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RESEARCH ARTICLE

Comparing Indigenous Soil Quality Knowledge Systems and Scientific Soil Assessment in a Traditional Upland Rice-based Agroecosystem in Southern Philippines

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Abstract

Like traditional agroecosystems worldwide, the Sarangani upland agroecosystem in Southern Philippines is presently under threat from myriad pressures such as environmental destruction, bio-cultural erosion, and agricultural modernization. In these marginal areas, farmland degradation is particularly devastating because of its implications for food security and the long-term survival of ethnic communities. Using a mixed-methods approach, this study revealed a significant linkage between farmers' soil quality knowledge systems (SQKS) and scientific soil fertility assessments despite their holistic and reductionist natures, respectively. Furthermore, both SQKS and scientific soil knowledge ascribed diminishing soil quality in the Sarangani uplands to unregulated resource extraction, natural calamities, hillside cultivation without soil conservation measures and the inherent vulnerabilities of the upland landscape. These results warrant a closer examination of SQKS and their utilization along with technical soil knowledge systems to craft a comprehensive soil management strategy specifically tailored to the conditions in the Sarangani uplands. Finally, while the study underscored close relationships between local soil assessment and scientific assessment paradigms, more comprehensive studies need to be undertaken before their integration into diverse and complex farming systems such as the Sarangani uplands.

Keywords: *soil quality degradation*, *Southern Philippines*, *traditional agroecosystems farmers' knowledge*

For agricultural systems in general, productivity and sustainability hinge mainly on the maintenance of soil nutrient capital. In traditional agroecosystems where tribal culture and environmental issues are largely intertwined, this dependence is very apparent. Unfortunately, traditional agroecosystems worldwide are presently being threatened by emerging socio-cultural, economic and ecological realities in these areas [1-3]. Among the negative effects of such pressures are soil erosion and the consequent decline in soil quality. Soil erosion, the stripping of the fertile topsoil, is the most widespread cause of soil degradation. Its negative effects on farmlands encompass both physical and chemical constraints to crop production. In the Philippines, where no comprehensive nationwide assessment of soil erosion has been done, severity estimates of this environmental problem vary greatly and are inconsistent [4]. Deeming severely eroded hillsides as permanently unsuitable for crop production, the Philippine government proposed the cultivation of *Jatropha curcas* L. in these areas for large-scale biodiesel production [5].

Ethnopedology is defined as *"the knowledge of soil properties and management possessed by people living in a particular environment for some period of time"* [6]. This valuable cache of information had been accumulated by farmers based on years of farming and observation in their fields. Drawing from this vast wealth of knowledge, farmers developed traditional soil indicators to distinguish fertile from infertile soils and to assess the extent of farmland degradation. The importance of farmers' knowledge about the selection of soil suitable for planting was underscored by studies carried out by Lima et al. and Gray et al. [7,8]. Incidentally, criteria such as soil color, weed abundance and stoniness were used in characterizing farmlands in Nepal [9] and Northern Laos [10], respectively. In Southern Brazil, indicators such as soil color, rice plant development and spontaneous vegetation were utilized by Lima et al. [7] while Omari et al. and Norgrove et al. [11, 12]] identified plant growth, soil color, texture and compaction as well as the presence of indicator plants and earthworms as important soil indicators in Ghana and West and Central Africa, respectively.

Sarangani, located in the southernmost fringe of Mindanao Island in the Philippines, is an oddly shaped province cut into eastern and western halves by General Santos City. Composed of 7 municipalities (viz. Malapatan, Alabel, Glan, Malungon, Maasim, Kiamba and Maitum), Sarangani has an overall terrain consisting primarily of flatlands, rolling hills and steep mountains. Of its total land area of 3,986.64 km2, roughly 52.7% is situated along an altitudinal range of 300-1,000 meters above sea level (masl), while 14.5% lies within 0-100 masl elevation range [13].

The upland areas of the province are inhabited predominantly by *Lumads* (tribes with non-Muslim ethnicity) whose presence in these areas predated the Spanish colonization of the Philippines (early 1500s). Effectively repulsed by Muslim forces in Mindanao, Spanish colonizers were unable to claim the island for their country. After the post-World War II period, migrants from Luzon and Visayas settled in Mindanao (including Sarangani) and drove the *Lumads* away from the lowlands into the upland areas where they presently reside [13-15].

In the Sarangani uplands, the dominant ethnic groups are Blaans, T'bolis and Tagakaolos with Blaans occupying a broader territorial range. This ethnic group inhabits the upland areas of Malapatan, Glan, Alabel, and Malungon. T'bolis inhabit Maitum, Kiamba and Maasim, while Tagakaulos reside exclusively in Malungon and Datal Anggas in Alabel (Sarangani Province, 2011). Moreover, these tribes cultivate upland rice (as a main caloric source) along sloping/steep terrains once a year, without synthetic inputs and under subsistence and rainfed conditions [15, 16].

Field visits in the Sarangani uplands during recent years revealed widescale farmland degradation due to slash-and-burn farming, extreme weather conditions, natural disasters and encroachment of modern agriculture, among other factors [15, 17]. The study was thus carried out to (1) identify traditional soil quality indicators used by Sarangani upland farmers to differentiate fertile from infertile soils, (2) examine the association between SQKS and science-based soil quality indicators and (3) document causes and effects of farmland degradation based on farmers' knowledge and perceptions. This study hypothesizes that these two soil quality assessment paradigms are closely related.

Materials and Methods

Preliminary Preparations

The study was carried out in 16 upland *barangays* (villages) in Sarangani Province in Southern Philippines (*viz*. Datal Bukay and New Aklan in Glan, Mutu Ladal in Maasim, Kihan, Kinam and Banlas in Malapatan, Ihan, Cabnis, Glamang and Datal Anggas in Alabel, Datal Tampal and Malabod in Malungon, *Upo*, Angko and Batian in Maitum and Malayo in Kiamba (Figure 1).

Before community visits, letters were sent to the governor, the mayor, heads of agriculture offices and the barangay captains. This was followed by courtesy calls to their respective offices to secure their permission and logistical support. Sitios/barangays were selected based on recommendations by local government and barangay officials. Study sites were essentially rice-based traditional upland agroecosystems. Furthermore, peace and order situations as well as the safety of the team were of prime consideration in the selection of study sites. Additionally, requisite permits from the National Council of Indigenous Peoples (NCIP) were incorporated in the overall NCIP permit secured by the Sarangani Provincial government for its *Sulong Tribu* project that sought to improve the plight of indigenous peoples in the upland areas.

Community Visits and Field Work

The researchers utilized a mixed-methods approach to attain study objectives. Based on the emic perspective, this study employed participatory rural appraisal (PRA) techniques (i.e. focus group discussions or FGD, semi-structured questionnaires, personal interviews, cursory farmland characterization and field observation) to determine indicators of soil quality and ascertain the causes and effects of farmland degradation in the upland farms. For FGD, 20-25 farmers (for each village) were chosen depending on their availability. FGD was done in selected sitios from late afternoon up to dinner time (while variable, dinner time was usually from 6:30 to 7:00 PM). This was the time when farmers came home after working in the fields for the whole day. For participant selection, priority was given to sitio officials and elderly farmers. FGD was done using the following steps: (1) introduction of the research

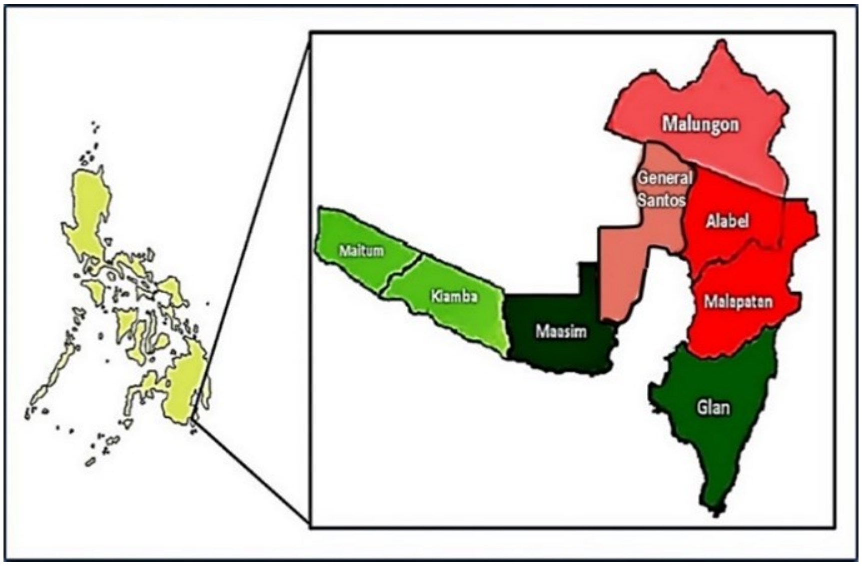

Figure 1. Location map of Sarangani Province (Source: Zapico et al. 2015). Municipalities or towns comprising the province are indicated. General Santos City, situated along the borders of Maasim, Malungon and Alabel, is not included in its jurisdictional territory.

team and orientation about the activity (2) questions (based on a guide) were raised for discussion and deliberation among the farmers and (3) the facilitator recapitulated everything and presented it to the group for validation. During deliberation, everyone was given opportunities to express his views. For FGD, the duration was variable, but usually ran for about 2-3 hours.

Household visits were carried out and a validated, semi-structured questionnaire was administered to 102 respondents using the Visayan dialect. In cases where the respondent only spoke the ethnic dialect, the field guide served as an interpreter. The questionnaire consisted of three broad categories: The first part elicited information about the farmers and their farms. The second part focused on the traditional indicators of soil quality while the third part determined the causes and effects of farmland degradation in the Sarangani uplands based on farmers' knowledge and perceptions. One cycle of questionnaire administration lasted for about 15-20 minutes. Furthermore, personal interviews were done with elderly farmers who were unable to participate in FGDs and with respondents whose answers required further probing. The process was purposive and opportunistic (conducted with potential participants available during field visits) in nature and prioritized farmers considered as *fu-long (*wise men) and those who held positions of authority. Conversations with interviewees were free-wheeling and exploratory. Before interviews were done, the potential interviewee was oriented about the study, his part to contribute, as well as the benefits of the study to the community and tribal culture. Verbal consent was obtained and the interviewee was assured of the confidentiality of the data that he/she will divulge. If permission was given, the researchers used an audio recording device, the contents of which were subsequently transcribed. When permission was not given, casual conversation was carried out and the interviewer put the information into writing right after the interview was finished. Moreover, while the nature of the questions was like those in the questionnaire, entries in the interview guide were more focused, open-ended and gave room for exploring.

Data Processing and Interpretation

Information from FGD and personal interviews was analyzed thematically and written in a narrative and qualitative fashion. As for the data from questionnaires, these were collated and presented as tables and graphs for easier analysis and interpretation. Descriptive statistics such as means and percentages were calculated using Microsoft Excel.

Farmland and Field Characterization

Farm/field profiling was done during the wet season (April to November). Geophysical coordinates (longitude, latitude, altitude) of the sites were recorded *in situ* using a handheld Garmin Global Positioning System (GPS) receiver. A field thermometer was also used to record midday temperature ranges/sites. Ocular inspection was done to document the type of farming system, topography, associated crops, and notable features of the site (i.e. bare rockface, eroded hillsides, vast fields of cogon grass, and unique land/water formations, among others). Soil color (based on farmers' observation) was likewise noted.

Soil Sampling and Laboratory Analysis

To provide a contrast to Sarangani farmers' ethnopedological knowledge, collected soil samples were subjected to laboratory analyses for pH, total nitrogen, available phosphorus, exchangeable potassium and organic matter content. Soil samples were collected from upland farms having standing rice crops (Figure 2). Based on farmer recommendations, areas exhibiting relative terrain homogeneity (flat) were sampled by collecting soil samples from ten sampling points in a zigzagging direction. As for steep areas, ten sampling points were selected along the slope. Soil samples were collected from a depth of up to 30 cm. These samples (approximately 1 kg) collected from different areas of the farmland, were bulked, appropriately labeled (with geophysical coordinates and farmers' names), air-dried for a few days and brought to the Regional Soils Laboratory of the Department of Agriculture RFO XII. Soil pH was determined using the glass electrode method while total nitrogen, available phosphorus and exchangeable potassium were determined using the Walkley-Black's rapid titration method [18], Mehlich method [19] and turbidimetric solid cobaltinitrite method [20], respectively.

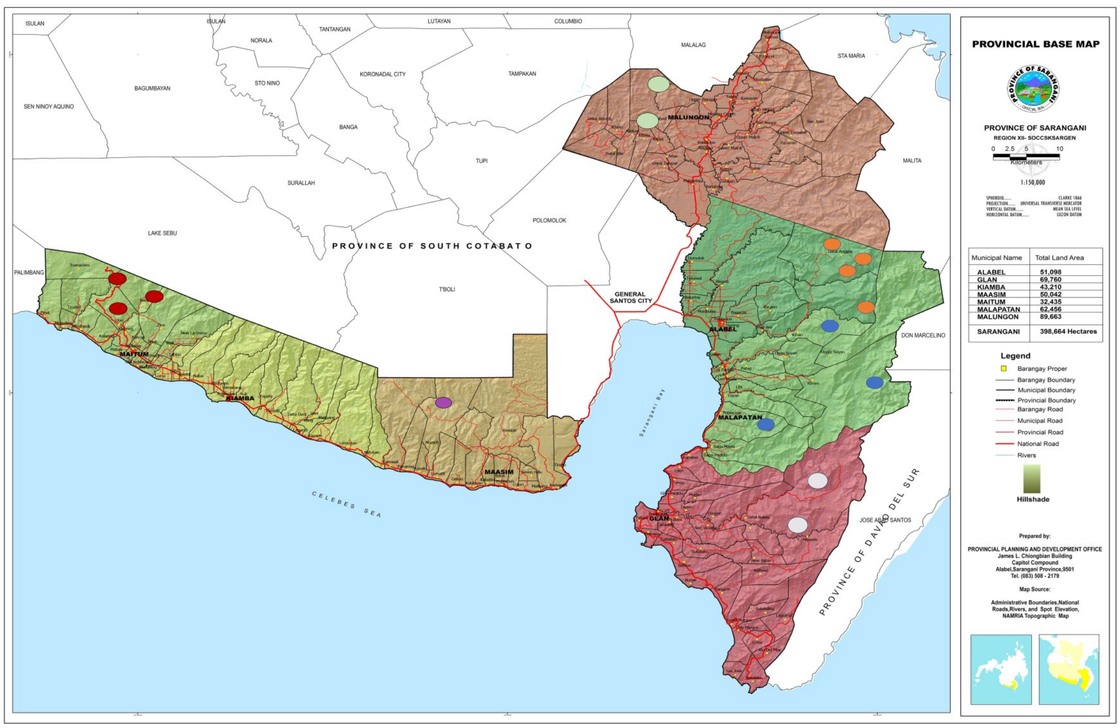

Figure 2. Upland Rice Farms from where soil samples were collected. (Dots indicate sampling points). There were no sampling sites in Kiamba because farmers had already shifted to abaca farming for local and international markets.

Results

Profiles of the Upland Farmers

Table 1 shows the demographic profiles of the farmer respondents. Of the 102 respondents chosen for the study, 65.6% were male farmers while the rest were female farmers who were relegated to lighter tasks in the farms. In terms of marital status, 96.8% were married, a reality that is borne out by early marriages among the tribal groups as part of their culture. Blaan farmers (77.2%) greatly outnumbered *Tbolis* and *Kaolos* and occupied broader jurisdictional areas. Moreover, most of the respondents (80%) only managed to acquire primary education owing to the distance of the schools. Students had to walk for several hours to reach their classrooms, with most of them leaving at daybreak. With the nearest high school located in the barangay proper, most of the students left school after graduating from elementary education.

Farmer respondents also had a mean age of 42.62 years and 25.9 years of mean farming experience. Most of the respondents (95.4%) likewise divulged that they relied solely on rice farming for sustenance and livelihood needs while the rest obtained additional income from other sources such as a small retail store (*sari-sari* store).

Table 1. Demographic Profiles of Farmer Respondents in the Sarangani Uplands (n=102).

Demographic Characteristics		
Gender (%)	Male	65.6
	Female	34.4
Marital Status (%)	Married	96.8
	Single	3.2
Ethnicity (%)	Blaan	77.2
	Tboli	16.3
	Kaolo	6.6
Education (%)	None	20.0
	Primary	80.0
	Secondary	0
Household Income Source (%)	Rice Farming	95.4
	Others	4.6
Average farming experience (years)		25.9
Average age of farmers (years)		42.6

Profile of the Upland Farms

Being subsistence farms, average landholdings (3.2 hectares) per household were quite small with mean farm areas recorded at 0.13 has/farms. Shown in Table 2 are pertinent features of Sarangani upland rice farms (geophysical features, topography, temperature range, and predominant ethnic group/s). For altitude, the recorded values reflect the lowest points in the sitios due to the inability of the research team to take note of altitudinal ranges. This is one limitation of the study. Of the 16 visited sitios, Muto Ladal in the uplands of Maasim had the highest elevation and consequently had the lowest recorded midday temperature. Ocular inspection of the area revealed a few remaining forest patches owing to unabated slash-and-burn activities in the area. Furthermore, owing to the distance of the sitio, the residents did not have access to basic social services from the government, with food and other essentials provided by occasional (but infrequent) mission work of lowland churches. In Maitum, communities like Upo and Batian proved difficult to access because of their steepness. It was in these areas where wide-scale slash-and-burn was noted. Other areas like Datal Tampal and Malabod in Malungon were accessible by motorcycles and 4x4 vehicles and had better access to the creature comforts found in lowland communities. In terms of the predominant ethnic groups, *Blaans* were found in majority of the sites, with Muto Ladal, Maasim, Upo, Angko and Batian in Maitum and Malayo in Kiamba inhabited by *Tbolis*. In Datal Anggas, Alabel, *Kaolos* lived peacefully alongside their *Blaan* counterparts. As for tribes' carbohydrate staples (URLs), these were cultivated as either monocrops or were intercropped with *Sige -sige* corn (recycled transgenic corn), mungbean, peanuts, root crops and adlai (Coix lacryma jobi). In a significant number of farms (83%), *Sige-sige* corn had displaced traditional rice in farmers' fields. Grown as a cash crop, transgenic corn is favored by farmers because it obviates the need for manual weeding, a task that they consider as tedious. Furthermore, personal conversations with farmers revealed that kaingin (slash-and-burn farming) is widely practiced in the area.

Soil Quality Indicators: Farmers' Knowledge and Scientific Analysis

Shown in Table 3 are traditional soil quality indicators used by Sarangani upland farmers to select a patch of land that is suitable for planting. Also shown are the scientific justifications for the mentioned indicators based on scientific studies. Visual inspection of soil in various farmlands in the province revealed the presence of reddish-black soils in Datal Bukay, Glan and Banlas, Malapatan. Both villages are located along the banks of a river that oftentimes swells and overflows its banks during torrential rains. When flood waters recede, reddish subsoil becomes exposed because of the removal of upper soil layers. Consequently, farmlands in Datal Bukay exhibited lower levels of total nitrogen, available phosphorus and exchangeable potassium during field sampling. On the other hand, yellowish-black soils were noted in New Aklan, Glan, Muto Ladal, Maasim and Kihan, Malapatan while light brown soil was observed in Kinam, Malapatan. Farmlands visited in these areas were erosion- and flash-flood prone due to the unregulated planting of upland rice and *sige-sige* corn along steep mountain slopes without soil conservation measures. Moreover, along with Ihan, Alabel, these areas showed tell-tale signs of widescale slash-and-burn activities and forest denudation. From their experience in the fields, Sarangani farmers classified red, yellow and light-colored soils as having low fertility. In extreme cases, erosion negatively alters soil structure by compacting it and making it break into rock-size clods rather than a fine crumbly tilth when tilled. This classification by the farmers is borne out by very low total nitrogen, organic matter (for Malapatan), available phosphorus and exchangeable potassium levels in the abovementioned sites. In terms of soil type, most farmlands in the Sarangani uplands had clay loam soil that is best suited for upland rice cultivation according to farmers. Moreover, soil acidity was noted in Malapatan and Alabel farms with the remaining areas manifesting acceptable pH levels.

Table 3 shows that the majority of Sarangani farmers considered the predominance of

Table 2. Upland Farms and their Pertinent Features. This table includes geo-physical profiles, ethnic groups that inhabit the area, predominant farming systems and land/ water features apparent during overt site characterization. Altitudinal values shown below reflect lowest points in the village with actual sampling sites being higher.

Sitio/ Barangay	Town	GPS Co-ordinates	Altitude*	Topography	Temperature Range	Farming System Used	Predominant Ethnic Group	Pertinent Features of Farmland
Datal Bukay	Glan	N 05°49'47.4" E 125°19'41.7"	>337m	Plain to Mountainous	24.5°C - 27°C	Slash and burn/monocrop	Blaan	Located beside a flood-prone river
New Aklan	Glan	N 05°45'00.4" E 125°21'57.2"	>430m	Plain to Mountainous	23°C - 25°C	Monocrop	Blaan	Denuded hills due to slash and burn
Muto Ladal	Maasim	N 05°57'37.0" E 124°54'24.0"	>1,016m	Mountainous	21.8°C - 23°C	Slash and burn	Tboli	Denuded hills due to slash and burn
Kihan	Malapatan	N 06°07'00.6" E 125°24'51.9"	>222m	Rolling to Mountainous	25°C - 30.6°C	Slash and burn/intercrop	Blaan	Landslide/ flashflood prone
Kinam	Malapatan	N05°58'33.250 E125°25'5.58	>273m	Plain to Mountainous	25°C - 31°C	Slash and burn	Blaan	Landslide/ flashflood prone
Ihan	Alabel	N 06°12'21.7" E 125°22'21.7"	>975m	Rolling to Mountainous	23°C - 25°C	Monocrop	Blaan	Denuded hills
Cabnis	Alabel	N 06°11'57.2" E 125°26'51.0"	>896m	Rolling to Mountainous	23°C - 25°C	Monocrop	Blaan	Denuded hills
Glamang	Alabel	N 06°11.995' E 125°27.158'	>421m	Rolling to Mountainous	24°C - 26°C	Slash and burn/ monocrop	Blaan	Denuded hills
Datal Tam-pal	Malungon	N 06°20.818' E 125°12.477'	>298m	Plain to Mountainous	25°C - 30.6°C	Intercrop	Blaan	Accessible
Malabod	Malungon	N06°24'9.390 E125°12.5'5.83	>350m	Plain to Mountainous	25°C - 30.6°C	Intercrop	Blaan	Accessible
Upo	Maitum	N 06°08.950' E 124°29.205'	>591m	Rolling to Mountainous	23°C - 25°C	Slash and burn	Tboli	Slash and burn widely practiced
Batian	Maitum	N 06°09'34.8" E 124°29'35.6"	>496m	Rolling to Mountainous	23°C - 25°C	Slash and burn	Tboli	Slash and burn widely practiced
Malayo	Kiamba	N 05°57.442' E 124°45.773'	>500m	Plain to Rolling	25°C - 30.6°C	Monocrop	Tboli	Denuded hills; de-forestation noted
Banlas	Malapatan	N 06^{0}06'003" E 125^{0}28'05"	>156m	Plain to Mountainous	24^{0}C - 30.5^{0}C	Mono- and Intercrop	Blaan	Slash and burn widely practiced
Datal Ang-gas	Alabel	N 06^{0}11'57.20" E 125^{0}26'51.00"	>857m	Rolling to Mountainous	21^{0}C - 26.5^{0}C	Slash and Burn/Monocrop	Blaan/ Tagakaolo	Denuded hills
Angko	Maitum	N06^{0}01'42.9" E124^{0}29'82.5"	>496m	Rolling to Mountainous	24.5^{0}C - 30^{0}C	Intercrop	Tboli	Denuded hills

cogon grass as one of the most telling indicators of soil quality. Cogon grass, which grows profusely in rice fields in the aftermath of repeated slash and burn–fallowing cycles, was considered by most farmers as a tell-tale sign of soil impoverishment. In contrast, a handful of farmers (10%) in the area considered cogon grass presence as an indication of soil fertility. Furthermore, soil texture (stony/sandy soils) and friability as well as biological indicators (*i.e.* spontaneous vegetation, crop growth and colour, earthworm casts) were also mentioned by farmers as important soil quality indicators in the Sarangani upland farms.

Table 4 shows the physico-chemical features of the soils as well as some remarkable site features that negatively impact the Sarangani agroecosystem. Soil pH readings of the 16 soil samples ranged from 4.57 – 7.16 with a mean pH of 5.77. Of the 16 farms, six (6) rice farms (in Malapatan, Alabel and Maitum) recorded acidic soils (>5.5) while the rest of the farms had soil pH (pH 5.5 – 8.0) that is deemed suitable for rice

Table 3. Soil quality indicators based on farmers' knowledge were documented during field visits. Categorized into 4, *viz*. biological, intrinsic soil characteristics, physical and holistic (plant performance), these indicators were documented based on farmers' traditional knowledge, stated in the prevailing dialect, and translated to English. Furthermore, scientific support (if any) to soil indigenous knowledge is also included in Table 3.

Indicators	% of Farmers who named indicator	Farmers' Statements (*Blaan*)	English Translation	Scientific/Technical Equivalent
Biological				
Earthworms	10%	*Ku dee alyaku fye itana.*	Earthworms indicate fertile soil.	Soil has high organic matter content, neutral pH (*Lima et al. 2011*)
Spontaneous vegetation	35%	*Ku dee bnas fye itana.*	The presence of various types of vegetation indicates fertile soil.	Soil has an adequate supply of nutrients (*Lima et al. 2011; Ahmed, N. and Al-Mutairi, K.A. 2022)*
Imperata cylindrica L (cogon grass)	85%	*Ku cagon I tmabu lah tabi I tana.*	If cogon grass alone grows in a farmland, then it is badly degraded.	Predominance of cogon grass indicates poor soil (*Saito et al. 2006; Rakotoson et al. 2009; Desbiez et al. 2004*)
Intrinsic Soil Characteristics				
Soil color	85%	*Fye I fili ku fitam itana.*	Black soil is good for planting	Indicator of fertile soils; has high organic matter (*Sanchez et al. 1989; Brady and Weil, 1996; Lima et al. 2011*)
Physical				
Sandy and stony soils	65%	*Ku bnatu mman falak itana la fye I tabu I fili.*	Plants do not grow well in stony and sandy soils	Shallow topsoil; Sandy soil easily loses water (*FAO 1973*)
Tilth	32%	*Too fye fnili un mlal bnugal itana*	Soil exhibiting good tilth easily crumbles and is best for planting	Optimal sand, silt, clay fractions; ideal for plant growth *(Brady and Weil 1996; Tisdale et al. 1993; Munkholm 2011)*
Plant Performance				
Root growth	60%	*Ku mgal itana la fye I tabu I dalil.*	Compact soil stunts root growth	Plant roots cannot penetrate hardpan soils *(FAO 2008)*
Plant color and growth	44%	*Tabi itana ku fye kulur I tabu d fili.*	Soil fertility can be ascertained by looking at plant color and growth	An adequate supply of nutrients and growth factors results in healthy plant color and vigorous growth (*Lima et al. 2011;Tisdale et al. 1993)*

farming [21]. Nitrogen, organic matter, phosphorus, and potassium levels were also discovered to be below threshold levels in some farming sites (Table 3), an urgent situation that necessitates macro- and micronutrient amendments.

Field visits in the selected villages were done sporadically from 2016 to 2019 in the selected upland rice farms in Sarangani Province. Owing to the COVID-19 pandemic, further field visits were discontinued because the researchers could unwittingly bring the virus to these isolated villages. Cursory site characterization, done upon arrival in the villages and preceding FGDs, revealed widescale ecological devastation in all visited areas. Except for small patches of forests in some gullies, the entire upland landscape was dominated by denuded mountains, landslide- and flood-prone areas because of unregulated slash-and -burn farming (Personal communications with sitio officials).

Sarangani Farmers' Perceptions about Farmland Degradation

To identify badly degraded farmlands, farmers enumerated the following physical features according to decreasing levels of importance: the presence of cogon grass, red soil, an abundance of pebbles and stones, hardpan soil, thin/no topsoil,

Table 4. Physico-chemical Profiles of Sarangani Upland Farms were determined from actual field characterization and soil analysis in the laboratory. Soil color was based on farmers' traditional classification and indigenous knowledge. Standards for adequacy of soil nutrient content were based on those used by the Soils Laboratory - Department of Agriculture- DA-RFO XII in Koronadal, Cotabato.

Farm Number	Location	Physical Features		Chemical Features				
		Soil Color	Soil Type	pH	Total Nitrogen %	Organic Matter %	Available Phosphorus (ppm)	Exchangeable Potassium (ppm)
1	Glan	Reddish Black	Clay Loam	5.67	0.21**	4.28*	2.61***	97.53***
2	Glan	Yellowish black	Clay Loam	5.97	0.16***	3.10*	4.18***	125.68**
3	Maasim	Yellowish Black	Clay Loam	6.01	0.13***	2.51**	2.50***	62.99***
4	Malapatan	Yellowish Black	Clay Loam	4.88	0.06***	1.19***	16.28*	29.58***
5	Malapatan	Reddish Brown	Sandy Loam	5.54	0.09***	1.83**	4.67***	101.11**
6	Alabel	Brown	Sandy Loam	6.34	0.10***	1.99**	24.94*	130.42**
7	Alabel	Black	Clay Loam	5.28	0.31*	6.15*	7.73**	349.48*
8	Alabel	Brown	Sandy loam	5.12	0.29**	5.84*	5.66***	205.51*
9	Malungon	Brown	Clay Loam	6.08	0.23**	4.68*	3.88***	275.45*
10	Malungon	Brownish Black	Loam	5.88	0.23**	4.70*	9.49**	236.33*
11	Maitum	Black	Loam	6.75	0.28**	5.66*	53.24*	275.87*
12	Maitum	Dark Brown	Loam	5.28	0.37*	7.43*	3.79***	276.36*
13	Kiamba	Dark Brown	Clay Loam	6.50	0.34*	6.70*	31.83*	361.29*
14	Maitum	Black	Clay Loam	7.16	0.29**	5.74*	17.43*	276.65*
15	Alabel	Dark Brown	Clay Loam	5.36	0.16***	3.21*	1.23***	105.1**
16	Malapatan	Light Brown	Sandy Loam	4.57	0.34*	6.82*	2.21***	219.22*

Legend for Soil Nutrients
* Adequate
** Marginal
*** Deficient

Legend for Soil pH
< 5.5 – acidic soils
> 8.0 – alkaline soils
Soil pH between 5.5 and 8.0 not a constraint to crop production
(soilquality.org.au/factsheets/soil-ph-south- austral)

presence of gullies, low floral diversity, and yellow soil. Furthermore, the majority of the Sarangani upland farmers (62.5%) reported that soil erosion had been increasing in severity during the past 15-20 years due to intense rainfall events (93%), cultivation on steep slopes (37%), deforestation (37%), unregulated herbicide use (6.7%), short fallow period (3.3%) and lack of tenurial status (6.7%). One farmer related that a neighbor plowed his farmland and then abandoned it, resulting in loose soil being dumped in low-lying areas after torrential rains. When asked about the deleterious effects of soil erosion that they experienced, farmers enumerated the following: decreasing yield (93%), unproductive soil (52%), increased workload (24%), invasion of cogon grass (16%) and landslide (4%). Furthermore, Sarangani farmers chose several criteria in choosing fertile farmlands which incidentally pose very little risk of soil erosion. These were: soil color and texture (92%), soil richness (53%), soil moisture retention (56%), presence of lush vegetation (44%), ease of weeding/plowing (32%), presence of few stands of cogon grass (32%) and presence of fewer pebbles (16%).

Discussion

Soil Quality: Reconciling Ethnopedological and Scientific Soil Knowledge

Several studies espouse the holistic nature of farmers' traditional soil knowledge [7,9,10]. As opposed to the scientist's inherently reductionist perspective, traditional soil knowledge is not delimited to a few variables but instead incorporates a wide range of factors that influence plant growth and development (*i.e.* biological aspects, crop performance and water availability). On the other hand, comprehensive analyses of soil quality indicators and their effects become impeded by their apparent associations with multiple aspects of soil quality [18]. In Southern Brazil, tribal farmers encountered difficulties when asked to rate soil quality indicators according to their perceived order of importance due to these confounding interrelationships. For instance, Lima et al., Saito et al., Sanchez et al. and Bradi and Weir [7, 10, 22,23] reported about correlations between black soil with high organic matter content, diverse floral diversity, high nutrient content, good texture, good growth of plants and high water-holding capacity. In another study, Tisdale et al. [24] revealed apparent correlations of soil tilth with better water retention, rich nutrient supply, sufficient soil aeration and consequently, better plant growth.

In the Sarangani uplands, soil quality indicators mentioned by farmers were limited to visually and tactilely observable signs such as soil color, texture, presence of indicator plants and plant vigor and color. Essentially qualitative, these traditional indicators are based on surface soil characteristics and the farmers' long-term practical experience in the fields. Sarangani farmers identified black soil as ideal for planting because of its inherent fertility and better water-holding capacity. These views were confirmed by Saito et al [10] who reported that black soils have higher pH, total nitrogen, total carbon and cation exchange capacity (CEC). In contrast, tribal farmers categorized red and yellow soils as very poor soils because they tended to dry up quickly and because of observed inhibition of plant growth. The distinct coloration of these latter soil types is attributable to very low organic matter content and elevated levels of iron and aluminum oxides and hydroxides. Upon the erosion of fertile topsoil, the underlying soil appears reddish owing to iron oxide-rich subsoil. Other negative effects of soil erosion include nutrient/organic matter depletion, salinization, acidification, siltation in low-lying rivers, soil compaction and subsidence [4,5]. A flurry of studies coming from many parts of the world during the early 2000s likewise reported soil color as the most important soil quality indicator. Among these were Lima et al., Desbiez et al. and Barrios and Trejo [7,9,25] from Latin America, Nepal, the Philippines and Southern Brazil, respectively.

Physical attributes of the soil were also considered important indicators by Sarangani upland farmers. The presence of pebbles and stones, in particular, is equated with the shallowness of upper soil layers due to extensive weathering and soil erosion [7]. Because of the thinness of the topsoil, fertility declines, weeding is difficult and yields are generally low. Sandy soil, on the other hand, is usually dry, nutrient-deficient, fast-draining and is relatively incapable of conveying moisture from deeper soil layers to the surface. Tilth, a soil indicator considered favorably by Sarangani farmers, allows for soil clods to be easily crumbled, making land preparation easier. According to interviewed farmers, good soil structure is essential for optimal growth of the rice crop. Inversely, compaction in upper soil layers hinders root growth, limits aeration and prevents percolation of surface water to inner layers [7]. Because of reduced infiltration, surface water rushes down to lower-lying areas, further aggravating soil losses. In their respective studies, Lima et al., Saito et al. and Siderius and Debakker [7, 10, 26] underscored the importance of these physical soil indicators to agricultural production.

Also, of prime importance in determining soil quality for Sarangani farmers are biological indicators, *viz.* spontaneous vegetation, earthworm presence and crop growth and color. The presence of a wide array of weeds, their dark green color and lush growth indicate that the soil in which they thrive is fertile. In erosion-prone Sarangani upland farms, broad-leaved plants are either sparse or nonexistent owing to the slash-and-burn type of farming. Instead, grasses and herbs predominate when the farm is left to fallow. In Southern Brazil, Lima et al [7] revealed that local farmers use rice plant growth and color as proxy indicators of soil quality. Desbiez et al., Saito et al., Omari et al., De Foresta and Michon and Rakotoson et al. [9, 10, 11, 27, 28] reiterated these views based on their studies conducted in Nepal, Southeast Asia, Northern Laos, Ghana and Madagascar, respectively. Moreover, the predominance of cogon grass in disturbed areas was considered by farmers as indicative of poor soils. Cogon grass is an aggressive colonizer and once established, crowds out crops/native vegetation and consequently transforms formerly pristine landscapes into grasslands with extremely low biological diversity and richness [11]. Due to its capacity to tolerate soils with acidic pH and low fertility, out-compete other plant species for nutrients and suppress the establishment of growing plants, cogon grass has become a ubiquitous presence in the upland areas. Hagan et al. [29] further added that cogon grass maintains dominance through allelochemicals it produces along with its mutualistic interaction with mycorrhiza that heightens its competitiveness on unfertile soils. In contrast to these findings, Omari et al. [11] disclosed that Ghanan farmers consider lush cogon grass growth as a sign of soil fertility.

Furthermore, earthworm presence was reported by several studies as an important indicator of soil fertility [7, 9, 12, 30, 32]. Acting as soil conditioners, earthworms improve soil structure by mixing soil layers, increasing nutrient availability, and binding soil with organic matter (OM), thereby making it more readily available to plants. Earthworms also improve soil aeration/ drainage and allow for the fastening of nitrogen due to plant growth hormone secretion [30]. In the Sarangani farms, their rare presence can be ascribed to hillside agriculture with no soil conservation measures. Lastly, plant color (especially dark green leaves) indicates adequate levels of nitrogen and incidentally, good soil quality. In the Sarangani farms, poor plant health was indicative of infertile soils in Glan, Malapatan, Alabel and Maitum. These farms, which recorded low nitrogen levels, were located along flashflood- and erosion-prone areas due to unregulated slash and burn, cutting of trees and the subsequent harvesting of remaining saplings for charcoal production.

In terms of their physico-chemical profiles, farms # 4 and 16 in Malapatan were noted to have acidic soils at pH values of 4.88 and 4.57, respectively. Acidic soils inhibit plant growth by negatively affecting microbial activity, reducing the availability of essential nutrients, and causing various kinds of soil toxicities [31]. Most of the farms had pH levels falling within the 5.5 – 6.6 pH range which Landon and De Datta [33, 34] reported as optimal for rice farming. Furthermore, the predominantly clayey constitution of the soil in many areas of the Sarangani uplands makes the area suitable for planting rice. Landon and De Datta [33, 34] asserted that soils with elevated clay levels are ideal for rice production since they retain essential nutrients and moisture. In terms of soil nutrient status, identified major limiting factors in Sarangani upland farms were nitrogen deficiency and the inadequate amounts of available phosphorus and exchangeable potassium in some areas. Needed by the plant for the synthesis of proteins, nucleic acids and chlorophyll, nitrogen when deficient is a very serious agricultural problem. Symptoms of nitrogen deficiency include general yellowing of older leaves, stunting and growth slowdown in plants [35]. Amendments of nitrogen in the form of organic fertilizers, manure and beneficial plants (*e.g.* legumes) are therefore needed to improve soil status in the Sarangani uplands. As for the rest of the farms, soil potassium and phosphorus levels, though not optimal, were adequate for the growth of the rice crop.

It can thus be mentioned that SQKS is essentially holistic and considers the soil as a function of interacting and complex factors [36]. Soil science, on the other hand, generally employs a reductionist approach and elucidates structure and function of the soil in terms of its individual components. To cite an example, a scientist can study a particular soil parameter (e.g. pH, nutrient content) based on its impacts on plant growth [37]. Since the past decades, however, there has been an increasing shift to more holistic and integrative soil quality assessment approaches for more effective land management and sustainability [38].

The results of this study will greatly benefit smallholder farmers who do not have access to soil management inputs and testing facilities. Through shared knowledge between farmers and scientists, innovative, cost-effective, and robust soil fertility assessment methodologies can be developed for specific agroecological conditions in an area.

Farmland Degradation: The Bane of the Sarangani Traditional Agroecosystem

In the Sarangani traditional agroecosystem, farmland degradation can be ascribed to a complex interplay of socio-cultural, economic and ecological factors. Shifting of rice farmers *en masse* to recycled transgenic corn (*Sige-sige* corn) cultivation along steep hillsides and the accompanying herbicide use resulted in more frequent occurrences of soil erosion during the past years (Figures 3a and 3b). Farmers likewise revealed that planting rice along steep slopes with no soil conservation measures further exacerbated soil erosion problems in the Sarangani uplands (Figure 3e). Yao and Garcia [39] and Prokop and Poreba [40], who concurred that problems relating to farmland degradation are attributable to improper land use, likewise identified soil erosion as the most serious environmental problem besetting upland areas worldwide. From a study in Negros Oriental, Philippines, Elauria et al. [41] pointed out that upland agriculture is the major cause of soil erosion in the country. Paningbatan [42] likewise asserted that soil erosion is "*the most serious environmental problem affecting 63-76% of the country's total land area*". Ironically, Filipino farmers in these two studies did not consider soil erosion as an important upland problem and were, instead, completely oblivious to its devastating effects. In Sarangani Province, the recent granting of concessions to a mining company for mineral extraction is expected to create more environmental problems in the uplands of Maitum (Personal conversations with farmers and prospectors). During field visits, the researchers came across a team of geologists doing preliminary prospecting tasks. When these kinds of anthropogenic activities impinge on vulnerable traditional agroecosystems like the Sarangani uplands, wide-scale destruction is the most likely outcome (Figure 3c). During recent years, farmland degradation has severely constrained agricultural production in the Sarangani upland farms, causing rice varietal losses on an unprecedented scale (Personal conversations with farmers and sitio officials).

Incidentally, the implementation of the Special Areas for Agricultural Development (SAAD) project by the government resulted in the shrinking of the remaining forest cover in some areas of the province. The SAAD project was conceptualized to address problems of food insufficiency through agricultural expansion in the Sarangani uplands. This was, unfortunately, an ill-conceived project that failed to take into account the innate limitations of the upland terrain. Many SAAD farmer-beneficiaries, having no farmlands to plant rice on, razed secondary forest patches in the mountains of Kiamba and Maitum (Figure 3d). Coxhead [43], from his analysis of the interrelationships between economic growth/ development policy and the status of the environment, likewise revealed the propensity of the Philippine government to promote developmental projects that accelerate land degradation. Furthermore, the actual physical features of the upland landscape also make it vulnerable to natural calamities and extreme climatic events. Surface soil that is loosened because of deforestation, herbicide use and continuous cultivation, gets carried downhill in the event of torrential rains and flash floods.

One glaring fact, however, is that despite its devastating effects, the slash-and-burn practice was not identified by farmers as a definitive cause of environmental degradation in the Sarangani uplands (Figure 3c and 3e). Styger et al. [44] maintained that this kind of agricultural practice is profitable in the short term but unsustainable in the longer term. Presently, the recurrent slash and burn - shorter fallow farming practice is taking a severe toll on the Sarangani traditional agroecosystem and

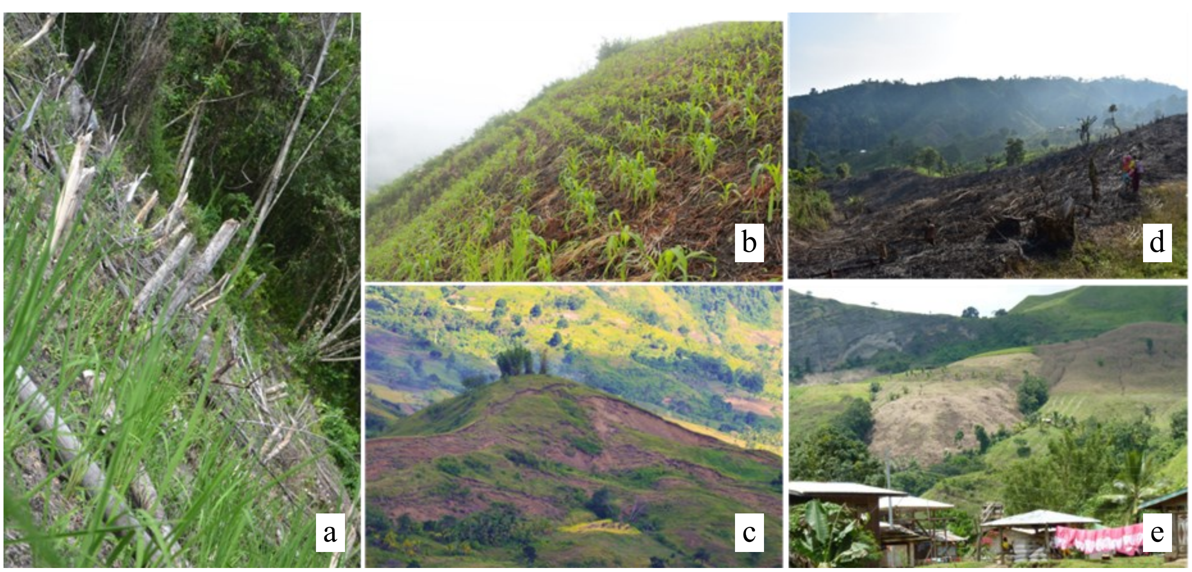

Figure 3. Images of soil-related ecological devastation in the Sarangani uplands were documented during field visits. These include: (a) clearing of steep slopes in preparation for farming; (b) *Sige-sige* corn cultivation; (c) denuded hills; (d) aftermath of slash and burn; and (e) village located at the foot of an erosion-prone mountain. 3a-d are due to anthropogenic activities while Figure 3e shows a community located in a disaster-prone area.

the people who rely on it for food. During field visits, lower yield, food shortages and rampant malnutrition were observed in the upland communities. If current trends are left unchecked, upland farms in Sarangani Province will eventually fail to support agricultural production in the area in the coming years. The consequences, when this happens, will be dire.

Conclusion

This study revealed important traditional soil indicators *(i.e.* soil color, predominant vegetation, sandiness/stoniness of the soil and crop growth and development) used by Sarangani upland farmers to distinguish between fertile and infertile soils. Laboratory analysis done on obtained field samples provided scientific bases for farmers' traditional indicators, revealed soil impoverishment in some areas and underscored the need for nutrient amendments to improve soil status. The study also revealed the prevalent problem of soil erosion and the complex interplay of factors that underlie it. For vulnerable agroecosystems like the Sarangani uplands, farmland degradation is expected to get worse unless measures are undertaken to improve environmental conditions. Sustainable, farmer-centered and bottom-up approaches including the following are thus recommended: (***1***) organic soil amendments and planting beneficial plants (i.e. legumes) to restore soil fertility; (***2***) utilization of sustainable agricultural practices based on fire-less farming alternatives; (***3***) education of farmers about the damaging effects of slash-and-burn farming; (***4***) implementation of soil conservation measures (i.e. terracing, contouring) especially in steep slopes; (***5***) environmental rehabilitation using endemic floral species; (*7*) more studies relating to the effects of planting *Sige-sige* corn and herbicide use along steep slopes. Finally, actions must be taken to reconcile the holistic (traditional knowledge) and the reductionist (scientific knowledge) approaches so that effective, sustainable, and farmer-friendly strategies for soil conservation and sustainable land management can be arrived at.

Authors' Contributions

FLZ is credited for the conceptualization of the study, field work, data analysis and manuscript preparation. JTD and ESF are acknowledged for providing over-all guidance on the bases of their expertise.

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