PRODUCTIVE LANDSCAPES (PROLAND)

PRIORITIZING INVESTMENTS IN LAND-BASED CLIMATE MITIGATION IN THE PHILIPPINES

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ACRONYMS AND ABBREVIATIONS

AFOLU	Agriculture, Forestry, and Other Land Use
AMIA	Adaptation and Mitigation Initiatives in Agriculture
AWD	Alternate Wetting and Drying
B-LEADERS	Building Low Emission Alternatives to Develop Economic Resilience and Sustainability
CAIT	Climate Access Indicators Tool
CBFM	Community-Based Forest Management
CCAFS	Climate Change for Agriculture and Food Security
CH_4	Methane
CO_2e	Carbon Dioxide equivalent
EF	Emission Factor
FAO	Food and Agriculture Organization of the United Nations
FOLU	Forestry and Other Land Use
GDP	Gross Domestic Product
GFW	Global Forest Watch
GHG	Greenhouse Gas
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
IRRI	International Rice Research Institute
MAC	Marginal Abatement Cost
Mt	Million Tons (metric)
$MtCO_2e$	Million Tons (metric) of Carbon Dioxide Equivalent
N	Nitrogen
N_2O	Nitrous Oxide
NAMA	Nationally Appropriate Mitigation Action
NDC	Nationally Determined Contributions
NTFP	Non-Timber Forest Product
PES	Payments for Ecosystem Services
ProLand	Productive Landscapes Project
REDD+	Reducing Emissions from Deforestation and Forest Degradation
SL	Sustainable Landscapes

tC/ha	Tons (metric) of Carbon per Hectare
tCO_2e	Tons (metric) of Carbon Dioxide Equivalent
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development

EXECUTIVE SUMMARY

The Philippines has a rapidly growing economy that is close to transitioning from a lower-middle income country to an upper-middle income country. This is the result of rapid economic growth of 6.3 percent per year in the period from 2010–2017 (World Bank, 2018). Gross greenhouse gas emissions, excluding emissions from forestry and other land use (FOLU), rose at a slower rate than the overall economy over a similar time period: they increased by 2.4 percent annually, from 142.8 million metric tons (Mt) carbon dioxide equivalent (CO_2e) in 2004 to 181.6 $MtCO_2e$ in 2014 (CAIT, 2019). This indicates an improvement in the carbon intensity of the economy.

The FOLU sector in the Philippines is estimated by national reporting to be a net sink of greenhouse gas emissions that in 2014 compensated for about one-third of gross national emissions. FOLU emissions of -60.3 $MtCO_2e$ (i.e., sequestration of 60.3 Mt), when added to gross national emissions of 181.6 $MtCO_2e$, reduce the national net figure to 121.3 $MtCO_2e$. The agriculture and livestock sectors contribute 53.2 $MtCO_2e$, representing 43.9 percent of national net emissions or 29.3 percent of the gross total.

OPPORTUNITIES FOR CLIMATE MITIGATION: SCALE, TIMING AND COST

The largest sectors for emissions abatement opportunity are in the FOLU sector (Table 1). Estimates from the B-LEADERS project suggest that forest protection contributes 73.2 percent of the national potential for land-based climate mitigation, while forest restoration and reforestation contribute an additional 14.5 percent. Opportunities in rice production include improving nutrient management, the promotion of alternate wetting and drying (AWD), and crop diversification. These rice-sector opportunities together represent another 10.4 percent of the potential of the emissions reduction opportunities that were assessed.

Table 1: Opportunities identified by B-LEADERS project (ranked by total mitigation potential)

Category	Opportunity	Total 2015-2050 mitigation potential ($MtCO_2e$)	Net cost ($ / tCO_2e)	Rank in cost-effectiveness
FOLU	Forest protection	1101	16.44	6
FOLU	Forest restoration, reforestation, and agroforestry	218	-29.85	1
Agriculture	Improved nutrient management (promotion of organic fertilizer)	83.9	-0.92	3
Agriculture	Crop diversification	44.9	1.62	5
Livestock	Biodigesters	29.2	-5.42	2
Agriculture	Alternate wetting and drying	28.2	0.14	4

Expectations are that investments in the rice sector in general and in AWD in particular can take place quickly: the United Nations Development Program (UNDP) is promoting a large-scale national AWD program and expects to achieve the majority of its work in the first five years following program initiation. The growth of forest plantations or trees within cropland is much slower. While sequestration starts immediately, maximum carbon storage may take up to 60 years in the case of some agroforestry systems. In the case of forest protection, the climate benefits are immediate if a forest-clearing event is prevented. However, the reliance of forest protection efforts on improved governance and capacity building mean that in practice, forest protection is likely slower than reforestation or agricultural technology changes in its ability to achieve emissions reduction.

DATA QUALITY AND UNCERTAINTY

One of the challenges with a prioritization exercise is the variability in data quality among emissions sectors. For example, emissions from rice agriculture are very well quantified which allows relatively precise estimation of emissions abatement potential from activities related to rice cultivation. In the forest sector, data tends to be of moderate quality for estimates of emissions and sequestration related to changes in forest area (i.e., deforestation and reforestation). However, regional-level estimates for carbon density are generally the basis for these estimates, meaning that variation in emissions and sequestration related to forest quality are frequently not well captured. Data on emissions from forest degradation—and by association, data on the sequestration that results from forest restoration—is often of relatively poor quality, making it difficult to make acceptable estimates of the climate impact of activities that target degradation and restoration.

In addition to the issue of data quality, there is the issue of causal uncertainty. Some interventions can be relatively easily traced from investment to greenhouse gas outcome, while others rely on indirect causal linkages which, while potentially important, are much more difficult to quantify. This is particularly true of investments in capacity building and improved governance. The B-LEADERS project based its cost estimates (Table 1) on previous and planned project investments; they include project investments in capacity building. However, it is difficult to make assumptions about the degree to which we can directly attribute emissions abatement to these project components.

GOVERNANCE-BASED INTERVENTIONS

The largest area for potential land-based climate mitigation in the Philippines is, as stated above, in preventing deforestation and forest degradation. This sector also relies more heavily than do others on the quality of governance at different administrative levels. The areas of the Philippines with the highest deforestation rates also tend to be ones with relatively poor levels of governance and less effective law enforcement (Table 10). A central component of the government's National REDD+ Strategy is to decentralize forest management further than has already been done and to expand and empower community-based forest management areas. This will further raise the importance of local governance capacity.

Two previous USAID-funded projects, Environmental Governance Phase 1 (2001–2004) and Phase 2 (2004–2011), invested in the environmental management capacity of more than 100 local government units in 21 provinces. Experience from those projects could usefully inform future investments in improved environmental governance that would be an essential part of efforts to address deforestation and other drivers of emissions in the Philippines.

SELECTING OPTIONS BASED ON DIFFERENT PRIORITIES

Table 2 summarizes six SL strategies and presents the potential scale of mitigation, cost of abatement, likely focal geographies, potential co-benefits, risks, and barriers to implementation of each of the six. In very general terms, forest conservation offers the largest potential but the most uncertainty regarding costs and timelines. It also has the largest benefits for biodiversity. Investments in the rice sector have smaller–but still large–abatement potential and may have a higher likelihood of success than forest conservation. Rice-sector opportunities are concentrated in the northern part of the country, are relatively cost-effective, and have associated benefits in water use and water quality. Livestock-sector investments likely have the smallest overall abatement potential but may offer the most cost savings to producers and offer additional benefits in water quality and health. These SL opportunities each offer distinct advantages and disadvantages; as such, choosing between them depends on the priorities of the investment being made.

Table 2: Multi-criteria assessment of SL strategies

Strategy	Average annual potential 2015-2050 ($MtCO_2e$)	Cost per unit abatement $\$/tCO_2e$	Likely regions of geographic focus (in approximate order)	Associated co-benefits	Potential Risks	Barriers to implementation
Forest protection	1101	16.44	• Palawan • Cagayan Valley • Caraga • Davao	• Very high biodiversity values in the Philippines that will be positively impacted by forest conservation. • Reduced risk of landslides, erosion, and flooding. • Increased availability of NTFPs. • Improved consistency in surface water flows.	• Wildfire is difficult to predict and can rapidly reduce carbon stores in areas affected; firefighting capacity is apparently low. • Danger faced by forest conservation activists may risk safety of project partners.	• Population movement and limited land availability leave households with few options apart from forest clearing. • Opportunity cost relative to high value commodities such as oil palm. • Historic logging efforts established infrastructure and population centres that remain in forested areas. • Limited law enforcement capacity. • Danger faced by forest conservation activists may reduce participation.
Forest restoration, reforestation, and agroforestry	218	-29.85	• Cagayan Valley • Davao	• Increased availability of fuelwood and NTFPs, particularly in areas with low current forest cover. • Hillslope stability; reduced landslides and erosion. • Positive impact on biodiversity. • Improved consistency in surface water flows.	• Lack of clarity around timber harvesting permits and regulations leading to groups or individuals investing in reforestation and being unable to recoup planned revenue. • Markets for timber species can change given long return time to investments.	• Up-front investment costs and long return time to returns (either in case of fruit crop, NTFP, or timber). • Lack of legal clarity around tenure and rights of CBFM groups may limit potential. • Competition with high-value agricultural commodities.

Strategy	Average annual potential 2015-2050 ($MtCO_2e$)	Cost per unit abate-ment $\$/tCO_2e$	Likely regions of geographic focus (in approximate order)	Associated co-benefits	Potential Risks	Barriers to implementation
Improved nutrient management	83.9	-0.92	• Central Luzon • Ilocos • Cagayan Valley • Western Visayas	• Reduction in fertilizer use reduces runoff and improves surface water quality. • Improves soil health. • Organic fertilizers less susceptible to price swings and can reduce risk of economic shock for farmers.	• Risk of yield reduction, particularly when practices are newly-adopted and farmers are less experienced.	• Involvement of multiple techniques entails significant requirements for technical assistance.
Crop diversification	44.9	1.62	• Central Luzon • Ilocos • Cagayan Valley • Western Visayas	• Can reduce pest loads by breaking pest life cycles. • Reduction in fertilizer and pesticide requirements improves surface water quality. • Improves soil health.	• Reduced farm income risks harming livelihoods if compensation is insufficient.	• Will lead to reduced revenue by farmers that will only be partly compensated for by reduced fertilizer costs. • Traditional agricultural practices are well-established and may be difficult to change.
Alternate wetting and drying	28.2 *based on modest area assumptions – another study suggests max potential of 119	0.14	• Central Luzon • Ilocos • Cagayan Valley • Western Visayas	• Cost savings for farmers. • Reduces overall water use.	• Increased emissions of N_2O could offset CH_4 reductions if fertilizer use is excessive or inappropriately timed.	• AWD is a divergence from well-established traditional rice production methods. • Reduced revenue from irrigation fees (due to reduced water use) could potentially lead to resistance from governing bodies of irrigation networks.

Strategy	Average annual potential 2015-2050 ($MtCO_2e$)	Cost per unit abatement $\$/tCO_2e$	Likely regions of geographic focus (in approximate order)	Associated co-benefits	Potential Risks	Barriers to implementation
Biodigesters	29.2	-5.42	• Central Luzon • Western Visayas	• Reduced runoff into surface water sources. • Health benefits from cleaner fuel; potential positive impact on gender equity.	• Up-front investment with slow repayment may be a risk for financially insecure households. • Lack of capacity to maintain biodigesters could lead to units ceasing to function before investment recovered.	• Up-front investment of $500-$1000 per household; financing likely important.
Improved livestock management	Maximum potential estimated to be ~20-30% reduction in livestock sector.	Estimate not available, but should provide cost savings to producer	• Central Luzon • Western Visayas	• Cost savings for farmers. • Improved soil health. • Reduced runoff into surface water sources.	• Improved forage systems require more labor inputs which can be a risk for producers; these increased inputs should be offset by improved returns but represent an up-front investment.	• Requires high level of technical assistance. • Up-front investment in transitioning forage type and in equipment.

1.0 INTRODUCTION

The purpose of the ProLand project is to provide assistance to USAID to catalyze change in land management systems so that people and institutions in developing countries can make informed, actionable, and effective development decisions. One of the tasks under the ProLand project is to provide tools and evidence in support of decision-making. As part of that task, a need was identified to develop a prioritization framework for USAID's sustainable landscapes programs that would assist USAID missions in selecting an optimal set of program opportunities for emissions mitigation and associated social and economic benefits.

A set of national case studies will provide support to decision-making for sustainable landscapes programming in the study countries and develop a broader framework for prioritization of sustainable landscape activities. This report on the Philippines is the second of those case studies. In addition to contributing to a broader learning process regarding activity prioritization, the report's specific goal is to identify and prioritize greenhouse gas emissions mitigation and sequestration enhancement activities in the agriculture, forestry, and other land uses (AFOLU) sector in the Philippines.

1.1. METHODOLOGY

The three phases of our study were: (1) to characterize emissions and sequestration in the AFOLU sector in the Philippines in order to understand which subsectors were most dominant in total contribution and in rate of change; (2) to identify a comprehensive suite of options for reducing those emissions; and (3) to prioritize among those actions and identify areas of synergy among them. For the first task, we assessed the overall emissions profile in the AFOLU sector using data from World Resources Institute, the Food and Agriculture Organization, and the Government of the Philippines. Where we identified discrepancies among data sources, we have noted those in the report and explained our decision to use a particular source.

In order to identify a suite of options to evaluate, we began with two overarching sources, one at a global scale (Griscom et al., 2017), and one Philippines-focused source developed by the B-LEADERS project (IRG, 2015). Each of these sources identified AFOLU-sector mitigation and sequestration opportunities, which provided the starting framework for our analysis. We cross-checked the identified options against primary emissions sectors to determine if the identified actions under-addressed any sectors. We also turned to the National REDD+ Strategy for further specification of climate mitigation options in the forests and other land uses (FOLU) sector, as the B-LEADERS study provided limited detail in this area. Following the identification of opportunities, we evaluated each one according to a consistent set of criteria as described below.

1.2. PRIORITIZATION APPROACH

Our approach to prioritization was to evaluate a given activity with respect to four fundamental components:

1. Magnitude of potential emissions reduction or sequestration enhancement;
2. Likelihood of success;
3. Cost per unit of emissions reduction / sequestration;
4. Non-greenhouse gas (GHG) effects of the activity

The activity sectors proposed by the Government of the Philippines in order to reach its national GHG reduction commitments have been assessed in terms of the magnitude of their potential emissions mitigation or sequestration, the expected costs to land users of each activity sector, and the cost per unit of mitigation or sequestration. We refer to these estimates throughout the report but also supplement them with alternate sources. For each identified activity, we also present an assessment of any potential barriers to implementation that would affect the likelihood of success as well as any additional benefits or harms that may result from the activity that would need to be considered.

In addition to examining activities individually, we considered synergies among activities based on complementarity of activity type and in terms of geographic overlap. In the Conclusion, we discuss sets of activities where synergies among the activities or geographic proximity may be advantageous.

1.3. COST ASSESSMENT

We have included cost assessments for all of the climate mitigation opportunities considered in this report, and we have attempted to ensure that these assessments are comprehensive and consistent. Our most important single source of cost data was the B-LEADERS project (IRG, 2015); however, we have further supplemented the B-LEADERS estimates with data from other projects where possible.

Estimates from the B-LEADERS project are generally comprehensive, although we must note some important caveats. In the cases of forest protection, reforestation, and alternate wetting and drying—opportunities that by the project's estimate represent more than 90 percent of the total mitigation potential—costs included are comprehensive and include project implementation costs, capacity building programing, direct costs to landholders, opportunity costs, and other associated costs. However, in the case of the other three (smaller) opportunities examined—organic fertilizer, biodigesters, and crop diversification—only costs to landholders and opportunity costs are included; project implementation costs or costs for capacity building are lacking. For this reason, we consider costs in those categories to be underestimates.

1.4. DOCUMENT STRUCTURE

The following section (Section 2) of the document contains a summary of AFOLU emissions in the Philippines, highlighting rates of change and the largest subsectors by total emissions and by mitigation potential. Section 3 provides details on the land-based climate mitigation options that have been propsed in the Philippines in the land-use and agriculture sectors. Section 4 provides information on likely areas of geographic focus of the opportunities, and Section 5 summarizes and concludes.

1.5. NOTES FOR USERS

There is no single best way to prioritize Sustainable Landscapes investments. Prioritization exercises will differ depending on the specific goals of the decision-makers undertaking the exercise. Some questions that may help frame how best to approach prioritization are:

- Is the goal of the program to maximize climate mitigation for a given level of investment? Should the program also prioritize other goals, such as livelihood benefits or biodiversity conservation?
- Are there specific geographies that a program should target or avoid, for reasons of feasibility or for reasons of compatibility with other programs?
- Are there other existing or planned investments that an SL program should be designed to complement?

The goals of the present report are to familiarize the reader with possible SL interventions in the Philippines; to evaluate each of those potential interventions according to criteria that include cost, co-benefits, and practical feasibility; identify areas of geographic focus; and identify gaps and limitations in the existing data.

2.0 OVERVIEW OF EMISSIONS SECTORS AND MITIGATION OPPORTUNITIES

The Philippines, in the process of transitioning from a lower-middle-income country to an upper-middle-income country, has a rapidly growing economy. This is the result of economic growth of 6.3 percent per year in the period from 2010–2017 (World Bank, 2018). Gross greenhouse gas emissions in the Philippines, excluding emissions from forests and other land use (FOLU), rose at a slower rate than the overall economy over a similar time period, indicating an improvement in the carbon intensity of the economy. Gross emissions, excluding FOLU, increased by 2.4 percent annually, from 142.8 million metric tons (Mt) carbon dioxide equivalent (CO_2e) in 2004 to 181.6 $MtCO_2e$ in 2014 (CAIT, 2019).

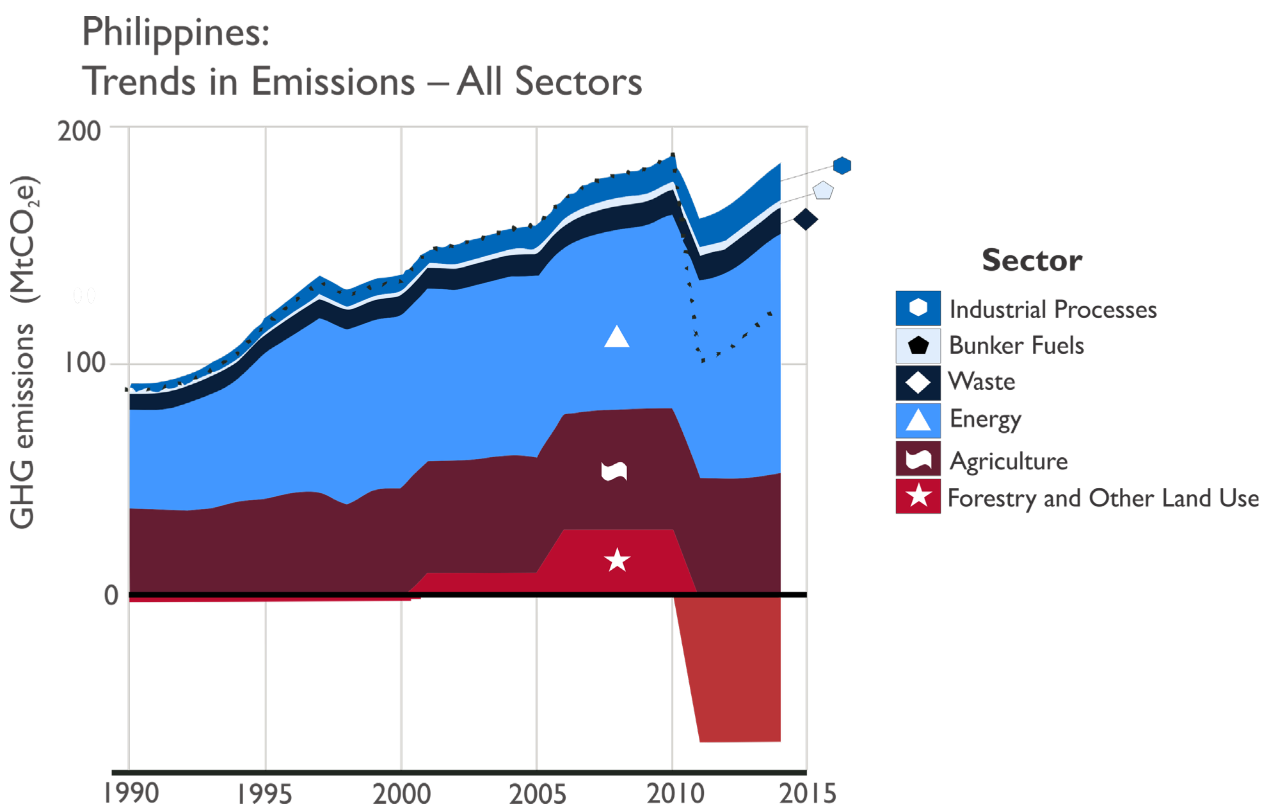

Figure 1: Trends in emissions in the Philippines; all sectors included. The sharp drop between 2010 and 2011 resulted from a change in the forest inventory, specifically in the accounting of plantations and of open-canopy forests. The more recent values include sequestration in commercial plantations, while earlier values do not.

2.1. EMISSIONS BREAKDOWN BY SECTOR

The largest sector of emissions in the Philippines is energy, representing 56 percent of total gross emissions in 2014. The agriculture sector was 29 percent of gross emissions in 2014, down slightly from 2012 percent in the plot below because of a very rapid increase (18 percent) in energy emissions in those two years (Figure 1). The recent rapid increase in the energy sector results in part from the current government's prioritizing of household electrification (77 percent of households electrified in 2012, while the goal was 90 percent by 2017). The share of energy generation from oil decreased by 66 percent from 1990–2012 while the share from coal increased from 7 percent to 39 percent of the total (USAID, 2016).

In the agriculture, forestry, and other land use sector (AFOLU), the largest source of well-documented AFOLU emissions is rice cultivation, particularly from CH_4 (Figure 2; Table 3). Rice cultivation was also the largest source of increase in AFOLU emissions from the 2002–2007 period to the 2012–2017 period. Enteric fermentation from livestock was the second-largest emitter on average in the 2012–2017 period; however those emissions declined between 2002–2007 and 2012–2017. Fertilizer use was the third-largest source of emissions in 2012–2017 and was the second-largest source of increase in AFOLU emissions between 2002–2007 and 2012–2017 (Table 3).

Table 3. Annual emissions in the AFOLU subsectors, 1000s of tons CO_2e. Ranking of total emissions and of rates of change is indicated by shading in the three right-most columns. Food and Agriculture Organization of the United Nations (FAO), 2019.

Sub-sector	Average 2002–2007	Average 2007–2012	Average 2012–2017	Rank of 2012–2017 emissions	Rank of absolute increase 2002–07 to 2012–17	Rank of relative increase 2002–07 to 2012–17
Ag: Rice Cultivation	28,679	31,133	32,864	1	1	2
Ag: Enteric Fermentation	7,246	7,117	6,556	2	7	6
Ag: Synthetic Fertilizers	3,442	3,177	3,708	3	2	4
Ag: Manure Management	3,492	3,643	3,362	4	6	5
Ag: Burning - Crop residues	389	416	424	5	4	3
FOLU: Burning Biomass	234	269	346	6	3	1
Ag: Burning - Savanna	30	25	20	7	5	7
FOLU: Forest land	14,931	11,513	-60,353	8	8	8

Philippines reports net sequestration in the FOLU sector, although this result shifted dramatically between their first national communication (1999, with inventory of 1994) and their second and most recent national communication (2011, with inventory of 2000). This shift was largely a result of methodological changes rather than true changes in inventory. In the first communication, net FOLU emissions were very slightly negative, with forest conversion nearly balancing regrowth. The second communication estimated land-cover change to represent net sequestration. The change resulted largely from a change in the accounting of plantations and of open-canopy forests, with the inclusion of forest plantations in the later inventory leading to an apparent increase in forest sequestration. As of 2011, no accuracy assessment of either of the forest inventory efforts had been completed, thus providing no clear way to evaluate data quality in either inventory (Agoncillo et al., 2011).

Despite the inconsistency in inventories, the fact that the Philippines has large areas of net gain of forest is not disputed; the FAO's 2015 Global Forest Resources Assessment (FAO, 2016) identifies the Philippines as the country with the fifth-largest total area of forest expansion from 2010–2015, after China, Australia, Chile, and the USA. The Philippines also had a faster rate of forest expansion relative to total forest extent (3.3 percent) than any of the other countries in the top ten for areal increase (FAO, 2016). This expansion of forest cover results in significant carbon sequestration, and national-scale reporting from the Philippines suggests that the FOLU sector has significant net sequestration overall.

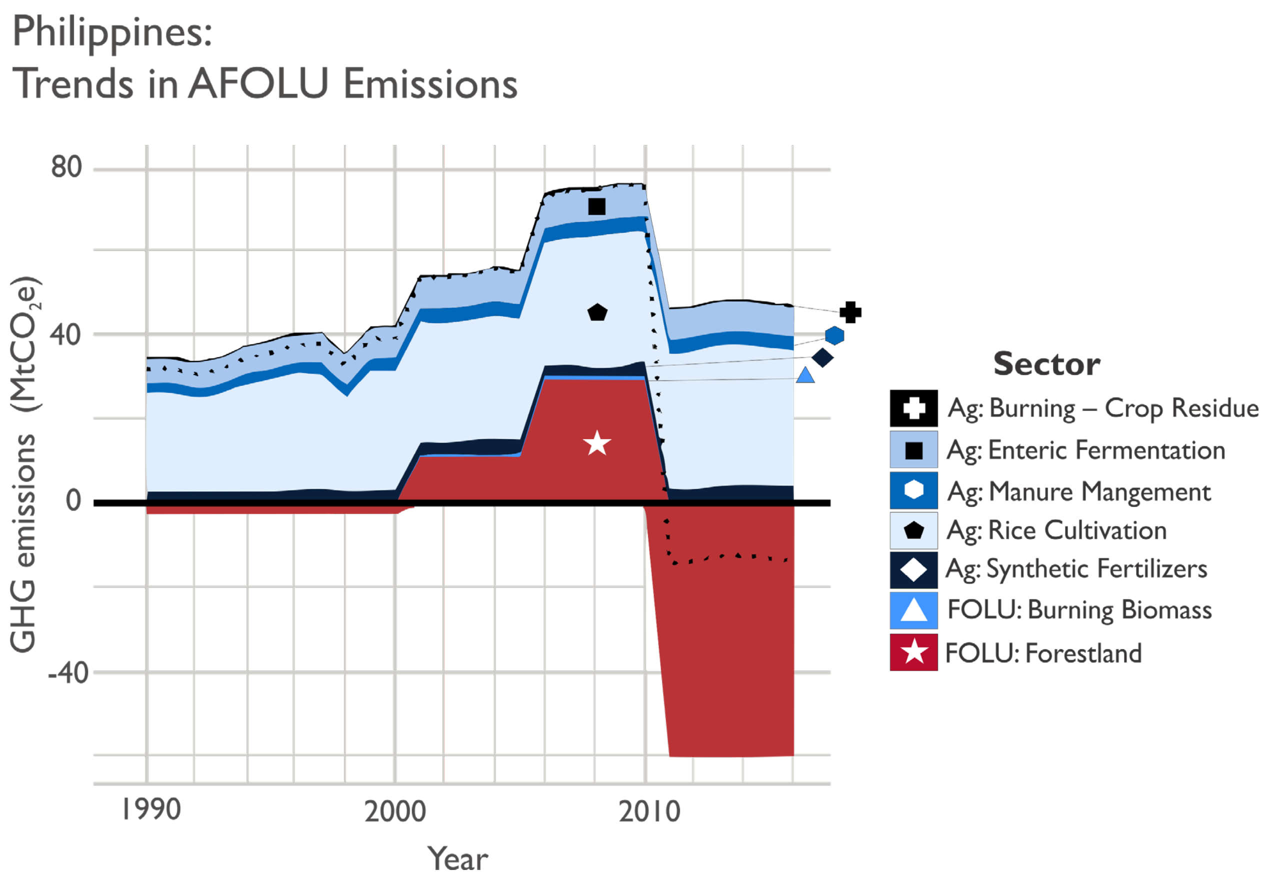

Figure 2: Trends in AFOLU emissions in the Philippines. The sharp drop between 2010 and 2011 resulted from a change in the forest inventory, specifically in the accounting of plantations and of open-canopy forests. The more recent values include sequestration in commercial plantations, while earlier values do not.

Net carbon flux in the FOLU sector represents the sum of emissions resulting from the loss of carbon in land cover (with forest loss being the largest contributor), and of sequestration resulting from the gain of carbon in land cover (with forest growth or expansion of forest area being the largest contributors). In the Philippines, the high rates of forest expansion and associated carbon sequestration have the effect of masking significant (but poorly quantified) emissions from forest conversion. Despite the net sequestration in the sector overall, there remain significant climate mitigation opportunities in the FOLU sector. Lasco and Pulhin (2000) state that in 1999–2000, forest land sequestered 30.5 Mt carbon per year (equivalent to 112 $MtCO_2e$), while releasing 11.4 Mt carbon (41.8 $MtCO_2e$) per year because of deforestation and harvesting. Global Forest Watch estimates that between 2001 and 2017, tree cover loss resulted in an average of 25.3 $MtCO_2e$.

2.2. MITIGATION OPPORTUNITIES IN THE AFOLU SECTOR

Griscom et al. (2017) described 20 pathways of land-based opportunities for climate mitigation (referred to as "natural climate solutions" by that study), estimated global potentials for all 20 of the pathways, and provided national-scale estimates for ten of those pathways. Those estimates were constrained by safeguards preventing negative impacts on food, fiber, or biodiversity—in particular by assuring that cropland area was not reduced and by ensuring that forest establishment would not take place in areas where forests were not the original ecosystem. The 20 pathways are described in full in Table A1 in the Appendix. The ten pathways for which national-scale data was available represented more than 75 percent of the global total potential of the 20. That analysis suggested that those ten pathways for land-based mitigation can generate nearly double the emissions reductions and enhanced sequestration required to meet the Philippines NDC reduction target of 70 percent reduction below business as usual (estimated to represent a reduction of 84 $MtCO_2e$ annually). Cost-effective opportunities—defined as those opportunities that have a better-than-positive net present value when the social cost of carbon is set to $100 per ton in 2030—can supply 77 percent of the national NDC target. Of those cost-effective opportunities, reforestation and avoided forest conversion together represent 82 percent of the potential of the ten pathways for which national-scale data was available (Figure 3).

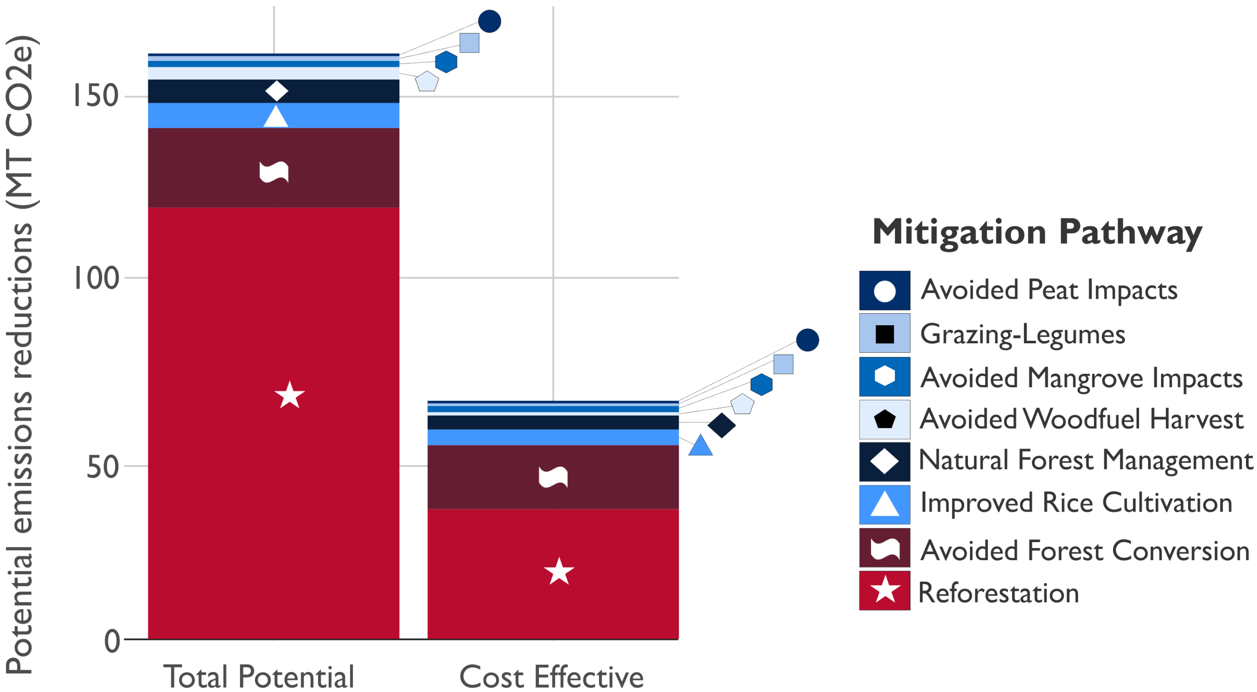

Figure 3: Potential for AFOLU-sector climate mitigation options in the Philippines (providing for safeguards for biodiversity and for food and fiber supply) as identified by Griscom et al. (2017). Stacked bars on the left represent the total potential for emissions reduction or sequestration, given safeguards, while bars on the right represent the potential that is cost effective at an assumed social cost of carbon of $100 in 2030.

An updated version of the Griscom et al. (2017) analysis includes updated data and information on additional pathways at national scale (Griscom et al., 2020). The most significant changes between the two studies are that estimates for reforestation potential are much more conservative in the updated study and that estimates have been made for more pathways. Between the two studies, country-specific estimates for cost-effective potential are provided for 14 pathways while estimates for maximum potential—while respecting safeguards—are provided for 13 pathways (maximum potential for the reforestation pathway is not estimated in the updated data). One of the 14 pathways (improved fire management in savannas) is not relevant for the Philippines; Figure 4 displays the cost-effective potential for the remaining 13 pathways based on the updated estimates. The ordering of the three pathways of the largest potential remains the same: reforestation, avoided forest conversion, and improved rice cultivation. However, data for the trees in agriculture pathway was newly estimated in the updated paper and is estimated to be the fourth-largest pathway in the Philippines. Additionally, although reforestation remains the largest single pathway in the country, its estimated potential is lower in the new data such that the difference between reforestation and avoided forest conversion potentials is very small in the updated data (Figure 4).

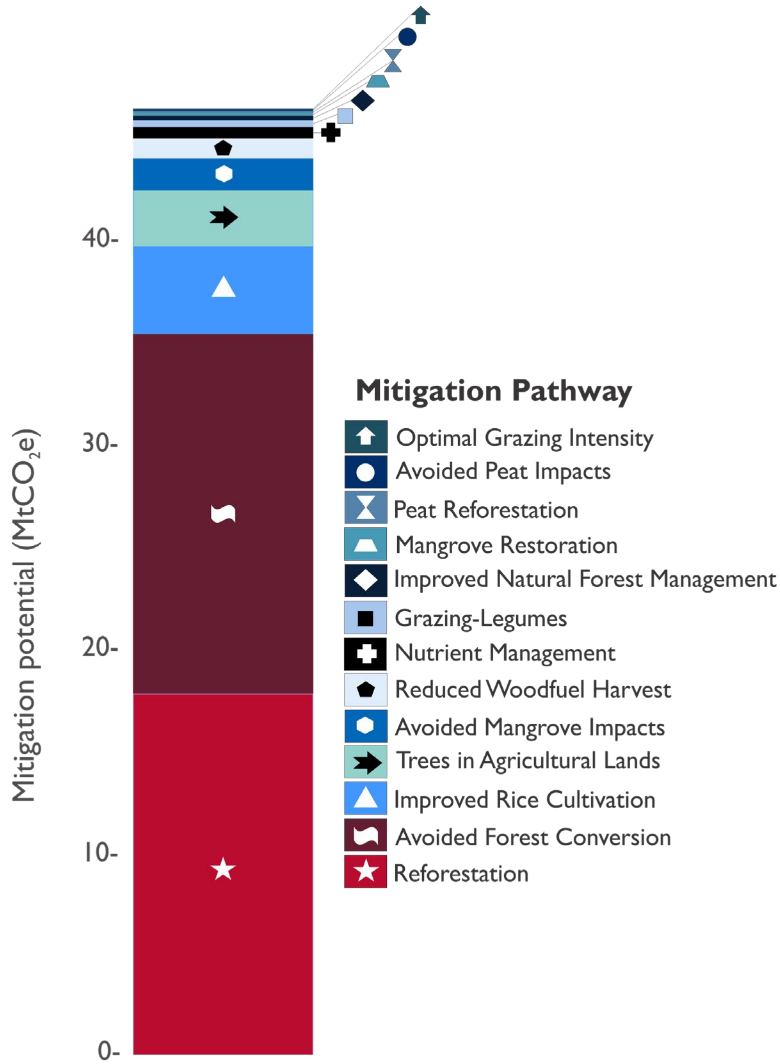

Figure 4: Updated cost-effective potential, providing for safeguards, for 14 of 20 land-based climate mitigation pathways based on Griscom et al. 2020.

The Griscom et al. (2017; 2020) studies are useful as they provide a consistent and comparable overview of mitigation opportunities that has been designed to be comprehensive. However, being global studies, they do not provide context that is specific to the Philippines. National-scale studies can fill this gap; however, national studies in some cases are not as comprehensive in their assessment of options. A paired approach using both global and national studies is likely the best approach.

The Philippines' INDC states that "Reduction of CO2e emissions will come from energy, transport, waste, forestry and industry sectors" (Government of the Philippines, 2015, p.3). It is noteworthy that the INDC does not identify any opportunities in the agriculture sector, although other sources identify significant opportunities for climate change mitigation in the agriculture sector in the Philippines. In particular, the UNDP is promoting a large-scale project to promote alternate wetting and drying (AWD) in the rice sector nationwide (Arnaoudov et al., 2015). To date, there have not been any Philippines-linked NAMAs registered with the UNFCCC (UNFCCC, 2019).

A USAID-funded project, Building Low Emission Alternatives to Develop Economic Resilience and Sustainability (B-LEADERS), identified opportunities for emissions reduction and sequestration enhancement across all emissions sectors in the Philippines and calculated estimates for total potential and cost per unit of each opportunity. In the AFOLU sector, the B-LEADERS project identified six categories of opportunity (IRG, 2015). We summarize these below in Figure 5 and Table 4. The scale of total mitigation potential is generally consistent with the Griscom et al. assessments (2017; 2020). Those two studies taken together estimate that 76.2 percent of the cost-effective potential for land-based climate mitigation in the Philippines comes from avoided forest conversion and reforestation, while the B-LEADERS project put that percentage at 87.6 percent (IRG, 2015). The two sources are also in general concordance that the third most important area of opportunity is in the rice sector. B-LEADERS estimates that rice represents 7.4 percent of the mitigation potential in the AFOLU sector (60.2 percent of the agriculture and livestock sectors) for the period 2015–2050. Griscom et al. (2017) estimates that rice cultivation represents 6.6 percent of the cost-effective mitigation opportunity.

Table 4: Opportunities identified by B-LEADERS project (ranked by total mitigation potential)

Category	Opportunity	Total 2015–2050 mitigation potential (MtCO2e)	Net cost ($ / tCO2e)	Rank in cost-effectiveness (and ID key for Figure 5)
FOLU	Forest protection	1101	16.44	6
FOLU	Forest restoration, reforestation, and agroforestry	218	-29.85	1
Agriculture	Nutrient management (promotion of organic fertilizer)	83.9	-0.92	3
Agriculture	Crop diversification	44.9	1.62	5
Livestock	Biodigesters	29.2	-5.42	2
Agriculture	Alternate wetting and drying	28.2	0.14	4

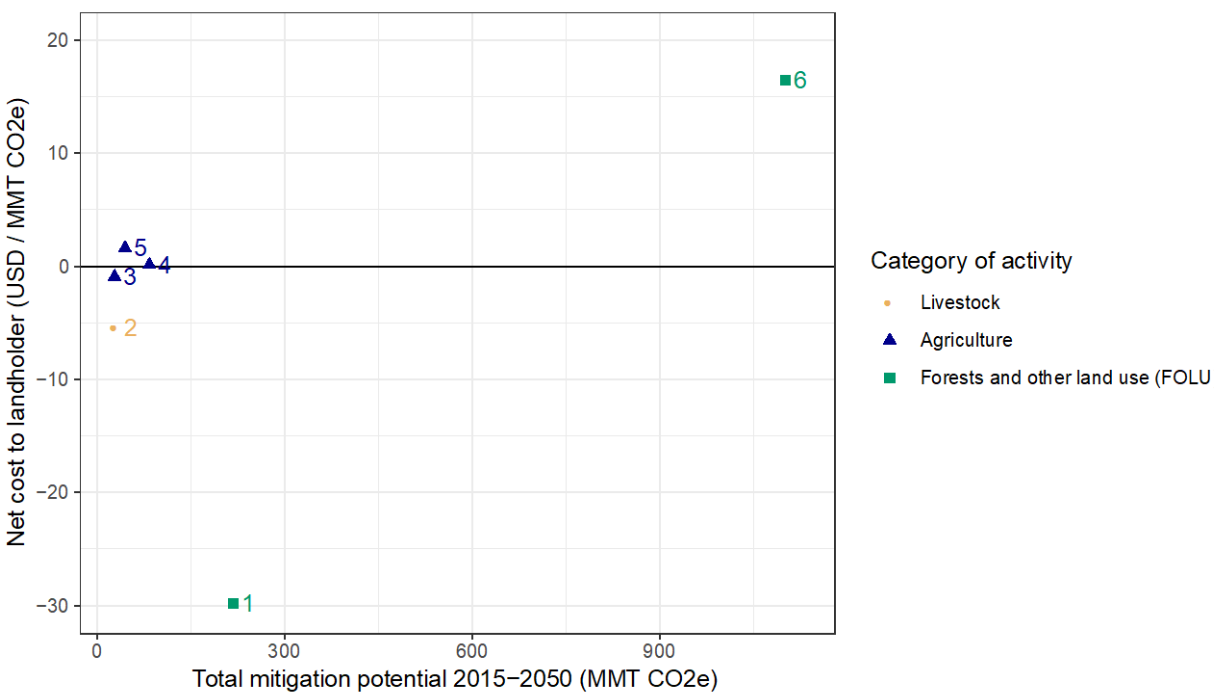

Figure 5: Opportunities for mitigation in the AFOLU sector identified by the B-LEADERS project. Numeric codes are the rank by cost-effectiveness and can be used with Table 4 as a key to the opportunities shown in this chart.

3.0 EMISSIONS ABATEMENT STRATEGIES

3.1. FORESTS AND OTHER (NON-AGRICULTURAL) LAND USE

The largest opportunities for land-based climate change mitigation in the Philippines are in the forests and other land use (FOLU) sector. On this point, the Philippine-specific analysis by the B-LEADERS project (IRG, 2015) and the Philippine component of the two Griscom et al. studies (2017; 2020) are consistent, with the former estimating that FOLU options represented 87.6 percent of the total mitigation potential of all assessed options while the latter estimated 82.8 percent.

The B-LEADERS assessment (IRG, 2015) estimates that protection of existing forests can provide 73.2 percent of the total AFOLU abatement potential from 2015-2050 while forest restoration and rehabilitee can provide 14.5 percent. That assessment does not provide a quantitative assessment of component strategies under these two broad categories of actions, nor does it provide in-depth detail on potential strategies. The National REDD+ Strategy (Philippine REDD+ Strategy Team 2010), however, provides more specificity regarding FOLU-sector emissions abatement that are either existing or proposed in the Philippines. Specifically, the actions identified are to

- Intensify forest protection, specifically through expanded investment in firefighting and forest law enforcement.
- Promote reforestation, assisted natural regeneration, mangrove rehabilitation, and agroforestry expansion.
- Strengthen community forest governance.

3.1.1. Forest Protection

MITIGATION POTENTIAL

National reporting in the Philippines shows net sequestration in the FOLU sector. However, this net figure includes both significant sequestration from forest growth and conversion of agriculture to forest as well as significant emissions from forest degradation and conversion of forest to agriculture, plantations, or other uses. Global Forest Watch estimates that 114,000 hectares of forest were lost in the Philippines between 2001 and 2017, representing an average of 25.3 $MtCO_2e$ of greenhouse gas emissions annually (GFW, 2019). This estimate is nearly as large as the national emissions from the entire rice sector (32.8 $MtCO_2e$ annually in the 2012-2017 period), despite being obscured by the expansion of plantations in national emissions accounting.

The original forest in the Philippines is some of the most carbon-dense globally. IPCC tier 1 estimates (i.e. global classifications without national ground-truthing) are that tropical rainforests in the Philippines have carbon density of 225 tons of carbon per hectare (tC/ha) while tropical moist deciduous forests and tropical mountain forests have densities of 169 tC/ha and 122 tC/ha, respectively (Figure 6; Reusch and Gibbs, 2008). Country-specific estimates are higher–for the highest-density primary forests, national plot measurements have found values for aboveground carbon as high as 518 tC/ha (Lasco and Pulhin 2009). Nationally-specific studies estimate that about 50 percent of the carbon found in primary forests is emitted when those forests are logged and left as forests in a degraded state (Lasco and Pulhin, 2000; 2009). Conversion to agriculture results in the emission of the majority of the carbon stored in forests as lands with annual crops have very little aboveground carbon: croplands in the Philippines contain between 3.1 and 12.5 tC/ha where rice has the lowest carbon density, sugarcane the highest (of annual crops), and other crops intermediate between those two (Lasco and Pulhin, 2009).

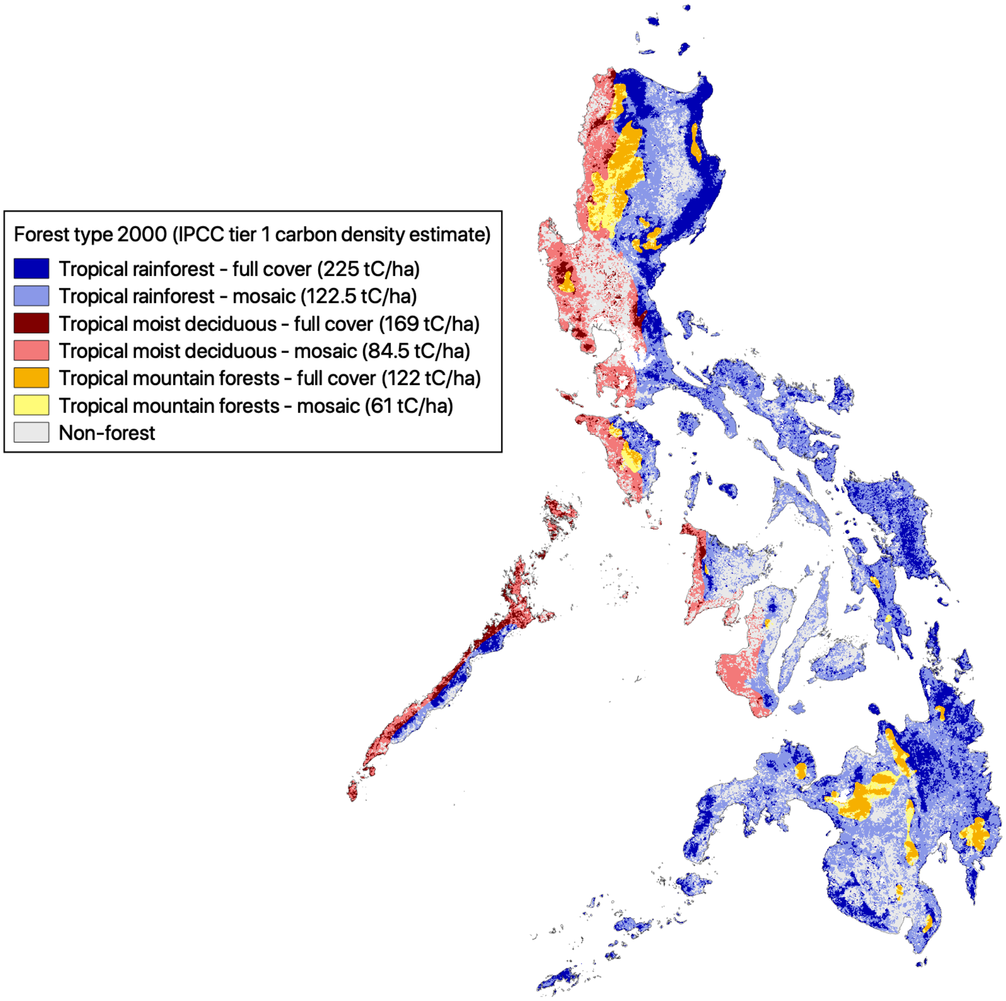

Figure 6: Tier 1 estimates of forest type and carbon density in the Philippines (data from Reusch and Gibbs, 2008).

COST ESTIMATES

Estimating cost per unit of abatement in forest conservation is particularly difficult because estimates for emissions avoided are made relative to a hypothetical future event that was avoided rather than for an activity that was directly implemented. In addition, investments that target the underlying drivers of deforestation, although critical for success, have complex and often indirect effects on emissions that are difficult to assess quantitatively.

The B-LEADERS project in the Philippines (IRG, 2015) estimated that forest protection would cost $16.44 USD per ton CO_2e of emissions mitigated. This includes both direct costs and indirect costs, with indirect costs being nearly double the direct costs (84 percent larger). The direct costs are based on two cost components: opportunity costs and program implementation costs. Opportunity costs were the lost revenues associated with activities that would be displaced by forest protection, particularly from the reduction in timber harvest and from reduction of shifting cultivation and other agricultural practices. Implementation costs include the cost of agency staff enforcing forest policy and conducting monitory, technical assistance, and other costs related to monitoring, reporting, and enforcement.

The indirect costs, which are nearly two-thirds of the total cost of forest protection, result from the reduction in the availability of fuel wood–the primary fuel used for cooking in the Philippines–and the associated cost in increased purchases of fossil fuels or electricity for cooking (IRG, 2015). Of note, the forest restoration and reforestation option evaluated by the B-LEADERS project increased the availability of fuelwood and so represented savings in fuel costs; however, the savings in fuel costs from the reforestation and restoration option were only 10 percent to15 percent of the magnitude of the additional fuel costs from the forest protection option (IRG, 2015).

The overall cost of $16.44 per ton for forest protection is within the range of regional estimates for the costs of REDD+ projects in Southeast Asia. An analysis of 57 REDD+ projects in the region, including two in the Philippines (both on the northern part of Luzon), found costs that ranged from $9 to $75 per ton CO_2e abated (Graham et al., 2016). Generally, the highest-cost projects are those that involved buying land that was slated for oil palm development, and neither of the Philippines projects included that option, so it is likely that their costs were lower. The two Philippines projects included reforestation and investment in protected areas, activities that had regional-average costs of $9.0 and $13.4 per t$CO_2$e, respectively.

Previous efforts to protect forest in the Philippines have included the establishment of payments for ecosystem services (PES) systems, efforts to modernize forest policy, expansion of community rights to manage forests, and investments in forest law enforcement (Lasco et al., 2013). A PES project implemented by the USAID-funded EcoGov 2 project established a watershed-based PES program that was estimated to avoid the release by deforestation of 31,147 tons CO_2e per year with through an annual investment of $22,727. This represents an investment of only $1.37 per ton (Chemonix, 2011).

An important caveat regarding estimates of the cost of reducing deforestation is that there are some cost components that estimates generally exclude, and these omissions are likely to be relatively larger in the case of avoiding deforestation than in the case of other strategies. As mentioned above, the B-LEADERS project estimated direct management costs, opportunity costs, and effects on fuel consumption. The Graham et al. (2016) regional study, in a similar vein, estimated opportunity costs, management costs, and transaction costs. The cost of addressing underlying drivers, and in particular efforts to address governance challenges are essential to success in limiting forest loss; however, they are difficult to translate into costs-per-emissions-abatement values. As an example, for an investment that focused on the modernization of the national forest policy, the reported investment per estimated ton of CO_2e emissions avoidance would equate to more than $9600 (Chemonix, 2011). This number is orders of magnitude higher than estimates for other strategies; however, it should not be taken to suggest that investments in policy modernization are not effective SL investments, but simply as an indication of the difficulty of establishing direct causal connections between governance-linked investments and emissions abatement.

BARRIERS TO IMPLEMENTATION

The underlying drivers of deforestation in the Philippines are in many cases linked to processes remote from forested areas themselves. Population movement into upland forested areas, infrastructure and population legacies of historic logging, a policy and market environment that is unfavorable to community-based forest management, and ineffectiveness or corruption within enforcement agencies are all complex and systematic issues that play important roles in Philippine forest loss.

An analysis of four deforestation "hot spots" in upland forests ranked the drivers of deforestation as follows (Carandang et al., 2013):

Ranking of direct drivers of deforestation:

1. Kaingin making (shifting cultivation or "slash-and-burn" agriculture)

2. Mining (very high impact, but affects a limited number of sites)
3. Conversion to oil palm and rubber plantations
4. Settlement
5. Forest fire

Ranking of direct drivers of degradation:

1. Logging
2. Natural disasters
3. Timber poaching
4. Charcoal making
5. Fuelwood collection

The pressure on upland forests caused by shifting cultivation results to a great extent from large-scale conversion of lowland agricultural land to residential, commercial, and industrial uses (Sheeran, 2006). Loss of land in the lowlands, in turn, displaces farmers to the uplands and increases pressure on upland forests through increased intensity of shifting cultivation and small-scale permanent cultivation. In the case of mangrove forests, the conversion to aquaculture ponds is the main driver of loss (Castillo et al., 2018).

Existing infrastructure and settled employees from former timber licensing agreements (TLAs) remain in many forested areas of the Philippines and constitute a barrier to forest conservation in those areas. TLAs were granted to private companies through the 1970s and 1980s, until they were phased out in 1987 in favor of other modes of forestland management that included more revenue sharing with local communities. In fact, that phase-out of TLAs created a disincentive for forest conservation: the former privately managed forestlands became essentially open access when TLAs ceased operations, while the infrastructure from previous logging endeavors remained (Carandang et al., 2013). This existing infrastructure, as well as the presence of former TLA employees who remain in the area in logging settlements, remains a barrier for forest conservation many years after the TLA phase-out.

It is important to note the changing nature of deforestation in Southeast Asia, including the Philippines: Specifically, the role of small-scale farmers in forest clearing has declined in importance relative to large-scale agribusiness and commodity crop production (Rudel et al., 2009; Leblois et al., 2017; Austin et al., 2017). Land distribution is highly skewed in the Philippines, particularly with respect to tenure over forestland (Sheeran, 2006).

Community-based forest management programs (CBFM) represent a promising avenue for forest conservation in the Philippines, with CBFM agreements covering more than 1.6 million hectares as of 2013 (Carandang et al., 2013). However, CBFM faces several challenges. One of these is the lack of technical capacity among CBFM implementers. Perhaps more challenging are the threats that CBFM areas face from illegal loggers and incoming migrants whom CBFM implementers, as well as local governments, have limited capacity to stop (Carandang et al., 2013).

Enacted with the intent of conserving forests, existing bans on logging in old-growth primary forest may in some instances constitute a challenge to forest conservation. On one hand, the bans, coupled with weak enforcement and corruption, have increased illegal logging in the country and thus decreased the ability of the government to regulate the extraction that takes place. In addition, the bans have created uncertainty surrounding resource tenure in CBFMs that further limits development of the latter (Carandang et al., 2013).

GOVERNANCE CHALLENGES

Governance is often identified as a factor increasing the rate of deforestation and forest degradation. This term embraces a range of factors, including the existence of an environmental policy framework and the integration of that framework with the rest of a jurisdiction's laws; the existence of environmental NGOs; and the general rule of law (Wehkamp et al., 2018). Because many deforestation hotspots tend to be remote, they tend to have lower institutional capacity and law enforcement effectiveness. The governance hypothesis of deforestation is the idea that improving governance leads to reducing rates of deforestation (Wehkamp et al., 2018). Many academic circles put forward this argument, which is implicitly accepted by 54 of 70 National REDD+ Strategies that identify governance issues as a concern for forest conservation (FCPF and UN-REDD via Wehkamp et al., 2018). One mechanism through which this governance-deforestation link can manifest is the elite capture of resources upon decentralization (Yilmaz & Venugopal, 2013). This is a central challenge for decentralized resource management regimes.

Corruption is a challenge in the Philippines, with a legacy of entrenched patronage and clientelist systems as well as regulatory capture by the elite. During the administration of President Aquino, government-implemented measures to address corruption were considered by Transparency International (2013) to have had positive impacts. The status of anti-corruption efforts under the new administration is not clear; however, indications are that promoting forest conservation is likely much more difficult now than it was prior to President Duterte's election in 2016 (Global Witness, 2018).

The Philippines undertook an assessment of governance quality at municipal and provincial levels in 2005 and 2008 that led to the creation of the Good Governance Index (GGI) (PSA, 2010). This index includes data on government expenditure on social services, voter turnout, and crime-solving effectiveness. It also includes many indicators in health and education that may correlate with good governance, but would generally not be considered indicators of governance quality per se. The inclusion of many indicators that are not specific to governance and the fact that the most recent data is 2008 both suggest that the GGI is not an ideal metric. However, it is the best sub-national data on governance quality in the Philippines that we have found to date.

In the Philippines, there is at least a spatial correlation between poor governance and deforestation rates. Out of the five provinces with the highest rates of emissions from forest cover loss, four have governance rankings that place them in the bottom third of Philippine provinces (Table 9; Figure 9; PSA 2010). The limited presence of law enforcement in deforestation hotspots in provinces such as Palawan, in particular, is an important factor in continued deforestation and contributes to the dangers faced by local activists who seek to address it (Carandang et al., 2013, Global Witness, 2019)

USAID has previously invested in environmental governance in the Philippines through the Environmental Governance Phase 1 (2001–2004) and Phase 2 (2004–2011) projects (EcoGov). These projects worked with local government units (LGUs) to improve management in the forest, marine, and waste sectors with the first-level goal of improvement resource management and the second-level goal of improving the capacity of LGUs for effective environmental management. EcoGov 2 met or exceeded its goals as assessed by independent evaluation (Chemonix, 2011) and some components of the project had demonstrable climate impacts as well, particularly its PES scheme.

CO-BENEFITS

The primary motivation for many forest conservation efforts in the Philippines was a reduction in landslides and flooding that resulted from high levels of deforestation in the 1980s and 1990s (Bugayong, 2006). Limiting landslides and flooding remains an important co-benefit of forest conservation in the Philippines.

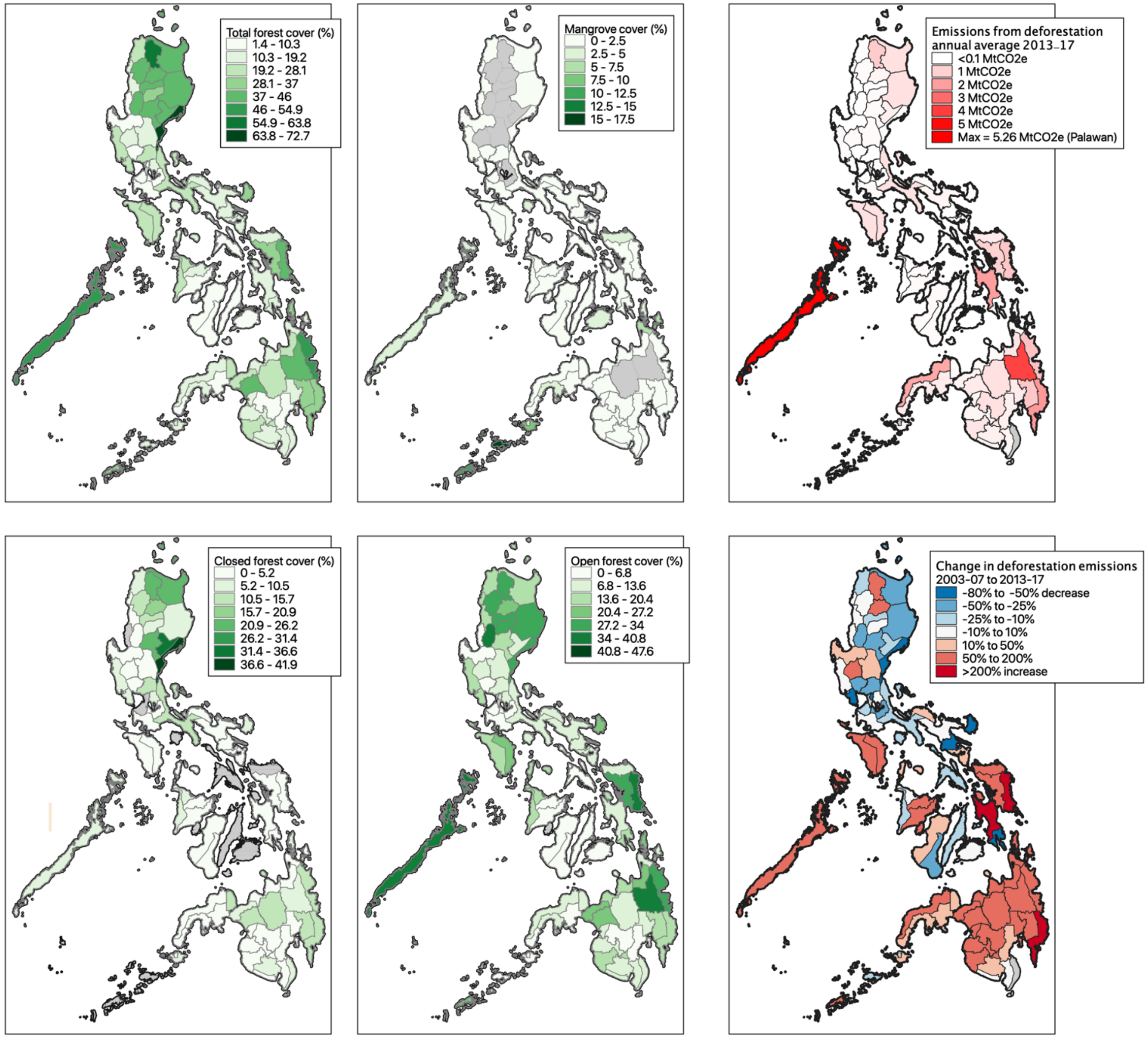

Figure 7: Emissions from deforestation in the Philippines (data from GFW, 2019).

The Philippines is a megadiverse country with high levels of species endemism. It is estimated that nearly half of its 1100 vertebrate species are endemic to the Philippine archipelago and that 45 to 60 percent of its vascular plants are similarly endemic (Posa et al., 2008). The losses of pristine upland forests, of mangrove forests, and of coral reefs are the most important drivers of biodiversity loss in the country (Posa et al., 2008). Forest conservation in the Philippines, particularly of the remaining pristine upland forests, has very high benefits for biodiversity.

Maintaining natural forest cover has economic benefits for local populations by maintaining supplies of fuel wood and of NTFPs such as bamboo, rattan, fruit, and meat (Chokkalingam et al. 2006; Carandang et al. 2013). Wood is the primary fuel used for cooking in the Philippines, and maintaining forest cover can maintain fuelwood supply (IRG, 2015). This may be particularly important in regions that have relatively low forest cover and will have a relatively smaller effect in areas with more forest cover (Chokkalingam et al, 2006).

3.1.2. Forest Restoration, Reforestation, and Agroforestry

Much of the sequestration in FOLU sector in the Philippines results from the expansion of plantations, either for forestry production or for agricultural commodities such as oil palm (the latter being a more recent trend). In a smaller number of cases, reforestation efforts have recreated more natural species composition (Chokkalingham et al., 2006).

Agroforestry provides significant opportunities for climate mitigation in the Philippines. Agroforestry is already a common practice in the country: the Philippines ranks seventh globally in terms of total biomass carbon on agricultural land (Zomer et al., 2016). In addition, out of the forty countries with the largest total biomass carbon on agricultural land, the Philippines ranked eighth in terms of absolute increase between 2000 and 2010—an increase of 4.6 percent over the decade (Zomer et al., 2016).

One of the most frequently-promoted agroforestry techniques in the Philippines is known as sloping agricultural land technology, or SALT (Lasco and Pulhin, 2000). SALT is a form of alley cropping that establishes trees along slope contours so as to provide protection against erosion. In general, it is employed in association with annual crops such as rice or corn. SALT is effective at soil conservation–a particular priority in the Philippines where flooding and landslides associated with deforestation were a primary motivation for national efforts to curb logging (Bugayong, 2006). Additionally, SALT has been shown to have positive impacts on yield, making its potential for adoption much more favorable (Lasco and Pulhin, 2000). As far as carbon sequestration, however, while SALT sequesters more carbon per hectare than annual crops alone, its carbon densities are lower than for forest plantations and for some other forms of agroforestry.

MITIGATION POTENTIAL

Agroforestry systems are diverse, and their carbon densities—and thus their sequestration potential—differ accordingly. Estimates from elsewhere in Asia show aboveground carbon densities in agricultural systems ranging from 16 to 77 tons of carbon per hectare (Kumar, 2011; Nath and Das, 2012). Agroforestry also benefits soil carbon, retaining 45 to 79 percent of soil carbon that would have been present in primary forest before clearing (van Noordwijk et al., 2002). One note regarding these estimates is that the data for agroforestry systems regarding carbon stock and sequestration rates is often of lower quality than similar data for forests (Nair, 2012). In the Philippines, data on carbon sequestration in commercial plantations is quite robust; however, data on carbon sequestration by trees in agricultural systems is more limited.

The Philippines National REDD+ Strategy (PRST, 2010) used an estimate of 45.4 tons of aboveground carbon per hectare of agroforestry land which comparing with 208 tons in secondary forests, a range of 90–260 for primary forests, and only 12 tons per hectare of grassland. Additionally, agroforestry provides economic opportunities for smallholders that can improve program buy-in (Shively et al., 2004). This is particularly important in cases where the competition for land is with high-value commodity crops. Shively et al. (2004) found that agroforestry with the Southeast Asian timber species *Falcataria moluccana* (the Moluccan albizia) sequestered carbon at a lower cost per ton than when planted in a tree-only plantation.

The carbon density of plantations varies greatly depending on species; Lasco and Pulhin (2009) reported estimates that ranged from an average for Teak of 35 tC/ha to an average for Mahogany of 264 tC/ha (Lasco and Pulhin, 2009). That study and another (Sarmiento and Varela, 2015) reported carbon densities and sequestration rates for a combined total of 46 reforested areas of different species and ages. Table 5 presents those estimates and shows the range in both sequestration rates and carbon density. The highest reported rate of sequestration (17.5 tC/ha/yr) was in an *Acacia crassicarpa* plantation over its first four years; however, generally the fastest rates were in the range of 8 to 11 tons of carbon per hectare per year. Converting into CO_2e, that equates to 29 to 40 tons CO_2e sequestered per year per hectare. At the lowest end, plantations sequester significantly less than one ton CO_2e per hectare per year. It is also worth noting that although 16 of the estimates for plantation sequestration rates are in the Luzon island group, these 16 are all in the bottom half of the 46 estimates. These studies were not necessarily designed to assess differences among island groups, but it is plausible that that represents a real pattern of lower productivity in the more northern Luzon group relative to the (central) Visayas and (southern) Mindanao.

Table 5: Carbon densities and annual sequestration rates of tree plantations of different species in the Philippines. Estimates taken from two sources indicated in the rightmost column: (1) Lasco and Pulhin, 2009 and (2) Sarmiento and Varela, 2015.

Species	Location	Island group	Age (Years)	C density (tC/ha)	Ann. seq. C (tC/ha/ yr)	Source
Acacia crassicarpa	Iloilo	Visayas	4	70.1	17.5	1
Paraserianthes falcataria	Caraga	Mindanao	5	56.4	11.3	2
Acacia mangium	Caraga	Mindanao	5	49.8	10.0	2
Acacia neriifolia	Iloilo	Visayas	4	39.2	9.8	1
Acacia mangium	Leyte	Visayas	11	88.1	8.0	1
Gmelina arborea	Leyte	Visayas	4	31.6	7.9	1
Acacia falcataria	Mindanao	Mindanao	4	31.3	7.8	1
Acacia auriculiformis	Leyte	Visayas	4	28.6	7.1	1
Leucaena leucocephala	Caraga	Mindanao	5	34.8	7.0	2
Acacia falcataria	Mindanao	Mindanao	5	34.0	6.8	1
Acacia mangium	Leyte	Visayas	4	25.6	6.4	1
Acacia aulacocarpa	Iloilo	Visayas	4	25.4	6.3	1
Acacia falcataria	Mindanao	Mindanao	7	43.4	6.2	1
Gmelina arborea	Mindanao	Mindanao	9	54.3	6.0	1
Eucalyptus citrodora	Iloilo	Visayas	4	23.6	5.9	1
Eucalyptus tereticornis	Iloilo	Visayas	4	22.4	5.6	1
Gmelina arborea	Mindanao	Mindanao	7	38.6	5.5	1
Eucalyptus cloeziana	Iloilo	Visayas	4	21.7	5.4	1
Acacia falcataria	Mindanao	Mindanao	9	48.7	5.4	1
Leucaena leucocephala	Cebu	Visayas	6	31.8	5.3	1
Eucalyptus deglupta	Caraga	Mindanao	5	26.2	5.2	2
Gmelina arborea	Mindanao	Mindanao	9	39.3	4.4	1
Acacia holosericea	Iloilo	Visayas	4	15.5	3.9	1
Eucalyptus pellita	Iloilo	Visayas	4	15.3	3.8	1
Pinus kesiya	Nueva Ecija	Luzon	13	48.5	3.7	1
Swietenia macrophylla	Mt. Makiling	Luzon	80	285.8	3.6	1

Species	Location	Island group	Age (Years)	C density (tC/ha)	Ann. seq. C (tC/ha/ yr)	Source
Gmelina arborea	Leyte	Visayas	16	55.8	3.5	1
Swietenia macrophylla	Mt. Makiling	Luzon	80	254.2	3.2	1
Parashorea malaanonan+ Anisoptera thurifera	Mt. Makiling	Luzon	80	241.3	3.0	1
Pinus kesiya + broadleaf spp.	Nueva Ecija	Luzon	13	37.5	2.9	1
Acacia auriculiformis	Nueva Ecija	Luzon	9	20.8	2.3	1
Acacia auriculiformis	Nueva Ecija	Luzon	9	19.1	2.1	1
Acacia auriculiformis	Nueva Ecija	Luzon	9	17.9	2.0	1
Casuarina equisitifolia	Iloilo	Visayas	4	7.0	1.8	1
Acacia auriculiformis	Nueva Ecija	Luzon	9	14.4	1.6	1
Parashorea malaanonan+ Dipterocarpus grandiflorus	Mt. Makiling	Luzon	80	125.6	1.6	1
Gmelina arborea	Nueva Ecija	Luzon	6	7.8	1.3	1
*Dipterocarp**	Mindanao	Mindanao	100	119.4	1.2	1
Tectona grandis	Nueva Ecija	Luzon	13	10.0	0.8	1
Acacia auriculiformis	Nueva Ecija	Luzon	6	4.5	0.8	1
Swietenia macrophylla	Leyte	Visayas	11	7.7	0.7	1
Gmelina arborea	Nueva Ecija	Luzon	6	3.5	0.6	1
Acacia auriculiformis	Nueva Ecija	Luzon	6	3.3	0.6	1
Casuarina cuminghiana	Iloilo	Visayas	4	1.4	0.4	1
Tectona grandis	Nueva Ecija	Luzon	13	3.9	0.3	1
Leucaena diversifolia	Iloilo	Visayas	4	0.3	0.1	1

COST ESTIMATES

National reforestation efforts were largely driven by public financing, including international donors. These and other sources invested at least $570 million in reforestation in the Philippines between 1970 and 2000 (Chokkalingham et al., 2006). The great majority of this planting was for commercial plantations of exotic species, in particular mahogany (*Swietenia macrophylla*) and various *Acacia* and *Eucalyptus* species. Enrichment planting and restoration of existing natural forests, approaches that are much more beneficial for biodiversity, played a much smaller role (significantly less than 20 percent) (Chokkalingham et al., 2006).

A 14-year reforestation effort funded by the Asian Development Bank and the Japanese Bank for International Cooperation planted 299,000 hectares. Taking total project budgets, this equaled $382 per hectare in 2001 dollars (Chokkalingham et al., 2006). However, it should be noted that survivorship of plantations that have been planted in the Philippines is only about 50 percent (Agoncillo et al., 2011). Taking only this fact of poor survival rate and the inflation from 2001–2019 (~40 percent) would suggest that planting a hectare of forest that survives long term in 2019 would cost at least $1070. Additionally, reforestation with mixed native species and forest restoration is significantly more expensive than planting a monoculture, so that cost is likely to be higher still if reforestation is done in a way that promotes biodiversity (Chazdon et al., 2016).

An overview of reforestation efforts in the Philippines undertaken by CIFOR (2003) found widely differing reforestation and restoration practices and accordingly widely differing costs. That study reported total budget and areal coverage data for seven projects between 1988 and 2003 and calculated cost per hectare of reforestation (Table 6; not corrected for inflation). Costs varied widely from a community-based forest management project that reforested for $319 per hectare to a community forestry project where the budget and total area targeted resulted in a cost per hectare of $21,430. That project had a much wider remit than simply reforestation, however, in that it also focused on land tenure clarification, promotion of agroforestry practices, and land use planning.

Table 6: Project costs per hectare of selected reforestation costs in the Philippines (CIFOR, 2003).

Project	Budgeted expenses (millions USD)	Target coverage (hectares)	Cost per hectare
Watershed Rehabilitation/Forestry Sector Project 1988–92	283.0	507,657	557
Watershed rehabilitation/Forestry Sector Project 1993–2003	80.0	68,663	1,165
Camiguin Sustainable Community-based Reforestation Project 1994–97	0.4	300	1,424
Philippine-German Community Forestry Project - Quirino (CFPQ) 1994–2001	17.6	821	21,430
Cordillera Highland Agricultural Resources Management Project (CHARM) Reforestation Component 1999–2003	6.1	n/a	n/a
Southern Mindanao Integrated Coastal Zone Management Project (SMICZMP) 1999–2005	30.4	9,210	3,301
Developing tropical forest resources through Community-Based Forest Management 2001–02	1.0	3,000	319

Lasco et al. (2013) assessed the direct cost of reforestation–i.e. the cost without additional investment in institutions, governance, or local capacity–in comparison to measured carbon sequestration rates and found that costs of sequestration via reforestation of $7.44 and $9.02 per ton CO_2e.

BARRIERS TO IMPLEMENTATION

There are several challenges to reforestation to date in the Philippines. One is technical: in many cases, projects have chosen inappropriate species, often from a small number of dominant species, specifically *Gmelina arborea*, mahogany (*Swietenia macrophylla*), and narra (*Pterocarpus indicus)*. This has led to poor survivorship and performance in some areas (Choklongham et al., 2006).

Economic incentives are also poorly aligned for reforestation. Although reforestation can be a very cost-effective option when the overall costs and benefits are evaluated (IRG, 2015), the apportionment of those costs and benefits often means that there are frequently poor incentives for people who are making decisions over the land. One issue is that harvest and transport regulations in the timber sector have made it very difficult for plantations in upland areas to be profitable (Choklongham et al., 2006). In addition, large government shares of returns to harvesting and high taxes per area of land give large landholders little incentive to rehabilitate land and manage it for long-term sustainability (Choklongham et al., 2006).

Community-based forest management (CBFM) groups are one potential institutional arrangement under which reforestation efforts could take place; however, these face several challenges in the Philippines. One issue relates to logging bans, as discussed above. Although logging bans, widely used across the Philippines, were established for the purposes of forest conservation, their implementation has increased uncertainty surrounding use rights and resource tenure by CBFMs (Bugayong, 2006; Carandang et al., 2013). This reduces the incentives for investment in reforestation.

For small-scale landholders, lack of incentive to reforest often stems from the long return time for investments in reforestation. High poverty levels in many upland areas, coupled with limited agricultural land relative to population, puts many small-scale landholders in a position where they cannot afford to wait for the relatively slow returns to planting trees. As such, engaging in shifting cultivation or in continued logging of newly opened areas is more economically feasible in the immediate term, even if long-term returns would suggest that reforestation would be advantageous (Choklongham et al., 2006; Carandang et al., 2013).

CO-BENEFITS

Reforestation of deforested areas and restoration of degraded forests generate many benefits for local populations. In the Philippines, some of the most important are the reduction in landslides, soil erosion, and flooding (Bugayong, 2006; Estoque et al., 2019).

Depending on the species planted, local populations may benefit by collection of NTFPs such as rattan, bamboo, or fruit. A study of reforestation efforts in three different regions found that the importance of NTFP and fuelwood benefits varied greatly depending on the location of reforestation. Reforestation projects in Luzon and in the Central Visayas had important positive economic impacts that resulted from increased availability of NTFPs. However, in Southern Mindanao, the higher level of remaining forest cover and existing NTFP availability meant that the impact of increased NTFP supply was relatively less important in its economic impact (Chokkalingam, 2006). Timber production and employment can be important outcomes of reforestation efforts; however, marketing timber products can be difficult because of weak markets and an unfavorable regulatory environment for legal timber production (Chokkalingam et al., 2006; Carandang et al., 2013).

Reforestation or forest restoration can result in important biodiversity benefits; however, these will depend on the type of planting that takes place. Establishing commercial mono-cultures, as is the case in the majority of the projects described in Table 5, may have some biodiversity benefits relative to a scenario of annual crops or of degraded bare lands; however, these benefits will be much less than would be the case with restoration of more natural forest ecosystems (Chazdon and Uriarte, 2016).

3.2. AGRICULTURE AND LIVESTOCK SECTORS

For the overall Philippine economy, GDP growth in 2017 was 6.68 percent, and for the agriculture sector, growth was 3.96 percent (PSA, 2019a). Agriculture and fisheries combined contribute about 10 percent of the national GDP (Cruz et al., 2017). As of 2018, the World Bank estimates that 25 percent of the total employed population work in agriculture (World Bank, 2019).

There are approximately 13.5 million hectares of land currently in crop production in the Philippines. Of this land, the largest planted areas are for rice (4.8 million hectares), coconut (3.6 million hectares), and corn (2.5 million hectares). Sugarcane and banana are each grown on approximately 440,000 hectares (PSA, 2019a). By value of production, rice is by far the most important crop, followed by banana, coconut, and corn. Swine and poultry are the most important livestock subsectors in the Philippines.

The most important agricultural regions of the Philippines for rice are the Cagayan Valley and Central Luzon, with about one-third of national rice production (Figure 9). Over one-half of national corn production comes from Mindanao, mostly Northern Mindanao, and Soccsksargen. Mindanao also dominates coconut production. Almost 58 percent of the sugarcane production comes from Western Visayas. Swine production exists throughout the country, but over 35 percent comes from Central Luzon and Calabarazon (Figure 9). Over 57 percent of the poultry production also comes from these two regions.

The estimated baseline (2010) level of GHG emissions from the agricultural sector is 49.2 MtCO_2e. Over 39 percent of this is attributed to methane emissions from rice cultivation, and over 21 percent is a result of N2O flux from agricultural soils (Table 7). Under the BAU scenario, GHG emissions from the agricultural sector are projected to increase by 38 percent to a total of 67.9 MtCO2e by 2050 (IRG, 2015). The sources expected to have the greatest increase in emissions are N2O from agricultural soils, CH_4 from manure management, and non-CO2 from burning field residues. N2O from soils is expected to grow by more than 60 percent and become almost as large as CH_4 from rice cultivation.

Table 7: Estimated GHG emissions from agriculture in the Philippines for 2010.

Subcategories	Emissions $MtCO_2e$	Percent of Total
CH_4 from rice cultivation	19.2	39.1
N2O from agricultural soils	10.4	21.2
Livestock: CH_4 from enteric fermentation	8.6	17.4
Livestock: CH_4 from manure management	5.0	10.1
Livestock: N2O from manure management	1.2	2.4
Non-CO2 from burning of agricultural residues	3.6	7.4
CO2 from liming soils	0.4	0.9
Silvipasture burning	0.4	0.8
Grassland burning	0.3	0.6
Total	**49.2**	**100.0**

Source: B-LEADERS Project (IRG, 2015)

The B-LEADERS project (IRG, 2015) assessed costs and mitigation potential for four mitigation options in the agriculture sector (Table 8). The costs included were both direct costs–capital, operation and management (O&M), and implementation–as well as the indirect costs (or savings) generated by changes in the use of fuel or other inputs. Total GHG mitigation potential was estimated from 2015 to 2050 and cost-effectiveness was assessed as the total cost per ton of mitigation.

Table 8: Cost and abatement potential of mitigation options in the agricultural sector

Mitigation option	Costs compared to baseline: cumulative 2015–2050 (billion 2010 USD) discounted at 5%			GHG mitigation potential 2015–2050 ($MtCO_2e$)	Cost per ton mitigation 2015–2050 without co-benefits (2010 USD)
	Capital, O&M, implementation costs	Costs of fuel and other inputs	Total net cost		
Formula	*A*	*B*	*(A+B) = C*	*D*	*C / D = E*
Organic fertilizer	0.0	-0.078	-0.078	83.9	-0.92
AWD	0.0039	0.0	0.0039	28.2	0.14
Crop diversification	0.0	0.073	0.073	44.9	1.62
Biodigesters	0.4	-0.4	0.046	29.2	1.58

Source: B-LEADERS Project (IRG, 2015)

3.2.1. Overview of Rice Agriculture in the Philippines

Rice is an incredibly important crop globally; no other food supplies more calories to the world's population. According to the Global Rice Science Partnership (2013), the per capita consumption of rice in the Philippines is 123kg per year, which represents almost 45 percent of caloric intake. Rice cultivation is also estimated to produce 11 percent of anthropogenic methane emissions globally (Runkle et al., 2018) and is responsible for close to 2.5 percent of total global warming potential (GWP) (Kritee et al., 2018).

Rice is the primary staple food for most of the Philippines' population, and grown on approximately 4.8 million hectares, with about 2.7 million of the hectares irrigated. The Philippines is also one of the largest rice importers in the world (Labios & Malayang, 2015). Considered the "rice bowl" of the Philippines, the Central Plain of Luzon is the source of about 20 percent of all the rice grown in the country.

Paddy rice production generally involves continuously flooded fields, which provide ideal conditions for methanogens (bacteria that produce methane gas) due to the breakdown of organic matter in the water, which creates a hypoxic environment. The B-LEADERS project (IRG, 2015) used the Agriculture and

Land Use Greenhouse Gas Inventory (ALU) model to estimate that rice production in the Philippines emits 49.2 MtCO2e. This is equal to an average emission of 2.0 kg/ha/day, which is more than 50 percent greater than the IPCC emission factor (EF). Using the IPCC baseline EF for methane from continuously flooded rice of 1.3 kg/ha/day, rice would emit an estimated 31.2 million metric tons (Mt) of CO2e annually in the Philippines—thus demonstrating a significant benefit by moving the country's rice production closer to the global average in terms of its greenhouse gas intensity.

Although rice is a critically important staple food and the dominant crop grown in the Philippines, productivity lags far behind other Asian nations (Bordey et al., 2015). Average yield in the Philippines, at 9.5 tons per hectare, is close to the bottom among the major Asian rice-producing nations. It is less than half of the average yield of Vietnam, which is 20.6 tons per hectare, partly because Vietnam has higher per-season yields and because they often get three crops per year. However, the price that Philippine farmers receive for rice is almost two times higher than the price farmers receive in Vietnam, after accounting for the purchasing power of the currency in each country (Bordey et al., 2015). Net returns per acre from rice production for Philippine farmers were also second from the bottom, even though the price paid for rice is relatively high. The low net returns result from the high cost of production and the low yields, especially in the wet season.

Table 9: Provinces with the largest area of irrigated rice and the largest area of expansion of irrigated rice between 2010 and 2018. Top ten provinces in each category included. Governance scores from GGI indicated for reference in right-most column.

Province	Area of irrigated rice (km^2)	Area of irrigated rice as percent of land area	Increase in area of irrigated rice from 2010–2018 (km^2)	Increase in area of irrigated rice, 2010–2018, as percent of area	Provincial Good Governance Index (GGI) rank in 2008 (change in rank from 2005)
Nueva Ecija	3000	54.5	390	7.1	66 (-21)
Isabela	2589	24.7	265	2.5	67 (-6)
Pangasinan	1729	33.5	120	2.3	46 (+14)
Cagayan	1526	17.3	109	1.2	13 (+11)
Camarines Sur	1362	25.8	117	2.2	78 (-2)
Tarlac	1245	41.9	2	0.1	57 (-17)
Iloilo	1128	23.9	55	1.2	47 (+8)
Sultan Kudarat	963	22.8	30	0.7	68 (-15)
North Cotabato	936	16.0	55	0.9	45 (-4)
Pampanga	897	42.4	80	3.8	18 (-5)
Oriental Mindoro	891	21.2	211	5.0	31 (-8)
Bukidnon	850	9.1	124	1.3	43 (+7)
Bulacan	687	25.3	97	3.6	19 (-9)
Palawan	558	3.9	199	1.4	55 (+14)
Antique	479	17.5	133	4.9	71 (-3)

3.2.2. Alternate Wetting and Drying (AWD)

Alternate wetting and drying (AWD), developed by IRRI, is being introduced across Asia. It is a flood management practice used to maximize rainfall capture and reduce irrigation pumping. AWD introduces periods during the growing season when the water level in the flooded rice field is allowed to recede below the soil surface. The timing, frequency, and extent of the dry periods will depend on many factors, such as the stage of growth, as well as on weather and field conditions. The Government of the Philippines is encouraging the use of AWD in all national irrigation systems as a way to address increasingly limited water resources (Sander et al., 2017).

Mid-season drainage, a simple form of AWD with one aeration (dry period) lasting about 7 days just at the end of the vegetative growth stage, has been widely practiced in China and Japan for the past several decades (Sander et al., 2015). There has been a substantial amount of research on AWD across Asia. The countries with the most experience in AWD seem to be Vietnam, Philippines, Bangladesh, China, and Thailand (Sander, personal communication, 2019).

Approximately 75 percent of rice production in the Philippines is irrigated (provinces with largest areas of irrigated rice shown in Figure 9 and Table 9), and irrigated production represents 86 percent of CO2e emissions from rice. Most of the emissions from irrigated rice production (92 percent of CO2e) take the form of CH_4 emissions from anaerobic decomposition. AWD involves reducing the length of time during which rice fields are flooded, which improves soil aeration and can reduce emissions of CH_4 by about 60 percent (Bautista et al., 2015). It can also reduce labor demands, improve efficiency of water use, and maintain yields. However, its effectiveness (especially the sensitivity of yields to the practice) may vary with site conditions, particularly soil type and pH (Carrijo et al., 2017). Finer-scale study will be important to better scope the geographic potential.

An analysis by Sander et al. (2017) shows that overall, up to 60 percent of rice land in the Philippines is suitable for AWD. In the dry season, this number reaches 90 percent; in the wet season, only 34 percent. The climate change benefits of AWD can be difficult to achieve in the wet season, as the soil may not get the opportunity to dry out enough to interrupt methanogenesis. The GHG reductions produced by the B-LEADERS project (IRG, 2015) assume the adoption of AWD on 10,000 ha per year in the Philippines from 2015 to 2050, which represents less than 10 percent of the country's rice area. By comparison, the Adaptation and Mitigation Initiatives in Agriculture (AMIA) project spearheaded by the UNDP envisions converting 50 percent of irrigated rice fields in the Philippines to AWD (Arnaoudov et al., 2015).

MITIGATION POTENTIAL

The dry period allows the soil to regain an aerobic condition, which reduces methanogenesis and methane emissions that result from anaerobic decomposition of plant material on flooded rice paddies. According to IRRI, reduction in GHG emissions, mostly methane, from paddy rice will range from 30 to 70 percent (IRRI; see http://ghgmitigation.irri.org/technologies/awd). The scaling factor for AWD using multiple aeration is 0.52, representing an average reduction of 48 percent from the baseline EF of 1.3 kg/ha/day (Tirol-Padre, 2018).

It is important to note that paddy rice also emits nitrous oxide (N_2O). A recent study from the Philippines found that AWD increased N_2O emissions by 97 percent; this offset the reductions in the methane and rendered the mitigation potential from AWD insignificant (Sibayan et al., 2018). This finding is inline with that of Kritee et al. (2018), who found in India that under certain conditions, AWD can increase N_2O emissions enough to negate reductions in methane. This is in contrast, however, to the findings of scientists in IRRI (Sander, personal communication, 2019). Sander et al. (2015) note the following:

> The available data . . . suggest that the incremental N_2O emission through AWD is insignificant as long as the N fertilization remains within a reasonable range. Thus, the combination of AWD with efficient fertilization techniques, such as Site-Specific Nutrient Management, is the best way to avoid excessive N levels in the soil and thus, negative trade-offs in terms of mitigation potentials.

A recent analysis by Sander et al. (forthcoming 2020) that measured GHG flux from irrigated rice fields under CF and AWD for seven consecutive rice seasons reported that increased N_2O flux only offset the decrease in CH_4 emissions by 15 percent and "did not jeopardize the strong reduction of the GWP."

They found that CH_4 was reduced by 73 percent in the dry season and by 21 percent in the wet season. They are recommending that AWD be further incentivized in the Philippines.

Additionally, a recent study by Chidthaisong (2018) in Thailand has shown that use of AWD did not increase N_2O flux. This study found that use of AWD reduced total methane emissions by 49 percent, which is very close to the 48 percent reduction associated with the IPCC scaling factor of 0.52. Regardless, clearly understanding the potential trade-offs between methane and N_2O for each eco-region, for specific field conditions and under various intensities of AWD, seems prudent to help ensure that all efforts are achieving their proposed mitigation results.

Because of discrepancies in the literature on the impact of AWD on N_2O flux, it seems very important to combine all efforts to increase AWD adoption with additional efforts to minimize N_2O flux and look at changes in the overall GWP of interventions. Harrison-Kirk et al. (2013) showed that N_2O emissions were highest with a combination of clay soils and high soil organic matter. Assessing the suitability of sites for AWD to reduce GWP is important. Improved nutrient management will also be important, as the literature indicates that the amount of N and the timing of applications are both critical to minimizing N_2O spikes with the use of AWD.

The B-LEADERS project (IRG, 2015) used the ALU model to estimate the potential net GHG reductions from a set of opportunities identified for the Philippines. Using the ALU model, they estimated that AWD could mitigate 28.2 MtCO2e from 2015–2050. Sander et al. (2017) estimated that maximum potential reduction from AWD in the Philippines is 265,000 tons CH_4 per year. Using this figure and allowing for a 25 percent offset resulting from potential increased N_2O emissions, we calculate that that maximum reduction is 4.968 MtCO2e per year. Modeling a gradual adoption rate between 2015 and 2050 gives an estimate of slightly more than 119 MtCO2e that could be reduced from the use of AWD on rice during the 2015-2050 period.

COST ESTIMATES

The literature seems clear that AWD benefits the farmer financially, making this intervention a win-win. Rejesus et al. (2011) estimated that AWD reduces irrigation hours required by 38 percent, with no reduction in yield or profit. Although, this represents a cost saving for the producer, a cost of $21.33 per hectare was assigned to account for the salaries and expenses of the staff doing the education and outreach to farmers on AWD. This brings the net cost per ton CO2e to $0.14. Although this represents a small overall cost, it represents a fairly substantial savings at the farm-level.

BARRIERS TO IMPLEMENTATION

Access to reliable irrigation water throughout the growing season is essential for successful use of AWD. Lack of reliable access to water when needed to re-wet the fields could impact yields and represents an important potential barrier to AWD implementation. Because AWD is different from traditional rice production methods used in the Philippines, widespread adoption will not happen very quickly. It will require coordinated and effective education and outreach, as well as technical assistance to farmers.

Resistance to AWD from the governing bodies of the irrigation networks is possible due to reduced water use and revenues from irrigation fees. Education and outreach to the irrigation network managers on the private and public benefits of AWD and on the importance of improving the financial performance of the farmers they serve may be important to lessen this potential barrier and speed adoption by farmers.

CO-BENEFITS

A report was recently published by IRRI that focused on the co-benefits of the AWD production system (Allen & Sander, 2019). The benefits discussed include:

- Improved soil health and soil structure from the aeration;
- Improved human health from reduced mosquito and waterborne diseases, as well reduced availability of arsenic and mercury to the plants;
- Reduced nitrogen and phosphorus runoff by 30 percent, and up to 89 percent reduction in pesticide runoff; and
- Reduced need to burn straw, causing improvements in air quality.

3.2.3. Improved Nutrient Management

Synthetic fertilizers represent 7.2 percent of 2016 emissions from agriculture (the third-largest category) and 12.2 percent of the net increase in agricultural emissions between 2000 and 2016. The focus of this opportunity is to reduce N_2O emissions from soils, and to decrease emissions from rice straw burning as well as through better management of poultry manure.

MITIGATION POTENTIAL

This mitigation opportunity, as developed by the B-LEADERS project, assumes that synthetic fertilizer on rice fields could be decreased by 5 percent every 10 years from a baseline level in 2010, resulting in a 20 percent reduction by 2050. In lieu of the nutrients inputs reduced, crop residues and composted chicken manure would be added in amounts to replace the nitrogen from the synthetic fertilizer that was removed. This scenario also includes a reduction in rice straw burning from 90 percent to 70 percent by 2050, as well an increase of 20 percent in composted manure amendments to agricultural soils.

COST ESTIMATES

Historical fertilizer prices were used to project the increase in prices out to 2050. The historical application rate of fertilizers on rice has been flat in the Philippines, and the projections used to 2050 assume that this will continue in the baseline case. The B-LEADERS project estimated that the transition from synthetic to organic fertilizers and the associated practices of improving use of crop residues and manure could reduce 83.9 $MtCO_2e$ with a cost savings of $0.92 (i.e. a net negative cost) per ton CO_2e.

BARRIERS TO IMPLEMENTATION

Improved nutrient management on agricultural land represents a potential win-win opportunity. However, affecting behavior change requires effective education and outreach to farmers throughout the Philippines or in targeted regions. As is the case with AWD, this education and outreach to farmers will have a cost that partially offsets the savings and we assume that this cost is factored into the calculations the B-LEADERS project, but it is not explicitly stated in their report.

CO-BENEFITS/RELATED OPPORTUNITIES

Rice straw is a by-product of rice-grain harvesting. An average of 6 to 8 tons of straw are produced per hectare per year in Asia (IRRI website https://www.irri.org/rice-straw-management). Organic amendments to rice paddies tend to increase methane emissions and the rate of emissions per unit of organic amendment. This increase in emissions is greatest for straw amendments to the field and is much lower for adding compost (Yan et al. 2005). Straw removal is not included in the available literature for the Philippines but could be an important opportunity for the country, given its almost 5 million hectares of rice production. A recent study by Romasanta et al. (2017) showed that the GWP of straw removal in the Philippines was 3.47 tCO_2e per hectare, compared with 8.02 tCO_2e per hectare for full straw incorporation. This potential reduction of over 4.5 tCO_2e per hectare per year could translate into a reduction of 4.5 $MtCO_2e$ if rice straw removal can be implemented on 25 percent of rice land in the Philippines.

A vast increase in the number and availability of rice straw balers will be needed to implement improved use of rice straw residue. The development of profitable uses for the straw will reduce the net cost of this opportunity. IRRI is working on several possible uses for harvested rice straw, including composting and using as a soil amendment, bio-energy production, and producing fiber-based materials such as plates, cups, baskets, and packing materials. For Vietnam, rice straw removal was estimated to cost $12.20 per ton CO_2e; there is no corresponding cost estimate available that is specific to the Philippines, but the Vietnam cost could be assumed to be roughly similar.

3.2.4. Crop Diversification

MITIGATION POTENTIAL

This opportunity, developed by the B-LEADERS project, is based on planting of legume crops to fix nitrogen in the soil and reduce the amount of synthetic nitrogen (N) needed for crop production. The scenario focused on increasing the land area that receives a leguminous crop, such as mung bean, cowpea, or soybean by 20 percent over four decades with a corresponding reduction of synthetic fertilizer on rice land. This type of crop diversification was estimated by the B-LEADERS project to have the potential to reduce 44.9 $MtCO_2$e from 2015-2050.

COST ESTIMATES

The estimated average cost of implementing this opportunity is $1.62 per ton. The B-LEADERS scenario bases estimated costs on the reduction of purchased synthetic nitrogen fertilizer and the relative profitability of rice versus mung bean. It is unclear why the B-LEADERS project selected mung bean and did not look at additional crops. Rice is a more profitable crop, so reducing one crop per year of rice and substituting a crop of mung beans has an opportunity cost to the farmer of reduced net profits from the land. The average gross revenue for rice is approximately 60,000 PhP per hectare, but only 30,000 PhP for mung bean. This cost outweighs the reduced cost for fertilizer on average and makes the cost of mitigation greater than zero; the project estimates the cost as $1.62 per tCO_2e.

The difference in profitability per hectare between rice and the substitute crop is an important component in the cost calculation for this opportunity. Any crop for which the difference in profitability per hectare is less than the cost savings for fertilizer will result in a negative marginal abatement cost. If a negative cost (i.e., an increase in farm profit) can be demonstrated, adoption by farmers will be more rapid.

CO-BENEFITS/RELATED OPPORTUNITIES

The co-benefits of introducing a crop rotation into a continuous monocrop such as rice are likely to be significant. This is particularly true of an N-fixing crop. Crop rotation usually helps to break the life cycle of certain pests, which can reduce the need for pesticide application. This can in turn reduce costs of production and increase human health and safety. Certain crop rotations can also help to increase soil organic matter and improve soil health, which can have long-term benefits for food production and food security. Building soil organic matter will help to increase the soil's water-holding capacity, which helps improve resiliency under drought conditions and mitigate flooding.

This mitigation opportunity of crop rotation could also be applied to corn land or any other monocrop that has a significant amount of N fertilizer application. Finding a nitrogen-fixing crop that can be grown cost-effectively to reduce fertilizer application rates and N_2O emissions, as well as produce significant improvements in soil health and/or other co-benefits, is an important area for further research.

In one study in the Philippines, Weller et al. (2015) found that growing corn results in lower yield-scaled GWP than rice, including under AWD, across all fertilizer treatments, because of the higher yield from corn. However, they recognize that there are nutritional and social acceptance factors that make adoption of this change more difficult.

3.2.5. Biodigesters

There are more than 14 million head of hogs in the Philippines, produced mostly in small operations around the country. The greatest concentration of swine production is in Central Luzon and Calabarazon (Figure 9). The Philippine Statistics Authority estimates that there will be more than 32 million hogs by 2050. Swine manure is a very important contributor to the GHG emissions, both methane and N_2O, from animal manure, which represents 12.5 percent of all GHG emissions from agriculture. Methane from manure management is projected to increase faster than most other GHG emissions from the agricultural sector in the Philippines. Thus, the production of biogas from animal manure represents an important mitigation opportunity.

MITIGATION POTENTIAL

Using the ALU model, the B-LEADERS project estimated that manure management can reduce 29.2 MtCO2e from 2015 through 2050. The project bases this estimate on a gradual increase of swine manure handled through biodigesters from 2 percent to 12 percent by 2040, and remaining at 12 percent through 2050. This scenario assumes that small-scale biodigesters are not cost-effective and, therefore, the increase in processing swine manure through biodigesters will only take place on commercial swine operations.

COST ESTIMATES

The B-LEADERS project estimated the cost for GHG reductions from biodigesters for swine manure to be $1.58 per ton CO_2e. Our recent analysis of mitigation options for Vietnam calculated that very small-scale biodigesters could reduce GHG emissions for a cost of between $6 and $25 per tCO2e. The use of small-scale digesters also has great potential in the Philippines. These digesters cost between $500 and $1000 each, depending on the size. They are able to reduce between 4 and 8 tCO2e per year, with a useful life of around 20 years. If the unit ran for 10 years and produced 4 tCO2e per year, it would produce reductions at a cost of $25 per tCO2e. If it ran for 20 years and produced 8 tCO2e per year, the cost would be $6.25 per tCO2e. The value of the collected methane for the household as a fuel source also has an important value in regions where many rural households do not have access to electricity. When this value is factored in, the marginal abatement cost of small-scale digesters becomes negative, making it a good decision for the household as well as for the environment. The co-benefits of small-scale biodigesters include the improved health of each household that is now burning a cleaner fuel for cooking.

CO-BENEFITS/RELATED OPPORTUNITIES

The B-LEADERS project estimated that the co-benefits from this opportunity are $200 million from 2015 through 2050. This results from the improved human health effects of displacing energy production from burning coal with energy from biogas production.

3.2.6. Improved Livestock Management

Livestock and feeding management is not part of the set of mitigation opportunities in the cost-benefit analysis completed by the B-LEADERS project, or in other recent analyses. However, because livestock production is a large and growing sector of the agricultural economy in the Philippines, and because low-cost and win-win solutions are needed, we believe this is an important area to look at in greater depth. Due to the lack of estimates of mitigation potential and costs, this sub-section is presented as a more general description of the opportunity.

Improving livestock management to reduce the emission intensity of meat and dairy products is an important potential mitigation opportunity for any country with a large or growing livestock sector. There are several ways to improve livestock production practices that will benefit the farmer and reduce GHG emissions. Pathways include reducing enteric methane emissions through improved feeding, breeding, and husbandry; reducing methane and N_2O emissions through improved manure management; and sequestering C in the soil through better land and pasture management.

A recent FAO report (2017) estimates that improved livestock management has the potential to reduce GHG emissions by 20 to 30 percent across all production systems. Because enteric methane is by far the largest single source of GHG emissions from livestock production, better feeding management is crucially important. For cows, improving the digestibility of the forages that they consume is a win-win strategy. The higher the digestibility, the greater the feed efficiency, which means that the animal is using a larger percentage of intake nutrients for production and a smaller percentage is being wasted. Enteric methane emission represents energy that the cow is not using. Similarly, with higher feed digestibility fewer nutrients are excreted in feces, which lowers the impact on ground and surface water.

Some types of forages, such as many leguminous species, tend to be more digestible, on average, than are other forages. Using in-country or regional research results to identify which forages will work well for livestock feeding and making efforts to get those more widely used by livestock farmers will have value for both agriculture and the environment. Further, forages that are less mature at harvest or grazing will be more digestible than they are when more mature. The trade-off for the farmer is that as forages become more mature, there is a greater volume of feed available for the animals. However, it is generally more profitable to harvest or graze forages at the optimal growth stage to achieve higher feed efficiency than it would be to feed greater quantities of more mature forage. Harvesting more frequently will require more labor but will also generally produce more forage overall throughout the year.

Rotational grazing works on this same concept: providing cows, dairy or beef, with pasture forage that is at a consistent and immature growth stage, will maximize nutrient intake and feed efficiency for the herd, as well as productivity per hectare. Additionally, because of the permanent vegetative cover and the physical and biological interactions between the animals and the soil, rotational grazing has the potential to sequester large amounts of C in the soil.

There is a lot of current research around the globe on the potential of feed additives to reduce methane production in the rumen of cows. Such additives include oregano and seaweed, among many others. Initial lab results show great promise, but the important open question regards the economic feasibility of making these additives available at scale for a reasonable price.

There are several additional pathways to reducing emissions from livestock production and the emissions intensity of livestock products. These include improving the genetics, reproductive efficiency, and productive life of livestock herds. There are breeds and genetic traits that can improve feed efficiency and improving the reproductive efficiency and extending the productive life of animals will reduce GHG emissions per unit of production. Improving each or any of these factors will also strengthen the financial performance of the farms using them. In the long term, this represents a pathway toward sustainable intensification.

4.0 PRIORITIZING GEOGRAPHIES

Throughout this report, tables and maps (Figures 7 and 9) display data at the scale of the 81 provinces in the Philippines. However, in the text of this section and in the identification of areas of geographic focus in Table 11, we identify focal areas at regional level (Figure 8).

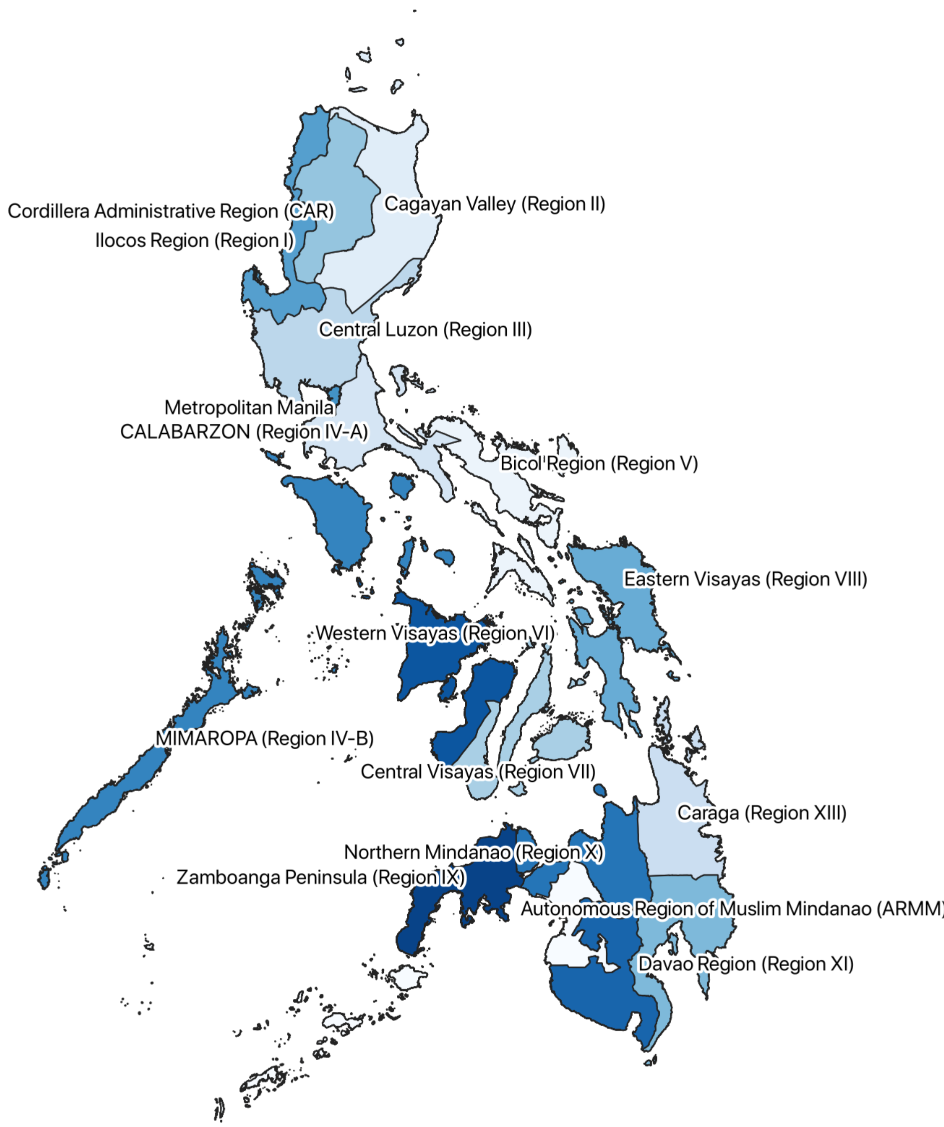

Figure 8: Regions of the Philippines

The mitigation strategies discussed in Section 3 fall generally into three categories: forests and agroforestry, annual crops, and livestock raising. We assume that the spatial potential for mitigation options in the annual crop and livestock raising categories follow the distribution of crops and livestock. However, this potential is mediated by additional factors: specifically, the feasibility of working in a given region or province and the level of existing implementation of climate-smart techniques in the agriculture and livestock sectors. With respect to feasibility, one indicator is the Good Governance Index (GGI; Table 9; Figure 9). However, the GGI was last calculated in 2008 and has additional limitations (discussed in section 3.1.1), so it is an imperfect indicator. Regarding the level of existing implementation of climate-smart agricultural and livestock practices, we have not found any existing data at sub-national level. This would be an important avenue for further evaluation in the effort to prioritize SL investments.

In the case of annual crops, we use irrigated rice production as a proxy for crops generally because rice production is responsible for 70 percent of national agricultural emissions (Table 3) and the mitigation options that have been developed for the Philippines generally focus on rice. Figure 9 shows irrigated rice area (top left panel) and can be used as a general indicator of potential for rice-based mitigation options. The areas of highest potential for investment in the rice sector appear to be in the regions of Central Luzon and Ilocos; however, this needs to be further evaluated in the context of the existing level of adoption of technologies such as AWD and improved nutrient management.

For the livestock sector, we use data on swine inventory as an indicator of spatial potential because swine manure is expected to be the primary material used in biodigesters (IRG, 2015). Swine are generally concentrated in Central Luzon and in the Western Visayas (Figure 9; bottom left). As above, these areas likely have the highest potential for investment in biodigesters, but that conclusion would need to be evaluated further with data on existing levels of adoption.

For forest-based interventions, we have highlighted the provinces of the country with the highest rates of emissions from forest loss based on data from Global Forest Watch (2019). Emissions from deforestation in the Philippines are highly concentrated with more than 25% of emission from deforestation coming from two provinces (Palawan and Agusan del Sur) and 50% coming from the top nine provinces out of 81 (Table 10; Figure 7; GFW 2019). Palawan had the highest emissions from forest cover loss of any province in the Philippines and was about 35% higher than the second-highest province, Agusan del Sur.

Table 10: Emissions from deforestation in the Philippines in the top 10 provinces by the 2013-2017 emissions. Total emissions, ranks, rates of change, and Good Governance Index rank are shown.

Province	Average annual emissions from deforestation ($MtCO_2e$) (Rank)		Increase in annual average; 2003-07 to 2013-17 (Rank)	Rate of increase (2003-07 to 2013-17)	Rank nationally (/79) in Good Governance Index 2008 (change from 2005)
	2003–2007	2013–2017			
Palawan	2.57 (1)	5.26 (1)	2.68 (1)	104%	55 (+14)
Agusan del Sur	1.63 (2)	3.89 (2)	2.26 (2)	138%	59 (+4)
Davao Oriental	0.49 (11)	2.07 (3)	1.59 (4)	325%	27 (+3)
Leyte	0.23 (30)	2.06 (4)	1.82 (3)	779%	77 (-3)
Zamboanga del Norte	1.05 (3)	1.79 (5)	0.74 (6)	71%	60 (-1)
Surigao del Sur	0.64 (8)	1.32 (6)	0.69 (7)	107%	75 (-8)
Eastern Samar	0.32 (16)	1.16 (8)	0.84 (5)	266%	49 (-14)
Compostela Valley	0.59 (9)	1.16 (7)	0.57 (8)	96%	10 (+29)
Apayao	0.72 (7)	1.09 (9)	0.37 (13)	51%	9 (-4)
Samar	0.53 (10)	0.94 (10)	0.41 (10)	78%	73 (-1)

At regional scale, the region with the largest emissions from deforestation is MIMAROPA, particularly Palawan. The regions of Caraga and Davao also have high levels of emissions from forest conversion. The Cagayan Valley region has significantly lower levels of emissions from deforestation; however, it has some of the highest levels of closed forest cover in the country (Figure 7) and as such could be prioritized for its importance to biodiversity. It also has generally better levels of governance as judged by the GGI (Figure 9) which may improve project effectiveness in that area given the importance of governance to any forest conservation intervention.

We do not have specific data on the spatial potential for reforestation or for agroforestry. However, for reforestation we can use emissions from deforestation as a general proxy on the reasoning that areas of current forest loss are likely to have potential for replanting. Access to market was identified by Chokkalingam et al. (2006) as a key limitation to the profitability and therefore viability of tree planting for timber. This may limit the potential in some of the higher-deforestation regions, specifically Palawan and Caraga. As such, the areas of highest potential for reforestation may be the areas of significant forest loss that have better market access–i.e. Cagayan Valley and Davao.

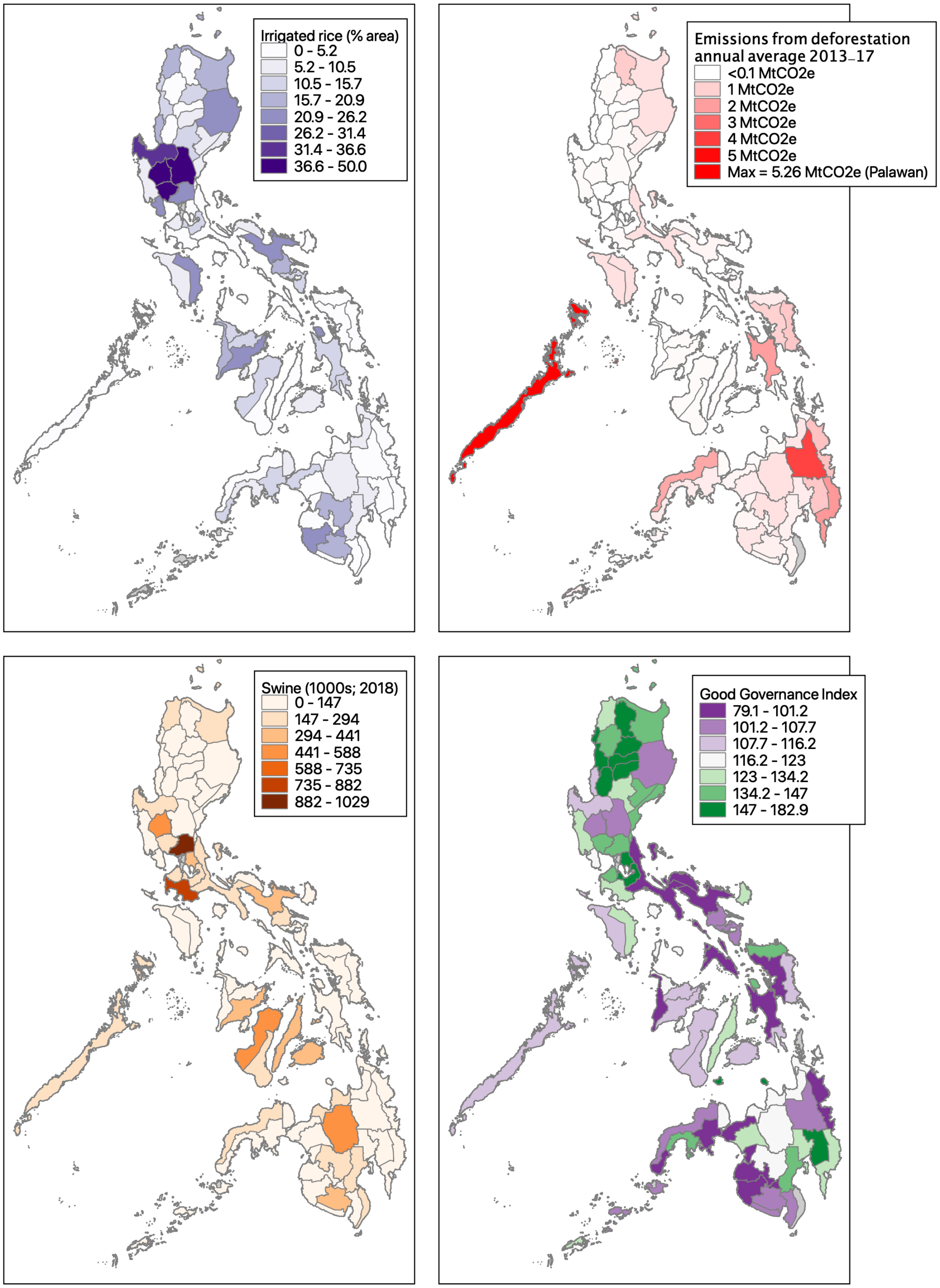

Figure 9: Indicators of spatial potential for different strategy options. Irrigated rice production as a percentage of total provincial area (PSA, 2019a); emissions from deforestation by province (GFW, 2019); and total swine in 1000s (PSA, 2019b) can be used as indicators for spatial potential of rice-based investments, forest-based investments, and biodigesters, respectively. The good governance index (bottom right; purple is worse governance, green is better) may provide an indicator of the level of difficulty of working in a given province (PSA, 2010).

5.0 SUMMARY AND CONCLUSION

The largest biophysical potential for land-based climate mitigation in the Philippines is in the forests and other land use (FOLU) sector: forest protection, forest restoration, reforestation, and agroforestry. Forest protection in particular represents 73.2 percent of the 2015–2050 land-based climate mitigation potential of the options that were identified by the B-LEADERS project (IRG, 2015). This conclusion is broadly consistent with the conclusions of the global studies of Griscom et al. (2017; 2020). In the agriculture sector, the largest opportunities relate to rice cultivation, specifically in the promotion of organic fertilizer and associated technologies to improve nutrient management implementation and in the promotion of alternate wetting and drying (AWD).

With respect to AWD, the UNDP is already spearheading the ambitious AMIA program that seeks to see AWD established in 50 percent of Philippine rice production area by 2020. This project is in collaboration with the Philippine Department of Environment and Natural Resources and has the stated eventual goal of 100 percent AWD coverage in the country. Because of the far-reaching nature of this existing national program, further investments in AWD should potentially be designed so as to complement or integrate with AMIA. Other activities in the rice sector, such as improved fertilizer management and improved use of rice straw, also offer significant opportunities for abatement at very low cost (potentially with net cost savings to the landholder). Coordination with the large AMIA program may also be advisable for these other rice-oriented activities.

Data on potential for investment in the livestock sector is limited. The B-LEADERS study (IRG, 2015) evaluated the use of biodigesters for cost and abatement potential but did not assess any other options related to livestock, although we identify other possible options in section 3.2.6. The two Griscom et al. studies (2017; 2020) only provide country-level estimates for two of their four identified livestock-related pathways (Table A1). It is unlikely that investments in the livestock sector in the Philippines will rival investments in the rice or forest sectors in terms of overall climate impact. However, the opportunities that have been identified can offer cost savings to producers as well as significant co-benefits in soil health and water quality; as such, these options may be worth considering depending on investment priorities.

As stated above, the forest sector represents the largest biophysical potential for climate mitigation by a wide margin. This includes forest protection, reforestation, and agroforestry. Reforestation is generally a cost-effective measure in terms of cost per unit of carbon sequestered; however, costs and sequestration rates can vary widely depending on species planted, location, and the degree to which projects need to invest in institutions and governance (Tables 5 and 6). Opportunity costs for reforestation or restoration efforts are largely determined by the presence of high-value competing land uses such as oil palm or other commodity crops. Another factor determining cost is the degree to which reforestation programs attempt to emulate natural forest composition–doing so increases costs substantially relative to timber species. As such, there may be some tension between planting that maximizes climate benefit for a given investment and planting that is designed to have positive biodiversity benefits.

Forest protection is estimated to be more expensive per unit of abatement than reforestation or agroforestry; however, the total biophysical potential nation-wide is significantly greater than all of the other opportunities combined. It also has the largest benefits to biodiversity. Forest protection, however, is likely more complex than the other investments, so the large scale of its potential should be treated carefully. While all of the identified opportunities face implementation challenges, the barriers facing forest conservation are particularly difficult. These barriers include the underlying drivers of forest loss itself–population movement, limited agricultural land, and legacies of historic logging practices–as well as weak enforcement of forest regulations as well as personal dangers faced by activists working in conservation in the country. These barriers are discussed more fully in 3.1.1 and summarized in Table 11.

Investments in environmental governance—as USAID has made before with EcoGov 1 and 2—represent an important opportunity for forest conservation and climate mitigation, although one that is difficult to quantify in terms of tons of CO_2 abatement. Governance is central to addressing deforestation and degradation at a large scale. The two provinces that together are responsible for 25 percent of Philippine emissions from deforestation have particular governance challenges and poor rule of law. Even though it is more difficult to quantify the greenhouse impact of investments in this sector, the best opportunities for addressing deforestation may be through strengthening local governance capacity. This is likely to become increasingly important in future as the government, as part of the National REDD+ Strategy, moves to continue decentralizing forest management.

Prioritizing among SL opportunities in the Philippines depends on many factors, for example the scale of the planned investment, geographical preferences, and any associated priorities such as biodiversity, governance support, or livelihood improvements. Table 11 summarizes the available options across a range of metrics with the intent of supporting decisions on SL options that best reflect the priorities of the planned investment.

Table 11: Multi-criteria assessment of categories of SL strategies

Strategy	Average annual potential 2015-2050 ($MtCO_2e$)	Cost per unit abatement $\$/tCO_2e$	Likely regions of geographic focus (in approximate order)	Associated co-benefits	Potential Risks	Barriers to implementation
Forest protection	1101	16.44	• Palawan • Cagayan Valley • Caraga • Davao	• Very high biodiversity values in the Philippines that will be positively impacted by forest conservation. • Reduced risk of landslides, erosion, and flooding. • Increased availability of NTFPs. • Improved consistency in surface water flows.	• Wildfire is difficult to predict and can rapidly reduce carbon stores in areas affected; firefighting capacity is apparently low. • Danger faced by forest conservation activists may risk safety of project partners.	• Population movement and limited land availability leave households with few options apart from forest clearing. • Opportunity cost relative to high value commodities such as oil palm. • Historic logging efforts established infrastructure and population centres that remain in forested areas. • Limited law enforcement capacity. • Danger faced by forest conservation activists may reduce participation.
Forest restoration, reforestation, and agroforestry	218	-29.85	• Cagayan Valley • Davao	• Increased availability of fuelwood and NTFPs, particularly in areas with low current forest cover. • Hillslope stability; reduced landslides and erosion. • Positive impact on biodiversity. • Improved consistency in surface water flows.	• Lack of clarity around timber harvesting permits and regulations leading to groups or individuals investing in reforestation and being unable to recoup planned revenue. • Markets for timber species can change given long return time to investments.	• Up-front investment costs and long return time to returns (either in case of fruit crop, NTFP, or timber). • Lack of legal clarity around tenure and rights of CBFM groups may limit potential. • Competition with high-value agricultural commodities.

Strategy	Average annual potential 2015-2050 ($MtCO_2e$)	Cost per unit abate-ment $\$/tCO_2e$	Likely regions of geographic focus (in approximate order)	Associated co-benefits	Potential Risks	Barriers to implementation
Improved nutrient management	83.9	-0.92	• Central Luzon • Ilocos • Cagayan Valley • Western Visayas	• Reduction in fertilizer use reduces runoff and improves surface water quality. • Improves soil health. • Organic fertilizers less susceptible to price swings and can reduce risk of economic shock for farmers.	• Risk of yield reduction, particularly when practices are newly-adopted and farmers are less experienced.	• Involvement of multiple techniques entails significant requirements for technical assistance.
Crop diversification	44.9	1.62	• Central Luzon • Ilocos • Cagayan Valley • Western Visayas	• Can reduce pest loads by breaking pest life cycles. • Reduction in fertilizer and pesticide requirements improves surface water quality. • Improves soil health.	• Reduced farm income risks harming livelihoods if compensation is insufficient.	• Will lead to reduced revenue by farmers that will only be partly compensated for by reduced fertilizer costs. • Traditional agricultural practices are well-established and may be difficult to change.
Alternate wetting and drying	28.2 *based on modest area assumptions – another study suggests max potential of 119	0.14	• Central Luzon • Ilocos • Cagayan Valley • Western Visayas	• Cost savings for farmers. • Reduces overall water use.	• Increased emissions of N_2O could offset CH_4 reductions if fertilizer use is excessive or inappropriately timed.	• AWD is a divergence from well-established traditional rice production methods. • Reduced revenue from irrigation fees (due to reduced water use) could potentially lead to resistance from governing bodies of irrigation networks.

Strategy	Average annual potential 2015-2050 ($MtCO_2e$)	Cost per unit abate-ment $\$/tCO_2e$	Likely regions of geographic focus (in approximate order)	Associated co-benefits	Potential Risks	Barriers to implementation
Biodigesters	29.2	-5.42	• Central Luzon • Western Visayas	• Reduced runoff into surface water sources. • Health benefits from cleaner fuel; potential positive impact on gender equity.	• Up-front investment with slow repayment may be a risk for financially insecure households. • Lack of capacity to maintain biodigesters could lead to units ceasing to function before investment recovered.	• Up-front investment of \$500-\$1000 per household; financing likely important.
Improved livestock management	Maximum potential estimated to be ~20-30% reduction in livestock sector.	Estimate not available, but should provide cost savings to producer	• Central Luzon • Western Visayas	• Cost savings for farmers. • Improved soil health. • Reduced runoff into surface water sources.	• Improved forage systems require more labor inputs which can be a risk for producers; these increased inputs should be offset by improved returns but represent an up-front investment.	• Requires high level of technical assistance. • Up-front investment in transitioning forage type and in equipment.

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APPENDIX

Table A1: Description of all 20 mitigation pathways described in Griscom et al. 2017 with updated data from Griscom et al. 2020. Much of the text in the pathways description column is taken verbatim from the Griscom et al. 2017 Supplemental Information. Pathways are ranked from largest to smallest in their total estimated potential globally. Green shading in the left-most column represent forest-sector pathways; yellow are agriculture sector; and blue are wetlands and coastal. The right-most column is an indicator of uncertainty in the estimation of each potential—it presents the ratio between the upper and lower bounds of the 95 percent confidence interval in the estimate.

Pathway	Description and activities included	Philippines maximum potential ($MtCO_2e$ / year)	Philippines cost-effective potential ($MtCO_2e$ / year)	Global maximum potential ($MtCO_2e$ / year)	Uncertainty in global estimate (ratio of upper: lower bounds)
Avoided Forest Conversion	Emissions of CO2 avoided by avoiding forest conversion. Baseline emissions derived from Tyukavina et al. (1), which defined "forest" as >25% tree cover.	22.0	17.63	3,603	1.4
Reforestation	Conversion of land from non-forest (< 25% tree cover) to forest (> 25% tree cover) in areas ecologically appropriate and desirable for forests	n.d.	17.67	10,124	6.6
Natural Forest Management	Additional carbon sequestration (aboveground and belowground) in native forests managed non-intensively for wood production. Maximum scenario is defined as the deferral of all harvests for 50 years (meets safeguard by assuming that plantations can cover fiber needs)	6.5	0.25	1,470	8.9
Improved Rice Cultivation	Avoided CH4 and N2O emissions in from rice cultivation resulting from periodic draining of rice paddies and from the removal of crop residues from flooded and upland rice production lands.	7.1	4.2	265	1.4
Trees in Croplands	Carbon sequestration in both aboveground and belowground tree biomass and soil carbon that results from the integration of trees into croplands at levels that do not reduce crop yields.	7.4	2.77	1,040	4
Cropland Nutrient Management	Avoided N2O emissions due to reduced fertilizer use and improved application methods	0.63	0.57	706	2.4

Pathway	Description and activities included	Philippines maximum potential ($MtCO_2e$ / year)	Philippines cost-effective potential ($MtCO_2e$ / year)	Global maximum potential ($MtCO_2e$ / year)	Uncertainty in global estimate (ratio of upper: lower bounds)
Avoided Woodfuel Harvest	Avoided emissions, all gases, due to reduced harvest of woodfuel used for cooking and heating, without reducing heating or cooking utility	3.29	0.99	367	1.2
Peatland Restoration	Re-wetting of freshwater wetlands (tropical, temperate, and boreal peatlands) to avoid oxidation of soil carbon and to enhance soil carbon sink.	0.23	0.11	815	3.5
Avoided Coastal Wetland Impacts	Avoided emissions from loss of above- and belowground biomass as well as from loss of soil carbon that would result from degradation or loss of coastal wetlands (mangroves, salt marshes, and seagrass beds)	1.72	1.55	304	3.3
Avoided Peatland Impacts	Avoided emissions from loss of above- and belowground biomass as well as from loss of soil carbon that would result from degradation or loss of freshwater wetlands (tropical, temperate, and boreal peatlands)	0.05	0.05	754	5.1
Grazing - Legumes in Pastures	Additional soil carbon sequestration due to sowing legumes in planted pastures	0.74	0.44	147	107.1
Grazing - Optimal Intensity	Additional soil carbon sequestration due to grazing optimization on rangeland and planted pasture. Prescribes a decrease in stocking rates in areas that are overgrazed and an increase in stocking rates in areas that are undergrazed	0.09	0.05	148	4.7
Fire Management	Additional sequestration and avoided emissions in above- and belowground tree biomass due to three forms of additional fire management: (i) prescribed fires; (ii) fire control practices (e.g., fire breaks) applied to edges of forests; and (iii) use of early season fires in savanna ecosystems to avoid higher emissions from late season fires	n.d.	n.d.	212	2.5
Biochar	Carbon sequestration by amending agricultural soils with biochar derived from crop residue	n.d.	n.d.	1,102	2.3
Coastal Wetland Restoration	Re-wetting of coastal wetlands (mangroves, salt marshes, seagrass beds) to avoid oxidation of soil carbon and to enhance soil carbon sink.	0.37	0.11	841	1.7

Pathway	Description and activities included	Philippines maximum potential ($MtCO_2e$ / year)	Philippines cost-effective potential ($MtCO_2e$ / year)	Global maximum potential ($MtCO_2e$ / year)	Uncertainty in global estimate (ratio of upper: lower bounds)
Grazing - Improved Feed	Avoided methane emissions due to reduced enteric fermentation from the use of more energy dense feed and the associated reduction in total animal numbers needed to supply the same level of meat and milk demand.	n.d.	n.d.	680	29
Improved Plantations	Additional carbon sequestration achieved by extending harvest rotations to biologically optimal rotation lengths	n.d.	n.d.	443	6
Conservation Agriculture	Additional soil carbon sequestration by planting cover crops during the part of the year when the main crop is not growing, where appropriate given climate factors and cropping systems	n.d.	n.d.	413	1.7
Grazing - Animal Management	Avoided methane emissions due to reduced enteric fermentation as a result of improved livestock breeds and management techniques that increase reproductive performance, animal health, and weight gain, and the associated reduction in total animal numbers needed to supply the same level of meat and milk demand	n.d.	n.d.	200	2.9
Avoided Grassland Conversion	Avoided soil carbon emissions by avoiding the conversion of grasslands (including savannas and shrublands) to cropland	n.d.	n.d.	116	5

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