approach. Alternatively, and most appropriate in local scale approach, field work can be planned to collect baselines data on selected indicators. Other useful results from survey work and inventories would help generate maps, establish the current state of resources and habitats and other valuable uses of primary data.

12. The R2R conceptual framework on spatial prioritization and planning procedures provide clear and easy to follow sets of guidelines to identify and select priority coastal areas and site for the conservation and sustainable use of ecosystem goods and services. This is implemented through the following steps for tracing land-sea linkages are follows:-

- Model the sediment export and plume under present conditions and each deforestation scenario;
- Identify coral reef areas exposed to significant change in sediment for e4ach scenario compared to present; and
- Identify the watersheds supplying the most sediment (>40%) to those coral reef areas.

13. In summary, the regional guidelines on R2R spatial prioritization procedures would assist stakeholders who may be engaged directly or indirectly in managing natural resources across land and sea continuum. The procedures were trialled in Vanuatu and soon in the Solomon Islands, and

the results serve as basis for developing these guidelines. A clear and stepwise model application of the national- and local- scale approach or method will be developed and appended to these guidelines. This is a useful template for interested persons to practice and learn how to use the R2R spatial prioritization and planning procedures.

5. Stepwise application of the R2R Spatial Prioritization Procedures

14. Useful steps to follow when undertaking spatial prioritization work to identify and select priority future coastal areas or sites for protection.

- (i) Participatory planning processes – consult widely and work with host agency to prepare an implementation plan and mobile team and resources. Carry out a literature review and collect national spatial data.
- (ii) Develop potential future land-use or marine-use change scenarios[1] locally relevant to the PICs, agree on quantifiable criteria such as resilience indicators (e.g. clean water or fisheries supply) for the identification of priority R2R sites, and reflect the importance of sites from the range of biological, environmental, cultural and socio-economic conditions at the national level.
- (iii) Identify relevant data gaps important for analyses and inputs into land-sea models
- (iv) If there are data gaps in certain areas important for modelling work, then prepare to carry out field work and collect primary data. This includes consulting widely within and out of the country to solicit and access relevant information and advice.
- (v) Develop and agree on sampling protocols or designs for field work to collect primary data not already available. Coordinate logistical arrangements including teams of people involved and their roles.
- (vi) Carry out field work closely adhering to sampling design and following deadlines and details set out in the implementation plan.
- (vii) Data processing and analyses – this includes transcribing raw data, cleaning, collating and entering data into dbase, extraction and formatting data for model inputs, calibrate the models, and conduct spatial analysis on model outputs.
- (viii) If required, prepare to do additional survey work to optimise calibration of marine and terrestrial models. The exercise should be participatory to promote capacity building.
- (ix) Prepare technical reports that include clear documentation of methods employed, model outputs, maps depicting priority areas and sites, and packaged models. The narratives should clearly explain the model outputs and use that to inform advice and recommendations on priority areas or sites to protect (watersheds, forests, coral reefs, etc.).
- (x) Present and discuss methods and outputs with other actors or peer review and refinement, taking into consideration the needs and usefulness of end products.
- (xi) Use existing data to define criteria and identify national level priority sites or target areas.

[1] Scenario design can be done in collaboration with the decision makers to understand better and select resilience indicators. For example, for Vanuatu trials, the focus was on deforestation because it is one of the major threats to terrestrial ecosystems and known to also impact marine ecosystems, and related ecosystem goods and services (biodiversity, water, fisheries).

(xii) Use the results to support national planning for ICM. The information obtained through land-sea modelling should highlight those priority areas most critical to protect.

6. National-Scale R2R Framework

15. The national scale approach R2R framework for selecting priority sites covers the whole country and it will use all available datasets and information useful for land-sea modelling. In the Pacific region, numerous studies and research been undertaken on various ecosystems goods and services including land, water, forest, coastal and marine areas. This is the case for Vanuatu when trialling the spatial prioritization procedures. Notwithstanding, there remain gaps requiring further research to better understand ecological systems and biological diversity of species and their interactions.

16. That said, the guidelines needed to progress national-scale approach land-sea modelling, is primary centred on diffusing sediment into the marine environment, using a plume model in GIS coupled with marine geography datasets. The potential marine impact from sediment export is estimated by linking to source watersheds, in order to identify the priority conservation areas that mutually benefit the land and sea.

17. The national-scale approach provides for a number of analyses and modelling work that generate the following results:-

(i) Present land use/cover (LUC) – forest, grass/ shrub-land, human LUC (e.g., agriculture, human settlement, plantation)
(ii) Low and high deforestation scenario – convert forest to human LUC where deforestation trends have been observed (e.g., low elevation, gentle slopes)
(iii) Present sediment export – ton/yr or ton/km2/yr
(iv) Change in sediment export - ton/yr or ton/km2/yr
(v) Marine impact assessment– habitat area (km2), coral cover (%), fish biomass (kg or tons)
(vi) Prioritize watersheds – rank based on potential impact of sediment runoff on coral reefs
(vii) Prioritize forest areas – erosion prone areas in priority watersheds
(viii) Social & economic drivers in the prioritization – e.g. watershed(s) providing essential ecosystem goods and services (e.g., drinking water) to nearby cities and towns

18. The results include maps-depicting priority watersheds linked to coral reefs through sediment run-off, and coral reefs at risk as well as relative potential impact (low, medium, high). Another important result identified forest areas that most prone to erosion, and thereby contributing the most to coral reef impacts through sedimentation. Similarly, it is important to account for the social and economic factors in the prioritization of sites, particularly those with vital roles in supporting the surrounding environment and the well-being of the population residing in the broader area.

7. Local-Scale R2R Framework

19. Like national-scale approach above, the local scale approach uses similar downscaled procedures and guidelines applied to demonstration sites of interests. For instance, trial work of the procedures in Vanuatu was done in the Tagabe catchment within the Mele Bay R2R system. The IW R2R project demonstration sites in all project countries are operating at the local-scale or subnational level. Again, the science- and evidence-based approach is the starting point guideline to

ensure adequate data and information is available to enable land-sea modelling. If the primary and secondary data and indicators are not adequate, then field work is needed to collect baseline and primary data.

20. The sediment and plume models are developed for a localised area and the model results of projected land use changes are then linked to potential marine impacts. The InVEST SDR is coupled with a GIS-based plume model to derive the sediment export per watershed and generate sediment plume maps.

21. Next, the following list provides the tasks and details related to processing of information, analyses and modelling, which in turn help generate maps of selected priority areas under different terrestrial and marine management scenarios. The scenario analysis involves predicting the distribution of coral reef benthic and fish indicators under present conditions and each scenario. It also calculates the coral reef indicators change for each scenario compared to present. The modelling procedure is set out below:-

(i) Design scenarios representative of management actions
(ii) Watershed analysis and plume maps are used to characterise sediment inputs to the marine environment under present and proposed management conditions;
(iii) Model the effects of sediment runoff and marine habitat on benthic indicators and associated fish indicators[2] and map their distribution;
(iv) Model calibration on present conditions – may involve collection of additional datasets on habitats and resources to better calibrate the models. For example, coral reef models are calibrated using empirical data collected from addition surveys on "X[3]" number of random coral reef sites using an equal random-stratified survey design based on depth and distance to stream mouth (see notes on strata below).

    a. Benthic models = sediment[4] (mediated by humans) + habitat
    b. Fish models = sediment + fishing (mediated b humans) + habitat + benthic indicators

    Notes: strata used (i) shallow (1-5 m), moderate (5-12 m), deep (12-21 m); and, (ii) near (0-1.5 km), medium (1.5-3 km), far (3-4.5 km)

(v) [5]Number of watersheds in or adjacent to the demonstration site, linking to coastal/ marine environment – enclosed or semi-enclosed bay, open sea areas
(vi) Characteristics of the demonstration site – drinking water, dependency on coastal/ marine resources, population indices (urbanization and trends)
(vii) [6]Governance – watershed management plan, marine management plan linking to challenges and actions (protect drinking water, restore forest & nearshore fisheries, improved livelihoods)
(viii) Demarcated ecosystems –update land cover map by digitizing recent satellite imagery; watersheds, land-modelling boundaries, marine-modelling boundaries, coral reef areas; [7]modelling boundaries are set prior calibrating the models;

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[2] For example, herbivore fishes are selected as indicators of coral reef resilience to climate change bleaching impact and targeted fish because it is a proxy for ecosystem goods and services
[3] At least 30 sites required for any statistical analysis – 58 sites were selected for trialling work in Tagabe, Vanuatu
[4] The scenarios affect this variable which can mediated by management actions, the same applies for fishing pressure
[5] Trial work in Vanuatu selected 4-watersheds discharging in to Mele Bay because they all contribute to the sediment plume affecting coral reefs, and can be controlled with appropriate R2R management approaches, and document or test changes in Tagabe over time
[6] Management scenarios inform scenario design which is first done in the process
[7] In Vanuatu trials, modelling boundaries were done for 4-watersheds of Mele bay because they all contribute to the sediment budget downstream

(ix) Management scenarios – after calibrating the models on present conditions, then run management scenarios and look at what changed – e.g. management (forest restoration, urbanization); marine management (fishing pressure, marine closure)

22. The local-scale approach results:-

(i) Calibrated coral reef models defining the relationships (positive, negative, concave or convex) between:
   a. the benthic indicators (hard coral, macro-algae, turf algae), and the environmental benthic drivers (terrestrial, marine)
   b. the fish indicators (total biomass, herbivore biomass, targeted biomass), and the environmental fish drivers (terrestrial, marine, and human)

(ii) maps depicting sediment impacted coastal/ marine areas (extent impact % or g/m2 of benthic and fish indicators) under different scenarios

(iii) maps depicting the impact of current fishing pressure and management scenarios such as marine closures on fish/ benthic indicators.

(iv) maps depicting the impact of management scenarios such as forest restoration on:
   a. native forest (ha) and subsequent levels of sediment export (ton/yr) and range of impacts to the adjacent coastal/ marine areas
   b. change in habitat quality (ha) due to increase/ decrease/ no change in macroalgae, subsequent impact of fish biomass (ton), and "X" tons when coupled with marine closure

(v) maps depicting the impact of urbanization scenario relative to human land-use trends (ha) and therefore further influence of sediment export (ton/yr); as well, corresponding change in habitat quality (ha), fish biomass (tons), and when coupled with marine closure (tons)

(vi) Benefits of the R2R approach are broad ranging and potentially more useful than other sector- or ecosystem-focused approach because it promotes:
   a. Restoring native forest and land use best-practice
   b. Reducing volume of sediment export and increasing the retention of soils on land
   c. Restoring or protecting marine habitats and fish biomass

8. Spatial prioritization benefits and implications

23. The R2R spatial prioritization and planning procedures will benefit future R2R investments and planning. It exerts confidence for donors and partners that science- and evidence-based principles were the basis for identifying and selecting priority sites for protection.

24. The steps for spatial prioritization on land:-

(i) Characterize the potential marine impact using selected indicators[8] which may change on case by case basis, recognising linking indicators to what are being measured;

(ii) Prioritize watersheds by potential marine impact; and

(iii) Identify land areas exposed to significant change in sediment export under each scenario compared to present.

[8] For instance, health of habitat and healthy stocks can use indicators such as coral % cover and fish biomass from empirical data. Other indicators are also relevant for measuring health of biodiversity, governance, socio-economic and traditions, improved livelihoods.

25. The successful application of the spatial prioritization procedures requires collaborative management between the government agencies and communities because it provides information to foster a dialogue between decision-makers. It can also be applied as part of an interactive decision-making process.

26. Moreover, the spatial prioritization procedures support and inform policy development and decision making. On the one hand the procedures assist in the identification and prioritization of conservation areas at the national-scale that can benefit both terrestrial and marine environments. It also supports local decision-making by testing policy actions and estimating potential outcomes prior implementation.

9. Key Challenges

Data & data gaps

27. Integrated land-sea planning requires the ability to trace where land-based pollutants come from and where they are likely to cause an impact once they enter the marine environment.

28. This project adapted, applied and scaled up a linked land-sea decision support tool (Delevaux et al. 2018), to quantify, track, and map the impact of land-use change on coral reefs at the sub-watershed scale.

- (i) The soils, rainfall, bathymetry, and current data used in this study are derived from **global datasets,** freely available, making this approach useful for regions with limited resources.
- (ii) Field data used to conduct the marine impact assessment was collected by SPC and the monitoring programs of local government agencies.
- (iii) Terrestrial and marine **habitat maps** were provided by SPC GEM.
- (iv) The modeling framework relies on two freely available software packages (i.e., InVEST SDR, and R) and the proprietary software ArcGIS (also available with open access QGIS) (ESRI 2011, Team 2014, 2015, Hamel et al. 2015).
- (v) This tool is coupled with scenario planning to inform local conservation actions and identify priority areas on land that can foster coral reef resilience.

Decision support tool in data-poor region

29. Firstly, prioritize working on the **resolution** of the input foundational layers, including the soils (~ 900 x 900), bathymetry (~ 500 x 500), and currents (9 x 9 km), are coarse resolution for some of the islands.

- (i) Because **soil and rainfall maps** are coarser resolution than the DEM input, at which SDR operates, it may obscure small scale processes and spatial nuances which can occur in small watersheds and narrow reef systems often found in tropical island environments.

- (ii) Note **bathymetry and current maps** were interpolated nearshore to fill in the gaps along the shoreline, which may create erroneous values. This may impact the dispersion of the TSS plumes in some regions.

(iii) For instance, the **coastal plume models** could over- or under- estimate the TSS proxy values because we could not account for the effect of fine-scale marine topography or tidal-driven transport on sediment dispersal and settling rates due to the lack of data.

(iv) Future work should investigate how these modelled plumes of TSS compare to local knowledge from coastal communities, satellite imagery, and/or in-situ data as those become available. Also, future research should focus on generating more refined bathymetry data using satellite imagery, which can help refine the plume dispersion models and provide input layers for species distribution modelling.

(v) However spatial planning requires information to prioritize efforts on that ground and these **global datasets** are freely available for data poor regions; and spatial prioritization requires spatial consistency in the datasets used, otherwise conservation actions tend to focus efforts in data rich places. The global data inputs used in this analysis provide consistent coverage of the entire country.

30. Secondly, the decision support tool relies on static modelling. While **sediment models** accounted for the connectivity across the landscape, the **marine models** are not dynamic and do not explicitly model the response of coral indicators to TSS change. However, it can give an estimate of the directionality of change when coupled with scenarios. The scenario approach is a simple way to circumvent dynamic modelling which is data intensive and hard to calibrate in data poor regions, but can still demonstrate changes.

31. This framework can give an idea of where and what may degrade or recover but it is not a dynamic model where it is possible to see impacts through measuring indicators. In the trial work in Vanuatu, the following were executed:-

(i) Undertake an **overlay analysis** assuming a potential adverse impact where significant changes in TSS occurred over a coral reef habitat.
(ii) Empirical research has shown that coral reefs chronically exposed to high turbidity can be less vulnerable to sediment impacts. In that case, it is possible that we overestimated the impact of increased TSS on the reefs located near the source of the sediment plume and under-estimated the impact offshore.
(iii) Characterised the potential impact of TSS on coral reefs in terms of coral cover area (km2) and fish biomass (kg).

10. Suggested Approach

32. The guidelines provide the following suggestions and approach towards curbing some of the above challenges, but also to achieve the goal of identifying and selecting priority sites for future R2R planning.

(i) First inform the modelling tool using data layers representing current conditions so that the results represent the effect of current land-use on sediment runoff once it enters the marine environment;
(ii) Apply land-use scenarios to quantify the potential impact of TSS on reefs under increasing levels of development and deforestation.

(iii) Undertake scenario analysis to identify priority land areas within a large number of priority watersheds (around 50% if the country has several hundred watersheds), where forest conservation can reduce TSS risk to downstream coral reefs

(iv) For restricted bays and related marine areas adjacent to the mouth of the river, reef areas located directly downstream from the watersheds experience deforestation. Therefore the model outputs would show the connections for the watersheds contributing the largest change in TSS.

(v) Determine where soils are more likely to erode under land-use change can inform where conservation actions on land or sustainable land-use practices can provide benefits downstream.

(vi) Determine the direct and indirect impacts of sedimentation and turbidity on benthic habitat at local scales, or if known, downstream from all watersheds.

(vii) Land-use planning requires coordinating across difference agencies, such as government or non-government agencies or institutions responsible for fisheries and the environment.

(viii) Identify where coral reefs are more or less vulnerable to local human impacts can inform area-based management actions and spatial prioritization to minimize risks (i.e. probability of disturbance) – determine risk levels by areas.

   a. Low risk conservation approach protect nearshore reefs that not susceptible to sediment impacts;
   b. High risk conservation approach protect reefs which are more vulnerable to sediment runoff that may support high coral cover and fish biomass – important fishing grounds for nearby villages.

11. Conclusion

33. The regional guidelines on the application of the R2R spatial prioritization and planning procedures aimed to assist stakeholders identify and select priority sites for future R2R planning. These guidelines recognise the limitation of the procedures relative to the adequacy and quality of data inputs into land-sea modelling. Further research and trials would certainly improve the application of the procedures.

34. Moreover, the guidelines on spatial prioritization and planning procedures and related information serve to inform land-sea planning and help prioritize local conservation actions. Simultaneously the procedures can evaluate the effect of land-use change, sediment runoff, coral reef habitat, and associated fish communities. The packaged land-sea model outputs and maps provide scientific evidence supporting potential trade-offs and synergies that may result from modelling land and sea connectivity under different land-use scenarios. Next steps would be to build a suite of land-use management scenarios within the priority areas identified, and then evaluate tradeoffs to identify optimal management solutions.

35. By adopting a ridge-to-reef conservation planning process, protected areas can be designed for multiple benefits that include improvements in biodiversity, drinking water, and reef fisheries. These findings can also help inform priorities for future conservation leases or other payment for ecosystem service schemes by: (1) identifying relevant communities, (2) facilitating communication using maps as visuals, and (3) locating where forest conservation or restoration actions can benefit coral reefs and improve fisheries livelihoods.

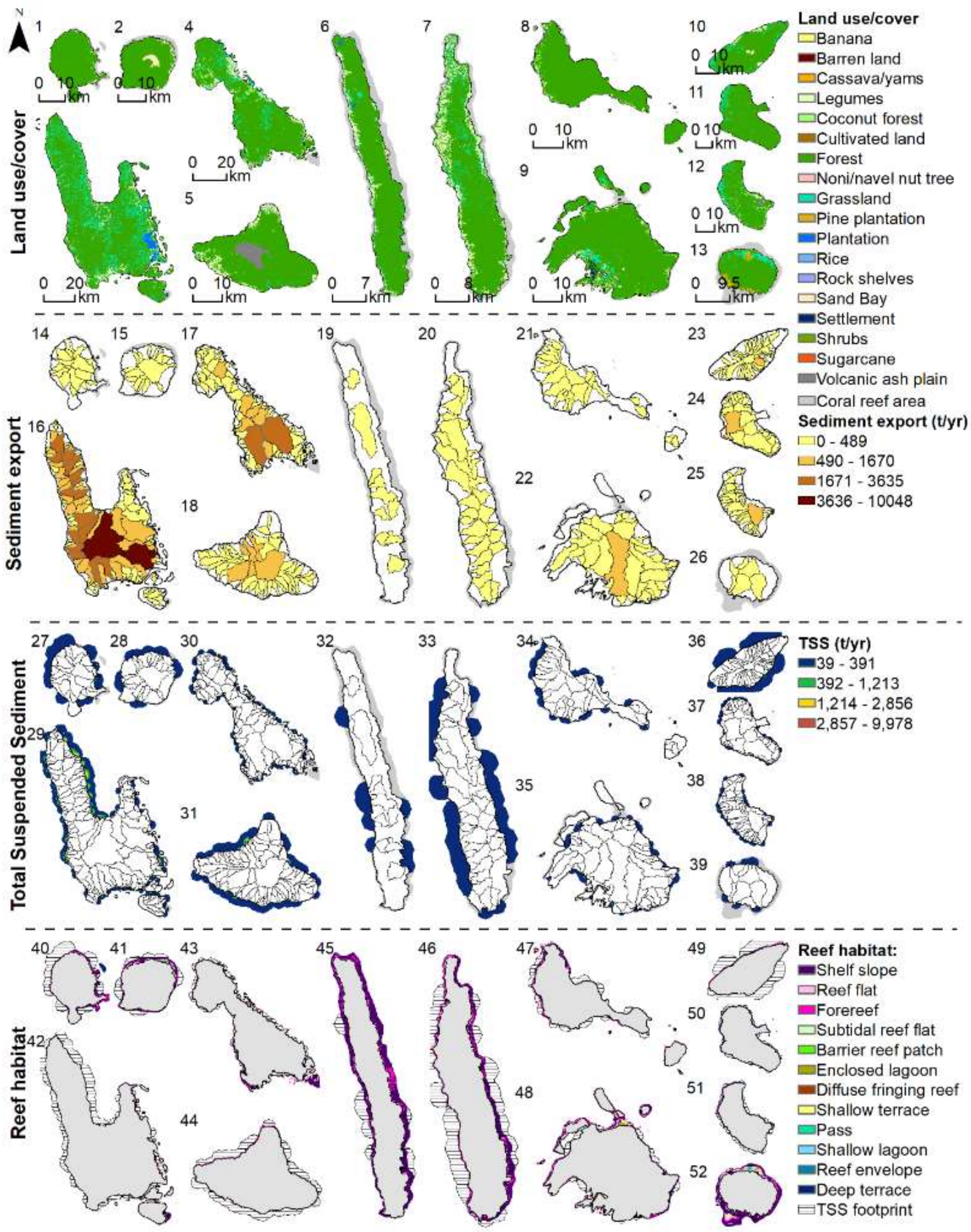

Fig 1. National scale model framework, Present ridge to reef model. (1-13) Present land use/cover, (14-26) InVEST SDR results - sediment export (t/yr) summarized by watershed, (27-39) modeled TSS plumes (t/yr), and (40-52) coral reef habitats exposed to modeled TSS.

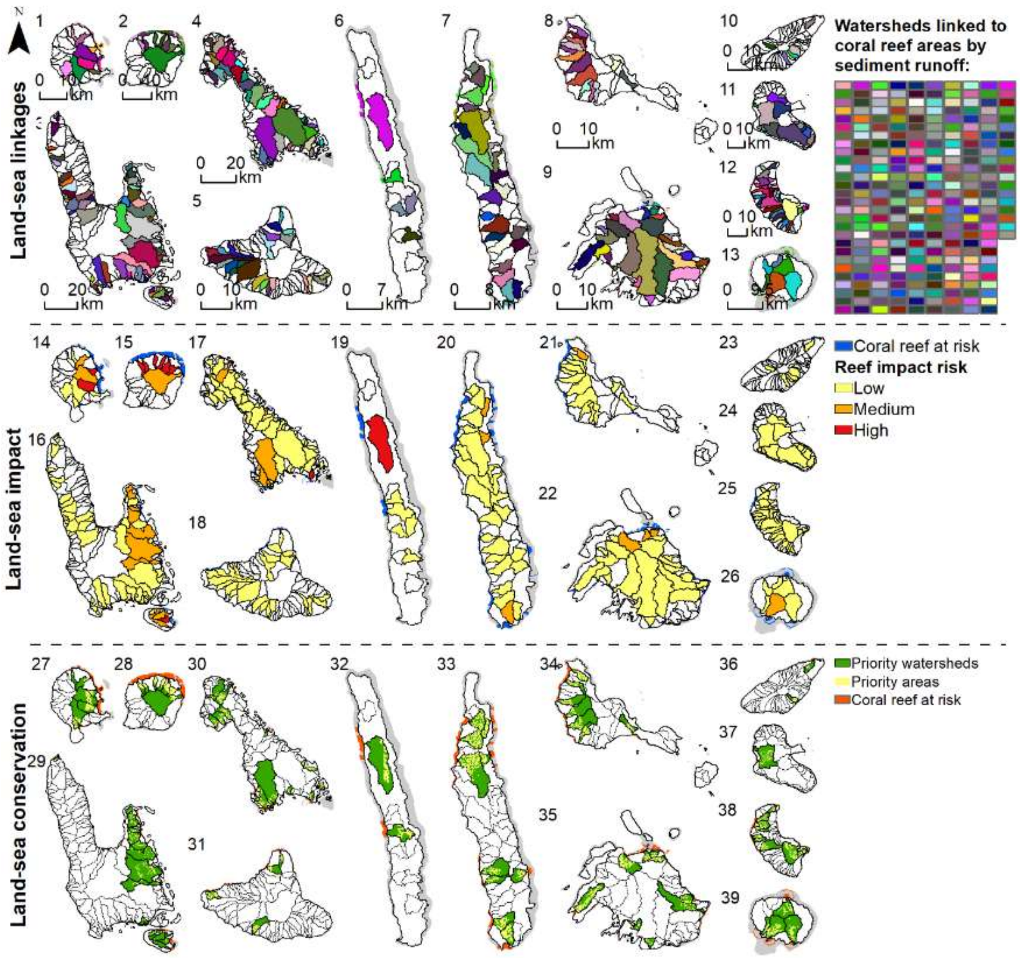

Fig 2. National scale model framework, Linked land-sea planning under the low deforestation scenario. (1-13) Watersheds linked to coral reef areas are indicated by matching colors. Under the low deforestation scenario, watersheds are linked to coral reef areas vulnerable to their sediment runoff. (14-26) land-sea impact ranked by the coral reef area, coral cover, and total fish biomass potentially at risk, and (27-39) Priority watersheds where conservation (i.e., avoiding deforestation) can benefit coral reef areas are indicated in green, and priority areas for conservation actions within watersheds are shown in yellow and coral reef areas vulnerable to human impacts under the low deforestation scenario are shown in orange.

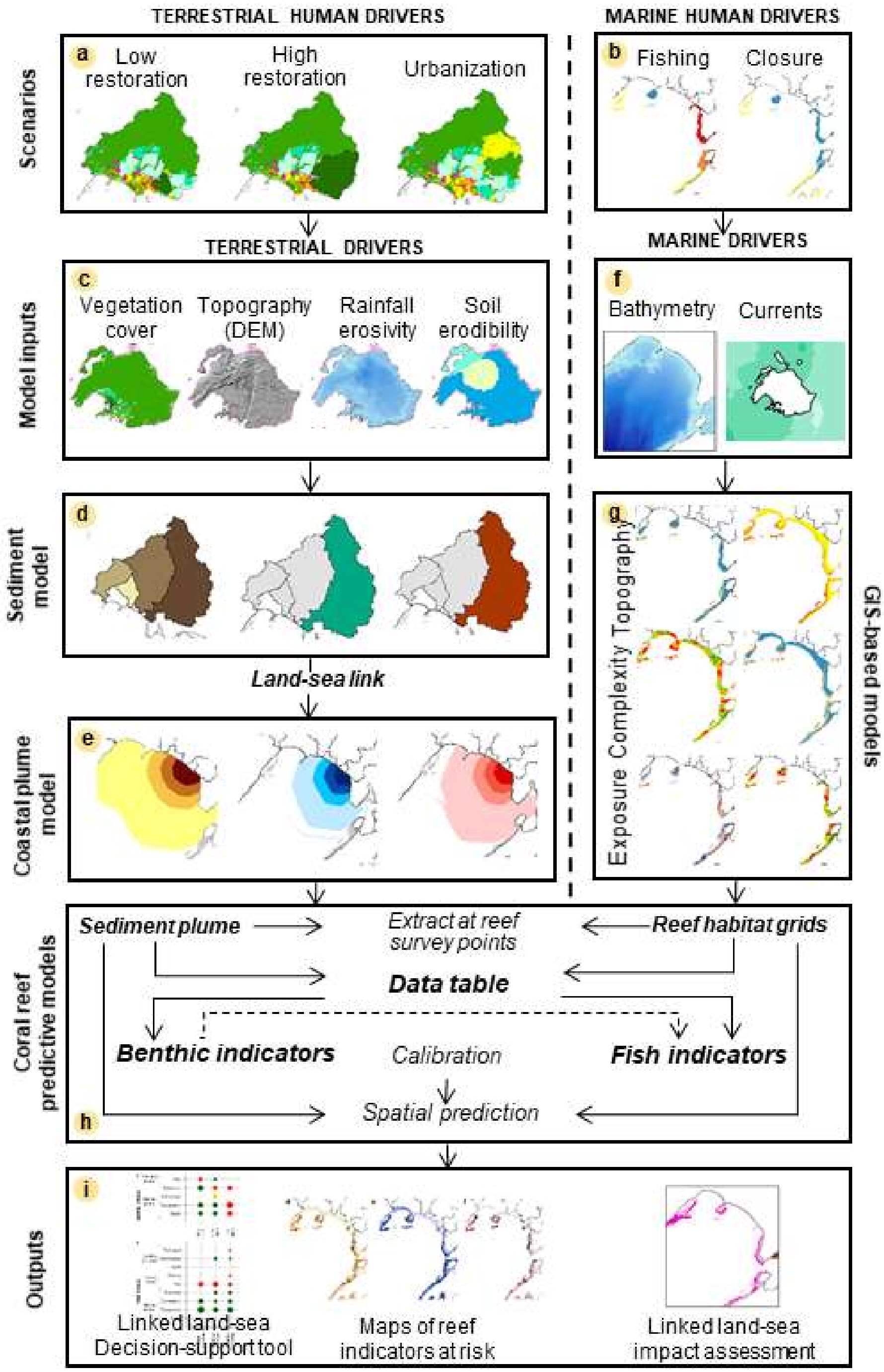

Fig 1. Local scale model framework, Ridge-to-reef modeling framework. (a) Land-use change scenarios were coupled with the linked land-sea decision support tool. (b) Marine management scenario. (c) Land cover, topography, rainfall, and soil erodibility data were inputs in (d) the InVEST Sediment Delivery Ratio (SDR) model to quantify sediment export (t/yr). Sediment export values were assigned to (e) pourpoints at the shoreline and combined with (f) bathymetry and current maps into a coastal discharge model using a GIS distance-based dispersion models to generate sediment plume maps (t/yr). Bathymetry and the habitat map were combined with (g) GIS-based models to derive the marine driver grid data (i.e., habitat topography, geography, exposure and complexity). (h) The coral reef predictive models were calibrated on coral reef survey data. (i) Outputs were: (1) a linked land-sea decision-support tool, (2) maps of benthic (% cover) and fish (g/m^2) indicators, and (3) a linked land-sea impact assessment.

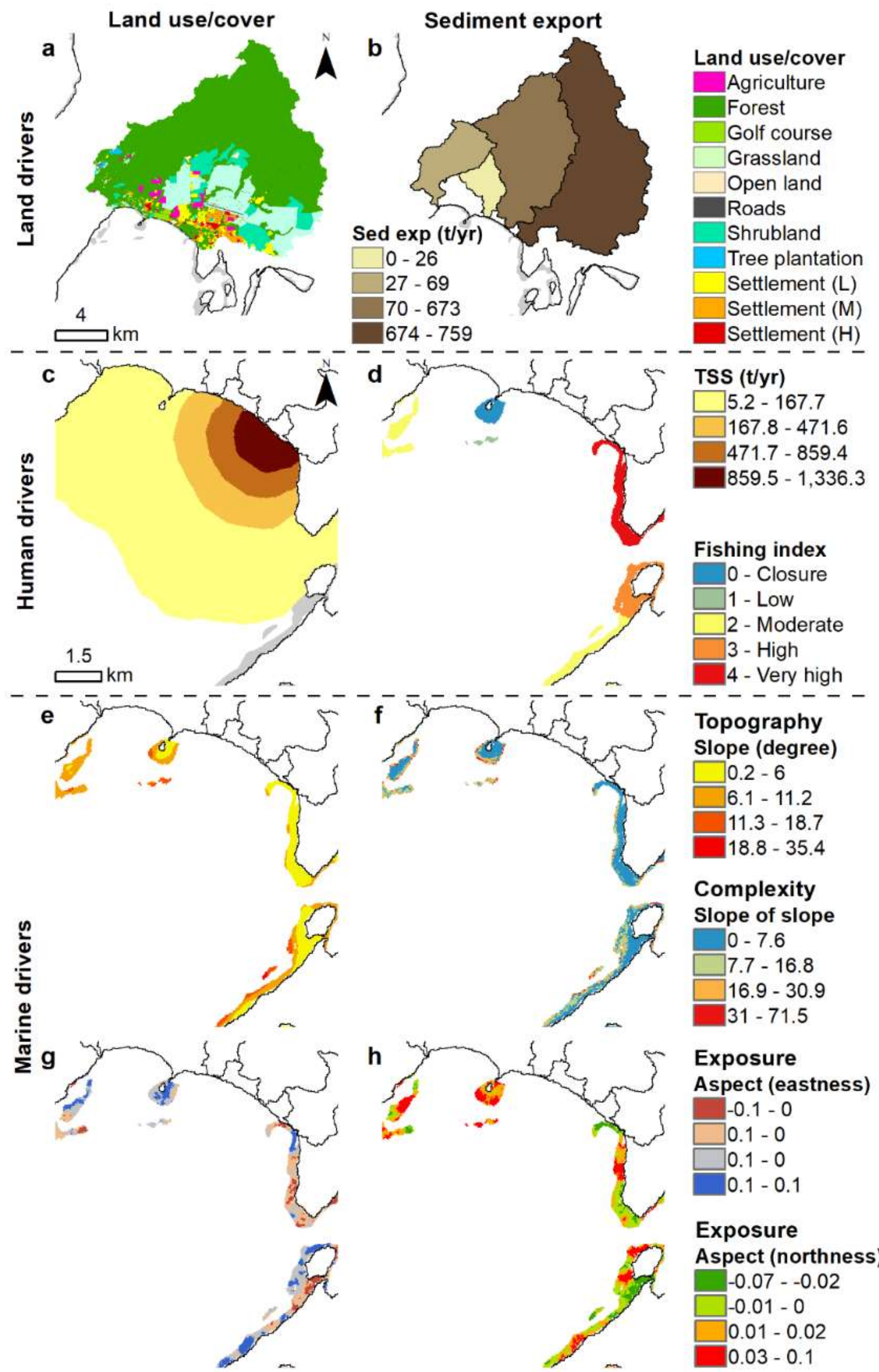

Fig 2. Local scale model framework, Present ridge to reef drivers. (a) Present land use/cover, (b) InVEST SDR results - sediment export (t/yr) summarized by watershed. The human drivers are represented by (c) modeled TSS plumes (t/yr) and (d) fishing pressure index. The marine drivers include (e) habitat topography (f) complexity, and exposure to wind and currents (g) eastness and (h) northness.

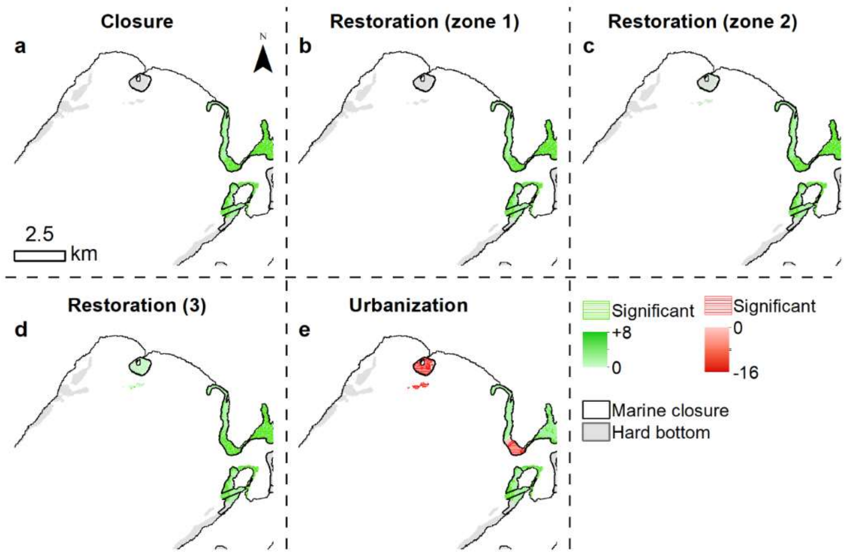

Fig 9. Local scale model framework, Maps of targeted fish indicator change under combined land-use change and marine management scenarios. Relative change in targeted fish biomass indicator (g/m^2) is shown under: (a) marine management, (b) marine management combined with restoration (zone 1) scenario, (c) marine management combined with restoration (zone 2) scenario, (d) marine management combined with restoration (zone 3) scenario, and (e) marine management combined with urbanization scenario.