Geo-informatics for the Land capability of Khabaung Watershed Area by Using Stories Index Rating (SIR), Bago Region

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Abstract

Soil Erosion, one of the serious land degradation problems has been increased throughout the 20th Century. The watersheds of Myanmar depending on erosion risk, mismanagement and land used types have different degrees of degradation. Khabaung Chaung (*Creek*) selected for this research, because of the luck of soil erosion measurement, mismanagement under the tropical forested area has flooding during rainy season, shifting cultivation, extract commercial timber, floating timbers, and expansion of cultivated land. The objectives of this paper are to develop GIS-based procedures in evaluating land management practices in terms of soil loss potential and to identify the hazard zone of soil erosion in watershed area, Myanmar. To examine land potential, land capability classification is carried out using Storie Index Rating (SIR). It was based on the variables of slop, landform and elevation. The land classification reflects the capacity of the land to support a particular landuse in a long-term sustainable manner. Soil erosion, land capability and watershed class's parameters were modeled in GIS platform. This study is only intended to develop a model based on spatial information. Finally, suitable sites for forest plantation are proposed from which further conservation and restoration activities will be facilitated.

Keywords: GIS, SIR, erosion hazard zone, watershed area, land capability

Introduction

Land capability for watershed area is considered as one of the critical environmental problems in the world. According to the FAO (2005) report, forestry (about 51 per cent of the total Land area) and agriculture (about 27 percent) are the two main sectors with regards to the management of land and land-based resources. A number of these forest areas now face the additional threat of the shifting cultivation and expended agricultural land, to indiscriminate slash for fuel such as firewood, charcoal, etc., to extract commercial timber and to construct of national infrastructure. When many reservoirs were constructed along the river's valley in Myanmar during the last two decade, the settlers near the valley experience flooding in the rainy season and water scarcity in the summer. Khabaung Chaung, one of the Sittaung tributaries, was including one of the the multi-purpose reservoir construction of Sittaung Valley project with the aimed designed to prevent floods in monsoon, to supply irrigation water and clean drinking water in summer and to fulfill the electricity needs if possible. This Khabaund reservoirs was opened at 26 March, 2008 but does not have a sought watershed management policy to implement soil conservation and restoration.

According to the watershed management mentioned above, the present study is using Storie Index Rating (SIR) to assess of land capability classification. Land capability classification is executed to determine the relationship between soil erosion and land capability classes. Soil erosion and deposition by using RUSLE and USPED was presented in the Mandalay University of Distance Education Research Journal (Yu Yu Maw, 2014). Land capability classification is carried out through Storie Index Rating (SIR) developed by R.E. Storie in the early 1930's. Generally, lower capability classes are more susceptible to soil erosion since they usually have less favoured soil properties with unlikely topographic features such steep slope, complex land form etc.

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The Storie rating system is an index for numerical rating of soils and expresses numerically the relative degree of suitability, or value of a soil for general intensive agriculture. The rating is based on soil characteristics only and is obtained by evaluating specific soil factors. Other factors, such as availability of water for irrigation, climate, and distance from markets that might determine the desirability of growing certain plants in a given locality are not considered. Future land use changes, especially involving forest clearance or the introduction of agro-forestry or agricultural land expansion or construction of infrastructures in this area, would require careful planning to avoid detrimental impacts on watershed area.

Objectives

The main objectives of the present work are to develop GIS-based procedures in evaluating land management practices in terms of soil loss potential, and to fulfill specific requirements about the ability of potential land utilization class for rural settlements and decision-makers

Study Area

The watershed of Khabaung Chaung, Bago Division of Myanmar is situated one of the right tributaries of Sittaung River between latitudes 18º 40′ 17″N to 19º 10′ 03″ N, and longitudes 95º 50′ 47″E to 96º 28′ 48″E (Fig. 1). It is bounded by the northern side of Yedashae Township, the southern of Pyu Township, the eastern side of Bago Yoma (Range) and the western side of Sittaung River. The Khabaung catchment's covers 1,678.7 sq. km (107,4363 Acres). The valuable natural forest resources and national park are mostly found on Bago Yoma. Being demarcated with the medium catchment's area sizes of 418 sq.miles, it could be categorized as to be perennial with more or less significant stream flow through out the year. The total length of this Chaung is estimated 2.23 miles (11774 ft.) long, based on Landset ETM satellite image which origins from the Bago Yoma. Khabaung dam had being built up in this area since 2006 and finished in May 2008 to prevent floods in monsoon, to supply irrigation water in summer and to support of electricity; Furthermore, during the last three years Myanmar's new capital (Naypyidaw) was established near this area. This area may be transformed to urban infrastructure.

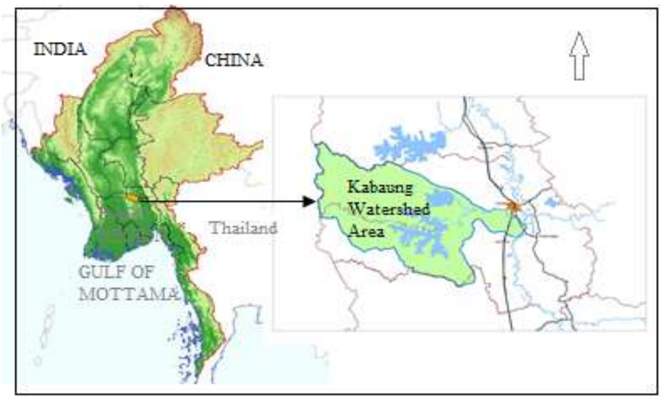

Fig. 1 Location of the study area

This area may be transformed to urban infrastructure within this decade. Therefore the information obtained from this research may be useful for decision-maker, urban planner or land management will be able to decide that this area should be totally protected or sustained for land capability.

Normally used three season concept: summer season (March to mid-May), rainy season or monsoon period (mid-May to the end of October) and winter season (November to the end of October). It exists within the Taungoo and Oktwin Townships but Toungoo meteorological station is situated near the study area. Thus, rainfall data are obtained surrounding areas from Taungoo, Bago, Pyinmana and Pyay Stations which are located near the Khabaung watershed area. Mean annual temperature is about 27°C with an average hottest month 31°C in April and average coolest month 23°C in January. Khabaung watershed situated within tropical monsoon climate receives heavy rain during monsoon season. Stream flooding problems have been faced because of shifting cultivation, overloading, floating timbers and expansion of cultivated land.

According to the FAO/UNESCO classification, there are 24 main soil types being recognized in the Union of Myanmar. Khabaung Watershed area consists of three soil types of classification. They are Meadow and Meadow Alluvial Soil (*Gleysol and fluvic Gleysol*), Yellow Brown Forest soil (*Xanthic ferralsol*) and Lateritic Soil (*Plinthic Ferrasol*) (Fig-3). Meadow and Meadow Alluvial Soil (*Gleysol and fluvic Gleysol*) are occurring in the flood plains, Yellow Brown Forest soil (*Xanthic ferralsol*) is covering the low hills of Bago Yoma at the elevation of 300 to 1500 feet above sea level land (*Plinthic Ferrasol*) which is found in the lower slope of the hills of Bago Yoma with the elevation not higher 300 feet above sea level.

The digital land cover map of this watershed area was derived from the Landsat ETM+ satellite image (February 6th, 2010). Several enhancements (ratios, NDVI) and classification techniques (broad and fine cluster analysis) were used. A maximum likelihood supervised classification was using band 2, 3, 4 and 5 to recognize the unique spectral signatures associated with those land features (Fig. 2).

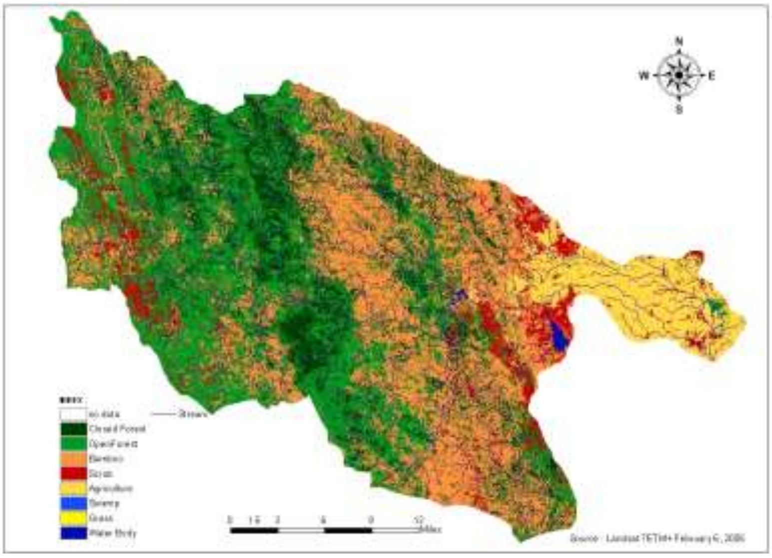

Fig. 2 Land cover classification of the study area

According to this image, More than 50 per cent of the whole watershed is occupied as forest products. About 24 per cent of the forested area has been changed to bamboo cultivated areas because of depleting by over logging and shifting cultivated. The eastern alluvial plain of the Khabaung watershed area is defined as the agriculture cultivated lands with above 13 per cent of this total area.

Methodology

This study was used The revised universal soil loss equation (RUSLE), USPED, RSI and other suitable techniques like remote sensing and GIS to assess the land capability associated with the watershed management. RSI was to classify of the land capability.

The Storie Index Rating (SIR)

Land Capability Classification proposed by the Storie Index Soil Rating (SIR) Division of Agricultural Sciences University of California. This method is based on soil characteristics that govern the land potential utilization and productive capability (R.E. Storie, 1978). Percentage values are assigned to the characteristics of the soil itself, including the soil profile (factor A); the texture of the surface soil (factor B); the slope (factor C); and conditions of the soil nutrient and drainage (factor X). The most favourable or ideal conditions with respect to each factor are rated at 100 per cent. The equation is

$$SIR = A^* B^* C^* X^* 100$$

Where, SIR = Storie Index Rating

A = Rating on Characteristics of Physical profile

B = Rating on basis of surface texture

C = Rating on basis of Slope

X = Rating on conditions other than those in factor A, B, C and X such as nutrient, salinity, acidity. A rating of 100 per cent expresses the most favorable or ideal condition, and lower percentage ratings are given for conditions that are less favorable for crop production. The index rating for a soil is obtained by multiplying the factors, A, B, C, and X and dividing by 100, thus each factor contributes to the final rating.

A, B, C and X layers are generated in digital format in able to use in ARCVIEW for further analysis with other layers. A and B layers are mainly concerned with physical properties of soil and it can enhance from the soil sample analysis. Factor C is topographic factor and it was retrieved from Slope factor of USLE. X layer was prepared form e chemical properties of soils and drainage pattern. The Storie rating system is an index for numerical rating of soils and expresses numerically the relative degree of suitability, or value of a soil for general intensive agriculture. The rating is based on soil characteristics only and is obtained by evaluating specific soil factors. Other factors, such as availability of water for irrigation, climate, and distance from towns that might determine the desirability of growing certain plants in a given locality are not considered.

Conversion of parametric scores to rank categories are as follow:

Grade/ land capability class I (excellent)

Soil that rate between 80 and 100 percent and which are suitable for wide range of crops including alfafa, orchard, truck and field crops.

Grade/land capability class II (Good)

Soil that rate between 60 and 79 percent and which are suitable for most crops. Yields are generally good to excellent.

Grade/ land capability class III (fair)

Soil that rate between 40 and 59 percent and which are generally of fair quality, with less wide ranged of suitability than grade II and I. Soils in this grade may give good with certain specialized crops.

Grade/land capability class IV (poor)

Soils that rate between 20 and 39 percent and which have a narrow range in their agriculture possibilities. For example, a few soils in this grade may be good for rice but not good for many other uses.

Grade/land capability class V (very poor)

Soils that rate between 10 and 19 percent are of very limited use except for pasture, because of adverse conditions such as shallowness, roughness, and alkali content.

Grade/land capability class VI (Non Agricultural)

Soils that rate less than 10 percent include, for example, tide lands, river wash, and soils of high alkali content, and steep broken land.

Three parameters will be modeled to extract the most critical places for watershed conservation activities. Areas where soil erosion rate has increased (by RUSLE) with decreased deposition rate (by USPED) and poor land capability (by SIR) to suitable only for conservation and agro-forestry were extracted from previous analyses and overlaid giving weights to be able to categorize according to priority. This study attempted to identify and categorize critical areas needing urgent intervention. In Geographical Information System, it is possible to overlay and extract layers spatially performing various mathematical and statistical functions. The map shows recommended conservation sites for integrated watershed management.

Land Capability Index

Watersheds are disturbed in different degrees caused by human or natural phenomenon. Rugged terrains with over population pressure destroyed the biophysical structures mostly vegetations as the easiest. Expansion of agriculture land with pasture decreased forested lands those are important for maintaining overall watershed quality. Watershed management plan must address problems such as deforestation, soil erosion, land degradation etc., and categorized according to threat and drew conservation program. This study attempted to extract the most critical places for watershed conservation activities. Areas where soil erosion rate has increased with poor land capability were extracted as conservation sites for integrated watershed management.

Land capability was derived mainly from soils series taken from the soil map (scale 1: 250000) by regrouping based on differentiation and similarities of soil properties. Land capability was classified basically by using stories parametric system (Storie Index Rating) with some modification in order to accommodate the available soil data. Classification was mainly based on the physical and chemical properties of the soil and some site characteristics of land that were described for each soil series. Soil map, physical and chemical properties was acquired from Land Use Department, Ministry of Agriculture, 2004 (Fig. 3 & Table 1).

Table (1) Soil properties

No.	Soil Name	Texture	Soil Depth	Soil pH	Plant Nutrients		
					N	P	K
1	Meadow and Meadow Alluvial Soil	Clay Loam Loamy Sand	Thick (>36 inches)	6.0-7.0	L	L	H
2	Yellow Brown Forest soil	Clay Loam, Sandy Loam	Medium (20-36 inches)	5.0-6.5	L	L	M
3	Lateritic Soil	Sandy Soil, Clay Loam	Medium (20-36 inches)	4.0-5.5	L	L	M

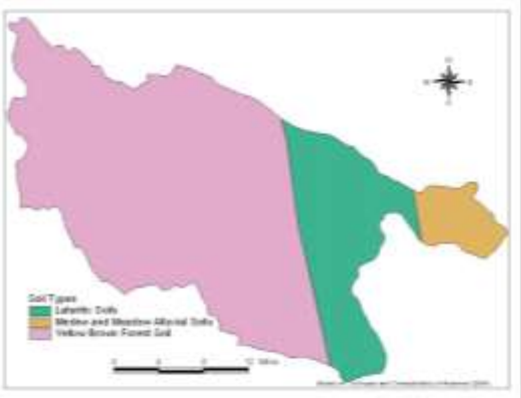

Fig. 3 Soil Types of The Study Area
Sources: Based on Soil types and characteristics of Myanmar, 2004

Nutrients: Nitrogen M (94-6 milligram/100 gm soil), Phosphorus L (<5 milligram/100 gm soil), Potassium M (10-20 milligram/100 gm soil)

Physical Profile Factor (A)

The physical character of soil profile determines the depth and soil development (Table.2). During the rainy season, flood intrudes the lower part of the eastern part of this area and deposits forming the alluvial plain. There is no systematic research on the soil formation but this area can be found that the soils are on alluvial plain or terraces having hardpan subsoil layers.

Table 2 Physical profile index

No.	Soil Type	Landform	Soil Depth	A_ Index
1	Gleysols (Fluvic)	Plain	Thick(>36 inches)	80
2	Xanthic ferralsol	Mountain (300-1500 ft.)	Medium (20-36 inches)	65
3	Plinthic Ferrasol	Mountain (<300 ft.)	Medium (20-36 inches)	60

Surface Texture Factor (B)

Table 3 examines the texture of soil groups in the upper 30 cm. *Gleysol and fluvic Gleysol* can be found in the flood plains with the texture of clay loam and loamy sand. *Xanthic ferralsol* is covering the low hills of Bago Yoma at the elevation of 300 to 1500 feet above sea level. These soils contain clay loam and sandy loam. *Plinthic Ferrasol* is dominated the hills slop of Bago Yoma with the elevation not higher 300 feet above sea level. The surface texture of this Khabaung watershed area is having medium texture soils.

Table (3) Surface texture Index

No.	Soil Type	Texture	Texture Class	B_ Index
1	Gleysols (Fluvic)	Clay Loam, Loamy Sand	Medium Texture	90
2	Xanthic ferralsol	Clay Loam, Sandy Loam	Medium Texture	80
3	Plinthic Ferrasol	Sandy Soil, Clay Loam	Medium Te	70

Slope Factor (C)

This factor determined the slope steepness. The general elevation of the Khabaung watershed area is between 26 meter (85 ft.) and 1387 meter (4551 ft.) above sea level and its general topography is undulating and rolling. Land resources can be divided into 80 percent of the upland, 11 percent of the slope land and 9 percent of flatland. Slope land is defined as land with an elevation of 100 feet to 300 feet, or with a 10% gradient. Figure 4 based on the DEM (SRTM-WGS-84, UTM Zone- 47) slope land can be divided into six steps. Table 4 Slope index shows the slope factor ranging.

Table (4) Slope Index

No.	Slope	Slope Percent	C_Index
1	Nearly Level	0 to 2%	95
2	Gently Undulating	3 to 10 %	90
3	Moderately Sloping	11 to 15 %	85
4	Strongly Sloping	16 to 30 %	75
5	Steep	30 to 45%	50
6	Very Steep	45 % and over	15

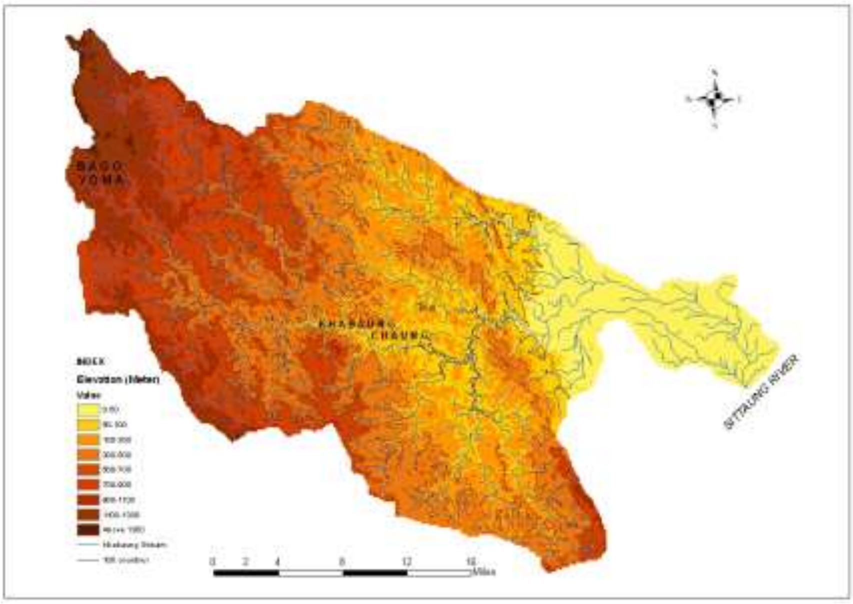

Fig. 4 Slope percentage of the study area

Soil Fertility Factor (X)

Drainage and fertility of soil are examined in X factor (Table 5). The drainage system of this area is well on the upland area to moderate in the plain area. As dominate soil type, Ferralsols are well drain, having good structure. Most of soil properties were generated from Soil types and Characteristics of Myanmar, 2004 due to luck of detail soil information of this area.

Table (5) Soil Fertility Index

No.	Soil Type	Drainge	Alkaline	Acidity	Nutrient	X_Index
1	Gleysols (Fluvic)	Moderate	Moderate	Fair	High	60
2	Xanthic Ferralsol	Well	Slight	High	Fair	75
3	Plinthic Ferrasol	Well	Slight	High	Poor	70

Based on Soil types and characteristics of Myanmar, 2004

Result of Land Capability Classification

Land is classified according to its physical characteristics i.e. soil and topographical features, including steepness and drainage. The classification reflects the capacity of the land to support a particular land use in a long-term sustainable manner. Land classes are numbered 1-6; the higher the class number, the greater the limitations or potential hazard to use. Land capability was mapped by the soil types and characteristics of Myanmar 2004 and SRTM image WGS-84, UTM zone47.

Table (6) Land Capability Classes

No.	Land Capability Classes	Cell Value	Area (Km2)	%
1	Class I (Excellent)	138787	1191.66	71.0
2	Class II (Good)	17575	150.91	9.0
3	Class III (Fair)	371	3.19	0.2
4	Class IV (Poor)	38392	329.64	19.6
5	Class V (Very Poor)	363	3.12	0.2
6	Class VI (Non Agriculture)	21	0.18	0.0
	TOTAL	195509	1678.69	100

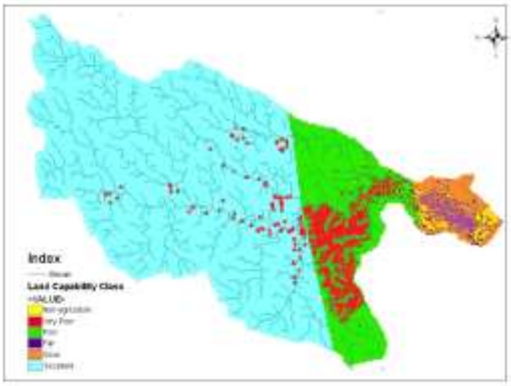

Fig. 4 Land Capability Classification of the Study Area
(Based on SIR = A* B* C* X* 100)

About 71 percent or 1191.66 sq. km of the whole watershed was fell into the excellent capability class (class 1) for crops and most of this area covered by forested area. This land is the best retained under a canopy of green timber with limited grazing and shifting cultivation. Good capability class (class 2) covered with 9 per cent or 150.91 sq. km suitable for most cultivated crops such as rice, maize or cereal crops. This land is level or almost level land with virtually no physical limitation. This land can be used for a wide range of agricultural uses but it may be subject to flooding. Rice can be sown in this plain during monsoon period and rice and other cereals may be also grown during the winter and summer seasons where water is available by irrigation from Khabaung Chaung. Most of farmers within this area need to grow rice for subsistence of the farm family and cash crops such as pulses, sugarcane, maize or cereal crops for extra cash.

Small parcels of fair capability class (class 3), totally 3.19 sq. km, are found within the alluvial plain capability class 2. Land capability poor class (class 4) accounted 19.6 per cent or 329.64 sq. km with few limitations for cultivated crops. This land is not suitable for regular cultivation due to slope gradient, soil erosion hazard, shallowness or rockiness or a combination of these factors. Its areas productivity varies due to soil erosion, soil depth and soil fertility. It is suitable for cropping and pastures on a rotational basis. About 3.12 sq. km or 0.2 per cent is not suitable for regular cultivation named very poor land capability class (class 5). Land capability non-agriculture class (class 6) is some small urban areas within the catchment, including the some villages of Taungoo and Oktwin townships. This land capability classes were able to generate from available soil and slope sources and it certainly needs to be improved using more detail soil information.

Finding and Suggestion

Land capability classification by Storie Index Rating (SIR) developed by R.E. Storie in the early 1930's is applied in this study for its simple parameters and methodology. Soil and topographic information were spatially modeled to different indices and generated a final land capability map. Soil information was extensively used both physical and chemical properties. Topographic parameters such as landform, slope steepness and gravelly were included in the analysis process as of important considerations for capability classification. Finally, areas worst affected by land degradation were identified in GIS using spatial analyst tool which can perform various mathematical and statistical function in geo-spatial term. Overlaying only selected areas improved the quality of analysis by avoiding other areas which were categorized in previous data processing.

To prevent land degradation, reliable and up-to-date information on the potential and constraints of the watershed areas and the production potential of each of them based upon systematic and quantitative land capability, crop suitability and productivity assessments are required. To educate the farmers, to conduct mixes cropping, to reduce shifting cultivation, to encourage terrace cultivation and plantations are the main measures which are being undertaken. Without proper plan for integrated development of all sectors, there will be diverse affect on environment locally as well as nationally. There has no a single methodology for determining soil erosion yet in a larger scale and researches were made baseed on existing theories and equations. Soil erosion has increased significantly from 1990 to present. Only few areas were able to reduce soil erosion rate mainly in lowland agriculture. It is obvious that the increase of deforestation in watershed contribute erosion rate of that area. In addition, due to the lack of a well-defined land use policy for the whole country, conservation and preservation of watershed forest and plantations are not adequate.

Conclusion

This watershed area, one of the mismanagement of watershed conservation projects, was selected as a research study area based on the luck of soil erosion measurement in this area. The tropical rain forest area- the centre of the fascinating area “Bago Yoma”, Bago mountain ranges and also one of the right tributaries of Sittaung River Valley. It has multipurpose project- building up the reservoir since 2006 to prevent floods in monsoon, to supply irrigation water in summer and to support of electricity. Scio-economic condition– the presence of renewable and non-renewable of natural resources: reserved forests, timber and bamboo productions, natural park, shifting cultivation, agricultural practices, etc.

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