Generational Local Ecological Knowledge on the Benefits of an Agroforestry Landscape in Mindanao, Philippines

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ABSTRACT

Agroforestry landscapes in the Philippines provide benefits or ecosystem services that have traditionally and sustainably supported food production for rural communities and the protection of natural resources. However, the very continuity and sustainability of agroforestry is in question because of the rise of new generations of landscape users that can ascribe different values toward these benefits. Thus, this study highlights age-based local ecological knowledge (LEK) on these agroforestry-based ecosystem services to understand differences in the generational persistence and sources of their LEK. A structured survey was conducted with 36 youth, 36 middle-aged, and 36 elderly users of an agroforestry landscape in Libungan-Alamada Watershed in Mindanao, Philippines. This survey focused on the presence of LEK on seven provisioning and five regulating ecosystem services previously identified through multiple participatory exercises in the agroforestry landscape. Results indicated high LEK (more than 50% of knowledgeable respondents in all age groups) across all the ecosystem services, highlighting strong social-ecological interdependence on the agroforestry landscape. While generational persistence of local knowledge was observed, the knowledge sources varied depending on the age group or the ecosystem service. Intergenerational transfer of knowledge was prominent for provisioning ecosystem services. However, institution-based learning was essential for regulating services (e.g. climate change mitigation), especially for the youth. Experiential learning was the primary mode of knowledge acquisition for regulating services (e.g., biodiversity conservation) for the older generations. These results provide strong evidence to help guide policy actors, decision makers, and program managers as they promote, conserve, and restore agroforestry practices, especially in production-protection landscapes such as the Libungan-Alamada Watershed. The revised policy should be based on age-targeted interventions and proper learning entry points that have been found effective in this study.

Keywords: agroforestry, local ecological knowledge, watershed, ecosystem services, learning

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INTRODUCTION

Agroforestry, or the land use system that combines aspects of forestry and agriculture (Van Noordwijk, Coe, and Sinclair 2016), provides natural benefits or ecosystem services (Costanza et al. 1997; Daily 1997), which have traditionally supported the livelihoods of rural communities across the globe while conserving the environment (Buck, Lassoie, and Fernandes 1999; Nuberg, George, and Reid 2009; Wangpakapattanawong et al. 2017). In addition, scientific reviews have shown that agroforestry, through integration with trees and perennials, can potentially solve some of the most pressing environmental problems such as climate change through improved carbon sequestration and reduced deforestation (Lasco, Delfino, and Espaldon 2014); biodiversity loss by providing habitat and other critical ecosystem services for floral and faunal wildlife (Torralba et al. 2016); and land desertification by increased soil organic matter content and soil erosion control (Masebo and Menamo 2016).

In the Philippines, agroforestry landscapes are the prominent features of rural communities, composed of interacting units of various forms of agroforestry systems. Traditionally, these forms of agroforestry have included indigenous systems such as the forest-rice terraces (e.g., *muyong-payoh*) in the Cordillera region (Camacho et al. 2015), swidden-based agroforestry (i.e., *pengingiweran*) in central Mindanao (Neyra-Cabatac, Pulhin, Cabanilla 2012), and traditional ruminant-based rotational silvopastoralism in southern Luzon (Calub 2003) that have been integral not only in the community livelihoods but in various groups' cultural identities. Smith and Dressler (2017) claim that agroforestry technologies and agroforestry-based livelihood interventions in the Philippines became prominent during the 1980s in the government's quest to reduce the shifting cultivation practices in the Philippines to conserve and restore the country's forest resources. Forms of agroforestry systems have then been developed and introduced over time such as the intercropping of high-value fruit trees with fruit crops, hedge-row systems of cash crops with multi-purpose trees, alley cropping of tree and vegetable crops, rainforestation farming or agricultural production under native Philippine tree species, shelterbelts or spatially mixed tree crops across rice farms, and animal production with native legumes, among many others (Calub 2003; Harrison et al. 2009; Catacutan et al. 2012; Chiong-Javier et al. 2012; Wangpakapattanawong et al. 2017). Hence, agroforestry has become an essential component that shapes both agricultural development and natural resource management in the Philippines (PCAARRD 2003).

While the exact areas of the lands under these various agroforestry systems are relatively unknown (PCAARRD 2003), Lasco, Evangelista, and Pulhin (2010) estimate that there are around half a million hectares of agroforestry farms under the Philippine community-based forest management (CBFM), the primary strategy of inhabited forest lands in the country. However, this estimate does not take into account those agroforestry systems that are not under the CBFM such as indigenous agroforestry systems and agricultural lands in which integrated trees play critical roles (Van Noordwijk, Coe, and Sinclair 2016).

Local ecological knowledge (LEK) among landscape users, or those who both directly and indirectly interact with the landscape for livelihood, shelter, and for other ecosystem services, is significant in the stewardship of these ecosystem services provided by agroforestry landscapes (Ballard, Fernandez-Gimenez, and Sturtevant 2008). Olsson and Folke (2001, p. 87) define LEK as "knowledge held by a specific group of people about their local ecosystems…a mix of scientific and practical knowledge." It varies from traditional ecological knowledge (TEK), since LEK does not include related beliefs that are all transferred over time through strong cultural transmissions (Berkes 1999). However, Rahman et al. (2019) asserts that LEK evolves as TEK when it is validated by socio-cultural norms throughout multiple generations.

Presence, changes, and differences on LEK can significantly influence and foster local actors' behaviors and actions, management and survival, and ultimately, their appreciation of their environment (Colloff et al. 2017; Jim and Chen 2006; Sagie et al. 2013). All these have strong implications on conservation of these landscapes and their respective ecosystem services as local knowledge can be used for targeted conservation actions (Bennett 2016; Swapan, Iftekhar, and Li 2017; Cortés-Avizanda et al. 2018). Moreover, profiling local knowledge on ecosystem services can reveal local contexts including the status of the landscape and its ability to generate various benefits for landscape users (Anadón et al. 2009; Glenk 2011; Hamilton, De Mitcheson, and Aguilar-Perera 2012; Oort et al. 2015; Paudyal et al. 2015). Ultimately, knowledge of local actors is one of the key variables that dictates the long-term sustainability and stewardship management of resources (Ostrom 2009).

Studies on LEK and perceptions on ecosystem services have been growing in number over the past years. These knowledge and perceptions vary among actors' diverging interests, awareness, and socioeconomic characteristics such as gender, education, and origin (Muhamad et al. 2014; Chen and Hua 2017; Lau et al. 2018). This study aims to understand generational differences on LEK toward ecosystem services generated by an agroforestry landscape in Mindanao, Philippines. It explores how age, as a variable, influences the level and the sources of these knowledge.

This assumption on age-based differences is grounded on the theory on generational differences that Reeves and Oh (2007) summarized, as sharing a common set of characteristics, including shared knowledge, derived from shared historical experiences, economic and social conditions, technological advances, and other societal changes. Thus, specific age groups can have different preferences and requirements than others (Reeves and Oh 2007; Villanen and Jonsson 2013), shaping social systems (Herley 2009), and affecting cultural relationships with nature (Merriweather and Morgan 2013). Studies on generation cohorts have already shown huge differences among younger generations in terms of various socio-demographic, economic, and household dynamics (Dimock 2019) as well as values toward authority, relationships, system, career, technology, and the future (Mohr and Mohr 2017). These differences on LEK can also influence and drive changes to values, including attitude and practices related to agroforestry, eventually reshaping the dynamics of agricultural development in rural Philippines.

In fact, the UN Food and Agriculture Organization (FAO) argued in 2008 that these impacts of age-based demographic shifts in the context of the Asia-Pacific will include significant (a) forests and land use changes; (b) resource use changes; (c) housing demand and its implications on natural resources; and (d) environmental demands such as urban greening/forestry, recreational demand, and water availability and usage (Basnyat 2009). Hence, it is acknowledged that agroforestry landscapes can be subjected to these impacts with changing social-ecological dynamics, including changes in LEK.

The Philippines is facing changes in age structure (Mapa 2015; NEDA 2017). Specifically, the latest Philippine census done in 2015 (PSA 2019) shows that the median age is at 24.3 years old, indicating that more than half of the population is part of the young generation cohorts. Once these portions of the population become the active primary working force as agroforestry landscape users/managers, differences in LEK, together with other values, can pose the changes projected by FAO (Basnyat 2009), even at levels of agroforestry landscapes.

This study provides one of the early age-specific data and discussions on LEK that can be used by decision-makers at multiple levels for targeted conservation interventions in their respective landscapes. As the Philippines and the whole Asian region are about to face demographic shifts that will influence both the social and ecological dimensions of rural communities, this profiling can be used for more effective management of the ecosystem services provided by landscapes, especially those time-tested sustainable agroforestry landscapes.

METHODOLOGY

Study Site

The Libungan-Alamada watershed (7°19'40.2"N, 124°30'57.4"E) is in the western portion of Cotabato, a province located in the big island group of Mindanao in southern Philippines. The entire watershed is estimated to be 52,820 ha (Cotabato PPDO 2012) and encompasses a total of 20 villages in the municipalities of Alamada and Libungan. It is a designated production-protection area by the Department of Environment and Natural Resources, which means that communities can practice agriculture without having to compromise the watershed's environmental integrity.

Through multiple village transects (Calub 2004), the watershed can be characterized as an agroforestry landscape with prominence of different forms of agroforestry systems (Table 1) in which trees and perennial shrubs play significant roles in agricultural production. Seven agroforestry systems have been identified, including (1) homegardens, (2) grasslands with trees (Figure 1A), (3) tree plantations (with both grasslands and tree plantations serving as silvopastoral fields), (4) cash crop farms with tree windbreaks or integrated with trees within, (5) multi-story farms (Figure 1B), and the communal areas in the watershed—(6) riparian forests located beside water bodies (e.g., river, irrigation systems); and (7) secondary forests on hills that also served as important agroforestry sites.

Table 1 describes the components in each of the seven types of agroforestry systems being practiced in the watershed. This current landscape configuration of the watershed aligns with its production-protection designation discussed

Table 1. Agroforestry systems practiced in the Libungan-Alamada Watershed

Agroforestry System	Components of the Agroforestry System						Description
	Vegetables	Cash crops	Small livestock[1]	Large livestock[2]	Trees[3]	Shrubs/ grasslands	
Homegardens[4]	P	NP	P	NP	P	NP	Households maintain crops and perennials around homesteads for various purposes.
Multi-story farms	P	P	P	NP	P	NP	Intercropping of crops with trees. After harvest of crops, livestock are allowed to graze.
Grasslands for silvopastoralism	NP	NP	NP	P	P	P	Grasslands with interspersed trees serve as grazing areas. Trees provide shade and are sources of cut-and-carry feedstuff.
Cash crop farms integrated with trees within and/or around	P	P	NP	NP	P	NP	Trees are spatially mixed within or around the farm for various purposes.

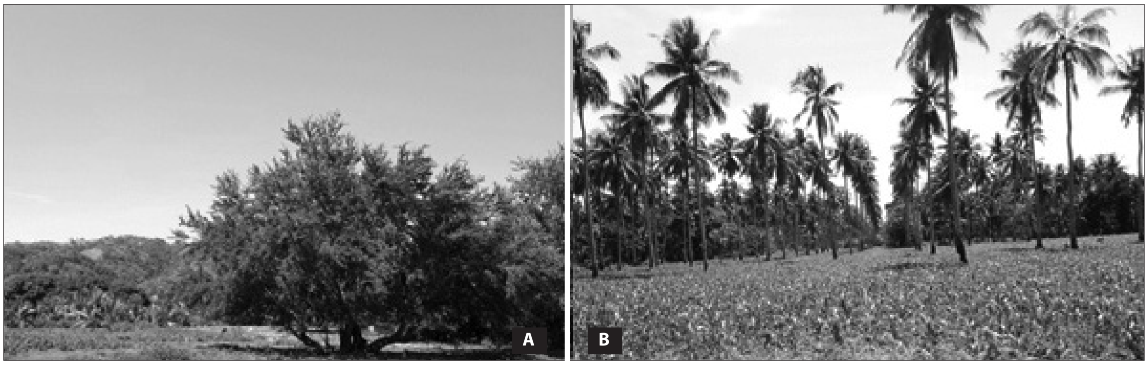
Continued on next page

Table 1 continued

Agroforestry System	Components of the Agroforestry System						Description
	Vegetables	Cash crops	Small livestock[1]	Large livestock[2]	Trees[3]	Shrubs/ grasslands	
Plantation-based silvopastoralism	NP	NP	P	P	P	P	Tree plantations serve as grazing areas for large ruminants.
Riparian forests[5] for silvopastoralism	NP	NP	NP	P	P	NP	Forests or cluster of trees and perennials serve as grazing areas or as sources of cut-and-carry feedstuff.
Secondary forests as agroforests	P	P	NP	NP	P	NP	Secondary forests on top of hills have agriculturally important products, which are integrated naturally or by accident (i.e., by animals).

Notes: P=Present; NP=Not Present
[1]Poultry, swine, small ruminants
[2]Large Ruminants
[3]Timber, fruit, native
[4]Located around homesteads
[5]Located beside the river, creek, or irrigation system

Figure 1. Examples of agroforestry systems



Grasslands serving as silvopastoral fields where trees provide benefits especially for livestock production

Multi-story farms where cash crops are intercropped with perennials, trees, and shrubs earlier. For the remainder of this paper, the term "agroforestry landscape" refers to the Libungan-Alamada Watershed, which is comprised of the various forms presented in Table 1 and their respective components.

Based on the province-disaggregated results of the 2015 Philippine Census (PSA 2017) for the Province of Cotabato, the combined population (113,200) in the two municipalities occupying the watershed under study (i.e., Libungan and Alamada) , has the following age distribution: 0-19 years old (45%), 20-39 years old (31%), 40-59 years old (18%), and over 60 years old (7%). It is clear from this distribution that a demographic shift is expected as almost half of the population is still below 20 years old.

Identification of Common Ecosystem Services

A participatory exercise was implemented in three representative villages to generate the lists of various ecosystem services from the agroforestry landscape. These villages represented the upper, middle, and lower reliefs of the watershed. Each participatory exercise included 15-20 people, most of whom were farmers. Females, young and elderly, and a known indigenous group (i.e., *Menuvus*) were all well represented in each exercise. These participants were selected in coordination with village local government councils, elderly councils, youth councils, and farmers' associations. Each of these groups was requested to provide names of participants, urging them to consider gender distribution and affiliation within the indigenous group. Groups were instructed to ensure that all participants considered should be long-term residents of each village and should have or should be from families with ownership or regular interactions with the various agroforestry systems (Table 1). These criteria assured the researchers that local ecological knowledge on the landscape's ecosystem services has been sufficiently captured (Villamor et al. 2014).

For each exercise in each village, the discussions were in their local language, one village with Hiligaynon and two with Cebuano. Participants were all initially oriented regarding the purpose of the exercise, which was to elicit information on the ecosystem services provided by the Libungan-Alamada Watershed based on their personal knowledge and experiences. During the first stage, participants were subdivided into smaller groups, with each group shown various photographs representing the agroforestry systems within the watershed. Subgroups were asked to list all the natural benefits they personally obtained from the watershed based on the photograph they were assigned with. This initial list of natural benefits was then presented across the whole group for further discussion. During this second stage, participants from other groups were given opportunity to add more benefits not yet included in the subgroup discussion. This two-stage process allowed exhaustive listing of the ecosystem services generated within the landscape.

For the purpose of the survey, only common ecosystem services were targeted. Specifically, only ecosystem services that crosscut all three villages were included. Hence, those that were uniquely identified by only two or one village were excluded from this study.

For this study, a total of 12 common ecosystem services were recognized. These ecosystem services were classified based on the Millennium Ecosystem Assessment or MA categories, namely: provisioning services, or the benefits directly obtained by people from the ecosystem; regulating services, or the benefits acquired through the regulation of ecological processes; and cultural services, or the nonmaterial benefits (MA 2005). Seven provisioning services and five regulating services were classified. None of the 12 common ecosystem services is classified as cultural ecosystem services since all cultural ecosystem services identified during the participatory exercises are all distinct for each village. This also reflects the high specificity of cultural services that are unique even to small social units. Table 2 presents these ecosystem services and the descriptions derived from these exercises.

Conduct of Survey

A survey questionnaire was then formulated based on the list of common ecosystem services

Table 2. Ecosystem services and their descriptions based on multiple participatory exercises conducted in Libungan-Alamada Watershed

Ecosystem Service	Classification Based on the MA	Description Based on the Context of Libungan-Alamada Watershed[1]
Food	Provisioning	Includes crops, fruits, meat, and other items that can be directly eaten or prepared to be eaten
Raw materials	Provisioning	Includes raw plant and/or animal-based materials either used directly or processed for other purpose such as selling (e.g., fiber)
Biomass for animal feed	Provisioning	Materials provided to animals, both livestock and domestic, as feedstuff including roughages and fodder, which are obtained through grazing and/or cut-and-carry
Fuel	Provisioning	Materials used for various fire-based activities, especially for daily cooking
Herbal medicine	Provisioning	Materials used to or believed to treat or alleviate pain from certain diseases or physical problems
Organic fertilizer	Provisioning	Materials used, usually decomposed plant materials, applied to improve plant and/or soil health following the organic standard
Timber wood	Provisioning	Wood used for various purposes, especially as furniture or as homestead building material
Microclimate enhancement	Regulating	Improvement of the landscape climate through provisions of fresh air, shade, and balanced temperature and humidity
Soil erosion control	Regulating	Keeping soil protected from erosion agents such as running water and strong winds
Water conservation	Regulating	Protecting available water supply obtained in the landscape, which is used for both domestic, agricultural, and industrial purposes
Biodiversity conservation	Regulating	Protecting the landscape's flora and fauna, both micro and macro
Climate change mitigation	Regulating	Contributing to the reduction or control of carbon and other greenhouse gases

Note: [1] The agroforestry landscape studied

identified. This survey questionnaire included two parts, namely: (1) presence or absence of LEK, and (2) knowledge sources of these ecosystem services for those who are knowledgeable. For the knowledge portion, respondents were asked whether they know the ecosystem service. Since this study is grounded on the premise that LEK is characterized not only by awareness, but also by a substantial comprehension obtained through rooted place-based experiences mixed with practical sources (Olsson and Folke 2001; Rahman et al. 2019), each respondent was asked to briefly describe the ecosystem service before a "yes" answer was considered valid.

If a respondent answered with a validated "yes", then s/he was asked to choose among options of knowledge sources provided. Each respondent must choose only one, giving more weight to those sources that had given her/him more in-depth knowledge rather than a simple awareness. Options on knowledge sources also reflected the earlier premise and represented the various knowledge entry points through experience, peer-processes, or study (Hess and Ostrom 2007).

For this survey, a total of 36 youths (below 20 years old), 36 middle-aged people (30–50 years old), and 36 elderly (above 60 years old) were selected systematically from representative lower, middle, and upper relief villages of the watershed. This age grouping reflects the generational sharing proposed by Reeves and Oh (2007) in which people born within a 20-year period share numerous characteristics. However, to qualify this proposal for the objectives of this study, a 10-year difference among age groups has been implemented to observe more explicitly the potential generational gaps and differences. It is assumed that without this time gap, there will be unclear gradients of difference within the 20-year periods.These age groupings also mirror the socio-legal definitions in the Philippines, wherein youth is below 30 years old, the prime working group are those within 30-49 years old (Mapa 2015), and the senior citizens or the elderly are above 60 years old. In addition, these groupings also reflect the generation cohorts in which the youth is part of "Generation Z," majority of the middle-aged are "Millennials," and all of the elderly are part of the "Baby Boomers" (Mohr and Mohr 2017; Dimock 2019).

RESULTS

Profile of Respondents

Based on the deliberate systematic sampling of this study, respondents of the survey included a perfect distribution of 12 representatives from each age group and each of the selected villages in the landscape. In terms of gender (Table 3), all age groups have more female than male respondents. While almost two thirds of all the respondents are either single youths (32%) or married middle-aged (31%), a significant number are either widows or widowers, especially among elderly respondents (15%). All the youths have had at least seven years of education, indicating that they all completed elementary education. In terms of residency in the landscape, the majority are youths who have lived in the landscape between 11 to 20 years (28%) and elderly people who have lived in the landscape for more than 50 years (21%). However, for the middle-aged respondents, most are migrants from neighboring villages or towns who have been brought to live in the landscape when they married. The majority in all age groups of respondents acknowledged farming as their family's main source of income. However, especially for those with at least one family member who is employed in a more regular job, the influence of income from other forms of employment is also apparent.

Table 3. Socioeconomic profile of the respondents by age-group in Libungan-Alamada Watershed

Age Group	Youth (n=36)	Middle-Aged (n=36)	Elderly (n=36)
	%	%	%
By gender			
Male	12	4	6
Female	21	30	28
By marital status			
Married	1	31	18
Widowed/widower	0	2	15
Single	32	1	1
By years of education			
1 to 6	0	10	16
7 to 10	16	11	8
11 to 14	18	12	9
By length of residency			
1 to 10	6	4	1
11 to 20	28	6	1
21 to 30	0	2	0
31 to 40	0	11	6
41 to 50	0	12	5
More than 50 years	0	0	21
By primary source of income of their family			
Farming only	19	19	20
Farming and employment	3	8	6
Employment only	12	6	6

Note: Percentage is in terms of the total number of respondents (n=108) regardless of the age group. For example, out of 108 respondents, 12 percent are approximately male youth, 4 percent are middle-aged male, 6 percent are male elderly, 21 percent are female youth, 30 percent are female middle–aged, and 28 percent are female elderly.

Survey results also showed that homegardens have the highest percentage of ownership (Table 4). It should be noted that more than half of the respondents own at least three types of agroforestry systems. Mostly, this is a combination of homegardens, multi-story farms, and cash crop farms. This is understandable, since homegardens and cash crop farms are major sources of staple food for the families, while multi-story farms provide additional financial resources. In addition, these three agroforestry systems are also the smallest in terms of spatial scale, usually ranging from 100 m^2 to at most a quarter of a hectare or 2,500 m^2 for each of these three systems. Tree plantations, while usually the largest farms in terms of area that can span multiple hectares, are owned by fewer respondents (40%). Field observations indicate that these tree plantations include mangoes, coconuts, oil palms, and timber trees such as mahogany (*Swietenia macrophylla* King) and gmelina (*Gmelina arborea* Roxb).

Even if not all respondents own all seven types of agroforestry system described, almost all respondents have accessed all seven types of agroforestry systems in the landscape, either intentionally or unintentionally. Unintentional access includes daily interactions for non-agricultural purposes, such as some youth respondents who go to school need to pass by cash-crop farms with trees, or some women respondents who need to wash clothes in the rivers where riparian strips are located.

Table 4. Percentage of respondents who own and accessed each type of agroforestry system in the landscape

Agroforestry System	Owned (%)	Accessed (%)
Homegardens	97	99
Multi-story farms	62	98
Grasslands for silvopastoralism	49	98
Cash crop farms integrated with trees in and/or around	57	99
Plantation-based silvopastoralism	40	96
Riparian forests for silvopastoralism	N/A[1]	95
Secondary forests as agroforests	N/A[1]	98

[1]N/A means that the agroforestry system is communal and cannot be owned.

General Local Ecological Knowledge on Ecosystem Services

The second columns of Tables 5 and 6 highlight the percentage of knowledgeable respondents among three generations of landscape users on ecosystem services generated by the agroforestry landscape. All provisioning ecosystem services (Table 5) are known by more than half of the respondents for all age groups. This trend is also true for all regulating services (Table 6). Among the most known ecosystem services are provision of food, micro-climate enhancement, and biodiversity conservation in which all of the respondents, regardless of age groups, indicate their knowledge. All middle-aged respondents have knowledge on six of the seven provisioning services. All the middle-aged and the elderly respondents have knowledge of four of the five regulating services.

While differences across age groups are not explicit, general trends show that more youth respondents are less knowledgeable of provisioning services. This is particularly observed for the cases of organic fertilizers and timber wood in which only 69 percent and 72 percent, respectively, of the youths stated that they have valid knowledge of such ecosystem service.

However, the opposite is observed for climate change mitigation, a regulating service, in which a higher percentage of youth respondents indicated knowledge of. On the contrary, the middle-aged and elderly show a low percentage of knowledgeable respondents on the climate change mitigation service of the landscape.

In response to the follow-up questions, a number of youth respondents shared that climate change mitigation and biodiversity conservation are two regulating services that are often discussed in school (discussed further under the Discussion section). When tested on the depth of their knowledge regarding these two, the youth respondents had better explanations on biodiversity conservation than on climate change mitigation. The youth could expound on the roles of trees and other perennial cover on agroforestry farms as habitat and as critical resources for native flora

Table 5. Local knowledge and knowledge sources on the provisioning services provided by the agroforestry landscape

Age Group	Knowledge (% Among All Respondents for Each Age Group)[1]	Parents/ Grandparents	Siblings	Peers	Experience and Observation	Formal Education	Other Forms of Education
		% Among knowledgeable respondents for each age group[2]					
Food							
Youth (n=36)	100	86	0	3	8	3	0
Middle-aged (n=36)	100	75	0	0	25	0	0
Elderly (n=36)	100	72	3	0	25	0	0
Raw materials							
Youth (n=36)	94	82	3	3	6	6	0
Middle-aged (n=36)	100	75	0	8	17	0	0
Elderly (n=36)	100	72	0	3	22	0	3
Biomass for animal feed							
Youth (n=36)	86	87	0	6	6	0	0
Middle-aged (n=36)	100	64	0	14	22	0	0
Elderly (n=36)	89	63	3	3	28	0	3
Fuel							
Youth (n=36)	94	74	3	3	21	0	0
Middle-aged (n=36)	100	64	0	11	25	0	0
Elderly (n=36)	100	67	0	0	33	0	0
Herbal medicine							
Youth (n=36)	94	88	0	3	0	3	6
Middle-aged (n=36)	100	78	0	3	14	6	0
Elderly (n=36)	100	72	8	0	11	0	8
Organic fertilizer							
Youth (n=36)	69	58	0	4	8	21	8
Middle-aged (n=36)	92	30	0	3	18	9	39
Elderly (n=36)	81	45	0	10	3	0	41
Timber wood							
Youth (n=36)	72	77	4	12	0	4	4
Middle-aged (n=36)	100	53	0	17	17	0	14
Elderly (n=36)	89	50	0	16	25	0	9

[1]Example: 94 percent of the 36 youth respondents are knowledgeable on herbal medicine

[2]Example: 74 percent of the knowledgeable youth respondents on herbal medicine learned this provisioning service from their parents and/or grandparents

Table 6. Local knowledge and knowledge sources on the regulating services provided by the agroforestry landscape

Age Group	Knowledge (% Among All Respondents for Each Age Group)[1]	Parents/ Grandparents	Siblings	Peers	Experience and Observation	Formal Education	Other Forms of Education
		% Among knowledgeable respondents for each age group[2]					
Microclimate enhancement							
Youth (n=36)	100	33	0	0	33	33	0
Middle-aged (n=36)	100	22	0	2	39	14	19
Elderly (n=36)	100	28	0	0	69	3	0
Soil erosion control							
Youth (n=36)	97	14	0	0	0	83	3
Middle-aged (n=36)	100	28	0	3	11	31	28
Elderly (n=36)	100	31	0	3	11	11	44
Water conservation							
Youth (n=36)	97	31	0	3	9	54	3
Middle-aged (n=36)	100	28	0	0	22	22	28
Elderly (n=36)	100	28	0	3	28	11	31
Biodiversity conservation							
Youth (n=36)	100	14	0	3	22	58	3
Middle-aged (n=36)	100	14	0	6	53	14	14
Elderly (n=36)	100	22	0	3	61	6	8
Climate change							
Youth (n=36)	92	6	0	0	0	91	3
Middle-aged (n=36)	64	0	0	0	0	35	65
Elderly (n=36)	78	0	0	14	0	7	79

[1]Example: 97 percent of the youth respondents are knowledgeable on water conservation
[2]Example: 31 percent of the knowledgeable youth respondents on water conservation learned this regulating service from their parents and/or grandparents

and fauna in the agroforestry landscape. However, the limited understanding of youth respondents on climate change mitigation was in the need to integrate more trees in the farming systems to reduce carbon dioxide in the atmosphere.

Sources of LEK on Provisioning Services

Majority of the respondents (50% or more) with knowledge in all provisioning services indicated that their parents/grandparents were their sources of knowledge, except in the case of organic fertilizers. The incidence of this knowledge source was particularly high in the case of youth respondents (75%).

Knowledge on organic fertilizers showed more varied sources among generations. In the case of the middle-aged and the elderly, other forms of education were indicated as major sources of knowledge. When asked to specify, respondents in these age groups indicated that they had been given training on organic fertilizer production, usually hosted by the local government or nongovernment organizations. It is worth noting that knowledge among peers became more apparent for this ecosystem service.

General trends also show that next to parents/grandparents, experience and observation are the second most prominent source of LEK on provisioning services. This was especially observable among the elderly, of which at least a quarter indicated this source in knowing the landscape's capacity to provide food, biomass for animal feed, fuel, and timber wood.

A few of the respondents also claimed that their peers are sources of LEK on provisioning services. In particular, a tenth of the respondents for each age group claimed that their knowledge on timber woods were obtained from their peers. During interview, most of the middle-aged and elderly shared about how they learned which wood to use as timber from their peers involved in home construction and local furniture makers.

Sources of LEK on Regulating Services

While intergenerational knowledge transfers from parents/or grandparents are also observed in all age groups, data on regulating services (Table 6) show more varied sources of LEK. For majority (more than 50%) of the youth, formal education is the main knowledge source for all regulating services except microclimate enhancement.

On regulating services, results of this study show that formal education declines in influence with higher age groups. For majority of the elderly (more than 50%), experience and personal observation were credited for obtaining the knowledge on microclimate enhancement and biodiversity conservation. Responding to follow-up questions, a number of respondents shared their own personal accounts of experiencing cooler temperatures with better humidity under or near agroforestry systems and seeing a number of wild flora and fauna while doing their daily farm work.

For climate change mitigation, the roles of capacity and knowledge building programs through workshops and seminars have once again been highlighted in the case of the middle-aged and the elderly. More than 60 percent of the respondents in these age groups indicated other forms of education as their primary sources of LEK. It is also interesting to note how 14 percent of the elderly respondents credited learning from their peers about climate change mitigation by the landscape.

Parents/grandparents as sources of LEK are also well-documented for regulating services. This is particularly observed for water conservation in which a quarter of the respondents in all age groups learned from their parents/grandparents.

DISCUSSION

Results of this study show that there is high LEK (more than 50% of the respondents) for all the 12 ecosystem services generated by the agroforestry landscape studied in Libungan-Alamada Watershed. This presence of high LEK and the matching of knowledge among all age groups implies the multifunctionality of the watershed in both provision of needs to various age groups and regulation of ecosystems in its current structural-functional configuration (Glenk 2011; Hamilton, De Mitcheson, and Aguilar-Perera 2012; Koster et al. 2016; Oort et al. 2015). This persistence of LEK across multiple generations is essential for community-based stewardship and monitoring of natural resources (Ballard, Fernandez-Gimenez, and Sturtevant 2008; Anadón et al. 2009). LEK on these benefits translates to better understanding, appreciation, and action on the need for conservation of the agroforestry-based configuration of the Libungan-Alamada Watershed (Frick and Wilson 2004; Jim and Chen 2006; Ostrom 2009; Duerden and Witt 2010; Collof et al. 2017; Swapan, Iftekhar, and Li 2017).

This can aid local decision makers to implement support measures such as incentivizing local households to continue observing agroforestry practices. By doing so, the Libungan-Alamada Watershed can continue to adhere to its designation as a production-protection area and continue its provision of community needs and regulation of significant ecological processes (e.g. conservation of biodiversity). Local decision makers who have lower resources for science-based monitoring should also integrate these age-based LEK for the continuous, yet cheaper, monitoring on the status and supply of these ecosystem services (Topp-Jorgensen et al. 2005; Dahdouh-Guebas et al. 2006; Brook and McLachlan 2008).

As discussed by Olsson and Folke (2001), upon which the operational definition of this study is grounded, sets of LEK are site-specific. Thus, the LEK across all age groups, complemented by the data on livelihood dependency on agroforestry farming (Table 3) and high accessibility of these agroforestry farms (Table 4), highlights that there is strong social-ecological integration in production-protection landscapes (Folke et al. 2010; Moberg and Simonsen 2014; Scheyvens and Shivakoti 2019). The agroforestry landscape provides strong community interdependence on the various benefits.

Traditionally, people gain LEK through their practical involvement with components of the environment, usually through acquisition of personal and household needs and earning of livelihoods with their surroundings (Berkes 1999; Frazão-Moreira, Carvalho, and Martins. 2009; Hamilton, De Mitcheson, and Aguilar-Perera 2012; Olsson and Folke 2001). It can be passed on intergenerationally or passed out intragenerationally (Berkes 1999; Hamilton et al. 2005). It is continually dynamic as LEK evolves with new technologies, new observations, and is tested on refinements against a backdrop of changing cultural, political, environmental, and institutional factors (Davis and Wagner 2003; Dove 2004; Frazão-Moreira, Carvalho, and Martins 2009). These factors affect the very social-ecological interactions within landscapes such as the Libungan-Alamada Watershed.

Our results provide critical evidence on the dynamicity of LEKs such that, while these persist across temporal gradients (i.e., different generations), these are obtained through various sources depending on the ecosystem service it involves. In the case of provisioning services, this study has highlighted the large role of intergenerational transfer of knowledge. This has also been documented in provisioning services, such as production of herbal medicines (Murali, Redpath, and Mishra 2017), provided by other types of landscape.

The provisioning services included in this study (except for organic fertilizer) – food, raw materials, biomass for animal feed, fuel, herbal medicine, and timber wood – could be considered "traditional" provisioning services. The authors consider these as benefits that have sustained social-ecological dependence within the landscape by providing the basic needs of the communities throughout long periods of time. Newman and Hatton-Yeo (2008) explain this intergenerational exchange as a way to keep new generations grounded in their socio-cultural history and link them to the past. Hence, the LEK on these provisioning ecosystem services have been kept as part of the landscape's social-ecological memory (Barthel, Folke, and Colding 2010; Nykvist and Von Heland 2014). This plays a critical role in maintaining how landscapes, especially those critical ones like the Libungan-Alamada Watershed, are being managed with sustainability and resilience (UNU-IAS 2013).

However, the authors would also like to posit that this type of system memory should be tested for malleability and iteration over time both within and between generations. For example, while general local knowledge on an ecosystem service (e.g., knowledge that the agroforestry landscape generates fuel) may persist as part of this memory delivered through intergenerational transfer of knowledge, the dynamic nature of LEK implies that differences may occur in specific details (e.g., types of plant species used) as generational passage progresses. These transfers are affected by the societal changes with generational conditions such as increased migration, influence of modern-day practices, acculturation, and other social-learning opportunities (Dove 2004; Koster, Bruno, and Burns 2016; Tekken et al. 2017). How the integrity of this memory changes over time and/or between generations and how this malleability and iteration of intergenerational LEK impact social-ecological interaction in the landscape require further longitudinal studies.

On the other hand, in cases of provisioning services (e.g., organic fertilizers, which follow international standards and procedures to generate), which are not inherent to this social-ecological memory, other sources of LEK become prominent such as formal/informal education and peer-to-peer transfer. Further studies to evaluate which provisioning services can be considered inherent within the landscape's intergenerational process of retaining social-ecological memory would warrant further study.

For regulating services, this study has highlighted the role of education as the youth's prominent source of LEK. This reflects both how curriculum has evolved (e.g., new discussion of ecosystem services such as climate change mitigation) and how education has become more accessible over time (e.g., elderly respondents had more difficulty entering schools in their time), as mirrored in the socioeconomic profile of the respondents (Table 3). New interventions have been piloted in the Philippines such as integrated school-and-home gardens (Manalo et al. 2016; Calub et al. 2019; Tupas 2019) to introduce and emphasize new or more scientific ecosystem services (e.g., climate change mitigation, biodiversity conservation) from agro-diverse farming systems such as agroforestry.

On the other hand, the role of experience/personal observation, except in climate change mitigation, has been more apparent for older generations in terms of regulating services. This indicates how the elderly have been more attached to their surroundings to personally observe the role of landscape in regulating the ecosystem. These results align with those of Christie et al. (2012) who indicated in their study that older generations depend on experiential learning, unlike the younger generations that rely more on scientific and study-based sources.

Muhamad et al. (2014), in their study of an agroforestry landscape, also discussed how perceptions of various ecosystem services were acquired with direct interaction with their landscape. The study of Lagbas and Habito (2016) has also indicated that the Filipino youth also tend to know less about regulating services that are hard to imagine or are less visible. In the case of regulating services that require more temporal exposure to be observed (e.g., conservation of biodiversity, soil, and water), there is also a need for longer landscape interactions. However, the increasing access to education (i.e., more time in school than on the field), growing digital dependence, and changing family priorities (i.e., finding non-agricultural careers), among many other factors (see Aswani, Lemahieu, and Sauer 2018), are gradually shaping these traditional social-ecological interactions, especially in the younger generations.

For climate change mitigation that requires the longest temporal exposure among all the ecosystem services studied, all age groups indicated education as their primary source. For younger generations, discussions of climate change are integrated in school curricula. For older generations, data in this study show how knowledge-based interventions (e.g., training, workshops) have been essential in a production landscape, as is true across such landscapes in Southeast Asia (Kozar et al. 2019; Kozar et al. 2020).

For both cases, this study suggests the persistence of LEK on ecosystem services across multiple generations through generationally changing sources of knowledge. This provides strong evidence of how generational changes are gradually manifesting within the context of LEK of ecosystem services, providing new knowledge not only for socio-ecological science, but for generational scholarship as well (Reeves and Oh 2007).

While this study focused only on the primary sources of information, the authors recognize that individuals, especially younger generations who are in place within a fast-changing societal context (Aswani, Lemahieu, and Sauer 2018), can have multiple sources of knowledge. Information from primary sources can also be supplemented, complemented, enhanced, or expanded (Colding and Folke 2001; Olsson and Folke 2001; Gilchrist and Mallory 2007). In the study of Frazão-Moreira, Carvalho, and Martins (2009), younger generations in a Portuguese landscape originally learned the landscape's ethnobotanical services through their parents, but knowledge was further supplemented with learning from schools. However, the authors posit that these secondary sources of LEK relatively vary in terms of the place-based specificity and contextuality from primary sources. A related longitudinal study over years is recommended to assist in gaining a more nuanced view about how local knowledge systems are impacted by maturing within generations versus different constructs of knowledge between generations under this premise of multiple knowledge sourcing.

Establishing these trends on sources of LEK across generations can help facilitate learning strategies for intergenerational and age-targeted conservation measures in the Libungan-Alamada Watershed, and similar other landscapes designated for production-protection purposes. As this study has also shown formal institutions like schools having significant roles, especially for the younger and incoming generations, curriculum and pedagogy should be strengthened. This could be done through the use of school gardens as a learning laboratory in which there is a combined experiential and instruction-based learning. However, one current limitation of school gardens is its inclination to crop agriculture. Thus, it is also suggested that woody perennials be incorporated so that students can see for themselves how these play beneficial roles in food production, as in the case of the agroforestry landscape. Local government and non-governmental organizations can further improve their current local seminars and workshops, which have been found to be the middle-aged and elderly's source of information for a number of regulating services.

CONCLUSIONS

The need to conserve the time-tested production-protection benefits of agroforestry has never been as important and urgent as it is now, with the rise of less diverse and unsustainable agricultural practices threatening the continuity of agroforestry across Philippine landscapes. These trends threaten to reshape the country's agricultural development towards greater unsustainability. This study aims to stimulate further discussion on generational LEK toward ecosystem services, or the benefits provided by agroforestry landscapes in Southeast Asia. The case of the Libungan-Alamada Watershed with high LEK across all age-groups provides a positive view on how its current structural-functional configuration allows for these benefits to accrue to multiple generations of landscape users. In another perspective, the discovery of this high local knowledge presents the basic understanding and recognition among landscape actors on the need to maintain the agroforestry structure of the landscape and to integrate trees on various agricultural systems. Such knowledge can be used by decision makers to be more aggressive in the promotion, conservation, and restoration of agroforestry practices in rural communities, especially those which are designated as production-protection areas, as exemplified by the Libungan-Alamada Watershed.

This study has provided strong evidence on how local knowledge on the benefits of agroforestry can persist across generations. This persistence can be attributed to the kinds of knowledge sources that vary across generations. This study has specifically highlighted the roles of intergenerational transfer, institution-based learning, and experiential learning to acquire LEK on the benefits of agroforestry. To sustain such persistence, it is imperative to pursue programs, whether for landscape management or for education, that are tailored to specific age groups and knowledge sources, even as intergenerational activities that highlight discussions on agroforestry ecosystem services should also be explored.

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