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RESEARCH ARTICLE

TYPOLOGY OF DRIVERS OF EROSION AND EROSION POTENTIAL IN THE PROVINCE OF LANAO DEL SUR, PHILIPPINES.

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Abstract

Soil erosion is a serious problem, a threat that may result to temporary or permanent loss of soil productivity. Left unchecked, and with a population that continuous to increase, food will become a serious problem. A threat on soil erosion become evident and hinders soil productivity. Today and in the recent past, remote sensing technology is utilized as part of any developmental work. The aim of this study was to analyze the typology of the drivers of erosion in the Province of Lanao del Sur and to develop an erosion potential map using arcGIS. The total land area of Lanao del Sur is 1,294,728 ha, mostly of the Mountain soil type, undulating to rolling slope, forest reserve land classification, closed canopy and mature trees covering >50% land cover. It has a Type III climate according to Corona classification. The erosion potential of the province is moderate as drawn from the erosion potential map extracted from the attributes of data. The results further suggest the application of control measures such as cover cropping and application of Sloping Agricultural Land Technology (SALT) are necessary to lessen the erosion potential in the province. Reservation of the forest and maintenance of at least >70% cover of the land to dissipate the erosive potential of rainfall is also recommended. Overall, the province of Lanao del Sur was not exploited to cause serious problem in erosion.

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Introduction:-

Soil is vital for the survival of human race. Almost everything we need comes from the soil like food, clothing, shelter, paper, timber, medicines, shade, and oxygen. Soil is considered a non-renewable resource and degradation of it due to human activities should be taken into consideration because an inch of soil could take thousands of years to be developed.

The world is now facing various environmental problems and soil degradation is one of these serious problems. Soil degradation's negative effects are often associated to loss of property, death, and in agricultural aspects this results to loss of OM and tremendous amount of mineral nutrients which make the soil unproductive. Soil erosion is as important as social and economic concerns not only for the people but also to maintain ecosystem functions and health. According to Steiner (1996), 5 to 7 million hectares of agricultural land becomes unproductive every year due to physical and chemical deterioration and this is more severe in tropical than temperate countries. In the Philippines, FAO reported soil loss higher than the 10t/ha tolerable loss (PCARRD, 1999). Soil erosion is considered a threat to food security with 5.2 million hectares seriously degraded resulting to 30-50% reduction in soil fertility (National Action Plan, 2004). Moreover, soil erosion hazard is the second biggest environmental challenges after population growth causing land degradation, desertification and water deterioration. Its impacts on watersheds include loss of soil nutrients, reduced reservoir capacity through siltation which may lead to flood risk, landslide, high water turbidity, etc (Sholagberu, 2017). These problems become more pronounced in human altered mountainous areas through intensive agricultural activities, deforestation and increased urbanization among others (Sholagberu, 2017).

Land degradation is defined as temporary or permanent reduction of productivity of land as a result of human activities. When the International Soil Research and Information Center (ISRIC) in cooperation with UNEP undertook an inventory of the status of global induced soil degradation, Global Assessment of Soil Degradation (GLASOD) was structured based on the type, severity, extent of degradation, and its major causes. Thus, it has become the basis for evaluating soil erosion potential in the land using the standard equation of Universal Soil Loss Equation (USLE). This is a function of rainfall erosivity, soil eordibility, slope length and gradient, cover and management practices.

The management of the data is now made easy by remote sensing tools and ArcGIS is one of these in particular. Through linking location to information is a process that applies to decision making in any developmental plan (ESRI, 2012). With the advancement of technology, it becomes easier to manage the information necessary to push through plans especially in agricultural aspects. Before going to the field, a data can be readily viewed from a map (ESRI, 2012). This shows much more advantage on a part of the researcher and development worker. Geographical information system (GIS) is computer software that links geographical information to that of descriptive information. It has many advantages like cost saving, better decision making, improved communication, better geographical information record keeping, and geographical management. In agriculture, crop suitability is the most important feature of GIS (ESRI, 2012). Using ArcGIS, the results indicates that 33.82%, 35.44%, and 30.74% of the study area were under low, moderate, and high actual erosion risks, respectively using remote sensing in Turkey (Yuksel et.al, 2008).

Lanao del Sur covers 1,294,728 ha and is located more than 900 meter above sea level (masl). Due to some factors, the area is not penetrable and the conduct of any developmental work is at stake. Considering the situation, the location itself suggests potential risk of erosion. Thus, there is a need to evaluate the status of land degradation in the province. By using ArcGIS, the erosion potential is identified and drawn from this study and control measures will be applied to further combat the negative effects of soil degradation in the province.

Objectives:-

1. Analyze the drivers of soil erosion in the province of Lanao del Sur using ArcGIS application.
2. Develop erosion potential map to determine the tension of erosion in the province of Lanao del Sur.

Methodology:-

Study Area:-

Lanao del Sur is a province of ARMM and borders Lanao del Norte to the north, Bukidnon to the east, and Maguindanao and Cotabato to the south. The total land area of Lanao del Sur is 1,294,728 ha. To the southwest lies Illana Bay, an arm of the Moro Gulf. Found in the interior of Lanao del Sur is Lanao Lake, the largest lake in Mindanao, where Maria Cristina Falls, the largest waterfall in the country is located (CAAM-SEDP, undated). There are 40 municipalities in the Province of Lanao del Sur namely Kappai, Bubong, Ditsaan-Ramain, Mulundo, Lumba Bayabao, Tagoloan, Taraka, Tamparan, Poona Bayabao, Bumbaran, Buntong, Lumbayanague, Butig, Marogong, Sultan Pumulondong, Kapatagan, Malabang, Balagtas, Tubaran, Maguing, Bumbaran, Sultan Gumander, Calanogas, Madamba, East Balot Island Pualas, Ganassi, Bayang, Binidayan, Pagayawan, Piagapo, Marantao, Buadi Poso, Saguiaran, Marawi City, Madamba, Balidong and Tugaya (Figure 1).

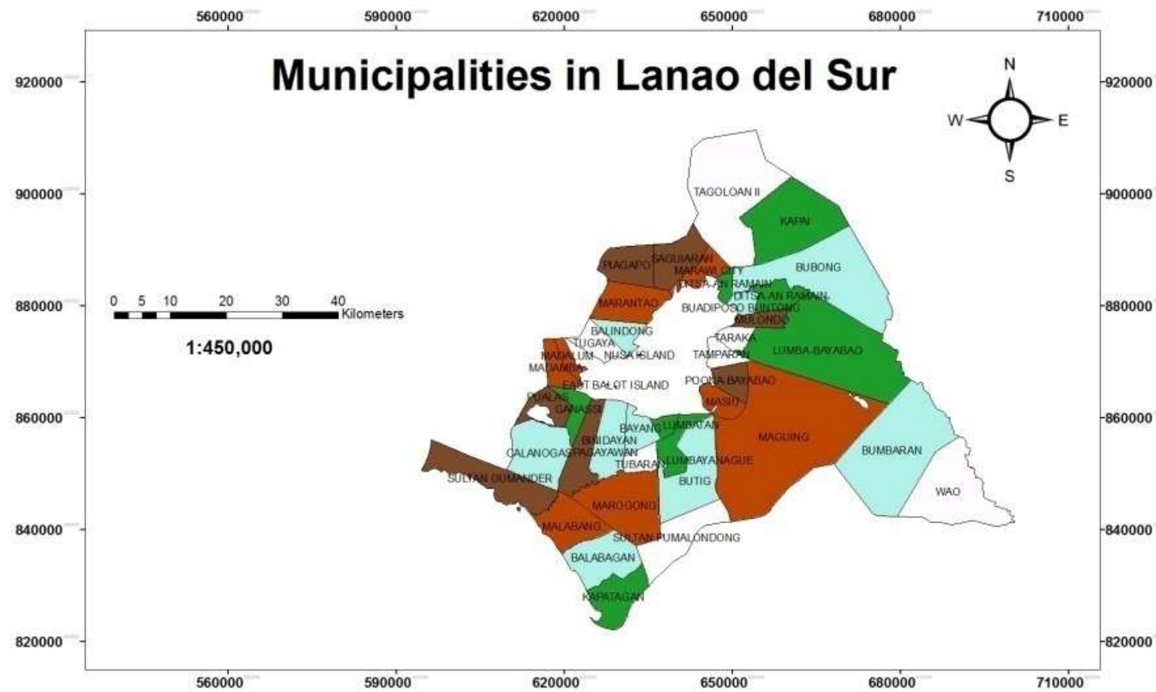


Fig.1:- Municipalities of Lanao del Sur

Data Source:-

Secondary data were used in this study. Using the application from ArcGIS (ESRI, 2012), a data provided by DA-BAR (www.dabar.com.ph) was utilized to create a map. The drivers of soil erosion considered in this study were soil type, slope gradient, land classification, climate type, land cover, and current soil erosion.

Data Management:-

Soil type for Soil Erodilibilty (K)

The soil type of the study was determined using the CORINE methodology on Soil Erosion Risk and Important Land Resources in the Southeastern Regions of the European Community (Corine,1992). The following table represents the distribution of potentiality of erosion.

Soil Texture	**Potential Erodibility**
Clay, Sandy clay, Silty Clay	Slightly Erodible
Silty Clay Loam, Clay Loam, Silty Clay Loam, Loamy Sand	Moderately Erodible
Loam, Silty Loam, Sandy Loam	Highly Erodible

Rainfall erosivity (R)

The rainfall erosivity was determined from the Fournier index (variability index) and Bagnouls-Gaussen Aridity Index (Corine,1992):

Erosivity Index = Variability Class x Aridity Class

Erosivity	**Potential Erodibility**
< 4	Slightly Erodible
4 – 8	Moderately Erodible
> 8	Highly Erodible

Slope/Topography (LS)

The potential risk for erosion in slope/topography considered the following ranges (Corine,1992):

Slope/Topography	**Potential Erodibility**
0 – 5	Slightly Erodible

5 – 11	Moderately Erodible
> 11	Highly Erodible

Land Cover (C)
The land cover was modified from the standard set from CORINE methodology (CORINE,1992):

Land Cover	**Potential Erodibility**
Fully protected	Slightly Erodible
Partially protected	Moderately Erodible
Not protected	Highly Erodible

Land Class (P)
Weight for land classification was modified as follows (CORINE,1992):

Land Class	**Potential Erodibility**
Forest Reserve and Public Forest	Slightly Erodible
Civil Reservation and Miscellanous	Moderately Erodible
Alienable/Disposable	Highly Erodible

Data Spatial Analysis:-

Each driver of erosion was superimposed on a base map of municipalities, selected the layer of Lanao del Sur, clipped, projected, featured to raster, reclassified using the guide from CORINE (1992), and subjected to raster calculator for spatial analysis. Raster images of all factors were given as input for weighted sum in ArcGIS, assigning equal weightage to each factor for qualitative assessment. Output result was then reclassified into five soil erosion classes as per erosion severity.

Creation of Soil Erosion Potential Map:-

The creation of soil erosion potential map used the same method in the analysis of drivers of soil erosion. All the drivers of soil erosion were superimposed to a base map. Upon reclassification, the standard as set by Corine (1992) was used: (1) slightly erodible, (2) moderately erodible, (3) highly erodible.

Results and Discussion:-

Soil Type of Lanao del Sur

There were 16 soil types identified in the Province of Lanao del Sur. Mountain soils occupied the largest area for soil type. It was followed by Adtuyon clay loam, Langkong sandy, Binidayan silt loam Malabang sandy, Ruguan clay loam, Adtuyon-La Castellana Complex, Kidapawan clay/clay loam, Ramain clay loam, Caromatan clay loam, Adtuyon clay, Kudarangan clay, Bog deep, Salaman loam, Bolinao clay loam, and Hydrosol (Table 1).

The texture of the soil is an important consideration to determine the erosion potential of the area. Adtuyon clay, Adtuyon-La Castellana complex, Kidapawan clay/clay loam, Kudarangan clay were soils high with clay content which resists detachment thus decrease the erodibility. Langkong sandy and Malabang sandy soils were coarse textured and easily detached but produce low runoff. Ramain clay loam, Caromatan clay loam, Salaman loam, Bolinao clay loam were moderately susceptible to detachment and produce moderate runoff.

Table 1:- Area covered of soil type identified in the Province of Lanao del Sur

Soil Type	**Area covered (ha)***
Mountain soils	111,812
Adtuyon clay	3,358
Bolinao clay loam	1,520
Kidapawan clay/clay loam	4,476
Adtuyon clay loam	80,016
Salaman loam	2,117
Ramain clay loam	4,070
Bog deep	2,734
Adtuyon-La Castellana complex	8,641
Ruguan clay loam	8,683
Caromatan clay loam	3,586

Binidayan silt loam	42,366
Langkong sandy	47,716
Malabang sandy	34,150
Hydrosol	183
Kudarangan clay	2,960

***Only available data**

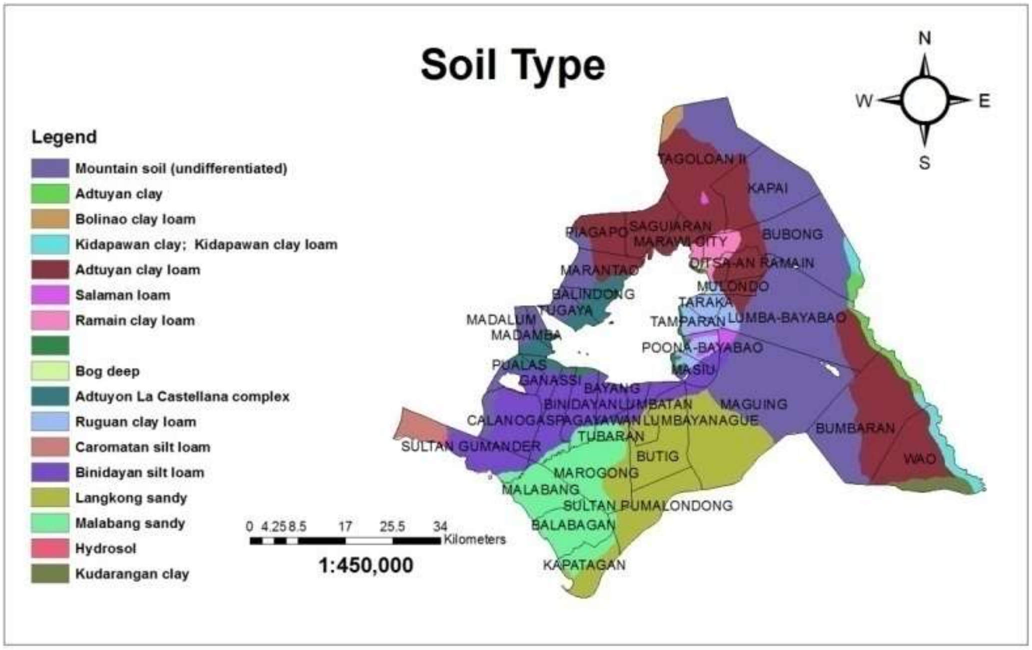


Fig. 2:- Spatial distribution of soil type identified in the Province of Lanao del Sur.

Slope Classification of Lanao del Sur

Largest area for slope classification of the province is undulating to rolling followed by rolling to moderately steep. Level to nearly level, steep, very steep to gently sloping and undulating also defined the Province of Lanao del Sur under slope classification.

Soil loss increases with slope steepness, hence more areas are prone to soil erosion in the province because majority of the areas were with undulating to rolling topography. The accumulation of runoff water leads to greater erosion because water erosion increases with steepness of the field. Furthermore larger areas have increased erosion potential due to increased velocity of water which permits greater degree of scouring or carrying capacity of sediments (Balasubramanian, 2017).

Table 2:- Number of hectare of slope identified in the Province of Lanao del Sur

Slope Classification	**Area covered (ha)***
Level to nearly level	32,184
Rolling to moderately steep	91,273
Gently sloping to undulating	18,424
Steep	42,424
Very steep	15,195
Undulating to rolling	154,602

**Only available data*

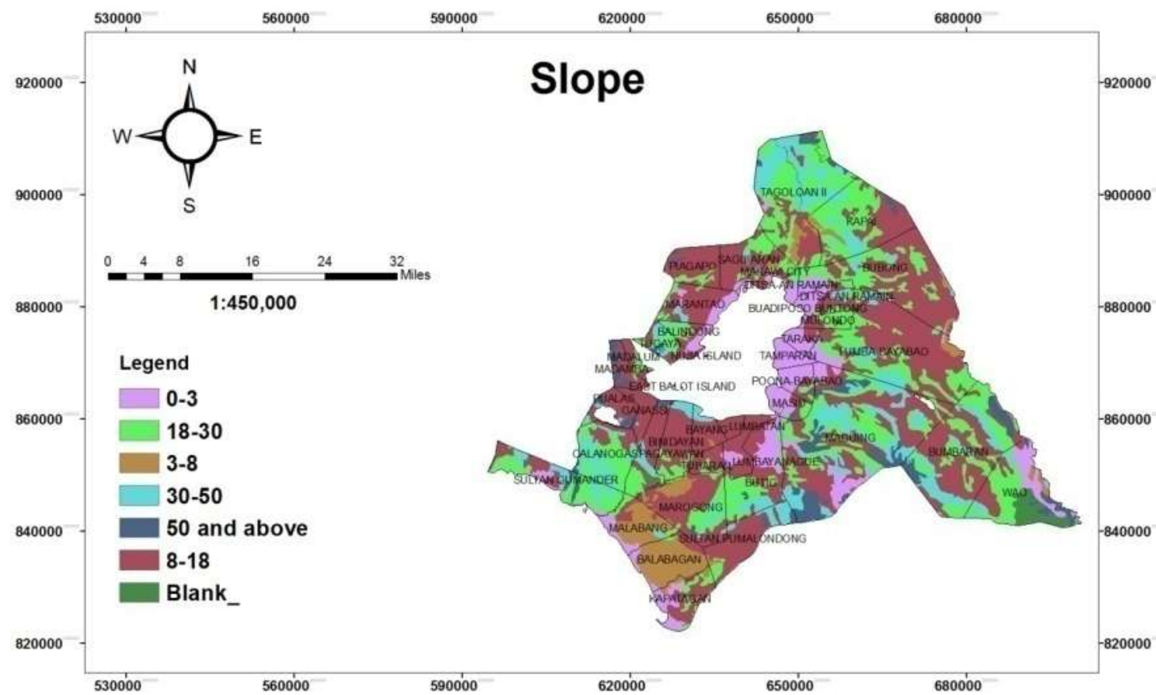


Fig. 3:- Spatial Distribution of Slope in the Province of Lanao del Sur

Land Classes of Lanao del Sur

Land classes in the province belonged mostly to forest reserve and alienable or disposable. Few land area were utilized for miscellaneous, civil reservation and unclassified public forest.

It was noted that the land classification under forest reserve which promote further soil conservation. Alienable and disposable lands were usually more prone to soil erosion because these were usually utilized for agricultural purposes. Smaller fields and portion of land use promote further soil conservation.

Table 3:- Number of hectare of land class identified in the Province of Lanao del Sur

Land Class	**Area covered (ha)***
Alienble/Disposable	125,615
Forest Reserve	168,143
Civil Reservation	895
Miscellanous	2,869
Unclassified Public Forest	198

**Only available data*

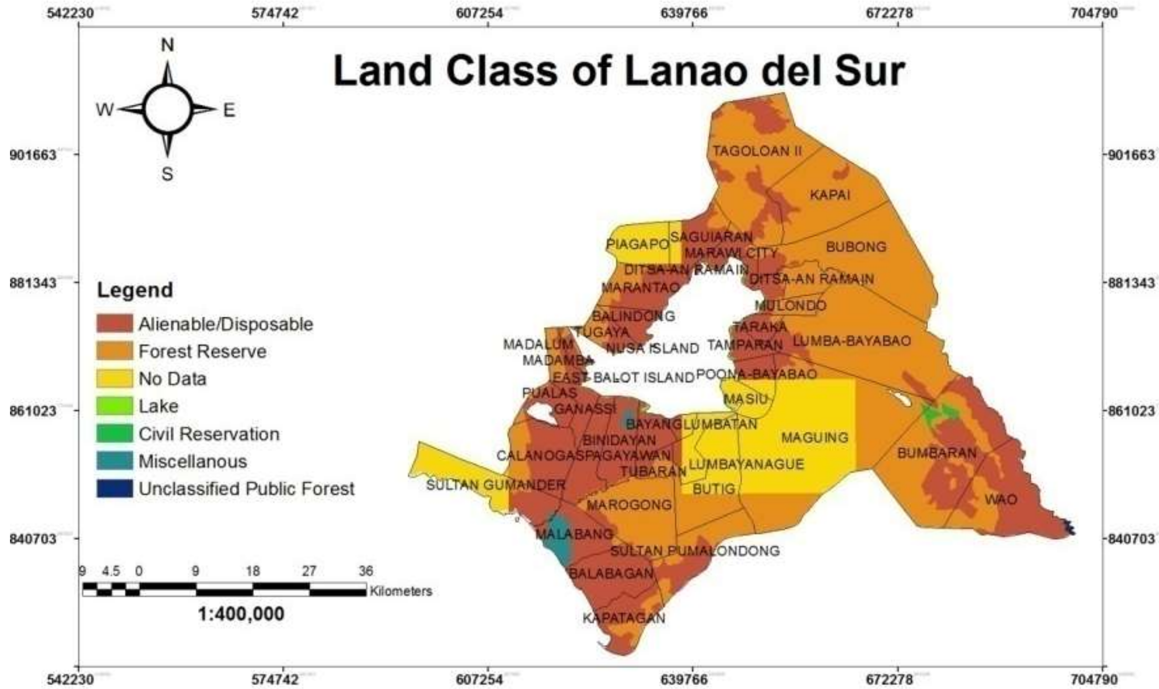


Fig. 4:- Land classification in the Province of Lanao del Sur

Land Cover of Lanao del Sur:-

Closed canopy, mature trees covering >50% occupies most land cover in the province. Arable land, crops mainly sugar and cereals and cultivated area mixed with brushland/grassland were next in terms of land area for land cover. Other land use and cover were open canopy, mature tree covering <50%, coconut plantation, grassland, grass covering >70%, other plantations, cropland mixed with coconut plantation, cropland mixed with other plantation, built-up area and marshy area and swamp.

Plant and residue cover protects the soil from raindrop impact and splash, tends to slow down the movement of runoff water and allows excess surface water to infiltrate (Balasubramanian, 2017). Where most of the area in the province had closed canopy of mature trees covering >50%, this becomes a shelter from the erosive rain. Only few areas are much prone to soil erosion in the province.

Table 4:- Area land cover identified in the Province of Lanao del Sur

Land Cover	**Area covered (ha)***
Cultivated area mixed with brushland/grassland	53,738
Open canopy, mature tree covering <50%	35,195
Arable land, crops mainly sugar and cereals	103,740
Closed canopy, mature trees covering >50%	138,753
Built-up area	496
Grassland, grass covering >70%	8.769
Marshy area and swamp	77
Cropland mixed with other plantation	792
Cropland mixed with coconut plantation	2,450
Coconut plantation	12,117
Other plantations	1,482

**Only available data*

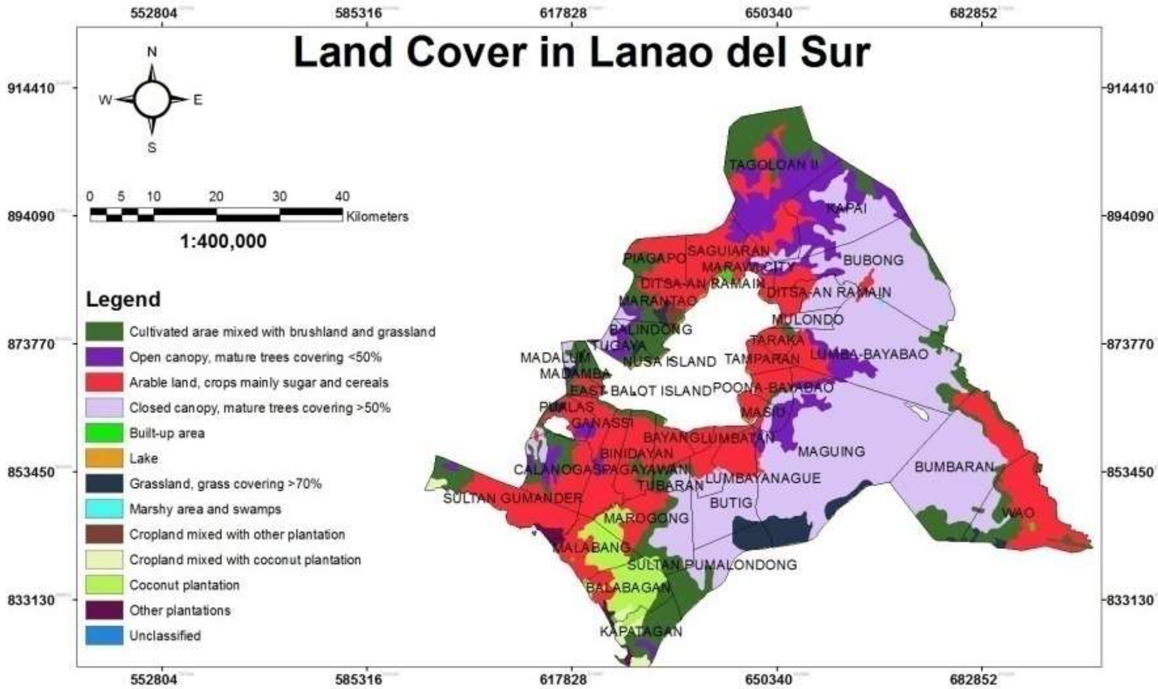


Fig. 5:- Land cover in the Province of Lanao del Sur

Climate Type of Lanao del Sur:-

The climate type of the province falls under Type III according to Corona classification. This type of classification explains that season is not very pronounced. It is usually dry from November to April and wet for the rest of the year.

The rainfall erosive/intensity factor is considered the most important factor in determining the erosion. Lanao del Sur receives sufficient rain throughout the year, this might be a problem in the province.

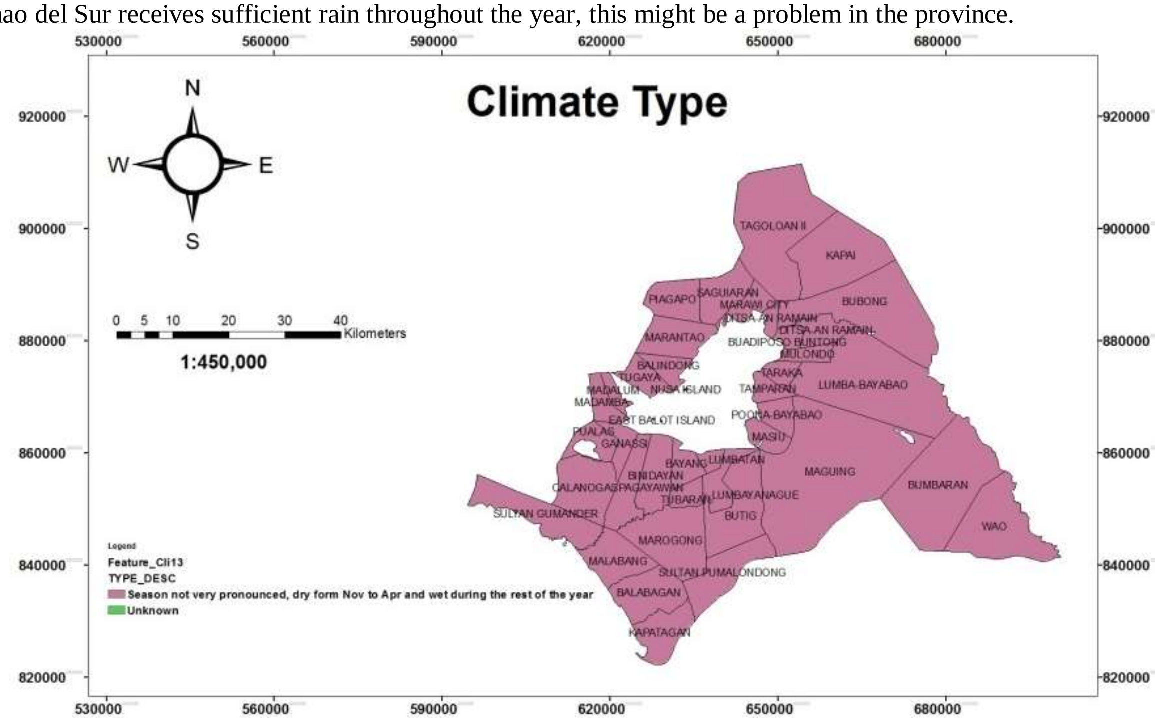


Fig. 6:- Climate type in the Province of Lanao del Sur

Current Erosion Status in the Province of Lanao del Sur:-

The current soil erosion status of the province is classified under moderate erosion. It is followed by severe, slight erosion, and no apparent erosion. Small land area is considered under unclassified erosion. Moreover, it shows that the province of Lanao del Sur is not exploited to cause much erosion. This moderate erosion status is an important consideration which leads further to maintenance of the drivers of soil erosion such as soil type, slope gradient, land classification, climate type, land cover, and current soil erosion.

Table 5:- Current soil potential in the Province of Lanao del Sur

Soil Erosion	**Area covered (ha)**
Severe Erosion	54,280
Slight erosion	50,179
Moderate erosion	223,728
No apparent erosion	28,950
Unclassified	369

**Only available data*

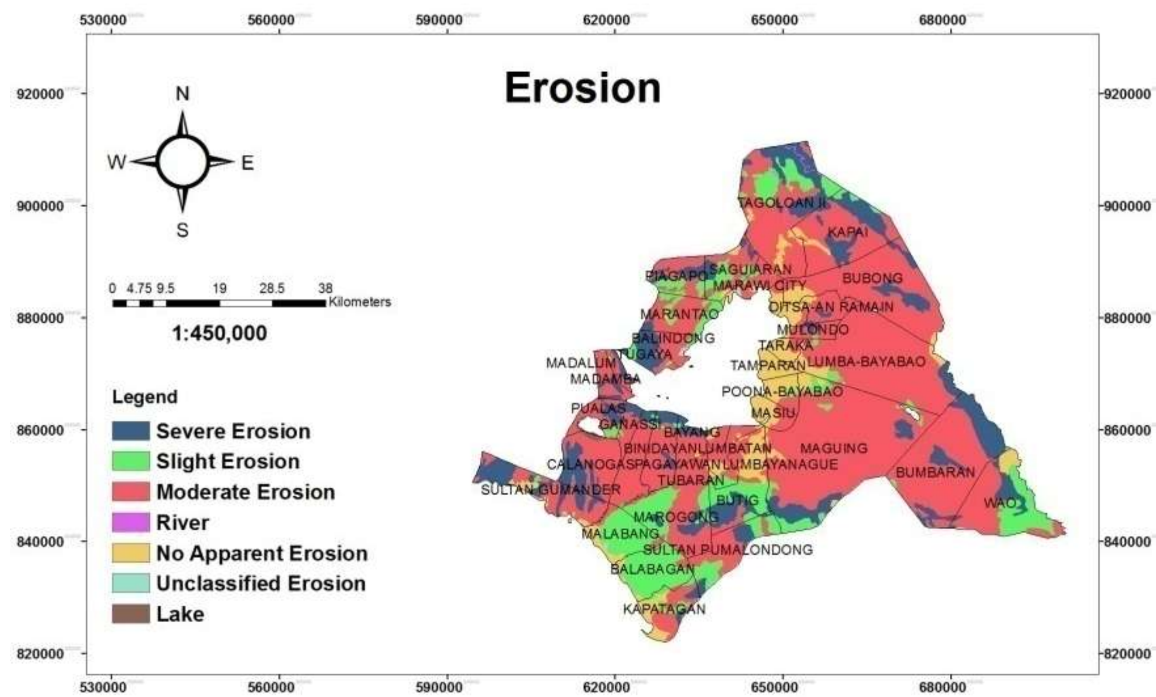
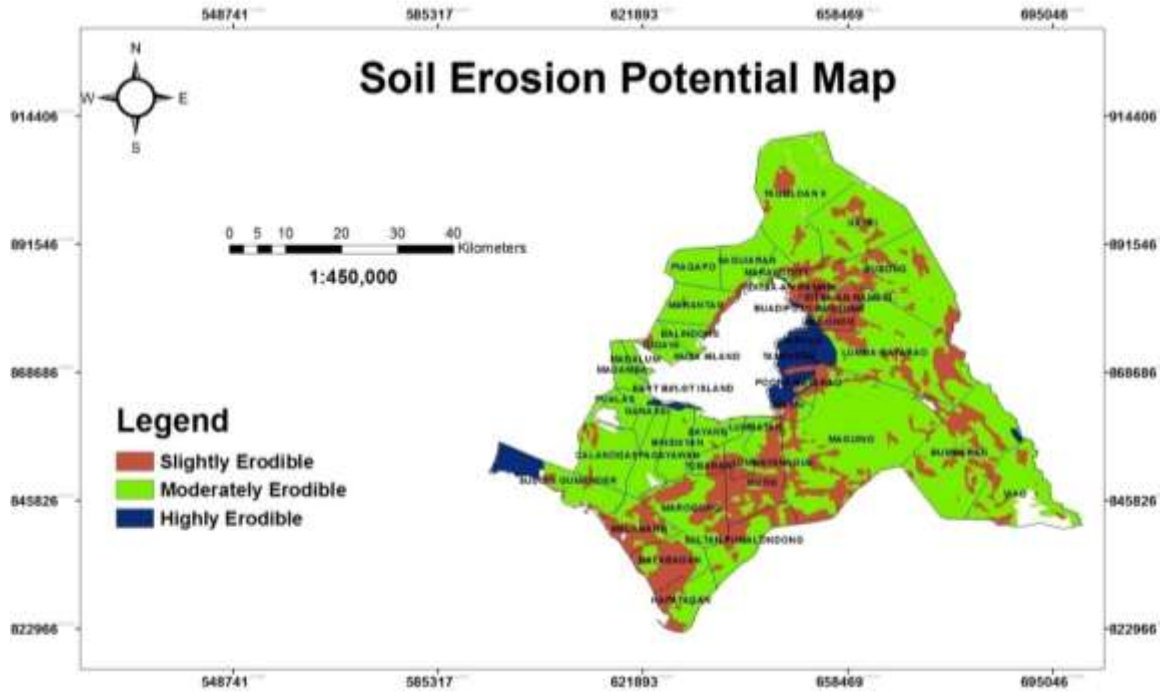


Fig. 6:- Current erosion status in the Province of Lanao del Sur

Soil Erosion Potential Map:-

The figure shows that most of the land area in the Province of Lanao del Sur was moderate erodible. Municipalities like Kappai, Bubong, Ditsaan-Ramain, Lumba Bayabao, Tagoloan, Poona Bayabao, Bumbaran, Buntong, Lumbayanague, Butig, Marogong, Sultan Dumalondong, Kapatagan, Malabang and Balagtas, Tubaran, Maguing, Bumbaran, Calanogas, Madamba, East Balot, Pualas, Ganassi, Bayang, Binidayan, Pagayawan, Piagapo, Marantao, Buadi Poso, Saguiaran, Marawi City, Madamba, Balindong and Tugaya had slight to moderate erodible soil. Highly erodible soils were extracted for Sultan Gumander, Taraka, Mulondo, Poona Bayabao, Tamparan, Masiu, and Bumbaran.

The data further suggest about the critical area of possible soil erosion. Application of control measure as as modifying the drivers of erosion vis-à-vis soil slope, land cover, soil type and rainfall erosivity through reducing the potential of rain to cause erosion. This result further supported by the study of Kamaludin, et.al. (2013) that higher risk of erosion in found near higher closer to the river mouth because of the topographic character, climate, vegetation type and density, and land use within the drainage basin.



Conclusion:-

Mountain soil type, undulating to rolling slope, forest reserve land classification, closed canopy, mature trees covering >50% land cover, Type III climate according to Corona classification and with moderate erosion. The erosion potential of the province is moderate as drawn from the erosion potential map extracted from the attributes from ArcGIS. The application of control measures in necessary to areas where moderate to highly erodible potentials soil are identified.

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