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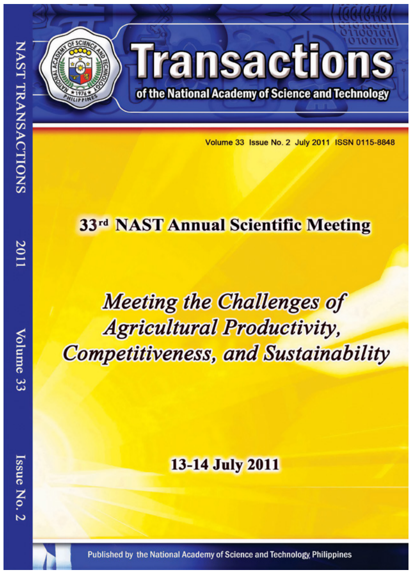

Sustaining Ecological Services for Agricultural Productivity, Sustainability and Competitiveness

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SUSTAINING ECOLOGICAL SERVICES FOR AGRICULTURAL PRODUCTIVITY, SUSTAINABILITY AND COMPETITIVENESS

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Abstract

Philippine agriculture is dependent on natural ecosystems for its productivity, competitiveness and sustainability. The last century witnessed massive destruction of terrestrial, wetlands, and marine ecosystems in the country. This has adversely affected agriculture productivity. Provision of water from watersheds has been impaired and soil resources have been degraded. There is a need to engage in massive rehabilitation activities in the country's watersheds. Biodiversity resources are being decimated. This could have long term impacts on sustainability of agriculture production. The ability of natural systems to regulate climate has been impaired. However, there is potential for carbon sequestration in forests. Natural ecosystems can also help small holder farmers adapt to a changing climate. There is need to re-examine policies and institutions so that ecological services are restored and enhanced. One promising approach is through the use of rewards and incentives to conserve natural ecosystems and the services they provide.

Introduction

For agriculture to flourish in the Philippines, a healthy natural resource base is a necessity. Natural ecosystems provide supporting, provisioning, regulating and cultural services to farmers (**Figure 1**) which help them adapt to climate risks. For example, watersheds supply water for irrigation. A diverse set of plant species in forests provide genetic material for food, fiber and tree crops. Forested landscapes minimize soil erosion that could damage water reservoirs and farm lands through silt deposition.

Unfortunately, the Philippines have a severely degraded natural resources capital base which has adversely affected the environmental services they provide. In the early 1900s, it was estimated that 70% of the country was covered with 21 million ha of forests (Garrity et al. 1993). However, at present only about 7 million ha of forests remain (FMB 2011). Thus, in the last century alone, the Philippines lost almost 15 million ha of tropical forests.

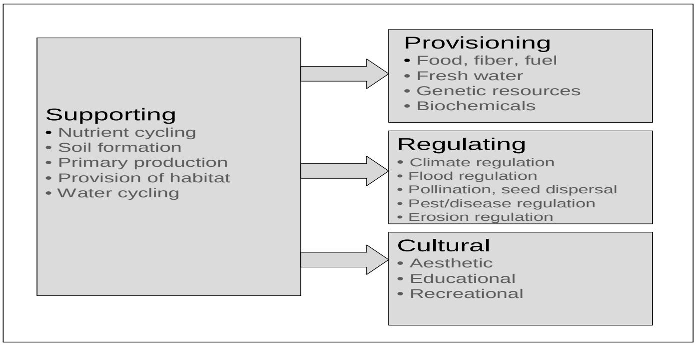

Figure 1. Ecological services provided by natural ecosystems to agriculture (adapted from the Millennium Ecosystem Assessment 2005a).

Since the early 1970s, when extensive reforestation efforts began in the Philippines, various incentives schemes have been devised and implemented to encourage people to plant trees on private and public lands. However, after more than three decades of support, reforestation in the Philippines has largely been ineffective and inefficient (Chokkalingam et al. 2006), partly because the incentives provided were either inappropriate or neglected the long-term nature of reforestation. For instance, on public forest lands, the 25-year renewable instrument of land tenure is not a sufficient incentive to invest in long-term forestry and environmental protection (Garrity et al. 1993). Moreover, resource-use rights are transferred just partially. Short-term contracts and direct payments to farmers were not able to draw a genuine interest in tree planting either.

This has resulted in the rapid deterioration of ecological services from forest ecosystems and watersheds of the country. For example, water for irrigation has been decreasing and the supply has been erratic. Intensive agricultural production in the uplands was observed to affect supply of irrigation water in the lowlands (Lantican et al. 2003). Annual flooding events destroy millions of pesos worth of agricultural crops and produce. Accelerated soil erosion decimates thousands of hectares of prime agricultural lands through sedimentation (Coxhead and Shively 2005).

In this paper, we analyzed the key ecological services that impact agricultural productivity, sustainability and competitiveness. We focused on water and soil conservation, biodiversity resources, and climate change. In addition, we discussed relevant policies and institutional issues and present the potential of rewarding and/or paying local communities for the ecological services they provide.

Water and Soil Resources

State and drivers

Water and soil resources are two of the most essential natural assets needed to sustain agricultural productivity in the Philippines. However, soil and water are also two of the most extensively degraded natural resources due mainly to anthropogenic activities (Vorösmarty et al. 2010, Cruz et al. 2011). Soil and water resources degradation is largely driven directly by widespread land use and land cover change through land conversion, rapid urbanization, accelerated industrialization, overuse of natural resources, species introduction and infrastructure development (Cruz and Folledo 2005, LLDA and ICRAF 2005, Millennium Ecosystem Assessment 2005a, 2005b and 2005c). In turn, land use change is influenced by output prices (Coxhead et al. 2001). As climate change intensifies, the adverse influences of the above direct drivers are likely to be amplified with serious implications on water supply, soil fertility and land productivity. These direct drivers of soil and water degradation are underlain by fundamental demographic, socioeconomic, political, institutional, scientific, technological and cultural drivers (**Figure 2**).

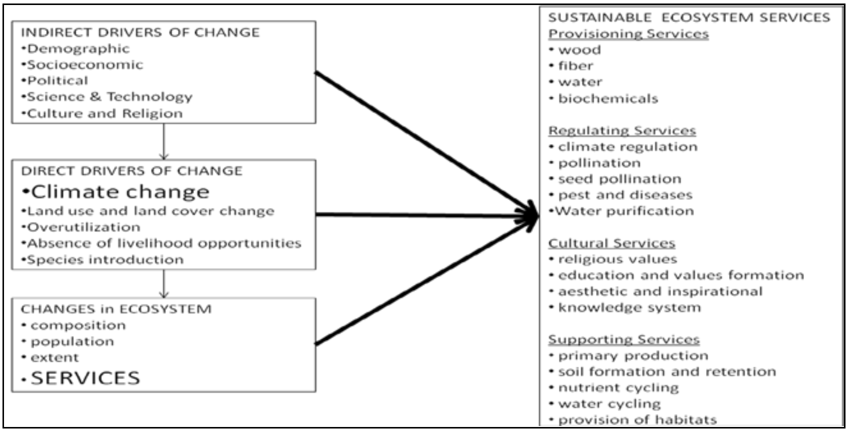

Figure 2. Drivers of changes in ecosystems and its services.
Source: Cruz et al. 201

The loss of forest cover in most watersheds in the Philippines has been severe. Based on the latest estimates of forest cover in the country (**Table 1**) only watersheds in Regions 2, 4, 8 and 11 have more than 30% of land area with forest cover, while Regions 5 and 7 have less than 10% forest cover (Cruz et al. 2011). The ratio of forest cover to irrigated and irrigable lands in many large watersheds is generally low, which could have serious implications on the rate of soil erosion and the availability and quality of water for irrigation. As forest cover dwindles because of the unregulated cultivation and illegal harvesting of timber, soil erosion worsens with the downstream siltation of rivers, lakes, reservoirs, farms, coastal and marine ecosystems that translate into substantial economic losses.

Table 1. Philippine forest cover (by region in ha) as of December 31, 2003

REGION	CLOSED FOREST	OPEN FOREST	MAN-GROVE	PLANTATION FOREST	TOTAL FOREST
NCR	0	2,790	30	*	2,820
CAR	384,877	246,848	0	40,595	672,320
R-01	37,723	117,217	151	34,710	189,801
R-02	503,149	604,473	8,602	33,621	1,149,845
R-03	226,241	304,214	368	58,672	589,495
R-04a	117,162	161,165	11,346	*	289,673
R-04b	484,866	604,246	57,567	48,465	1,195,144

R-05	50,618	90,284	13,499	2,075	156,476
R-06	105,873	104,686	4,600	49,355	264,514
R-07	2,231	43,026	11,770	17,842	74,869
R-08	36,473	410,111	38,781	34,483	519,848
R-09	29,652	126,790	22,278	3,474	182,195
R-10	107,071	226,400	2,492	1,530	337,493
R-11	177,503	240,986	2,010	536	421,035
R-12	126,385	218,858	1,350	2,641	349,234
R-13	64,729	431,832	26,731	*	523,292
ARMM	106,319	96,661	45,786	1,580	250,346
PHILIPPINES	**2,560,872**	**4,030,588**	**247,362**	**329,578**	**7,168,400**

The decline of the country's forest cover is perhaps the most important direct driver of the changes in key ecosystem services and resources, particularly soil and water. The recent economic downturn and subsequent stagnation have further forced marginalized rural population to recourse to unsustainable interventions in ecosystems such as illegal logging, slash and burn, overgrazing and use of harmful chemicals that have been destroying the foundation of long-term land productivity and ecosystem integrity. As a long term impact, the local people are deprived of an important resource base for sustaining their livelihood and their access to food and water are critically reduced.

With respect to the country's Forestry Code, watersheds with 18 percent slope should be vegetated. Yet it is hard to find a watershed in the Philippines with ≥ 18 percent slope which is not at least 50% deforested, with virtually no soil and water conservation strategy in place (Tabios et al. 2008). There is a need to understand more specifically what role forests and reforestation play in soil hydrology dynamics and proper study must be undertaken on how to make reforestation programs more cost effective. This is where science and technology can be employed as indirect drivers of change as indicated in **Figure 2**.

Box 1. Prioritizing reforestation in the Lower Agno River Basin

Tabios et al. (2007) illustrates how to prioritize watershed reforestation efforts with limited resources to minimize soil erosion for the case of the Lower Agno River Basin. Using 70 years of stochastically generated hourly rainfall data, the watershed flows and sediment yields of each of the 164 subwatersheds of the Lower Agno River Basin were calculated using a physically-based watershed model for the existing land use and soils data. The total sediment yield from all these subwatersheds in 70 years is 155.5 MCM (million cubic meters) or an average of 2.22 MCM per year. **Figure 3** shows the watersheds with the highest sediment yields by volume (left figure) and per unit area (right figure). The information provided in these two figures can be used to prioritize watersheds to implement sediment control measures.

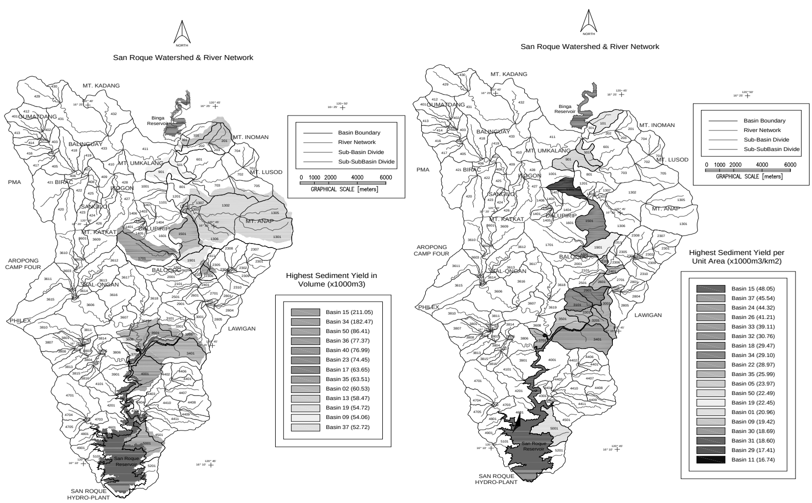

Figure 3. Watersheds with highest sediment yield according to volume (left) and according to unit area (right).

Assuming reforestation is implemented to increase soil infiltration rates by 50 percent, model results show that the total sediment yield in 70 years is 90.2 MCM or an annual average sediment inflow of 1.29 MCM. This implies that reforestation resulted in a reduction of about 65.2 MCM or 42 percent from 155.5 MCM in 70 years. However, a reforestation program for the entire Lower Agno River watersheds may be financially prohibitive. Reduction of the total sediment yield of about 122 MCM in 70 years or 1.75 MCM annual sediment inflow may be based on reforestation efforts only in subwatersheds with the highest sediment yield by volume or per unit area as shown in **Table 2**. The left table shows that a total of 133.48 km^2. in 13 subwatersheds (listed as basin numbers in the table) either need to be reforested or their land-use modified according to watersheds with highest sediment yield by volume. In contrast, model results show that only a total area of 40.82 km^2 in 19 watersheds either need to be reforested or their land-use modified according to watersheds with highest sediment yield by unit area (right table). Thus, it would be more cost effective if the reforestation program will be prioritized based on highest sediment yield by unit area.

Table 2. Accumulative list of subwatersheds to reduce the annual sediment inflow by about 22 percent from 2.22 MCM to about 1.75 MCM according to: (a) highest sediment yield by volume (table on left); and, (2) highest sediment yield by unit area (table on right).

Basin Number	Annual Sediment Inflow(MCM)	Basin Area (sq.km).
15	2132	4.39
34	2.056	10.66
50	2.019	14.50
36	1.987	70.22
40	1.955	75.12
23	1.923	89.04
17	1.896	94.90
35	1.870	97.35
2	1.844	102.03
13	1.819	127.10
19	1.796	129.54
9	1.774	132.32
37	1.752	133.48

Basin Number	Annual Sediment Inflow (MCM)	Basin Area (sq.km.)
15	2.132	4.39
37	2.110	5.55
24	2.099	6.15
26	2.080	7.23
33	2.060	8.47
32	2.044	9.71
18	2.034	10.52
34	1.958	16.79
22	1.954	17.09
35	1.927	19.53
5	1.913	20.96
50	1.877	24.80
19	1.854	27.24
1	1.836	29.31
9	1.813	32.10
30	1.796	34.35
31	1.778	36.63
29	1.763	38.67
11	1.748	40.82

Another key fundamental driver of forest cover loss and soil and water resources degradation in the country is the absence of an integrated, system-based development and management framework within which the multiple uses and functions of forests, soil and water resources can be optimally harmonized amid the growing demands of population and climate impacts. To date, there is no legislation for a unified land use planning and management framework from the national down to the local level leading. This lack leads to uncoordinated land uses and inequitable land allocation, erosive land uses and undue exposure of communities, properties and livelihoods to natural hazards as a result of indiscriminate disposition of lands that are unfit and unsafe for human habitation and related uses. The comprehensive land use plans (CLUPs) at the LGU level are highly localized and often are largely not implemented and hence fail to contribute in promoting the efficient and coordinated uses of land resources.

The absence of an integrating framework also manifests in the fragmentation of authority and jurisdiction over the management of water resources that is unduly shared by more than 30 government agencies. **Figure 4** shows the various agencies with varying mandates concerning water resources administration, development and use. Proliferation of agencies concerned with water complicates the process of drawing a unified vision for the water sector and breeds conflicts amongst the various agencies that often favor decisions that are politically acceptable but are usually technologically and scientifically unsound.

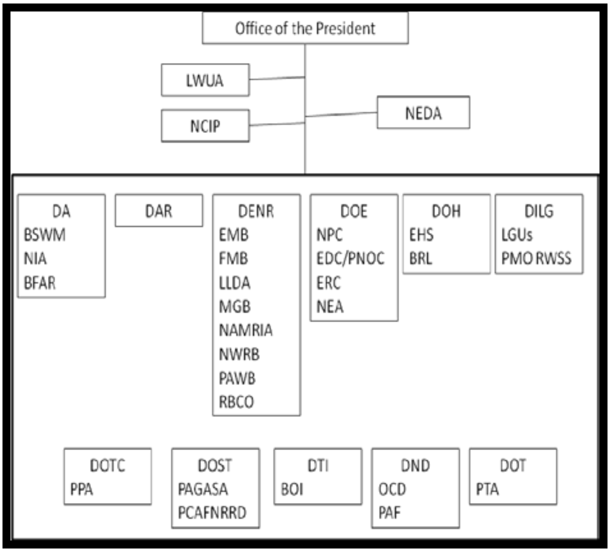

Figure 4. Government agencies with water and watershed related mandates and functions.

Another illustration of how different water agencies can be fragmented and mandated with overlapping range of functions is shown in **Figure 5**. It may be noted that the Philippine Water Code of 1973 already embodied integrated water resources management (IWRM) even before the 1992 Rio Earth Summit. However, the implementing rules and regulation of the Philippine Water Code adopted in June 1979 still recognized the legislated roles of so many players in the water sector resulting in coordination problems and overlap of water management functions. For instance, the mandate of watershed conservation is with the Department of Environment and Natural Resources (DENR), domestic water supply is with the Local Water Utilities Administration (LWUA), irrigation water supply is with the National Irrigation Administration (NIA) and flood control management is with the Department of Public Works and Highways (DPWH). This is in contrast to water district organizations in the United States where watershed conservation, utilization of water for domestic or irrigation water supply, and flood control is the responsibility of one major water agency or district.

	NWRB	LWUA	DENR	WD's	LGU's	DPWH	DOH
Policy Planning	●	●	●	●		●	●
Monitoring	●	●	●	●	●	●	●
Enforcement		●	●	●	●	●	●
Setting of Rates	●	●		●	●		
Adjudication of Complaints	●	●	●	●	●		
Project Implementa-tion and Financing		●	●	●	●	●	●

Figure 5. Fragmented and overlapping range of functions of key Philippine water-related agencies.

Equally a challenging fundamental driver of degradation of forests, soil and water resources is the rapidly growing population that triggers increases in demands and competition for land, water, food and other resources including livelihood opportunities and social services. With the continuous rise in population the scarcity of ecosystem resources, goods and services together with opportunities for development sets in leading to pervasive poverty and degradation of the forests, soil, water and other natural resources. Intuitively, this attribution can be seen in the declining trend of forest cover alongside the rising trajectory of the country's population over the last 450 years or so **(Figure 6)**. Extreme poverty forces people to defy good judgment and sound practices in using land and other natural resources. This is why many people continue to encroach into legally and physically constrained areas such as forests in steep slopes and continue to buck the odds against them and the marginal opportunities these areas offer to make a decent living. The increasing number of people in the fragile sloping lands led to clearing of vast tracts of logged over and primary forests in many parts of the country and the eventual conversion of these areas into mostly agricultural lands that are unsuitable for cultivation purposes.

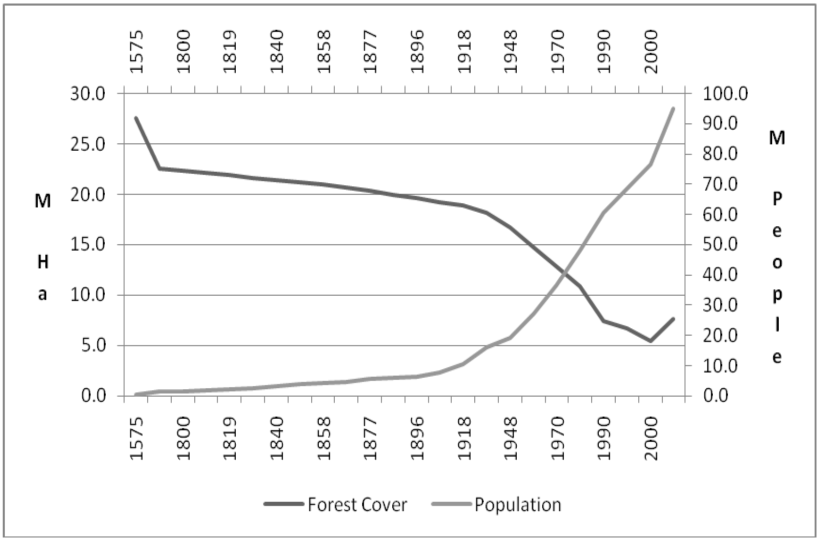

Figure 6. Forest cover and population trend over the years
(Revised MFDP 2005, NCSB 2004, Cruz et al. 2011).

Other fundamental drivers of natural resources degradation in the country include the following (Cruz 2001):

- Poor governance characterized by corruption, weak participation by key stakeholders in development programs and projects, poor accountability, absence of transparency, unpredictable policies, strong political interference;
- Weak capacities of institutions for law enforcement and implementation of appropriate programs;
- Poor coordination among implementing and planning agencies;
- Weak monitoring and feedback system; and
- Fragmented and uncoordinated development planning across various sectors and agencies.

Global, regional and local environmental changes represent an immediate and unprecedented threat to agricultural productivity, sustainability and competitiveness. These changes affect food security especially those who depend on small-scale agriculture for their livelihoods.

Some studies at the global level have reported evidences of a broadly homogenous trend of changes in annual runoff which are attributed to non-climate drivers, as well as climate drivers such as changes in temperature and precipitation (Bates et al. 2008). Moreover, while there is no observed globally consistent trend in the levels of freshwater lakes, other levels of lakes in other parts of the world have declined due to combined effects of many factors such as drought, warming and anthropogenic activities (Bates et al. 2008). In the Philippines, water depths of major lakes have been reduced due mainly to siltation attributed to human activities such as land use changes, accelerated soil erosion, and shifts in agricultural production systems.

Multiple uses of available water resources, including inputs for agricultural production, are determined by local changes in population, food consumption, technological advances, lifestyle and societal views on the value of freshwater ecosystems. The quality of water resources in many rivers in the country have been degraded by pollution from residential, commercial, industrial and agricultural areas (**Figure 7)**. Because of the excessive pollution from these areas, 16 rivers throughout the country have become usually biologically dead during the summer months.

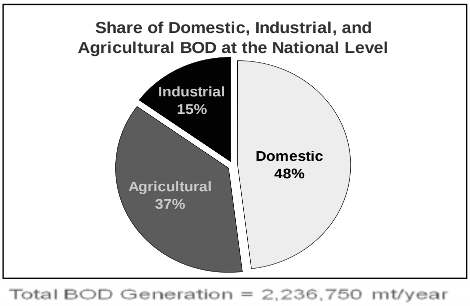

Figure 7. Sources of water pollution in the Philippines
Source: World Bank,2003

The demand for water across all users is rising and by 2025, all user groups in various regions of the country would experience water deficits (**Tables 3** and **4**). Increasing water pollution, worsening climate change and variability, inefficiencies in distributing and using water and continuous degradation of watersheds will exacerbate the situation.

Table 3. Current and projected demand by major user groups

Annual Water Demand (m^3)	1995	2025
Domestic	1958	7430
Agricultural	25533	72973
Industrial	2234	3310- 4998

Source: NWRB Master Plan

Table 4. Water demand in major cities (m^3/yr)

Cities	1995	2025	Groundwater availability	Surplus/(Deficit) (per cent)	
				1995	2025
Metro Manila	1 068	2 883	191	(82)	(93)
Metro Cebu	59	342	60	2	(82)
Davao	50	153	84	69	(45)
Baguio City	12	87	15	21	(83)
Angeles City	11	31	137	1 148	343
Bacolod City	37	111	103	179	(7)
Iloilo City	9	47	80	788	70
Cagayan de Oro City	29	98	34	18	(65)
Zamboanga City	28	203	54	92	(73)

Source: 1998 NWRB Master Plan

Impacts on agricultural productivity

Freshwater resources have an important role in agricultural food production at the local and global levels. Agricultural productivity, especially in rain-fed areas, is dependent on the availability of rainfall to meet the requirements for yield production. Thus, water plays a crucial role in ensuring food security in such an area. Limited water makes agricultural production systems vulnerable to environmental stresses such as droughts. But excess water also makes them vulnerable to floods which destroy crops and affects livelihood activities.

As population increases rapidly at a seemingly uncontrolled rate coupled with depleting trends of water availability, freshwater resources are approaching a critical state in many parts of the country, threatening both agricultural production and livelihoods. Drivers of environmental change are exerting tremendous pressures on the already limited land and water resources for rice production in the country (Lansigan et al. 2007). Changing land use often results to reduction in agricultural lands particularly for rice farming due to conversion of productive farmlands for urban and/or industrial uses. In particular, the sustainability of rice production system in the Philippines is dependent on the availability of adequate suitable agricultural lands as well as the availability and access to adequate water.

Historically, however, significant changes in land use and land cover also lead to modifications of the hydrologic regime of the watershed altering the temporal and spatial patterns of water flows and water resources availability (Lansigan et al. 2007, Bates et al. 2008). Use and management of land and water resources including forests continue to be conducted in a fragmented manner with often limited consideration and attention to the finite nature and interconnections of the ridge-to-reef ecosystem. Maintenance of the ecological flows in rivers and creeks are not even considered. It is observed that despite the comprehensive land use plan (CLUP), conversion of land from agricultural food production to other uses is often not rationalized in the context of food security, watershed integrity, and environmental conservation.

Table 5 shows the scope of land degradation due to water erosion while **Table 6** shows the soil fertility decline in various soil areas in the country and some South East Asian (SEA) countries. Water induced erosion primarily surface soil erosion and gully formation lead to land degradation and reduce the capacity of soils to support the production of food and fiber crops to supply the needs of the growing population in the Philippines and the SEA sub-regions.

Close to 80% of the country’s total land area are affected by soil erosion of which about 45% suffers from moderate to severe soil erosion (DA-DENR-DOST-DAR 2004). The high rate of soil erosion induces

Table 5. Distribution of subtypes of water erosion per country in million ha (Concepcion 2006)

Countries	Total land area	Loss of topsoil (wt)					Terrain deformation (wd)				
		Negligible	Light	Moderate	Strong	Extreme	Negligible	Light	Moderate	Strong	Extreme
Malaysia	33.5	8.0	3.2	1.7	-	-	-	-	-	-	-
Myanmar	66.6	0.4	1.3	0.4	-	-	-	3.4	2.6	-	-
Philippines	29.2	0.4	1.4	4.0	3.7	1.9	-	-	0.6	0.4	-
Thailand	51.4	-	-	7.8	-	-	-	-	0.1	-	-
Vietnam	38.6	0.9	4.2	3.3	0.2	-	-	-	-	-	-
Total	451 Million Hectare excluded Brunei Darussalam										

Source: van Lyuden and Oldeman 1997
Note: - No significant occurrence, + Less than 0.1 M. ha but more than 0.01 M. ha
wt: loss of topsoil by sheet erosion/surface washes
wd: terrain deformation by gully and/or rill erosion or mass movement

Table 6. Distribution of the dominant subtypes of chemical deterioration per country in million ha (Concepcion.2006)

Countries	Total land area	Fertility decline (Cn)					Salinisation (Cs)				
		Negligible	Light	Moderate	Strong	Extreme	Negligible	Light	Moderate	Strong	Extreme
Malaysia	33.5	7.6	2.2	1.7	+	-	-	-	-	-	-
Philippines	29.2	1.6	+	-	-	-	-	-	-	-	-
Thailand	51.4	-	1.1	24.5	-	-	-	-	1.0	-	1.0
Vietnam	38.6	0.2	3.6	0.8	0.4	-	+	0.3	+	-	-

Source: van Lyuden and Oldeman 1997
Note: - no significant occurrence, + less than 0.1 M. ha but more than 0.01 M. ha
Cn fertility decline and reduced organic matter content
Cs salinisation/alkalinisation

sedimentation that reduces the storage and water holding capacity of rivers, lakes and major reservoirs altering water supplies for domestic, industrial, irrigation and power-generation purposes. The country has several large scale dams mostly located in Luzon and Mindanao that are used mainly for irrigation, domestic water supply and power generation. From 1973 to 1998, the area irrigated during the dry season decreased by 20-30% due to the decrease in the storage capacity of reservoirs caused by severe siltation (DENR 1999).

Agricultural productivity of staple crops such as that of rice production systems is a function of the biotic and abiotic factors including climate variability, soil fertility, nutrient and water availability. However, current practices do not promote sustainable rice productivity as well as efficient and optimal use of land and water resources. Crop yields continue to decline due to depletion of soil fertility, inadequate water supply, and other environmental stresses associated with continued reduction in ecological services provided by watersheds. Sustainability of rice production system particularly in the rain-fed farm areas in the Philippines requires an effective and integrated management of land and water resources within the watershed which have to be protected.

2.3 Issues, gaps and research agenda

The succinct foregoing description of the state and drivers of soil and water resources points to the need to explore integrated and comprehensive solutions to the interrelated problems besetting the sustainability of services provided by forests and related ecosystems. The complexity of the interacting drivers and cascading impacts of soil and water degradation **(Figure 8)** underscores the proposition for comprehensive policy, research and technology interventions described below. Once in place the comprehensive solutions will not only ensure the sustainability of agricultural productivity but also bring along co-benefits such as renewable energy supply enhancement, reduction of water related disaster risks and health hazards.

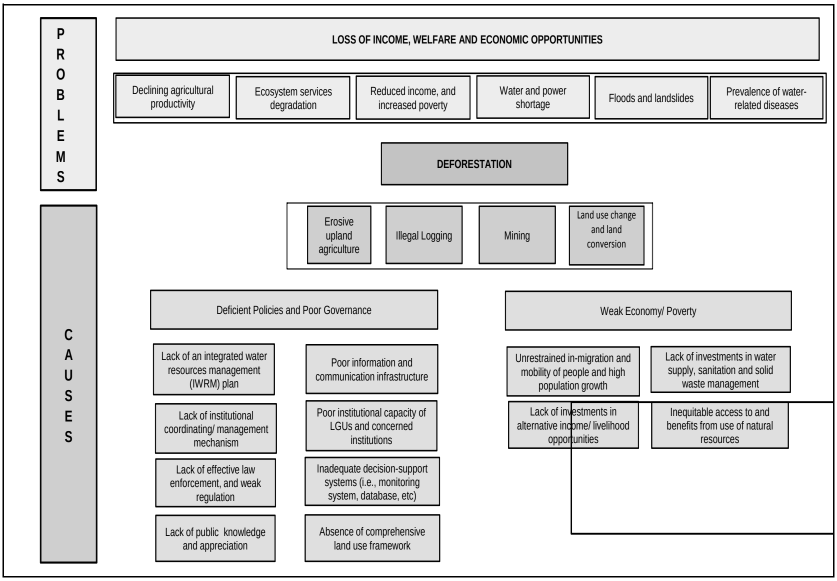

Figure 8. Climate and non-climate related sources of stress on forests and downstream communities, ecosystems and resources
Source: Cruz and Bantayan, 2011

While research continues to improve the intrinsic ability of crop varieties to produce more yields (i.e. potential yield), knowledge how other factors extrinsic to crops could be enhanced to promote greater productivity should also be examined. This also needs a comprehensive approach to address land degradation due to soil erosion, increasing water scarcity, decreasing arable lands due to conversion of crop lands to other uses, underdeveloped production potential of irrigated and irrigable lands, pervasive inefficiency in the use of water and land resources, and other factors that limit crop productivity (Lansigan et al. 2007).

Moreover, it is commonly known that the sustainability of soil and water is critical to the success of watershed management (Cruz 2006). Deterioration of soil and water leading to reduction of ecological services of watersheds will have wide ranging impacts on agriculture as well as on livelihoods, and practically all other sectors of the society. Thus, it is imperative that soil and water resources should be conserved through improved process of determining the best land uses and suitable land use practices that may be allowed in an area, protection of the natural forests and other critical terrestrial ecosystems, restoration and rehabilitation of degraded areas, stabilization of areas prone to erosion and floods, and reduced impact use of the land and other natural resources. Monitoring of land use and land use practices will also prove critical and helpful in the conservation of soil and water resources.

It is recognized that unsustainable agricultural practices as well as current uses and management of natural resources are threatening food and water security. It is estimated that about one-third of the population of the world (circa 2.7 billion people) will experience severe water scarcity by 2025. At current levels of water productivity and water use, a 34% increase in agriculture would be needed (IWMI 2000).

There is a crucial need for a systematic accounting procedure within a spatial accounting framework that considers human security, water and food security, biodiversity, and ecosystem protection. This tool is helpful to be able to reconcile the competing multiple uses of limited soil and water resources as well as maintaining ecological services to conserve biodiversity while satisfying the human requirements for various needs (Vorösmarty et al. 2010). Such tool is also useful for prioritizing policy and management interventions and responses that takes into account agricultural productivity, sustainability and competitiveness of production systems.

Moreover, a strategy has to be developed that considers environmental flow requirements in the revision of the operational rules of reservoirs and dams which may also affect the multiple uses of water resources (Bates et al. 2008). This involves a paradigm shift on the use and management of resources using an integrated ecosystem-based water resources management (IEWRM).

It is also observed that water resources are rapidly being depleted with water withdrawals exceeding recharge rates. Often, water supply is being provided through an overdraft of groundwater resources. Competing multiple uses for water resources due to increasing human demands usually lead to reduction in water for agricultural use in favor of other uses such as domestic and industrial uses, and also for environmental flow. Emerging water scarcity is further exacerbated by the rapid denudation of watersheds. As farmlands, forests and water within a watershed are interlinked in terms of biophysical and social processes; change in one affects the other components. Changes in the forest conditions results in alteration in water regime of the watershed and also lead to changes in social dynamics in the area. These processes and interrelationships have to be better understood so that knowledge-based solutions can be determined to come up with management strategies for optimal use of limited resources as well as meeting the environmental flow requirements to maintain ecological services. This is where the establishment of a network of learning watersheds in key strategic places around the country will be indispensable as venue for long term integrative and comprehensive watershed biophysical and socioeconomic studies.

The extent by which available forest and water resources constrain rice production in the upland and lowland watersheds is a function of efficient use and management of these resources. Efforts should be exerted to lessen the competition for water resources which will enhance local food security, and also make more water available for nature, domestic and industrial uses. Addressing the interrelated issues of food security through self-sufficiency in rice, impending water scarcity, and environmental protection requires an integrated framework and approaches that consider the interconnections of component biophysical and social processes, and interrelated drivers of change. A collective strategy involving the contributions of individuals, groups and sectors will be needed to achieve sustainable rice production and forest resources management vis-à-vis water security.

Sustainable ecosystem management requires a sound planning and policy formulation that will provide a framework conducive to facilitating sustainable land use and ecosystem management practices. Some ecosystems are remote, but share generic characteristics for which common approaches can be undertaken to enhance land use and ecosystem management practices and techniques. Some ecosystems that encompass multiple countries require trans-boundary intervening measures.

In the light of changes in land use and land cover, together with changing climate, there is a need to re-evaluate the dependability of water supply from watersheds particularly in critical agricultural crop production areas. The types and magnitudes of potential changes due to climate change and other drivers of change as well as changes in hydrology have to be determined. These include re-analysis of frequency of droughts and floods, changes in seasonal patterns, water withdrawals, and also water quality.

In adopting a comprehensive agricultural water and land management system, some elements of integrated flood management (IFM) advocated by the World Meteorological Organization-Global Water Partnership (WMO-GWP 2009) may be adopted as follows. In the context of agricultural water and land management, the first major element is *to manage the water cycle* as a whole such that it includes management of all water sources (rainfall, forest streams, upland and lowland lakes and rivers, brackish water near coastal areas), and that management plans should include normal flows, floods and droughts, and that the quantity and quality of both water and agricultural return flows should be managed. Another major element is *to integrate land and water management* so that land-use planning and water management should be in one synthesized plan to enable the sharing of information between land-use planning and water management authorities. The third element is *to manage risk and uncertainty from a holistic point of view* since agricultural risks, although more related to climatologic, hydrological and geologic uncertainties, can also be overwhelmed by social, economic and political risks and uncertainties (e.g., unpredictable changes may come from drastic population growth and unexpected political changes).

Finally, it is strongly suggested that to efficiently implement agricultural land and water resource management strategies, a computerized decision support system (DSS) is needed to link science and technology (i.e., hydrology, ecology, agriculture, sociology, economics and policy science) and the policy actors (civil society, stakeholders, government agency, financial institutions and non-government organizations). When policy makers, planners, regulators, operators and stakeholders seat together to make important water and land policies and management decisions for sustainable agriculture, the DSS can be a very useful tool as a processor, integrator and feedback control of knowledge and actions to develop policy options and decisions.

Biodiversity Conservation

State and Drivers

The Millennium Ecosystem Assessment (2005a) concluded that in the past 50 years, humans have changed ecosystems more rapidly and extensively than in any comparable period of time in history. These changes have been made mainly to meet the rapidly growing demands for food, fresh water, timber, fiber and fuel. These changes have resulted in a substantial and largely irreversible loss in Earth's biodiversity. It is expected that climate change will exacerbate existing pressures on biodiversity resources.

The Philippines is one of 18 mega biodiversity countries due to its geographical isolation, diverse habitats and high rates of endemism (PAWB 2009). It is ranked 5th globally in terms of the number of plant species and maintains 5% of the world's flora. Species endemism is very high covering at least 25 genera of plants and 49% of terrestrial wildlife. It also ranks 4th in bird endemism. In terms of fishes, there are about 3,214 species with 121 endemic and 76 threatened species. The Philippines is one of the world's most threatened hotspots as it continues to lose its rich biodiversity resources (Conservation International 2011). As a leading indicator of the state of its biodiversity, forest cover declined by 50% in the last century **(Figure 9)**.

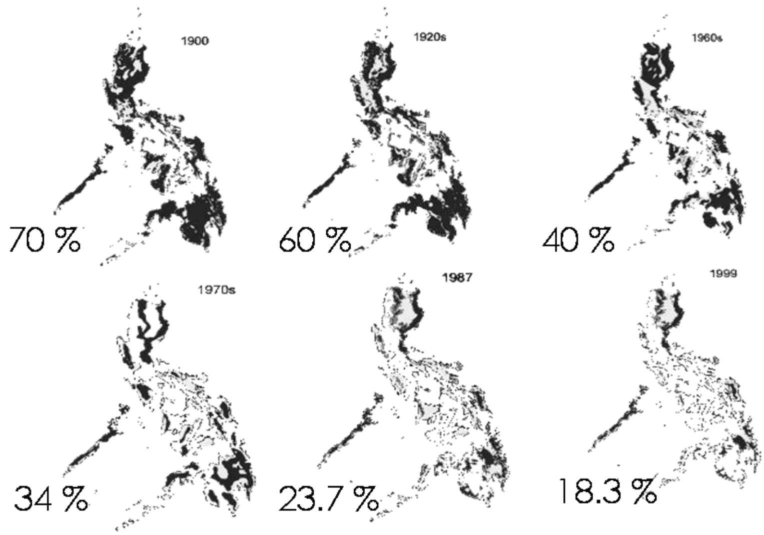

Figure 9. Extents of forest cover in the Philippines for the last 100 year (adapted from Dolom and Dolom 2006)

The key drivers of biodiversity loss include deforestation due to logging and conversion to agricultural land, mining, land conversion and introduction of exotic species (Conservation International 2011, PAWB 2009). Between 1969 and 1988, 2,000 km² were logged annually, three times the global rate for tropical forest conversion. With forests dwindling, logging has recently been banned in all natural forests. However, illegal logging activities still persist. There are more than 10 million people, mostly very poor, who depend on agriculture production in the uplands. The government is promoting mining activities but many of the mining areas overlap key biodiversity areas. The introduction of exotic species has also taken a toll both in terrestrial and freshwater ecosystems.

In addition, there are also governance issues that constrain the country's ability to conserve its biodiversity resources. There are overlapping mandates between the DENR, LGUs, NCIP and other stakeholders in public (forest) lands creating confusion on the ground.

Impacts on Agricultural Productivity

Biodiversity is essential to sustainable agriculture. In general, natural ecosystems and their biodiversity provide many services critical to agriculture such as water as discussed earlier and climate regulation as will be discussed below. Within agricultural systems there is also a range of diversity of plants and animals. This has given rise to a new field of study called agrobiodiversity. "*Agrobiodiversity refers to all crops and animal breeds, their wild relatives, and the species that interact with and support these species, e.g., pollinators, symbionts, pests, parasites, predators, decomposers, and competitors, together with the whole range of environments in which agriculture is practiced, not just crop lands or fields*" (Jackson et al. 2005). From this point of view, agrobiodiversity is the natural capital from which agriculture draws its productivity. In addition, the diverse set of plants and animals in an agricultural landscape provides resilience or ability to change in the long run ("*sustainagility*") (Jackson et al. 2010).

The government recognizes the critical role of biodiversity in sustaining agriculture in the country. The diversity in agricultural ecosystems provides food, medicine and shelter, and indirectly, sustains the sources of farmer's livelihoods (PAWB 2009). It also promotes soil and water conservation, maintenance of soil fertility and biota, and pollination. At the genetic level, it can provide plants and animals the ability to adapt to changing environment by increasing their tolerance to frost, high temperature, drought, water-logging, pests, parasites and diseases.

Issues and Policy Implications

There are still very limited studies on the role of biodiversity in enhancing agricultural productivity in the Philippines. There is a lack of information on the level of supporting, provisioning, and regulating services provided by biodiversity. For example, there is still misunderstanding on the role of forests in providing water and preventing floods. The role of agrobiodiversity in sustainable agriculture is still poorly defined. For example, some sectors of civil society recently raised concerns on the safety of genetically modified crops.

It is recommended that a Philippine ecosystems assessment be conducted similar to the global Millennium Ecosystem Assessment to provide policy makers an overall perspective on the role of natural ecosystems in the life of Filipinos. A panel of eminent scientists from various disciplines such as from the National Academy of Science and Technology (NAST) can be constituted to perform the assessment.

Climate Regulation and Adaptation

Climate change is one of the critical issues of our time. It is projected that small holder farmers will suffer the brunt of its impacts being one of the most vulnerable sectors.

There are two ways by which forest ecosystems can help small holder farmers cope with climate change. On the global scale, forests ecosystems can help in climate change mitigation by conserving carbon stocks and accelerating carbon sequestration from the atmosphere. At the local scale, natural ecosystems can promote adaptation of small holder farmers to changes in climate. This has been called “ecosystems-based adaptation” (EBA).

There is considerable interest on the role of terrestrial ecosystems in climate change, more specifically on the global carbon cycle. The world’s tropical forests covering 17.6 million km^2 contain 428 G t C in vegetation and soils. It is estimated that about 60Gt C is exchanged between terrestrial ecosystems and the atmosphere every year, with a net terrestrial uptake of 0.7 ±1.0Gt C. However, land use, land-use change and forestry (LULUCF) activities, mainly tropical deforestation, are also significant net sources of CO2, accounting for 1.6Gt C/yr of anthropogenic emissions (Denman 2007, Watson et al. 2000). Tropical forests have the largest potential to mitigate climate change amongst the world's forests through conservation of existing carbon pools (e.g. reduced impact logging), expansion of carbon sinks (e.g. reforestation, agroforestry), and substitution of wood products for fossil fuels (Nabuurs et al. 2007).

The Philippines has a small land area so the global contribution of our forests ecosystems is not large. However, each nation must do its share to mitigate climate change. In total, it is estimated that there are around 1,100 Tg C stored in the Philippine uplands composed of forests and other vegetation types (Lasco and Pulhin 2000, Lasco and Pulhin 2001). In relative terms, total carbon stored in forest lands is equivalent to about 40 times the 1994 net C emissions of the Philippines (Lasco and Pulhin 2009). On a per unit area basis, natural dipterocarp forests may contain up to 260 tC per ha while a grassland area will only have < 5% of that value **(Table 7)**. Logging activities lead to a loss carbon stocks which is slowly recovered as the forest regenerate. In Mindanao, about 50% of carbon stocks were lost right after logging (Lasco et al. 2006). On the other hand, deforestation will lead to the loss of more than 90% of carbon stocks.

Table 7. Above ground biomass and carbon density of forest land cover in the Philippines

Land Cover	Biomass (t/ha)	Carbon (tC/ha)
A. Protection Forests		
1. Old growth	370-520	165-260
2. Mossy	409	184
3. Pine	185	90
4. Mangrove	402	177
B. Secondary Forest	466	208
C. Brushlands	64	29
D. Tree Plantation	132	59
E. Grasslands	29	12
F. Agroforestry	103	45

Source: Lasco and Pulhin, 2003

In terms of carbon sequestration, tree plantations have the fastest rate as expected while natural forests have the lowest because they are mature ecosystems **(Table 8)**. As will be discussed later, there is some interest in the Philippines on obtaining carbon credits through forestry projects that sequester carbon. Examples of these are the projects in Quirino, Nueva

Viscaya and Laguna Lake basins which are in various stages of preparation (Villamor and Lasco 2006, Lasco and Villamor, 2010).

Table 8. Mean annual increment (MAI) of above ground biomass and carbon in the Philippines

Land Cover	Biomass MAI (t/ha)	Carbon MAI (t/ha)
Secondary Forest	3.5	1.1
Brushlands	9.5	4.3
Tree Plantation	9.1	4.2
Agroforestry (improved fallow)	10.6	5.3

Source: Lasco et al. 2003

The research community must also ensure that relevant information are made available to project developers. Among the knowledge gaps that need to be filled include:

- Carbon sequestration rates of Philippine trees, especially in various agro-ecological zones of the country;
- Economic analysis of forestry carbon projects;
- Models of production systems (e.g. agroforestry) that will optimize carbon and economic benefits.

On the national scale, there is a need to assess the forestry sector's contribution to the national GHG emissions and sinks using the new 2006 IPCC guidelines. On the policy side, incentives must be provided to project developers of carbon forestry projects. At the same time, proper safeguards must be put in place but without over-burdening project participants. The government must actively participate in the UNFCCC negotiations related to role of forests especially on REDD (reducing emissions from deforestation and forest degradation).

With the expected change in climate, many sectors are assessing how natural and social systems can prepare for this inevitability. Natural ecosystems can help small holder farmers adapt to climate change. EBA is increasingly being used in the international arena such as by IUCN (IUCN 2009). The ecosystem management approach, from which the concept of EBA is based, is supported by many national and international organizations including UNEP, World Bank, IUCN, WCMC and many others (UNEP 2010).

EBA includes a range of local and landscape scale strategies for managing ecosystems to increase resilience and maintain essential ecosystem service and reduce the vulnerability of people, their livelihoods and nature in the face of climate change (IUCN 2009). It addresses the role of ecosystem services in reducing the vulnerability of natural-resource dependent societies to climate change. It is a set of adaptation policies or measures that address jointly the vulnerability of ecosystems and the role of ecosystem services in reducing the vulnerability of society to climate change, in a multisectoral and multiscale approach. EBA involves national and regional governments, local communities, private companies and NGOs in managing ecosystems for reducing the vulnerability of ecosystems, people and economic sectors to climate change (Locatelli 2009 *pers comm*). Fundamentally it is an approach to ensure the provision of the essential ecosystem services that human society depends on.

For example, the Provincial Government of Albay is spearheading the rehabilitation of mangrove forests. Once established mangrove forests will help stabilize coastal zones and those who reside there. The concept of EBA is still new and there are very limited information on this. Research areas include: assessment of the role of forests and natural ecosystems in enhancing the resilience of small holder farmers to climate risks, documentation of indigenous practices, and economic analysis of EBA practices.

In the last decade or so, the climate change issue had already emerged as a burning issue but it appears that there is still skepticism, hesitation or complacency in most sectors of society to seriously take on the climate change issue and challenge. Perhaps one reason is that climate change is a slow process and internalizing this issue on the part of our planners and decision makers is even a slower process with no sense of urgency. Another reason is that truth verification or validation for investments in climate change mitigation or adaptation measures is an evolution in reality, thus the wait-and-see attitude. But perhaps, even with or without climate change, current management strategies and infrastructures are not even developed or designed to deal or handle the historical climate variabilities, anomalies or extremes. For instance, flood control infrastructures in major cities in the country are designed to provide only at 20-year or 30-year return period level of protection when almost yearly, 50-year to 60-year return period floods occur somewhere in the country (Tabios 2010). In order to bring the climate change issue and challenge to the government and people, there should be a national effort to define the climate change scenarios and parameters with support from international and local climate experts. This requires deciding what global climate change scenarios to adopt, deciding what global climate models are appropriate for our country, then deciding what is the appropriate downscaling methodology - tasks that can be tackled by researchers and professionals. Then, finally, translate these climate change scenarios into planning, design or management parameters useful to climate change adaptation measures at the local government units or community level through specific water resources, crop yield, agricultural production and other climate change-related studies.

Governance and Policies

Water

To sustain ecological services by water, i.e. irrigation water, a watershed-based water resource management framework is suggested (Rola et al. 2004a). This framework proposes for the watershed as the primary unit of water resource planning, just as a barangay is the primary administrative unit in the Philippines. It has four elements:

- biophysical, resulting from a watershed-based water resource management strategy;
- legal-institutional, to provide the legal basis and supporting institution to implement the proposed water resource management strategy;
- economic, that is led by economic efficiency consideration; and
- socio-political, defined by the need to have wide support from local communities and political/government units.

What is needed is to define a watershed unit that a given group of administrative units could co-manage (Francisco 2004). The need for a legal and institutional framework to support this coalition of administrative units belonging to a watershed is an important element. Since the watershed transcends administrative units, the need to have a watershed council or authority seems to be a move in the right direction. For instance, Bukidnon province is divided into seven watershed clusters, each cluster consisting of several towns (Rola 2011), and each cluster having its own watershed management plan, consistent with the larger watershed as well.

Local governments also play a major role in water resource management. Key to the success of the required local governance structures are (a) the support of water users; (b) the LGUs' responsiveness to local conditions; (c) the availability of information databases (rather than theoretically better but unavailable information); and (d) the adaptability to the evolving environment. In the Philippines, local governments are empowered to manage natural resources within their spheres of influence and are in a position to make residents comply with best practices in water resource management. However, sometimes capacity to do so is absent, or local officials just refuse to order compliance because they cannot reprimand a "brother" (Rola 2011). In Bukidnon, community water watchers volunteered to monitor river water quality (Deutsch et al. 2001), but have not caught any violator. On the other hand, the economic efficiency consideration requires that situations be created to allow water to flow where its value is highest. These situations include the provision for charging the full water price and clearly defining property rights to water use/access. There is considerable scope to increase the efficiency of water use by introducing market-based instruments. Examples of said instruments are water charges, water markets and imposing effluent charges. It also calls for the payment of compensation to those who provide environmental services (e.g., watershed protection) by those who benefit from these services.

To implement the framework, the NWRB, which is planned to be transferred to the DENR's jurisdiction, could also be strengthened and given more funds to pursue its mandate. At the local level, LGUs can establish water councils or watershed authorities. There is a need to establish a legal environment that allows advocacy initiatives to happen at the local level (Contreras 2004).

Forest Land and Soil

Property rights shaped the fate of forest land and its ecological services. Open access of forest resources contributed to the decline of the forest cover especially upon the advent of logging as the forest land was opened by commercial loggers who were granted a Timber License Agreement (TLA). As these lands became alienable and disposable, and coupled with favorable prices, agricultural land use in the uplands shifted from the traditional perennials such as coffee to erosive annuals such as corn and vegetables (Coxhead et al. 2001), thereby causing soil degradation and water pollution. Protected areas are also in danger of conversion into other uses such as mining, despite the existence of the current laws, such as the Public Land Act and the National Integrated Protected Areas Systems (NIPAS).

The agriculture sector is threatened by this conversion. There is a need to have both a national land use policy and respect for local Comprehensive Land Use Plans. If there is a law to protect the watershed functions (NIPAS), there must be a law to protect the prime agricultural lands. To date there is no legislation on the framework for land use planning and management from the national down to the local level that protects such function as food security. What's available are different versions of the National Land Use Bill awaiting for Congress' approval.

Biodiversity Conservation

Based on the empirical evidence at the ecosystem level, institutions such as the PAMB and policies such as decentralized governance could potentially have an important impact on biodiversity conservation and bio resource management. While the ecosystems serve as habitats of species, what is perceived to be urgently needed are measures to assure that species are themselves managed properly, in as much as loss of species qualify the country as "hot spots" in terms of internationally crafted biodiversity indicators. Several innovative ideas are summarized in Rola et al. (2007):

- Make bio resources management as an integral part of the development plans, where planning exercise starts at the lowest level of governance.
- The science community can build capacities at various levels, like introducing participatory approaches and good governance indicators. Fund management skills by local officials are also to be developed.
- Science contributed to the protected area management planning by supplying the necessary data to the decision makers. In ideal situations, scientists shall continue to work with the other sectors

including government to help develop monitoring and evaluation methods in order to monitor outcomes and evaluate the performance of these management strategies.

- Bio resource indicators are biological variables; management and governance concerns are social sciences, therefore a multidisciplinary team is needed to work with the implementers of the management plan. Researchers and development workers can also help in evolving community based institutions that would be relevant for bio resource management.
- The question of benefit sharing in the commercial use of bio resources should be studied rigorously, to have potential sources of funds for management.
- Study the indigenous peoples' governance and management practices, considered as having sustainable outcomes. Most of the studies in the past focused on resource management practices, including anthropologic and cultural norms. Studies can also include governance sanctions, norms, and incentives.
- Another area of challenge would be how to integrate information and communication technology in bio resource governance. Maps will be needed, so use of GIS can be handy. Mapping will not only be an exercise of identifying and locating the specie, but also of knowing its value or use.
- More efforts on theory development will be needed for meso- level analysis of factors that condition governments, the private sector, local organizations and other stakeholders to work together to support a more sustainable, equitable and efficient bio-resources management decisions.

Climate change

Aside from the threats to food security due to reduction in area of prime agricultural lands, climate change also poses some serious threats. Lasco and Markus-Liss (2008), in their assessment of mainstreaming climate change impacts on the agriculture, forestry and natural resources (AFNR) sector policies in the Philippines showed the lack of recognition of climate hazards. There are currently no existing policies or measures which directly address climate change and its impacts on the population, natural resources, and infrastructures. However, there are a number of laws, which may not directly deal with climate change, but could contribute in strengthening of adaptive capacity to deal with the impacts of climate change in agriculture. For instance, current laws provide for the wise use of water resources, which is largely affected by climate variability. In the near future, the Climate Change Commission (Climate Change Act 2009) can enhance institutional capacity to tackle climate change issues and assure the Philippines' food security needs.

Payments and Rewards for Ecological Services

Maintaining and enhancing ecological services in support of agricultural productivity demands new paradigms. One of most the promising approaches is to use rewards, incentives and/or payments to encourage local communities to protect and conserve natural resources.

There is a lot of interest in payments for environmental services (PES) schemes around the world (Landell-Mills and Porras 2002). An environmental service payment or reward refers to compensation for service, merit or effort, and/or incentive for maintaining or enhancing environmental service functions, received by the sellers or paid by the buyers of the environmental service(s) (van Noordwijk 2005). It is a voluntary transaction in which a well-defined environmental service (or a land use likely to secure that service) is "bought" by a (minimum of one) buyer from a (minimum of one) provider if and only if the provider continuously secures the provision of the service (conditionality) (Wunder 2005). Compensation and incentives can be financial, social and moral. These may be made in terms of direct payments, financial incentives, or in kind. Rewards and payments in kind may include the provision of infrastructure, market preference, planting materials, health and educational services, skills training, technical assistance or other material benefits. In addition to indirect and direct monetary payments, rewards can take the form of land tenure security (which may be considered an economic incentive). Social and moral incentives and rewards may address non-material aspects of poverty including recognition and respect in the community, and personal satisfaction for doing something, which is currently considered beneficial to the society now or in the future or in some cases, the recognition of the service providers in maintaining or enhancing ecosystem services.

Partly in response to the limited success of government-initiated programs, a number of local governments, research organizations and NGOs in the Philippines are testing various PES schemes as a way of reversing environmental degradation. The environmental services being compensated in existing projects include water resources, carbon sequestration, seascape and landscape beauty, and biodiversity.

Watershed functions are considered to be the first environmental service function that has been recognized for payments due to its immediate relevance to the people (van Noordwijk 2005). Communities from different parts of the world are benefited from the commodities that are derived from watersheds such as water flow regulation, water quality maintenance, erosion and sediment control, land and salinisation reduction/ water table regulation and maintenance of aquatic habitats (Landell-Mills and Porras 2002). Countries such as Columbia, Ecuador and Costa Rica are among the countries with established payment schemes for such kind of functions.

In the Philippines, the World Agroforestry Centre's (ICRAF) Rewarding the Upland Poor for Environmental Services (RUPES) project is pilot testing various mechanism for compensating the upland poor. The conditions for developing payments for carbon sequestration and watershed services mechanism have been studied (Lasco and Villamor 2010). After ten years of limited project development in carbon sequestration projects, several lessons have emerged. First, the Philippines have a great potential for climate change mitigation projects in forestry. Planted trees can sequester significant amount of carbon (ca 5 tC/ha/yr). The country has a long experience in reforestation and tree farm development albeit with mixed success. Second, initial economic studies have shown the income from carbon credits is not sufficient to recover the cost of tree planting (using standard government costs). This implies that carbon credits are best used as a supplemental source of income for farmers and project developers. Third, the initial or base costs (including upfront costs, establishment and admin costs) of engaging of forestry carbon projects are enormous (up to US$ 200,000 per project) and could prove to be the most significant barrier to project fruition. One way to overcome this barrier is to partner with a potential buyer who may be able to shoulder the upfront costs as in the case of LLDA and the World Bank projects. Also, government institutions particularly the DENR-FMB must find ways to encourage project developers by simplifying rules and regulations for forestry carbon projects. As it is, forestry projects have few takers because of its complexity and high transaction costs.

The research community must also ensure that relevant information is made available to project developers. Among the knowledge gaps that need to be filled include: carbon sequestration rates of Philippine trees, especially in various agro-ecological zones of the country; economic analysis of forestry carbon projects; models of production systems (e.g. agroforestry) that will optimize carbon and financial benefits.

For watershed payments, the key lessons that have emerged from the Philippines experience are as follows (Lasco and Villamor 2010). First, the value of payments for water services is more easily recognized at various levels from local to national and by different stakeholders. Second, various forms of payments exist but most of them do not satisfy the two main criteria as set by Wunder (2005): voluntary and conditional. Third, the involvement of the government, especially LGUs, is important for the success of PES schemes. Fourth, PES works when threat (e.g. water scarcity), value (e.g. strategic point for commerce), opportunity (e.g. people see the benefits from ES in watershed rehabilitation) and trust are met (e.g. local trust between government, local people and buyers).

While PES offers a promising approach to sustainable financing for the conservation and management of natural ecosystems, there are still many knowledge gaps. A research agenda on PES could focus on: developing PES schemes suited to Philippine conditions, assessment of policy and governance barriers to PES implementation, economic analysis of PES schemes, and pilot testing PES schemes.

Synthesis and Conclusions

Philippine agriculture is dependent on natural ecosystems for its productivity, competitiveness and sustainability. However, the last century witnessed massive destruction of terrestrial, wetlands, and marine ecosystems in the country. This has modified water flows, degraded soils, decimated biodiversity, and reduced climate regulation function. There is no single approach that can address all these challenges. The science community could help by developing options for a more holistic approach in natural ecosystems management.

In order to achieve sustainability, productivity, and competitiveness of agricultural production systems a holistic and ecosystems-based integrated approach is needed to address soil and water resources degradation driven largely by land use and land cover change, rapid urbanization and industrialization, and non-optimal use of natural resources. This requires an integrating framework in the management and multiple uses of resources such as forests, land and water in the continuum from the upper catchment, down to the hilly lands, lowlands and coastal areas.

Optimal use of natural resources to achieve the multiple objectives can be facilitated by the use of a systematic accounting procedure with a spatial analysis in the form of a decision support system (DSS) that consider food security, biodiversity, and ecological services.

The observed changes in hydrologic regimes as well as in land use and land cover changes require the re-assessment and analysis of the dependability of water resources in key and strategic agricultural production areas in critical watersheds. Moreover, re-assessment will also involve the re-evaluation of frequencies of occurrences of floods and droughts, rainfall patterns, and seasonal distribution of hydrologic events that affect agricultural production systems.

There is still very limited information on the role of biodiversity in enhancing agricultural productivity in the Philippines. We recommended that a Philippine ecosystems assessment be conducted similar to the global Millennium Ecosystem Assessment to enlighten policy makers on the role of natural ecosystems in the life of Filipinos. A panel of eminent scientists from various disciplines such as from the National Academy of Science and Technology (NAST) can be constituted to perform the assessment.

Unequivocal climate change which adversely affects agricultural production systems requires appropriate location-specific adaptation strategies and coping mechanisms. This also calls for the mainstreaming of adaptation not only in national and local government planning and operations but also in local communities and farm levels. Strategies which are ecosystem-based adaptation are expected to increase climate resilience as well as maintain ecological services. These strategies and measures should all be incorporated in the Comprehensive Land Use Plan (CLUP) which takes into account for the processes and factors that bring about the changes in natural resources, hydrologic regimes, and livelihoods.

Novel sources of sustainable financing could be explored to support the maintenance and rehabilitation of natural ecosystems. There is a growing interest on payments and rewards for ecological services. The Philippines can explore ways of the emerging global and local markets to ensure that natural ecosystems support our aspirations for sustainable and competitive agriculture.

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