Pacific Community
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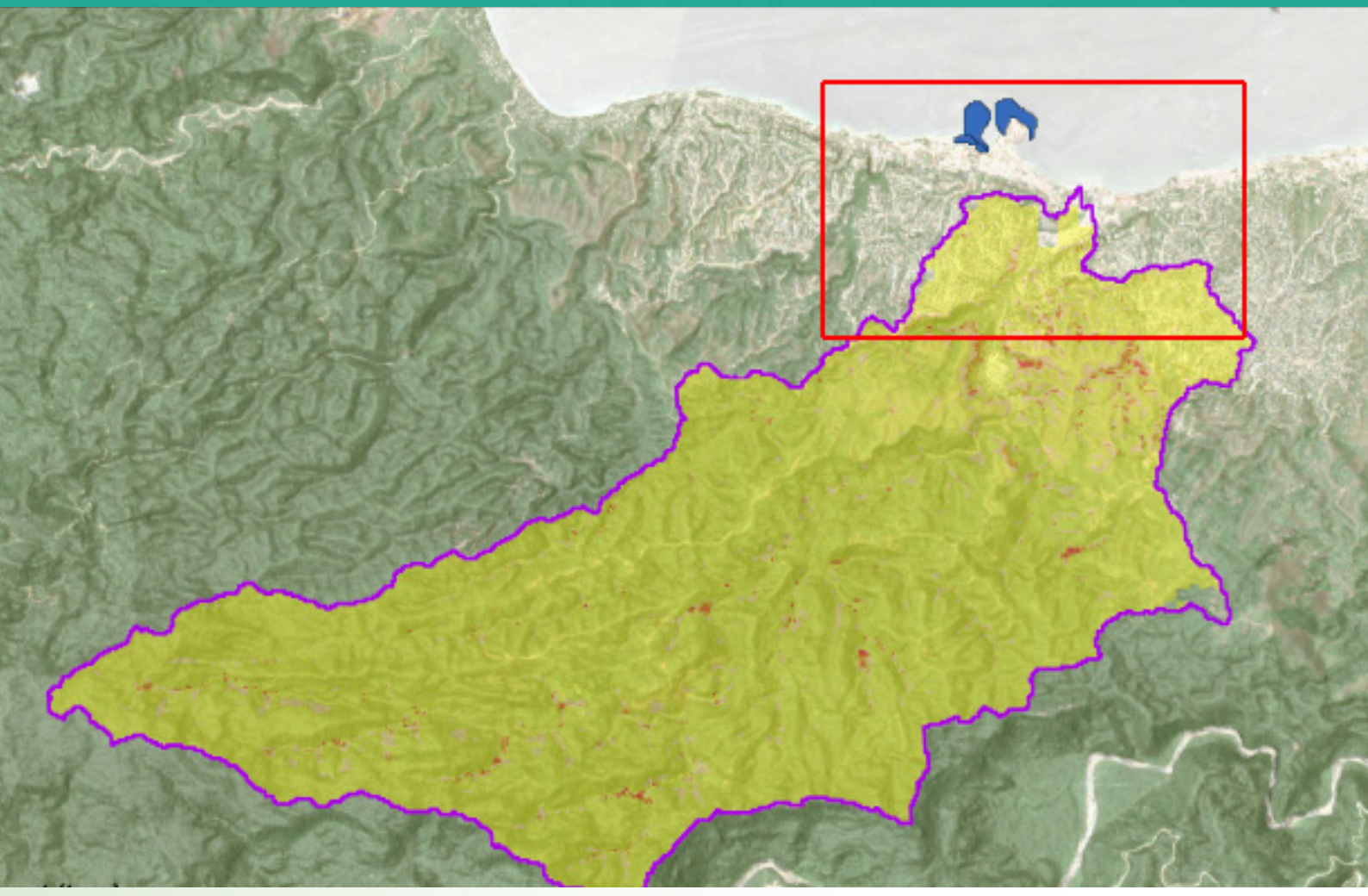
# Development and trialing of a procedure for the identification of priority Ridge to Reef sites in the Solomon Islands

## Consultancy Report



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# Technical Report:
# Development and trialing of a procedure for the identification of priority R2R sites in the Solomon Islands

Consultancy Report

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# Contents

# Abbreviations

GEF – Global Environment Facility

GIS – Geographic Information Systems

InVEST – Integrated Valuation of Ecosystem Services and Tradeoffs

IW R2R – International Waters Ridge to Reef

LULC – Land Use Land Cover

NDVI – Normalized Difference Vegetation IndexPIC – Pacific Island Countries

RSTC – Regional Science and Technical CommitteeSDR – Sediment Delivery Ratio

SPC – Pacific Community

TSS – Total Suspended Solids

# Acknowledgement

I wish to thank the GEF Pacific International Waters Ridge to Reef Project and Pacific Community for providing the opportunity to work on this consultancy and project. Specifically, I wish to thank Dr. Samasoni Sauni, Sachindra Singh, Nicholas Metherall, James A. Carreon, George Naboutuiloma, Jose Antonio, and Dr. Fononga Vainga of Pacific Community's Ridge to Reef Regional Programme Coordination Unit for their valuable guidance and feedback during the project and for their review of the report.

# Introduction

## Background of the consultancy

The Regional International Waters Ridge to Reef (IW R2R) Project is executed regionally by the Pacific Community (SPC), based in Suva Fiji. The Regional IW R2R Project is part of the larger 5-year GEF funded Regional Pacific Ridge to Reef Program being implemented by UNDP, UNE and FAO, and SPC across fourteen Pacific Islands countries: Cook Islands, Federated States of Micronesia, Fiji, Kiribati, Nauru, Niue, Palau, Papua New Guinea, Republic of the Marshall Islands, Samoa, Solomon Islands, Tonga, Tuvalu and Vanuatu.

In bringing together countries that face similar threats to fresh and coastal water systems, the Regional IW R2R Project aims to test the mainstreaming of ridge to reef, climate resilient approaches to integrated land, water, forest and coastal management in the PICs through strategic planning, capacity building and piloted local actions. The project is implementing a variety of practical approaches to

safe-guarding water systems and coastal habitats in the fourteen participating countries with the aim of engaging and supporting national governments and local communities to build the knowledge base to better understand the cause-and-effect relationship of 'whole-of- island' environmental degradation and develop the skills and systems to better manage these impacts.

Within project activities there is also focus on strengthening of scientific understanding of the current state of priority coastal areas, and support for the development and endorsement of national and regional strategic action frameworks for ICM/IWRM. The aim of these strategic action frameworks is to meet the regional need for the mainstreaming of ridge to reef approaches in national development planning. Strengthened national coordination for ridge to reef integrated land, water, forest and coastal management, including climate change adaptation, in the participating countries is also supported.

The major Regional IW R2R activities over the remaining period of the project are to deliver on key deliverables of the science-policy framework. These include baseline data and rapid assessments, diagnostic analyses, spatial planning procedures, state of the coast reports and strategic action plans. A thorough assessment of socio-political and environmental systems is the best way to design integrated water resource and/or coastal management plans, however, in the case of the Pacific wherefunds and capacity are a limiting factor, a cost-effective rapid assessment procedure can provide the foundation for selecting target sites around which to begin participatory planning processes.

This consultancy supported delivering on the science-policy deliverables, specifically providing scientific and technical support through the development of a procedure that would incorporate quantifiable criteria and indicators for the identification of priority R2R sites and reflect the importance of sites from the perspectives of the range of biological, environmental and socio-economic conditions at the national level. The developed procedure integrates existing frameworks that were developed for the spatial prioritization of R2R sites within Vanuatu and the Solomon Islands with modifications implemented for this application.

## Objectives

The main task of the consultancy was to complete development and trialing of a procedure for the identification of priority sites for R2R/IC/IWRM interventions. The activities of the consultancy consist of fully assessing the replicability of the InVEST SDR model and address the range of barriers of the replicability of this model for the trialing in the Pacific IW R2R Solomon Islands project.

## Expected outputs

Expected outputs of the consultancy included an inception meeting, R2R spatial prioritization procedures, technical report, and the final consultancy report. During the inception meeting, expected outcomes included finalization of a workplan and an inception report. Expected outputs of the R2R spatial prioritization procedure included clean data sets, model calibration, packaged models and maps. Additional outputs for the technical report included the detailed methodology and development of the spatial prioritization procedure and a final report on the prioritization procedure, identified challenges, and potential solutions. Expected outputs for the final consultancy report included this document indicating highlights and lessons, a presentation of the results to the 7th RSTC, and a manuscript for a peer reviewed journal article if time permitted.

The revision of the previous water quality model used in the Vanuatu spatial prioritization project and development of scenarios to better assess the flexibility of the full prioritization procedure created additional steps to the process and resulted in some delays in the final deliverables. As a result, the presentation to the 7th RSTC consisted of preliminary results and the consultancy was given a no-cost extension until February 28, 2022 to allow additional time to fulfill the objectives of the consultancy.

## Methodology, Approach, Duration

The consultant met with the RPCU on November 26, 2021 to discuss the consultancy workplan and finalized comments into an inception report on November 29, 2021.

Data needs and potential data sources were reviewed, compiled, and stored in a database viewable to project partners via Google Sheets. Local data sources (e.g. Solomon Islands or Pacific Region derived resources) were given preference over global datasets, however only global datasets were mostly available as input data for models. The consultant researched data on the Pacific Data Hub and country environmental data portals to identify relevant datasets available for use. Input datasets were calibrated and validated using a variety of methods, however, sedimentation data were not available to validate the results of the model outputs. The Natural Capital Project's Integrated Valuation of Ecosystem Services and Tradeoffs Sediment Delivery Ratio Model (InVEST SDR version 3.9) was used to model annual soil erosion and sediment export for catchments within the Solomon Islands. Clean datasets with metadata, calibrated models and output, maps detailing priority sites and results, and a draft report detailing methodology were packaged and delivered to the IW R2R team on December 25, 2021. InVEST SDR results were summarized and presented to RPCU on December 30, 2021 for discussion of input datasets used for analysis and interpretation of the results.

During the review of SDR model results, the consultant and RPCU discussed the needs for inclusion of a water quality model and scenario modelling to complete the full spatial prioritization procedure for

the Solomon Islands. The consultant reviewed the water quality model developed for a previous spatial prioritization procedure for Vanuatu and then modified the approach by including a settling rate to account for sediment deposition as it diffuses through the water column. A Sediment Extent Model (SEM) was used to model sediment plumes based on ocean surface current velocities and direction, a soil particle settling rate, and ocean depth derived from bathymetry data. Additionally, this project used a threshold to identify areas of high sediment export on land and quantified the percentage of area within each catchment that is considered having high sediment export. The total amount of sediment load,

area of high sediment export and coral area impacted under the sediment plume were used to rank and prioritize catchments within the area of interest. A total of 3,104 catchments were modelled for the nine regions in the Solomon Islands.

In addition to ranking catchments for prioritization based on current conditions, scenario modelling was used to estimate conditions under alternative management practices. To demonstrate the flexibility of this procedure for spatial prioritization of R2R sites over a temporal scale, scenarios were created at both the local and national scale by: 1) changing any grassland areas in the Mataniko Catchment that had high sediment export (> 22.0 t.ha-1.yr-1 or > 2.0 t.pixel-1.yr-1) to forest LULC to simulate a reforestation project aimed at decreasing sedimentation to the outlet, 2) a 10-year projection of continued forestry practices (business-as-usual) across all of the watersheds within the Solomon Islands, and 3) a scenario that uses the 10-year deforestation projection on Guadalcanal Island but simulates increased protected area designations by increasing a buffer around streams from 50-m to 100-m.

The revision of the previous water quality model used in the Vanuatu spatial prioritization project and development of scenarios to better assess the flexibility of the full prioritization procedure created additional steps in the anticipated methodology and resulted in some delays in the final deliverables. As a result, the presentation to the 7th RSTC consisted of preliminary results and the consultancy was given a no-cost extension until February 28, 2022 to allow additional time to fulfill the objectives of the consultancy.

# Executive Summary

The land-sea linkage framework developed during this process outlines a multi-tier hierarchical approach for identifying and prioritizing R2R sites and projects that uses free and open-sourcesoftware and tools. This proposed approach uses a sedimentation model to estimate erosion resulting from surface overflow and the total annual amount of sediment that is exported to the outlet of a watershed/catchment. Sediment that reaches the outlet is then modelled using a water quality/plume model to estimate how sediment travels in the marine ecosystem and quantify the potential impact to marine resources. National reporting could be used as an initial identifier of problematic catchments for which R2R data collection could be focused. Once sedimentation and other supporting data are collected at sites, these data can then be used to calibrate and validate model results. With calibrated models, intra-catchment assessments that identify areas of high sediment export or connectivity can be identified and scenario modelling can be used to measure the relative success of the intervention, protection, or restoration projects.

At the national scale, baseline conditions indicate that Guadalcanal, Western, and Isabel regions have the highest sedimentation rates in the Solomon Islands. The Guadalcanal and Western regions have some of the steepest slopes within the Solomon Islands and regardless of the LULC present at high slope areas, steep slopes result in higher sediment export areas due to the slope-length factor of the RUSLE equation in the InVEST SDR model. The Isabel, Malaita, and Western regions have the highest amount of coral area under plumes and are therefore the regions with the highest connectivity to potential coral reef impacts. The Choiseul, Malaita, and Guadalcanal regions had catchments with the highest amount of TSS impacting coral reef areas and Isabel and Western regions had catchments withmoderate levels. The medium and high-ranking catchments may be considered for closer examinationand detailed analysis at the catchment scale to determine prioritization for R2R projects.

Local-scale reporting for the Mataniko Catchment demonstrates the flexibility in this framework to identify site-level interventions for future applications throughout the region. Areas of highest sediment export included the deforested grassland area located near Honiara. Using scenario modelling, the reforestation of the high export grassland areas demonstrated a considerable (10%)reduction in sedimentation at the outlet.

The 10-year deforestation scenario resulted in increased sedimentation export for all regions and a relatively similar ranking of catchments between the baseline and deforestation scenarios. While deforestation scenarios did not change the overall relative inter-and intra-regional of catchments, there was still an evident, yet varying, increase in sedimentation export even when logging was restricted to the Solomon Islands Forest Code regulations and guidelines.

Data availability in Pacific Island countries can be sparse and the technical capacity needed to reproduce some of the input data required for these models may be limited. The approach outlined in this study utilizes open-source software such as Google Earth Engine, InVEST SDR model, program R and QGIS to access, manipulate, and model globally available data at various scales. Both the preprocessing of input data for models, construction and application of the plume model, and summarization of ranking across regions and catchments requires intermediate knowledge of spatial analysis and GIS functions. To assist in replicability, this report includes detailed procedures for some of these processes in the methodology and supplemental material.

While increasing national GIS capacity and support is one method to boost the replicability of R2R spatial prioritization across PICT's, specific datasets could also be pre-processed and made available to these countries to facilitate the modelling process on either the GeoNode or Digital Pacific. However, these datasets should still be validated using some expertise to prevent erroneous model results and interpretation and therefore funding, if available, should also be directed at collecting validation and calibration data in addition to making these datasets available to partner countries.

# Highlights of the outputs and achievements

## Inception Meeting

The consultant met with the RPCU on November 26, 2021 to discuss the consultancy workplan and finalized comments into an inception report on November 29, 2021.

## R2R Spatial Prioritization Procedures

The Natural Capital Project's Integrated Valuation of Ecosystem Services and Tradeoffs Sediment Delivery Ratio Model (InVEST SDR version 3.9) was used to model annual soil erosion and sediment export for catchments within the Solomon Islands. Nearly all input data were calibrates using external datasets and verified for accuracy. A total of 3,104 catchments were modelled for the nine regions in the Solomon Islands. Clean datasets with metadata, calibrated models and output, maps detailing priority sites and results, and a draft report detailing methodology were packaged and delivered to the IW R2R team on December 25, 2021.

A Sediment Extent Model (SEM) was used to model sediment plumes based on ocean surface current velocities and direction, a soil particle settling rate, and ocean depth derived from bathymetry data. Additionally, this project used a threshold to identify areas of high sediment export on land and quantified the percentage of area within each catchment that is considered having high sediment export. The total amount of sediment load, area of high sediment export and coral area impacted under the sediment plume were used to rank and prioritize catchments for the 3,104 catchments. In addition to ranking catchments for prioritization based on current conditions, scenario modelling was used to estimate conditions under alternative management practices.

## Technical Reports

A technical report was submitted for review to SPC and Solomon Islands government staff on February 15, 2022. The technical report provides detailed methodology and development of the spatial prioritization procedure and a final report on the prioritization procedure, identified challenges, and potential solutions. The report includes annexes with detailed methodology for preprocessing input data using R programming language and Google Earth Engine as well as detailed steps for building the water quality model in both ArcGIS and QGIS.

## Final Consultancy Report, Presentation to the 7th RSTC, and Manuscript for Journal Article

The final consultancy report was submitted to SPC on February 28, 2022. The revision of the previous water quality model used in the Vanuatu spatial prioritization project and development of scenarios to better assess the flexibility of the full prioritization procedure created additional steps in the anticipated methodology and resulted in some delays in the final deliverables. As a result, the presentation to the 7th RSTC consisted of preliminary results and was given on January 11, 2022. The consultant will work with SPC staff to convert the technical report into a manuscript for a peer reviewed journal article in the near future.

# Overall conclusion and recommendations

## Conclusion

The objectives of this consultancy were completed but the original scope was modified to incorporate a revised water quality/sediment plume model and scenario modelling in order to thoroughly investigate the flexibility of the procedure. Due to increased additional time needed to incorporate these features, the consultancy was amended as a no-cost extension with the completion deadline extended from January 21, 2021 to February 28, 2022.

The land-sea linkage framework developed during this process outlines a multi-tier hierarchical approach for identifying and prioritizing R2R sites and projects. National reporting could be used as an initial identifier of problematic catchments for which R2R data collection could be focused. Once sedimentation and other supporting data are collected at sites, these data can then be used to calibrate and validate model results. With calibrated models, intra-catchment assessments that identify areas of high sediment export or connectivity can be identified and scenario modelling can be used to measure the relative success of the intervention, protection, or restoration projects.

Lack of calibration data for both the sedimentation and water quality model likely limits the interpretation of absolute values derived from this study. In this case study, results from the InVEST SDR model likely over-predict sediment export at the catchment outlet and the averaged ocean current data likely exaggerates the footprint of the sediment plume since extreme weather events may skew the mean values. While input data were reviewed to ensure it was reasonable and accurate, there are a few parameters that can only be optimized using calibration data collected during field studies to further refine these models. Despite the difficulty of interpretation of the absolute results due to lack of calibration, the relative ranking of catchments can still be used for inter-and intra-regional comparisons as a preliminary assessment of where to prioritize more detailed data collection for calibrated model runs.

At the national scale, baseline conditions indicate that Guadalcanal, Western, and Isabel regions have the highest sedimentation rates in the Solomon Islands. The Guadalcanal and Western regions have some of the steepest slopes within the Solomon Islands and regardless of the LULC present at high slope areas, steep slopes result in higher sediment export areas due to the slope-length factor of the RUSLE equation in the InVEST SDR model. The Isabel, Malaita, and Western regions have the highest amount of coral area under plumes and are therefore the regions with the highest connectivity to potential coral reef impacts. The Choiseul, Malaita, and Guadalcanal regions had catchments withthe highest amount of TSS impacting coral reef areas and Isabel and Western regions had catchments with moderate levels. The medium and high-ranking catchments may be considered for closer examination and detailed analysis at the catchment scale to determine prioritization for R2R projects.

Local-scale reporting for the Mataniko Catchment demonstrates the flexibility in this framework to identify site-level interventions for future applications throughout the region. Areas of highest sediment export included the deforested grassland area located near Honiara. Using scenario modelling, the reforestation of the high export grassland areas demonstrated a considerable (10%)reduction in sedimentation at the outlet. As with all models, caution needs to be taken in terms of

interpreting results without validation. The Natural Capital Project cautions against interpreting InVEST SDR results at the pixel level scale since there may be spatial errors associated with the varyingmultiple-scale input variables, each themselves representing varying degrees of uncertainty.

However, using the approach that targets areas of high sediment export in the manner presented in this study tends to identify larger areas that may reduce the noise associated with pixel-level interpretation.

The 10-year deforestation scenario resulted in increased sedimentation export for all regions and a relatively similar ranking of catchments between the baseline and deforestation scenarios. The region

with the largest change in sediment export and high sediment areas as a result of deforestation was the Central region. The Central Region is also one of the regions with the smallest landmass and the highest rate of forest conversion in this scenario. The scenario also simulated expanded deforestation from grassland areas and catchments that are already cleared, and therefore already ranked high for export, which is likely also the same catchments that had expanded deforestation. In reality, deforestation due to logging will differ from the simulated scenario but the scenario process and results may be used to help identify which regions may be more susceptible to increased soil erosion and impacts on the marine environment. While deforestation scenarios did not change the overall relative inter-and intra-regional of catchments, there was still an evident, yet varying, increase in sedimentation export even when logging was restricted to the Solomon Islands Forest Code regulations and guidelines.

Deforestation scenarios for Guadalcanal resulted in less than 1% increase in both sedimentation export at the catchment and total area of high sediment export while representing over 7% deforestation across Guadalcanal. However, the overall total sediment export and downstream impacts in Guadalcanal are still substantial in magnitude and represent the highest export in the Solomon Islands. While these scenarios show that deforestation impacts are likely minimal when the forestry code is followed, site-level efforts to stabilize the steep slopes that are contributing to the estimated output are probably warranted.

## Recommendations

Data availability in Pacific Island countries can be sparse and the technical capacity needed to reproduce some of the input data required for these models may be limited. Additionally, many Pacific Island countries are limited by the availability of hardware, GIS software, and the technical expertise to preprocess data, run models, and interpret the results. The approach outlined in this study utilizes open-source software such as Google Earth Engine, InVEST SDR model, program R and QGIS to access, manipulate, and model globally available data at various scales. The InVEST SDR model is well documented by the Natural Capital Project with support provided in the form of a user guide, user forums, and videos on model usage and interpretation of the results. Both the preprocessing of input data for models, construction and application of the plume model, and summarization of ranking across regions and catchments requires intermediate knowledge of spatial analysis and GIS functions. To assist in replicability, this report includes detailed procedures for some of these processes in the methodology and supplemental material (please see Annexes).

While increasing national GIS capacity and support is one method to boost the replicability of R2R spatial prioritization across PICT's, specific datasets could also be pre-processed and made available to these countries to facilitate the modelling process. For example, the R code used to calculate soil erodibility values could be used to generate country-level soil erodibility data and then could be hosted on SPC's R2R GeoNode or Digital Pacific repository as a resource for countries. Additional datasets that are derived from Google Earth Engine could also be processed for each country and hosted on either the GeoNode or Digital Pacific. However, these datasets should still be validated using some expertise to prevent erroneous model results and interpretation and therefore funding, if available, should also be directed at collecting validation 10 and calibration data in addition to making these datasets available to partner countries.

# Annexes/Attachments