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Glossary (Acronyms)

ACIAR	Australian Centre for International Agricultural Research
APT	Agriculture Production Threats
BSWM	Bureau of Soils and Water Management
CFRA	The Comprehensive Framework of Response Assessment
DPSIR	Drivers, Pressures, States, Impacts, Responses
ERI	Effective Response Index
ESS	Ecosystem services
ESS	Ecosystem Services
EST	Ecosystem Services Threat
FAO	The Food and Agriculture Organization of the United Nations
LDN	Land degradation Neutrality
LPD	Land productivity Dynamics
LULC	Land use / Land cover

MODECERA	The Monitoring and Detection of Ecosystems Changes for Enhancing Resilience and Adaptation
NAMRIA	National Mapping and Resource Information Authority
PCAARRD	The Philippine Council for Agriculture, Aquatic, and Natural Resources Research and Development
PhilCat	Philippine Conservation on Approaches and Technologies
SARAI	Smarter Approaches to Reinvigorate Agriculture as an Industry in the Philippines
SDG	Sustainable Development Goals
SEAMS	SARAI-Enhanced Agriculture Monitoring System
SLM	Sustainable Land Management Practices
SOLAW	State of Land and Water for Agriculture
UNCCD	United Nations Convention to Combat Desertification
WOCAT	The World Overview of Conservation Approaches and Technologies

Selected SLM technologies

- Conservation agriculture with minimum soil disturbance and tillage practice
- Conservation practices to reduce soil loss on the sloping and erosion-prone land
- Implement soil moisture conservation techniques
- Installation of buffers between cropland and water body
- Integrated crop-livestock management
- Integrated plant nutrition management to enhance soil productivity
- Organic agriculture practice management
- Recycling and re-use of stormwater, wastewater and grey water
- Smallholder irrigation management
- Sustainable natural forest management
- Sustainable planted forest management
- Use of improved plant varieties

1 Acknowledgments

The team of researchers would like to acknowledge and sincerely thank colleagues from PCAARRD, BSWM, FAO-Philippines for participation, advice and tremendous support during the co-design process. We are to acknowledge the support of WOCAT, the global network on Sustainable Land Management (SLM) that promotes the documentation, sharing and use of knowledge to support adaptation, innovation and decision-making in SLM. This study would not have been possible without the support of WOCAT. The team also wishes to record their special thanks to ACIAR staff for their support and guidance.

2 Executive summary

Sustainable management of land, soil, and water is important to tackle the growing dual challenges of food insecurity and environmental degradation in the Philippines. Ecosystems in many regions of the Philippines are under significant pressure due to increasing trade-offs between agriculture and other ecosystem services, unsustainable practices, increasing demands for human consumption, and climate change. It is manifested as severe land degradation through soil erosion, nutrient depletion and off-site eutrophication due to higher loads of nitrogen and other pollutants.

There have been extensive efforts to manage these challenges. However, several gaps could be identified based on existing knowledge, such as, Aligned Philippine National Actional Plan to Combat Desertification Land Degradation and Drought FY 2015- 2025 (BSWM 2015a); PhilCAT- Philippine Case Studies on Sustainable Land Management Approaches and Technologies (BSWM 2015b)as well as the updated Philippine National Action Plan to Combat Desertification(BSWM 2018), and expert consultations:

- First, adoption of sustainable land management (SLM) in the Philippines are very scattered, and there is slow diffusion of innovations in SLM practices and limited scaling up and scaling out of practices without a comprehensive understanding of how these practices address the trade-off between agricultural production and other ecosystem services embedded in the complex socio-ecological system.
- Besides the technical reasons, the non-adoption/slow adoption could be attributed to the socio-economic and political issues. SLM technologies benefits are mainly realized over a long term while the farmers consider immediate benefits. Other reasons behind slow adoption of SLM include land tenure, where most farmers in the upland tilled the land that belong to others so they cannot adopt SLM technologies without active engagement of the landowners.
- Second, lack of understanding of dynamic conditions and interlinkages between land water and soil (on-farm and off-farm level) and externalities leads to poorly targeted investment and unintended environmental consequences with higher social costs.
- Finally, a systems approach and thinking in assessment and implementation are needed to capture the interlinkages. There is no comprehensive assessment framework that could be used to produce higher-resolution integrated problem assessments and in-depth effective response assessments. The project contributes to this gap.

This project was designed to refine and test the previously developed Comprehensive Framework of Response Assessment (CFRA) for sustainable management of agricultural systems (land, soil, and water) jointly supported by FAO and ACIAR for the Philippines. The steps undertaken in the project are as follows: 1) further refine the CFRA based on existing literature and in-country expert consultations; 2) Co-design; 3) Synthesizing and harmonization of related data; 4) comprehensive analysis of the effectiveness of different SLM solutions to understand the trade-offs. We outline each of these steps below.

Development of a refined CFRA: Extending our previous work on drivers, pressures, state, impact and response (DPSIR) framework the refined CFRA focus on the trade-offs between agriculture production and other ecosystem services both in terms of state variables and effectiveness of response variables. Several linear and non-linear functions have been tested.

Consultation and co-design: Based on existing literature and expert opinion a preliminary list of drivers, pressures, states, impacts, and responses were prepared for the Philippines. Several workshops and meetings were organized to co-design the study scope and methodology, get feedback on the trade-off matrix and preliminary analysis and results.

Synthesizing and harmonization of related data: Country-specific data from government databases, global databases and existing literature have been collected, compiled, and harmonized. Data on response categories or interventions have been collected from PhilCat where information on around 35 interventions are available. Fieldwork was undertaken to collect additional SLM data.

Assessment: Threat assessment index and maps have been produced for agriculture production and other ecosystem services threats. Effectiveness of SLM interventions have been produced for agriculture production and ecosystem services. Geo-spatial analysis and econometric process have been carried out to understand/explain the effectiveness of different responses and the underlying trade-offs.

The major achievements from the project are as follows:

- Stakeholder dialogue with key partners and organisations in the Philippines to understand the scope and application of CFRA, identify case studies as well as develop the theory of change.
- Developing a methodology to calculate threats to agriculture production and other ecosystem services and understanding the trade-off relationship between agriculture production threat (APT) and ecosystem service threat (EST)
- Revised methodology to calculate effective response Index to address the trade-off and incorporate non-linear relations of the effectiveness as a function of the state of land degradation.

Key recommendations from the project include:

- The risk of increasing ecosystem services threat, policies need to emphasise the ecosystem services in adopting SLMs and accelerate the diffusion of innovations in nature-based solutions/SLM.
- It may require an incentive mechanism and reward system to increase the benefit-cost ratio and support the farmer for higher and wider adoption of farm-based solutions to address the trade-off between agriculture production and other ecosystem services.
- It would also require strengthening of institutional partnerships and engaging the community using the participatory, interdisciplinary approach. It is important to engage policy and decision makers at national and local level particularly at LGUs in the process of resource assessment and the testing of the tools. There is a stronger need to prioritise sustainable land and water management practices and actions and target resources towards them. It entails developing, validating and implementing a standardised methodology for determining the effectiveness of responses for scaling up and out of sustainable management techniques and approaches of land, water and soil in the Philippines.
- Involvement of LGUs in the governance of natural resources could be increased to facilitate prioritization and implementation of sustainable land and water management practices and actions.

3 Introduction

Ecosystems in many regions of the Philippines are under significant pressure due to increasing trade-offs between agriculture and other ecosystem services, unsustainable practices, increasing demands for human consumption, and climate change. It is manifested as severe land degradation through soil erosion, nutrient depletion and off-site eutrophication due to higher loads of nitrogen and other pollutants.

Soil erosion is one of the most serious forms of land degradation in the Philippines, and about 70% of the country's land area has been degraded with soil erosion as the dominant form of land degradation, which greatly affects the population and the environment. Further, the landscape is very sensitive to changes in climate conditions.

There has been substantial work ongoing in the Philippines to identify and encourage sustainable land management (SLM) practices through government policies and programs. Promotion of SLM is a strategic component to combat desertification in the updated Philippines Development Plan (2017-2022) (NEDA 2017). United Nations Development Programme (UNDP), Bureau of Soil and Water Management (BSWM), and other relevant departments in the Philippines focused on regulatory, institutional, and financial reform to facilitate greater uptake of SLM practices (UNDP, 2015, 2020). It achieved these goals through a participatory approach involving key stakeholders (such as the Philippine Department of Agriculture, Department of Environment and Natural Resources, and Department of Interior and Local Development), field investment promoting SLM technology in vulnerable farming communities, and establishing SLM demonstration sites (UNDP, 2015). The department of Science and Technology (DOST) through PCAARRD supported the SLM program, with the National Program on Conservation Farming Village (CFV) as the modality for enhancing technology transfer of SLM technologies. PCAARRD coordinated the implementation through five phases, from the plot-scale validation of SLM technologies to the community-based development. While impacts can be realized after several years, the program has realized intermediate states towards attaining its intended impacts which are improved soil condition or reduced land degradation, increased agricultural productivity and eventually increased income of farmers.This approach has already been documented and downloaded in the WOCAT database.

Other program include Sustainable Agriculture & Natural Resource Management (SANREM) and watershed Management. SANREM focused on promoting the participatory involvement of farmers and other key decision-makers and implementers in the development of sustainable natural resource management at the farm, landscape, and provincial levels and in later phases reaching decision-makers on the national, regional, and global levels. Building on these efforts, the SANREM Innovation Lab seeks to increase smallholders' food security through the introduction of conservation agriculture production systems (CAPS).According to some recent estimates it seems that the proportion of the total land degraded has declined. Using the 2003 and 2010 Land Cover Map of NAMRIA, Land Productivity Dynamics Data from the Joint Research Centre of the European Space Agency, Soil Organic Carbon Map generated by BSWM and application of the UNCCD Guidelines, it was estimated that about 11.13 M ha or 37% of total land area are suffering from negative trends that could be translated into potential state of land degradation. In 2018, the 2015 Land Cover Data from NAMRIA became available along with the most recent LPD and Soil Organic Carbon data. The geo-spatial analysis undertaken by BSWM shows improvements in terms of reduced area having negative trends at 8.52 M ha or just 29% from 2010 to 2015. Adoption and effectiveness of sustainable land management practices and policies could be one of the major reasons for the decline in land degradation proportion.

While substantial progress was made by this program, two key important actions are identified for greater uptake of SLM practices**. These are 1. a landscape-scale approach to help inform decision making, and 2. evidence supporting the benefit of local investment in SLM techniques (UNDP, 2019).**

The above actions also need to address the following specific challenges -

First, adoption of SLM in the Philippines are very scattered, and there is slow diffusion of innovations in SLM practices and limited scaling up and scaling out of practices without a comprehensive understanding of how these practices address the trade-off between agricultural production and other ecosystem services embedded in the complex socio-ecological system. There is lack of evidence supporting the benefit of local investment in SLM techniques in the short run(UNDP, 2019), and hence there is a dearth of confidence in the scaling up and scaling out of SLM innovations. Apart from technological issues, non-adoption/slow adoption could be to the socio-economic issues. SLM technologies benefits are seen more on the long term while the farmers are looking at the immediate benefits. As the farmers care about the immediate benefits they prefer cash crops that can be grown and harvested in the short time. Further, another contributory factor is the ownership or land tenure, where most upland farmers tilled the land that belong to others and long-term benefits from the land conservation are not in decision making criteria. It also leads to poor adoption SLM technologies.

Given only a decade left to achieve major SDG targets, we urgently need a framework that strongly connects agroecosystem problem assessment with the assessment of SLM practices in a living manner; and helps to prioritise investments, develop incentive based strategies and policies and facilitate scale up and scale out of relevant SLM practices, technology. It entails addressing the weak link between research and extension and compounded by the policies on natural resource management.

Second, lack of understanding of dynamic conditions and interlinkages between land water and soil (on-farm and off-farm level) and externalities leads to poorly targeted investment and unintended environmental consequences with higher social costs. Hence, a systems approach and thinking in assessment and implementation are needed to capture the interlinkages.

Third, in the Philippines, a large proportion of farmers are small-scale producers living in rural areas who rely on agriculture and related activities for their livelihood and are vulnerable to critical resource degradation and disaster risks. There is a need to identify the vulnerable population and design gender-sensitive responses. There is also a need to optimise monitoring and assessment to deepen disaggregation and analysis for the vulnerability assessment.

Fourth, the timeliness of assessment is important. The natural rate of change of resource conditions are slow; however, with climate change dynamics and interconnectedness, we see the rapid rate of changes in our food systems. Without an updated version, policy and decision-makers don't see the effectiveness of past and present policies on the current conditions which limits the ability to prioritise their policy responses and investment strategy.

Fifth, the value of complementarity between agriculture and other ecosystem services with respect to time and scale is unknown at a comprehensive scale, and the design of the SLM solutions don't consider such trade-offs. Hence, the existing SLM solutions have a limited impact on sustainability.

There is a research opportunity here to address some of the above challenges and support the government-led initiatives in producing higher-resolution integrated problem assessments and in-depth effective response assessments. It will help to prioritise actions (when and where to invest) in sustainable landscape management practices that help close yield gaps, resolve the trade-off with other ecosystem services, and enhance the resilience of land resources and communities that directly depend on them while restoring and avoiding further degradation.

The ACIAR SLAM/2020/138 project has brought together a multidisciplinary team of experts led by Griffith University to develop a comprehensive framework of response assessment (CFRA) to compare technical, institutional and policy responses or interventions to address global land, water and soil degradation in collaboration with FAO. The CFRA aims to offer a standardised methodology for assessing the relative costs, benefits and effectiveness of different responses. The CFRA will aid in identifying the priority and sequence of responses for investment decisions and also in scaling up effective responses.

The current project funded by ACIAR (SLAM/2021/104) aims to codesign the CFRA with users in the Philippines for applicability and to test the methodology and assess response effectiveness of the CFRA under local conditions concerning the sustainable management of the land, water, and soil system. The vision of success for this work is to produce a high-resolution response assessment that will test the validity and practicality of the CFRA approach in assessing the effectiveness of different responses. The enhanced framework will also allow further refinement of the methodology that should support its utility in other regions as a component of a broader SOLAW-Live initiative led by FAO. If this vision is achieved, the Philippines CFRA case study will help to prioritise sustainable land and water management practices and actions, target resources towards them, and will provide a pathway for the CFRA to be delivered through the SOLAW-Live initiative in other countries. If successful, in the medium term, this will help to close yield gaps, resolve trade-offs with other ecosystem services, and enhance the resilience of land resources and the communities that directly depend on them while at the same time restoring these resources and avoiding further degradation.

The purpose of this report is to highlight and share the preliminary findings of the report with the following objectives:

- Showcase the refined methodology of CFRA and demonstrate the functionality, scope and applicability of CFRA in the Philippines through illustrations of preliminary results.
- Understand the limitations of the framework in terms of data availability and potential future scope.

The report is structured as follows. The following section describes the key land and water challenges in the Philippines. Section 5 discusses the methodology and the refinements of CFRA. Section 6 presents preliminary results. Section 7 discuss the findings of the co-design workshop highlighting the proposed case study areas to understand the limitations of the applicability of the CFRA in the assessment and replication of its response for sites/locations with similar conditions as well as the Theory of Change to understand the impact pathway for CFRA in the Philippines. The final section summarises the results with a description of key lessons learnt, and it outlines the future work area of the project.

4 Key challenges in the land, water and soil management in the Philippines

A combination of physical and social factors has resulted in the Philippines experiencing particularly severe land degradation through soil erosion and associated off-site impacts to catchments and receiving marine waters. The Aligned Philippine National Actional Plan to Combat Desertification Land Degradation and Drought (2015-2025) supports the national agenda examines natural and human-induced factors and existing framework relevant to sustainable land management. The major land and water-related challenges are illustrated in Table 1. The country has steep topography, with around 60 percent being defined as mountainous and some islands having slopes higher than 18 percent (Tejada & Carating, 2014). Combined with the presence of friable soils in some locations and a wet tropical climate affected by a high frequency of typhoons, the region is susceptible to increased soil erosion rates due to land-use change (Tejada & Carating, 2014; UNDP, 2015). Such land-use changes have occurred in the country, with forest cover reducing from approximately 90 percent in the 16th century to approximately 23 percent in 2005 (Tejada & Carating, 2014; UNDP, 2015). These land-use changes were driven by rapid population growth and a shortage of arable land which led many farmers, and particularly poorer farmers, to initiate agriculture on steep land, susceptible to erosion (Asio et al., 2009; Myers, 1988; Ravago et al., 2019; UNDP, 2015). The increased erosion rates caused by the removal of forest from this steep land, increased sediment transport which impacted multiple economic sectors downstream. The direct threats and several root causes that result in land degradation, as highlighted in the Philippine Scenarios on Land Degradation Droughts, include unsustainable land use practices, land conversion, extensive conventional agriculture, and unregulated human settlement expansion, deforestation and other illegal practices within the forest zone. The root causes are mostly related to enforcement of existing policies, implementation of programs, lack of knowledge and capacities, high population growth, and poverty incidence. The Philippines also experiences water scarcity and as well as water quality issues particularly diffused pollution and salinity. According to WEPA, water pollution's effects cost the Philippines approximately $1.3 billion annual.

Challenges in Land Degradation	**Challenges in Water Management**
Unsustainable land use practices	Disparities between supply and demand
Land conversion	Lack of a water allocation formula
Extensive conventional agriculture	Decline of surface water quality (pollution) due to various human activities and
Unregulated human settlement expansion	Consequent algal blooms/eutrophication and water hyacinth proliferation, pathogens, resulting in death of aquatic life, shellfish toxicity, and the clogging of river systems
Deforestation	Poor enforcement or weak regulations on water use

Impacts of biodiversity degradation in terms of increased incidence of pests and diseases,	Inefficient water use, and waste due to poorly-maintained water supply and drainage systems
Loss of natural predators (biological control)	Excessive groundwater extraction due to unlicensed wells
	Fragmented management, with too many government agencies working on water
	No widespread adoption of technologies to save water during the rainy season for eventual use in the dry season
	Slow adoption of climate smart technology

Table 1: Key Challenges in Land degradation and Water Management in the Philippines

These are due to both non-climatic and climatic drivers that further put more pressure on the country's water resources. Non-climatic drivers consist of human-induced activities brought about by the growing population, industrial and economic growth, rising standard of living, and land-use change, which has domino effects that may ultimately lead to socioeconomic risk, water being indispensable to socioeconomic development. The agricultural sector of the Philippines is particularly vulnerable to climate extremes, with typhoons frequently destroying crops, buildings and equipment (Ravago et al., 2019; Thomas et al., 2016). Extremes of above and below-average rainfall are predicted to become more severe under climate change in the Philippines, which increases the risks posed to farmers as growing conditions change from those experienced historically (Ravago et al., 2019; Thomas et al., 2016; UNDP, 2015).

The importance and true value of resources and the need to address land degradation and water-related challenges together could be better understood if the on-farm and off-farm impacts are considered. There is evidence of strong interlinkage between on and off farm impacts in the Philippines. With soil erosion as the most prominent form of land degradation in the country, its on-site impacts include soil nutrient loss, disturbed nutrient cycling and reduced water holding capacity of soils that may ultimately result to poor crop growth. According to Briones (2009), the total on-farm impact of soil erosion has an equivalent cost of about 0.60 percent of the Gross Value Added in Agriculture. On the other hand, the off-site impacts of soil erosion in terms of siltation, pollution of our rivers, flooding and reduced streamflow were costlier and is almost equivalent to 0.80 percent of the country's Gross Domestic Product. Due to the impact of increased sediment loads on regional fish habitat, one such economic sector was fishers, who are also often among the poorest demographics in the nation. In addition, these land-use changes resulted in biodiversity loss, loss of natural predators and increased incidence of pests and diseases (Tejada & Carating, 2014). Even the more productive agricultural areas on lower slopes face challenges, as sustained fertiliser use and continuous cultivation to meet surging demand from the growing population has led to soil nutrient and organic matter depletion and declining productivity (Asio et al., 2009; Tejada & Carating, 2014). It is estimated that the combined and interacted on-farm and off-farm degradation leads to a total economic impact of about 3 billion dollars per year.

5 Comprehensive Framework for Response Assessment

Assessment of agricultural sustainability is needed for adaptive responses to address the challenges explained in the above section and promote sustainable land management for the production of goods to meet the changing human needs while simultaneously ensuring their long-term productive potential. However, such assessment is complex as it encompasses multifaceted interactions between technology, environment, policy, economics, and society. It is even more complex to identify suitable policy strategies to respond to such dynamic interacting systems (Turner et al. 2016, Cerretelli 2018).

An appropriate systems framework would assess information relevant to sustainable rural livelihoods and emphasise social and economic dimensions of sustainable development at a relatively smaller (local or micro) scale (Hu 2020) while assessing environmental impacts of use and management of critical resources like land, water, and soil at global, regional and local scales. Such a framework would also propose effective and efficient response options (appropriate at different scales).

Currently, there are many research gaps in the absence of a comprehensive framework which can connect solutions and problems. There exists unbalanced attention for model development rather than model application, and trade-off analysis has not sufficiently or appropriately taken into account the diversity in resource availability, the objectives of its diverse end-users, or the broader institutional and policy environment within which they function. Many of the current research studies focus on single ecosystem services and use a "partial equilibrium" approach. Systems approach is missing in such studies without the capability to avoid double counting or perverse effects.

Efforts to understand and assess the land, water, and soil resources and their interacting complexities on food production have been fragmentary at best. These have been often focused on particular "sectors" or resources, while in reality, the challenges are indeed cross-cutting and interrelated in the domain and are multi-sectoral. They include the domains of food, land management, water security, economic development, carbon mitigation, climate adaptation and disaster risk reduction. This fragmentation has arisen in part from the lack of a coherent framing, both in terms of understanding and in terms of monitoring and interpreting the observable phenomena and trends in integrated land, water and soil conditions.

The concept of the CFRA has been designed to prioritise responses that provide the acceptable and sustainable trade-off between agricultural production and other ecosystem services in a dynamic and complex socio-ecological system. Figure 1 illustrates the concept where the vertical axis depicts agricultural production as a societal and economic imperative, and the horizontal axis depicts other ecosystem services (ESS) that possess varying values for on- and off-site stakeholders. For the sake of simplicity, we depict a curvilinear trade-off relationship, but the shape of the trade-off frontier will be changed depending on the ESS, context, and stakeholders. Such relationships are exhibited in challenges related to the conversion of natural landscapes to agricultural land, which involves a trade-off between the production of essential food, animal feed, fibre, and biofuels and the potential consequences of degraded land, soil and water. Such trade-offs have important consequences for the ability of land and water systems to provide critical ecosystem services such as carbon sequestration and maintaining biodiversity, and thus mitigate climate change (Deng et al., 2016, Ruijs et al., 2017).

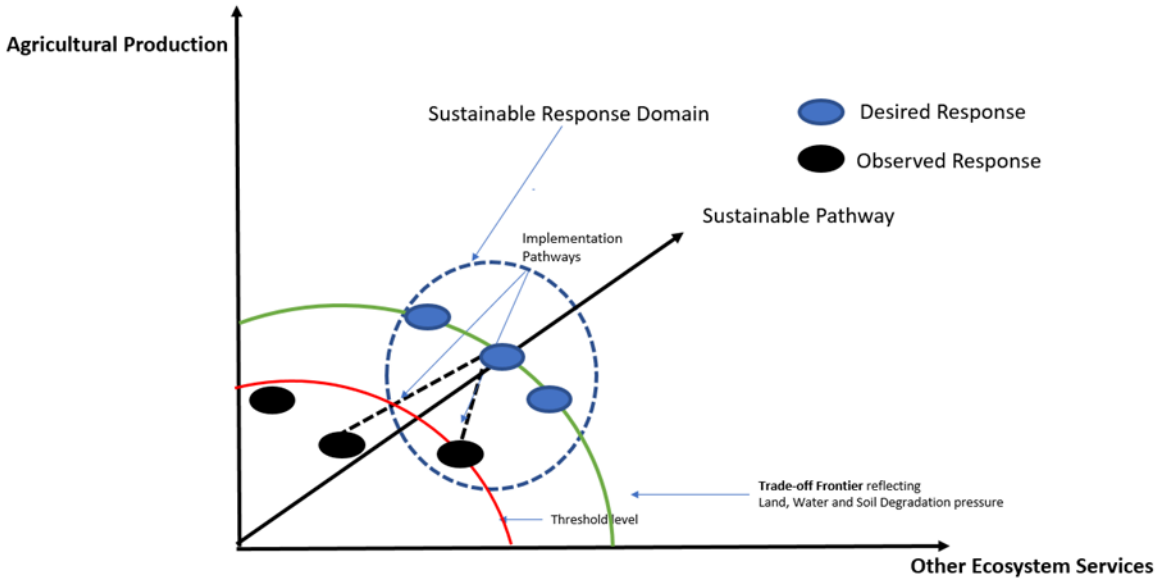

Figure 1:Key guiding concept of assessment of sustainable responses

Anthropogenic pressure and degradation of resources may exacerbate the trade-off frontier (i.e., reducing agricultural and ecosystem service benefits) until it reaches the threshold level where irreversibility may be reached at a great ecological and economic cost. The desired responses are those that are aligned to the objectives and principles of sustainable management of land, water, and soil and lie on the frontier curve. The distance between the desired response and observed response represents the implementation pathway which entails measuring the impact of observed responses and re-designing solutions based on multi-stakeholder perspectives. CFRA follows a systems approach and uses a causal framework for describing the interactions between society and the environment. It offers a solution-oriented assessment relevant at the local level and design principles to scale up the most effective responses for a broader impact.

The CFRA uses spatial and temporal data at the global, regional, and local levels to assess the effect of different responses on the land, water, and soil conditions. Extensive baseline data mining is conducted to assess initial biophysical and socioeconomic conditions, as well as impacts on these factors and costs of the responses post-adoption. Baseline biophysical conditions reflect the state of land, water and soil as well as other ecological conditions. Changes to the biophysical state are a significant indicator of the effectiveness of responses under different enabling conditions.

There are several distinct aspects of a CFRA, which are described below and provided diagrammatically in figure 2.

Identification of responses: Following a causal systems approach like DPSIR, key responses are identified that are linked to different elements of Pressure, State, and Impact of the agricultural system. The responses are classified according to three major categories: technical, management and planning, social and institutional.

Data mining: CFRA involves extensive data mining on initial biophysical and socioeconomic conditions (before the adoption of response) as well as biophysical and socioeconomic impacts and costs of responses. Initial biophysical conditions reflect the state of land, water, soil, and other ecological conditions, a significant factor in understanding the effectiveness of responses under different enabling conditions as part of the contextual analysis.

Data unification: CFRA unifies different databases and information on land, water, and soil degradation conditions such as soil properties, climate, land use, and topography (from Global and National database) as well as socioeconomic data.

Analysis: Analytical work within CFRA demonstrates and provides information on the relationship between response and ecological and biophysical impacts. The analysis will help to conduct geospatial projection of the expected impacts, and trade-off analysis of agriculture production and other ecosystem services, and identifying the effectiveness of different responses given different physical, biophysical, and socioeconomic contexts.

It involves the use of archetype, cluster analysis, and multivariate space analysis methods to systematically classify agro-ecological regions and other physical, biophysical and socioeconomic characteristics on the response implementation. The responses are scored in the framework through the construction of an Effective Response Index, that is based on derived conditions. The normalised scores of the Index enables comparison of different responses to address challenge areas in the area of land, water and soil degradation.

Key outputs of a CFRA: CFRA can identify regions where responses with potential impacts can be implemented. The effectiveness of the key interventions are predicted at the national and local levels. The application of CFRA at the regional or national context enables understanding of the local relevance of the responses.

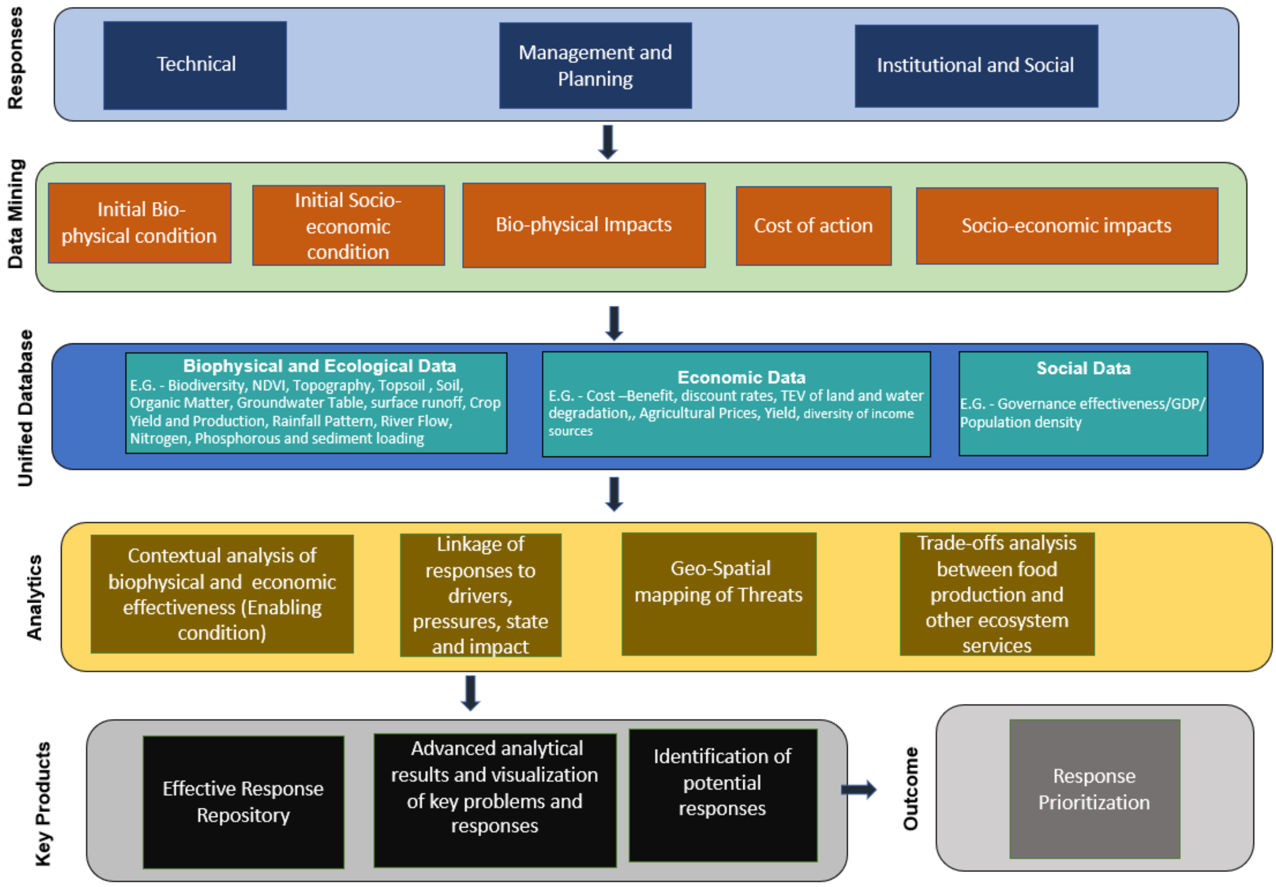

Figure 2:Comprehensive framework of response assessment

5.1 Data and Methodology

5.1.1 Determining agricultural production threat (APT) and ecosystem service threat (EST) priority areas

One of the key functionalities of the CFRA is to assemble and harmonise different spatial databases, including biophysical, socioeconomic data, to quantify various stressors while accounting for the externality effects for evaluation of the trade-off relationship between agriculture and other ecosystem services and effectiveness of the responses with respect to the trade-off.

The following figure (Figure 3) demonstrates the methodology workflow to evaluate the Agricultural production threat (APT) and ecosystem service threat (EST) based on the key drivers in the Philippines. First, the data is layered at a spatial level in each micro basin of the Philippines' territory. Similar to the methodological approach adopted by Vorösmarty et al. (2010), the flow routing (upstream to downstream accumulation effects) was considered for some of the drivers (e.g., organic loading, Nitrogen and Phosphorus concentration, water availability, and minimum flow). Next, all drivers are standardised in a 0 to 1 scale, applying a cumulative distribution function, where values close to 0 indicate lower threats and higher values elevate threats. Subsequently, the drivers are grouped into APT and EST.

For APT, data were compiled reflecting the themes: watershed disturbance and pollution, agricultural development, and climate change. For EST, data were compiled under the themes: watershed disturbance, pollution, agricultural development, and biotic factors.

At this stage, different weights are applied for each driver and correspondent themes based on expert opinions. Different weightings were applied to each set of drivers under the agricultural production threats and other ecosystem services threat and/or relationships to be applied. For example, agricultural water use may be strongly and positively related to agricultural production but weakly and negatively related to impacts to other ecosystem services. An Effective Response Index (ERI) was created to understand the overall impact of an intervention given the combined state of biophysical condition. Finally, the effectiveness of the response was analysed with the respect to the trade-off between APT and EST.

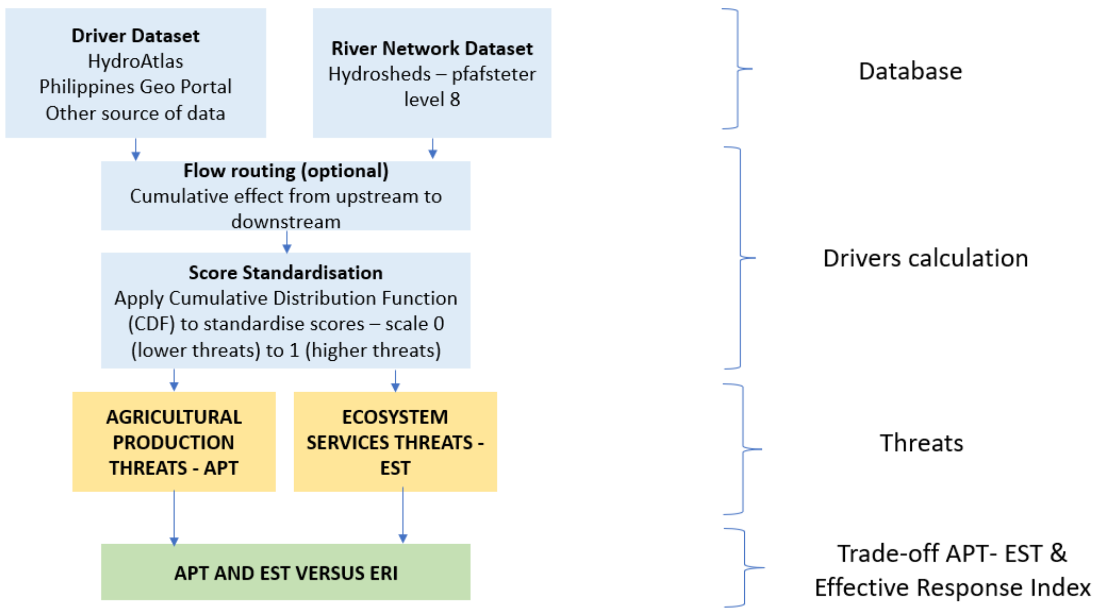

Figure 3: Workflow of the methodology

The methodology allows identifying regions with different magnitudes of trade-offs between these APT and EST. For example, low, medium and high threat categories were defined for both APT and EST, then compared with each other to result in nine categories of various threat levels ranging from low APT and EST threat to high APT and EST threat.

The main source of data used to calculate all the relevant drivers were gathered from the HydroATLAS package (Linke et al., 2019). The data on total water granted for consumptive uses, applied to estimate the Consumptive Water Loss driver, were gathered from the Philippines geoportal (https://geoportal.gov.ph/).

HydroATLAS compiled and downscaled data from various global studies to approximately 500m resolution (Figure 2). According to Linke et al. (2019), the HydroATLAS offers a global compendium of hydro-environmental sub-basin and river reach characteristics at 15 arc-second resolution. The attributes are then linked to hierarchically nested sub-basins at multiple scales and individual river reaches, both extracted from the global HydroSHEDS database at 15 arc-second (~500 m) resolution. The authors demonstrate that the micro basins dataset offers a suite of 12 layers, each containing nested sub-basins that were subdivided and coded using the topological concept of the Pfafstetter[1] system.

For the purposes of this study, relevant drivers were examined at the Pfafstetter level 8 sub-catchment resolution. As mentioned, the data compiled in HydroATLAS included variables that reflected the sub-watershed of interest as well as all upstream sub-watershed draining to this point and therefore allow for some simplified representation of routing. See the Appendix for a complete list of the data sources used for each driver. As mentioned

[1] According to Stein (2018), the Pfafstetter scheme delineates hierarchically nested catchments guided by the topology of the drainage network and the size of the drainage area. One of the most useful properties of the Pfafstetter coding is its ability to indicate topological relationships in a catchment. Network position is inferred from the ordinal value of a digit and by whether it is odd or even. A larger digit indicates a section of river further upstream while an even digit designates a tributary off the main channel. With simple algebraic queries on the Pfafstetter codes it is possible to determine whether or not an activity is upstream and thus likely to affect a particular river section without reference to a map or flow routing functions in a GIS (Stein, 2018).

previously, the drivers were grouped in themes of each main component (APT and EST), with associated weights. The tables 2 and 3 describe the data used for the drivers, while Table 4 and 5 show the list of the drivers considered for APT and EST with the respective weights. The weights were derived using expert opinion and based on existing literature.

Currently, work is ongoing to redefine the drivers for APT and EST according to the Ecosystem Services Framework with weights derived from multi stakeholder's perspective. Appendix Tables 10.15 and 10.16 provide an updated version of the set of drivers with weights. The final report will use the updated drivers and weights.

Themes	Drivers	Source of the data[2]	Indicator	Unit	Obs[3]
Watershed disturbance and Pollution	Slope + runoff + Land Use/Land Cover (LULC) (potential sediment production)	HydroAtlas	Potention sediment production	Adimensional	Calculation by team overlaying slope, runoff and land use and land cover
	Erosion	Hydroatlas	Soil erosion	Average rate in kg / hectare per year	-
	Dam density	Hydroatlas	Degree of regulation	Adimensional	-
	Organic loading	Hydroatlas	BOD concentration	mg / m3	Calculation by the team with upstream total BOD load estimative divided by the annual discharge
Agricultural development	Groundwater Table Depth	Hydroatlas	Average table depth	Centimeters	-
	Agricultural water loss	Phillipines Geoportal	Total superficial water granted for irrigation use	m3 / s	Grants overlayed with micro basin database
	Water availability	Hydroatlas	Natural discharge – annual average	m3/s	-
	Crop production	Hydroatlas	Crop production per hectare	Crop. Production / hectare	-
Climate change	Water shortage	Hydroatlas	Global aridity index	Adimensional	-
	Rainfall	Hydroatlas	Average annual precipitation	mm	-

Table 2:Data compiled for APT drivers

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[2] *HydroAtlas catalog available at: https://www.hydrosheds.org/images/inpages/BasinATLAS_Catalog_v10.pdf. / Phillipines Geoportal data available at: https://www.geoportal.gov.ph/.*

[3] *Fields without additional information in the column indicate that the team used the indicator exactly as provided in HydroAtlas.*

Themes	Drivers	Source of the data[4]	Indicator	Unit	Obs[5]
Watershed disturbance	Wetland disconnectivity	Hydroatlas	Proportion of wetland areas in a microbasin with urban and / or cropland area	Adimensional	-
	Dam density	Hydroatlas	Degree of regulation	Adimensional	-
Pollution	Organic loading	Hydroatlas	BOD concentration	mg / m3	Calculation by the team with upstream total BOD load estimative divided by the annual discharge
	Phosphorus loading	Hydroatlas	Phosphorus concentrantion	mg / m3	
	Nitrogen loading	Hydroatlas	Nitrogen concentration	mg / m3	
Agricultural development	Consumptive water loss	Phillipines Geoportal	Total superficial water granted for consumptive uses	m3/s	Grants overlayed with micro basin database
	Crop production	Hydroatlas	Crop production per hectare	Crop. Production / hectare	-
	Water availability	Hydroatlas	Natural discharge – annual average	m3/s	-
Biotic factors	Minimum flow	Hydroatlas	Average annual minimum flow	m3/s	-
	Forest	Hydroatlas	Proportion of forested area within the grid cell	Adimensional	-

Table 3:Data compiled for EST drivers.

[4] HydroAtlas catalog available at: https://www.hydrosheds.org/images/inpages/BasinATLAS_Catalog_v10.pdf. / Phillipines Geoportal data available at: https://www.geoportal.gov.ph/.

[5] Fields without additional information in the column indicate that the team used the indicator exactly as provided in HydroAtlas.

Themes	Drivers	Weights	
		Theme	Driver
Watershed disturbance and Pollution	Slope + runoff + LULC (potential sediment production)	0.3	0.25
	Erosion		0.25
	Dam density / degree of regulation		0.25
	Organic loading		0.25
Agricultural development	Groundwater Table Depth	0.4	0.3
	Agricultural water loss		0.2
	Water availability		0.3
	Crop production		0.2
Climate change	Water shortage	0.3	0.5
	Rainfall		0.5

Table 4:Themes and drivers used in the calculation of Agricultural Production Threat (APT) with respective weights

Themes	Drivers	Weights	
		Theme	Driver
Watershed disturbance	Wetland disconnectivity	0.22	0.5
	Dam density		0.5
Pollution	Organic loading	0.28	0.4
	Phosphorus loading		0.3
	Nitrogen loading		0.3
Agricultural development	Consumptive water loss	0.3	0.3
	Crop production		0.3
	Water availability		0.4
Biotic factors	Minimum flow	0.2	0.5
	Forest		0.5

Table 5:Themes and drivers used in the calculation of Ecosystem Service Threat (EST) with respective weights

5.1.2 Data on the Impacts of SLM solutions

The project relied on information from existing case studies in the Philippines to understand the effectiveness of the response. Data on the effectiveness of SLM was collected from the Philippines Conservation Approaches and Technologies (PhilCat) as part of World Overview of Conservation Approaches and Technologies (WOCAT). PhilCat has already documented SLM practices in the country (34 SLM technologies and nine SLM approaches), using the WOCAT tools and methodologies (See Figure 3 for SLM sites). This includes relevant information on the attributes and impacts of different responses.

WOCAT is a global Network to compile, document, evaluate, share, disseminate, and apply SLM knowledge. SLM are community-based initiatives and have been adopted to improve land management in a sustainable manner. WOCAT has documented the knowledge from site-specific field-tested SLM practices and developed a standardised methodology in the form of questionnaires. The community-based SLM initiatives under WOCAT are recorded as SLM technology and/or SLM approach. SLM technology is a physical practice that controls land degradation and/or enhances productivity and consists of one or several measures. SLM approach comprises the ways and means to implement one or several SLM technologies, including technical and material support and stakeholder engagement. This study focussed on SLM technologies with information on resource pre-conditions as well as economic, social and biophysical impacts. It includes data on production impacts, cost-benefit, soil and resource availability conditions. WOCAT provides data on aspects relevant to land degradation, i.e., land use and climatic conditions, the type of degradation they addressed and what land degradation response they pursued, which SLM groups they belonged to and, most importantly, how well they contributed to achieving land degradation neutrality (LDN).

The impacts are classified as highly positive (+3), positive (2), slightly positive (1), no impact (0) slightly negative (-1), negative (-2) and highly negative (-3).

WOCAT maintains records of individual interventions implemented at the local level. Each record has been carefully examined and re-coded according to the response categories used in the DPSIR regional surveys. This was done to ensure compatibility in terms of the presentation of results.

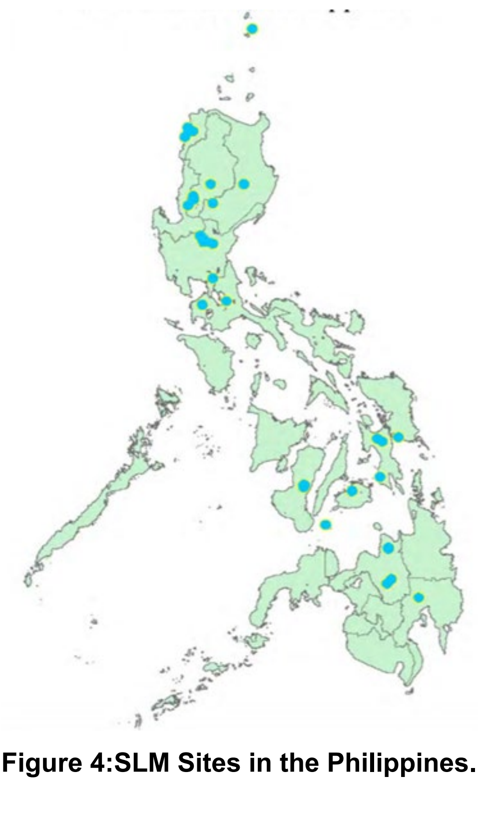


Figure 4:SLM Sites in the Philippines.

Other than PhilCat data, currently farm level survey is in progress to collect data from 100 additional sites in the Southern Mindanao. The sample survey form can be found in Appendix 10.17.

5.1.3 Effective Response Index (ERI) of sustainable land management (SLM) techniques

In the current study, an ERI was calculated to understand the overall impact of an intervention on physical states relating to agricultural production or other ecosystem services. There are 35 interventions (technologies) that can be classified into 12 groups that are applied in the Philippines according to the WOCAT database. They are mainly conducted in Central Visayas, Northern Mindanao, Central Luzon and Eastern Visayas autonomous regions (Table 4 and Figure 6).

The SLM technologies and the location of application in different island groups of the Philippines are reported in Table 6. There were 35 examples of SLM technology in total, with roughly even splits between the Luzon and Mindanao Islands (16 and 12 respectively), and a smaller number reported in the Visayas Island group (7). The most common practices were 'Conservation practices to reduce soil loss on the sloping and erosion-prone land' (8 examples), 'Organic agriculture practice management' (6 examples), and 'Smallholder irrigation management' (5 examples). Within each region, the largest number of SLM technology sites were in central Visayas (6), central Mindanao (6) and central Luzon (5)(Figure 6).

Technology	**Island group**			**Total**
	Luzon	**Mindanao**	**Visayas**	
Conservation agriculture with minimum soil disturbance and tillage practice	1	0	0	1
Conservation practices to reduce soil loss on the sloping and erosion-prone land	3	1	4	8
Implement soil moisture conservation techniques	0	0	1	1
Installation of buffers between cropland and water body	0	1	0	1
Integrated crop-livestock management	1	0	0	1
Integrated plant nutrition management to enhance soil productivity	1	1	0	2
Organic agriculture practice management	3	1	2	6
Recycling and re-use of stormwater, wastewater and grey water	0	1	1	2
Smallholder irrigation management	4	1	0	5

Sustainable natural forest management	0	0	2	2
Sustainable planted forest management	3	1	1	5
Use of improved plant varieties	0	0	1	1
Total	**16**	**7**	**12**	**35**

Table 6:Sustainable Land Management (SLM) technologies compiled in WOCAT for the Philippines by island group

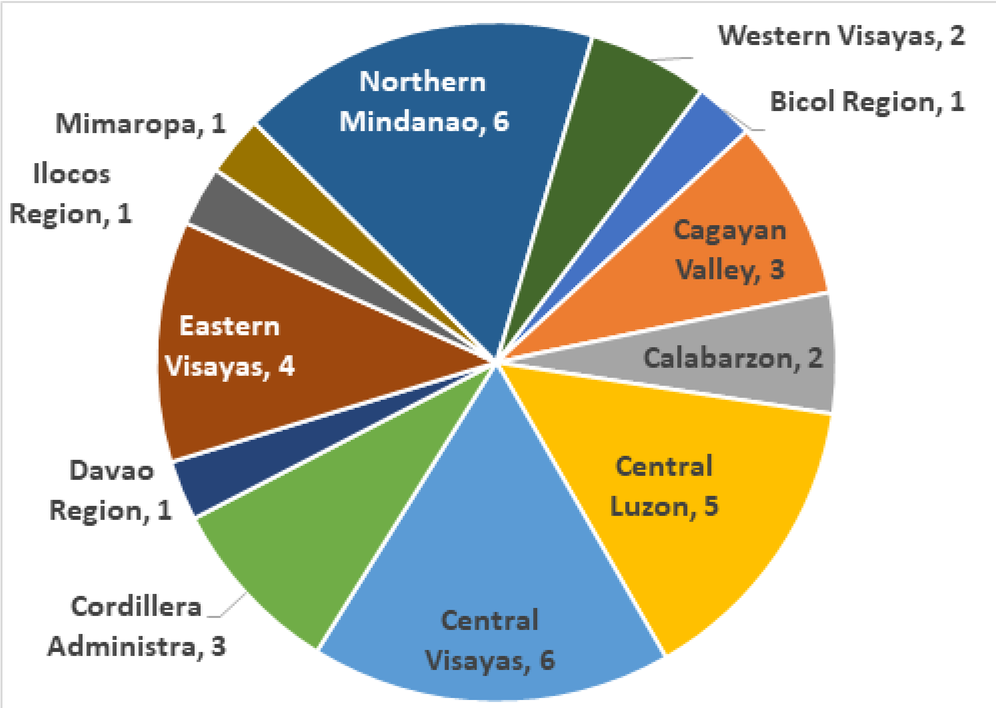


Figure 5:Sustainable Land Management (SLM) technologies compiled in WOCAT for the Philippines by the autonomous region

In this project, the calculation of ERI was revised and updated compared to the earlier ACIAR project (ACIAR SLAM/2020/138) when CFRA was first developed. In the earlier project, ERI was created on a linear scale to understand the overall impact of an intervention in the following key dimensions: Crop Production, Soil Loss, Surface Runoff Land Management, Land and Water right as well as economic benefit and cost. The linear relationship between the ERI and the different dimension implies that change in the dimension have a fixed effect on the change in ERI. However, the relationship between the dimensions could be nonlinear which means the rate of change can depend on the conditions of the state. This project considered a nonlinear relationship between the impact and states. Further, the ERI was calculated separately for agricultural production and ecosystem services. For agricultural production, impacts on crop, fodder and wood production were included in relation to states reflecting slope, soil degradation and ecological zones (Table 7). For ecosystem services, factors reflecting a range of on and off-site impacts were included, from soil conservation, pest damage and food security to nutrient runoff and sedimentation of waterways (Table 8).

Impacts	**States**	
Impacts on crop production	Crop land use type	Slope (reverse scale) Soil degradation (reverse scale) Number of ecological zones
Impacts on fodder production	Fodder land use type	
Impacts on wood production	Wood land use type	

Table 7:Impacts and States related to agricultural production in the WOCAT database used in the calculation of the ERI

Impacts	**Range**		**States**	**Range**	
	Min	**Max**		**Min**	**Max**
Nutrient Run-off	0	3	Nitrogen (reverse scale)	0	1
Sedimentation of Water ways	-3	1	Slope (reverse scale) Soil degradation (reverse scale)	0.25 0.25	1 1
Pest Damage	-3	1	Nitrogen (reverse scale) Phosphorous (reverse scale) Temperature (reverse scale)	0 0 0	1 1 1
Food Security	0	3	Off-farm Income Wealth GDP per capita	0.333 0.25 0.385	1 0.75 1
Soil water Retention	0	3	Soil depth	0.25	1
Water Purification	0	2	Land use type Population density (reverse scale)	0.25 0	1 1
Water Supply	0	3	Land use type Water supply	0.25 0.333	1 1
Soil Conservation	0	3	Soil depth Soil degradation (reverse scale)	0.25 0.25	1 1

Table 8:Impacts and States related to ecosystem services in the WOCAT database used in the calculation of the ERI

The ERI was calculated using the impacts and states for agricultural production and ecosystem services as defined in Table 7 and Table 8 and the formula presented below. This formulation allowed the impact of a given intervention to be weighted relative to the current state at the WOCAT location so that if that location was in a more degraded state currently, a given impact would be more effective, and therefore have a higher ERI. The ERI lies on a scale between 0 and 1, where a score of 1 signifies most effective response while a score of 0 signifies the least effective.

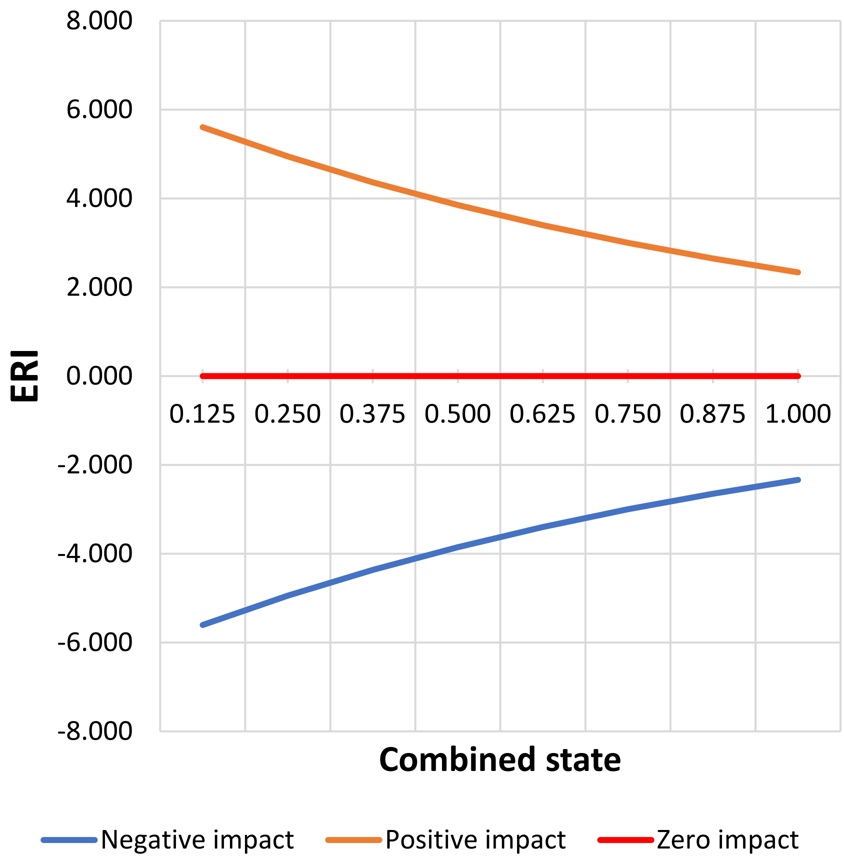


Figure 6:Example of varying ERI based on impacts and states

The $ERI_{each\ impact}$ was calculated using the formula below, where 'each impact' relates to either agricultural production or ecosystem services:

$$ERI_{each\ impact} = [Impact] \times e^{1-[combined\ state]}$$

$$[combined\ state] = \frac{\sum state\ value}{no.\ of\ states}$$

Note that some impacts are associated with more than one state (Table 6). Therefore, values for states are averaged to get a combined state value. Following the calculation of ERI for each impact, the overall ERI for agricultural production and ecosystem service was calculated using the below formula:

$$ERI_{agricultural\ production} = \frac{\sum ERI_{agricultural\ production}}{no.\ of agricultural\ productions}$$

$$ERI_{ecosytem\ services} = \frac{\sum ERI_{ecosytem\ service}}{no.\ of ecosytem\ services}$$

The results of the above ERI calculation allowed a trade-off frontier between agricultural production and other ecosystem services to be determined. Consequently, this allowed the interventions which more effectively move the complete agricultural and ecosystem service system closer to a sustainable level of production to be identified.

6 Results

This section presents the results from the APT and EST trade-off analyses combined with the results of the ERI to identify the most effective responses at different spatial priority locations.

6.1.1 Agricultural production threat (APT)

The APT drivers as defined for the current study for the Philippines are presented in Figure 8. The combined slope, runoff and Land Use/Land Cover (LULC) variable has hotspots in Panay Island in the Visayas region and lower Luzon region. Organic loading is generally highest in coastal catchments. Soil erosion is generally highest along the central section of the Philippines, with notable hot spots on Cebu and Negros Islands in the Visayas region and central to lower Mindanao. The water shortage variable follows a broadly similar distribution to precipitation.

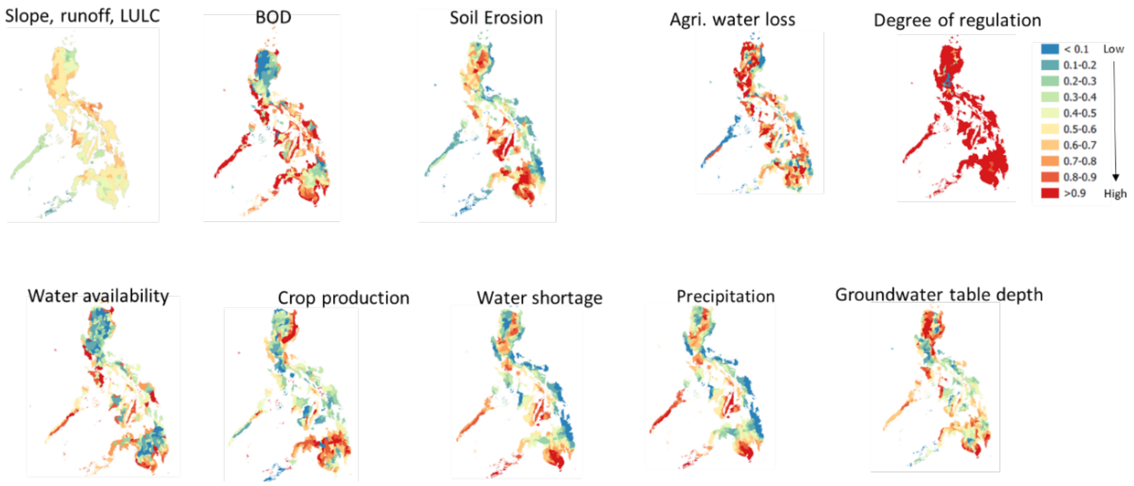


Figure 7:Scaled (between 0-1) drivers used in the calculation of agricultural production threat (APT) [6]

After assembling the APT drivers into themes and applying the weightings, the resulting distribution of APT threat is presented in Figure 9. These results indicate the majority of the Philippines is categorised as having a medium APT threat of between 0.4 and 0.6. This threat increases in some sections of upper and lower Luzon, many islands within the Visayas region, and the northern and southern coastal areas of Mindanao.

[6] *APT degree of regulation driver represents the benefit of the reservoirs in provide water availability for agricultural sectors. Regions with higher degree regulation (more dams) were evaluated as areas with lower threats. Because of this, Central Luzon has microbasins classified as lower threats. On the other hand, the effects of the dams in the EST were considered in a inverse scale, as can be seen in the EST approach.*

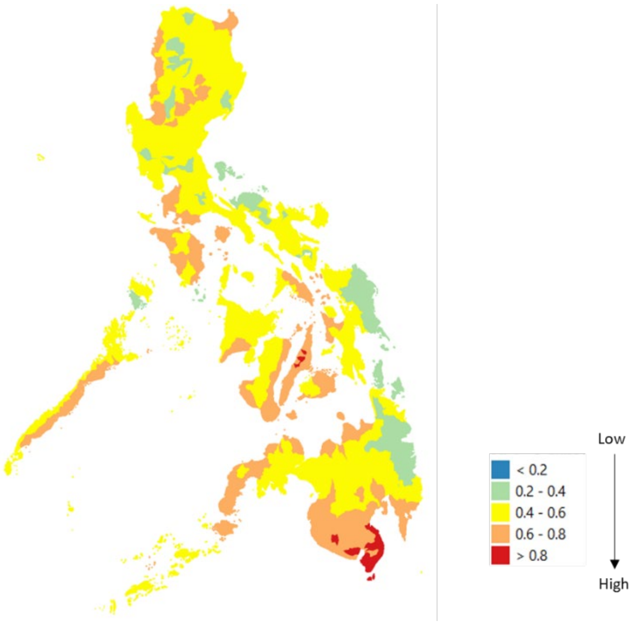


Figure 8:The distribution of agricultural production threats (APT) across the Philippines

6.1.2 Ecosystem service threats (EST)

The Ecosystem Service Threat (EST) drivers as defined for the current study for the Philippines are presented in Figure 10. The phosphorous, nitrogen and organic loading variables are all generally high along coastal catchments. Wetland disconnectivity is highest in central and lower Luzon, large sections of the Visayas region, and some isolated catchments in Mindanao. Forest cover is generally highest along the eastern coast of the Philippines.

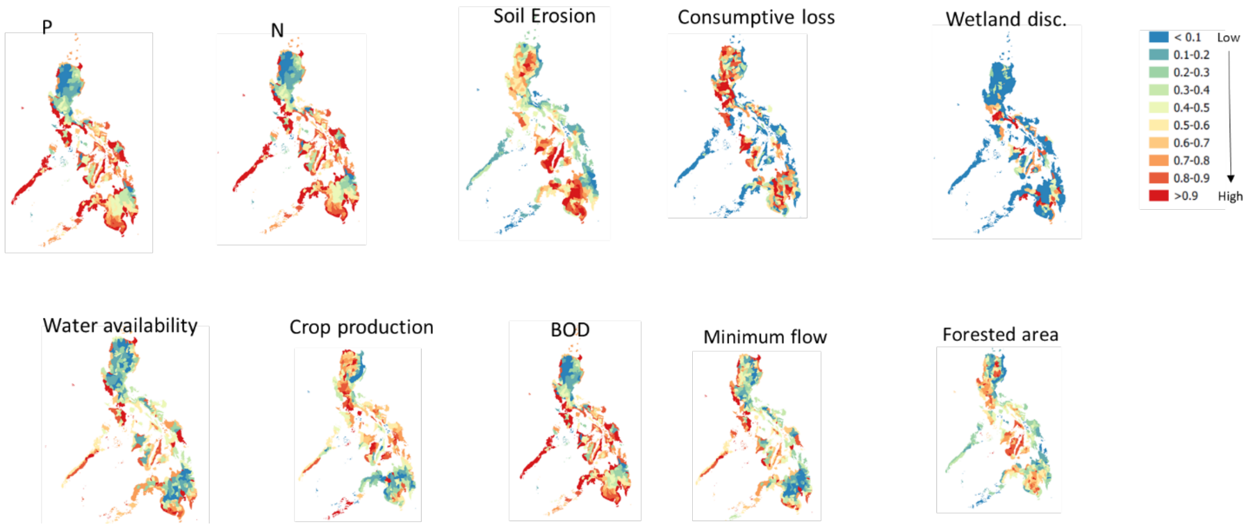


Figure 9:Scaled (between 0-1) drivers used in the calculation of ecosystem service threat (APT)

After assembling the EST drivers into themes and applying the weightings, the resulting distribution of EST threat is presented in Figure 11. These results indicate a roughly similar total distribution of low (0.2-0.4) and medium (0.4-0.6) threat in terms of total area across the Philippines. However, the low threats are generally concentrated in central and upper Luzon, and central and north-east Mindanao. Medium and higher EST threats occur in lower Luzon, many parts of the Visayas region, and western and southern sections of the Mindanao region. The higher threats in Davao del Norte are especially related with the significant values of the water pollution drivers (BOD, Nitrogen and Phosphorus), the Consumptive Water Loss, Water availability and Minimum flow.

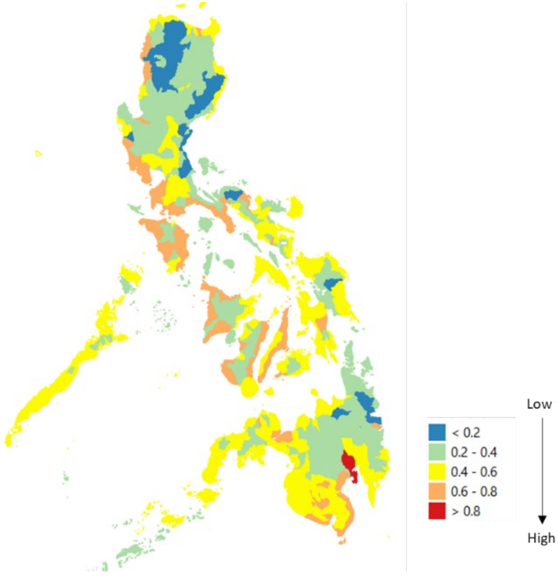


Figure 10:The distribution of ecosystem service threats (EST) across the Philippines

6.1.3 Trade-offs between Agricultural Production Threat (APT) areas and Ecosystem Service Threat (EST)

Trade-offs between APT areas and EST areas were quantified using the matrix presented in Table 7. There was not an even spread of data across these categories (Figure 12), but the results allowed an initial estimation of hot and cold spots of trade-offs between APT and EST to be estimated (Figure 13). These results indicate that areas of high APT and EST threat were located in north-western and south-western Luzon, central and western Visayas, and southern Mindanao. The majority of the Philippines sub-catchments mapped scored in the category of medium APT and EST threat (category 5) or medium APT threat and low EST threat (category 4). These regions occurred for the majority of Luzon, the eastern and western fringes of Visayas, and for the northern section of Mindanao.

		APT		
		Low	Medium	High
EST	High	3	6	9
	Medium	2	5	8
	Low	1	4	7

Table 9:Matrix of Agricultural Production and Ecosystem Service Threat Ratings

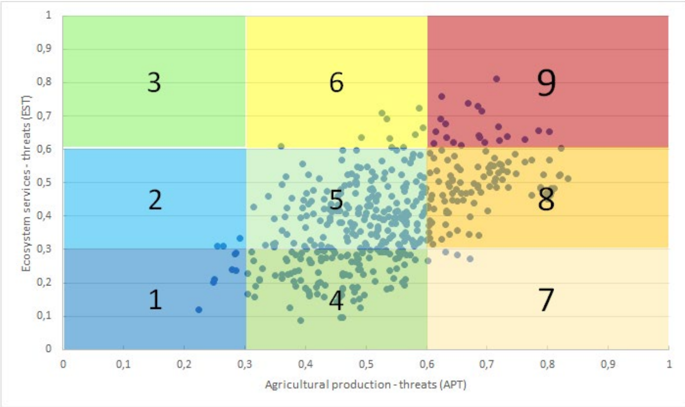


Figure 11: An example of relationship between APT and EST

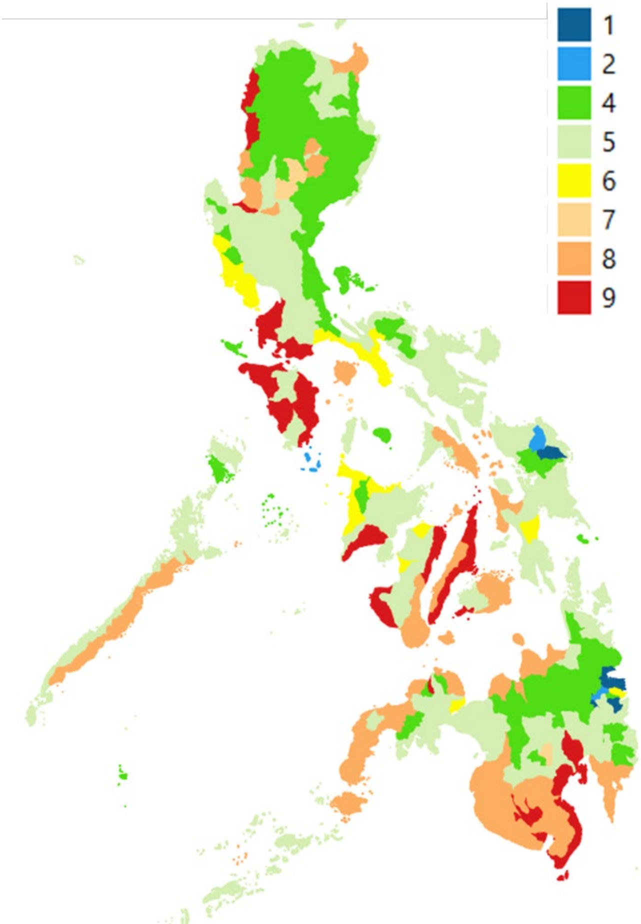


Figure 12:APT-EST trade-offs occurring across the Philippines

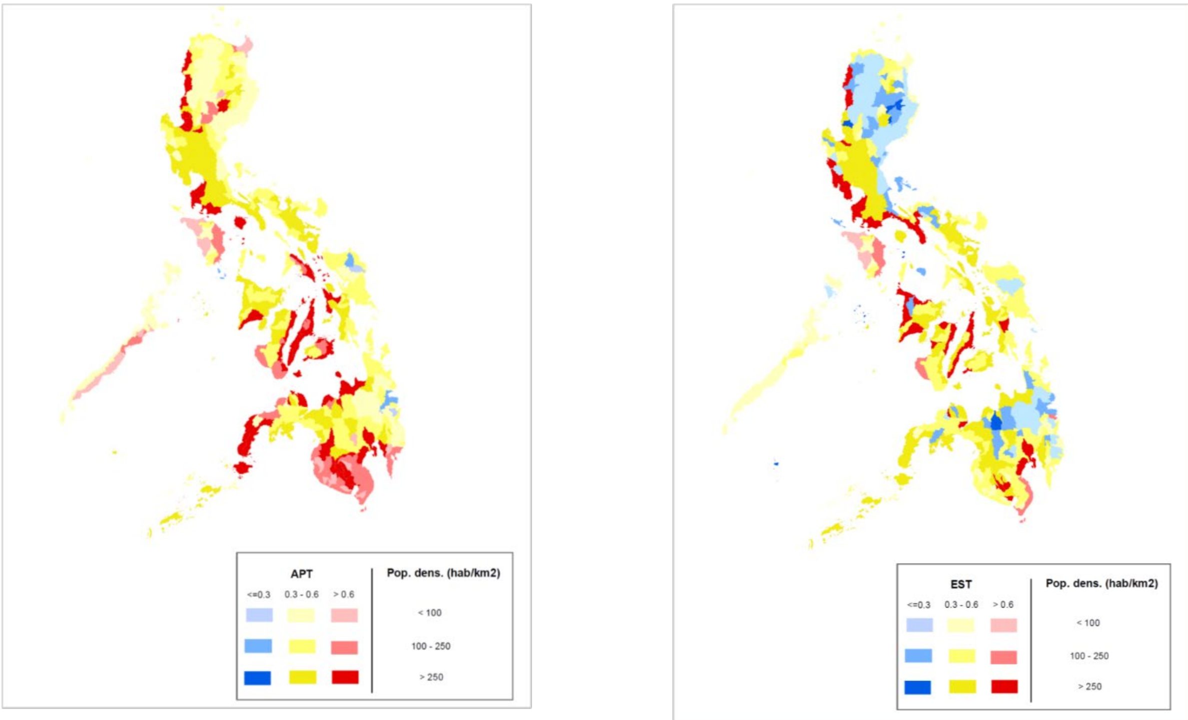


Figure 13:Agricultural Production Threat (APT) and Ecosystem Service Threat (EST) in relation to population density

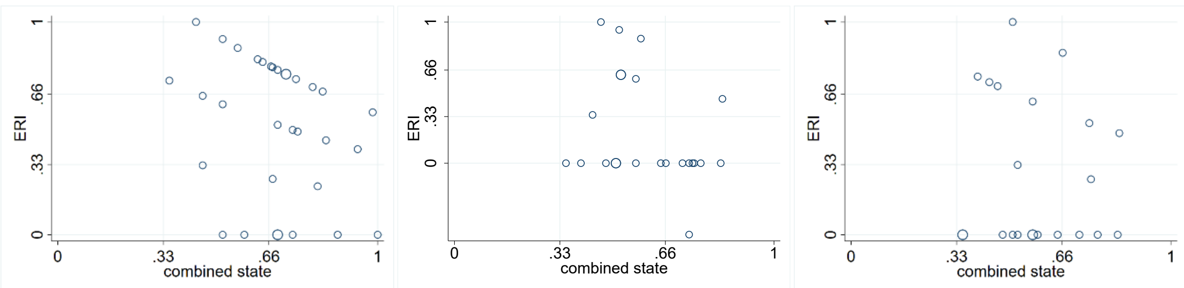
Figure 14 illustrates APT and EST in relationship to population density. The results suggest that about 50% of the higher APT threat areas are located where population density is high, and population density is also high in the majority of locations with high EST threat.

6.1.4 Effective Response Index (ERI)

ERI of Agricultural production and components

This subsection presents the results related to ERI, with discussion on the nonlinear relationships between the ERI and the state, between ERI related to agricultural production and other ecosystem services. The subsection also explores the effectiveness of the responses with respect to the trade-off between agriculture and other ecosystem services.

The calculated ERI for agricultural production is presented in Figure 15. These results indicate that crop and fodder production displays the clearest relationship between the combined state and the effectiveness of the response so that interventions that target these variables will result in the greatest improvement in the state of crop and fodder production.



ERI of crop production ERI of wood production ERI of fodder production

Figure 14:ERI of SLM practices affecting agricultural production

ERI of other ecosystem services and components

The ERI calculated for ecosystem services are presented in Figure 16. The ERI results for ecosystem services are much more variable than for agricultural production, with the most obvious relationships between the current state and effectiveness of response occurring for nutrient runoff, food security, soil water retention and soil conservation.

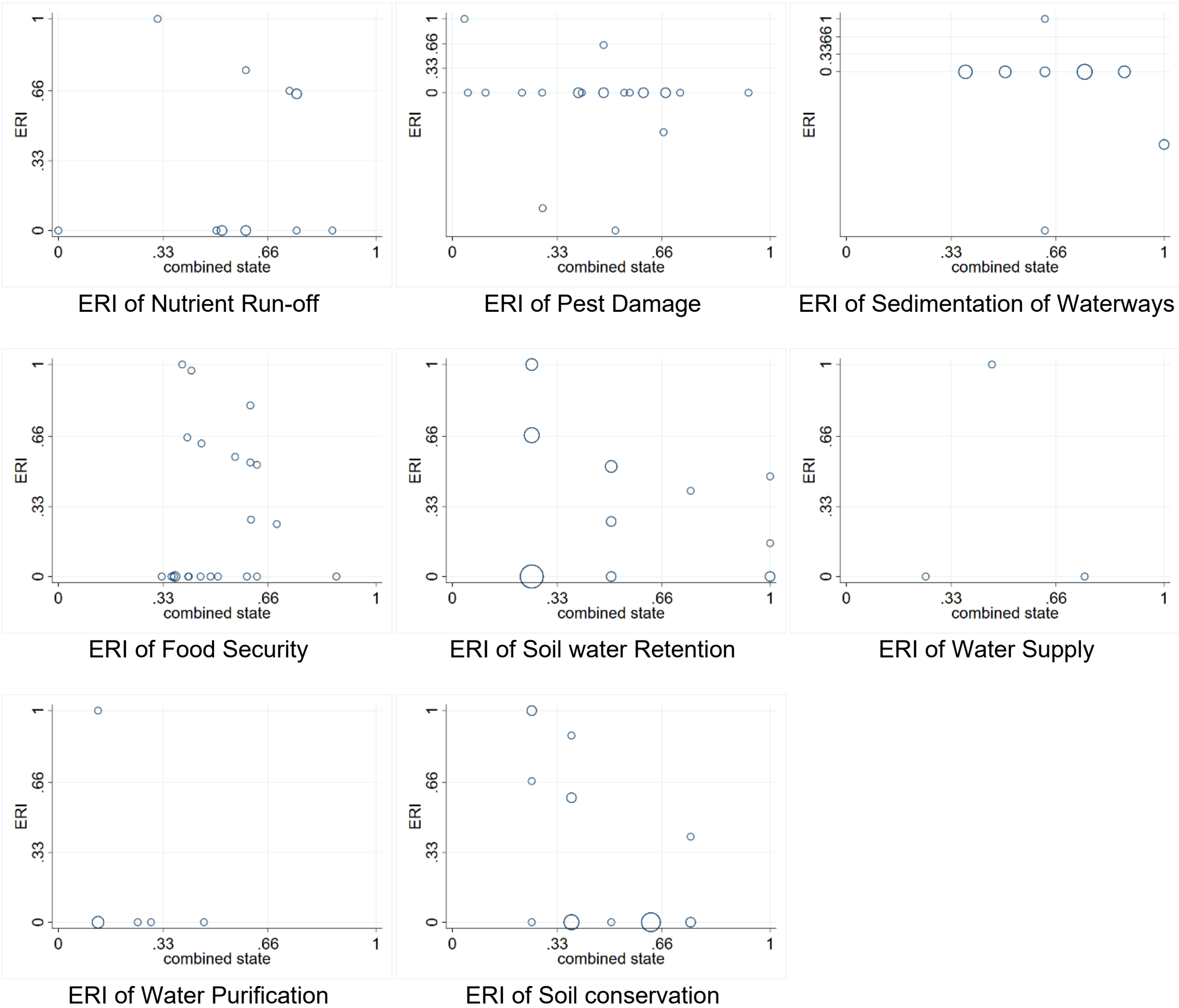


Figure 15:ERI of SLM practices affecting ecosystem services

Inter-relationship between ERI of provisioning services and other ecosystem services have been presented in Figure 17. It shows that smallholder irrigation management, installation of buffers between cropland and waterbodies, conservation agriculture have received higher scores on both fronts.

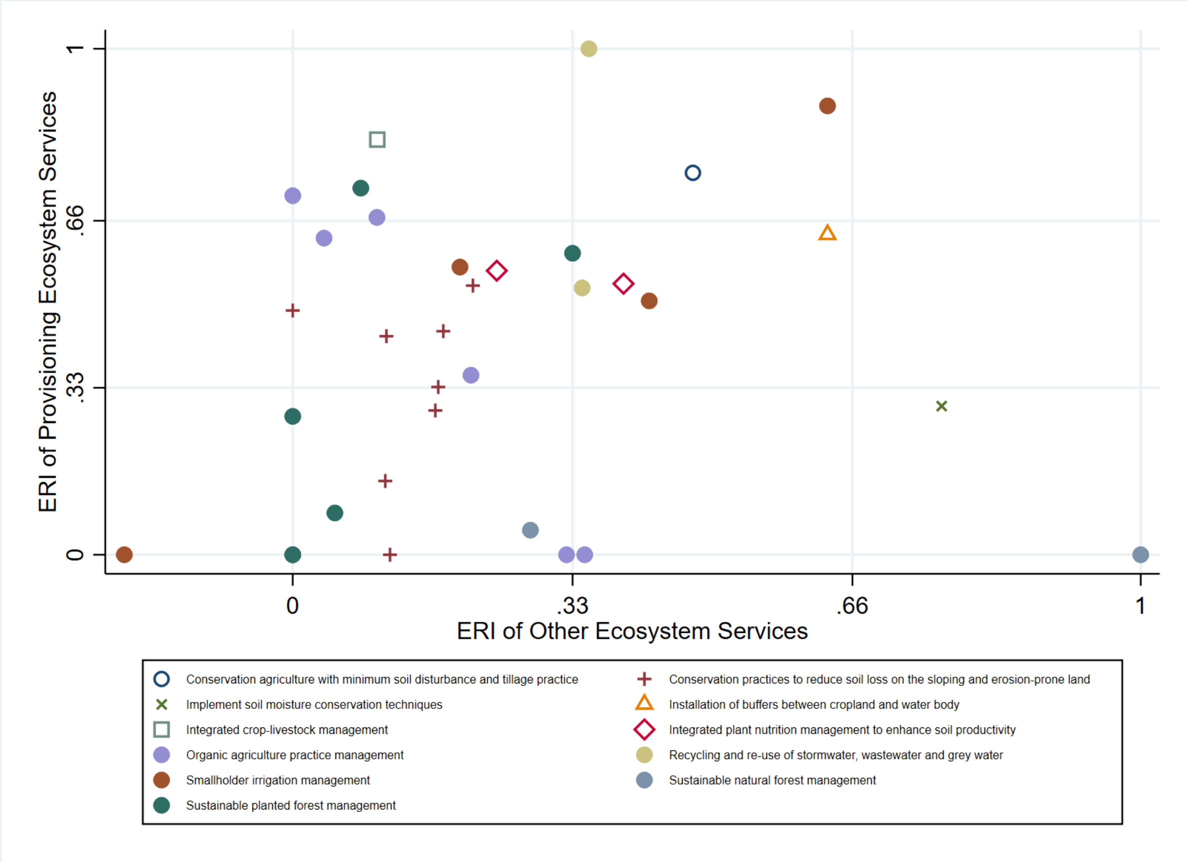


Figure 16:Inter-relationship between ERI of provisioning services and other ecosystem services

6.1.5 Agricultural production Effective Response Index (ERI) and Agricultural Production Threat (APT) and Ecosystem Services Threat

The combined results of the APT analysis and the agricultural production ERI is presented in Figure 18. These results indicate that the majority of the WOCAT SLM sites occur in medium APT threat areas, and that at these locations some responses are particularly effective (greater than 0.5). These sites occur at central and lower Luzon, eastern Visayas, and northern Mindanao regions.

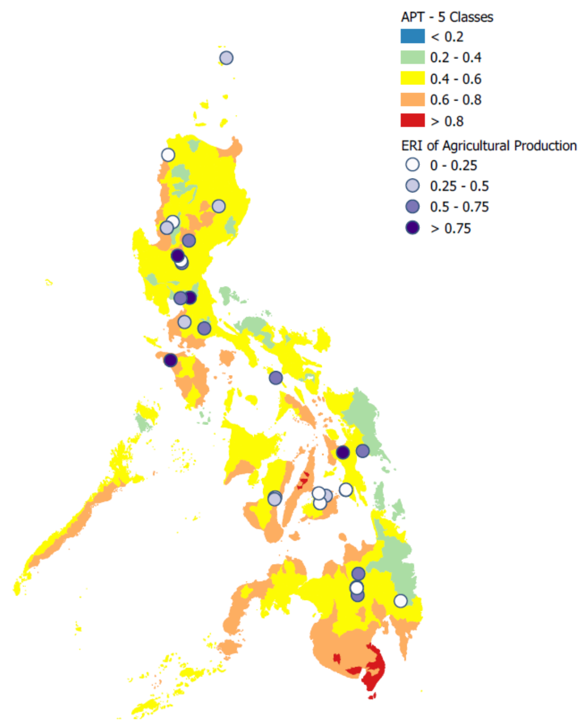


Figure 17:Effective Response Index (ERI) for Agricultural Production in relation to the Agricultural Production Threat (APT) categories

The combined results of the EST analysis and the ecosystem service ERI is presented in Figure 19. These results indicate a roughly even distribution of WOCAT SLM sites between low (less than 0.4) and medium (0.4 – 0.6) EST categories. The most effective SLM responses for ecosystem services appear in the Visayas region.

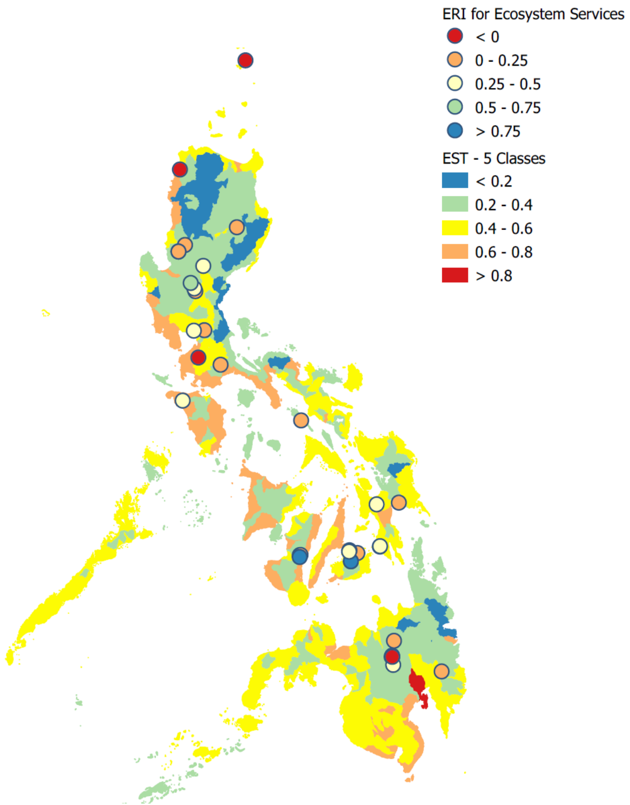


Figure 18:Effective Response Index (ERI) for Ecosystem Services in relation to the Ecosystem Service Threat (EST) categories

		APT		
		Low	Medium	High
EST	High	3	6	9
	Medium	2	5	8
	Low	1	4	7

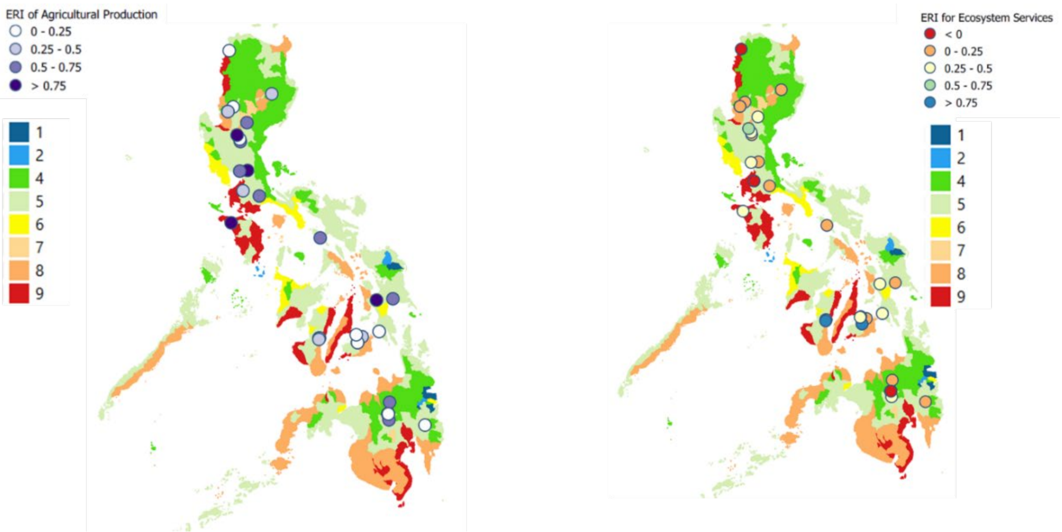


Figure 19:Effective Response Index (ERI) values in relation to APT-EST trade-offs occurring across the Philippines

Overall, most effective responses to reduce APT generally address medium APT and EST (category 5). There is only one highly effective response related to agricultural production that addresses both high APT and EST. On the other hand, effective responses related to ecosystem services addresses medium EST and either medium APT or high APT. Table 10 presents the benefit cost ratio of effective responses for different classes of trade-off between agriculture and other ecosystem services. We find that benefit cost ratio is the highest for the responses where there is high APT. This indicates that currently SLMs are designed to provide greater benefit to agriculture. Figure 21 explains different response and their ERI for agriculture production and ecosystem services under moderately high agriculture production in the Philippines. In higher APT threat areas, SLM provides greater benefit to other ecosystem services.

Installation of buffer between cropland and water body balances the threat reduction to both agriculture and other ecosystem services. The SLM related to conservation agriculture with minimum soil disturbance and tillage practices are most effective with relationship to other ecosystem services threat reduction.

	ERI		
class	Agriculture	Other Ecosystem Services	Benefit Cost Ratio
4	0.29	0.06	2.20
5	0.48	0.25	2.14
7	0.60	0.33	3.00
8	0.30	0.31	2.56
9	0.51	0.24	3.00
Total	0.41	0.24	2.35

Table 10:ERI and Benefit Cost ratio

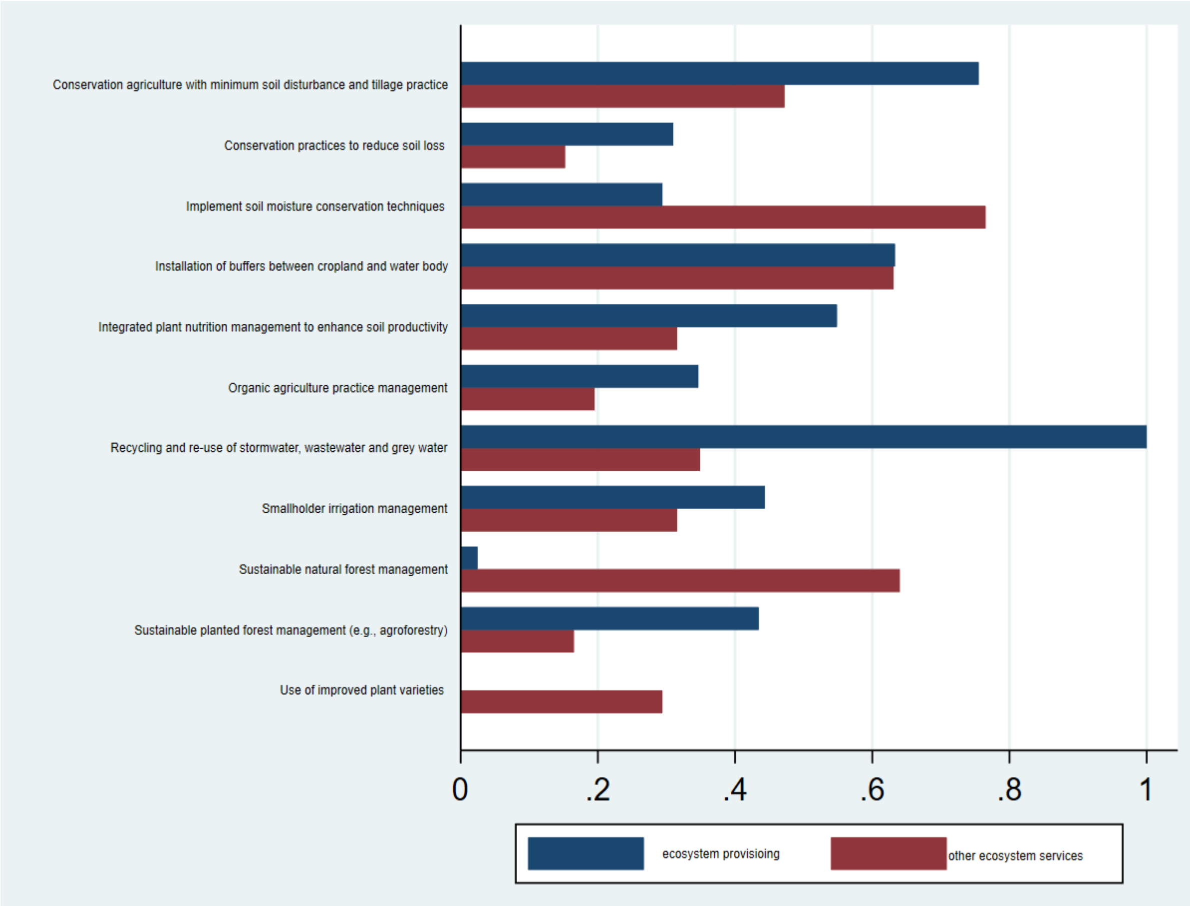


Figure 20:Effective Response Index under Moderately high Agriculture Production in the Philippines

7 Co-design Workshop

During the initial rounds of meetings with PCAARRD and BSWM, it has been agreed that both organisations will support the activities of the project, and a co-design workshop will be organised to define the methods of assessment and refine the details and alignment of the framework with other similar frameworks and tools for applications in the Philippines. The workshop will also provide an opportunity for the team to identify and discuss country datasets in the Philippines and resources for use in the assessment framework.

A two-day consultation workshop was organised by Griffith University, PCAARRD, BSWM and ACIAR on April 29th and 30th 2021 to define the methods of assessment and refine the details and alignment of the framework with other similar frameworks and tools for applications in the Philippines. The workshop was attended by the Director, BSWM, Directors at DOST-PCAARRD, FAO-PH, PAC-regional office Asia pacific, FAO HQ, Griffith University, the University of the Philippines Los Banos, the University of Southern Mindanao, Central Luzon State University, University of science and technology of Southern Philippines and the Visayas State University. The workshop provided an opportunity for the team to identify and discuss country datasets, methodology for customising, refining and the CFRA methodology for applications in the Philippines as well as project management.

7.1 Proposed Case study

In the proposed project, tests will be conducted to understand the limitations of the applicability of the CFRA in the assessment and replication of its response for sites/locations with similar conditions. The results of the CFRA (populated with data from PhilCat and other sources) regarding its effectiveness will be compared to the monitoring results of a few pre-selected cases in the Philippines for validation. The case studies could be selected according to the following criteria:

A. Well defined watershed and landscape zones

B. Pre-existing conditions of land degradation

C. A priority area of application of SLM approaches of BSWM

D. Availability of monitored data on selected responses

E. Availability of data on biophysical, ecological and socio-economic conditions

During the codesign workshop, the selection of the case study regions were discussed in details with the presentation of different case study regions. It includes the following

1. Community-Based Forest Management in LUZON
2. Conservation Farming Village in VISAYAS
3. LANDCARE - Claveria Landcare Association in MINDANAO

BSWM explained different land use and land degradation conditions of the suggested sites.

Also there were in depth discussion on the criteria of the selection of the sites.

1. The discussion leads to the development of the following criteria-
2. Good geographical representation of the country's major islands
3. Well-defined watershed and landscape zones
4. Pre-existing conditions of land degradation
5. A priority area of application of SLM approaches
6. Availability of monitored data on selected responses
7. Availability of data on biophysical, ecological, and socio economic conditions
8. Potential investment opportunity
9. Population growth rate, food security, and poverty incidence
10. Data reliability and variability

The colour code of the criteria has been designed based on priority. Green coloured font represents necessary factors while yellow and red represents other sufficient factors.

The project also explored the state of Land Degradation Neutrality (LDN) priority river basins with a combination of land degradation and high incidence of poverty using the results from CFRA. These priority river basins include the Cagayan River (northern Luzon), Pampanga River (central Luzon), Mindanao River (central Mindanao), Agusan River (north-east Mindanao), and Iloilo-Batiano River (western Visayas) (**Error! Reference source not found.**). The potential sites could be located in each of the region as well.

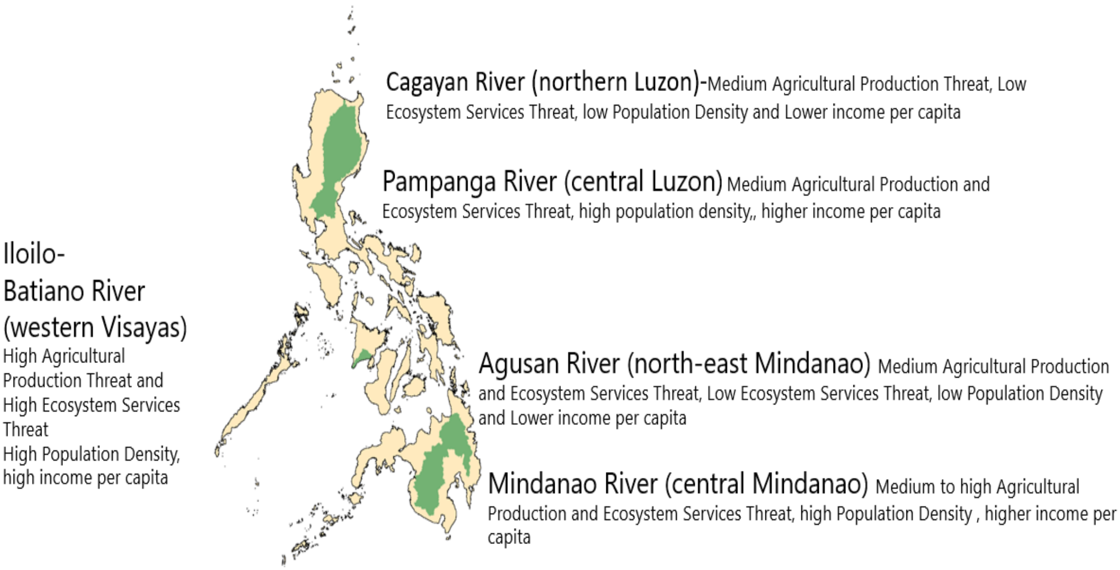


Figure 21:Priority river basins as determined by UNCCD (2018)

7.2 Theory of Change

Theory of Change is a methodology for planning, participation, and evaluation that is used in companies, philanthropy, not-for-profit and government sectors to promote social change. Theory of Change defines long-term goals and then maps backward to identify necessary preconditions.

To achieve impact at scale using the knowledge, capacity and tools developed in this project will require investment to support practice change, institutional change, and further knowledge and capacity development, as well as effective monitoring and evaluation. To help identify how improved land and water management for sustainable development can be achieved a draft Theory of Change was developed during the co-design workshop. The following key questions were discussed in detail to frame a draft Theory of change (Figure 23).

- What are the drivers of change that may affect the achievement of the goals?
- Who are the agents of change or who should be involved in making those changes happen?

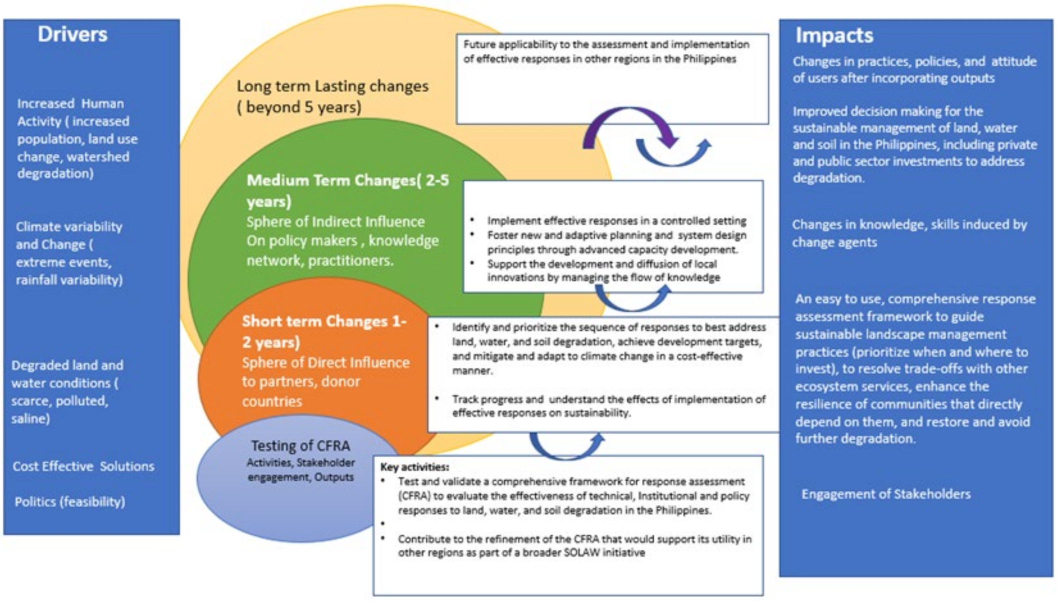


Figure 22:The draft Theory of Change for the project

The discussion suggested the addition of the following points on the impact and drivers of change

Impacts:

1. Benefit the decision-making process and governance at the regional and local level (e.g. CLUP and other sectoral plans like LCCAP, FLUP, etc.)
    1. Optimised use of land and water resources
    2. Preserving biodiversity/ culture
2. Change in knowledge, attitude, belief and practice (KABP) and behavior (consumption and production)
3. Biophysical change (i.e. improvement)
4. Socio-Economic impacts
5. Better collaboration among institutions, NGAs,

Drivers of Change:

1. Pandemic/epidemics (COVID-19, ASF), natural hazards (volcanic eruptions, earthquake, typhoons, etc.)
2. Science, Technology, and Innovation
3. Urbanization
4. Changing land use
5. Tenure/ security
6. An ageing phenomenon among farmers, youth’s disinterest, labour migration and remittances
7. Peace/security!
8. Policy environment

It was agreed during the workshop that the validation and monitoring of the impact of the project would be designed as a key activity of the project to maximise the benefits to the users of the project.

8 Conclusion and Recommendation

8.1 Conclusion

This report demonstrates a methodology that can contribute to knowledge and understanding of responses to natural resource management interventions in agriculture (land, soil and water) in the Philippines. It will support decision making so that adaptive management practices and policies can be designed to sustain land and water resources and reduce economic and productive losses under climate change and with increasing intensification of agricultural production. The project refined the CFRA in the context of the Philippines to help prioritise actions (when and where to invest) in sustainable landscape management practices.

The main contributions of this phase of CFRA development are the following:

- Stakeholder dialogue with key partners and organisations in the Philippines to understand the scope and application of CFRA, identify case study areas as well as develop the theory of change.
- Developing a methodology to calculate threats to agriculture production and other ecosystem services and understanding the trade-off relationship between APT and EST
- Revised methodology to calculate ERI to address the trade-off and incorporate non-linear relations of the effectiveness as a function of the state of land degradation.

8.1.1 Key findings:

The key findings of the project so far are

- High Agriculture Production Threats are found in Luzon (Mindoro Is), central Visayas, and southern Mindanao
- High Ecosystem Service Threats are found in central-southern Luzon, Central Visayas, and southern Mindanao
- A positive relationship exists between increasing Agriculture Production and Ecosystem Service Threats
- The majority of land areas in the Philippines are currently either under medium APT-EST threat or low EST-medium APT threat
- A small area exists with a high threat-trade-off between APT and other ecosystem services
- Population density area also coincides with the area of high APT threat while population density is high in the majority of locations with high EST threat
- Some responses are particularly effective in locations where there is medium APT (greater than 0.5)
- Related to other EST there is roughly even distribution of areas between low and medium EST categories. Most effective responses are in Visayas region, considering other ecosystem services threat reduction.

- Overall, SLM are designed to provide greater benefit to agriculture,
- In higher APT threat areas, SLM providing greater benefit to other ES.

8.1.2 Future Work on the Methodology

The report also identifies areas where the current work can be improved.

- Reframing of the theme of APT and EST according to Ecosystem services framework and ensuring no endogeneity in the constructed relationship between APT and EST. Currently, work has progressed in collecting spatial and temporal data (See Appendix 10.15 and 10.16).
- The prototype results need closer validation with higher resolution country data and ground-truthing.
- There is a need to harmonise different data across similar time scales
- Improvements and validation of expert opinion regarding the weights for different themes in the construction of APT and EST
- Needs validation of the weights of the ERI
- The current model is based on snapshot data- needs to be validated with Ecosystem services Model (Invest) and Agri production Simulation Models as well as participatory Analysis
- Future scenarios will include-climate impacts and how it influences the trade-off and ERI (including carbon sequestration)
- Future output includes scenario analysis of how each solution (response) type can influence the threat index. With limited data on solutions, currently, it may not be possible. It is proposed that further research should implement solutions and monitor impacts at sites to develop knowledge and understanding the effectiveness of the solutions. This will be more like "Follow the Innovation".

8.2 Recommendation

8.2.1 Policy Recommendation

1. The study recommends that the risk of increasing ecosystem services threat can be addressed through policies that emphasise and priorities ecosystem services in adopting SLMs and accelerate the diffusion of innovations in nature-based solutions/SLMS. This may require an incentive mechanism and reward system to increase the benefit-cost ratio and support farmers for higher and wider adoption of farm-based solutions to address the trade-off between Agriculture production and other Ecosystem services.

There is a stronger need to prioritise sustainable land and water management practices and actions and target resources towards them. This entails developing, validating and implementing a standardised methodology for determining the effectiveness of responses for scaling up and out of sustainable management techniques and approaches for land, water and soil in the Philippines. This can help Local Government Units to guide sustainable landscape management practices (prioritise when and where to invest) to resolve trade-offs with other ecosystem services, enhance the resilience of communities that directly depend on them, and restore and avoid further degradation. It can also support farmers in addressing the sustainable use of resources through use of the synthesised information on the dynamic state of land, water and soil.

However, beyond proving better knowledge and information in decision making, other factors are also key to the success of projects that promote SLM approaches for scale up and scale out. It includes strengthening institutional partnerships and engaging the community using the participatory, interdisciplinary approach. It is important to engage policy and decision makers at national and local level particularly at LGUs in the process of resource assessment and the testing of the tools.

8.2.2 Research Gap

There are a number of existing research gaps that this project identified, particularly in closing the gap in the effectiveness of the sustainable land management techniques in resolving the dynamic trade-off between agriculture provision and other ecosystem services (soil conservation, water quality regulation, habitat loss, biological pest control). There are knowledge gaps in understanding the policy and market instruments that can influence the trade-offs and induce behavioural change in the adoption of effective SLM.

Other identified research gaps include the following:

- How can technical efficiency at the farm level influence the nature of the trade-off?
- What are the effects of stochasticity (climate change meteorological factors –rainfall and temp) on the effectiveness of the SLM to reach the Pareto frontier between agriculture and other ecosystem services?
- What are the degrees of the spatial relationship between off-farm and on-farm trade-offs?
- What is the time frame in which a trade-off will occur?
- What determines the reversibility of the trade-offs?

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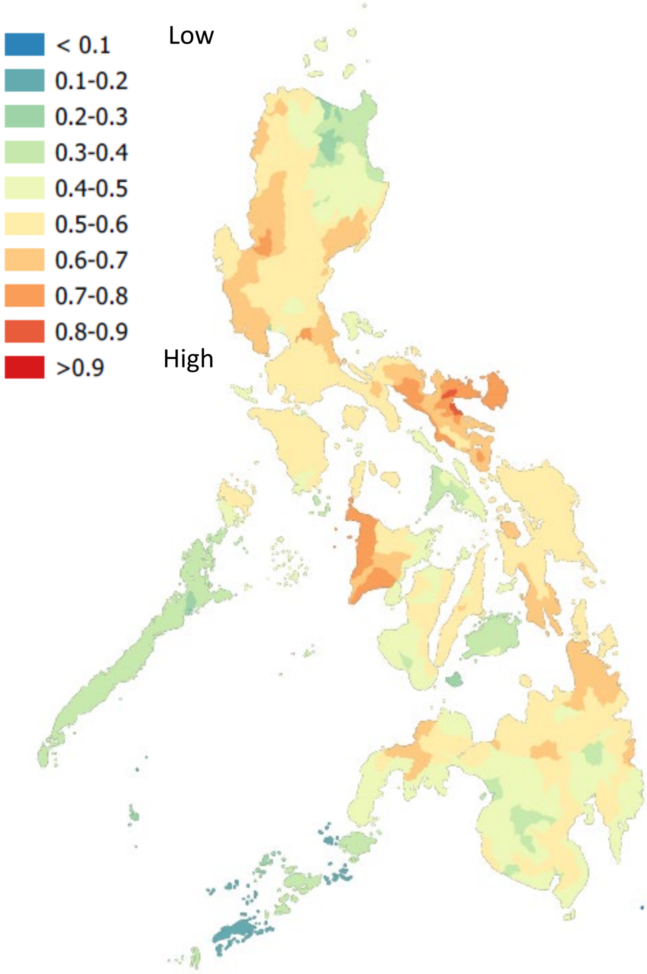
10 Appendixes

10.1 Driver: Slope + runoff + Land Use/Land Cover (LULC) (potential sediment production)

Driver calculation combining Slope, Runoff and LULC classes

- I1 – Slope:
    - value extracted directly from HydroAtlas
    - Higher slope => greater threat / lower slope => lower threat
- I2 – Runoff:
    - value extracted directly from HydroAtlas
    - Higher runoff => greater threat / lower runoff => lower threat
- I3 - LULC:
    - Pasture, agricultural and urban area within the grid cell
    - Higher values => greater threat / lower values => lower threat
- DRIVER: (I1 + I2 + I3) / 3

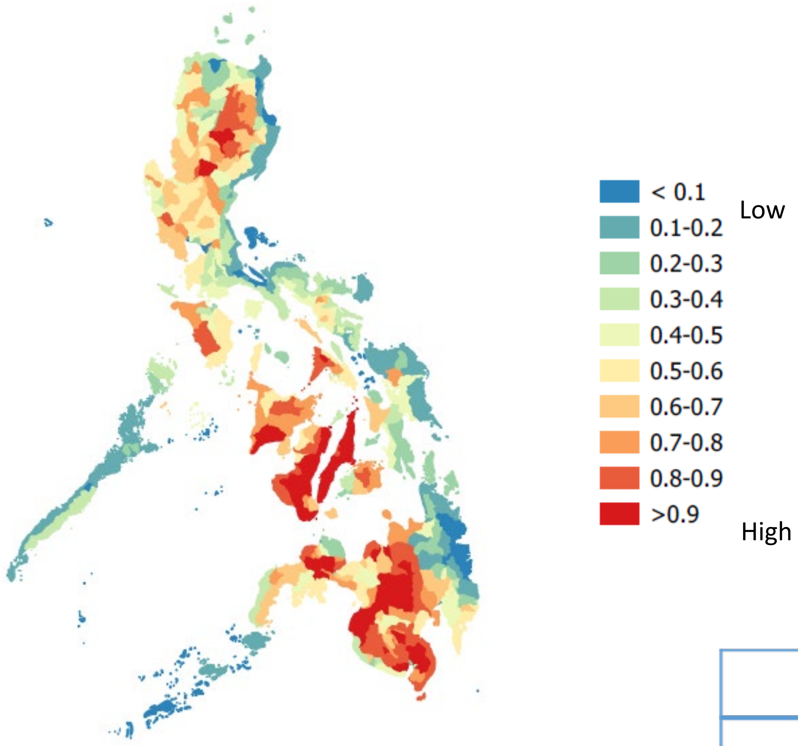


10.2 Driver: Erosion

Average erosion rate kg/hectare/year (HydroAtlas)

Higher Erosion rate => greater threat

Lower Erosion rate => lower threat



APT	**Yes**
EST	-

10.3 Driver: Dam density / degree of regulation

Degree of regulation (APT):

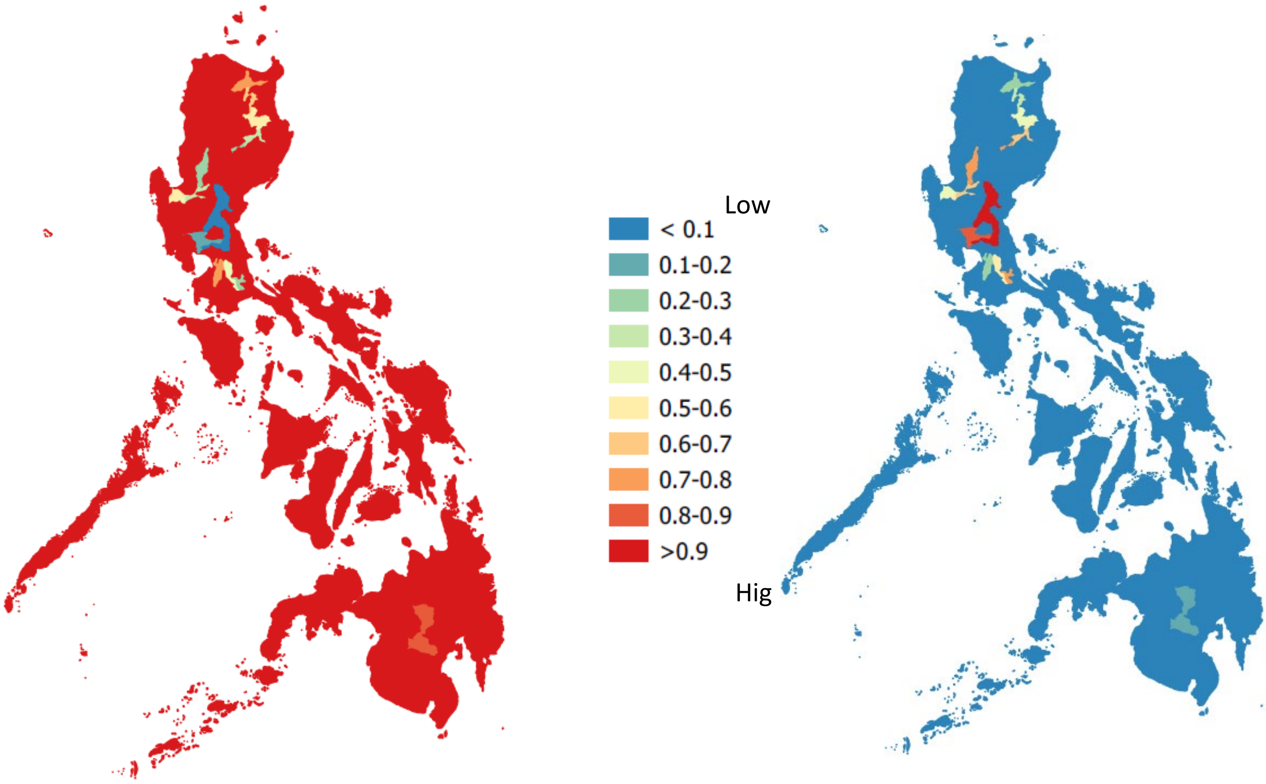
Higher Degree of regulation => lower threat

Lower Degree of regulation => higher threat

Degree of regulation (EST):

Higher Degree of regulation => higher threat

Lower Degree of regulation => lower threat



APT	**Yes**
EST	Yes **(inverted scale)**

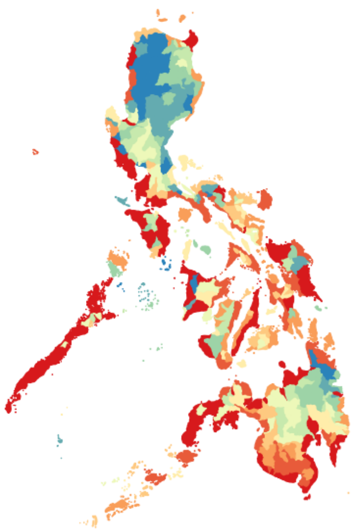
10.4 Drivers: concentration of BOD, Phosphorus and Nitrogen

- Calculation of drivers: export coefficient applied for the LULC classes (forest, pasture, agriculture and urban) in upstream areas (total load for each pollutant), and divided by the natural discharge (HydroAtlas attribute)
- Export coefficients: Moruzzi, R. B., Conceição, F. T., Sardinha, D. S., Honda, F. P., Navarro, G. R. B. Evaluation of diffuse loads and simulation of self-purification in the Água Branca River, Itirapina (SP). UNESP, Geociências, v. 31, n. 3, p. 447-458, 2012.

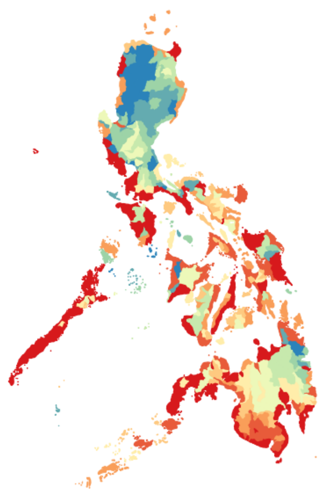
Urban (kg/km2/year)			Agriculture (kg/km2/year)			Forest (kg/km2/year)			Pasture (kg/km2/year)		
P	N	BOD	P	N	BOD	P	N	BOD	P	N	BOD
12.41	463.55	2058.6	126.29	1076.75	2671.8	14.235	219	438	18.25	328.5	821.25

Note: the estimation do not consider the upstream to downstream decay of the pollutant, and the effect of the reservoirs. Dams can retain the pollutant propagation. As a result, the estimation of the pollutant concentration can have been overestimated.

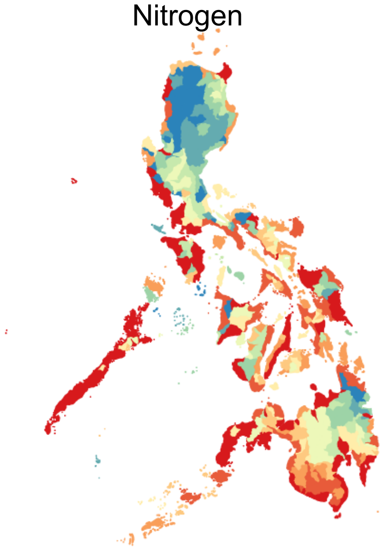
BOD



Phosphorus



Nitrogen



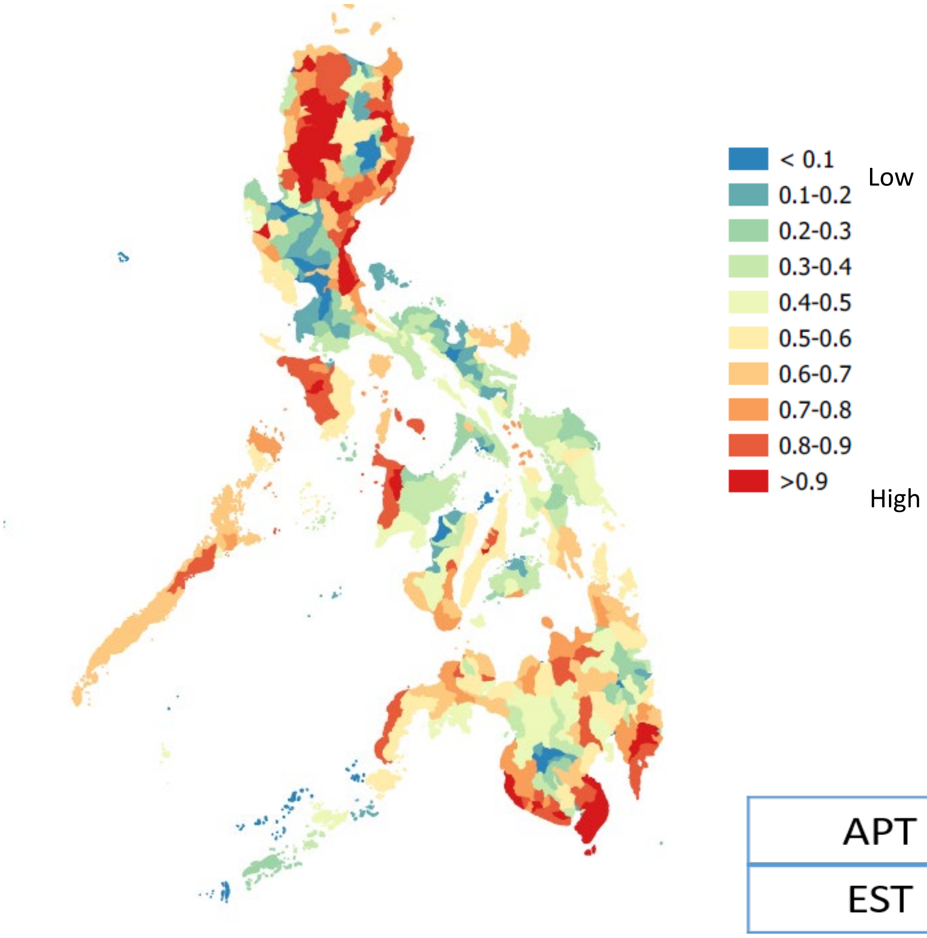
APT	**Yes** (BOD)
EST	Yes (BOD, P, N)

10.5 Driver: groundwater table depth

Groundwater table depth

Higher depth => greater threat

Lower depth => lower threat



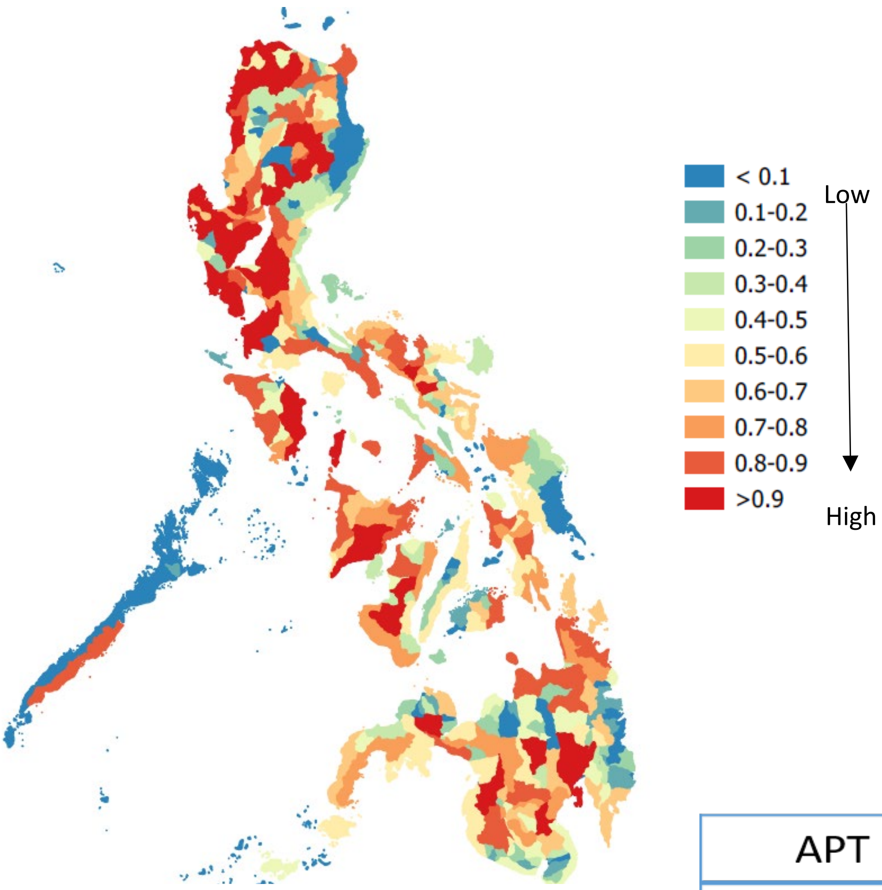
APT	**Yes**
EST	-

10.6 Driver: Agricultural water loss

Irrigated area

Higher irrigated area => greater threat

Lower irrigated area => lower threat



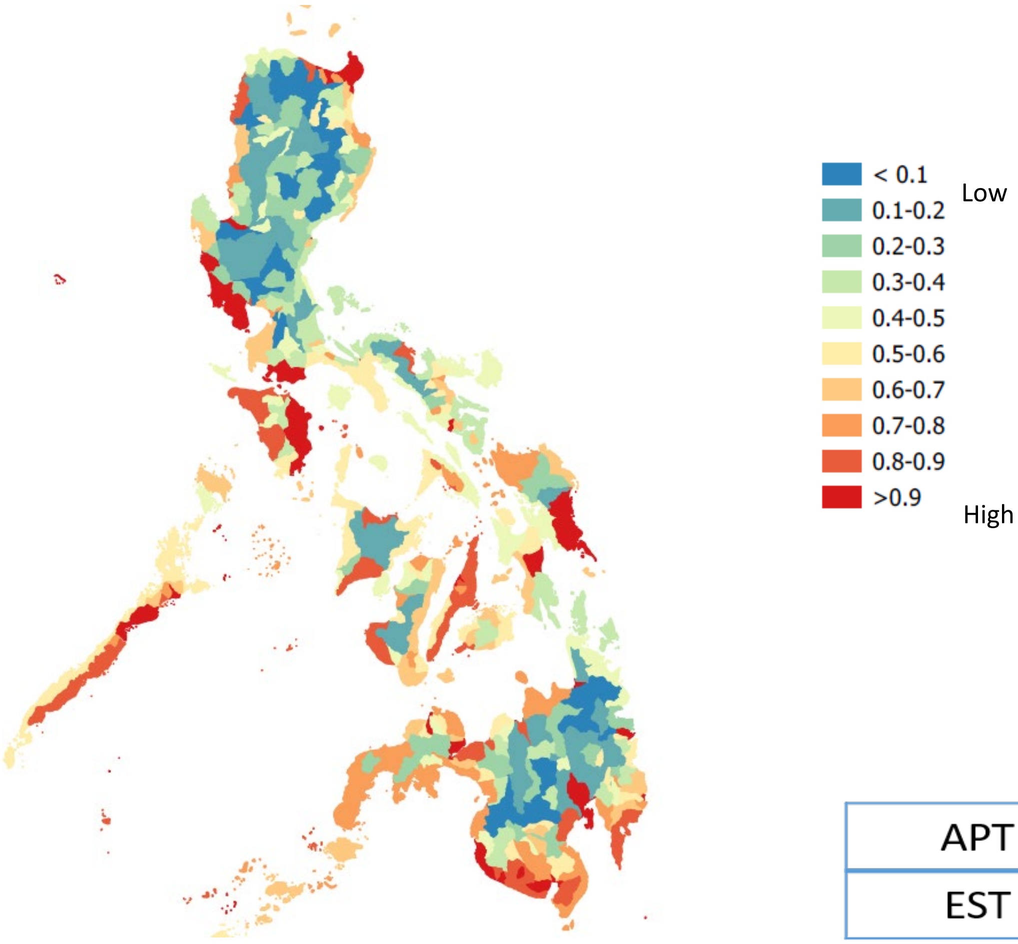
APT	**Yes**
EST	-

10.7 Driver: Water availability

Natural discharge – average flow

Higher natural discharge => lower threat

Lower natural discharge => higher threat



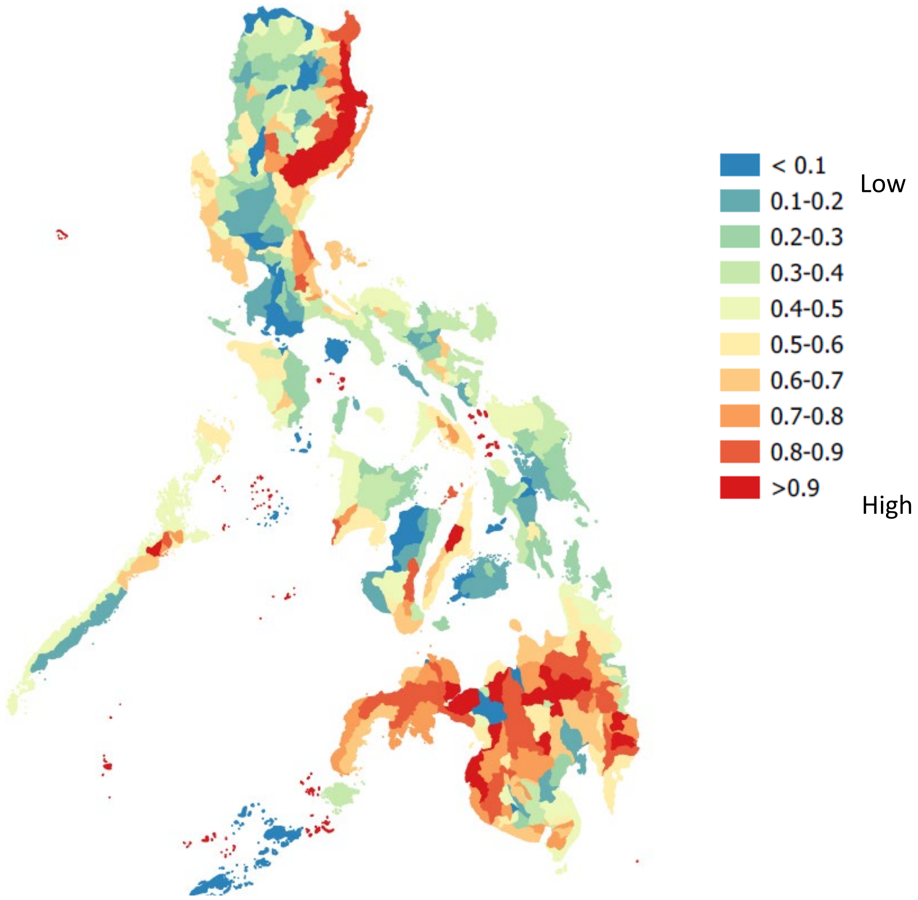
APT	**Yes**
EST	Yes

10.8 Driver: Crop production

Crop production (APT) – value per hectare

Higher crop production => lower threat

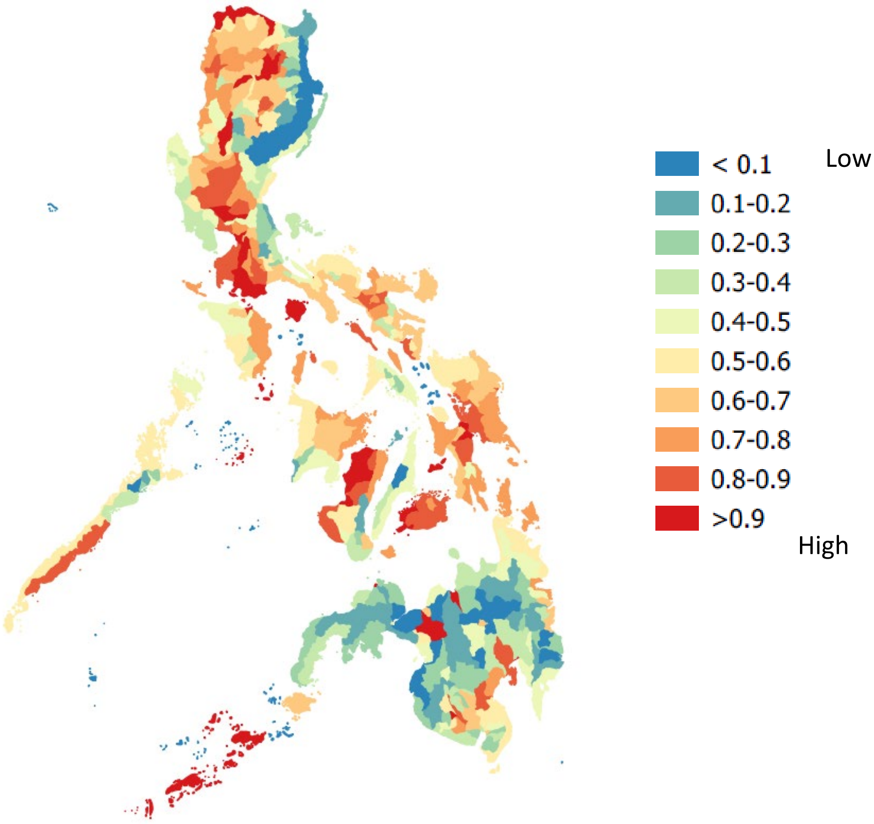
Lower crop production => higher threat



Crop production (EST) – value per hectare

Higher crop production => higher threat

Lower crop production => lower threat

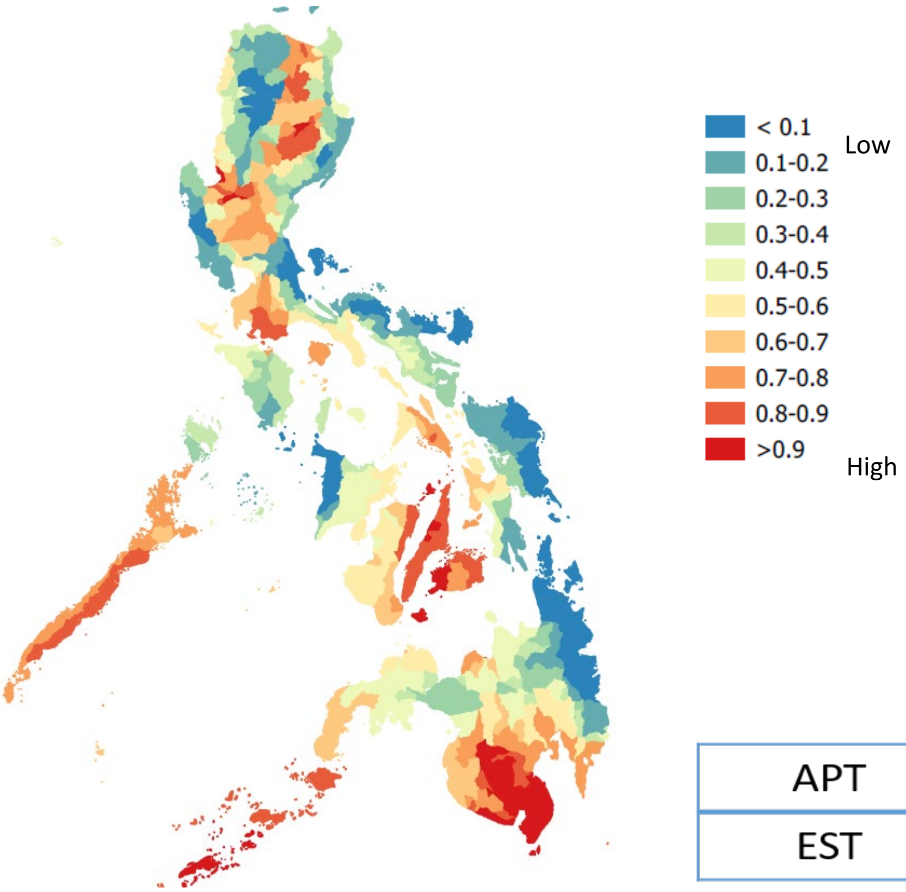


10.9 Driver: Water shortage

Global arid index - GAI

Higher index => lower threat

Lower index => higher threat



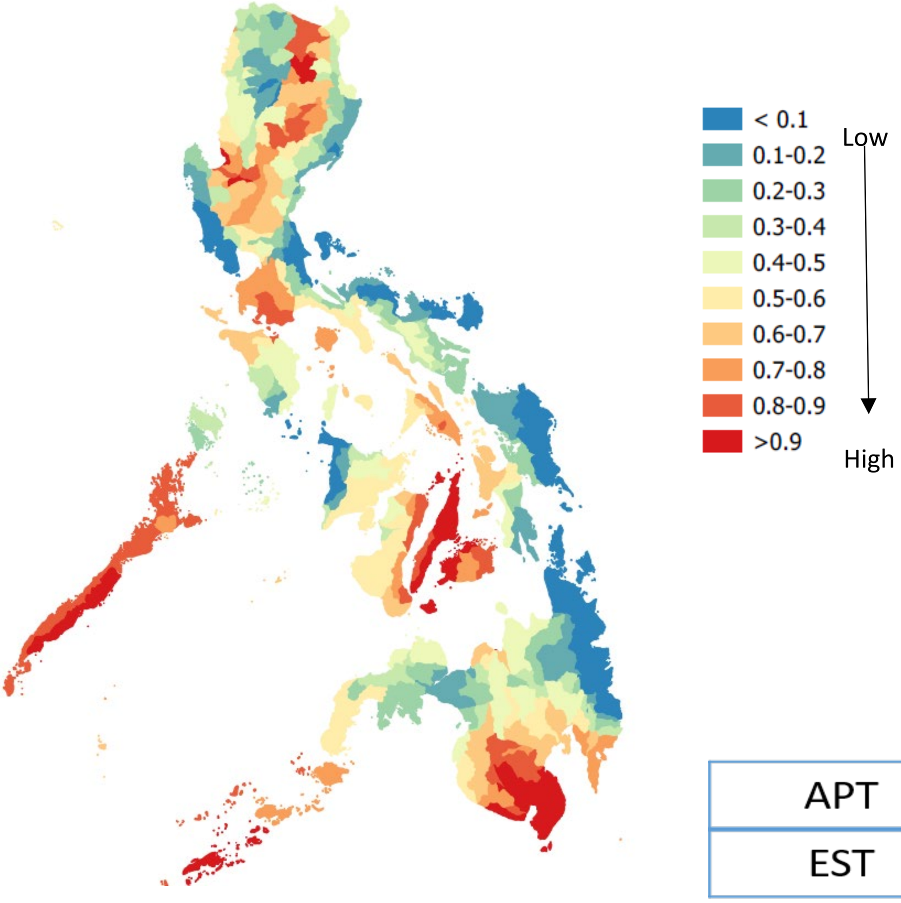
APT	**Yes**
EST	-

10.10Driver: Rainfall

Annual precipitation average

Higher precipitation => lower threat

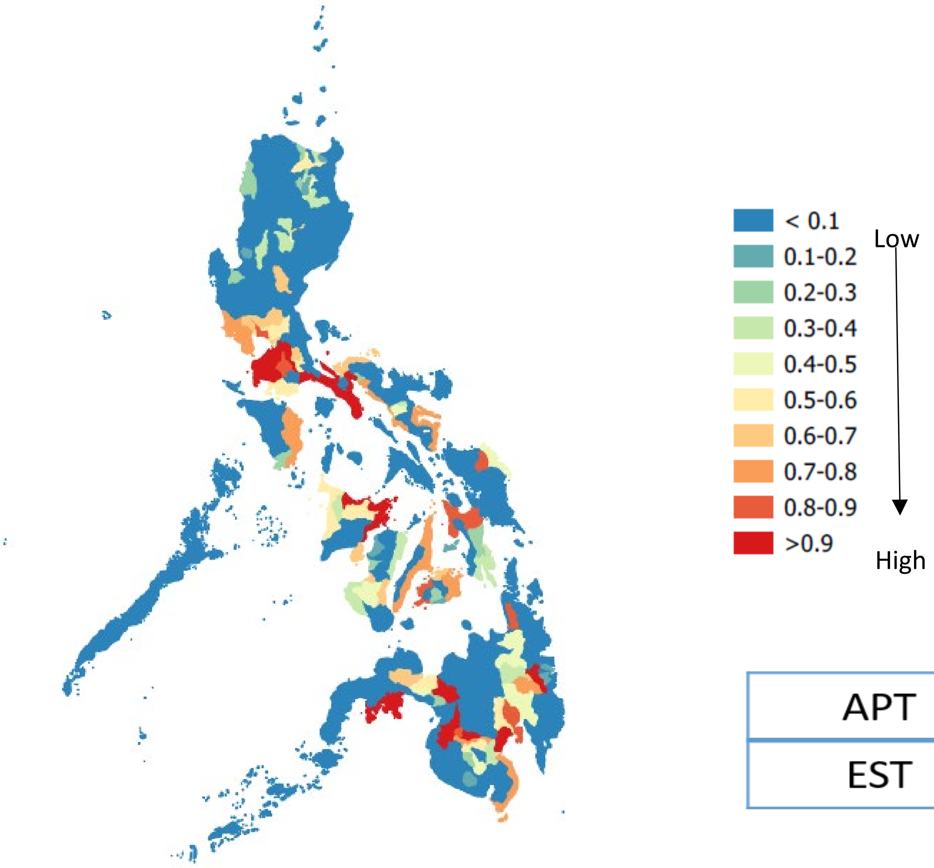
Lower precipitation => higher threat



APT	**Yes**
EST	-

10.11 Driver: Wetland disconnectivity

- Indicator: wetland area within the grid cell with cropland and / or urban areas
- Higher value of the indicator => higher threat
- Lower value of the indicator => lower threat



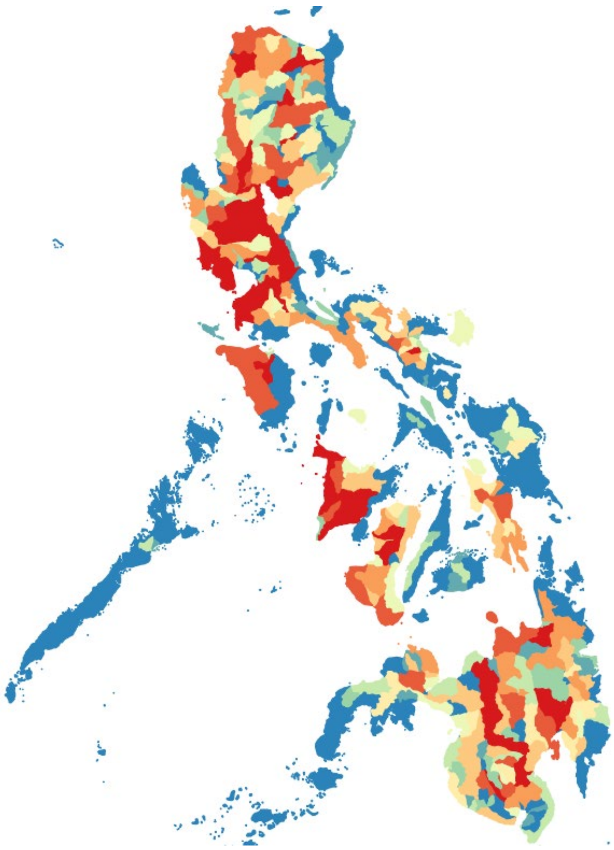
APT	-
EST	Yes

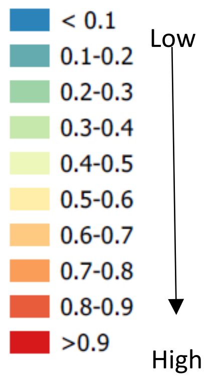
10.12Driver: Consumptive water loss

Water granted for consumptive uses: irrigation, industry, water supply, etc

Higher water granted => higher threat

Lower water granted => lower threat





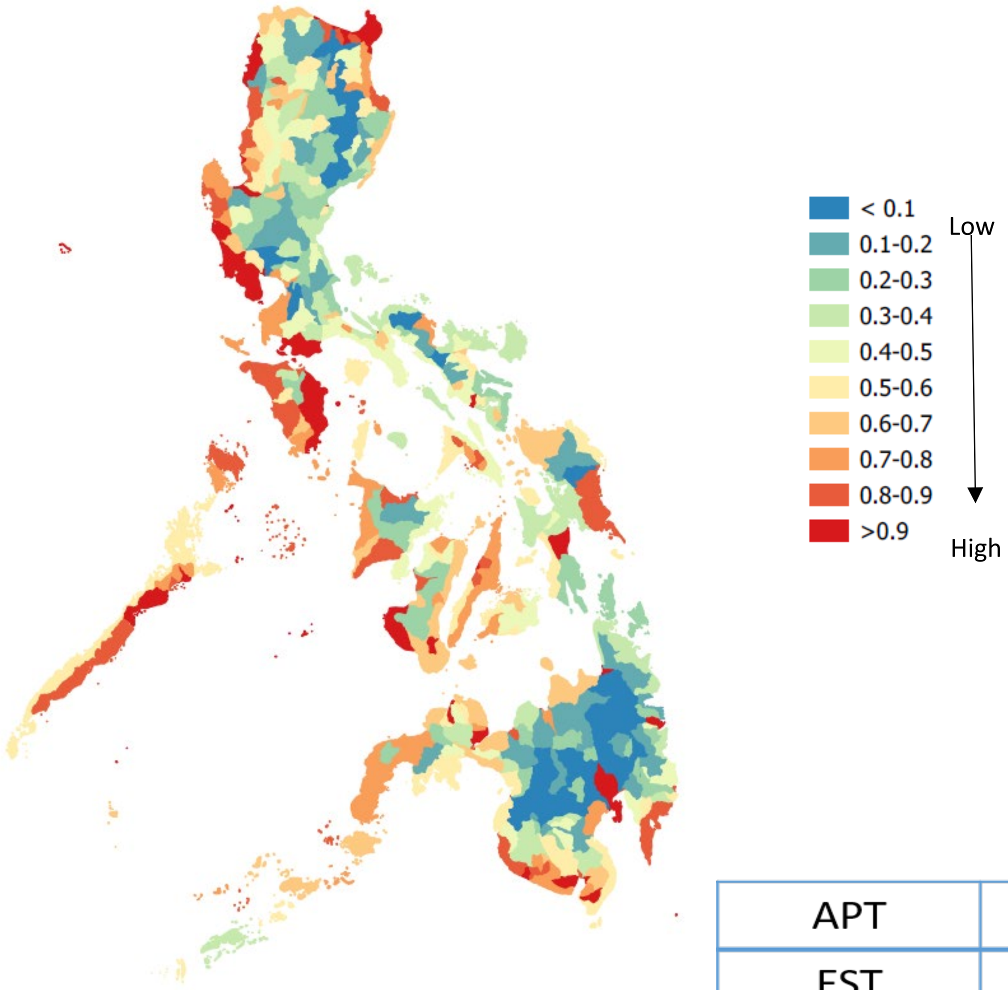
APT	-
EST	Yes

10.13Driver: Minimum flow

Natural discharge – minimum flow

Higher natural minimum discharge => lower threat

Lower natural discharge => higher threat



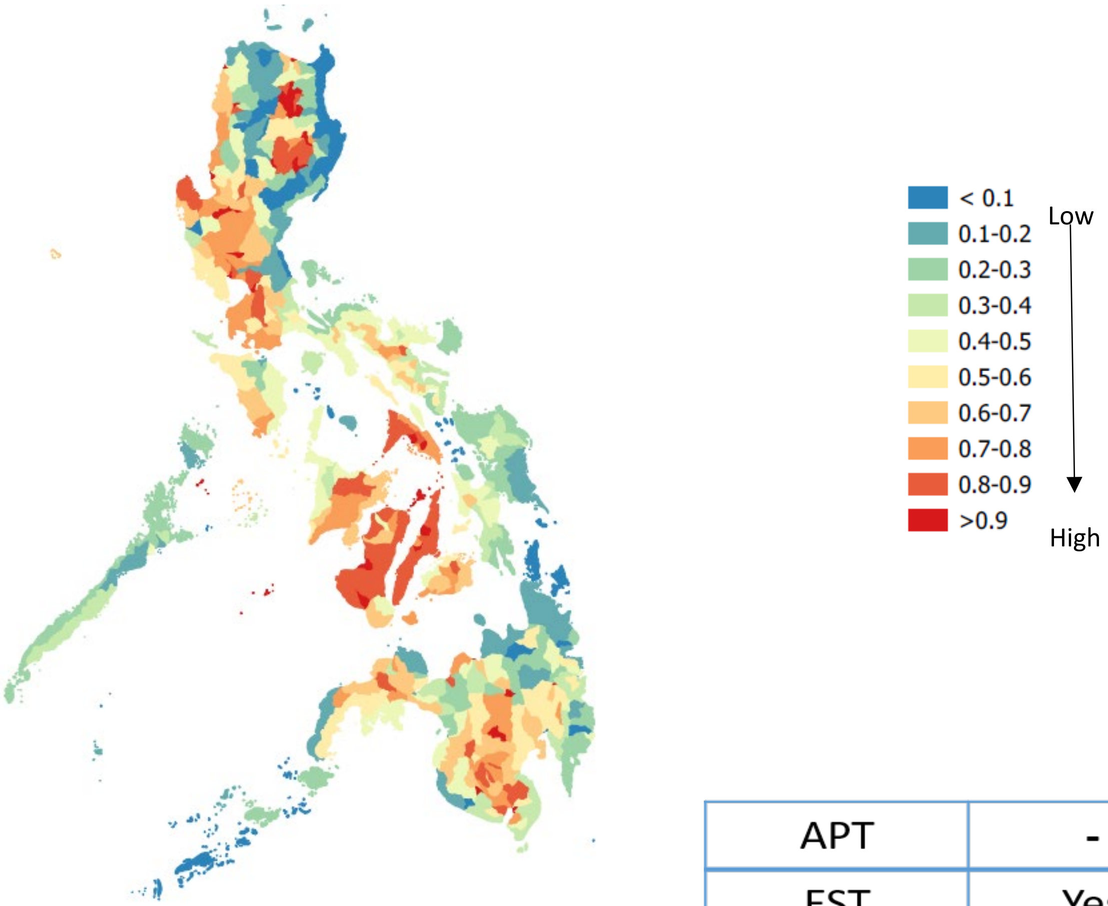
APT	-
EST	Yes

10.14Driver: Forested area

Total forested area upstream of the grid cell

Higher forested area => lower threat

Lower forested area => higher threat



APT	-
EST	Yes

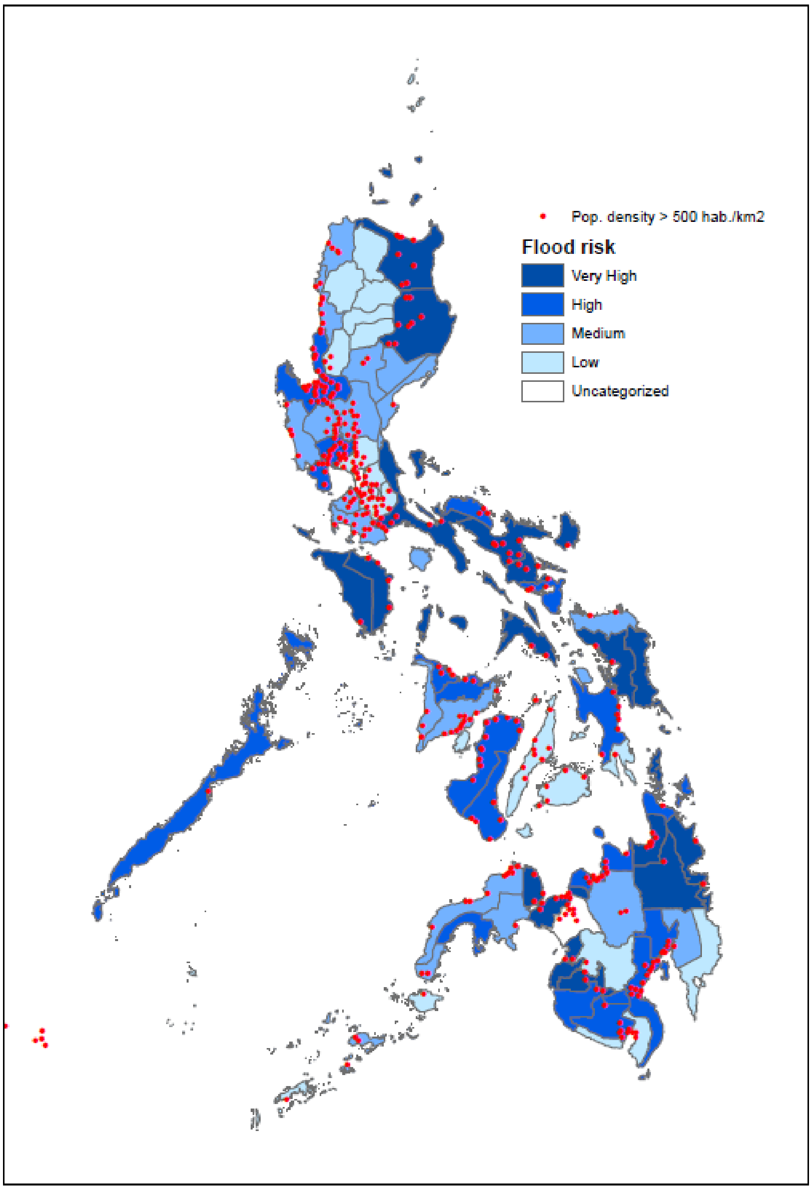
10.15 Updated Themes and drivers to be used in the calculation of Agricultural Production Threat (APT) with respective weights

Themes	Drivers	Indicator	Weights	
			Theme	Asia and Pacific
Supporting services	LULC	Cropland area	0.70	0.11
	NDVI	NDVI		0.03
	Soil Erosion (GLASOD)	Long-term annual soil erosion rates		0.14
	Groundwater	Groundwater table Depth		0.13
	Irrigated area (Blue Water)	Percentage of irrigated area by microbasin		0.15
	Water availability	Average natural discharge		0.13
	Soil moisture	Soil average water content		0.15
	Genetic Biodiversity	Genetic biodiversity		0.04
	Nitrogen cycle	Atmospheric Nitrogen		0.11
Regulatory services	CO2 (new) Atmoshperic Regulation	Daily CO2 emissions	0.30	0.24
	Temperature	Temperature - average		0.24
	Pollination	Pollen limitation of plant reproduction		0.52

10.16 Updated Themes and drivers to be used in the calculation of Ecosystem Services Threat (APT) with respective weights

Themes	Drivers	Indicator	Weights: Themes	Weights: Asia and Pacific
Non market services	**Other LULC (wetlands, forest cover)**	Forested area	0.39	0.22
	Minimum flow	Annual minimum flow		0.16
	Dam density (habitat loss)	Degree of regulation		0.16
	Wetland disconnectivity	Percentage of wetland areas within microbasin with cropland and urban LULC		0.23
	Precipitation	Annual precipitation - average		0.16
	Soil Organic Carbon	Soil organic carbon		0.06
Ecosystem Disservices	**Consumptive water loss**	Water flow divided by total population	0.60	0.18
	Crop intensity	Crop intensity		0.24
	Organic loading	Concentration of BOD, P and N (total load divided by average flow)		0.14
	Phosphorus loading			0.14
	Nitrogen loading			0.14
	Potential sediment production	Index derived from slope, LULC and runoff		0.17

11. Vulnerability to Flood Risk



12. Questionnaire for CFRA

General information

Name of the SLM Technology /Approach:

Region:

Municipality:

Town:

Number of sites:

Indicate year of implementation:

Is it still continuing? ○ Yes ○ No

If no, when did it stop?

Geo-referenced information of the sites

Location of the sites	Area	Latitude	Longitude

Spread of the Technology

○ Evenly spread over an area

○ Applied at specific points/ concentrated on a small area

The purpose(s) of the Technology

☐ Improve production (crop, fodder, wood/ fibre, water, energy)

☐ Prevent (avoid), reduce land degradation; restore/rehabilitate land (reverse land degradation) (soil, water, vegetation)

☐ Conserve ecosystem

☐ Preserve/ improve biodiversity

☐ Create beneficial economic impact

SLM group to which the Technology belongs

Assign the described Technology to one of the following SLM groups.

☐ Participatory land-use planning across sectors (e.g. forestry, fishery etc.) (PLUP)

☐ Organic agriculture practice management

☐ Rotational agriculture practice management

☐ Sustainable grazing land management

☐ Sustainable planted forest management (e.g., agroforestry)

☐ Sustainable natural forest management

☐ Smallholder irrigation management

☐ Promoting farmer innovation and participatory innovation development

☐ Integrated groundwater and surface water management

☐ Community-based natural resource management (CBNRM)

☐ Private sector investment in sustainable forest management

☐ Public sector investment in conservation agriculture (CA)

☐ Integrated plant nutrition management to enhance soil productivity

☐ National strategies and policies that strengthen resilience and adaptive capacity to natural disasters and climate-related impacts

☐ Efforts to combat desertification and land degradation at the national level

Integrated crop-livestock management (e.g., manage livestock density)

☐ Integrated approaches to improving productivity in rain-fed systems for adaptation to climate change

☐ Soil salinity management

☐ Restoration and rehabilitation of degraded land

☐ Modernizing irrigation systems (e.g. implementing drip irrigation)

☐ Use of smart Technology in agricultural production, selling, and buying of inputs

☐ Use of improved information systems for continuous monitoring of soils

☐ Conservation practices to reduce soil loss on the sloping and erosion-prone land (e.g. wind erosion and gully erosion control, cross-slope barriers)

☐ Increase efficiency of nutrient cycling and applied inputs to improve soil fertility and yield (e.g., precision agriculture, adequate and balanced use of fertilizers)

☐ Conservation agriculture with minimum soil disturbance and tillage practice

☐ Installation of buffers between cropland and water body

☐ Installation of large-scale dams and reservoirs

☐ Soil acidity control (e.g., liming)

☐ Training skilled farmers and professionals in information technology and data analytics

☐ Recycling and re-use of stormwater, wastewater and greywater

☐ Implement soil moisture conservation techniques (e.g. terracing, runoff diversion, and vegetative strips on contours)

☐ Use of improved plant varieties (high-yielding crops, seeds resistant to disease, pests, drought/scarcity/heat, salt-tolerant crops, transgenic crops, etc.)

☐ Agricultural biotechnology options

☐ Diversification of agricultural production and income

☐ Reduce the need for and optimize the use of antimicrobials in agriculture

☐ Reducing the cost of energy and promoting the use of renewable sources of energy

☐ Increasing efficiency in the value chain of agricultural products (from site selection to manufacturing processes)

☐ A macro-economic framework with reliable access to modern energy sources (e.g. electricity)

☐ A macro-economic framework with regulations and measures to ensure the proper functioning of food commodity markets and food safety

☐ Improved market information through information technology (e.g., strengthening Agricultural Market Information System)

☐ Government assistance in agriculture inputs

☐ Government assistance in agriculture outputs

☐ Strengthen the road infrastructure needed for urban-rural integrated development and agricultural connectivity

☐ Greater investment to ensure the conservation of biodiversity and genetic resources are mainstreamed in development sectors

☐ Adopt national legislation, regulations and policy frameworks to ensure fair and equitable sharing of benefits of genetic resources for food and agriculture

☐ Promote secured and formal systems of tenure and rights to land and water resources

☐ Social dialogue leading to equitable and participatory sustainable forest management

☐ Social dialogue leading to equitable and participatory sustainable land and water management

☐ Protect natural habitats and rehabilitate degraded habitats, in particular in mountains, forests, freshwater and coastal environments

☐ Strengthening international partnerships on sustainable soil, land and water management (e.g., global alliance on sustainable land and water management)

☐ Regional focus and initiatives to foster knowledge sharing, policy dialogue on regional issue

☐ Engage with the private sector in making the investments and developing the technologies and best practices needed to enhance productivity, efficiency, and sustainability in food value chains

☐ Public investments for primary agriculture product storage and processing infrastructure

☐ Strengthen the enabling environment and reform the institutional framework (e.g., national, regional)

☐ Sustainable choices such as sustainable diets with low environmental impacts

☐ Marketing consumer levels sustainable choices such as zero-km products and low water footprint (from the choice of meat to the packaging)

☐ Use of nationally appropriate social protection systems (e.g. government safety net or food security programs) to enhance the income of poor, vulnerable groups of society

☐ Improve nutrition and balanced diets addressing undernourishment and obesity

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Impacts

On-site impacts the Technology has shown

** On-site: the area to which the Technology is applied.*

** Instruction:*

- select the relevant impacts (☑ on the 1st column), several answers are possible

- for each selected impact, select one (01) out of four (04) options (◉) to specify

	Socio-economic impacts	Negative	Negligible impact	Positive	Potential impact/ Not realized yet	
	Production					
☐	crop production	○	○	○	○	
☐	crop quality	○	○	○	○	
☐	fodder production	○	○	○	○	
☐	fodder quality	○	○	○	○	
☐	animal production	○	○	○	○	
☐	wood production	○	○	○	○	
☐	forest/ woodland quality	○	○	○	○	
☐	non-wood forest production	○	○	○	○	
☐	risk of production failure	○	○	○	○	
☐	product diversity	○	○	○	○	
☐	production area (land under cultivation/ use)	○	○	○	○	
☐	land management	○	○	○	○	
☐	energy generation (e.g. hydro, biogas)	○	○	○	○	
	Water availability and quality					
☐	drinking water availability	○	○	○	○	
☐	drinking water quality	○	○	○	○	
☐	water availability for livestock	○	○	○	○	
☐	water quality for livestock	○	○	○	○	
☐	irrigation water availability	○	○	○	○	
☐	irrigation water quality	○	○	○	○	
☐	demand for irrigation water	○	○	○	○	
	Income and costs					
☐	expenses on agricultural inputs	○	○	○	○	
☐	farm income	○	○	○	○	
☐	diversity of income sources	○	○	○	○	
☐	economic disparities	○	○	○	○	
☐	workload	○	○	○	○	

	Sociocultural impacts	**Negative**	**Negligible impact**	**Positive**	**Potential impact/ Not realized yet**	
☐	food security/ self-sufficiency	○	○	○	○	
☐	health situation	○	○	○	○	
☐	land use/ water rights	○	○	○	○	
☐	cultural opportunities (spiritual, religious, aesthetic etc.)	○	○	○	○	
☐	recreational opportunities	○	○	○	○	
☐	community institutions	○	○	○	○	
☐	national institutions	○	○	○	○	
☐	SLM/ land degradation knowledge	○	○	○	○	
☐	conflict mitigation	○	○	○	○	
☐	situation of socially and economically disadvantaged groups (gender, age, status, ethnicity etc.)	○	○	○	○	
☐	***Other sociocultural impacts***					
☐	(specify): …………	○	○	○	○	
☐	(specify): …………	○	○	○	○	
	(specify): …………	○	○	○	○	

	Ecological impacts	**Negative**	**Negligible impact**	**Positive**	**Potential impact/ Not realized yet**
	Water cycle/ runoff				
☐	water quantity	○	○	○	○
☐	water quality	○	○	○	○
☐	harvesting/ collection of water (runoff, dew, snow, etc.)	○	○	○	○
☐	surface runoff	○	○	○	○
☐	water drainage	○	○	○	○
☐	groundwater table/ aquifer	○	○	○	○
☐	evaporation	○	○	○	○
	Soil				
☐	soil moisture	○	○	○	○
☐	soil cover	○	○	○	○
☐	soil loss	○	○	○	○
☐	soil accumulation	○	○	○	○

☐	soil crusting/ sealing	○	○	○	○
☐	soil compaction	○	○	○	○
☐	nutrient cycling/ recharge	○	○	○	○
☐	salinity	○	○	○	○
☐	soil organic matter/ below-ground C	○	○	○	○
☐	acidity	○	○	○	○
	Biodiversity: vegetation, animals				
☐	vegetation cover	○	○	○	○
☐	biomass/ above-ground C	○	○	○	○
☐	plant diversity	○	○	○	○
☐	invasive alien species	○	○	○	○
☐	animal diversity	○	○	○	○
☐	beneficial species (predators, earthworms, pollinators)	○	○	○	○
☐	harmful species (e.g. mosquitoes)	○	○	○	○
☐	habitat diversity	○	○	○	○
☐	pests/ diseases	○	○	○	○
	Climate and disaster risk reduction				
☐	flood impacts	○	○	○	○
☐	landslides/ debris flows	○	○	○	○
☐	drought impacts	○	○	○	○
☐	impacts of cyclones, rainstorms	○	○	○	○
☐	emission of carbon and	○	○	○	○
☐	greenhouse gases	○	○	○	○
☐	fire risk	○	○	○	○
☐	wind velocity	○	○	○	○
☐	micro-climate worsened	○	○	○	○
	Other ecological impacts				
☐	(specify): …………	○	○	○	○
☐	(specify): …………	○	○	○	○
☐	(specify): …………	○	○	○	○

Cost-benefit analysis

** Short term: 1-3 years; Long term: 10 years*

How do the benefits compare with the the total costs (from the land user's perspective)?

	negative	neutral/ balanced	positive
short-term returns:	○	○	○
long-term returns:	○	○	○

How do the benefits compare with the establishment costs (from the land user's perspective)?

	negative	neutral/ balanced	positive
short-term returns:	○	○	○
long-term returns:	○	○	○

How do the benefits compare with the maintenance/ recurrent costs (from the land user's perspective)?

	negative	neutral/ balanced	positive
short-term returns:	○	○	○
long-term returns:	○	○	○

Comments: ....

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13. List of participants in the Co-Design Workshop

List of Participants

Names	Position	Organisation
Juanito T. Batalon	Director, Agricultural Resources Management Research Division (ARMRD)	DOST-PCAARRD
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Names	Position	Organisation
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Names	Position	Organisation
	Division (LSD),	
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Names	Position	Organisation
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Names	Position	Organisation
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James Quilty	Research Program Manager Soil and Land Management Program	ACIAR
Mai Alagcan,	Country Manager, Philippines	ACIAR
Belinda Nielsen	Research Officer	ACIAR

Names	Position	Organisation
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Sayed Iftekhar	Senior Lecturer	Griffith University
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Joe McMahon	Research Fellow	Griffith University
Benjamin Vu	Research Fellow	Griffith University
Johnvie Goloran	Research Fellow	Griffith University