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Geohazard and Vulnerability Risk Analysis as Inputs in Mainstreaming Climate Change in Developing Country

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Abstract: The study generally provides analysis on vulnerability risk and geohazard clarification of the entire river system as inputs in mainstreaming climate change in developing country specifically Northern Mindanao, Philippines. It employed evaluative and analytical type of research with the use of primary and secondary data sources. The expected outputs include the GIS-Based category/classification maps and the vulnerability/susceptibility map for the pilot area project.
Findings revealed that in terms of slope, majority of the pilot project falls in the steep category (30-50%) and rainfall pattern did not change dramatically. Land use classification is pasture and vegetation type which is generally grassland. Soil type is generally adtuyon clay and geological history revealed pleiocene-pleistocene (ice-age). Geo-hazard classification of the Agroforestry site is Landslide+Drought while susceptibility map showed moderately susceptible to landslide. Generally, the area is vulnerable to landslide during heavy and prolonged rains and it is vulnerable to drought during prolonged dry seasons due to the very limited forest vegetation.
Keywords: Vulnerability, geohazard classification, mainstreaming climate change, developing country

I. INTRODUCTION

Philippines is a developing country where the watershed is critical in terms of its vulnerability to the many natural hazards. This is attributed to its strategic location within the Pacific Ring of Fire, its slope and topography and the rapid depletion of the pristine forests. Currently, the watersheds of the country are severely affected by the inevitable consequences of climate change brought about by the increased production of greenhouse gases (GHGs). The occurrences of typhoons have lately wreak havoc on the lives of people causing displacement and economic losses specifically in Cagayan de Oro City, Iligan City and Bukidnon, Philippines.

The Bukidnon landscape is one important focus of current post-Sendong rehabilitation efforts by both the government and non-government agencies as it has direct contribution to the Cagayan de Oro River Basin. In response to the call of the Philippine Climate Change Act (RA 9729) and the Intergovernmental Panel for Climate Change (IPCC) Third Assessment Report that stated " in the scarce information of the impacts of climate change on water resources and biodiversity, specifically lacking are integrated assessment of impacts, adaptation and vulnerability" (Lasco, 2007). After the Sendong tragedy, there were many collaborative efforts to address the reduction of hazards and vulnerability in the environs of the Cagayan de Oro River Basin, more specifically the Bukidnon landscape where there are many tributaries that feed the bulk of the Cagayan de Oro River.

According to Cruz (2000), watersheds are critical to the economic development and environmental protection in the Philippines. More than 70% of the total land area lies within watersheds. It is estimated that no less than 1.5 million hectares of agricultural lands presently derive irrigation water from watersheds. There are between 18 to 20 million people inhabiting the uplandsof many watersheds. Despite the tremendous value of the watersheds to Philippine economy and its environment, many watersheds are now in varying stages of deterioration basically attributed to anthropogenic activities.

Vulnerability assessment and geohazard analysis are adopted by many environmental scientists at different levels of decision-making process at different geographical scales. In making generalized assessments across larger geographical areas, it is important to identify such areas as requiring more detailed assessment. This study adopted such principle in its objective to determine the vulnerability of the established agro-forestry pilot site within the Pualas-Bukidnon sub- watershed which is a tributary to the Cagayan de Oro River system in Northern Mindanao, Philippines.

II. OBJECTIVES OF THE STUDY

The general objective of the study is to analyze the vulnerability uncertainties and geohazard of the Cagayan de Oro-Bukidnon landscape situated in Northern Mindanao, Philippines that affects the riverine system.

Specifically, this study aimed to:

A. Characterize the physical, geologic factors such as slope, land use, rainfall, soil type, nutrients and bulk density and anthropological factors along the environs of Watershed;

B. Identify the vulnerable and degraded areas in the upstream of Cagayan de Oro River situated in Baungon, Bukidnon;

C. Delineate the degree of sensitivity, exposure and adaptive capacity of the watershed in response to climate change;

D. Relate the vulnerability of the watershed to the occurrences of landslides, soil erosion and flashfloods;

E. Develop GIS-based maps to describe the vulnerability and susceptibility of the landscape as it affects the Cagayan de Oro River Basin;

F. Recommend appropriate adaptation strategies for the micro-watershed, the immediate ecosystem and social environment

III. METHODOLOGY

The study was conducted in the landscape of Bukidnon and Cagayan de Oro River located in Northern Mindanao, Philippines. Primary and secondary data were collected from different sources using the thematic maps sourced out from DENR database. A ground validation or ground truthing was undertaken to ascertain the information shown in the maps. The identified area as pilot site was delineated using a Geographic Positioning System (GPS) device (etrix Garmin). Coordinates of every corner of the area delineated were generated with the assistance of GPS operators from CENRO Talakag and Regional Office. Important bio-physical features of the area were likewise recorded like soil characteristics, land configuration, vegetation, land use, streams/tributaries, etc.

Electronic mapping was facilitated using Manifold software, a Geographic Information System (GIS). Using the available maps and the data generated during the actual delineation and ground truthing, the desired thematic maps are produced; drainage map, land use/land cover map, soil map, geology map, slope map, rainfall map, climatic map, vulnerability map, etc.

A. Vulnerability Assessment and Geohazard Analysis

There were two (2) major components adopted in assessing vulnerability risk uncertainties namely, Landslide Hazard and Soil Erosion Hazard respectively presented their framework in Figures 2 and 3.

1) Landslide Hazard (Physical and Anthropogenic Factors): This consist of major steps to consider in the analysis of landslide hazard such as: (a) identification of critical factors that affect the vulnerability of an area to landslide hazard that include slope, rainfall, land use or vegetative cover, soil type, and geologic formation; (b) mapping of critical factors for each of the identified factors affecting the occurrence of landslide; (c) preparation of landslide hazard category maps of the critical physical factors for the the slope of the area, five (5) slope ranges are categorized with its corresponding vulnerability rating from 1 to 5 wherein 1 has slopes ranging from 0-8% and 5 has the worst slope category of more than 50%. Table 1 shows the Rating of Critical Factors affecting Landslides;

Table 1 Rating of Critical Factors affecting Landslide (Physical Factor)

Vulnerability Class	Rating	Slope Range (%)	Rainfall (mm)	Landuse/Vegetative Cover	Soil Type	Geology
Not Vulnerable	1	0-8%	above 145	Close/open canopy forest	Adtuyon	Indahag, Limestone
Very Low	2	8.1-18%	145.1-156	Brushland/tree plantation	Kidapawan Clay	Indahag, Limestone
Moderate	3	18.1-30%	156.1-167	Grassland/Orchard	Alimodian Clay	Bukidnon Formation
High	4	30.1-50%	167.1-177	Agriculture (crops)	Bolinao Clay	Himalayan Formation
Very High	5	above 50%	above 177	Agriculture (banana/pineapple/etc.)	Mountain Soil (undifferentiated)	Quaternary Alluvium

(d) Preparation of landslide hazard category maps of the critical anthropogenic factors such as infrastructures (road networks) and farming systems. Below is Table 2 showing the landslide hazard due to farming systems.

Table 2. Landslide hazard values due to farming systems

Rating	Extent of Disturbance by Farming System
1	The farming systems in the area do not favor any landslide
2	The farming systems in the area slightly favor minor landslide
3	The farming system in the area slightly favor minor landslides
4	The farming system in the area highly favor minor landslides
5	The farming system in the area highly favor major landslides

(e) factors and weights for selection of physical critical factors and anthropogenic factors; (f) Overlaying of Hazard Category Maps of Physical Critical Factors and Determination of Landslide Vulnerability; (g) Overlaying of Hazard Category Maps of Critical Anthropogenic Factors; and (h) Generation of the Overall Landslide Hazard Vulnerability Map (Physical and Anthropogenic Factors)

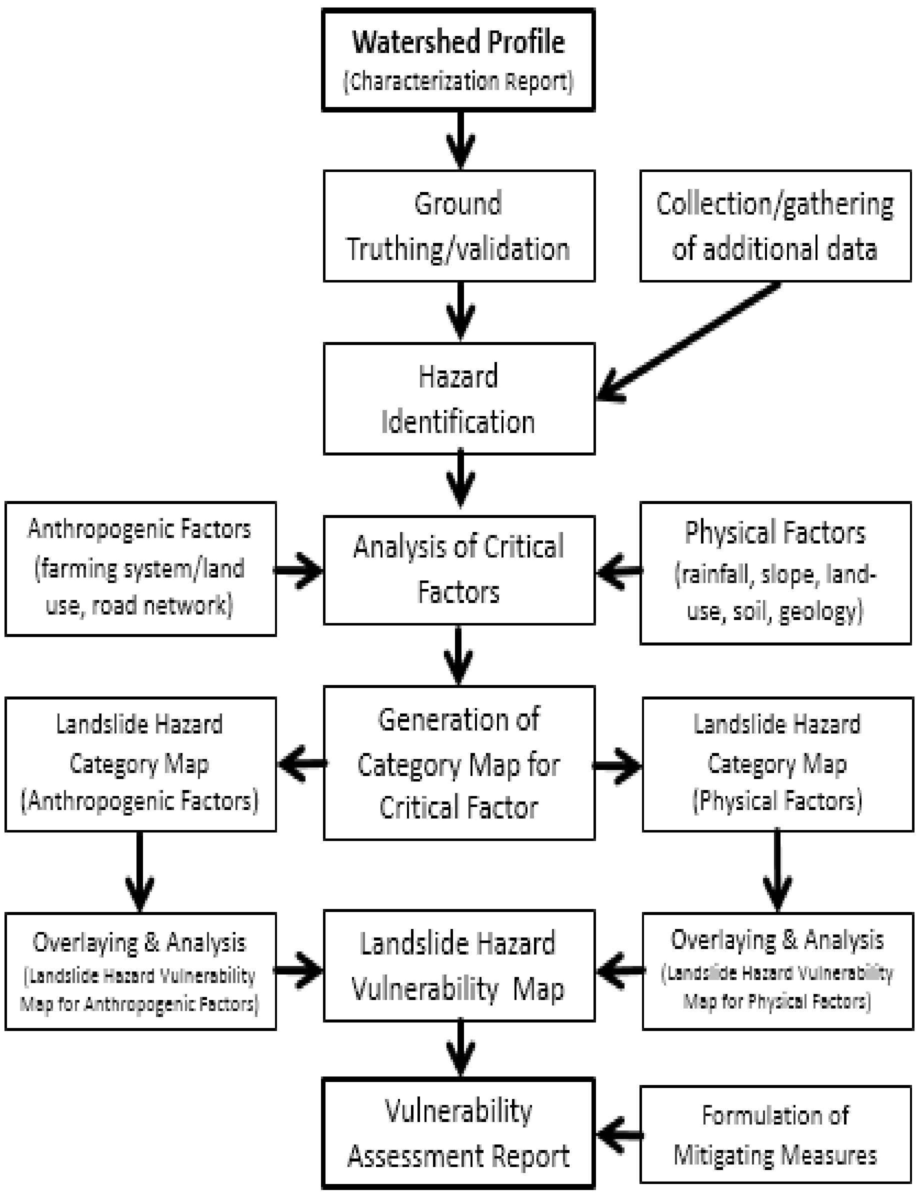

Figure 2. Framework of the Identification of Critical Factors Affecting Landslide Hazard

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2) *Soil Erosion Hazard Vulnerability Assessment:* The framework presented in Fig. 3 follows the vulnerability assessment and analysis of soil erosion hazard addressing the four steps namely: (a) Methods of assessing the vulnerability of the area to soil erosion hazard; (b) Identification of critical factors that influence the occurrence of soil erosion; (c) Generation of critical factors category maps and assignment of weights; and (d) Overlaying of physical factors category maps and determination of soil erosion hazard vulnerability map.

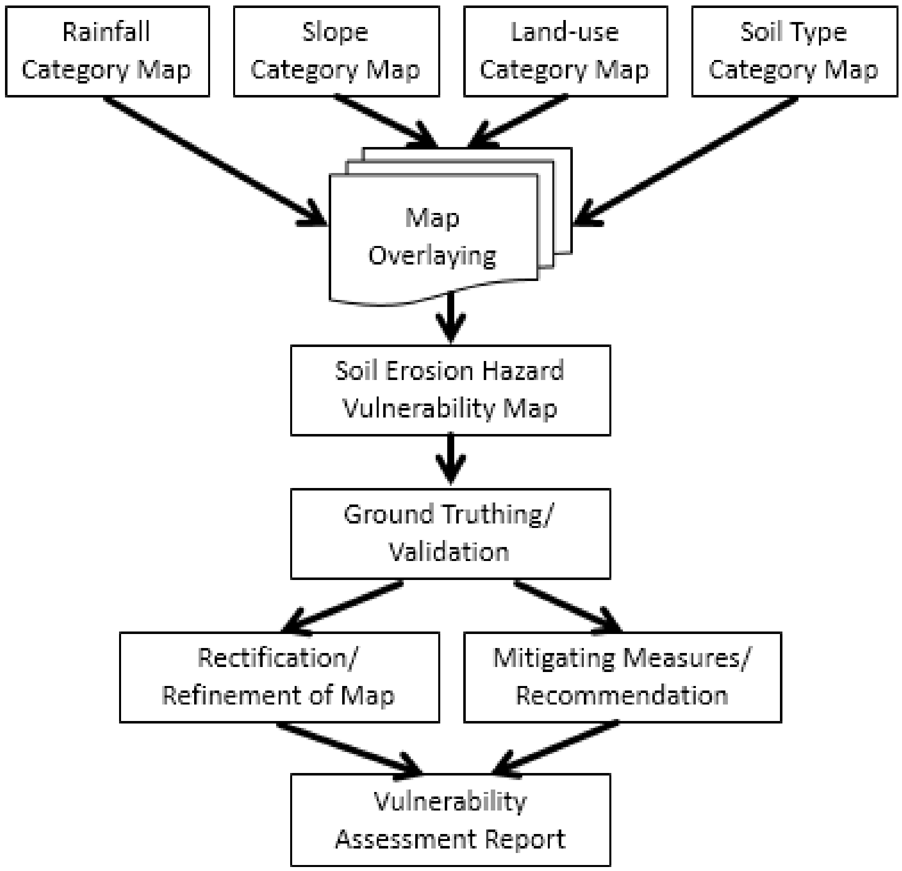


Figure 3. Framework of Soil Erosion Hazard Vulnerability Assessment

IV. RESULTS AND DISCUSSION

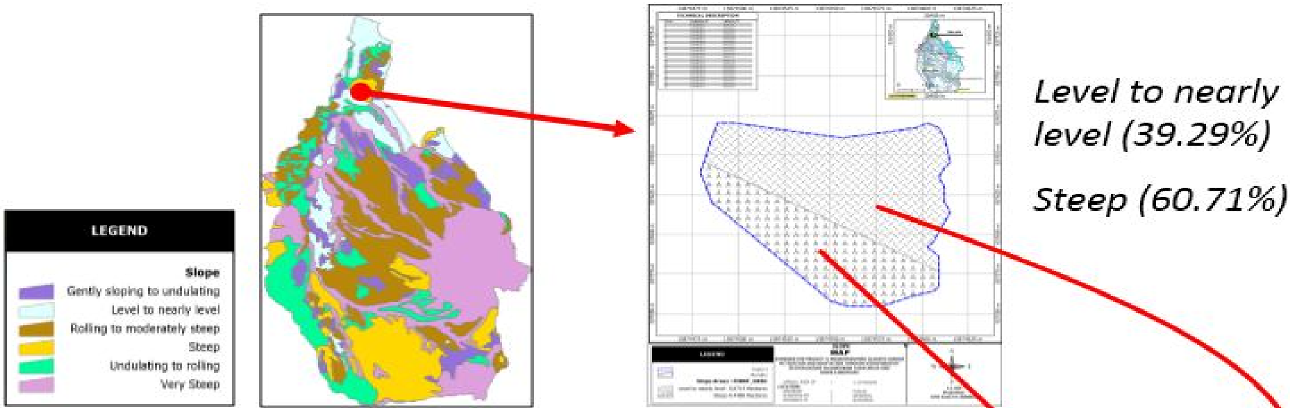
Findings on Bio-Physical and Geological Characterization

A. Slope Classification

Figure 4 presents the slope classification of the project site with reference to the Cagayan de Oro River basin, the Bubunawan sub-watershed and the entire landscape. The project site was classified under two slope categories: level to nearly level (0-3%) of about 39% of the total area and steep (30-50%) category consisting of about 61%. The table further presents that for the entire CDO River basin, 31% of its total land area belong to the Very steep category (50% and above); for the entire Bubunawan subwatershed,42% of it also falls under the same category. In the case of Pualas, about 66% of the barangay is classified as steep (30-50%) slope. Moreover, in all four locations presented in figure 4, there is a small percentage to the level to nearly level category.

The elevation gradually increases as the direction shifts to the north where an intermittent creek radiates to the west going downstream in the southeast direction, further joining other small tributaries that drain towards the Bubunawan River. In terms of the overall aspect, the Agroforestry (AF) pilot site can be described as generally exposed to sunlight during daytime. This location greatly favors the growth of agroforestry species planted in the site since enough sunlight is also necessary for plant growth.

Furthermore, the agro-forestry pilot site consisted of about sixty-seven per cent (67%) level to nearly level and about thirty-seven percent (37%) of steep slope. Per ocular inspection conducted, the steeper portions are generally covered with grass vegetation and the evidence of soil erosion was also noted.



BIO-PHYSICAL CHARACTERISTIC		WITHIN CDO RIVER BASIN (134,958.7552 Has.)	%	WITHIN BUBUNAWAN WATERSHED (26,668.38 Has.)	%	WITHIN BARANGAY PUALAS (1,673.24 Has.)	%	WITHIN PROJECT SITE (1.12 Has.)	%
SLOPE CLASSIFICATION	(%)	134,958.67	100.00%	26,668.38	100.00%	1,673.17	100.00%	1.12	100.00%
1 Level to nearly level	(0-3%)	8,737.26	6.47%	4,057.71	15.22%	292.02	17.45%	0.44	39.29%
2 Gently sloping to undulating	(3-8%)	11,827.56	8.76%	2,637.63	9.89%	113.45	6.78%	-	0.00%
3 Undulating to rolling	(8-18%)	21,408.23	15.86%	2,537.19	9.51%	129.96	7.77%	-	0.00%
4 Rolling to moderately steep	(18-30%)	30,921.51	22.91%	4,508.33	16.91%	96.92	5.79%	-	0.00%
5 Steep	(30-50%)	20,464.77	15.16%	1,372.46	5.15%	1,040.82	62.21%	0.68	60.71%
6 Very Steep	(50% and above)	41,599.34	30.82%	11,555.06	43.33%	-	0.00%	-	0.00%

Figure4. Slope Map of the Pilot Area

B. Rainfall data

The rainfall pattern of the area is culled from the data shown in Table 3 which is generated from five (5) sources in specified periods; the Malaybalay-based PAG-ASA (Synoptic) Station with a 30-year record (1971-2000) and a 4-year most recent record (2010-2013), the Baungon LGU rain gauge station with a 10-year record (1991-2000), the Talakag Municipal Agrarian Office with a 16-year record (1990-2006), the Lantapan Municipal Agriculture Agromet Station with a 29-year record (1977-2005), and the CDO Station at Lumbia with a 5-year record (2003-2007) and with a very recent 4-year record (2010-2013).

Table3. Rainfall Data obtained from different recording stations

Station	Malaybalay*	Baungon*	Talakag*	Lantapan*	CDO*	Malaybalay**	Lumbia, CDO**
Period	1971-2000	1991-2000	1990-2006	1977-2005	2003-2007	2010-2013	2010-2013
Month	Monthly average rainfall (mm)						
January	181.3	133.8	133.5	155.7	52.3	275.7	142.5
February	133.3	137.1	157.3	110.6	51.6	176.8	95.2
March	131.0	75.0	124.8	129.4	28.3	91.6	70.7
April	129.4	127.4	135.2	148.0	22.5	114.8	53.7
May	231.1	188.7	330.1	304.7	126.0	311.8	156.4
June	316.0	308.6	460.0	306.4	226.9	387.8	210.6
July	329.4	259.8	316.3	207.7	237.5	368.4	269.4
August	301.4	282.1	283.1	352.2	194.4	383.3	206.3
September	302.8	304.2	455.9	281.7	219.4	273.3	214.8
October	315.6	261.0	376.0	243.4	177.3	342.6	215.1
November	187.1	198.2	251.3	93.6	67.2	169.2	81.1
December	181.5	190.8	174.6	136.7	157.5	273.8	171.5
Ave. Monthly	228.3	205.6	266.5	205.8	130.1	264.1	157.3
Ave. Annual	2,739.9	2,466.7	3,198.1	2,470.0	1,561.0	3,169.0	1,887.2

Source: DENR10-ERDS, 2009; DOST-PAGASA 10

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The general trends from different recording stations show that the heaviest rainfalls usually occur in the months of June up to August (encircled with blue color) and the lowest precipitations occur during March to April (encircled with red color). This trend conforms to the climatic type of the watershed area which is described as "Season not very pronounced, dry from November to April and wet during the rest of the year" (Climatic Type III). This further show that dry season still occur during summer months while the onset of rainy season takes place usually at the later part of May. The highest average annual rainfall is observed and recorded in the nearby Talakag Municipal Agrarian Office. Based from data reflected in table 3, the average monthly and annual precipitation data from these two stations only differ slightly at 2,466.7 mm and 1, 887.2 respectively.

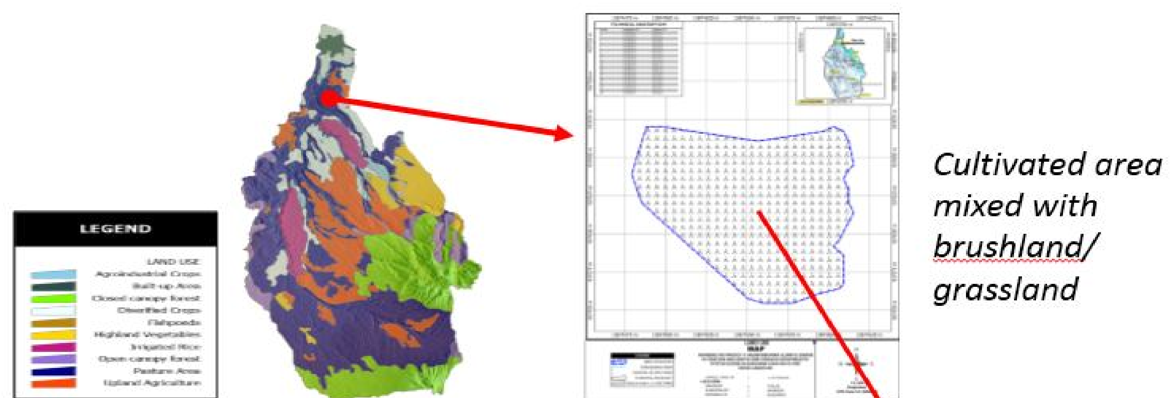
It can therefore be construed that the intensity of rainfall in these recent years is not the factor causing flash floods and landslides. The disastrous effect of heavy rains in these present years are therefore mainly caused by continuous deforestation (that lessens rain water infiltration/percolation, intensified surface runoff, increased erosion/landslides, and hastened sedimentation/siltation), erroneous/irresponsible land-use allocation including setting-up of settlement/built-up areas in geo-hazard areas and many others.

C. Vegetation cover/land use

The entire barangay has four land-use types; agro-industrial crop land (planted with mango, rubber, pineapple), diversified crop land (planted with different seasonal and perennial crops), upland agriculture (usually those under the CBFMA area), and pasture area (usually abandoned areas with poor soil condition).The land use of the project site per DENR classification is pasture area since most of grasses are found in higher grounds. However, it is only used occasionally as pasture by local residents. Aside from its being converted into a Community-Based Forest Management (CBFM) area, the site is already devoid of forest vegetation since it is dominantly vegetated with cogon, hagonoy, and other grasses that indicate poor soil condition caused by intensive farming or otherwise soil-degrading activities in the past.

In gully portions where intermittent streams are located, brushes composed of pioneer plant species like Buchanania arborescens (balinghasai/an-an) Antidesma ghasembilla (binayuyu), Wikstroemia sp. (native salago/sayapo) and others are observed. Typically, these are the common plant species that are usually found in the so-called mineralized type of soil.

Figure 5 shows the Land Use of the entire Bubunawan Sub-watershed of which the Pilot Site is situated within one component area, barangay Pualas.



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LAND USE	**134,958.69**	**100%**	**26,668.38**	**100.00%**	**1,673.25**	**100.00%**	**1.12**	**100.00%**
1 Agro-industrial Crops	1,803.37	1.34%	795.19	2.98%	3.95	0.24%	-	0.00%
2 Built-up Area	1,205.80	0.89%	728.48	2.73%	-	0.00%	-	0.00%
3 Closed canopy forest	26,661.53	19.76%	5,268.05	19.75%	-	0.00%	-	0.00%
4 Diverified Crops	10,258.88	7.60%	3,323.18	12.46%	84.70	5.06%	-	0.00%
6 Highland Vegetables	7,745.38	5.74%	5,999.17	22.50%	-	0.00%	-	0.00%
7 Irrigated Rice	6,485.13	4.81%	1,101.77	4.13%	-	0.00%	-	0.00%
8 Open canopy forest	5,289.97	3.92%	2,690.60	10.09%	-	0.00%		0.00%
9 Pasture Area	54,767.82	40.58%	5,723.81	21.46%	1,499.07	89.59%	1.12	100.00%
10 Upland Agriculture	20,740.82	15.37%	1,038.12	3.89%	85.53	5.11%		0.00%

Figure5. Land Use of the Pilot Site

As can be gleaned from table, about twenty-two percent (22%) of the entire Bubunawan watershed is classified as pasture in as much as grasses predominate. In the same manner, the identified CBFM-owned Agroforestry Pilot site is also occasionally used as pasture by the residents. The local community is engaged in diversified crop farming. This further shows that agro industrial crop production is higher within the Bubunawan watershed (2.62%) compared to the Cagayan de Oro River basin (1.32%) and much smaller in Barangay Pualas (0.20%). These data are attributed to the presence of pineapple, banana, and rubber crops established.

On the other hand, there is more percentage of open canopy forest in Bubunawan Watershed than within Cagayan de Oro River Basin which may suggest that there is a higher rate of forest degradation in Cagayan de Oro environs. The land cover map for the Agroforestry pilot site presented in figure 6, is categorized as pasture area then grasses predominate among other vegetative type.

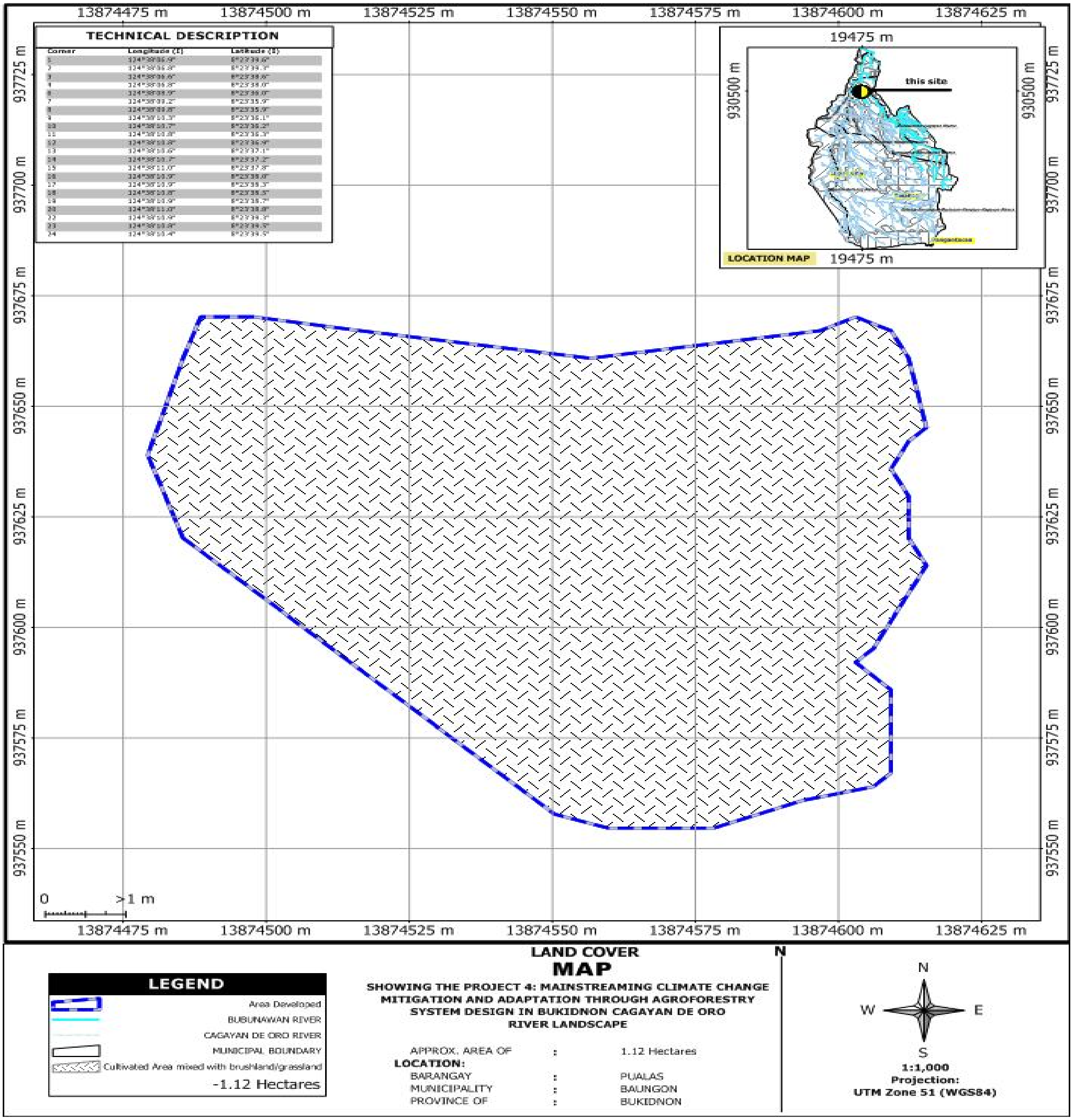

Figure 6. Land Cover Map of the AF Area

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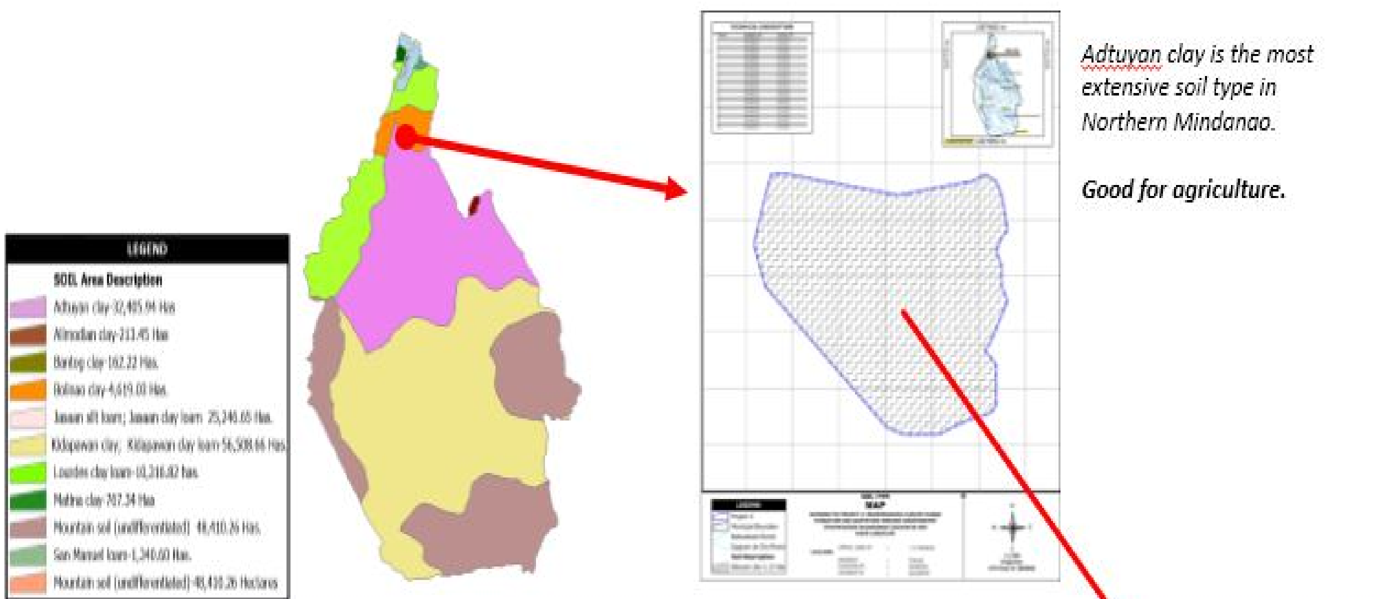
D. Soil type

The soil type of the area is generally adtuyon clay. Although there are nine (9) soil types within the Cagayan de Oro River Basin which are also found within the Bubunawan watershed, there are only two (2) soil types within Barangay Pualas; the adtuyan clay (39%) and the Bolinao clay (6.1%). However, within the pilot area, only adtuyon clay is present, which further described the layer of the soil as slightly heavier. Generally, Adtuyon clay is developed from volcanic lava or mudflows (lahar) composed of mixed boulders but chiefly andesites (fine-grained grayish volcanic rock) and basalt (hard, black volcanic rock). The texture of this soil is basically granular in nature which promotes easy water movement in the soil mass. This type of soil is agriculturally dull and unimportant (dela Cruz, 2004).A brief description of the soil types within the area and the whole river basin is presented in Figure 7.



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SOIL TYPE	**134,958.74**	**100.00%**	**26,668.38**	**100.00%**	**1,673.25**	**100.00%**	**1.12**	**100.00%**
1 Adtuyan clay	32,172.15	23.84%	11,179.15	41.92%	1,501.05	89.71%	1.12	100.00%
2 Alimodian clay	162.82	0.12%	162.82	0.61%	-	0.00%	-	0.00%
3 Bantog clay	160.88	0.12%	160.58	0.60%	-	0.00%	-	0.00%
4 Bolinao clay	2,536.71	1.88%	1,695.09	6.36%	172.20	10.29%	-	0.00%
5 Jasaan silt loam; Jasaan clay loam	10,292.60	7.63%	1,789.78	6.71%	-	0.00%	-	0.00%
6 Kidapawan clay; Kidapawan clay loam	56,084.67	41.56%	3,631.07	13.62%	-	0.00%	-	0.00%
7 Matina clay	59.41	0.04%	-	0.00%	-	0.00%	-	0.00%
8 San Manuel loam	32,499.89	24.08%	320.26	1.20%	-	0.00%	-	0.00%
9 Mountain soil (undifferentiated)	989.61	0.73%	7,729.63	28.98%	-	0.00%	-	0.00%

Figure7. Soil type

E. Soil Nutrient Status and Soil Bulk Density

The macro-nutrients are essential elements used for plant growth requirements; these are nitrogen, phosphorus, and potassium, and the micro-nutrients magnesium and calcium. Table 4 shows the level of macro and micro-nutrients of soil in the pilot agroforestry farm located in Pualas, Baungon Bukidnon.

Table 4. Soil Test Data of the Agroforestry Site in Barangay Pualas, Baungon, Bukidnon

	Soil Depth		
Soil Nutrients	Top Soil	Sub Soil	Standard
pH	7.5	7.3	5.6-6.5
Organic Matter	1.5	0.9	2.1-4.1
Phosphorus	27.8	22.2	7-30
Nitrogen	0.13	0.07	
Magnesium	2922	3075	
Potassium	52.4	48.7	36-250kg/ha
Calcium	20207	18478	250kg/ha
Cation Exchange Capacity	68.8	58.5	
Bulk Density	0.67	0.66	< 1.60

It was shown further that the pilot agroforestry farm has top soil pH of 7.5 and pH 7.3 in sub soil which indicates that the soil is slightly alkaline. A pH range of approximately 6 to 7 promotes the most readily available for plant nutrients. However, soil pH in the range of 7 to 8 is adequate for many plants, especially those adapted to arid environment. In terms of the organic matter concentration, it was noted that it has the value below 2.1- 4.1 standard of DA, top soil has 1.5 and sub soil has 0.9, thus we can conclude that soil has poor organic matter content.

Elemental Phosphorus present in the soil has value of 27.8 in top soil and 22.2 in subsoil which implied that it passed the standard set by Department of Agriculture, it supported the fact that Phosphorus is never readily soluble in the soil but is most available in soil with a pH range centered around 6.5, hence the soil pH in the area is above 6.5.

In terms of Nitrogen content, LaMonnette levels for NPK soil test has 0-15 ppm for low level N and 30+ for high level, thus the value 0.07-0.13 values for top soil and sub soil respectively shows that presence of nitrogen in the pilot agroforestry soil is low. Nitrogen is important for plant growth and development, and of the macronutrients, is often the one of most limiting. Soil nitrate (NO3) and ammonium (NH4) are both forms of inorganic nitrogen that are readily available for use by plants, they formed from the mineralization (by microorganisms) of organic forms of N, such as soil organic matter, crop residue and manures, but since organic matter is low, production of nitrogen is also low.

On the other hand, the value of magnesium is 29.22 -30.75 for top soil and sub soil respectively it means that it is within the standard of Department of Agriculture, it was noted that if the pH of the soil ranges 5.0-5-2 it requires the application of dolomite 250 kg/ha but since pH level is higher or slightly alkaline, it will no longer require application of dolomite.

Furthermore, in terms of Potassium, values of 52.4 on top soil and 48.7 for sub soil shows that it is within the DA standard which is 36-250kg/ha, Potassium is essential in building of protein, photosynthesis, fruit quality and reduction of diseases. Finally, calcium has value of 202.07 for top soil and 184.78 sub soil which indicates that calcium is lowered compared to the DA standard which is 250kg/ha.

In terms of cat ion exchange, it was revealed that the soil in barangay Pualas Baungon is likely to have a low CEC if it has been highly weathered and has a low organic matter content. If the soil has been protected from erosion most of its life and has high levels of organic matter, The rate of cation exchange in soils determines how quickly soil particles can replace cations once a plant's root system extracts nutrients from the soil.

Soil Bulk Density is an indicator of soil compaction. It reflects the soil's ability to function for structural support, water and solute movement, and soil aeration. It is used to convert between weight and volume of soil. It is also used to express soil physical, chemical and biological measurements on a volumetric basis for soil quality assessment and comparisons between management systems.High bulk density is an indicator of low soil porosity and soil compaction. It may cause restrictions to root growth, and poor movement of air and water through the soil. Compaction can result in shallow plant rooting and poor plant growth, influencing crop

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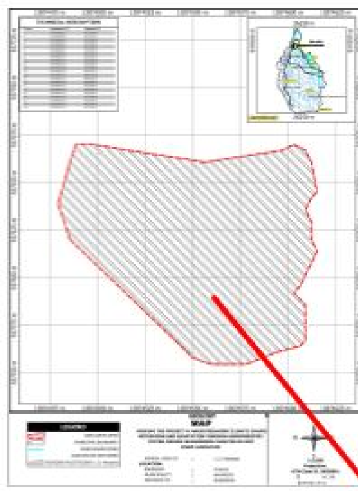
yield and reducing vegetative cover available to protect soil from erosion. By reducing water infiltration into the soil, compaction can lead to increased runoff and erosion from sloping land or waterlogged soils in flatter areas.

F. Geology

The geologic data for the agroforestry pilot site is culled from the existing data provided by DENR-10 baseline information.The infiltration capacity of the soil is an important consideration in the assessment of the occurrences of surface run-off and flashfloods. The Bubunawan watershed where the study area is located is underlain by different rock formation of varying ages and thickness (ERDS, DENR-10, 2009). Among the rock formations are: Himalayan formation, Bukidnon formation, Indahag limestone, Quaternary alluvium, and Cagayan terrace gravel as shown in Figure8. (Geologic Map of Bubunawan Watershed). Per available secondary data, within the study area is a formation from the early Pliocene and Quaternary Pleistocene to Holocene. These could greatly influence the vulnerability of the site to landslides.

Geology



Within the study area is a formation from the early Pliocene and Quaternary Pleistocene to Holocene.

GEOLOGIC DESCRIPTION	WITHIN CDO RIVER BASIN	%	WITHIN BUBUNAWAN WATERSHED	%	WITHIN BRGY. PUALAS	%	WITHIN PROJECT SITE	%
Neogene	6,454.26	4%	-	0%	-	0%		
Pliocene-Pleistocene	12,265.78	8%	2,146.05	8%	1,360.17	88%	1.12	100%
Pliocene-Quaternary	113,950.81	72%	21,550.33	80%	183.43	12%		
Recent	7,525.67	5%	2,474.02	9%	-	0%		
Undifferentiated (Sedimentary and Metamorphic Rocks)	17,946.90	11%	619.79	2%	-	0%		
Total	158,143.43	100%	26,790.19	100%	1,543.59	100%	1.12	100%

Figure 8. Geologic Map of the Area

V. VULNERABILITY ASSESSMENT AND HAZARDANALYSIS

A. Category Maps

Table 5 shows the geo-hazard classification of the Agroforestry (A) Pilot Area with reference to the major points namely, within CDO River Basin, within Bubunawan watershed, and within Barangay Pualas with the corresponding geo-hazard values (DENR-ERDS, 2009). As can be noted, the AF Pilot site is only 1.1% of the total geo-hazard percentage; due to its slope classification as previously identified, it is classified as Moderately Susceptible to landslide. On the other hand, Barangay Pualas has both Moderately Low and Moderate Susceptibility to landslide classification since there are portions of the barangay which is classified as Steep Slope (30-50%). Further, since there are Level to Nearly Level Slope Category (0-3%), about 5% of the Barangay has High Susceptibility to Flooding. However, it can also be noted that Within Bubunawan Watershed, a greater percentage has Low Susceptibility to Landslide.

Table 5. Geo-hazard classification of the area

BIO-PHYSICAL CHARACTERISTICS	WITHIN CDO RIVER BASIN (138,042.08 Has.)	%	WITHIN BUBUNAWAN WATERSHED (30,015.81 Has.)	%	WITHIN BARANGAY PUALAS (1,681.47 Has.)	%	WITHIN PROJECT SITE (1.12 Has.)	%
GEOHAZARD	138,112.3	100%	114,862.9	100%	1,681.5	100%	1.1	100%
1 High Susceptibility to Flooding	2,622.3	1.90%	2,622.3	2.28%	96.5	5.74%		
2 High Susceptibility to Landslide	34,580.9	25.04%	11,331.4	9.87%	269.3	16.02%		
3 Low Susceptibility to Landslide	80,361.2	58.19%	80,361.2	69.96%	659.8	39.24%		
4 Low to Moderate Susceptibility to Flooding	473.6	0.34%	473.6	0.41%		0.00%		
5 Moderate Susceptibility to Landslide	20,074.4	14.53%	20,074.4	17.48%	655.8	39.00%	1.1	100%

It was observed that since the AF Pilot Site which is part of the Bubunawan Watershed has negligible values for flooding a flood hazard map was not produced. However, a landslide hazard map was generated due to its slope values as mentioned in the preceding pages. Prior to the generation of the Landslide Hazard Map a Rating of Critical Factors Affecting Landslide was done as presented in Table 8.

Table 6: Rating of critical Factors affecting landslide

Vulnerability Class	Rating	Slope	Ranfall (mm.)	Landuse/ Veg. Cover	Soil Type	Geology (Age)
Not vulnerable	1	0-8%	<145	Close/Open canopy forest	Adtuyon	Indahag limestone
Very low	2	8.1-18%	145.1-156	Brushland/tree plantation	Kidapawan clay loam	Indahag limestone
Moderate	3	18.1-30%	156.1-167	Grassland/orchard	Alimodian clay	Bukidnon Formation
High	4	30.1-50%	167.1-177	Agriculture (crops)	Bolinao clay	Himalayan formation
Very high	5	>50%	>177	Agriculture (banana/ pineapple plantation)	Mountain soil	Quaternary alluvium

The critical factors considered were the values generated for slope, amount of rainfall, land use and vegetative cover, soil type and geological history of the site.

After the analysis of such factors, the values were further classified based on two observed anthropogenic activities: the farming system employed in the area and the relative distance of the site from road networks. Farming systems data were obtained from the socio-economic survey conducted and from secondary data generated from DENR-ERDS data and road network maps from DENR 10. The ratings of such parameters are important in order to produce the necessary geo-hazard maps. The results of values analysis yielded the following landslide hazard categories:

Table7. Landslide Hazard values due to Farming System

Vulnerability Class	Rating	Extent of disturbances by farming system
Very low vulnerability	1	The farming systems do not favor any landslide
Low vulnerability	2	The farming system slightly favor minor landslides
Moderately vulnerable	3	The farming system slightly favor major landslides
Highly vulnerable	4	The farming system highly favor minor landslides
Very highly vulnerable	5	The farming system highly favor major landslides

Table 8. Landslide Hazard based on relative distance from the road

Vulnerability Class	Rating	Relative distance from the road network
Very low vulnerability	1	>60 meters from the center of the road
Low vulnerability	2	45.1-60 meters from the center of the road
Moderately vulnerable	3	30.1-45 meters from the center of the road
Highly vulnerable, and	4	15-30 meters from the center of the road
Very highly vulnerable	5	<15 meters from the center of the road

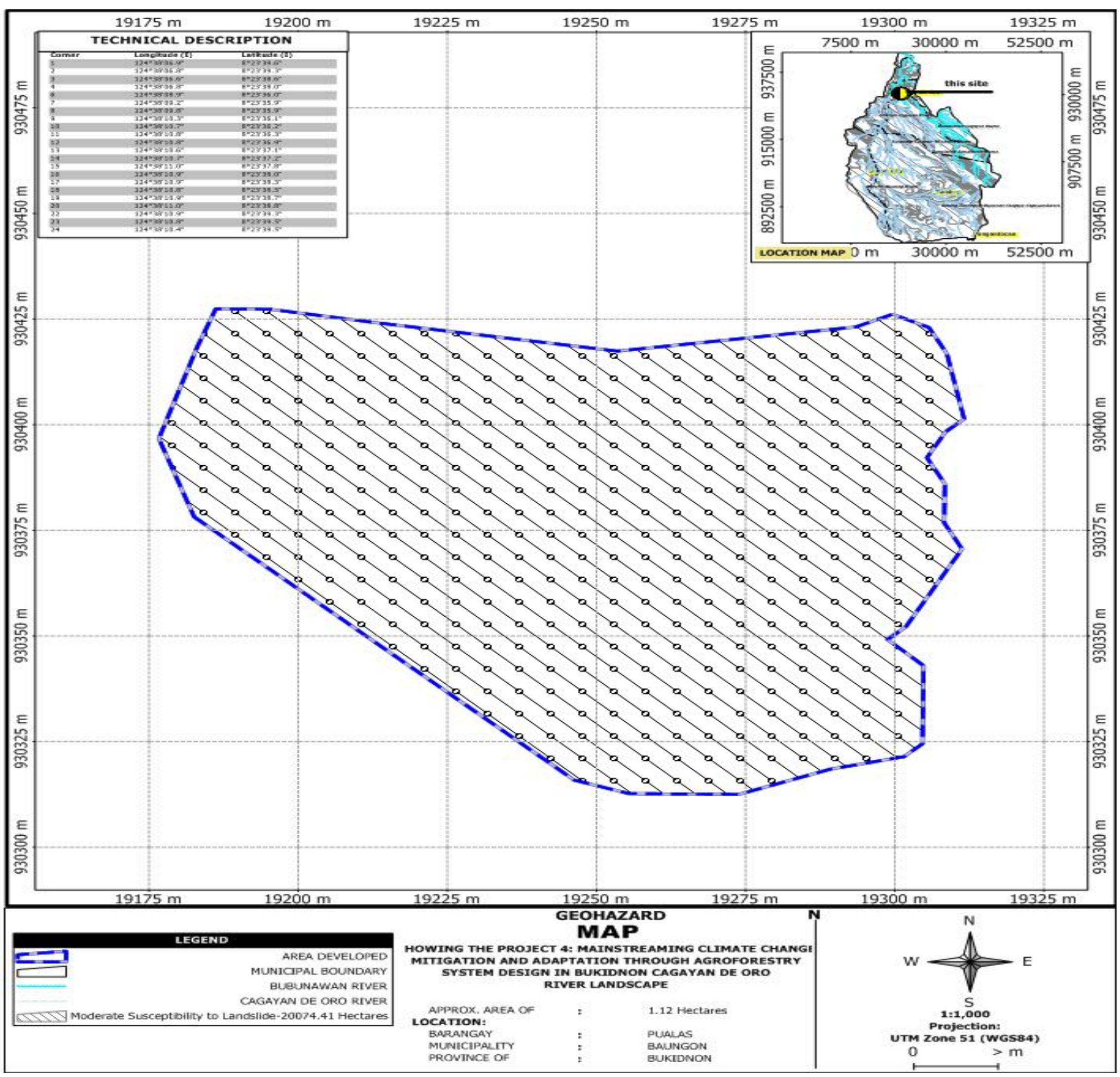


Figure9. Geo-hazard Map of the Area

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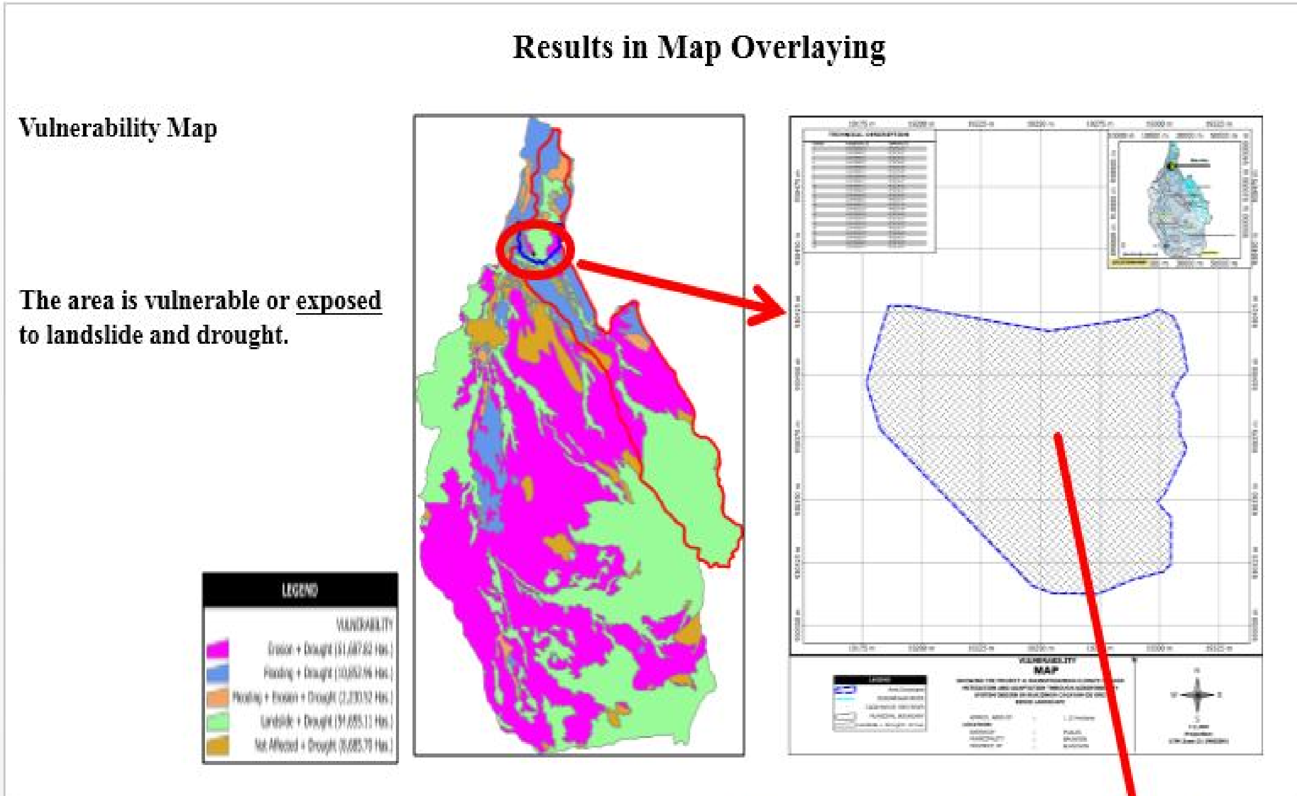
B. Vulnerability Classification

After the analysis of critical factors and category map were done, the hazard vulnerability maps were subjected to map overlays in order to develop the susceptibility map desired. Figure 10presents the vulnerability classification generated from the mapping of critical factors (anthropogenic factor and physical factor).



BIO-PHYSICAL CHARACTERISTICS	WITHIN CDO RIVER BASIN (138,042.08 Has.)	%	WITHIN BUBUNAWAN WATERSHED (30,015.81 Has.)	%	WITHIN BARANGAY PUALAS (1,681.47 Has.)	%	WITHIN PROJECT SITE (1.1[illegible] Has.)	%
VULNERABILITY	138,112.2	100%	30,016.4	100%	1,681.5	100%	1.1	100%
1 Erosion + Drought	61,687.8	44.67%	1,277.7	4.26%	332.2	19.76%		
2 Flooding + Drought	10,853.0	7.86%	6,751.6	22.49%	382.8	22.77%		
3 Flooding + Erosion + Drought	2,230.5	1.62%	7,030.8	23.42%	11.5	0.68%		
4 Landslide + Drought	54,655.1	39.57%	1,611.1	5.37%	925.1	55.02%	1.1	100%
5 Not Affected + Drought	8,685.7	6.29%	13,345.3	44.46%	30.0	1.78%		

Figure 10. Results in Map Overlaying

Figure 10 had five (5) vulnerability parameters considered namely, 1) Erosion +Drought; 2) Flooding + Drought; 3)Flooding + Erosion + Drought; 4) Landslide + Drought and; 5) Not affected + Drought. With respect to the vulnerability of the AF Pilot Site, it is classified as vulnerable to Landslide + Drought only. This can be attributed to the slope category of which more than 60% of the total area is steep (30%-50%) and the soil type (Adtuyon clay) prevailing in the site. Similarly, the entire Barangay Pualas, is also generally vulnerable to Landslide + Drought followed by the category on Flooding + Drought (22.7%) which implies that during heavy rains, the level to nearly level portions may become flooded and that during the dry periods of the year, drying up of the soil is higher since grasses predominates in the area.

With reference to the CDO River Basin and the Bubunawan Watershed, majority of these areas are classified as vulnerable to Erosion + Drought (44.67%) and Not Affected + Drought (44.46%) respectively. In the case of the CDO River Basin, its vulnerability to soil erosion and drought can be attributed to a relatively bigger area within the Very Steep (over 50% slope) category and a rapidly declining presence of forest vegetation which could greatly contribute to erosion during heavy rains and

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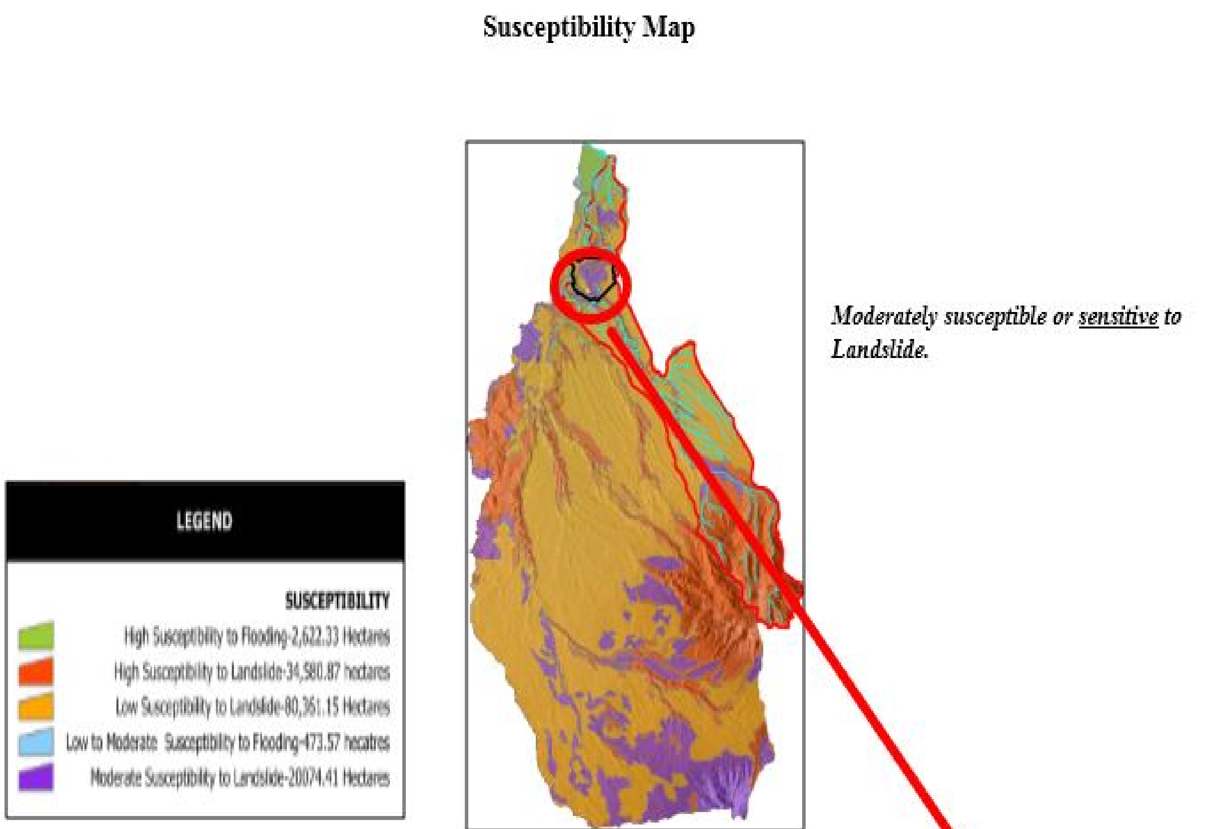
greater possibility of drought during the dry season due to the very limited forested area that performs the role of regulating the microclimate.

C. Degree of Susceptibility

The susceptibility assessment of the AF Pilot Site is conducted to determine the degree of susceptibility to the identified geo-hazards specifically flooding and landslide. Figure 11 presents the five (5) major susceptibility categories derived from the vulnerability data which are 1) High Susceptibility to Flooding; 2) High Susceptibility to Landslide; 3) Low Susceptibility to Landslide; 4) Low to Moderate Susceptibility to Flooding and; 5) Moderate Susceptibility to Landslide. It can be gleaned from the table that the entire AF Pilot Site is classified to be of Moderate Susceptibility Landslide only. From the bio-physical characteristics of the site generated, it suggests that critical factors like slope, soil type, land use and vegetative cover are the main considerations that favor for this susceptibility classification. The slope category of being Steep (30-50%) would have favored a high susceptibility to landslide if not for the soil type which is of clay type (Adtuyon) that would tend to hold the soil particles better than if it was sandy; the occasional pasturing by the local people also made it moderately susceptible to landslide because the existing vegetation can still hold the soil intact.



BIO-PHYSICAL CHARACTERISTIC	WITHIN CDO RIVER BASIN (134,958.7552 Has.)	%	WITHIN BUBUNAWAN WATERSHED (26,668.38 Has.)	%	WITHIN BARANGAY PUALAS (1,673.24 Has.)	%	WITHIN PROJECT SITE (1.12 Has.)	%
SUSCEPTIBILITY MAP	**134,958.65**	**100.00%**	**26,668.27**	**100.00%**	**1,673.17**	**100.00%**	**1.12**	**100.00%**
1 High Susceptibility to Flooding	2,287.39	1.69%	945.97	3.55%	98.34	5.88%	-	0.00%
2 High Susceptibility to Landslide	34,146.88	25.30%	11,121.40	41.70%	259.30	15.50%	-	0.00%
3 Low Susceptibility to Landslide	78,784.67	58.38%	12,371.56	46.39%	659.73	39.43%	-	0.00%
4 Low to Moderate Susceptibility to Flooding	399.88	0.30%	251.54	0.94%	-	0.00%	-	0.00%
5 Moderate Susceptibility to Landslide	19,339.84	14.33%	1,977.80	7.42%	655.80	39.20%	1.12	100.00%

Figure11. Susceptibility Map

VI. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusion

The existing biophysical conditions and geological data of the area may have great contribution to the vulnerability and the possible impacts of climate change to the people, farms, and other properties. Anthropogenic activities that degrade the natural environment can be more destructive than the physical attributes of the area combined. Deforestation and excessive water resource use may have a critical implication in the global climate change that the environment is currently experiencing.Moreover, the study area is vulnerable to landslide during heavy/prolonged rainfall because it is already devoid of vegetation. It is likewise vulnerable to drought. Most of the barangay/ village residents have limited knowledge on the concept of sustainable development/management of watershed resources as can be observed in current farming practices; not many farms can be observed employing such technologies as contour farming or sloping agricultural land technology (SALT). Hence, the establishment of the agroforestry pilot site is timely to mitigate the effects of climate change in this part of the region.

B.Recommendation

The pilot agroforestry site is found to be moderately susceptible to landslide and flooding which may be true to other farm holdings of the CBFM-PO members. However, it is suggested that the members help monitor future land use and resource utilization to prevent the site from becoming highly vulnerable to such hazards.

The CBFM-PO may consider replicating the agroforestry system design in other farm holdings to ensure that the lands awarded to the members become more productive thus enabling them to attain food sufficiency while at the same time prepare themselves for the impacts of global climate change.

The Barangay/Village Council of Pualas may consider a massive rehabilitation of denuded areas in the barangay classified as very steep slope to prevent the increase of soil erosion and possible occurrence of landslides and floods in the locality and increase the infiltration capacity of the soil to reduce runoff during heavy rains.

The area should be vegetated/developed by applying appropriate upland agro-forestry system/s. The CBFM-PO may help the DENR-10 monitor the land use practices and resource utilization that degrade the environment.

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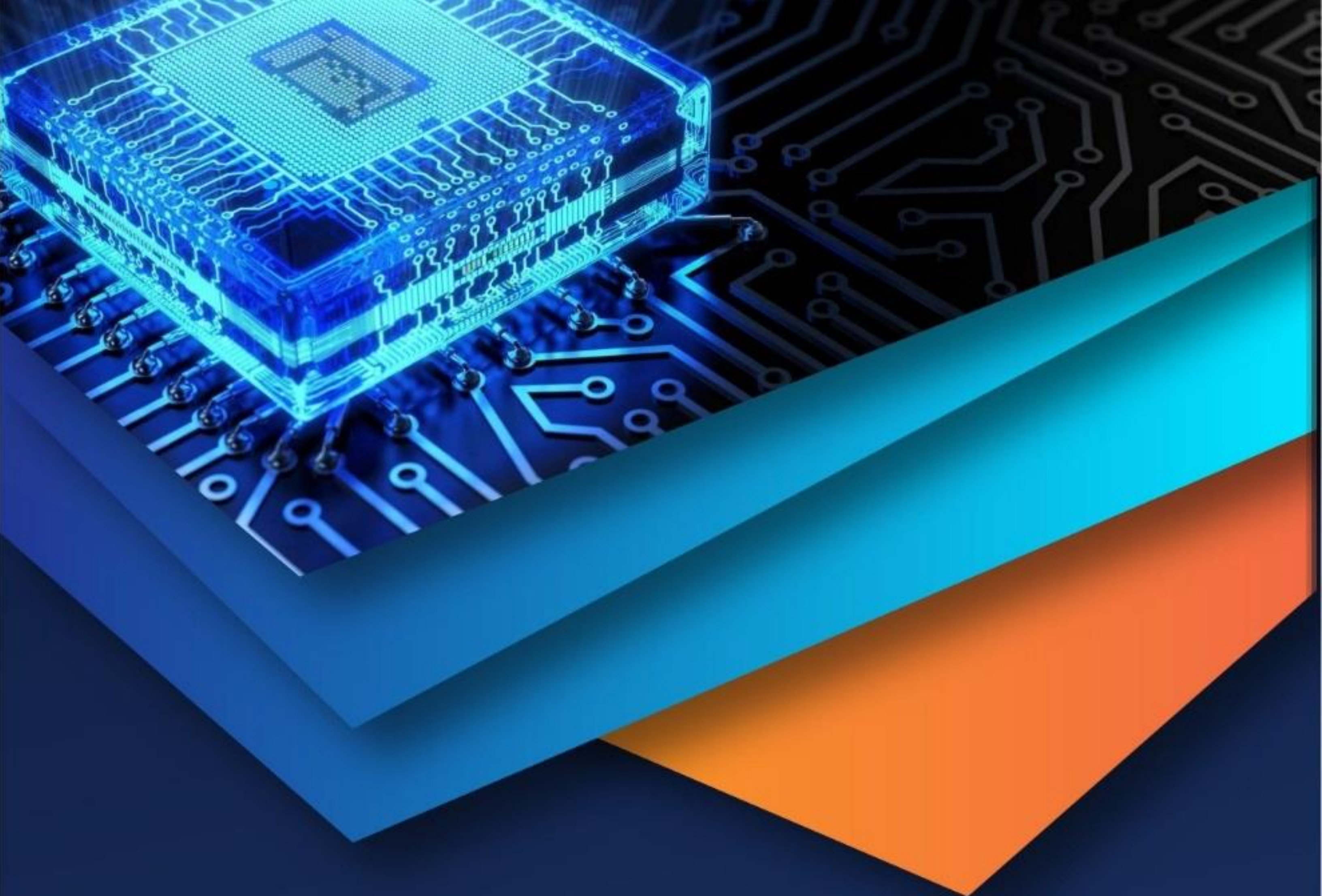

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