Kiwa WISH+
Watershed Interventions for Systems Health Plus

Kiwa WISH+ Decision Support Tool

Methodology Report

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Version 1
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Overview

The Kiwa WISH+ project supports integrated water resource management approaches that aim to strengthen ecosystem health, climate resilience, and human well-being across rural Melanesian watersheds. As part of the project, an online Decision Support Tool has been developed to support integrated watershed and disease-risk management strategies in Fiji, Solomon Islands, and Papua New Guinea.

The Decision Support Tool predicts infection risk factors for two critically important water-related infectious diseases in the region, leptospirosis and typhoid, and allows users to test how these factors may change under a range of different management intervention scenarios. The Intervention scenarios include a suite of actions, ranging from improvements to household water, sanitation, and hygiene services, to nature-based solutions that manage soil erosion and the spread of contaminated soil and water.

The Decision Support Tool uses Bayesian Belief Network (BBN) models to model key transmission pathways driving leptospirosis and typhoid infections, and provide mapped predictions on infection risk factors and overall Infection Risk.

In this Methodology Report, we outline how the BBN models supporting the Tool were developed. Please see the Instruction Manual document for instructions on how to use the Tool.

The tool and models behind it were developed in collaboration with the University of Queensland and Bayes Intelligence, with support from the Kiwa initiative and the Wildlife Conservation Society.

Decision Support Tool: https://wish.bayesian-intelligence.com/

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Background

The management of watersheds has far-reaching consequences for human health across Melanesia. Many communities across Melanesia are highly dependent on natural water resources for drinking, fishing, bathing, and household cleaning water, leaving them particularly vulnerable to watershed degradation. Access to safely managed drinking water remains among the lowest in the world, with approximately 37% of households lacking access to basic drinking water services and 7% relying directly on untreated surface water sources for drinking (WHO and UNICEF, 2025). At the same time, waterways are increasingly affected by sediment, nutrient, and pathogen pollution arising from human influences such as forest clearing, agriculture, and unsafely managed sanitation. The region has some of the world's lowest coverage of safely managed sanitation services, resulting in significant loads of untreated wastewater and excreta directly entering waterways. These close connections between communities and natural water systems, combined with limited access to safe water and sanitation, leave populations directly exposed to declining water quality and at increased risk of water-related infectious diseases.

The health impacts of these challenges are substantial. Water-related infectious diseases contribute significantly to morbidity and mortality across Melanesia, including a considerable proportion of deaths among children under five years of age (UNICEF, 2017; WHO, 2023). Diseases such as leptospirosis and typhoid are of particular concern, with severe outbreaks recognised as priority public health issues throughout the region (McIver et al., 2016; WHO, 2017; Hosking et al., 2023).

The effects of watershed degradation also extend beyond human health. Aquatic and coastal ecosystems underpin community wellbeing across Melanesia by supporting critical ecosystem services such as fisheries, tourism, cultural values, and coastal protection (Laurans et al., 2013; Lau et al., 2019). However, these ecosystems are increasingly threatened by the downstream transport of sediments, nutrients, and other pollutants generated within watersheds. It is estimated that more than 45% of coral reefs in Melanesia are threatened by land-based sediment and nutrient pollution (Andrello et al., 2022), highlighting the strong ecological connections between upstream land management and downstream marine ecosystem health.

These interconnected challenges present an opportunity to better align efforts across sectors and across watersheds to manage water resources and improve overall systems health. Increasingly, Pacific Island governments and non-government organisations are recognising the value of interdisciplinary approaches to water management that can simultaneously deliver benefits for human and ecosystem health. Such approaches seek to generate co-benefits across sectors, including reducing the burden of water-related diseases while improving the resilience and health of coral reef ecosystems (WHO et al., 2011; Wenger et al., 2020; Jupiter et al., 2024). An opportunity exists to combine knowledge, resources, and funding from across different water resources management, conservation, and public health sectors to better understand the watershed system and how to manage it more effectively.

The Kiwa Watershed Interventions for Systems Health Plus (WISH+) project promotes such integrated watershed management approaches across Fiji, Solomon Islands, and Papua New Guinea. The Kiwa WISH+ project aims to improve both human and ecosystem health while strengthening long-term systems health management through decision-support tools, sustainable financing mechanisms, and effective public policy. Central to the Kiwa WISH+ approach is addressing the shared drivers of poor health outcomes in both communities and ecosystems through coordinated interventions implemented across multiple spatial scales within watersheds (Jupiter et al., 2024). At the individual scale, interventions include aiming to boost immunity against water-related disease via vaccinations. Interventions at the community/residential scale include improved access to safely managed drinking water, sanitation, and hygiene (WASH) services. At the landscape level, nature-based solutions such as forest protection and crop management target sediment and nutrient pollution (Jupiter et al., 2024). Managing nesting levels of environmental health through this approach, from WASH to watersheds, offers numerous opportunities to help address both water-related infectious disease and coastal ecosystems challenges (Jenkins et al., 2018; Jupiter et al., 2024).

Effective implementation of integrated watershed approaches requires transparent and evidence-based decision-making founded on a strong understanding of health risks (Olsen and Christie, 2000; Lane, 2008; Álvarez-Romero et al., 2015). However, information on the likely health benefits from interventions remains limited, particularly with regard to nature-based solutions within watersheds. To help address this need, we developed a Decision Support Tool that maps typhoid and leptospirosis infection risk in the Solomon Islands, Fiji, and Papua New Guinea, and evaluates the potential influence of a range of interventions ranging from watershed-scale reforestation to community-based public health measures.

Methods

The Decision Support Tool uses BBN models to model key transmission pathways driving typhoid and leptospirosis infection risks, supported by a range of environmental and socio-ecological datasets, expert-elicited information, and literature. Here we outline the development of the BBN models informing the Decision Support Tool.

The BBN models predict typhoid and leptospirosis infection risks at the resolution of a defined spatial unit, allowing risks to be mapped within the Decision Support Tool. We developed a spatial unit relevant for both ecological and socio-demographic data by using the intersection of sub-watersheds and the smallest administrative boundaries for each region (e.g., enumeration areas in Fiji).

BBN overview

BBNs are a probabilistic modelling tool that rely on the construction of a network of variables, represented by nodes and links, that form a directed acyclic graph (Figure 1). Nodes can exist in various states and are directionally linked, pointing from a "parent node" to the "child node", depicting the conditional dependence of the child node on the state of the parent node(s). Each node is associated with a probability table that quantifies the chance of the node being in each possible state. As such, child nodes have conditional probability tables (CPTs) wherein the chance of each state is conditional on the state of the parent node(s). The BN structure (i.e., nodes, links, states) allows the calculation of influence from node to node using Bayes theorem (Pearl, 1988).

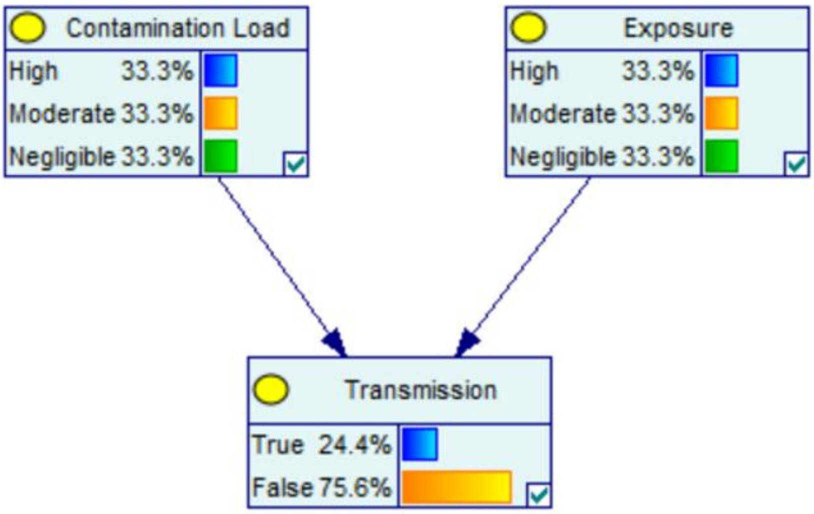

Figure 1. Example of a simple BBN structure with nodes represented as boxes and arrows representing links.

BBN models can incorporate a variety of data, assumptions, and sub-models within their intuitive structure, which can be readily reviewed with stakeholders, making them well suited to epidemiological modelling (Lau and Smith, 2016). For example, the nodes within BBNs can capture continuous or categorical data, and CPTs can be parametrised using parameter learning algorithms from available data and/or expert opinion where data is unavailable. Critically, BBNs allow for the simple inclusion and visualisation of causal relationships between variables, offering several key benefits, including a direct representation of interconnections within a system for users, the ability to model the effects of interventions (Borsuk, 2008; Marcot and Penman, 2019), and examining the intermediate processes through which outcomes arise. These characteristics make BBNs well suited to capturing the data-limited and complex system of factors influencing leptospirosis and typhoid infections across Melanesia.

BBN development

We developed the structures of the BBN models for each disease using an iterative, data-driven, and expert-led approach. The initial model structure was guided by a literature review, with particular reference to existing models developed for typhoid (Jenkins, 2017) and leptospirosis (Lau et al., 2017; Mayfield et al., 2018a, 2018b) and systematic reviews (e.g., Guernier et al., 2018; Hosking et al., 2023; Kharwadkar et al., 2024; Wakwella, 2026). This existing scientific understanding and modelling informed the overall modelling approach and helped identify key transmission pathways, variables and causal relationships. The first version of the BBN was developed by the BBN modeller, in consultation with the core project group, who have experience in modelling infectious disease in the region. The model structure then underwent several revisions over the course of the project. Revisions were informed by:

- Improved understanding of data availability;
- Interactive feedback from stakeholder interviews and workshops, both in-person and online;
- Refinement of the causal structure;
- Inclusion of intermediate variables to support clearer and more practical parameter elicitation

The stakeholders involved in workshops provided wide-ranging expertise across the research, epidemiology, prevention, and/or clinical aspects of water-related infectious disease burdens across the region, ensuring the BBN model reflected the disease's multi-sectoral relevance. In-person workshops included a session at the 2025 Oceania

Planetary Health Forum, as well as three in-country workshops conducted in the Solomon Islands, Papua New Guinea, and Fiji to review country-specific disease transmission pathways and risk factors. Several online interviews involving health experts were also conducted to assess these models, including both individual and group discussions, assisted by online questionnaires.

Through the model development process, we identified a BBN modelling approach consisting of three linked component models supported by a model of sediment exported to streams (Figure 2). Together, these components ultimately generate disease outcomes at the resolution of the defined spatial unit to allow mapping within the Decision Support tool. All BBN models were developed using GeNIe, and a bespoke BBN inference engine was developed to run the models within the user-friendly Decision Support Tool interface, allowing users to easily view various predictions from the BBN.

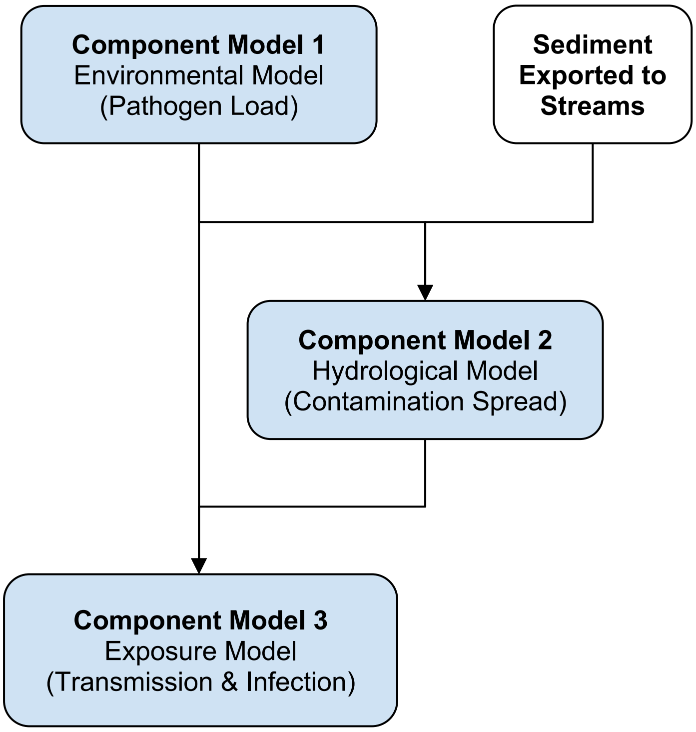

Figure 2. Flow diagram of the BBN modelling approach using three component models combined with modelled sediment exported to stream results that were used to estimate the probability that an individual in a destination spatial unit would become infected with either leptospirosis or typhoid.

The first component model estimates pathogen load for each spatial region. This contaminant load model captures the key pathogen reservoirs excreting pathogens for each disease (e.g., humans for typhoid and rats and other select mammals for leptospirosis) and the pathways by which the pathogens may be contaminating environments (e.g., soils, surface waters, groundwaters) within the spatial unit (see Appendix B for full BBN structure).

Key outputs from the contamination load model are then passed through the second component model, a hydrological model. The hydrological model incorporates pathogen loads, hydrological connections, and modelled sediment erosion inputs into surface waters (i.e., sediment export) to estimate the spread and accumulation of pathogen loads in surface water with consideration of both local and upstream contamination sources (Figure 3).

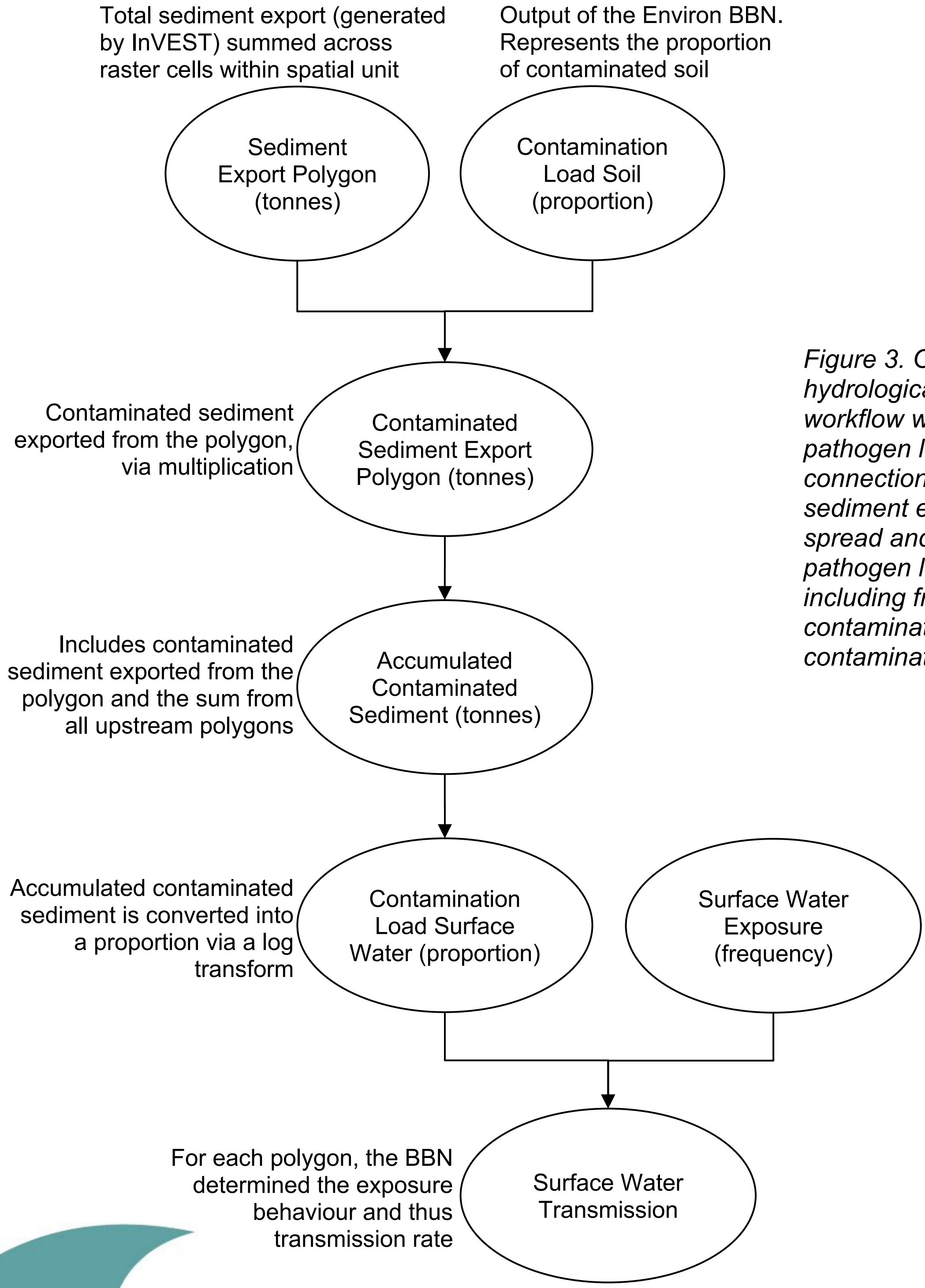

Figure 3. Overview of the hydrological component model workflow which incorporates pathogen loads, hydrological connections, and modelled sediment erosion to estimate the spread and accumulation of pathogen loads in surface water, including from both local contamination and from upstream contamination sources.

Capturing the hydrological movement and accumulation of pathogens within water from the erosion of soils is particularly relevant for both typhoid and leptospirosis transmission. While there is limited evidence that the pathogens responsible for each disease (i.e., pathogenic *Leptospira* and *Salmonella enterica* serovar Typhi) can multiply within soils and water, both pathogens can survive and persist within these environments for prolonged periods. This survival capacity creates a temporary environmental carrier of the pathogens that drives widespread disease transmission through the erosion and movement of contaminated waters and soils (Crump, 2019; Andrews et al., 2020; Bierque et al., 2020; Bradley and Lockaby, 2023). To determine likely sediment export, we incorporated the results of the sediment delivery ratio model from the Natural Capital Project's InVEST® toolkit (version 3.14.2; 2025), which estimates the delivery of soils into streams through overland erosion (see BBN parameterisation for further details) (Hamel et al., 2015).

The final component model combines outputs from the contamination and hydrological models with behavioural and household service variables such as access to WASH services. This final model estimates the probability that an individual in a destination spatial unit would become infected.

BBN parameterisation and validation

We were able to identify a range of socio-demographic, animal-host, and environmental data to assist in parameterising the BBN models. These data were sourced primarily from global environmental datasets, global health service datasets, and national censuses (summarised in Table 1).

The available datasets combined with the outcomes of the sediment delivery ratio model were sufficient to parameterise the root/input nodes of the BBN component models, and could easily be adjusted to replicate future conditions under potential Intervention Scenarios. The sediment delivery ratio model allows for the simple assessment of nature-based solutions that improve watershed condition by changing input land use and land management parameters (see Appendix D for parameterisation).

Table 1. Key data sources for parameterising disease models

Data source	Types of data included	Reference
Administrative boundaries	Shapefiles of administrative boundaries (e.g., wards, tikinas, districts, provinces)	Spatial Data Repository (2017); WCS (n.d.); SPC (2020)
Local government population, household, and agricultural censuses	Administrative area data on occupation, WASH, and livestock stock count	Fiji Bureau of Statistics (2007; 2017; 2022); Papua New Guinea National Statistical Office and ICF (2019); Fiji Ministry of Agriculture (2020); Solomon Islands National Statistics Office (2023)
Local population models	Raster of population density	Fiji Bureau of Statistics (2023)
Local land use data	Rasters of land use / land cover categories	Davies et al. (2021); SPC (2022); Ministry of Forestry (2016)
Global crop and livestock database	National livestock stock count data	FAO (2026)
Global health monitoring programmes	Rural and urban access to WASH service levels, national access to vaccinations	WHO (2026); WHO and UNICEF (2025)
OpenStreetMap data	Shapefiles of rivers and roads	Humanitarian OpenStreetMap Team (2026)
Global soil erodibility database	Soil erodibility	Borrelli et al. (2017)
Global climate database	Rainfall and temperature	Fick and Hijmans (2017)
Global hydrological and Topographical databases	Rasters of elevation and shapefiles of watershed boundaries	Lehner and Grill (2013); NASA SRTM (2013)
Global soil databases	Raster of soil clay content	Poggio et al. (2021)
Global land use database	Raster of land use / land cover categories	Potapov et al. (2022)

After the root/input nodes were a series of intermediate nodes that influence the final outcome node, Infection Risk. The intermediate nodes represent important but largely unobserved or data limited variables that drive transmission pathways. The inclusion on these intermediate nodes supports a more transparent and causal representation of disease transmission, whilst also allowing complex risk factor interactions to be captured within the model.

Unlike the root/input nodes of the BBN component models, intermediate nodes could not be parameterised by data. Several approaches to parameterise the intermediate variables were explored, including interpolation and direct elicitation based on expert understanding. The final parameterisation approach for intermediate nodes was based primarily on DeMorgan-style gates supported by expert judgement (Maaskant, 2006; Maaskant and Druzdzel, 2008; Druzdzel, 2009). DeMorgan gates are canonical noisy interaction functions, meaning they are standardised probabilistic functions that can be used to approximate complex relationships between multiple parent nodes and a child node. They generalise models known as canonical logic gates (i.e., noisy-OR and noisy-AND gates) by allowing the states of parent nodes to act as probabilistic causes, barriers, requirements, or inhibitors of the resulting state within the child node. Unlike deterministic logical relationships, DeMorgan gates include parameters representing the probability that a cause fails to produce the expected effect.

To implement DeMorgan gates for intermediate nodes, intermediate nodes were recast onto a 0-1 scale, representing the relative intensity or strength of the relevant process or condition. The probability distributions of intermediate nodes were then calculated using node functions that captured the relative influence of parent node states based on expert understanding. Node functions included “Switch” and “Logistic” functions implemented in GeNIE to incorporate the relative influence of categorical and continuous input nodes.

For categorical parent nodes, a “Switch” function was used to conditionally assign a weight value between 0 and 1 to the child node, based on the expected impact of each state on the child node. Where relevant, different weightings were used for each country if parent states had varying influences over the regional. A “Logistic” function was used to incorporate continuous input data by transforming input values to outputs between 0 and 1. A reference value was specified to define the midpoint (inflection point) of the “Logistic” function, where the output transitions most rapidly between 0 and 1. Both “Switch” function weights and “Logistic” function reference values were determined by experts. Probability distributions were used for input nodes to represent uncertainty in the underlying data and assumptions. See Appendix B and C for further details.

Because suitable empirical validation data were not available, model validation also relied primarily on expert judgement. Validation was undertaken through review by the expert group and through assessment of whether model behaviour was consistent with expert expectations. Future validation may be possible if suitable observational or surveillance data become available.

Intervention assessment

Through discussions with local stakeholders, we identified 28 potential Intervention Scenarios able to be assessed with our models (Table 2), representing 14 different types of interventions, each with two scenarios varying the coverage/effort of intervention. Scenario 1 represents the greater coverage/effort scenario, and Scenario 2 represents the more limited coverage/effort scenario. Specific parameterisation of the Intervention Scenarios for each country are provided within the Appendix C.

Interventions include the national application of vaccination (to improve immunity against infections), improvements to household WASH services (to reduce the spread of and exposure to pathogens), and watershed-scale nature-based solutions (to help retain and filter pathogens within the environment) under certain criteria. All interventions are intended to improve disease outcomes, with the exception of the nature-based scenarios relating to *Deforestation*, which illustrate the consequence of failing to protect forests.

Interventions relating to improvements to household WASH services focus on moving up the service level ladders defined within the World Health Organisations (WHO) and United Nations Children's Fund (UNICEF) Joint Monitoring Programme (JMP), which outline five categories of drinking water and sanitation ranging from “safely managed” to “no facility”, and three categories of hygiene ranging from “basic” to “no facility” (WHO and UNICEF, 2025). Nature-based solutions focus on watershed management strategies and are increasingly recommended as part of a holistic and integrated approach to addressing the broad determinants of water-related infectious diseases (Hernandez-Rodriguez and Trujillo-Rojas, 2022; Pham and Tran, 2022; Jupiter et al., 2024; Dickin et al., 2025).

Table 2. Summary of intervention scenarios assessed across countries

Intervention	Justification	Scenario 1	Scenario 2
Improving vaccine coverage *(only applicable for Typhoid)*	Improving Typhoid conjugate vaccine coverage reduces typhoid infection susceptibility (Date et al., 2014; Batool et al., 2024).	Increasing vaccine coverage to 90%.	Increasing vaccine coverage to 70%.
Improving handwashing facilities	Improving WASH service ladder level reduces the transmission of disease between individuals through several pathways, including directly reducing human exposure to pathogens (e.g., through drinking water that is treated to be free from contamination), as well as reducing the contamination of environments with pathogens (e.g., through improved containment of wastewater and excreta with safe sanitation) (WHO and UNICEF, 2025).	Increase "basic" hygiene coverage by 25% and take everyone from "no facility" to "limited" services.	Take everyone from "no facility" to "limited" or "basic" services.
Improving water reliability		Increase the amount of people who never have water reliability issues by 25% and take everyone who "often" has water reliability issues to "sometimes" or "never" has water reliability issues.	Take everyone who "often" have water reliability issues to "sometimes" or "never" have water reliability issues.
Improving drinking water services		Increase "safely managed" drinking water coverage by 25% and take everyone from surface water or "unimproved" services to "limited" or "basic" services.	Take everyone from surface water or "unimproved" services to "limited" or "basic" services.
Improving sanitation services		Increase "safely" managed sanitation coverage by 25% and take everyone from open defecation or "unimproved" services to "limited" or "basic" services.	Take everyone from open defecation or "unimproved" services to "limited" or "basic" services.
Improving land use practices	Nature-based solutions involving improved land-use management, reforesting, or forest protection reduce the erosion and spread of soils and other contaminants associated with soils. These strategies can reduce environmental pathogen loads by limiting the transport of contaminants through surface runoff (Bradford et al., 2013; Cho et al., 2016; Jenkins et al., 2016; Bierque et al., 2020).	Improve management of cropland (e.g., vetiver grass strips) in areas with high erosion (≥5 T/ha/year).	Improve management of cropland (e.g., vetiver grass strips) in areas with high erosion (≥11 T/ha/year).
Improving land use practices close to rivers		Improve management of cropland/bare land e.g., vetiver grass strips) in areas with high erosion (≥5 T/ha/year), within riparian buffer zone.	Improve management of cropland/bare land (e.g., vetiver grass strips) in areas with high erosion (≥11 T/ha/year), within riparian buffer zone.
Reforestation		Reforestation in cropland/bare land areas with high erosion (≥5 T/ha/year).	Reforestation in cropland/bare land areas with high erosion (≥11 T/ha/year).
Restoring erosional riparian buffer		Restore cropland/bare land with high erosion (≥5 T/ha/year) to forest within riparian buffer zone.	Restore cropland/bare land with high erosion (≥11 T/ha/year) to forest within riparian buffer zone.
Restoring riparian buffer		Restore all cropland/bare land areas to forest within riparian buffer zone.	Restore cropland/bare land to forest within riparian buffer zone and above 15 degrees slope.

Reduce grazing pressure in riparian buffer		Reducing grazing intensity within cropland/grassland in riparian buffer zone.	Reducing grazing intensity within cropland/grassland in riparian buffer zone above 15 degrees slope.
Deforestation		Loss of 25% of forest in areas where logging is currently permitted based on slope limits (e.g., in areas ≤25 degrees in Fiji; McIntosh 2013).	Loss of 25% of forest in subset of area where logging is currently permitted based on slope limits (e.g., in areas > 15 and ≤ 25 degrees in Fiji).
Reforestation + reducing grazing pressure in riparian buffer zone		Reforestation in cropland/bare land areas with high erosion (≥5 T/ha/year) AND Reducing grazing intensity within cropland/grassland in riparian buffer zone.	Reforestation in cropland/bare land areas with high erosion (≥11 T/ha/year) AND Reducing grazing intensity within cropland/grassland in riparian buffer zone above 15 degrees.
Improving land use practices + restoring riparian buffer		Restore all cropland/bare land areas to forest within riparian buffer zone AND Improve management of cropland (e.g., vetiver grass strips) in areas with high erosion (≥5 T/ha/year).	Restore cropland/bare land to forest within riparian buffer zone and above 15 degrees AND Improve management of cropland (e.g., vetiver grass strips) in areas with high erosion (≥11 T/ha/year).

NOTE:
Details on the specific intervention assessment methods per country are provided in Appendix E Table E1 (Fiji), Table E2 (Solomon Islands), and Table E3 (Papua New Guinea)

Table 3. Examples of actions to achieve each intervention. Note, this list is not exhaustive and is meant to be illustrative.

Intervention	Actions to achieve intervention
Improving vaccine coverage	Vaccine awareness raising Vaccine access
Improving handwashing facilities	Install/ upgrade handwashing facilities Hygiene awareness raising campaigns Improve access to soap
Improving water reliability	Strengthen water committees Dam upgrades to service more people Increase storage of rainwater and dam water
Improving drinking water services	Ecological purification system Dam upgrades to service more people Dam upgrades to add in filtration to meet Water Authority Standards Dam maintenance Clean and maintain rainwater tanks so that lids are closed and gutters are maintained Upgrade rainwater tanks Strengthen water committees
Improving sanitation services	Upgrading sanitation infrastructure Improving service delivery Septic tank emptying and transport to treatment facility or sanitary landfill
Improving land use practices	Vetiver grass planting around livestock pens Fencing livestock Implementing erosion control practices
Improving land use practices close to rivers	Moving agriculture away from water bodies Moving grazing areas away from water bodies Fencing or penning livestock Fencing water bodies to keep livestock out of the way Vetiver grass planting on riverbanks
Reforestation	Reforestation
Restoring erosional riparian buffer	Reforestation
Restoring riparian buffer	Reforestation
Reduce grazing pressure in riparian buffer	Reduce stocking rate Fencing water bodies to keep livestock out of the way
Protecting forest	Protected area creation

Discussion

The Decision Support Tool provides its predictions based on the best available understanding of key disease risk factors and transmission pathways identified through the literature and expert knowledge, and for which sufficient spatial data were available to produce predictive maps. The inclusion of the hydrological component model allows for users to see how management actions may have benefits across watershed-scales, e.g., by reducing the generation and/or spread of pathogens across waterways. However, the evidence base remains incomplete in several areas, which limits the predictive capacity of our models.

In many instances, data to help identify the location and severity of important risk factors were limited or unavailable, and/or there was incomplete understanding of the mechanism of infection. For example, the experts and literature identified poor solid waste management and community gatherings as important risk factors influencing both diseases, but there was limited spatialised information on these factors across the regions to include within the model. Additionally, despite obtaining feedback from a variety of experts, we were limited in the number of experts available and willing to participate in the consultation process. This may have restricted the diversity of perspectives represented in the review and refinement of the country-specific models. These limitations constrained model development and meant that some potentially important risk factors and infection dynamics could not be explicitly represented within the tool. Furthermore, without spatially explicit data on leptospirosis and typhoid infection burdens across the three countries, model outputs could not be validated and should therefore be interpreted with caution as predictions based on known and modellable risks. The predictions are consequently constrained by current scientific understanding of disease transmission, the availability of relevant risk factor data, and access to accessible spatial datasets within the region.

The Intervention Scenarios presented here are a collection of broad management options for disease prevention applied at a national scale, and we model how these Intervention Scenarios change disease outcomes if successfully implemented. However, there is considerable variability in the implementation success of different Intervention Scenarios across different contexts, as well as the range of actions required to implement each Intervention Scenario. For example, the costs and feasibility of different actions can be highly variable across a country due to influences such as social acceptability, political will, and available technical resources. We have avoided prescribing specific actions and costs to implement each Intervention Scenario due to this variability and limited locally relevant information. Consequently, even when an Intervention Scenario is predicted to be highly effective at reducing disease risks by the Tool, users should carefully consider the local implementation environment to further assess which actions are most suitable to implement the Intervention and whether they are locally applicable.

We identified several key data gaps where improved data collection and availability could substantially strengthen future modelling efforts and support more targeted public health interventions:

- Geolocated data on leptospirosis or typhoid infections
    - Spatially-explicit data on disease burdens (e.g., confirmed cases, syndromes, or seroprevalence data linked to households or communities) would enable modelled Infection Risk to be validated. Key model parameters could also be more accurately calibrated based on the relationships between observed infections and associated risk factors. This would substantially improve understanding of infection risk and the relative importance of different risk factors across the region.

- Locations of large community gatherings e.g., locations of large markets
    - Improved information on locations where large numbers of people congregate would help identify environments with a potentially elevated risk of faecal–oral disease transmission, including typhoid fever.
- WASH data collection in alignment with WHO/UNICEF JMP service level definitions
    - Using JMP service level classifications would improve understanding of population exposure to unsafely managed drinking water and sanitation services. Current datasets often focus on facility characteristics rather than service levels, limiting the ability to assess contamination risks and identify areas where environments may be affected by inadequately managed sanitation.
- Higher resolution local digital elevation model (< 90m)
    - Access to finer-scale elevation data would improve hydrological modelling and increase confidence in predictions of water movement and pollutant transport across landscapes.
- Transparent reporting of costs and feasibility of actions
    - Improved information on the costs, implementation requirements, and feasibility of interventions would support prioritisation of actions and enable future cost-effectiveness analyses.
- Agricultural stocking and rodent population data
    - More comprehensive data on livestock densities and rodent populations would improve understanding of leptospirosis host dynamics and support the identification of areas at greatest risk of transmission.
    - Future analyses could also assess rodent control interventions with such data, which may provide broader benefits through reduced disease transmission, lower agricultural losses, and alignment with government priorities for pest management and biodiversity protection.

- Waste and drainage management
    - Information on the kinds of waste disposal services and drainage systems (e.g., within key urban and rural environments) would help identify environmental conditions that may increase disease risks, e.g., support the proliferation of rodent hosts and contribute to leptospirosis transmission.

Acknowledgments

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Appendix A. Data Dictionary

Table A1. Bayesian Belief Network data dictionary for data driven nodes, including nodes, states, their definitions, and the source of data used for their parameterisation. Note: FJ = Fiji, SI = Solomon Islands, PNG = Papua New Guinea.

Data Node Name	Node Description/Justification	States	Data FJ	Data PNG	Data SI
Drinking water	The drinking water service level within households Service levels defined as per the WHO/UNICEF JMP drinking water service ladder. The source of drinking water, its accessibility, availability, and quality within each service level were used to determine corresponding risks of pathogen contamination and human exposure.	**dw_safe** - % households with safely managed drinking water **dw_basic** - % households with basic drinking water services **dw_limited** - % households with limited drinking water services **dw_unimproved** - % households with unimproved drinking water services **dw_nofacility** - % households with no facility (surface water)	WHO/UNICEF JMP 2025 rural and urban data on households updated to provide further spatial resolution using household data on “no facility” (i.e., surface water) and unimproved drinking water (i.e., unprotected springs and wells) within administrative units from local censuses (Fiji Bureau of Statistics, 2017; Papua New Guinea National Statistical Office and ICF, 2019; Solomon Islands National Statistics Office, 2023; WHO and UNICEF, 2025)		
Sanitation	The sanitation service level within households Service levels defined as per the WHO/UNICEF JMP service ladder. The type of facility, sharing between households, and excreta disposal within each service level was used to determine corresponding risks of pathogen contamination in environments and pathogen exposure to humans.	**san_safe** - % households with safely managed sanitation **san_basic** - % households with basic sanitation **san_limited** - % households with limited sanitation **san_unimproved** - % households with unimproved sanitation **san_nofacility** - % households with no facility (open defecation)	WHO/UNICEF JMP 2025 rural and urban data on households updated to provide further spatial resolution using household data on “no facility” (i.e., open defecation) within administrative units from local censuses (Fiji Bureau of Statistics, 2017; Papua New Guinea National Statistical Office and ICF, 2019; Solomon Islands National Statistics Office, 2023; WHO and UNICEF, 2025)		
Hygiene	The hygiene service level within households Service levels defined as per the WHO/UNICEF JMP hygiene service ladder. The presence and	**hyg_basic** - % of households with basic hygiene facilities **hyg_limited** - % of households with limited hygiene facilities (no soap or water) **hyg_nofacility** - % of households with no facility	Rural & urban level census data (Fiji Bureau of Statistics,	WHO/UNICEF JMP 2025 rural and urban data (WHO and UNICEF, 2025)	

Data Node Name	Node Description/Justification	States	Data FJ	Data PNG	Data SI
	accessibility of handwashing facilities with soap and water within each service level were used to determine corresponding risks of pathogen transmission and human exposure.		2022)		
Drinking water type	Main source of drinking water at household. Main source of drinking water facility type at households. Note not all states are present/relevant for all countries. The drinking water facility types were used to determine exposure to environmental water sources from household water use.	**dwt_m_pd** - % households with main drinking water source piped into dwelling (all countries) **dwt_m_pp** - % households with main drinking water source as metered water piped into compound, yard or plot (FJ & SI data) **dwt_m_pt** - % households main drinking water source as public tap/standpipe (all countries) **dwt_m_pn** - % households with main drinking water source as metered water piped to neighbor (FJ data) **dwt_d_pr** - % households with main drinking water source as protected dug well (all countries) **dwt_d_un** - % households with main drinking water source as unprotected dug well (all countries) **dwt_s_pr** - % households with main drinking water source as protected spring water (all countries) **dwt_s_un** - % households with main drinking water source as unprotected spring water (all countries) **dwt_r_t** - % households with main drinking water source as rain water (all countries) **dwt_sf** - % households with main drinking water source as open surface water including rivers, stream, dam lake (all countries) **dwt_c_t** - % households with main drinking water source as communal tank (FJ data) **dwt_c_p** - % households with main drinking water source as communal standpipe (FJ data) **dwt_bh** - % households with main drinking water source as borehole - treated or untreated (all countries) **dwt_FE** - % households with main drinking water source as FSC/EGM (FJ data)	Tikina-level census data (Fiji Bureau of Statistics, 2017)	Province-level census data (Papua New Guinea National Statistical Office and ICF, 2019)	Province-level census data (Solomon Islands National Statistics Office, 2023)

Data Node Name	Node Description/Justification	States	Data FJ	Data PNG	Data SI
		dwt_o - % households with "other" main drinking water source (all countries)			
Water reliability	Household water reliability/supply The reliability of household water supply. Used to determine reliability of drinking water safety level.	**wr_sometimesdry** - % households where water supply sometimes dries up. **wr_neverdry** - % households where water supply never dries up. **wr_oftendry** - % households where water supply often dries up.	Tikina-level census data (Fiji Bureau of Statistics, 2017)	National average used from Fiji	National average used from Fiji
Occupation	Main occupation within households. Main occupation of the working population in households. Note not all states are present/relevant for all countries.	**oc_carer** - % of 15+ working population with main occupation as personal care workers (FJ data) **oc_cropfarmer** - % of 15+ working population with main occupation as crop farmer (FJ data) **oc_animalfarmer** - % of [15+/12+] working population with main occupation as animal production/farming (FJ & SI data) **oc_animalvegfarmer** - % of 15+ working population with main occupation as mixed animal/veg farmers (FJ data) **oc_gathersfruits** - % of 15+ working population with main occupation as gathers fruits (FJ data) **oc_loggers** - % of 15+ working population with main occupation as loggers/forestry (FJ data) **oc_fisherman** - % of 15+ working population with main occupation as fishermen (FJ data) **oc_subsistencework** - % of 15+ working population with main occupation as subsistence work (FJ data) **oc_other** - % of Persons 12 years+ in other occupation (all countries) **oc_agriculturalland** - % of households owning agricultural land (PNG data)	Tikina-level census data (Fiji Bureau of Statistics, 2007)	Province-level census data (Papua New Guinea National Statistical Office and ICF, 2019)	Province-level census data (Solomon Islands National Statistics Office, 2023)
Residential setting	Household residential setting The dominant type of housing setting within the area. Used to help determine presence of	**Rural** - area designated as rural **Peri-urban** - area designated as peri-urban **Urban** - area designated as urban	Residential setting boundaries identified at the	Urban/rural settings identified at the ward-level from ward names and % of urban/rural households within wards	

Data Node Name	Node Description/Justification	States	Data FJ	Data PNG	Data SI
	several key risks, including exposure to livestock, soils, and water, and the presence of rodents.		enumeration area-level (SPC, 2020)	from census. Peri-urban areas identified as 2.5km buffer around urban areas. (Spatial Data Repository, 2017; Papua New Guinea National Statistical Office and ICF, 2019; Solomon Islands National Statistics Office, 2023; WCS, n.d.)	
Land use	Land use/land cover. Land use / land cover classes. Note not all states are present/relevant for all countries. Used to help determine presence and exposure to livestock and rodents.	**1 Water** - all countries **2 Mangrove / Wetland (any height)** - all countries **3 Shrubland** - FJ data **4 Native forest / Forest (any height)** - all countries **5 Softwood plantation forest** - FJ data **6 Hardwood plantation forest** - FJ data **7 Grassland** - all countries **8 Coconut plantations** - FJ data **9 Settlement / Built-up** - all countries **10 Sugarcane** - FJ data **11 Cropland / agriculture** - all countries **12 Barren land / True desert / Semi-arid** - all countries **13 Bare soil/rock** - FJ data **14 Other** - FJ data	% coverage of each category summarised to watershed/ administrative area-level from land use raster. Land use raster created from SPC 2010, Davies et al. 2021, and Ministry of Forest maps. See Appendix Table D1 and Table D3 for details (Ministry of Forestry, 2016; Davies et al., 2021; SPC, 2022)	% coverage of each category summarised to watershed/ administrative area-level from land use raster. Land use raster created from 2020 GLAD land use/land cover data reclassified into 14 classes based on erosion and animal habitat characteristics. See Appendix Table D2 and Table D4 for details (Potapov et al., 2022)	
Population	Density of people	Continuous value (average individuals/km2)	Density	Density summarised to	

Data Node Name	Node Description/Justification	States	Data FJ	Data PNG	Data SI
density	Density of people in the area. Used to help determine initial pathogen loads.		summarised to watershed/ administrative area-level using average values from population density raster (Fiji Bureau of Statistics, 2023)	watershed/ administrative area-level using average values from population density raster (WorldPop, and Bondarenko, 2020)	
Livestock density	Density of livestock. Includes cattle, goats, pigs, and horses. Used to help determine initial pathogen loads and exposure to animal hosts.	Continuous value (average animals/km2)	Density summarised to watershed/ administrative area-level using average values from livestock density raster. Livestock raster created using Province stock count data from census / Province area (Fiji Ministry of Agriculture, 2020; SPC, 2020)	Density summarised to watershed/ administrative area-level using average values from livestock density raster. Livestock raster created using national stock count data from FAO / country area (Spatial Data Repository, 2017; FAO, 2026)	Density summarised to watershed/ administrative area-level using average values from livestock density raster. Livestock raster created using Province stock count data from census / Province area (Solomon Islands National Statistics Office, 2023; WCS, n.d.)
Rainfall	Annual mean precipitation Annual mean precipitation. Used	Continuous value (average mm/year)	Precipitation summarised to watershed/ administrative area-level using average		

Data Node Name	Node Description/Justification	States	Data FJ	Data PNG	Data SI
	to help determine pathogen survivability in the environment.		values from WorldClim 2.1 historical precipitation raster (Fick and Hijmans, 2017)		
Temperature	Annual mean temperature Annual mean temperature. Used to help determine pathogen survival within the environment.	Continuous value (average °C)	Temperature summarised to watershed/administrative area-level using average values from WorldClim 2.1 historical temperature raster (Fick and Hijmans, 2017)		
Sediment export	Total sediment exported from each pixel that reaches the stream Used to help determine pathogen transport across environments from surface runoff.	Continuous value (metric tons/hectare/year)	Total sediment export summarised to watershed/administrative area-level using sum from sediment export raster. Sediment export raster created using sediment delivery ratio model (see Appendix D for details).		
Clay content	Content of clay within topsoils. Defined as mean proportion of clay particles (< 0.002 mm) in the fine earth fraction (g/kg) within 0-5cm depth. Used to help determine pathogen transport through soils into groundwater.	Continuous value (average g/kg)	Clay content summarised to watershed/administrative area-level using average values from SoilGrids clay raster (Poggio et al., 2021)		
River distance	Distance to river lines Distance to rivers. Used to help determine exposure to surface water.	**Near** - Greater than 100m from river lines **Far** - Less than or equal to 100m from river lines	% coverage of each category summarised to watershed/administrative area-level from distance to river raster. Distance to river raster created by calculating distance from river shapefiles. River shapefiles created by combining local river shapefiles with global river lines from OpenStreetMap (Ministry of Lands and Mineral Resources, 2004; Humanitarian OpenStreetMap Team, 2026; WCS, n.d., n.d.)		

Data Node Name	Node Description/Justification	States	Data FJ	Data PNG	Data SI
Slope	Slope gradient Slope gradient (i.e. slope steepness) in degrees of the flowpaths that pass through each grid cell. Used to help determine local water drainage / pooling of water.	Continuous value (average degree slope)	Slope summarised to watershed/administrative area-level using average values from slope raster. Slope rasters created from digital elevation model rasters (Lehner and Grill, 2013; NASA Shuttle Radar Topography Mission (SRTM), 2013) using terrain function in R package terra. See Appendix Table D1 and Table D2 for further details on obtaining digital elevation models.		
Vaccination	Coverage of typhoid vaccination Vaccination uptake within the target population, with good coverage associated with reduced population susceptibility and lower risk of typhoid transmission and outbreaks (Batool et al., 2024).	**Good** - A high proportion of the population has access to and/or received a typhoid vaccine **Poor** - A low proportion of the population has access to and/or received a typhoid vaccine	National level estimated via national vaccination coverage obtained from WHO vaccine coverage (WHO, 2026)		

Appendix B. Environment Sub-Model

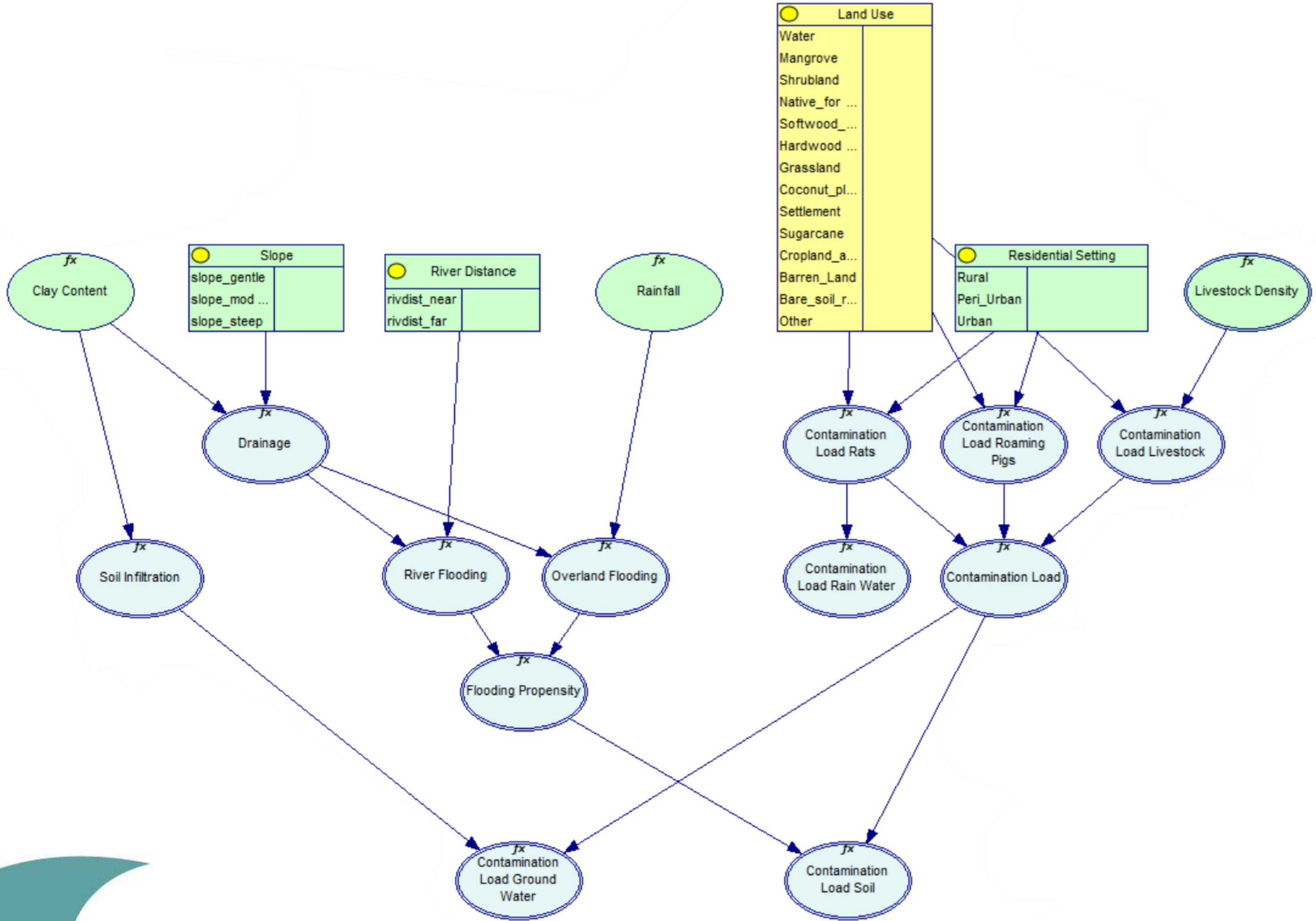

Figure B1. BN structure for the leptospirosis environment sub-model. Yellow and green nodes represent input variables, with yellow nodes indicating variables that can be modified through interventions currently modelled.

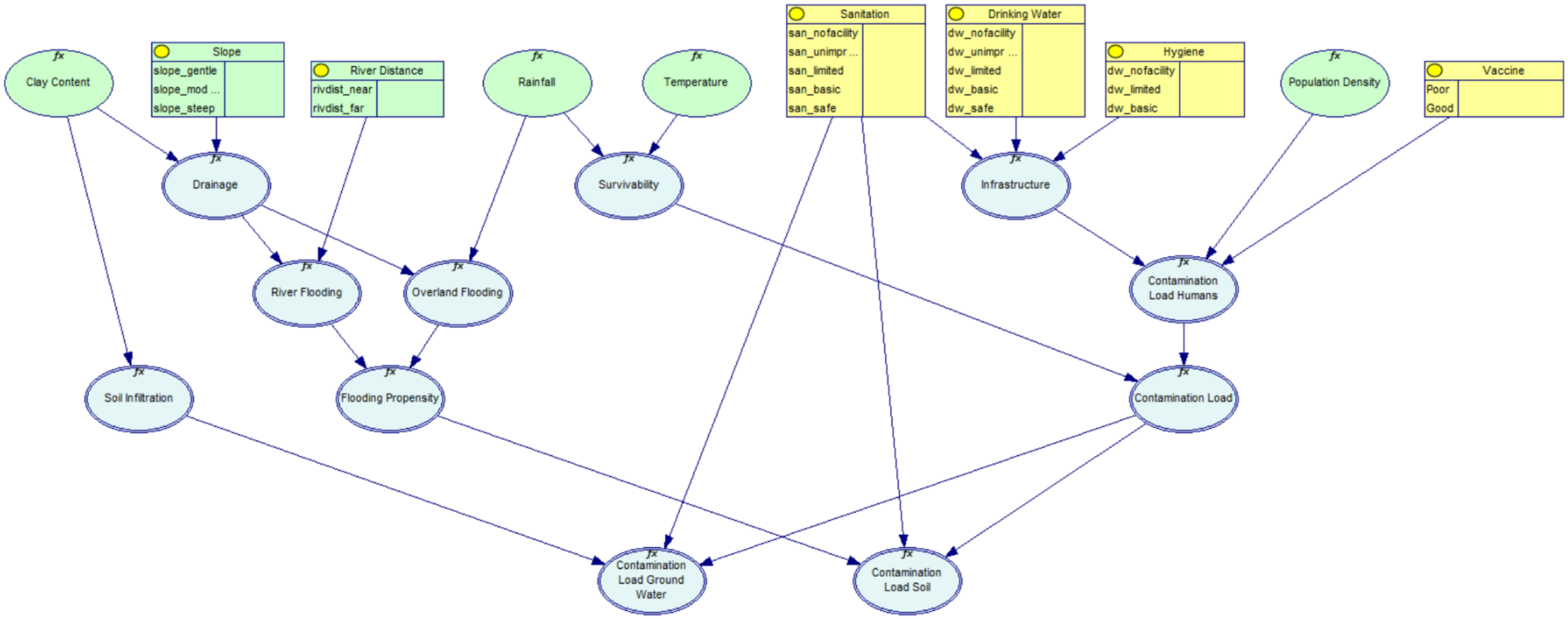

Figure B2. BN structure for the typhoid environment sub-model. Yellow and green nodes represent input variables, with yellow nodes indicating variables that can be modified through interventions currently modelled.

Table B1. Bayesian Belief Network dictionary for intermediate nodes within the environment sub-model, including description of nodes and the method (i.e., function + inputs) used to parameterise them. Functions were used to calculate the probability of the node based on parent node inputs and were supported by the use of type, and a repeated use of "Switch" and "logistic" functions. The 'Switch' function was used for categorical parent nodes, conditionally assigning a weight between 0 and 1 according to the parent node's state. The 'Logistic' function was used to transform continuous input data into a value between 0 and 1. A reference parameter defined the midpoint of the logistic curve (i.e., the point at which the output transitions most rapidly between 0 and 1). Note: FJ = Fiji; SI = Solomon Islands; PNG = Papua New Guinea; Typh = typhoid; Lepto = leptospirosis.

Variable	Description	Model	Function	Input Parameterisation
Infrastructure	<u>Summary of WASH service level</u> Used to assess risks of environmental pathogen contamination, pathogen transmission, and human exposure. Safely managed sanitation is the only service level to limit pathogen contamination in environments as, by definition, excreta are safely disposed of *in situ* or removed and treated offsite. Improved facilities (as are present in safe, basic, and limited service levels), by definition, hygienically separate excreta from human contact, so limit direct pathogen exposure to humans. Improved facilities that are not shared with other households (as are present in safe and basic service levels) also limit direct pathogen exposure to humans, however they may still be causing indirect pathogen exposure through groundwater contamination. Unimproved services contaminate environments and do not limit direct pathogen exposure to humans. Safely managed drinking water is the only service level that, by definition, is sourced from an improved water source that is accessible on premises, available when needed, and free from faecal and priority chemical contamination, thereby minimising pathogen exposure. Basic and limited services use improved water sources and therefore generally provide greater protection from contamination than unimproved sources; however, risks remain due to collection, transport, storage, or treatment limitations. Unimproved water sources and surface water are associated with the greatest risk of pathogen exposure due to inadequate protection from environmental contamination.	Typh	1- (1-Switch(Sanitation))* (1-Switch(Drinking_Water))* (1-Switch(Hygiene))	**Sanitation (weight):** no facility: 1 unimproved: 0.9 limited: 0.7 basic: 0.65 safe: 0.01 **Drinking water (weight):** no facility: 1 unimproved: 0.9 limited: 0.6 basic: 0.6 safe: 0.01 **Hygiene (weight):** no facility: 1 limited: 0.9 basic: 0.3

Variable	Description	Model	Function	Input Parameterisation
	Basic hygiene services, which, by definition, include a handwashing facility with soap and water available on premises, provide the highest level of protection by supporting effective hand hygiene and reducing person-to-person and faecal–oral transmission of pathogens. Limited hygiene services include a handwashing facility that lacks either soap or water and therefore provide reduced protection against pathogen transmission. Households with no hygiene service have no handwashing facility available, resulting in the highest risk of pathogen exposure and transmission due to limited opportunities for effective hand hygiene.			
Contamination_Load_Humans	<u>Relative *Salmonella enterica* serovar Typhi load initially present</u> At this initial step of the model, the aim is to get a simple/high-level measure of the background pathogen load based on key environmental factors: population density, safety of WASH services, and vaccination rates (Brockett et al., 2020; Batool et al., 2024; Boakye Okyere et al., 2025). The remainder of the model determines the chance that an individual transmission will occur based on more detailed risk factors and transmission pathways.	Typh	Logistic(Population_Density)* Infrastructure* Switch(Vaccine)	**Population density (reference):** 0.5 **Vaccination (weight):** poor: 1 good 0.5
Contamination_Load_Livestock	<u>Relative pathogenic *Leptospira* load initially present from livestock</u> At this initial step of the model, the aim is to get a simple/high-level measure of the background pathogen load from livestock based on their density. Although vaccination in some livestock animals is possible for some strains of the disease, it was excluded due to the lack of feasibility at a national level and limited information on strains. Due to the coarseness of livestock density data, we added a modifier to capture the propensity of livestock to inhabit different land-use classes based on expert input and literature (Naikatini et al., 2023)	Lepto	Logistic(Livestock_Density)* Switch(Land_Use)	**Livestock density (reference):** 150 **Land Use (weight):** water: 0 mangrove: 0 shrubland: 0.5 native forest: 0 softwood plantation forest: 0.5 hardwood plantation forest: 0.5 grassland: 1 coconut plantations: 1 settlement: 0.4 sugarcane: 1 cropland agriculture: 1 barren land: 0

Variable	Description	Model	Function	Input Parameterisation
				bare soil rock: 0 other: 0.5
Contamination_Load_Rats	Relative pathogenic *Leptospira* load initially present from rats At this initial step of the model, the aim is to get a simple/high-level measure of the background pathogen load from rats based on their density. Due to the lack of rat density data, residential setting and land use were used as proxies for the local rat populations, using expert input and literature (Olson et al., 2006; Harper and Bunbury, 2015; Naikatini et al., 2023) to help parameterise propensity to inhabit each.	Lepto	Switch(Residential_Setting)* Switch(Land_Use)	**Residential Setting (weight):** rural: 0.8 peri urban: 1 urban: 0.5 **Land Use (weight):** water: 0 mangrove: 1 shrubland: 0.5 native forest: 0 softwood plantation forest: 0.5 hardwood plantation forest: 0.5 grassland: 1 coconut plantations: 1 settlement: 1 sugarcane: 1 cropland agriculture: 1 barren land: 0 bare soil rock: 0 other: 0.5

Variable	Description	Model	Function	Input Parameterisation
Contamination_Load_Pigs	Relative pathogenic *Leptospira* load initially present from small-scale roaming, farmed, and/or feral pigs At this initial step of the model, the aim is to get a simple/high-level measure of the background pathogen load from small-scale roaming, farmed, and/or feral pigs that aren't captured in censuses, based on their density. These populations were only identified as important within Fiji and Papua New Guinea. Due to the lack of data on pig population density, residential setting and land use were used as proxies for the local populations, using expert input and literature (Naikatini et al., 2023) to help parameterise propensity to inhabit each.	Lepto	Switch(Residential_Setting)* Switch(Land_Use)	**Residential Setting (weight):** rural: FJ = 0.7; SI = 0; PNG = 0.7 peri urban: FJ = 0.7; SI = 0; PNG = 1 urban: FJ = 0.5; SI = 0; PNG = 0.5 **Land Use (weight):** water: 0 mangrove: 0 shrubland: 1 native forest: 0 softwood plantation forest: 0.5 hardwood plantation forest: 0.5 grassland: 1 coconut plantations: 1 settlement: 1 sugarcane: 1 cropland agriculture: 1 barren land: 0 bare soil rock: 0 other: 0.5
Contamination_Load	Total relative *Salmonella enterica* serovar Typhi load present across the environmental pathways This was determined from the contamination load in the local human population, modified by the survivability of the pathogen.	Typh	Contamination_Load_Humans* Survivability	
Contamination_Load	Total relative pathogenic *Leptospira* load present across the environmental pathways This was determined from the contamination load in the local livestock, rat and roaming pig populations - key animal hosts in the region (Guernier et al., 2018). Due to limited clear information on the influence of temperature and rainfall on survivability (Bierque et al., 2020), this was excluded.	Lepto	1-(1-Contamination_Load_Pigs)*(1-Contamination_Load_Livestock)*(1-Contamination_Load_Rats)	

Variable	Description	Model	Function	Input Parameterisation
Survivability	Relative ability for *Salmonella enterica* serovar Typhi to survive in the environment *Salmonella enterica* serovar Typhi persists longer in high humidity environments (i.e., high rainfall and temperature), so these factors were used to help predict survivability (Meiring et al., 2023).	Typh	Logistic(Rainfall)* Logistic(Temperature)	**Rainfall (reference):** 3500 **Temperature (reference):** 15
Drainage	The local drainage of water The effectiveness of local environmental conditions in removing accumulated contaminated water, mitigating against flooding impact. Drainage was determined by slope, which affects surface runoff, and soil type, which affects water infiltration into the soil. Poor drainage is an important risk factor of both diseases (Guernier et al., 2018; Kharwadkar et al., 2024; Boakye Okyere et al., 2025).	Both	Switch(Slope)* (1-Logistic(Clay_Content))	**Clay content (reference):** 0.3 **Slope (weight):** gentle: 0.1 moderate: 0.3 steep: 0.8
Overland_Flooding	Overland flooding propensity Overland flooding represents flooding caused by rainfall or surface runoff accumulating across the landscape before entering defined drainage channels or rivers.	Both	Logistic(Rainfall)* (1-Drainage)	**Rainfall (reference):** 3500
River_Flooding	River flooding propensity River flooding represents flooding caused by rivers or streams exceeding their channel capacity and inundating adjacent land.	Both	Switch(River_Distance)* (1-Drainage)	**River distance (weight):** near: 0.5 far: 0.1
Flooding_Propensity	The propensity of the local area to flood The combined impact of overland and river flooding mechanisms. Flooding is an important risk factor for both diseases, contributing to risks such as the spread of pathogens for both diseases (Lau et al., 2010; Guernier et al., 2018; Hosking et al., 2023; Boakye Okyere et al., 2025)	Both	1-(1-Overland_Flooding)* (1-River_Flooding)	
Soil_Infiltration	Filtration of pathogens by soil Intermediate node to capture the relative influence of soil permeability (or conversely, soil filtration of pathogens) leading to ground water contamination.	Both	1-Logistic(Clay_Content)	**Clay content (reference):** 0.3
Contamination_Load_Rain_Water	Relative pathogenic *Leptospira* load present in rainwater pathway Pathogen load is presumed to be proportional to the local rat contamination load, with rat urine contaminating rainwater tank	Lepto	Contamination_Load_Rats	

Variable	Description	Model	Function	Input Parameterisation
	catchments (e.g., roofs). Based on expert input.			
Contamination_Load_Soil	Relative *Salmonella enterica* serovar Typhi load present in soil pathway The potential contamination load from humans, flooding propensity, and the type of excreta disposal within each sanitation service level was used to determine corresponding risks of pathogen contamination within soils. Safely managed sanitation is the only service level to limit pathogen contamination in environments as, by definition, excreta are safely disposed of *in situ* or removed and treated offsite. Unimproved services do not adequately contain excreta and therefore are more likely to contaminate environments than limited and basic service levels, and no facility (i.e., open defecation) results in direct contamination of environments.	Typh	1-(1-Contamination_Load* Switch(Sanitation)* Flooding_Propensity)* (1-Contamination_Load* Switch(Sanitation))	**Sanitation (weight)**: no facility: 1 unimproved: 0.8 limited: 0.5 basic: 0.5 safe: 0.0
Contamination_Load_Soil	Relative pathogenic *Leptospira* load present in the soil pathway Contamination of local soils is incorporated through two pathways: direct contamination (as determined from animal host densities) and flood-mediated contamination.	Lepto	1-(1-Contamination_Load* Flooding_Propensity)* (1-Contamination_Load)	
Contamination_Load_Ground_Water	Relative *Salmonella enterica* serovar Typhi load in ground water pathway. The relative amount of leaching from each sanitation service level as well as the local soil infiltration was used to determine corresponding risks of pathogen contamination within groundwater.	Typh	Contamination_Load* Soil_Infiltration* Switch(Sanitation)	**Sanitation (weight)**: no facility: 0.5 unimproved: 1 limited: 0.9 basic: 0.9 safe: 0.01
Contamination_Load_Ground_Water	Relative pathogenic *Leptospira* load in ground water pathway The direct contamination (as determined from animal host densities) as well as the local soil infiltration was used to determine corresponding risks of pathogen contamination within groundwater.	Lepto	Contamination_Load* Soil_Infiltration	

Appendix C. Infection Sub-Model

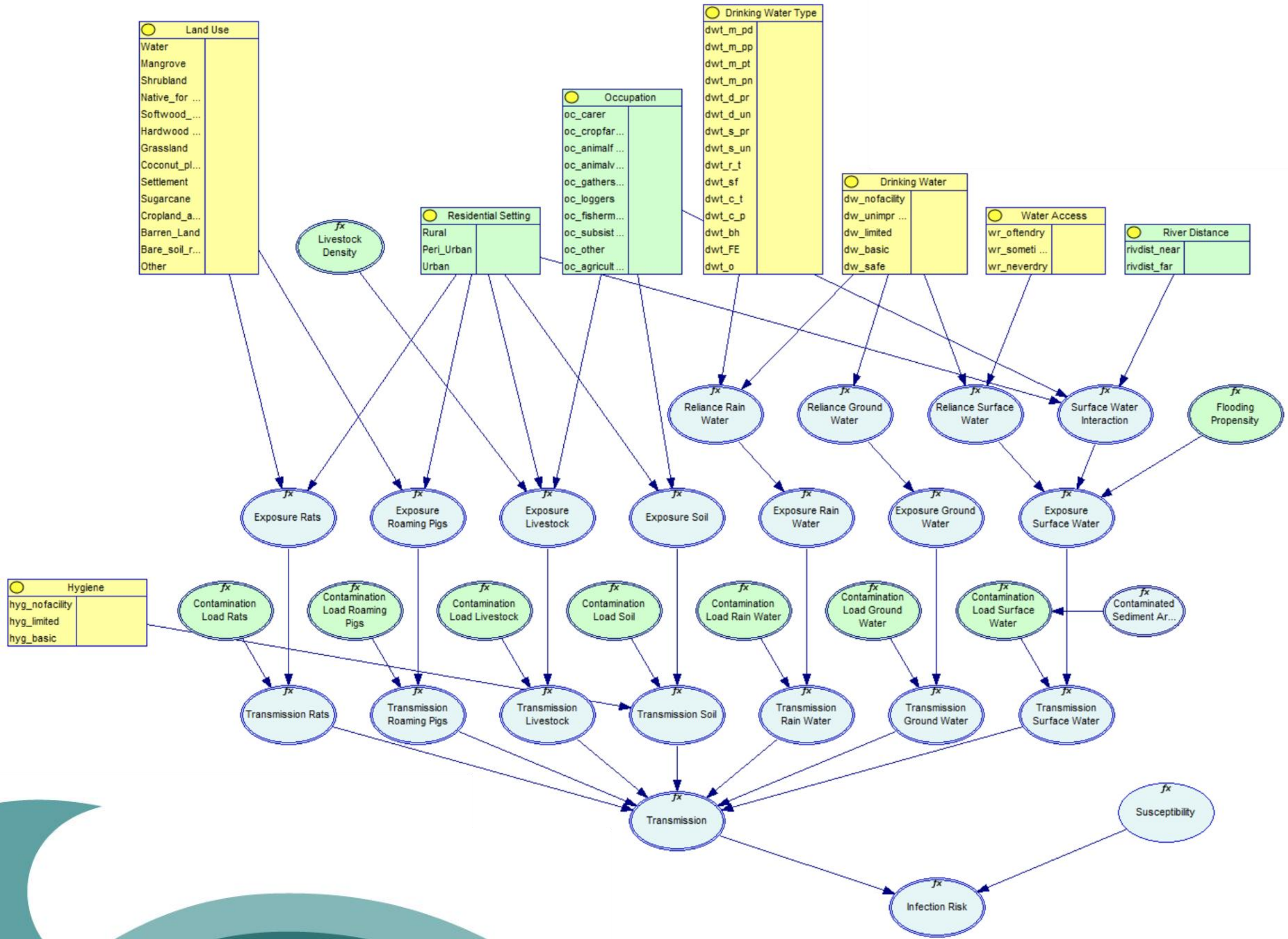

Figure C1. BN structure for the leptospirosis infection sub-model. Yellow and green nodes represent input variables, with yellow nodes indicating variables that can be modified through interventions currently modelled.

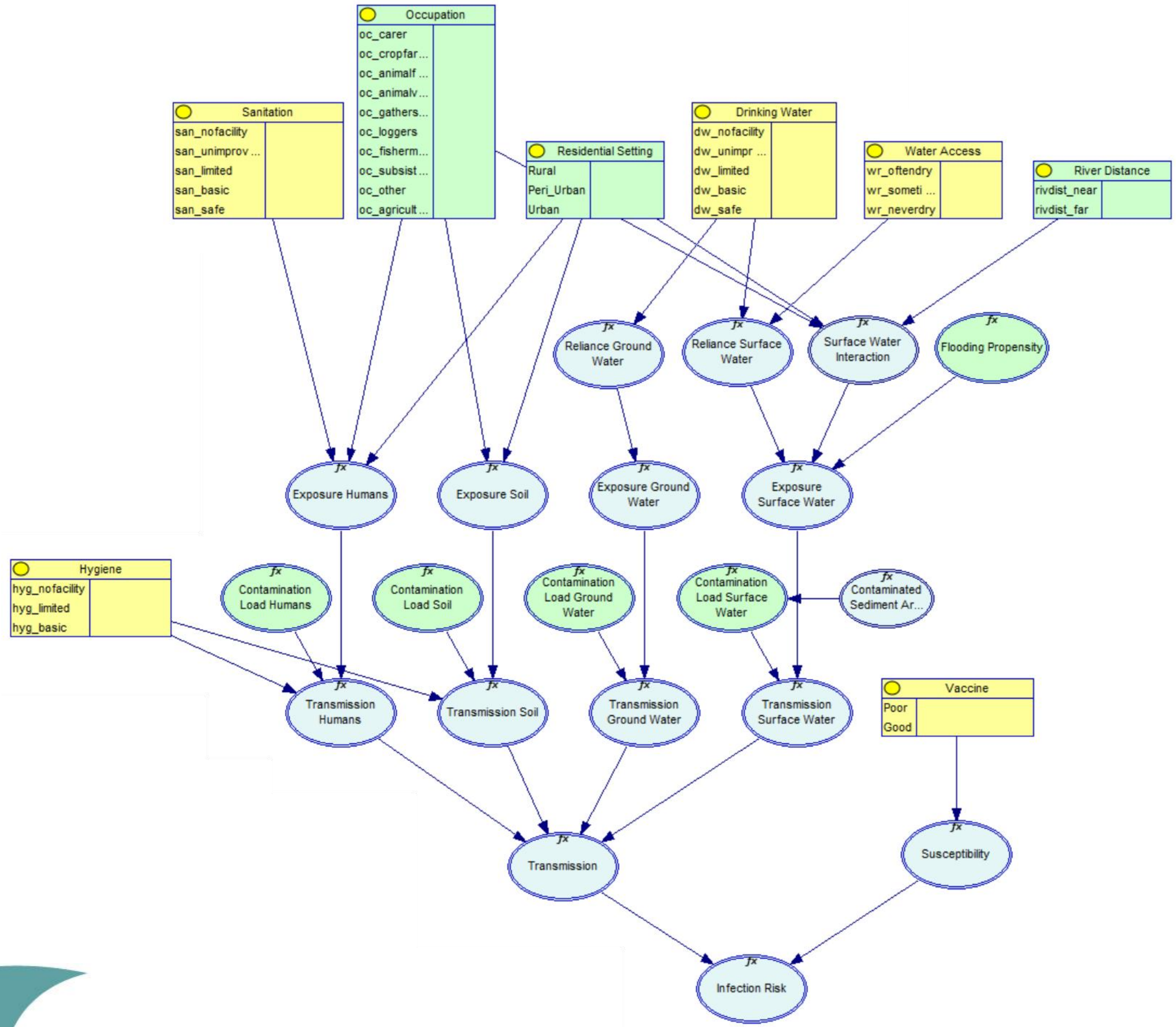

Figure C2. BN structure for the typhoid infection sub-model. Yellow and green nodes represent input variables, with yellow nodes indicating variables that can be modified through interventions.

Table C1. Bayesian Belief Network dictionary for intermediate nodes within the infection sub-model, including nodes, their definitions, and the method of calculation for their parameterisation. Note: FJ = Fiji; SI = Solomon Islands; PNG = Papua New Guinea; Typh = typhoid; Lepto = leptospirosis.

Variable	Description	Model	Function	Parameterisation of Data Input
Contamination_Load_Surface_Water	Relative pathogenic *Leptospira* load in surface water Represents the load of pathogens in local surface waters, from both local and upstream sources of contamination as determined from the hydrological sub-model. Due to limited information on dose loads needed for leptospirosis infection, a larger threshold for contamination was used compared with typhoid as a conservative estimate. This value also generated final Infection Risk values more aligned with previously published maps of leptospirosis seroprevalence where available (i.e., for Fiji, published in Mayfield et al., 2018a, 2018b; Wakwella 2026).	Lepto	Logistic(Contaminated_Sediment_Arrival)	**Contaminated_Sediment_Arrival (reference):** 50000
Contamination_Load_Surface_Water	Relative *Salmonella enterica* serovar Typhi load in surface water Represents the load of pathogens in local surface waters, from both local and upstream sources of contamination as determined from the hydrological sub-model.	Typh	Logistic(Contaminated_Sediment_Arrival)	**Contaminated_Sediment_Arrival (reference):** 5000
Reliance_Ground_Water	Relative level of reliance on unprotected groundwater Represents the reliance of the population on unprotected ground water for drinking. Drinking water service levels are used to estimate reliance, with "unimproved" services indicating primary reliance on unimproved springs or wells (i.e., groundwaters).	Both	Switch(Drinking_Water)	**Drinking water (weight):** no facility: 0.3 unimproved: 1 limited: 0.3 basic: 0.3 safe: 0.01
Reliance_Rain_Water	Relative level of reliance on untreated rainwater Represents the reliance of the population on untreated rainwater for drinking. Drinking water	Lepto	Switch(Drinking_Water_Type)* Switch(Drinking_Water)	**Drinking water (weight):** no facility: 1 unimproved: 1

Variable	Description	Model	Function	Parameterisation of Data Input
	facility type from censuses is used to estimate reliance on rainwater and drinking water service levels are used to estimate safety level.			limited: 1 basic: 1 safe: 0.01 **Drinking water type (weight):** dwt_m_pd: 0 dwt_m_pp: 0 dwt_m_pt: 0 dwt_m_pn: 0 dwt_d_pr: 0 dwt_d_un: 0 dwt_s_pr: 0 dwt_s_un: 0 dwt_r_t: 1 dwt_sf: 0 dwt_c_t: 1 dwt_c_p: 0 dwt_bh: 0 dwt_FE: 0 dwt_o: 0
Reliance_Surface_Water	Relative level of reliance on untreated surface water Represents the reliance of the population on untreated surface water for drinking. Drinking water service levels are used to estimate reliance, with "no facility" indicating primary reliance on untreated surface water. In addition, water access is included to account for situations where access to the primary water source is unreliable, leading households to use surface water as an alternative source regardless of the safety level of their usual drinking water supply.	Both	1-(1-Switch(Drinking_Water))*(1-Switch(Water_Access))	**Drinking water (weight):** no facility: 1 unimproved: 0.3 limited: 0.3 basic: 0.3 safe: 0.01 **Water reliability (weight):** often dry: 1 sometimes dry: 0.7 never dry: 0.01
Exposure_Ground_Water	Relative level of human exposure to groundwater Represents the relative level of human contact	Both	Reliance_Ground_Water	

Variable	Description	Model	Function	Parameterisation of Data Input
	with groundwater, which is later combined with contamination load within groundwater to estimate transmission risk. Contact is determined by the reliance on groundwater as the main drinking water source.			
Exposure_Rain_Water	Relative level of human exposure to rainwater Represents the relative level of human contact with rainwater, which is later combined with contamination load within rainwater to estimate transmission risk. Contact is determined by the reliance on rainwater as the main drinking water source.	Lepto	Reliance_Rain_Water	
Surface_Water_Interaction	Relative level of human interaction with surface water Represents the relative level of human interaction with local surface water (i.e., not through drinking), which is later combined with contamination load within surface water to estimate transmission risk. Two types of interaction are incorporated: 1) interaction for recreation and other activities, determined by the river proximity and residential setting; and 2) occupational interaction.	Both	1-(1-Switch(River_Distance)* Switch(Residential_Setting)* (1-Switch(Occupation))	**Residential Setting (weight):** rural: 1 peri urban: 0.7 urban: 0.1 **River distance (weight):** near: 0.7 far: 0.2 **Occupation (weight):** carer: 0.1 crop farmer: 0.6 animal farmer: 0.6 animal/vegetable farmer: 0.6 gathers fruits: 0.5 logger: 0.3 fisherman: 1 subsistence work: 0.6 other: 0.1 agricultural land: 0.6
Exposure_Humans	Relative level of human contact with humans Represents the relative level of direct human contact with humans, shared sanitation facilities, or foods, which is later combined with	Typh	1-(1-Switch(Residential_Setting))* (1-Switch(Occupation))* (1-Switch(Sanitation))	**Residential Setting (weight):** rural: FJ = 1; SI = 0.5; PNG = 0.5 peri urban: FJ = 1; SI = 1; PNG = 1

Variable	Description	Model	Function	Parameterisation of Data Input
	contamination load in humans to estimate transmission risk. There are three sub exposure pathways incorporated: 1) daily interaction, determined by residential setting; 2) occupational interaction; and 3) via shared sanitation facilities.			urban: FJ = 0.5; SI = 0.5; PNG = 0.5 **Occupation (weight):** carer weight: 1 crop farmer: 0.1 animal farmer: 0.1 animal/vegetable farmer: 0.1 gathers fruits: 0.1 logger: 0.1 fisherman: 0.1 subsistence work: 0.1 other: 0.5 agricultural land: 0.1 **Sanitation (weight)**: no facility: 1 unimproved: 0.75 limited: 0.25 basic: 0.1 safe: 0.05
Exposure_Livestock	Relative level of human exposure to livestock Represents the relative level of direct human contact with livestock, which is later combined with contamination load in livestock to estimate transmission risk. There are three sub-exposure pathways incorporated: 1) daily interaction, determined by livestock density 2) daily interaction, determined by residential setting; and 3) occupational interaction.	Lepto	1-(1-Logistic(Livestock_Density))*(1-Switch(Residential_Setting))*(1-Switch(Occupation))	ref livestock density: 150 **Residential Setting:** rural weight: 1 peri urban weight: 0.7 urban weight: 0.1 **Occupation (weight):** carer: 0.1 crop farmer: 0.7 animal farmer: 1 animal/vegetable farmer: 1 gathers fruits: 0.5 logger: 0.3 fisherman: 0.3 subsistence work: 1

Variable	Description	Model	Function	Parameterisation of Data Input
				other: 0.1 agricultural land: 1
Exposure_Soil	Relative level of human exposure to soils Represents the relative level of human contact with soil in the local environment, which is later combined with contamination load within soils to estimate transmission risk. There are two sub-exposure pathways incorporated: 1) daily interaction, determined by residential setting; and 2) occupational interaction.	Both	1-(1-Switch(Residential_Setting))*(1-Switch(Occupation))	**Residential Setting (weight):** rural weight: 1 peri urban weight: 0.7 urban weight: 0.1 **Occupation (weight):** carer: 0.1 crop farmer: 1 animal farmer: 0.8 animal/vegetable farmer: 1 gathers fruits: 0.6 logger: 0.6 fisherman: 0.3 subsistence work: 1 other: 0.1 agricultural land: 1
Exposure_Rats	Relative level of human exposure to rats Represents the relative level of direct human contact with rats, which is later combined with contamination load in rats to estimate transmission risk. Contact is assumed to be relative to the local rat population. Residential Setting and Land Use are used as proxies for rat density.	Lepto	Switch(Residential_Setting)*Switch(Land_Use)	**Residential Setting (weight):** rural: 0.8 peri urban: 1 urban: 0.5 **Land Use (weight):** water: 0 mangrove: 1 shrubland: 0.5 native forest: 0 softwood plantation forest: 0.5 hardwood plantation forest: 0.5 grassland: 1 coconut plantations: 1 settlement: 1 sugarcane: 1 cropland agriculture: 1 barren land: 0

Variable	Description	Model	Function	Parameterisation of Data Input
				bare soil rock: 0 other: 0.5
Exposure_Pigs	Relative level of human exposure to pigs Represents the relative level of direct human contact with pigs, which is later combined with contamination load in pigs to estimate transmission risk. Contact is assumed to be relative to the local pig population. Residential Setting and Land Use are used as proxies for pig density.	Lepto	Switch(Residential_Setting)* Switch(Land_Use)	**Residential Setting (weight):** rural: FJ = 0.7; SI = 0; PNG = 0.7 peri urban: FJ = 0.7; SI = 0; PNG = 1 urban: FJ = 0.5; SI = 0; PNG = 0.5 **Land Use (weight):** water: 0 mangrove: 0 shrubland: 1 native forest: 0 softwood plantation forest: 0.5 hardwood plantation forest: 0.5 grassland: 1 coconut plantations: 1 settlement: 1 sugarcane: 1 cropland agriculture: 1 barren land: 0 bare soil rock: 0 other weight: 0.5
Exposure_Surface_Water	Relative level of human exposure to surface water Represents the relative level of direct or indirect human exposure to surface water. This is later combined with contamination load to estimate transmission risk. There are three sub exposure pathways considered: 1) reliance on surface water for drinking/household use; 2) interaction with surface for recreation or other daily activities; and 3) exposure via flooding impact.	Both	1-(1-Reliance_Surface_Water)* (1-Flooding_Propensity)* (1-Surface_Water_Interaction)	
Transmission_Humans	Relative typhoid infection transmission risk through the human pathway	Typh	Contamination_Load_Humans* Exposure_Humans*	**Hygiene (weight):** no facility: 1

Variable	Description	Model	Function	Parameterisation of Data Input
	Represents the relative transmission risk associated with the direct human contact pathway (i.e., via contact with another infected human, contaminated food, contaminated household surface), calculated by combining pathway human contamination load with human exposure to other humans. Transmission via direct human contact after exposure is mitigated by hygiene practices.		Switch(Hygiene)	limited: 0.9 basic: 0.5
Transmission_Livestock	Relative leptospirosis infection transmission risk through the livestock pathway Represents the relative transmission risk associated with direct livestock contact, calculated by combining livestock population contamination load with human exposure to livestock.	Lepto	Contamination_Load_Livestock* Exposure_Livestock	
Transmission_Rats	Relative leptospirosis infection transmission risk through the rat pathway Represents the relative transmission risk associated with direct rat contact, calculated by combining rat population contamination load with human exposure to rats.	Lepto	Contamination_Load_Rats* Exposure_Rats	
Transmission_Pigs	Relative leptospirosis infection transmission risk through the pig pathway Represents the relative transmission risk associated with direct pig contact, calculated by combining pig population contamination load with human exposure to pigs.	Lepto	Contamination_Load_Pigs* Exposure_Pigs	
Transmission_Soil	Relative infection transmission risk through the soil pathway Represents the relative risk through contaminated soil, calculated by combining soil contamination load with human exposure to soil. Transmission via soil after exposure is mitigated by hygiene practices.	Both	Contamination_Load_Soil* Exposure_Soil* Switch(Hygiene)	**Hygiene (weight):** no facility: 1 limited: 0.9 basic: 0.5

Variable	Description	Model	Function	Parameterisation of Data Input
Transmission_Ground_Water	Relative infection transmission risk through the ground water pathway Represents the relative risk through contaminated ground water, calculated by combining ground water contamination load with human exposure to ground water	Both	Contamination_Load_Ground_Water* Exposure_Ground_Water	
Transmission_Surface_Water	Relative infection transmission risk through the surface water pathway Represents the relative risk through contaminated surface water, calculated by combining surface water contamination load with human exposure to surface water	Both	Exposure_Surface_Water* Contamination_Load_Surface_Water	
Transmission_Rain_Water	Relative leptospirosis transmission risk through the rainwater pathway Represents the relative risk through contaminated rainwater, calculated by combining rainwater contamination load with human exposure to rainwater.	Lepto	Contamination_Load_Rain_Water * Exposure_Rain_Water	
Transmission	Risk of typhoid transmission Represents the combined infection transmission risk across all infection transmission pathways. This includes direct human transmission, as well indirect soil, surface water, and groundwater pathways.	Typh	1-(1-Transmission_Soil)* (1-Transmission_Surface_Water)* (1-Transmission_Ground_Water)* (1-Transmission_Humans)	
Transmission	Risk of leptospirosis transmission Represents the combined infection transmission risk across all infection transmission pathways. This includes direct livestock, rat and pig pathways, as well as indirect soil, rainwater, surface water and groundwater pathways.	Lepto	1-(1-Transmission_Soil)* (1-Transmission_Surface_Water)* (1-Transmission_Rats)* (1-Transmission_Pigs)* (1-Transmission_Livestock)* (1-Transmission_Ground_Water)* (1-Transmission_Rain_Water)	
Susceptibility	Relative vulnerability of an individual to infection The relative vulnerability of an individual to infection was considered through the population's vaccination coverage. Other	Typh	Switch(Vaccine)	**Vaccination (weight):** poor weight: 1 good weight 0.5

Variable	Description	Model	Function	Parameterisation of Data Input
	susceptibility risk factors, such as age, were not considered due to having limited spatial variability, and also were not a variable that could be intervened on.			
Infection_Risk	Relative risk of an individual infection event Relative intensity of infection risk across modelled conditions. Shows combined and compounding influence of modelled risk factors and transmission pathways.	Both	Transmission*Susceptibility	

Appendix D. Sediment Export Data Dictionary

Table D1. Development of inputs and relevant data sources used for parameterising sediment delivery ratio model for Fiji.

Data	Description	Source(s)
Conditioned digital elevation model (DEM)	DEM raster created using globally available HydroSHEDs conditioned DEM merged with globally available Shuttle Radar Topography Mission (SRTM) DEM to fill data gaps across the anti-meridian. Prior to merging, voids/holes within the SRTM DEM were filled in using Inverse Distance Weighting interpolation (weight = 2), then the raster was reprojected to match the HydroSHEDS DEM using bilinear interpolation. Merging of the HydroSHEDS and filled SRTM DEM was performed using the “first” method & algorithm 1 in *terra*.	Lehner and Grill (2013); NASA SRTM (2013)
Watershed polygon	Hydrologically relevant watershed shapefile created using DelineateIt in InVEST toolkit to delineate watersheds from conditioned DEM (above) as input. Some smaller delineated watersheds were grouped (i.e., unionised) to create larger polygons that were more suitable for visualisation within the decision-support tool and better aligned with commonly recognised watershed boundaries. The grouping of small watersheds was determined by an overlay with watershed boundary data for Fiji provided by the Wildlife Conservation Society (WCS). The WCS watershed boundary data was not used directly as an input for the model as it has large areas of missing data (e.g., missing watersheds around coastlines).	Catchment shapefile from WCS
Rainfall erosivity (R factor)	R factor raster created using globally available annual precipitation raster from WorldClim. The WorldClim raster was reprojected to match conditioned DEM (above) using bilinear interpolation, and mean focal ("moving window") analysis used to fill holes/gaps in data. Filled raster was then multiplied by 0.5 to calculate rainfall erosivity as per Roose equation (Bols, 1978). The Roose equation has been shown to produce sediment export values a magnitude closer to observed ranges compared to other equations (Hutley et al., 2020). We selected a multiplier of 0.5 as is within the range expected for mountainous tropical areas near the ocean (0.2-0.6) (Wischmeier et al., 1978) and has been used successfully in other volcanic Pacific Islands (Wenger et al., 2018; Hutley et al., 2020).	Fick and Hijmans (2017)
Soil erodibility (K factor)	K factor raster created using globally available K_{GloSEM} raster from Borrelli et al., 2017. The K_{GloSEM} raster was reprojected to match conditioned DEM (above) using bilinear interpolation and mean focal ("moving window") analysis used to fill holes/gaps in data.	Borrelli et al. (2017)
Land use/land cover (LULC)	LULC raster created using LULC rasters of Fiji’s tikinas (administrative areas) from Davies et al. merged/reclassified with an older national 2010 LULC shapefile from the Pacific Community and a national forest shapefile from the Ministry of Forestry to fill data gaps. The 2021 LULC rasters were reprojected to match conditioned DEM (above) using nearest neighbor interpolation and merged using the “first” method & algorithm 1 in *terra* to create a national raster. The 2010 LULC shapefile was rasterised to match the national 2021 LULC raster allowing the two to be merged using the “first” method & algorithm 1 in *terra.* The values in the resulting LULC raster were reclassified to match the biophysical table (see below), including forested values refined with more detail from the national forest shapefile.	Davies et al. (2021); SPC (2022); Ministry of Forestry (2016)
Biophysical Table	Table D3	
Threshold flow accumulation	100 (To ensure small coastal flows were captured)	

Borselli k Parameter	2 (default value)
Max SDR	0.8 (default value)
Borselli IC0	0.5 (default value)
Max L	122 (default value)

Table D2. Development of inputs and relevant data sources used for parameterising sediment delivery ratio model for Solomon Islands & Papua New Guinea.

Data	Description	Source(s)
Conditioned digital elevation model (DEM)	DEM raster created using globally available HydroSHEDs conditioned DEM. The DEM was clipped to hydrologically relevant regions for each country through filtering of administrative areas and HydroSHEDs basins. The DEMs were then reprojected to "EPSG:9875" using bilinear interpolation.	Lehner and Grill (2013)
Watershed polygon	Hydrologically relevant watershed shapefiles were identified using globally available HydroSHEDs lvl 12 basins, which were filtered to each country using overlap with administrative areas, and reprojected to match DEM.	
Rainfall erosivity (R factor)	R factor raster created using globally available annual precipitation raster from WorldClim. The WorldClim raster was reprojected to match conditioned DEM (above) using bilinear interpolation, and mean focal ("moving window") analysis used to fill holes/gaps in data. Filled raster was then multiplied by 0.5 to calculate rainfall erosivity as per Roose equation (Bols, 1978). The Roose equation has been shown to produce sediment export values a magnitude closer to observed ranges compared to other equations (Hutley et al., 2020). We selected a multiplier of 0.5 as is within the range expected for mountainous tropical areas near the ocean (0.2-0.6; Wischmeier et al., 1978) and has been used successfully in other volcanic Pacific Islands (Wenger et al., 2018; Hutley et al., 2020).	Fick and Hijmans (2017)
Soil erodibility (K factor)	K factor raster created using globally available K_{GloSEM} raster from Borrelli et al., 2017. The K_{GloSEM} raster was reprojected to match conditioned DEM (above) using bilinear interpolation and mean focal ("moving window") analysis used to fill holes/gaps in data.	Borrelli et al. (2017)
Land-use/land-cover (LULC)	LULC raster created using global 2020 LULC raster from GLAD. The LULC raster was clipped to each country similarly to the DEM and then reprojected to match conditioned DEM (above) using nearest neighbor interpolation. The values in the resulting LULC raster were reclassified to match the biophysical table (see below).	Potapov et al. (2022)
Biophysical Table	Table D4	
Threshold flow accumulation	100 (To ensure small coastal flows were captured)	
Borselli k	2 (default value)	
Max SDR	0.8 (default value)	
Borselli IC0	0.5 (default value)	
Max L	122 (default value)	

Table D3. Land use/cover types and their associated cover management factor (C factor) and support practice factor (P factor) used to parameterise the sediment export model in Fiji.

Code	Land use description	C factor	P factor	Reference
1	Water	0	1	Falinski (2016)
2	Mangrove	0.001	1	Wischmeier et al. (1978); Falinski (2016)
3	Shrubland	0.15	1	FAO (2000)
4	Native forest*	0.006	1	Wischmeier et al. (1978); FAO (2000)
5	Softwood plantation forest*	0.009	1	FAO (2000)
6	Hardwood plantation forest*	0.05	1	FAO (2000); Chicas and Omine (2015)
7	Grassland*	0.4	1	FAO (2000)
8	Coconut plantations*	0.3	1	FAO (2000)
9	Settlement*	0.2	1	Wischmeier et al. (1978); FAO (2000)
10	Sugarcane	0.5	1	FAO (2000)
11	Cropland/agriculture*	0.9	1	Wischmeier et al. (1978); FAO (2000)
12	Barren Land	0.85	1	Roose (1977)
13	Bare soil/rock	1	1	FAO (2000)
14	Other	0	1	Falinski (2016)
15	Cropland managed^	0.54	0.51	Ebabu et al. (2022)
16	Grassland managed^	0.16	0.51	Ebabu et al. (2022)
15	Cropland grazing pressure reduced^	0.4	1	FAO (2000)
16	Grassland grazing pressure reduced^	0.2	1	FAO (2000)

***NOTE that the following categories were created by combining land use types:**
Grassland = Grassland + Open Land/Grassland
Coconut plantations = Coconut Crops + Coconut Forest + Coconut Plantation
Settlement = Settlement + Urban/impervious
Native forest = Tree + Forest + does not overlap with plantation forest defined by Ministry of Forestry (2016)
Softwood plantation forest = Tree + Forest + overlaps with softwood (i.e., pine) timber plantation forest defined by Ministry of Forestry (2016)
Hardwood plantation forest = Tree + Forest + overlaps with hardwood (i.e., mahogany) timber plantation forest defined by Ministry of Forestry (2016)
Cropland/agriculture = Cropland/agriculture + Grazing Land/Trace of Maize/Paddy
^NOTE that the following categories only apply within intervention scenarios:
*Cropland managed^* = Selected cropland/agriculture areas (depending on the scenario) with vetiver grass applied as erosion management
*Grassland managed^* = Selected grassland areas (depending on the scenario) with vetiver grass applied as erosion management
*Cropland grazing pressure reduced^* = Selected cropland/agriculture areas near rivers (depending on the scenario) with reduced grazing pressure applied
*Grassland grazing pressure reduced^* = Selected grassland areas near rivers (depending on the scenario) with reduced grazing pressure applied

Table D4. Land use/cover types and their associated cover management factor (C factor) and support practice factor (P factor) used to parameterise the sediment export model in Solomon Islands and Papua New Guinea.

Code	Land use description	C factor	P factor	Reference
1	True desert	0.85	1	Roose (1977) (as barren land)
2	Semi-arid	0.85	1	Roose (1977) (as barren land)
3	Grassland	0.4	1	FAO (2000)
4	Forest 3-10m	0.003	1	Panagos et al. (2015); Benavidez et al. (2018)
5	Forest 11-18m	0.002	1	Panagos et al. (2015); Benavidez et al. (2018)
6	Forest >18m	0.001	1	Panagos et al. (2015); Falinski (2016); Benavidez et al. (2018)
7	Wetland	0.01	1	Yang et al. (2003); Eichelberger (2022)
8	Wetland 3-10m	0.04	1	Yang et al. (2003); Eichelberger (2022)
9	Wetland 10-18m	0.03	1	Yang et al. (2003); Eichelberger (2022)
10	Wetland >18m	0.02	1	Yang et al. (2003); Eichelberger (2022)
11	Open surface water	0	1	Falinski (2016)
12	Snow	0	1	
13	Cropland	0.9	1	Wischmeier et al. (1978); FAO (2000)
14	Built-up	1	1	Wischmeier et al. (1978)
15	Ocean	-	-	*NA*
16	Cropland managed^	0.54	0.51	Ebabu et al. (2022)
17	Grassland managed^	0.16	0.51	Ebabu et al. (2022)
16	Cropland grazing pressure reduced^	0.4	1	FAO (2000)
17	Grassland grazing pressure reduced^	0.2	1	FAO (2000)

^NOTE that the following categories only apply within intervention scenarios:
*Cropland managed^* = Selected cropland/agriculture areas (depending on the scenario) with vetiver grass applied as erosion management
*Grassland managed^* = Selected grassland areas (depending on the scenario) with vetiver grass applied as erosion management
*Cropland grazing pressure reduced^* = Selected cropland/agriculture areas near rivers (depending on the scenario) with reduced grazing pressure applied
*Grassland grazing pressure reduced^* = Selected grassland areas near rivers (depending on the scenario) with reduced grazing pressure applied

Appendix E. Intervention Scenario Data Dictionary

Table E1. Method of modelling changes to sediment export from land-use management scenarios in Fiji.

Intervention	Scenario 1	Area impacted	Scenario 2	Area impacted
1. Improving vaccine coverage *(for typhoid)*	Increasing good vaccine coverage from ~52.7% (WHO, 2026) to 90% nationally.	National	Increasing good vaccine coverage from ~52.7% to 70% nationally.	National
2. Improving handwashing facilities	Increase basic hygiene coverage by 25% plus take everyone from no facility to limited/basic services.	National	Take everyone from no facility to limited/basic services.	National
3. Improving water reliability	Increase the amount of people who have never water reliability issues by 25% and take everyone who often has water reliability issues to sometimes/never has water reliability issues.	National	Take everyone who often has water reliability issues to sometimes/never has water reliability issues.	National
4. Improving drinking water services	Increase safely managed drinking water coverage by 25% plus take everyone from surface water or unimproved services to limited/basic services.	National	Take everyone from surface water or unimproved services to limited/basic services.	National
5. Improving sanitation services *(for typhoid)*	Increase safely managed sanitation coverage by 25% plus taking everyone from open defecation or unimproved services to limited/basic services.	National	Take everyone from open defecation or unimproved services to limited/basic services.	National
6. Improving land use practices	Improve grassland and cropland management (p-factor, e.g., vetiver grass strips) in areas (≥1ha) with high erosion (≥5 T/ha/year).	327,431.25 ha	Improve grassland and cropland management (p-factor, e.g., vetiver grass strips) in areas (≥1ha) with high erosion (≥11 T/ha/year).	275,023.45 ha
7. Improving land use practices close to rivers	Improve grassland and cropland management (p-factor, e.g., vetiver grass strips) in areas (≥1ha) with high erosion (≥5 T/ha/year), within 100 m of major rivers and creeks.	17,531.42 ha	Improve grassland and cropland management (p-factor, e.g., vetiver grass strips) in areas (≥1ha) with high erosion (≥11 T/ha/year), within 100 m of major rivers and creeks.	11,808.85 ha
8. Reforestation	Reforestation in cropland and bare/barren land areas (≥1ha) with high erosion (≥5 T/ha/year).	148,561.78 ha	Reforestation in cropland and bare/barren land areas (≥1ha) with high erosion (≥11 T/ha/year).	109,464.55 ha
9. Restoring erosional	Restore cropland and bare/barren land areas (≥1ha) with high erosion (≥5 T/ha/year) to forest within 100	11,602.33 ha	Restore cropland and bare/barren land areas (≥1ha) with high erosion (≥11 T/ha/year) to	6,792.83 ha

riparian buffer	m of major rivers and creeks.		forest within 100 m of major rivers and creeks.	
10. Restoring riparian buffer	Restore cropland and bare/barren land areas (≥1ha) to forest within 100 m of major rivers and creeks.	52,702.12 ha	Restore cropland and bare/barren land areas (≥1ha) to forest within 100 m of major rivers and creeks above 15 degrees.	24.25 ha
11. Reduce grazing pressure close to rivers	Change grazing intensity (c-factor) on grassland and cropland areas (≥1ha) within 100 m of major rivers and creeks.	66,836.29 ha	Change grazing intensity (c-factor) on grassland and cropland areas (≥1ha) within 100 m of major rivers and creeks above 15 degrees.	944.01 ha
12. Deforestation	Protect all forest ≤ 25 degrees (where logging is currently permitted; Based on Fiji logging code of practice limit of no logging >25 degrees). Impact assessed by modelling "counterfactual" of losing 25% of forest ≤ 25 degrees (cells are randomly sampled & converted to barren land; C-factor 0.85) that is not currently protected.	282,139.03 ha	Protect all forest > 15 and ≤ 25 degrees. Impact assessed by modelling "counterfactual" of losing 25% of forest > 15 and ≤ 25 degrees (cells are randomly sampled & converted to barren land; C-factor 0.85) not currently protected.	63,168.96 ha
13. Reforestation + reducing grazing pressure close to rivers	Reforestation in cropland and bare/barren land areas (≥1ha) with high erosion (≥5 T/ha/year) AND Change grazing intensity (c-factor) on grassland and remaining cropland areas (≥1ha) within 100 m of major rivers and creeks.	199,337.42 ha	Reforestation in cropland and bare/barren land areas (≥1ha) with high erosion (≥11 T/ha/year) AND Change grazing intensity (c-factor) on grassland and remaining cropland areas (≥1ha) within 100 m of major rivers and creeks above 15 degrees.	110,512.24 ha
14. Improving land use practices + restoring riparian buffer	Restore cropland and bare/barren land areas (≥1ha) to forest within 100 m of major rivers and creeks AND Improve management of grassland and remaining cropland (p-factor, e.g., vetiver grass strips) in areas (≥1ha) with high erosion (≥5 T/ha/year).	363,513.35 ha	Restore cropland and bare/barren land areas (≥1ha) to forest within 100 m of major rivers and creeks above 15 degrees AND Improve management of grassland and remaining cropland (p-factor, e.g., vetiver grass strips) in areas (≥1ha) with high erosion (≥11 T/ha/year).	275,031.82 ha

Table E2. Method of modelling changes to sediment export from land-use management scenarios in Solomon Islands (SI).

Intervention	Scenario 1		Scenario 2	
	Description	**Area Managed**	**Description**	**Area Managed**
1. Improving vaccine coverage *(for typhoid)*	Increasing good vaccine coverage from 0% to 90% nationally.	National	Increasing good vaccine coverage from 0% to 70% nationally.	National
2. Improving handwashing facilities	Increase basic hygiene coverage by 25% plus take everyone from no facility to limited/basic services.	National	Take everyone from no facility to limited/basic services.	National
3. Improving water reliability	Increase the amount of people who have never water reliability issues by 25% and take everyone who often has water reliability issues to sometimes/never has water reliability issues.	National	take everyone who often has water reliability issues to sometimes/never has water reliability issues.	National
4. Improving drinking water services	Increase safely managed drinking water coverage by 25% plus take everyone from surface water or unimproved services to limited/basic services.	National	Take everyone from surface water or unimproved services to limited/basic services.	National
5. Improving sanitation services *(for typhoid)*	Increase safely managed sanitation coverage by 25% plus taking everyone from open defecation or unimproved services to limited/basic services.	National	Take everyone from open defecation or unimproved services to limited/basic services.	National
6. Improving land use practices	Improve cropland and grassland management (p-factor, e.g., vetiver grass strips) in areas (≥1ha) with high erosion (≥5 T/ha/year).	12,306.00 ha	Improve cropland and grassland management (p-factor, e.g., vetiver grass strips) in areas (≥1ha) with high erosion (≥11 T/ha/year).	10,086.96 ha
7. Improving land use practices close to rivers	Improve cropland and grassland management (p-factor, e.g., vetiver grass strips) in areas (≥1ha) with high erosion (≥5 T/ha/year), within 100 m of major rivers and creeks.	388.06 ha	Improve cropland and grassland management (p-factor, e.g., vetiver grass strips) in areas (≥1ha) with high erosion (≥11 T/ha/year), within 100 m of major rivers and creeks.	282.99 ha
8. Reforestation	Reforestation in cropland and grassland areas (≥1ha) with high erosion (≥5 T/ha/year).	12,306.00 ha	Reforestation in cropland and grassland areas (≥1ha) with high erosion (≥11 T/ha/year).	10,086.96 ha
9. Restoring erosional	Restore cropland and grassland areas	388.06 ha	Restore cropland and grassland areas (≥1ha)	282.99 ha

riparian buffer	(≥1ha) with high erosion (≥5 T/ha/year) to forest within 100 m of major rivers and creeks.		with high erosion (≥11 T/ha/year) to forest (i.e., forest 11-18m, land use code 5) within 100 m of major rivers and creeks.	
10. Restoring riparian buffer	Restore cropland and grassland areas (≥1ha) to forest (11-18m) within 100 m of major rivers and creeks.	2,376.64 ha	Restore cropland and grassland areas (≥1ha) to forest (i.e., forest 11-18m, land use code 5) within 100 m of major rivers and creeks above 15 degrees.	121.16 ha
11. Reduce grazing pressure close to rivers	Change grazing intensity (c-factor) on cropland and grassland areas (≥1ha) within 100 m of major rivers and creeks.	2,376.64 ha	Change grazing intensity (c-factor) on cropland and grassland areas (≥1ha) within 100 m of major rivers and creeks above 15 degrees.	121.16 ha
12. Deforestation	Protect all forest ≤ 25 degrees (where logging is currently permitted; Based on Solomon Islands logging code of practice limit of no logging > 30 degrees). Impact assessed by modelling "counterfactual" of losing 25% of forest ≤ 30 degrees (cells are randomly sampled & converted to true desert; C-factor 0.85) that is not currently protected.	531,100.16 ha	Protect all forest > 15 and ≤ 30 degrees. Impact assessed by modelling "counterfactual" of losing 25% of forest > 15 and ≤ 30 degrees (cells are randomly sampled & converted to true desert; C-factor 0.85) not currently protected.	144,259.18 ha
13. Reforestation + reducing grazing pressure close to rivers	Reforestation in cropland and grassland areas (≥1ha) with high erosion (≥5 T/ha/year) AND Change grazing intensity (c-factor) on remaining cropland and grassland areas (≥1ha) within 100 m of major rivers and creeks.	14,208.16 ha	Reforestation in cropland and grassland areas (≥1ha) with high erosion (≥11 T/ha/year) AND Change grazing intensity (c-factor) on remaining cropland and grassland areas (≥1ha) within 100 m of major rivers and creeks above 15 degrees.	10,136.10 ha
14. Improving land use practices + restoring riparian buffer	Restore cropland and grassland areas (≥1ha) to forest (11-18m) within 100 m of major rivers and creeks AND Improve management of remaining grassland and cropland (p-factor, e.g., vetiver grass strips) in areas (≥1ha) with high erosion (≥5 T/ha/year).	13,865.86 ha	Restore cropland and grassland areas (≥1ha) to forest (i.e., forest 11-18m, land use code 5) within 100 m of major rivers and creeks above 15 degrees AND Improve management of remaining grassland and cropland (p-factor, e.g., vetiver grass strips) in areas (≥1ha) with high erosion (≥11 T/ha/year).	10,125.93 ha

Table E3. Method of modelling changes to sediment export from land-use management scenarios in PNG.

Intervention	Scenario 1		Scenario 2	
	Description	Area Managed	Description	Area Managed
1. Improving vaccine coverage *(for typhoid)*	Increasing good vaccine coverage from 0% to 90% nationally.	National	Increasing good vaccine coverage from 0% to 70% nationally.	National
2. Improving handwashing facilities	Increase basic hygiene coverage by 25% plus take everyone from no facility to limited/basic services.	National	Take everyone from no facility to limited/basic services.	National
3. Improving water reliability	Increase the amount of people who have never water reliability issues by 25% and take everyone who often has water reliability issues to sometimes/never has water reliability issues.	National	take everyone who often has water reliability issues to sometimes/never has water reliability issues.	National
4. Improving drinking water services	Increase safely managed drinking water coverage by 25% plus take everyone from surface water or unimproved services to limited/basic services.	National	Take everyone from surface water or unimproved services to limited/basic services.	National
5. Improving sanitation services *(for typhoid)*	Increase safely managed sanitation coverage by 25% plus taking everyone from open defecation or unimproved services to limited/basic services.	National	Take everyone from open defecation or unimproved services to limited/basic services.	National
6. Improving land use practices	Improve cropland and grassland management (p-factor, e.g., vetiver grass strips) in areas (≥1ha) with high erosion (≥5 T/ha/year).	1,214,686.00 ha	Improve cropland and grassland management (p-factor, e.g., vetiver grass strips) in areas (≥1ha) with high erosion (≥11 T/ha/year).	1,001,568.36 ha
7. Improving land use practices close to rivers	Improve cropland and grassland management (p-factor, e.g., vetiver grass strips) in areas (≥1ha) with high erosion (≥5 T/ha/year), within 100 m of major rivers and creeks.	77,095.85 ha	Improve cropland and grassland management (p-factor, e.g., vetiver grass strips) in areas (≥1ha) with high erosion (≥11 T/ha/year), within 100 m of major rivers and creeks.	58,397.12 ha
8. Reforestation	Reforestation in cropland and grassland areas (≥1ha) with high erosion (≥5 T/ha/year).	1,214,761.40 ha	Reforestation in cropland and grassland areas (≥1ha) with high erosion (≥11 T/ha/year).	1,001,517.45 ha
9. Restoring erosional	Restore cropland and grassland areas	77,095.85 ha	Restore cropland and grassland areas (≥1ha)	58,397.12 ha

riparian buffer	(≥1ha) with high erosion (≥5 T/ha/year) to forest within 100 m of major rivers and creeks.		with high erosion (≥11 T/ha/year) to forest (i.e., forest 11-18m, land use code 5) within 100 m of major rivers and creeks.	
10. Restoring riparian buffer	Restore cropland and grassland areas (≥1ha) to forest (11-18m) within 100 m of major rivers and creeks.	447,144.45 ha	Restore cropland and grassland areas (≥1ha) to forest (i.e., forest 11-18m, land use code 5) within 100 m of major rivers and creeks above 15 degrees.	19,831.76 ha
11. Reduce grazing pressure close to rivers	Change grazing intensity (c-factor) on cropland and grassland areas (≥1ha) within 100 m of major rivers and creeks.	447,144.45 ha	Change grazing intensity (c-factor) on cropland and grassland areas (≥1ha) within 100 m of major rivers and creeks above 15 degrees.	19,831.76 ha
12. Deforestation	Protect all forest ≤ 25 degrees (where logging is currently permitted; Based on PNG logging code of practice no harvest limit in areas of high relief on slopes >25° on average). Impact assessed by modelling "counterfactual" of losing 25% of forest ≤ 25 degrees (cells are randomly sampled & converted to true desert; C-factor 0.85) that is not currently protected.	8,914,153.30 ha	Protect all forest > 15 and ≤ 25 degrees. Impact assessed by modelling "counterfactual" of losing 25% of forest > 15 and ≤ 25 degrees (cells are randomly sampled & converted to true desert; C-factor 0.85) not currently protected.	2,116,386.71 ha
13. Reforestation + reducing grazing pressure close to rivers	Reforestation in cropland and grassland areas (≥1ha) with high erosion (≥5 T/ha/year) AND Change grazing intensity (c-factor) on remaining cropland and grassland areas (≥1ha) within 100 m of major rivers and creeks.	1,561,614.04 ha	Reforestation in cropland and grassland areas (≥1ha) with high erosion (≥11 T/ha/year) AND Change grazing intensity (c-factor) on remaining cropland and grassland areas (≥1ha) within 100 m of major rivers and creeks above 15 degrees.	1,007,302.31 ha
14. Improving land use practices + restoring riparian buffer	Restore cropland and grassland areas (≥1ha) to forest (11-18m) within 100 m of major rivers and creeks AND Improve management of remaining grassland and cropland (p-factor, e.g., vetiver grass strips) in areas (≥1ha) with high erosion (≥5 T/ha/year), within 100 m of major rivers and creeks.	1,561,542.40 ha	Restore cropland and grassland areas (≥1ha) to forest (i.e., forest 11-18m, land use code 5) within 100 m of major rivers and creeks above 15 degrees AND Improve management of remaining grassland and cropland (p-factor, e.g., vetiver grass strips) in areas (≥1ha) with high erosion (≥11 T/ha/year), within 100 m of major rivers and creeks.	1,007,352.26 ha

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