 DOI: 10.11598/btb.2017.24.1.621

ECOLOGICAL SERVICES OF AGROFORESTRY LANDSCAPES IN SELECTED WATERSHED AREAS IN THE PHILIPPINES AND INDONESIA

ROMNICK S. BALITON[1], CHRISTINE WULANDARI[2], LEILA D. LANDICHO[3*], ROWENA ESPERANZA D. CABAHUG[3], ROSELYN F. PAELMO[4], REYNALDO A. COMIA[3], ROBERTO G. VISCO[1], PITOJO BUDIONO[5], SUSNI HERWANTI[6], RUSITA[6] and ARNOLD KARL SA. CASTILLO[3]

[1]*Institute of Renewable Natural Resources, College of Forestry and Natural Resources, University of the Philippines Los Banos, College, Laguna 4031, Philippines*
[2]*Graduate Program of Forestry, Universitas Lampung, Bandar Lampung 35141, Indonesia*
[3]*Institute of Agroforestry, College of Forestry and Natural Resources, University of the Philippines Los Banos, College, Laguna 4031, Philippines*
[4]*Institute of Crop Science, College of Agriculture and Food Science, University of the Philippines Los Banos, College, Laguna 4031, Philippines*
[5]*Faculty of Social Science and Politic, Universitas Lampung, Bandar Lampung 35141, Indonesia*
[6]*Forestry Department, Faculty of Agriculture, Universitas Lampung, Bandar Lampung 35141, Indonesia*

Received 7 February 2016/Accepted 18 January 2017

ABSTRACT

This article argues that the practice of agroforestry provides ecological contributions to the smallholder farmers cultivating in the watershed areas. Specifically, this farming system provides contribution to carbon sequestration potential of the woody perennials and the biodiversity conservation of the other components of the system. This argument is based on the research conducted in Molawin-Dampalit Sub-Watershed, Mt. Makiling Forest Reserve in the Philippines and Way Betung Watershed in Indonesia. The research involved an interview session of 106 and 261 smallholder farmers and an assessment of 27 and 14 agroforesty plots for carbon stock assessment and biodiversity assessment, respectively. Results indicated that the total carbon found among the crop components was 52.32 MgC/ha in Molawin-Dampalit Sub-Watershed and 244.26 MgC/ha in Way Betung Watershed, which suggested the high carbon sequestration potential of the woody perennials and understory crops in an agroforestry system. The farm lots being cultivated by the smallholder farmers were found to contribute to biodiversity conservation having a moderate biodiversity index of 2.59 and 2.53, respectively. With these findings, promotion of desired agroforestry systems in suitable portions of the watershed areas should be intensified and heightened to contribute to ecological balance across the landscape. Agroforestry should always be an integral part of all initiatives toward ecological restoration with the cultivators/smallholder farmers as potential partners. The agroforestry system should consider all the technical and socioeconomic considerations toward having diverse components and ensure food security among the smallholder farmers throughout the year.

Keywords: Agroforestry, biodiversity index, carbon stock, Molawin-Dampalit Sub-Watershed, Way Betung Watershed

INTRODUCTION

Southeast Asia is among regions enlisted as biologically rich and diverse. Three countries, including Malaysia, Philippines and Indonesia, are in fact cited as mega-diverse countries in the region, being the homes of a number of plant and animal species. At present, however, Southeast Asia's biodiversity is highly threatened. Sodhi *et al.* (2004) highlighted that the International Union for the Conservation of Nature and Natural Resources (IUCN) listed three plant and eight animal species as already extinct in the region. Furthermore, the authors emphasized that the number of threatened species in Southeast Asia including in the IUCN categories of critically endangered (CE), endangered (EN) and vulnerable (VU) ranges from 20 (CE) to 686 (VU)

* Corresponding author: ldlandicho@gmail.com

species for vascular plants, 6 - 91 species for fish, 0 - 23 amphibian species, 4 - 28 reptile species, 7 - 116 bird species and 5 - 147 mammal species (Sodhi *et al.* 2004).

Biodiversity loss in Southeast Asia is attributed to a number of factors, including deforestation or clearing of the forest cover; conversion of agricultural lands to other economic purposes; natural calamities such as El Niño, extreme weather events, climate change, forest fires; continued dependence on forest resources as livelihood of the growing population; and, invasive species. These all boil down to the rapid ecological, social and economic changes that the world faces. Most often, the forest dwellers are accused as culprits of the biodiversity loss because of their continued dependence on the forest resources for economic and livelihood activities.

Two of the most popular watersheds in Southeast Asia are the Molawin-Dampalit Sub-Watershed located inside the Mt. Makiling Forest Reserve (MMFR) in the Philippines and the Way Betung Watershed in Indonesia. Besides being the habitat of different flora and fauna, both watersheds have similar conditions such that they are both forest reserves, and therefore, should be free from human occupancy. While policies for the protection, preservation and conservation of these two watersheds are being imposed by their respective governments, these areas continue to be the homes of a number of upland farmers and migrants.

Agroforestry is a land use management system which combines the production of agricultural crops, woody perennials and/or animals or aquatic resources for the twin purpose of production and conservation. Tolentino *et al.* (2010) highlighted that the diversity of plants used in agroforestry provides multiple benefits at different times of the year. These diverse combinations can help buffer its practitioners from the risk of income loss due to price variability, crop failure and other unanticipated problems. Ecologically, agroforestry helps enhance biodiversity of the environment. It is expected that as the diversity of agroforestry farms increases, farmers would have the opportunity to make use of the flora-fauna interaction to control pests and diseases, improve microbiology and nutrient cycling. All these are requisites for survival and improved plant growth.

This article highlights the respective biodiversity and carbon sequestration potentials of selected agroforestry landscapes in the Molawin-Dampalit Sub-Watershed in the Philippines and Way Betung Watershed in Indonesia.

MATERIALS AND METHODS

Study Site

Way Betung Watershed has an area of 5,260 ha, 51% of which is classified as the forest park area and the remaining 49% is classified as agricultural areas (Fig. 1). Most of the upland farmers are engaged in agroforestry, particularly

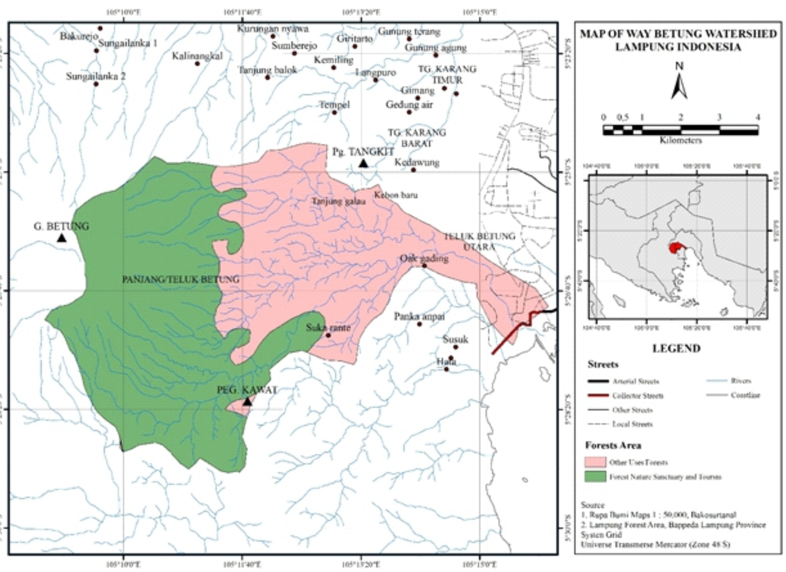

Figure 1 Map of Way Betung Watershed, Lampung, Indonesia

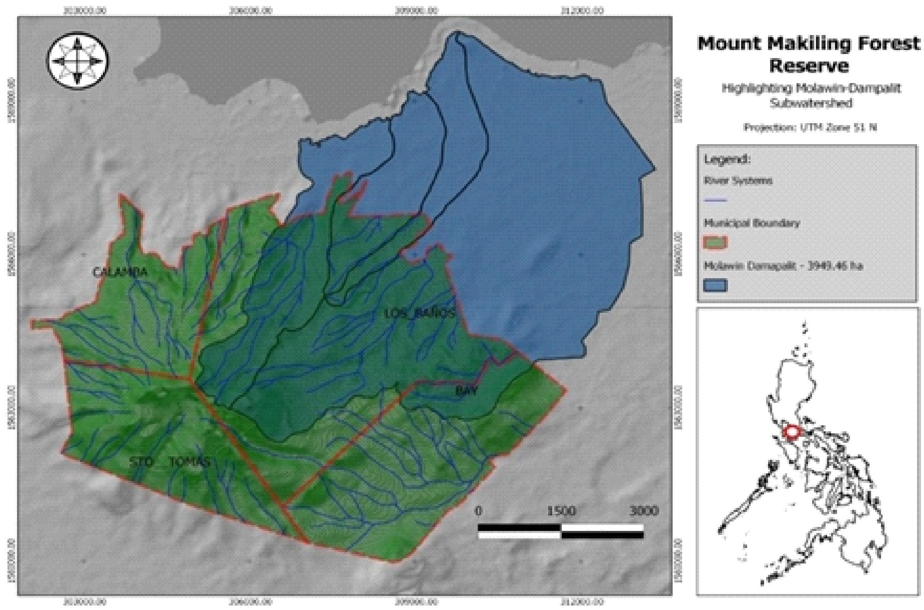

Figure 2 Map of the MMFR highlighting the Molawin-Dampalit Sub-Watershed as the study site in the Philippines

combining the major fruit tree species such as durian, mangosteen, jackfruit, integrated with cacao, coffee, rubber and other forest trees such as mahogany, Alstoria and other forest species.

The MMFR in the Philippines, on the other hand, is a 4,244-ha multiple use forest reservation area (Fig. 2). According to Sargento (1995), MMFR is a protection forest and a watershed reserve, specifically used for training and research laboratory, water source for surrounding communities, biological sanctuary and gene pool of many plant and animal species. This reserve, however, has become a home to a number of farmers and migrants who are engaged in farming. These farmers practice agroforestry, particularly the multi-storey system which combines the production of coconut, fruit trees and other agricultural cash crops.

Socioeconomic Characterization

The characterization was carried out using a pre-tested survey questionnaire. This questionnaire captured socioeconomic information, views and perceptions about agroforestry practices. A total of 106 respondents in Molawin-Dampalit Sub-Watershed and 261 respondents in Way Betung Watershed were selected using random sampling. Results of the socioeconomic survey were analyzed using descriptive statistics, such as frequency counts, percentages and weighted scores.

Biodiversity Assessment

The assessment was conducted by measuring the following parameters of biodiversity, i.e. population density or the number of individual species per unit area; frequency of species distribution; dominance value based on frequency, diameter or biomass; relative and importance values based on density and frequency; and diversity and evenness indices based on the relative and importance values.

Importance value (IV) was computed to determine the dominant species for each site. The IV is the sum of the relative density, relative frequency and relative coverage. These values were computed using the following formula:

$$\text{Density} = \frac{\text{Total Number of tree individuals counted per species}}{\text{Total Area Sampled}}$$

$$\text{Relative Density} = \frac{\text{Total Number of tree individuals counted per species}}{\text{Total Number of all Species}} * 100$$

$$\text{Species Dominance} = (0.7854) * (\text{DBH})^2$$

$$\text{Relative Dominance} = \frac{\text{Dominance of a Species}}{\text{Total Dominance of all Species}} * 100$$

$$\text{Species Frequency} = \frac{\text{Number of Plots species occur}}{\text{Total Number of Plots}} * 100$$

$$\text{Relative Frequency} = \frac{\text{Frequency of a species}}{\text{Total Frequency of all Species}} * 100$$

$$\text{Importance Value} = \text{Relative Density} + \text{Relative Coverage} + \text{Relative Frequency}$$

The measures of biodiversity were obtained using the Shannon-Wiener Diversity Index (H) (Magurran 2004) calculated using formula as follows:

$$H = \sum_{i=1}^{S} - (P_i * \ln P_i)$$

The Pielou's Evenness Index (J) was calculated using formula:

$$J = \frac{H}{\ln S}$$

where: H = Shannon-Wiener diversity index
J = Pielou's Evenness Index
P_i = fraction of the entire population made up of species i
S = total numbers of species encountered
$\sum$ = sum from species 1 to species S

Note: The power to which the base e (e = 2.718281828.......) must be raised to obtain a number is called the natural logarithm (ln) of the number

The index was calculated by dividing the number of individuals of each species found in the sample by the total number of all species (represented by P), multiplied by the fraction of its natural log (P_1 * ln P_1). This procedure was repeated for all of the different species. The sum of all the (P_1 * ln P_1) represents the value of H. Physical evidences of the movement of wildlife in the agroforestry matrix were noted in terms of frequency, duration and kind of species.

Carbon Stock Assessment

The carbon stock of different agroforestry systems was measured using the biomass estimation method. Tree biomass was calculated using the allometric equation of Brown (1997) (Equation 1). This was done by measuring the standing aboveground biomass of the woody perennials or live trees with Diameter at Breast Height (DBH) of 5 cm and above. The total tree biomass density and carbon stored in various agroforestry systems were calculated using Equation 2. Carbon stock of herbaceous (living non-perennial crops) and litter found in the soil surface was calculated to get the total aboveground biomass of each agroforestry system (Equation 3). Belowground biomass of trees and other perennials was obtained using the default value proposed by Delaney (1999) i.e. 15% of the aboveground biomass.

Equation 1:

TAGB= - exp(2.134+2.530 ln(DBH))

where:
TAGB = total aboveground biomass in kg/tree
exp {…} = "raised to the power of"
ln = natural log of {…}
DBH = Diameter at Breast Height in cm

Equation 2:

C stored (MgC/ha) = Tree biomass density *C content
Tree biomass density = Tree biomass (Mg)/Sample area in hectare

Equation 3:

$$\text{Total Dry Weight (kg/m}^2\text{)} = \frac{\text{Total fresh weight (kg) * Subsample dry weight (g)}}{\text{Subsample fresh weight (g) * Sample area (m}^2\text{)}}$$

C stored (MgC/ha) = Tree biomass density *C content

RESULTS AND DISCUSSION

Socioeconomic and Biophysical Characteristics of the Study Sites

Way Betung Watershed and Molawin-Dampalit Sub-Watershed are considered as watershed and forest reserves, which are inhabited by a number of people. Results of the socioeconomic characterization indicated that most of the farmers in the two study sites were male as represented by 73% of the total number of respondents (Table 1). This finding validated previous research which concluded that, in general, farming had become a male-dominated activity (Landicho *et al.* 2014; Landicho, 2015). Majority (86%) of them were married with an average household size of 5. Majority (51%) of the participants had family members ranging from 4 - 6 members. Concurrent with other research, this finding implied the availability of family labor and that the farm households in the upland communities were mostly big.

Table 1 also highlights that the age of farmers in the two study sites were entirely different. The age range of the farmers in Molawin-Dampalit Watershed was from 51 to 60. This data suggested that despite their age, the farmers were able to maintain their current farming systems. However, this finding also presented threat on the sustainability of their farming system, especially considering that not all family members

Table 1 Socioeconomic characteristics of the farmer-respondents in Molawin-Dampalit Sub-Watershed and Way Betung Watershed

Socioeconomic characteristic	Study site				Total	%
	Molawin-Dampalit		Way Betung			
	Frequency	%	Frequency	%		
Sex						
Male	63	59	204	78	267	73
Female	43	41	57	22	100	27
Subtotal	106	100	261	100	367	100
Civil status						
Single	9	9	5	2	14	4
Married	80	75	237	90	317	86
Separated	2	2	1	1	3	1
Widow/er	14	13	18	7	32	9
No answer	1	1	0	0	1	0
Subtotal	106	100	261	100	367	100
Household size						
1-3	40	38	87	33	127	35
4-6	41	39	147	56	188	51
> 6	23	22	27	10	50	14
No answer	2	1		0	0	0
Total	106	100	261	100	367	100
Average	5		5			
Age						
< 30	8		32		40	11
30-40	12		93		105	29
41-50	24		83		107	29
51-60	29		42		71	19
> 60	33		11		44	12
Subtotal	106	100	261	100	367	100
Average	54		43			
Number of household members involved in farming						
1-3	101	96	164	63	265	72
4-6	4	4	37	37	41	27
> 6	1	1	0	0	1	00.27
Subtotal	106		261		367	100
Income source						
Farming	44	41	214	82	258	70
Off-farm	0	0	27	10	27	7
Non-farm	2	2	20	8	20	5
Farming+Off-farm	2	2	0	0	2	1
Farming+Non-Farm	52	49	0	0	52	14
Farming +Off-farm+ Non-Farm	5	5	0	0	5	2
Subtotal	106	100	261	100	367	100

were trained to develop and maintain their farms. On the other hand, the farmers in Way Betung were still young and most probably in their productive age, as majority of them fell within the age range of 31 - 40 years old. This finding suggested that these farmers could already be the second-line farmers. These young farmers might have already been trained by the older farmers, and/or farming may have just started recently in Way Betung Watershed. Furthermore, this data indicated that these young farmers would have higher opportunities for improving their farms.

There were only 1 - 3 members of the family that were engaged in farm development activities. In most cases, though, only the husband and the wife concentrated in farming. It could be that their children were still young; busy in their schooling, or not interested in farming at all. While farming was the major source of income of most (70%) of the farmer-respondents, there were also households whose members were engaged in non-farm activities as an additional source of income. In general, farm income was relatively low with most of the respondents having an estimated farm income of less than USD 200 and USD 200 - 500 in the Philippines and Indonesia, respectively. The low farm income could be attributed to the biophysical conditions of their farm as well as the scope and orientation of their agricultural production.

In general, farm lots in the two study sites were cultivated by smallholder farmers. This was because majority (54%) of the farmer-respondents in the two study sites cultivated lands which were less than a hectare (Table 2). This farming practice provided them with an estimated annual income of less than USD 200 (Table 1).

Table 2 Biophysical characteristics of the farms being cultivated by the farmer-respondents in Molawin-Dampalit Sub-Watershed and Way Betung Watershed

Biophysical characteristic	Study site				Total	%
	Molawin-Dampalit		Way Betung			
	Frequency	%	Frequency	%		
Farm size						
< one hectare	51	44	149	57	200	54
1-3	45	46	111	42	156	43
3.1-5	6	6	1	1	7	2
> 5	4	4	0	0	4	1
Total	106	100	261	100	367	100
Status of farm ownership						
Owned	9	8	0	0	9	2
Tenant	19	18	17	7	36	10
Rented	1	1	0	0	1	1
In public lands	70	66	244	93	314	85
No answer	7	7	0	0	7	2
Total	106	100	261	100	367	100
Farm topography						
Rolling	48	45	132	51	180	49
Steep	10	9	57	22	67	18
Flat	31	29	72	27	103	27
Flat to rolling	16	15	0	0	16	15
No answer	1	1	0	0	1	1
Total	106	100	261	100	367	100
Source of water for crop irrigation						
Spring	12	11	60	23	72	19
River/Creek	5	5	35	13	40	11
Rainfed	85	79	166	640	251	68
Others (e.g. irrigation)	6	5	0		6	2
Total	108	100	261	100	369	100

Understandably, these farmers could not cultivate big farm sizes primarily because they were cultivating in the public/state lands. Thus, they were bound with certain rules and policies in their agricultural production. Most (85%) of the farmer-respondents did not own the lands that they cultivated, and therefore, agricultural expansion was not possible.

Smallholder farmers are described as those who cultivate less than three hectares of land area (ESFIM 2017). By this definition, farmers in the two study sites are categorized as smallholder farmers. While their production orientation was for subsistence, the surpluses were sold in the market for their additional household income. Besides being smallholder farmers, the biophysical characteristics of their farms were characterized as marginal. The topography was generally rolling (49%) and some with steep slopes (18%) and, therefore, the risk of soil erosion was high. However, the risk was being controlled with the practice of sustainable farming system, such as agroforestry. Crops are generally dependent on rainfall as the main source of water/irrigation. Thus, any drastic changes in rainfall and temperature patterns greatly affect their agricultural production.

Agroforestry Practices in the Two Study Sites

With the prevailing biophysical and socioeconomic conditions, the farmer-respondents were observed to maximize the land use of their farms. Most of the farmer-respondents were engaged in agroforestry (77%) and multiple cropping (20%) across the landscapes in the two study sites (Table 3).

The practice of agroforestry was noted in the high-elevation areas, while multiple cropping was highly observed in relatively lower elevation across the two landscapes. This was because the study sites were mostly dominated by forest and fruit trees. Thus, opening of areas to give way for the production of agricultural crops was not permitted. Farmers whose farms were located within the upper stream of the reserves/watershed planted other woody perennials with smaller canopy, root crops and other shade-

Table 3 Agricultural production systems being employed by the farmer-respondents in Molawin-Dampalit Sub-Watershed and Way Betung Watershed

Production system	Frequency				Total	%
	Molawin-Dampalit		Way Betung			
	Frequency	%	Frequency	%		
Cropping system						
Monocropping	7	7	1	0.40	7	2
Crop rotation	3	3	0	0	3	1
Relay cropping	4	4	0	0	4	1
Multiple cropping	43	42	31	12	74	20
Agroforestry	45	43	229	87.6	274	77
Forest plantation	2	1	0	0	2	1
Total	106	100	261	100	367	100
Crop components						
Vegetables	54	16	0	0	52	9
Rice	1	0.30	0	0	1	0.17
Corn	14	4	0	0	14	2
Root crops	56	16.7	0	0	56	9
Fruit trees	101	30	192	73.56	293	49
Herbs	2	12	0	0	2	0.33
Ornamentals	40	12	0	0	40	7
Forest trees	65	19	69	26.44	134	23
Total	333	100	261	100	594	100

tolerant crops as understory. On the other hand, farmers cultivating in open areas having lower elevation had higher opportunities for raising short-term and medium-term crop species.

Farmer-respondents in Molawin-Dampalit Sub-Watershed planted a variety of crop components compared with the farmer-respondents in Way Betung Watershed who planted only fruit trees (Table 3). Among crop components included vegetable crops (16%), fruit trees (30%), root crops (17%), cereals like rice and corn (4.34%), forest trees (19%) and ornamentals (19%).

Farmers in the Molawin-Dampalit Sub-Watershed might have enough open spaces where they could plant short-term crops, while farmers in Way Betung Watershed might have shaded spaces, which might not be suitable for cultivating short-term agricultural crops. Furthermore, almost 100% of the farmlands in Way Betung Watershed were considered as public lands, which made the farmers bound with policies and regulations on crop cultivation (Table 2). Farmlands in Molawin-Dampalit Sub-Watershed were bound for forest reserve. Farmlands located in the lowland ecosystems were still suitable for appropriate agricultural production.

Biodiversity Assessment

Species composition in the two watersheds

A total of 35 tree species with at least 5 cm DBH were found across the 25 sampling plots in Molawin-Dampalit Sub-Watershed (Table 4).

These identified species consisted of 333 individuals belong to 19 tree families. The data revealed that Fabaceae had the highest number of species (6), followed by Moraceae (5) and Meliaceae with three (3) species. Annonaceae, Malvaceae and Sapindaceae ranked 4th having two (2) species each, while the remaining families had one (1) species each. In terms of the total number of individuals, the dominant families recorded were Meliaceae with a total of 90, followed by Musaceae (84), Sapindaceae (50) and Fabaceae (30). Four families namely Euphorbiacea, Lamiaceae, Oxalidaceae and Sapotaceae ranked the least with only one individual recorded across the sampling areas.

In Way Betung Watershed, there were 14 families and 26 species, with 548 individuals found (Table 5).

The highest number of species belongs to family Fabaceae having six (6) species, followed by Myrtaceae, Meliaceae and Arecaceae. Family

Table 4 Summary of existing tree families with corresponding number of species and individuals in Molawin-Dampalit Sub-Watershed

Family name	Number of species	Number of individuals	Rank	
			# of species	# of individual
Anacardiaceae	1	8	5	8
Annonaceae	2	7	4	9
Arecaceae	1	9	5	7
Bignoniaceae	1	2	5	12
Caricaceae	1	6	5	10
Euphorbiaceae	1	1	5	13
Fabaceae	6	30	1	4
Fagaceae	1	2	5	12
Lamiaceae	1	1	5	13
Lauraceae	1	2	5	12
Malvaceae	2	16	4	5
Meliaceae	3	90	3	1
Moraceae	5	13	2	6
Musaceae	1	84	5	2
Oxalidaceae	1	1	5	13
Rubiaceae	1	5	5	11
Rutaceae	3	5	3	11
Sapindaceae	2	50	4	3
Sapotaceae	1	1	5	13
Total	35	333	--	--

Table 5 Summary of existing tree families with corresponding number of species and individuals in Way Betung Watershed

Family name	Number of species	Number of individuals	Rank	
			# of species	# of individual
Anacardiaceae	1	2	4	10
Arecaceae	3	9	2	9
Euphorbiaceae	1	161	4	1
Fabaceae	6	27	1	5
Gnetaceae	1	35	4	4
Lauraceae	1	16	4	7
Malyaceae	2	80	3	3
Malvaceae	1	154	4	2
Meliaceae	3	12	2	8
Myrtaceae	3	27	2	5
Rubiaceae	1	21	4	6
Rhamnaceae	1	2	4	10
Sapindaceae	1	1	4	11
Sapotaceae	1	1	4	11
Total	26	548	--	--

Euphorbiaceae had the highest number of individuals (161), followed by Malvaceae and Malyaceae.

These findings indicated a higher general species composition in Molawin-Dampalit Sub-Watershed compared to that in Way Betung Watershed. However, the number of individual species in Molawin-Dampalit Sub-Watershed was lower compared to that in Way Betung Watershed. This could be explained by the fact that the Molawin-Dampalit Sub-Watershed was one of the area severely hit by Typhoon Glenda (International name Rammasun) in 2014. This could explain why, at the time of the study, the floral components were still on their regeneration stage, mostly below 5 cm DBH.

Importance Value of identified plant species in agroforestry landscape

Across the sampling plots of Molawin-Dampalit Sub-Watershed, banana (*Musa sapientum*) was found to be the most dominant having the highest Importance Value (IV) of 62.07%. It was followed by rambutan (*Nephelium lappaceum*) and lanzones (*Lansium domesticum*) with IV of 36.47% and 32.59%, respectively. Other species having high IV were chico (*Manilkara sapota*) – 25.66%, mangga (*Mangifera indica*) – 21.58% and mahogany (*Swietenia macrophylla*) – 18.79% . Table 6 shows the summary of seven (7) dominant plant species with the highest IV.

The dominance of banana, rambutan and lanzones in Molawin-Dampalit Sub-Watershed

Table 6 Top seven dominant species across sampling plots in Molawin-Dampalit Sub-Watershed, Mt. Makiling Forest Reserve, Philippines

Species name	Scientific name	Importance Value (IV) (%)
Saging	*Musa sapientum*	62.07
Rambutan	*Nephelium lappaceum*	36.47
Lanzones	*Lansium domesticum*	32.59
Chico	*Manilkara sapota*	25.66
Mangga	*Mangifera indica*	21.58
Mahogany	*Swietenia macrophylla*	18.79
Durian	*Durio zibethinus*	12.00

Table 7 Top seven dominant species across sampling plots in Way Betung Watershed, Indonesia

Species name	Scientific name	Importance Value (IV) (%)
Rubber	*Hevea brasiliensis*	70.36
Durian	*Durio zibethinus*	59.72
Cacao	*Theobroma cacao*	48.07
Melinjo	*Gnetum gnemon*	22.54
Petai	*Parkia speciose*	12.46
Avocado	*Persea americana*	12.14
Coffee	*Coffea robusta*	8.87

Table 8 Shannon-Wiener Diversity Index and Pielou's Evenness Index across sampling plots in the two study sites

Main plot	Molawin-Dampalit Sub-Watershed	Way Betung Watershed
Circular Plot: 8.9 m Radius		
H	2.59	2.53
J	0.45	0.41

Table 9 Classification scheme of Shannon-Wiener Diversity Index (Fernando *et al.* 1998)

Relative value	Shannon-Wiener Diversity Index (H)
Very high	3.50 and above
High	3.00 – 3.49
Moderate	2.50 – 2.99
Low	2.0 – 2.49
Very low	1.99 and below

indicated the farmers' preference for cultivating these crops, primarily because of their economic value.

Meanwhile, this research found out that the dominant tree species in Way Betung was rubber tree (*Hevea brasiliensis*) with IV of 70.36%, followed by durian, cacao, melinjo, petai, avocado and coffee. Based on the IV, the dominance level of a species in a community can be known (Indriyanto 2006). Table 7 shows the top seven dominant species across the sampling plots in Way Betung Watershed. Rubber tree is one of the major high value crop that is being cultivated in Indonesia, Malaysia and Thailand because of its economic potential. This explains why this species was frequently found in Way Betung Watershed.

Shannon-Wiener diversity index (H) and Pielou's Evenness Index (J) across sampling plots in Molawin-Dampalit Sub-Watershed was 2.59 and 0.45, respectively (Table 8).

Sampling plots in Way Betung Watershed recorded Shannon-Wiener Diversity Index (H) of 2.53 and Pielou's Evenness Index (J) of 0.41. Based on the H value, diversity of the agroforestry landscape in Molawin-Dampalit Sub-Watershed and Way Betung Watershed was considered to be moderate (Fernando *et al.* 1998) (Table 9).

The computed Shannon-Wiener diversity index (H) indicated that employing an agroforestry practice/system in a landscape may increase the diversity of the landscape compared to employing monoculture type of farming system. Meanwhile, low value of computed Pielou's Evenness index (J) indicated that the number of individual per species in the agroforestry landscape was not evenly distributed.

This finding was validated by Noble and Dirzon (1997) who highlighted that agroforestry is increasingly being identified as an integrated land use that can directly enhance plant diversity while reducing habitat loss and fragmentation (Brent *et al.* 2006). Khanal (2011) also contends that traditional agroforestry practices contribute to the conservation of biodiversity in the western hills of Nepal through in-situ conservation of tree species on farms, reduction of pressure on remaining forests, and the provision of suitable habitat for a number of plants on farmland. This contention was supported by meta-analysis on the effects of agroforestry, biodiversity levels and ecosystems services conducted by Torralba *et al.* (2016). Torralba *et al.* (2016) argued that agroforestry can enhance biodiversity and ecosystem service provisions related to conventional agriculture and forestry in Europe. Furthermore, agroforestry can help the flow of wild plants' genes as well as increase fauna population size and diversity in protected area corridors, if it is tried as a buffer to connect patches of natural forests to facilitate habitat interconnectivity on a larger scale (Baguinon *et al.* 2007).

Carbon Stock Assessment

Biomass density of agroforestry landscape

A mean total of 116.26 Mg/ha was recorded in the agroforestry landscape of Molawin-Dampalit Sub-Watershed (Table 10).

The computed mean total biomass density in this study site was higher than the overall mean of agroforestry (102.80 Mg/ha) in the Philippines (Lasco & Pulhin 2003). Another study of Zamora (1999) on biomass density of narra (*Pterocarpus indicus*) + cacao agroforestry system in Makiling (191.6 Mg/ha) was also comparable with the results obtained in this study.

It can be noted that sampling plots in Way Betung Watershed were mostly forest and fruit trees which in turn contributed much on the biomass density with a mean total value of 542.80 Mg/ha. This was comprised mostly of 86.12%

Table 10 Biomass density (Mg/ha) of agroforestry landscape in Molawin-Dampalit Sub-Watershed and Way Betung Watershed

Item	Biomass density (Mg/ha)				
	Aboveground			Belowground	Mean total
	Trees and other perennial	Herbaceous	Litter	Trees and other perennial	
Molawin-Dampalit					
Minimum	1.98	0.27	0.34	0.30	116.26
Maximum	401.83	2.31	7.45	60.27	
Mean (μ)	97.87 (84%)	1.33 (1%)	2.38 (2%)	14.68 (13%)	
Standard deviation (±)	91.76	0.73	2.07	13.76	
# of Sample plots (n)	27	27	27	27	
Way Betung					
Minimum	168.74	1.58	1.78	25.31	542.80
Maximum	1,160.17	2.31	4.22	174.03	
Mean (μ)	467.47 (86.12%)	1.81 (0.33%)	3.40 (0.63%)	70.12 (12.92%)	
Standard deviation (±)	242.10	0.17	0.59	36.31	
# of Sample plots (n)	14	14	14	14	

Note: Values shown inside the parenthesis are the percentage compositions of different carbon pools

Table 11 Carbon stored in agroforestry landscape of Molawin-Dampalit Sub-Watershed and Way Betung Watershed

Item	Carbon density (MgC/ha)				
	Aboveground			Belowground	Mean total
	Trees and other perennials	Herbaceous	Litter	Trees and other perennials	
Molawin-Dampalit					
Minimum	0.89	0.12	0.15	0.13	52.32
Maximum	180.82	1.04	3.35	27.12	
Mean (μ)	44.04 (84%)	0.60 (1%)	1.07 (2%)	6.61 (13%)	
Standard deviation (±)	41.29	0.33	0.93	6.19	
# of Sample plots (n)	27	27	27	27	
Way Betung					
Minimum	75.93	0.71	0.80	11.39	244.26
Maximum	522.08	0.96	1.90	78.31	
Mean (μ)	210.36 (86.12%)	0.82 (0.33%)	1.53 (0.63%)	31.55 (12.92%)	
Standard deviation (±)	108.94	0.08	0.27	16.34	
# of Sample plots (n)	14	14	14	14	

Note: Values shown inside the parenthesis are the percentage compositions of different carbon pools

from the trees and other perennials, while the lowest was recorded in herbaceous and litter with less than 1%. These results were consistent with the previous study conducted by Wulandari (2013) in watershed areas in Indonesia.

Biomass density of the agroforestry landscape varied considerably in all carbon pools measured as indicated by high values of standard deviation. Huge variation in the biomass density could be attributed to the differences of the components of sampled agroforestry or farming systems. Based on the characterization of the farms, there were some farmers who cultivated fruit trees as their main crop which contributed much to the biomass density. Other farmers planted only few fruit trees. In addition, farming practices influenced the amount of biomass density of the herbaceous and litter pool, such as weeding and composting. These practices reduced the amount of herbaceous/undergrowth biomass in the area. Some farmers were doing these practices, while others were not.

Carbon stock of agroforestry landscape

The aboveground tree and other perennial crops (84%) ranked first in terms of percentage contribution to mean total carbon density of the area. It is followed by belowground tree and other perennial with 13%, then litter (2%) and herbaceous plants provided the least percentage contribution with 1% (Table 11).

The computed mean total carbon stock (52.32 MgC/ha) was comparable to the overall mean carbon density of secondary forests in the Philippines (59.0 MgC/ha) as reported by Lasco and Pulhin (2003). A study of Palma and Carandang (2014) reported a higher mean carbon stock (92.78 MgC/ha) of an agroforestry system in Misamis Oriental. Results of these studies already included soil carbon content in the analysis, while this research only focused on the total above and belowground biomass. Inclusion of the soil carbon pool could significantly increase the carbon stock due to high concentration of carbon in the soil.

Expectedly, the computed mean total carbon density of Way Betung Watershed was higher than that of the Molawin-Dampalit Sub-Watershed. Carbon density in Way Betung was 244.26 MgC/ha, which was almost four (4) times bigger than that in Molawin-Dampalit (52.32 MgC/ha). The huge difference could be directly attributed to the abundance of tree in agroforestry systems in Indonesia. Therefore, this research also validates the argument that agroforestry is a cost-effective strategy for climate change mitigation, particularly the tree-based farming systems.

CONCLUSIONS

Agroforestry farms and practices contribute to the conservation and protection of the Way Betung Watershed and Molawin-Dampalit Sub-Watershed. Diverse crop components in the agroforestry farms, including their interaction, promote biodiversity conservation in these watershed areas, both yielding a moderate level of diversity index. Woody perennials, herbaceous crops and litter components of the agroforestry farms contribute to carbon sequestration by having carbon stock of 244.26 MgC/ha in Way Betung Watershed and 52.32 MgC/hain Molawin-Dampalit Sub-Watershed. These ecological services are significant contributions of agroforestry to climate change mitigation.

IMPLICATIONS AND RECOMMENDATIONS

Agroforestry farming practices provide ecological contributions, particularly in carbon sequestration and biodiversity conservation. These contributions of agroforestry practices already offer potentials in addressing environmental degradation in many upland communities in Southeast Asia.

It is necessary to promote the use of agroforestry as a production technology of the government and/or non-government programs on sustainable forest management and upland development. Such programs or policies should put emphasis on the use of fruit tree-based agroforestry system to avoid further opening or clearing of forested areas in higher and mid-elevation areas. The use of fruit tree-based system can enhance the use of soil and water conservation measures and other supportive technologies to control soil erosion and degradation particularly in high-elevation areas.

Results of carbon stock assessment of various agroforestry systems can provide information on national Green House Gas (GHG) inventory which is mandated to the committed parties including the Philippines in the United Nations Framework Convention on Climate Change (UNFCCC).

Future research should dwell on analyzing the effects and contribution of each of the different types and variants of agroforestry systems to biodiversity conservation and carbon sequestration. This kind of research would generate empirical data that would guide researchers, extension workers and policy makers the most appropriate type of agroforestry system that should be scaled-up among the upland farming communities.

REFERENCES

Baguinon NT, Lasco RD, Macandog DM, Pasicolan PN, Villancio VT. 2007. Agroforestry and land use in the Philippines. Bogor (ID): World Agro-Forestry Centre. 236 p.

Brent S, Boffa JM, Scherr SJ. 2006. The potentials of agroforestry to contribute to the conservation and enhancement of landscape biodiversity. Chapter 11. World Agroforestry in the Future. http://www.worldagroforestry.org/downloads/Publications/PDFS/bc06146.pdf. Retrieved on 2 February 2017. p. 95-101.

Brown S. 1997. Estimating biomass and biomass change of tropical forest: a primer. FAO. Forestry Paper 134. Rome (IT): Food Agriculture Organization of the United Nations. 55 p.

Delaney M, Roshetko J. 1999. Field test of carbon monitoring methods for home gardens in Indonesia. Field tests of carbon monitoring methods in forestry projects. Arlington (US): Forest Carbon Monitoring Program, Winrock International. p. 45-51.

ESFIM [Internet]. 2017. Empowering Smallholder Farmers in Markets. Available from: www.esfim.org/wp/philippines_esfim_paper1_revjan29.doc. Philippines Country Report. Retrieved on March 17 2017.

Fernando ES, Balatibat JB, Perlas JR, Jumawid RJJ. 1998. Resource inventory and assessment of biodiversity in Subic Bay Metropolitan Authority (unpublished report).

Indriyanto. 2006. Ekologi Hutan. Edisi Pertama. PT Bumi Aksara. Jakarta. 210 p.

Khanal S. 2011. Contribution of agroforestry in biodiversity conservation and rural needs fulfillment: A case study from Kaski District. MS Thesis. Pokhara (NP): Institute of Forestry, Tribhuvan University. Available from: http://www.forestrynepal.org/images/thesis/THESIS_

SUMAN_KHANAL.pdf. Retrieved on 27 February, 2017.

Landicho LD, Paelmo RF, Cabahug RD, Visco RG, Abadillos MG. 2014. Prospects and dilemmas of promoting organic agriculture in the upland farming communities in the Philippines. Paper presented during the International Conference on Food Security and Nutrition, 30 March - 1 April 2014, Shanghai, China. IPCBEE Volume 67:60-5.

Landicho LD. 2015. Development pathways towards sustainability of upland farming communities in the Philippines. PhD Dissertation. Laguna (PH): University of the Philippines Los Banos. 230 p.

Lasco RD, Pulhin FB. 2003. Philippine forest ecosystems and climate change: carbon stocks, rate of sequestration and the Kyoto Protocol. Ann Trop Res 25(2):37-51.

Magurran AE. 2004. Measuring biological diversity. Carleton (AU): Blackwell Publishing. 264 p. Available from: http://www2.ib.unicamp.br/profs/thomas/NE002_2011/maio10/Magurran%202004%20c2-4.pdf. Retrieved on 31 January 2017.

Noble, I.R. and R. Dirzo. 1997. Forests as human-dominated ecosystems. Science 277:522-525. In: Brent S, Boffa JM, Scherr SJ. 2006. The potentials of agroforestry to contribute to the conservation and enhancement of landscape biodiversity. Chapter 11. World Agroforestry in the Future. http://www.worldagroforestry.org/downloads/Publications/PDFS/bc06146.pdf. Retrieved on 2 February 2017. p. 95-101.

Palma RA, Carandang WM. 2014. Carbon density of bagras (*Eucalypotus deglupta* Blume) in smallholder tree-based agroforestry systems in Northern Mindanao, Philippines. Philipp J Agrofor 1(1):73-80.

Sargento JO. 1995. Participation of major stakeholders in the conservation of the Makiling Forest Reserve. PhD Dissertation. Laguna (PH): University of the Philippines Los Banos.

Sodhi NS, Koh LP, Brook BW, Ng PKL. 2004. Southeast Asian biodiversity: an impending disaster. Trends Ecol Evolut 19(12):654-60. Available from: http://www.savethefrogs.com/threats/palm/images/2004-Sodhi-SE-Asia-TREE.pdf. Retrieved on 23 January 2017.

Tolentino LL, Landicho LD, de Luna CC, Cabahug RD. 2010. Chapter 20. Case study: agroforestry in the Philippines. In. Constance LT, editor. Handbook of Climate Change and Society. Oxford (UK): Routledge Publishing. p. 317-331.

Torralba M, Fagerholm N, Burgess PJ, Moreno G, Plieninger T. 2016. Do European agroforestry systems enhance biodiversity and ecosystem services? A meta-analysis. Agric Ecosyst Environ Volume 230:150-61. Available from: http://www.sciencedirect.com/science/article/pii/S0167880916303097. Retrieved on 3 February 2017.

Wulandari C. 2013. Pendugaan karbon di lahan agroforestry register 19 (carbon prediction on agroforestry area in register 19). Bandarlampung (ID): Lampung University.

Zamora D. 1999. Carbon dioxide (CO_2) storage potential of multistory agroforestry systems in Mt. Makiling. MSc Thesis. Laguna (PH): University of the Philippines.