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Potential Impacts of INREMP on Selected Ecosystem Services in the KABAMAAM Watershed, Philippines

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Abstract

This study estimates changes in the values of selected ecosystem services (ES) in the KABAMAAM watershed of the Upper Chico River Basin, Cordillera Administrative Region, where the Integrated Natural Resources and Environmental Management Project (INREMP) implemented forest landscape restoration (FLR) interventions from 2013 to 2021. These included conservation farming, agroforestry, commercial tree plantations, assisted natural regeneration, and afforestation/reforestation. Soil erosion and sedimentation control and water yield were quantified using the InVEST model. At the same time, carbon sequestration was assessed through the Rapid Carbon Sequestration Assessment under "without" and "with INREMP" scenarios. Based on domestic and hydroelectric water use, the value transfer method was used to estimate ES values. Results showed that the KABAMAAM watershed's capacity to provide ES improved under the "with INREMP" scenario. Carbon sequestration, erosion, sedimentation control, and water yield increased. Water provision for domestic use generated the highest value—ranging from US$10.5 million to US$15 million per year—while the total value of selected ES ranged from US$18.5 million to US$30.8 million annually. Given these values, replacing natural ES with man-made alternatives would be highly expensive. This study underscores the importance of sustained FLR interventions in enhancing ES that benefit multiple sectors. Thus, effectively managing the KABAMAAM watershed is essential to sustain and further improve its ecosystem service capacity.

***Keywords**:* ecosystem services, KABAMAAM watershed, INREMP, InVEST, RACSA, value transfer

1. Introduction

The Integrated Natural Resources and Environmental Management Project (INREMP) is a seven-year program implemented by the Department of Environment and Natural Resources (DENR), which began in 2013. It aims to reduce and reverse the degradation of watersheds and the environmental services they provide, caused by deforestation and unsustainable farming practices, in four major Upper River Basins in the Philippines: the Chico Upper River Basin (CURB) in the Cordillera Administrative Region (CAR), the Wahig-Inabanga River Basin in Bohol (Region VII), the Bukidnon Upper River Basin in Northern Mindanao (Region X), and the Lake Lanao River Basin in the Bangsamoro Autonomous Region in Muslim Mindanao.

INREMP employs five key mechanisms: protection, conservation, and management of both closed and open canopy natural forests (1); rehabilitation of degraded forestlands, environmentally sensitive areas, and mangroves (2); conservation of biodiversity and carbon offsets (3); income generation through sustainable land and resource use, including value-added activities such as timber and non-timber product processing (4); and payments for environmental services (PES) and resource-derived revenues, including transactions related to water regulation and soil conservation (5). For CURB, the implementation of Natural Resources Management (NRM) interventions mostly began in 2015. In 2018, INREMP partnered with World Agroforestry (ICRAF) to provide technical assistance, including developing sustainable financing schemes in CAR. This involved quantifying and valuing selected ecosystem services (ES) in a pilot site in CURB.

Watersheds and forests generate ES, some of which are traded in markets and have prices, while others remain unpriced due to the absence of markets and are often consumed freely. Land use changes can significantly affect the delivery of these ES. Understanding the value of these services is crucial for informed environmental decision-making and policy development.

CAR is recognized as the “watershed cradle” of the Philippines. CURB, one of its major river systems, is a critical water source for hydroelectric power, irrigation, municipal use, and recreation. Its headwaters are located at Mt. Data in Bauko, Mountain Province. However, the large-scale conversion of forest lands into vegetable gardens in Bauko threatens water resources downstream.

Quantifying ES at the watershed level was undertaken to estimate the ES generated and assess the potential impacts of projects or interventions.

Valuing ES is essential for effective watershed management, helping balance trade-offs among resource use strategies and designing equitable incentive systems between service beneficiaries and providers (Neugarten *et al*., 2018). This effort also supports Target 15.9 of Sustainable Development Goal 15, which aims to "*integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies, and accounts*" (United Nations Statistics Division, 2023).

Economic valuation demonstrates the importance or worth of ecosystems based on the benefits they provide to humans. Various methods have been developed to assess these benefits. Primary valuation involves generating original estimates for specific ecosystem services (Brander, 2013). When resources are limited, researchers may use existing valuation data through the value transfer method, which applies to ecosystem accounting (Grammatikopoulou *et al*., 2023) and international value transfers (Ready and Navrud, 2006).

This paper is based on a study by ICRAF, which aimed to estimate the changes in the values of selected ES in the KABAMAAM watershed resulting from INREMP interventions. Specifically, it presents models comparing ES quantities under "without INREMP" and "with INREMP" scenarios, and estimates the corresponding values of these services.

2. Methodology

2.1 The Study Site

The KABAMAAM watershed, located at the southernmost end of the Chico Upper River Basin (CURB), serves as its headstream (Figure 1). The name "KABAMAAM" is derived from its four tributary rivers: Kalawitan, Bayudan, Malitep, and Amlosong. Most of the watershed, including its expansive western portion, falls under Climate Type I, characterized by a dry season from November to April and a wet season for the remainder of the year. The rest of the watershed is classified under Climate Type III, which has no clearly defined rainy season and a short dry period lasting one to three months.

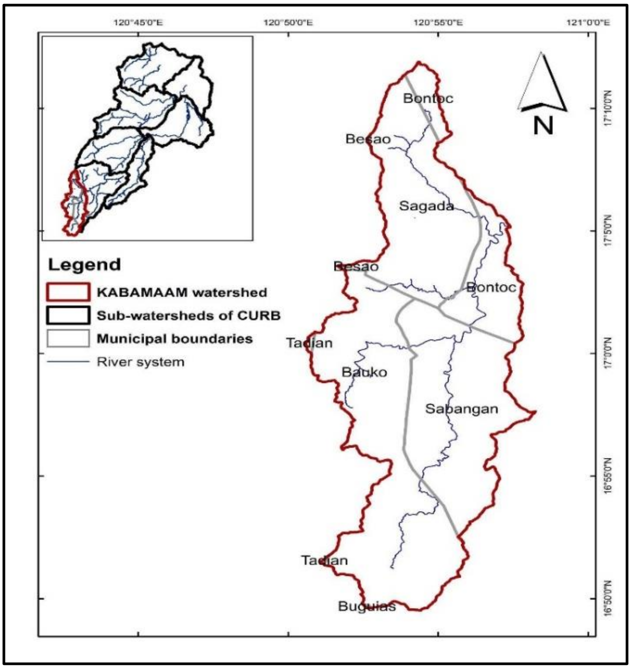

Figure 1. Administrative map of the KABAMAAM Watershed

KABAMAAM covers a total land area of 29,922 hectares (ha), accounting for 7% of the Chico Upper River Basin (CURB). As of 2015, the watershed was home to 9,690 households, with an average household size of four members. It falls under the political jurisdiction of the Municipality of Buguias in Benguet; the Municipality of Tinoc in Ifugao; and the municipalities of Bauko, Sabangan, Sagada, and Bontoc in Mountain Province.

Forests comprise the largest land cover in KABAMAAM (48%), followed by brush/shrubs (24%) and annual crops (19%) (National Mapping and Resource Information Authority [NAMRIA], 2015). The most commonly cultivated crops include cabbage, bell pepper, potato, broccoli, and lettuce.

Much of the KABAMAAM area is exposed to moderate to severe erosion risk, with particularly high susceptibility along its river networks. The Kalawitan River has been identified as a potential site for hydropower development. In 2013, a hydroelectric power facility was constructed in the barangays of Napua and Namatec in Sabangan.

2.2 Framework for the Quantification and Valuation of Ecosystem Services

The methodology is composed of two parts. The first part focuses on quantifying the selected ES of the KABAMAAM watershed, which is necessary before the second part, valuation, can proceed. Both the quantification and valuation of the ES used data and information about the KABAMAAM watershed, such as watershed characterization, that were already available in INREMP reports. The changes in ES due to INREMP were quantified and valued based on their respective appropriate methods (Figure 2). For water yield, the value was based on the replacement cost of water supply for domestic water use and the replacement cost of power production for hydropower use.

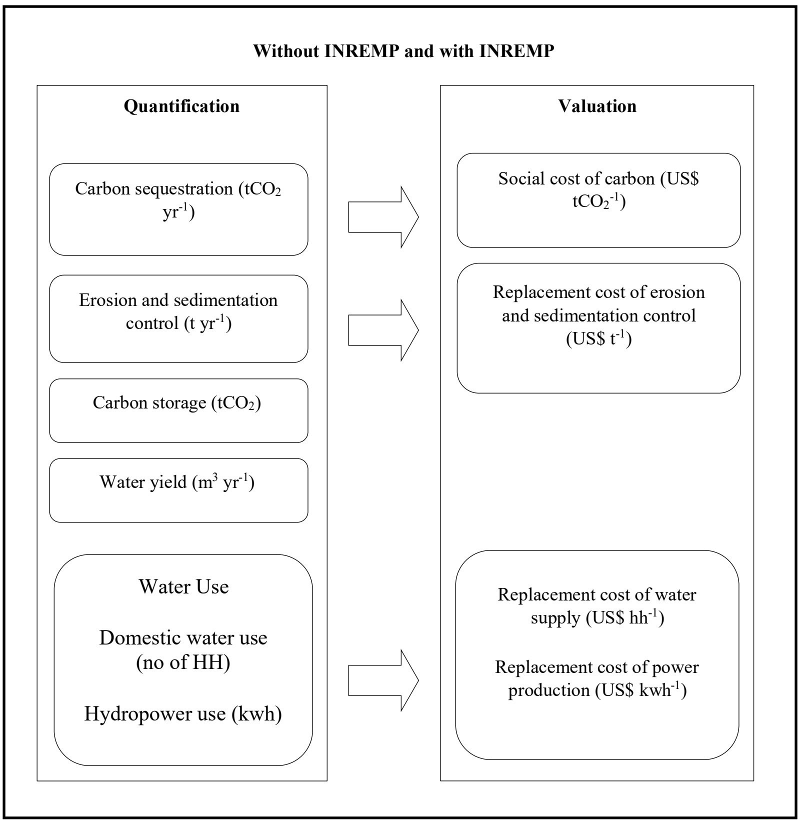

Figure 2. Framework for ES quantification and valuation in the KABAMAAM watershed

2.3 Quantification of Ecosystem Services

Watershed-level quantification of ecosystem services (ES) was conducted for the KABAMAAM watershed, focusing on carbon sequestration, erosion and sedimentation control, and water supply enhancement. These ES were modeled under two scenarios: "without INREMP" and "with INREMP," based on the areas developed by INREMP through interventions such as conservation farming, agroforestry, commercial tree plantations, assisted natural regeneration, afforestation/reforestation, and conservation and protection of natural forests. The modeling assumed that these interventions achieved their intended outcomes, such as increased vegetative cover.

The "without INREMP" scenario utilized only the 2015 land cover map from the National Mapping and Resource Information Authority (NAMRIA). In contrast, the "with INREMP" scenario incorporated the implemented INREMP interventions alongside the 2015 land cover map to reflect their potential contributions to ecosystem services.

2.3.1 Carbon sequestration and storage estimation

Carbon sequestration and storage were estimated using ICRAF's Rapid Carbon Stock Appraisal (RaCSA), a method designed to evaluate carbon under various scenarios that support improved local livelihoods and help alleviate rural poverty. RaCSA is a carbon accounting tool that provides baseline information for stakeholders involved in carbon credit negotiations. It consists of four main components and outputs: a socio-economic survey, carbon stock measurement, land use change and carbon stock assessment through spatial analysis, and simulation modeling (Hairiah *et al*., 2011) (Figure 3).

The socio-economic assessment of the KABAMAAM watershed was based on the survey and watershed characterization conducted by INREMP in 2015. For carbon stock estimation, the study adopted results from Racelis *et al*. (2023), conducted in the tri-boundaries of Benguet, Ifugao, and Mountain Province. The estimation included three carbon pools: aboveground biomass, litter, and belowground biomass. Of the six land cover types analyzed in their study, five were adopted in this study and matched with corresponding land cover classifications from NAMRIA (2015) (Table 1).

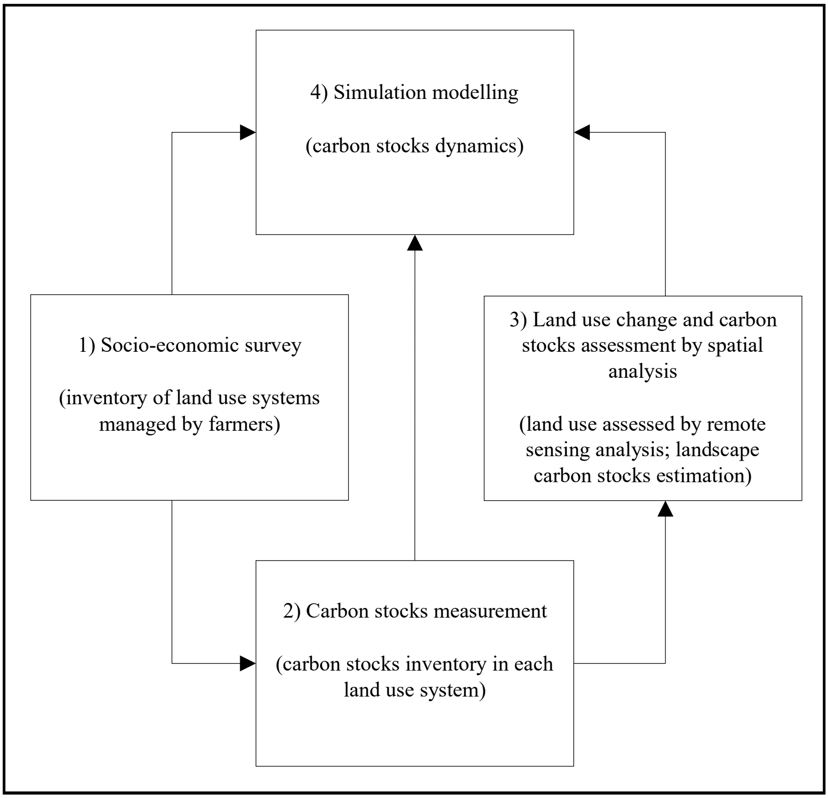

Figure 3. Four main components and outputs under RaCSA (Hairiah *et al*., 2011)

The study aimed to estimate the carbon sequestration benefits resulting from INREMP interventions. However, data on carbon sequestration remain limited due to the need for long-term monitoring (Lasco and Pulhin, 2003). The mean annual increment (MAI) is commonly used to estimate carbon sequestration, as it reflects the annual increase in carbon stock. While MAI data are available for interventions such as agroforestry (Lasco *et al*., 2010) and reforestation (Lasco and Pulhin, 2003), they primarily account for tree stands and exclude other carbon pools.

To address this limitation, the study estimated carbon sequestration by directly converting carbon stock into CO_2 equivalents, using the universal conversion factor of 3.67 (United States Department of Energy, 1998; Pascua *et al*., 2021).

Table 1. Harmonization* of land cover types used in carbon stock estimation

Land Cover Type		Average Carbon ($tC\ ha^{-1}$)	Average CO_2 eq (t)**
Racelis *et al*. (2023)	NAMRIA (2015)		
Closed forest, broadleaved	Closed forest	688.72	2,525.29
Open forest, broadleaved	Open forest	363.52	1,332.90
Open forest, coniferous	Open forest	238.92	876.03
Other wooded land/shrubs	Brush/shrubs	164.43	602.9
Other wooded land/wooded grassland	Grassland	147.48	540.77
Cultivated/farmland	Annual crop	161.67	592.8

**Harmonization of land cover types used by Racelis et al. (2023) and NAMRIA (2015)*
***tCO_2 eq was calculated by multiplying the tC by a conversion factor of 3.67*

For the “with INREMP” scenario, a land transition matrix was used to reflect corresponding changes in carbon stock. For annual crop areas with any Natural Resources Management (NRM) intervention, the study adopted a carbon stock value of 185 t ha^{-1} for agroforestry systems, as reported by Lasco *et al*. (2001), which closely aligns with the values observed by Parao *et al.,* (2015) in vegetable-based agroforestry systems in Benguet.

Brush/shrub and grassland areas that received forestry interventions such as afforestation/reforestation (AFF) and assisted natural regeneration (ANR) were assumed to transition into open forest, coniferous areas (Table 1). Meanwhile, areas under sustainable agriculture interventions—such as agroforestry (AF) and conservation farming (CF)—were assumed to increase their carbon stock to 185 t ha^{-1}, consistent with Lasco *et al*. (2001).

Open forest areas with forestry interventions were assumed to experience increased canopy cover, adopting the carbon stock estimates of Racelis *et al.* (2023) for open forest, broadleaved classifications (Table 1). However, community-based protection and monitoring (CBPM) interventions were excluded from the carbon estimation due to the lack of data on reduced deforestation rates, which represent the additionality the project seeks to capture.

2.3.2 Erosion and Sedimentation Estimation

The Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) Sediment Delivery Ratio (SDR) model—specifically its sediment supply component—was used to estimate erosion and sedimentation under both "without INREMP" and "with INREMP" scenarios. The InVEST SDR model estimates a landscape's sediment retention capacity by incorporating factors such as geomorphology, climate, vegetative cover, and land management practices (Natural Capital Project, 2023).

The model operated at a spatial resolution of 5 × 5 meters and a temporal resolution of one year. It followed three main steps: first, estimating the amount of soil erosion in each pixel; second, calculating the sediment export from each pixel to the stream; and third, determining the total sediment retention within the KABAMAAM watershed. The model is based on the Revised Universal Soil Loss Equation (RUSLE) as embedded in the software (Renard *et al*., 1997). Table 2 presents the data inputs used in the SDR model.

Table 2. Data used for the InVEST SDR model

Data	Data source
Digital elevation model, drainages, threshold flow accumulation, watershed, slope-length gradient	Interferometric Synthetic Aperture Radar (IFSAR) data from NAMRIA
River system	NAMRIA
Soil map (for rainfall erosivity index)	Bureau of Soils and Water Management
Ki values (for rainfall erosivity index)	Stone and Hilborn (2012)
Precipitation (for rainfall erosivity index)	Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), WorldClim (1x1km)
Land use/ land cover	NAMRIA (2015) for "without INREMP" scenario INREMP's NRM map (2020) for "with INREMP" scenario
Crop management factor (C)	Renard *et al.* (1997), Stone and Hilborn (2012), Roose (1996); David (1988)
Support practice factor (P)	Renard *et al*. (1997)
Maximum SDR, calibration parameters	Vigiak *et al.* (2012); Sharp *et al.* 2020

2.3.3 Water yield estimation

The InVEST Water Yield model was used to estimate the annual water supply in the KABAMAAM watershed. This model assesses the relative water contribution of different land cover types across the landscape and provides insights into how land use changes affect annual surface water yield. Two scenarios were modeled: the "without INREMP" scenario, which utilized 2015 land cover maps, and the "with INREMP" scenario, which incorporated land cover changes resulting from INREMP interventions.

The model calculates the amount of water running off each pixel as the difference between precipitation and evapotranspiration. It then aggregates and averages the water yield at the sub-watershed level. The model is primarily driven by annual average precipitation and the Budyko curve, which approximates actual evapotranspiration as a function of the aridity index. Among the empirical equations available to represent this relationship, the model applies the formulations proposed by Fu (1981) and Zhang *et al.* (2004), both of which are embedded in the software. The input data used for the water yield model are summarized in Table 3.

Table 3. Data used for the InVEST Water Yield model

Data	Data source
Precipitation	PAGASA daily data from selected gauging stations, Worldclim 1x1 km resolution
Reference evapotranspiration	Zomer *et al*. (2008), yearly resolution
Depth to root restricting layer	Dobos *et al*. (2012) cited in United States Department of Agriculture ([USDA], 2012)
Soil texture (for estimating plant available water content)	USDA (1998)
Root depth	Schenk and Jackson (2002) and Allen *et al*. (1998)
Crop coefficient	Allen *et al*. (1998)
Land use/ land cover	NAMRIA (2015) for "without INREMP" scenario and INREMP's NRM map (2020) for "with INREMP" scenario
Digital elevation model, watersheds, river system	IFSAR data from NAMRIA
Z parameter	Donohue *et al.* (2012) and Zhang *et al.* (2004).

2.4 Valuation of Ecosystem Services

The valuation of water was conducted in the context of its domestic and hydropower uses. The number of households in the KABAMAAM watershed was estimated using 2015 household data per local government unit (LGU) from the Philippine Statistics Authority (PSA, 2016), adjusted based on the proportion of households located within the watershed. The 2020 household population was projected using the 2015 data and the annual population growth rate of Mountain Province, which is 1.97%.

Only the municipalities of Bauko, Bontoc, Sabangan, and Sagada were included in the population projection, as PSA (2016) data are only available at the city/municipality level. Of the 63 barangays within KABAMAAM, 61 are under Mountain Province—including Bauko, Sabangan, Sagada, and Bontoc—while Benguet and Ifugao each have only one barangay. Mountain Province accounts for 97% of the watershed's total land area.

A single hydropower company currently uses water from KABAMAAM for power generation. According to the National Water Resources Board, the company was granted a maximum water extraction rate of 6,895 liters per second from the Chico River in September 2013.

This study employed the value transfer method for valuation, which involves estimating the value of an ecosystem service (ES) at a policy site—KABAMAAM—by applying existing values derived from similar ecosystems in other locations. While also referred to as the benefit transfer method, the term value transfer is more inclusive, as it can involve transferring either benefit or cost estimates. The approach was adapted from the Guidance Manual on Value Transfer Methods for Ecosystem Services by the United Nations Environment Programme (Brander, 2013).

The KABAMAAM watershed served as the policy site, with the focus on assessing the effects of INREMP interventions on the delivery of ES to beneficiaries. These services were identified in stakeholder workshops with participants from the Chico Upper River Basin (CURB), including Indigenous Peoples Organizations (IPOs) from Bauko (Mountain Province), Buguias (Benguet), and Tinoc (Ifugao), along with potential buyers from hydropower companies and other interested agencies.

The ecosystem services identified for valuation were water supply (provisioning) and carbon sequestration, erosion control, and sedimentation control (regulating). Baseline levels of ES provision and the extent of changes due to INREMP were quantified using watershed characterization and other INREMP reports, as described in the previous section. Data on affected populations, including number and household size, were drawn from INREMP documentation, official statistics, and related sources.

A literature review was conducted to identify valuation studies relevant to the Philippines and other comparable contexts. The studies were evaluated for relevance, quality, and methodological compatibility. Appropriate unit values were selected from this literature, considering whether values were expressed per beneficiary (e.g., US$ per household) or per unit of ES (e.g., US$ per ton).

Carbon sequestration, erosion control, and sedimentation control values were expressed per ton (US$ t^{-1}). In contrast, water yield values were expressed per household (for domestic use) and per power plant (for hydropower use). It was assumed that water use per household and kilowatt-hour of energy generated were comparable between KABAMAAM and the study sites used in the literature. Given the availability of suitable data and the similarity between the policy and study sites, the unit value transfer method was applied.

To ensure consistency over time, the transferred values were adjusted for inflation based on Gross Domestic Product (GDP) deflators from the World Bank Development Indicators. Adjustments were made using the standard formula presented in Equation 1:

$$WTPP = WTPS\ (DP/DS) \qquad (1)$$

where:

WTPP = willingness to pay at the policy site
WTPS = willingness to pay at the study site
DP = GDP deflator index for the year of the policy site assessment
DS = GDP deflator index for the year of the study site valuation

The adjusted unit values of the ecosystem services (ES) were then multiplied by the extent of change observed in the policy site, the KABAMAAM watershed. To account for possible uncertainties in the value transfer estimates, a range of values was generated for the different ES, where applicable.

3. Results and Discussion

3.1 INREMP Interventions in the KABAMAAM Watershed

Forest ecosystems provide a wide range of ecosystem services (ES), including provisioning, regulating, cultural, and supporting services, depending on their structure and ecological functioning. In the KABAMAAM watershed, the Project's Commercial Forestry Investment Sub-Projects (CFISPs) include several Natural Resources Management (NRM) interventions: afforestation/reforestation (AFF), assisted natural regeneration (ANR), agroforestry (AF), conservation farming (CF), and community-based protection and monitoring (CBPM). All these interventions aim to restore the watershed into a well-functioning, service-generating ecosystem.

The AF and CF interventions were initially selected by the project based on the biophysical characteristics of each parcel, such as slope and elevation. Despite differences in implementation, both approaches share the goal of enhancing land cover while offering sustainable livelihood opportunities for local farmers. For instance, crops such as coffee, pear, lemon, green tea, and Japanese tomato are integrated into both systems. Some farmers also incorporate trees like *Alnus japonica* (alnus), *Pinus kesiya* (Benguet pine), *Erythrina variegata* (dapdap), *Viburnum luzonicum* Rolfe (atelba), and *Clethra canescens* var. *luzonica* (Merr.) Sleumer (apiit), along with nitrogen-fixing agricultural crops such as peanuts. These systems differ slightly in the farmers' priority species and their planting density.

Table 4. Areas developed by INREMP in the KABAMAAM watershed by intervention

Year	AFF (ha)	AF (ha)	ANR (ha)	CF (ha)	CBPM (ha)	Total (ha)
2015	75.89	543.62	870.54			1,490.05
2016	49.81	71.95	139.6			261.35
2017		12.55	50.03	53.70	1,456.33	1,572.61
2018		10.10	20.02		2,047.30	2,077.42
Total	125.70	638.22	1,080.18	53.70	3,503.62	5,401.43

While ANR and AFF differ in approach, species selection under both interventions was largely influenced by the preferences of the people's organizations (POs) and the biophysical context of the sites. Benguet pine is the most commonly planted species due to its abundance in the area. Other commonly used species include *Syzygium subcaudatum* (Merr.) Merr. (beltik), dapdap, and atelba.

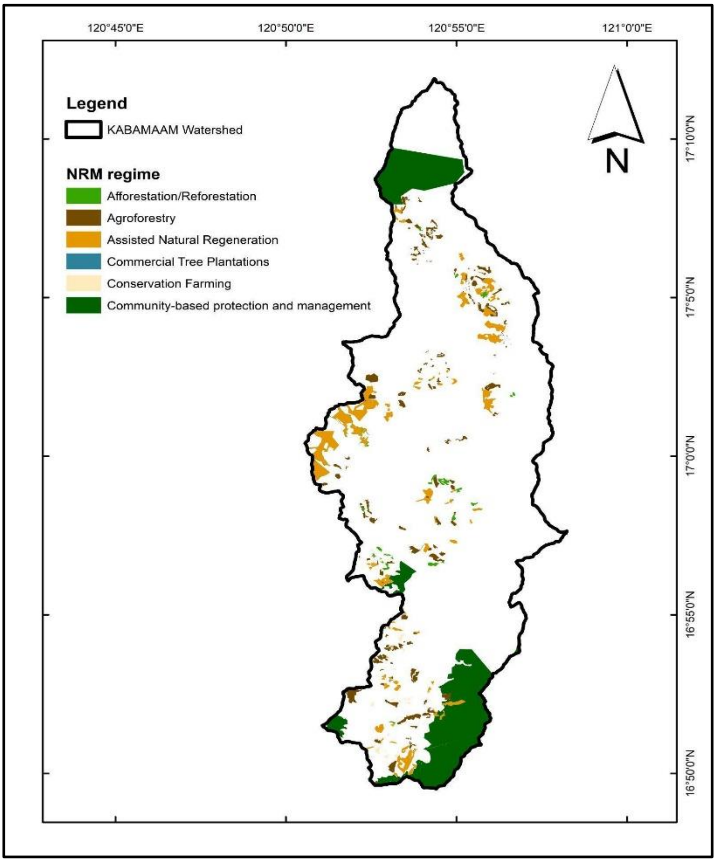

Figure 4. INREMP interventions by NRM regime as of 2020

As of January 2020, INREMP had established a total of 5,401 hectares under NRM interventions, consisting of 125.70 ha for AFF, 638 ha for AF, 1,080 ha for ANR, 54 ha for CF, and 3,504 ha for CBPM (Table 4). Two POs were contracted for large-scale conservation and protection efforts: Ahin Farmers Development Organization Inc., covering 902 ha, and Kabatangan Ancestral Domain Indigenous Peoples Organization (KADIPO) Inc., with 2,601 ha. The spatial distribution of these interventions within the watershed is presented in Figure 4.

3.2 Quantification of the Ecosystem Services of the KABAMAAM Watershed

Table 5 summarizes the results of the quantification of carbon sequestration, erosion, sediment export, and water yield. Under the "with INREMP" scenario, the estimated carbon stock was 8,338,795 tC yr^{-1}, which is 168,327 tC yr^{-1} higher than the "without INREMP" scenario. This increase can be attributed to the rise in tree and vegetation cover as a result of INREMP interventions. Conversely, both erosion and sediment export decreased under the "with INREMP" scenario by 165.977 t yr^{-1} and 39,660 t yr^{-1}, respectively, indicating improved erosion and sedimentation control services brought about by the project interventions.

Figure 5 presents the modeled sedimentation and water yield maps of the KABAMAAM watershed, highlighting sub-watersheds where INREMP interventions had the most significant impact. The watershed exhibited a general increase in water yield between the "without INREMP" and "with INREMP" scenarios. Specifically, water yield in the "without INREMP" scenario was estimated at 578,245,937 m^3 yr^{-1}, while the "with INREMP" scenario showed an increase of 2,057,026 m^3 yr^{-1}, resulting in a total water yield of approximately 580,302,963 m^3 yr^{-1}.

These results align with the findings of Li *et al.* (2022), who confirmed the significant positive influence of forest ecosystems on services such as carbon storage, water yield, and soil retention in the China–Mongolia–Russia Economic Corridor. Similarly, Kusi *et al.* (2020) used the InVEST model to quantify ecosystem services under three spatially explicit scenarios—trend, development, and conservation—and found that integrating forests with croplands through agroforestry systems enhances the provision of carbon sequestration, sediment retention, and water yield. Furthermore, Baskenta and Kaspar (2022) reported that increased afforestation and regeneration lead to more productive forests by improving basal area, growing stock, and volume increment, thereby enhancing associated ecosystem services. Van Meerveld *et al.* (2021) also highlighted that young regenerating tropical forests can improve hydrological ecosystem services by reducing overland flow, soil erosion, and local flood risk, and by contributing to groundwater recharge and baseflow. Additionally, Udawatta and Gantzer (2022) emphasized that agroforestry enhances soil, water, and land productivity and reduces flood damage, primarily due to the presence of perennial vegetation, minimized machinery operations, and reduced reliance on chemical inputs.

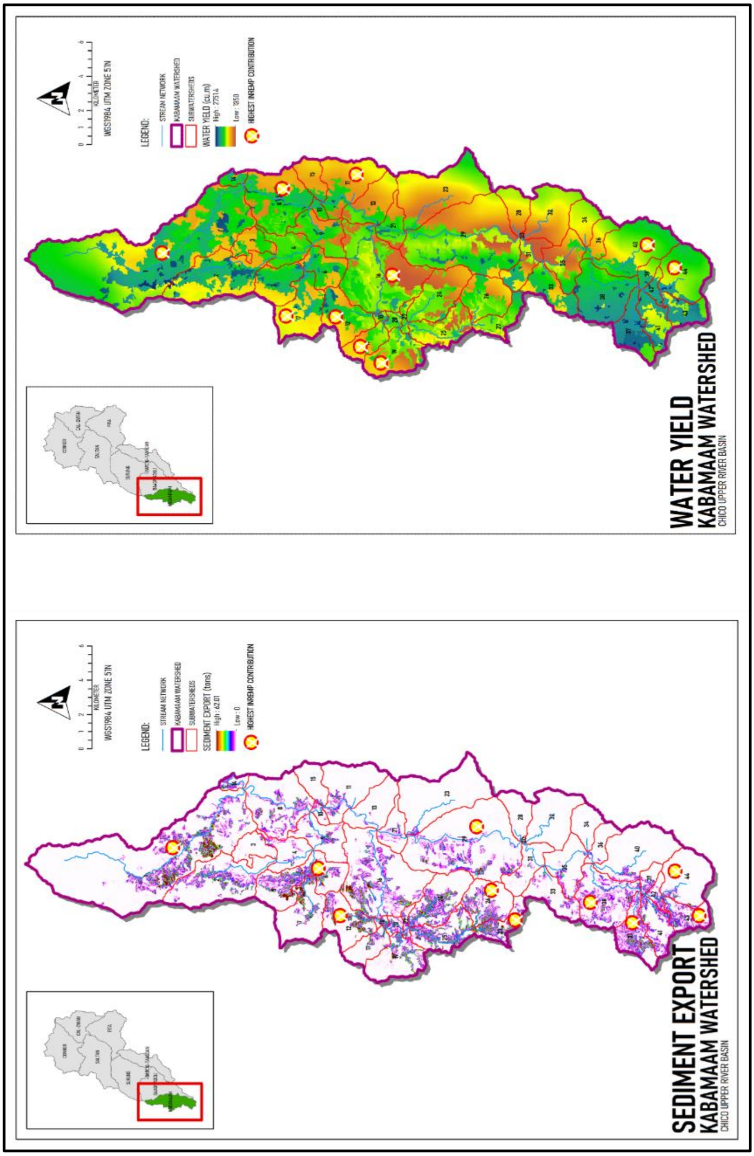

Figure 5. Sedimentation and water yield maps of KABAMAAM watershed

Table 5. Quantification of selected ecosystem services of the KABAMAAM watershed under the "without and with INREMP" scenarios

Ecosystem Service	Without INREMP	With INREMP	Difference
Carbon stock, t yr^{-1}	6,385,610	6,503,419	117,809
Carbon sequestration, tCO_2 equivalent (t yr^{-1})	23,435,188	23,867,549	432,361
Erosion (t yr^{-1})	6,381,738	6,215,761	-165,977
Sediment export (t yr^{-1})	1,028,348	988,688	-39,660
Water yield (m^3 yr^{-1})	578,245,937	580,302,963	2,057,026

3.3 Valuation of the Ecosystem Services of the KABAMAAM watershed

Table 6 summarizes the estimated values of the different ecosystem services (ES) in the KABAMAAM watershed. The valuation employed the value transfer method using data from two study sites: the DENR–PROFOR–World Bank study (hereafter referred to as the PROFOR Study) for carbon sequestration, erosion control, sedimentation control, and domestic water use (Rawlins *et al*., 2017), and the study by Saastamoinen (1994) for valuing water used in hydropower generation. The valuation approaches applied in the source studies were the replacement cost method for erosion and sediment control and water supply, and the social cost of carbon (SCC) for carbon sequestration. All transferred values were adjusted to 2020 using appropriate GDP deflators.

Although both carbon storage and carbon sequestration were estimated for the "with" and "without INREMP" scenarios, only carbon sequestration—the amount of carbon dioxide captured annually by vegetation—was assigned a monetary value. The implementation of four INREMP interventions is expected to increase carbon sequestration from 23,435,188 tCO_2 yr^{-1} to 23,867,549 tCO_2 yr^{-1}, or an additional 1,049,572 tCO_2 yr^{-1}. This translates to a value of approximately US$5.19 million per year (using a low SCC estimate of US$12.00 tCO_2^{-1}) to US$18.16 million per year (using a high SCC estimate of US$42.00 tCO_2^{-1}) (United States Environmental Protection Agency, 2017). Among the interventions, assisted natural regeneration (ANR) contributed the most to this increase due to its large implementation area across low-carbon-density zones such as brush/shrub, grasslands, and open forests. Agroforestry (AF) contributed the second-largest increase, as it was implemented across wide areas of annual crops and brush/shrub lands.

Table 6. Summary of values of selected ecosystem services of the KABAMAAM watershed

Ecosystem Service	Adjusted Study Site Value			Extent of ES (or Beneficiary)		Value of ES (US$ yr-1)	
	Low	High	Unit	Value	Unit	Low	High
Carbon sequestration	12.00[a]	42.00[a]	US$ tCO_2^{-1}	432,361	tCO_2^{-1}	5,188,332	18,159,162
Erosion control	3.14[b]	-	US$ t^{-1} yr^{-1}	165, 977[c]	t yr^{-1}	521,167	-
Sedimentation control	-	3.91[b]	US$ t^{-1} yr^{-1}	39,660[c]	t yr^{-1}	-	155,071
Water, domestic use	590.05[b]	842.13[b]	US$ HH-[1] yr^{-1}	17,802[d]	HH	10,504,070	14,991,598
Water, hydroelectric power generation	0.05[b]	-	US$ kwh^{-1}	55,000,000[e]	kwh yr^{-1}	2,750,000	-
Water, power generation for oil turbine plant(P/kwh)	0.17[b]	0.23[b]	US$ kwh^{-1}	55,000,000[e]	kwh yr^{-1}	9,350,000	12,650,000
Water, power generation for gas turbine plant (P/kwh)	0.23[b]	0.29[b]	US$ kwh^{-1}	55,000,000[e]	kwh yr^{-1}	12,650,000	15,950,000
Savings, HEP vs oil turbine	0.12[b]	0.18[b]	US$ kwh^{-1}	55,000,000[e]	kwh yr^{-1}	6,600,000	9,900,000
Savings, HEP vs gas turbine	0.18[b]	0.24[b]	US$ kwh^{-1}	55,000,000[e]	kwh yr^{-1}	9,900,000	13,200,000
TOTAL (if oil turbine)						22,813,569	43,205,831
TOTAL (if gas turbine)						25,113,569	46,505,831

[a]*Low and high values based on the SCC at 5% and 3% discount rates, respectively (www.epa.gov)*
[b]*1US$: PhP48.5(26Sep2020)*
[c]*Based on the result of watershed delineation through the InVEST SDR model*
[d]*Projected 2020 population was based on PSA census, annual population growth rate of 1.97, and percentage of households lying within KABAMAAM*
[e]*Energy output in 2017 based on the hydroelectric power company's output (2020)*

The reduction in erosion and sedimentation under the "with INREMP" scenario was attributed to the interventions' positive effect on regulating services. Erosion was reduced by 165,977 t yr^{-1}, valued at US$521,170 per year using a unit value of US$3.14 t^{-1}. This unit value is based on the cost of replacing the erosion control function with coco matting, which is widely used by DENR and other agencies for slope stabilization. Sedimentation was reduced by 39,660 t yr^{-1}, with an estimated value of US$155,070 per year, based on a unit value of US$3.91 t^{-1}. This value reflects the cost of mitigating sedimentation through check dam construction (capital cost) and routine desilting (recurring cost).

The valuation of water for domestic use was based on household water consumption rather than the modeled total water yield from InVEST. In the PROFOR study, the replacement cost method was used to value surface and groundwater in scenarios where watershed-sourced water is no longer available. The estimated replacement costs range from US$590.05 per household per year (Upper Marikina River Basin Protected Landscape) to US$842.13 per household per year (Libmanan-Pulantuna Watershed). Applying these values to the estimated 17,802 households in the KABAMAAM watershed results in a total annual value ranging from US$10.50 million to US$14.99 million for domestic water supply.

For the valuation of water used in hydroelectric power generation, two benchmark values from Saastamoinen (1994) were utilized. These represent the cost of replacing hydropower (adjusted to approximately US$0.05 kWh^{-1}) with alternative energy sources: oil turbines (US$0.17–0.23 kWh^{-1}) and gas turbines (US$0.23–0.29 kWh^{-1}). Assuming an annual hydropower output of 55 GWh, the cost of generation using hydropower is US$2.75 million. In comparison, generating the same amount of energy using oil turbines would cost between US$9.35 million and US$12.65 million, while using gas turbines would cost between US$12.65 million and US$15.95 million. Thus, hydropower generation results in annual savings of US$6.6 million to US$9.9 million compared to oil turbines, and US$9.9 million to US$13.2 million compared to gas turbines.

In summary, the estimated total value of the ecosystem services—carbon sequestration, erosion and sedimentation control, water for domestic use, and water for hydroelectric power generation (valued based on cost savings compared to oil and gas turbines)—ranges from US$22.81 million to US$43.21 million per year (using oil turbines as the alternative), and from US$26.11 million to US$46.51 million per year (using gas turbines).

The values derived using the replacement cost method represent the expenditures required for mitigating the loss of ecosystem services (United Nations *et al*., 2014). For instance, if the watershed's water resources were depleted due to degradation, it would become prohibitively expensive for upland communities to access water, primarily because water delivery services are costly in remote and elevated areas. Similarly, if hydropower potential is lost, electricity generation using oil or gas would incur significantly higher costs.

While projects such as INREMP demonstrate the potential to improve forest cover and enhance the delivery of key ecosystem services, it is equally important to consider the associated costs alongside the benefits. For example, Fiorini *et al*. (2020) evaluated a payment for ecosystem services (PES) project in Brazil and found that increases in forest cover were more often due to reduced deforestation than reforestation. Moreover, these outcomes came at an average cost of US$32,963 per hectare, largely financed through off-site mitigation funds.

4. Conclusions and Recommendation

This paper aimed to estimate the changes in the values of selected ecosystem services (ES) in the KABAMAAM Watershed, where the Integrated Natural Resources and Environmental Management Project (INREMP) implemented interventions such as agroforestry, reforestation, conservation farming, and assisted natural regeneration. The results demonstrate that the capacity of the KABAMAAM Watershed to provide ES—including carbon sequestration, soil erosion control, sedimentation control, and water yield for domestic use and hydroelectric power generation—is enhanced under the "with INREMP" scenario, assuming successful and sustained implementation of the interventions.

Among the ES assessed, water provision for domestic use generated the highest estimated value, ranging from US$10.50 million to US$14.99 million per year. The direct value of hydropower generation was estimated at US$2.69 million per year, while the cost savings from using hydropower instead of oil or gas turbines ranged from US$6.78 million to US$13.10 million annually. The value of carbon sequestration ranged between US$720,420 and US$2.52 million per year, and the values of erosion control and sedimentation control were estimated at US$521,610 and US$154,920 per year, respectively. Altogether, the total value of the selected ES in the KABAMAAM Watershed is estimated to range from US$18.53 million to US$30.77 million per year.

These findings highlight the vital role of watersheds—particularly the KABAMAAM Watershed—in delivering ecosystem services that benefit a wide range of sectors. Replacing these services with man-made alternatives would entail significant societal costs. Therefore, it is essential to sustain the natural resource management interventions initiated by INREMP to maintain and enhance the ecosystem's capacity to provide ES. Continued support—both financial and in-kind—for the upland communities managing these lands is critical to achieving the intended project impacts and improving both ecosystem function and local livelihoods.

The study successfully quantified and valued the potential changes in ES delivery resulting from INREMP interventions. In the context of developing a Payment for Ecosystem Services (PES) scheme, it is recommended to conduct ES quantification and valuation at smaller management units. This information could be used by Indigenous Peoples Organizations (IPOs) involved in INREMP as a basis for determining pricing in PES transactions. Furthermore, future studies should explore other dimensions critical to the development of PES in the KABAMAAM Watershed, including social, technological, ethical, political, and institutional considerations.

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