APPLICATION OF RS/GIS FOR THE ASSESSMENT OF YEZIN DAM WATERSHED AREA

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ABSTRACT

This paper deals with the application of RS/ GIS for the assessment of the Yezin Dam Watershed Area. A short literature review pertaining to the above topic and other relevant topics are presented. Methodologies pertaining to problems on erosion potential calculations, E30 Model developed by calculating 2 inputs namely NDVI (Normalized Difference Vegetation Index) and Slope Digital Terrain Model (Slope DTM), the nature and process of NDVI, Gradient of input under conditions (S), soil erosion map, flow chart of calculating annual soil erosion potential for Yezin Watershed Area and Steeply slope calculation of the soil erosion potential are also presented. Results and findings pertaining to the accuracy of the E30 models is also presented with 6 classes of slope map used by the Forest Department in the Dry Zone Mapping Survey. 6 classes of land cover are also presented in the Land Cover Map. Nine conclusions and recommendations are derived after a thorough analysis of the data and maps.

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1. INTRODUCTION

Watershed Management is defined as the processes of formulation and carrying out at a course of action involving manipulation of resources in a watershed to provide goods and services without adversely affecting the soil and water base (FAO, 1990). A watershed contains many kinds of natural resources: soil, water, forest, rangelands, agricultural land, wildlife and minerals etc. Any misuse of the land and its cover can seriously affect the watershed sustainability as well as environmental management in its broadest sense. For efficient and proper planning of the watershed, sufficient and reliable data are deemed necessary. Data used as important parameters for planning and managing the watershed are topographic data (location, size elevation, etc.), physical data (soils, vegetation/land use, geology, geomorphology, hydrology), climatic data, socio-economic data, as well as data on erosion and sedimentation processes.

Fresh water is indeed the most precious of our planet's natural resources. It is the ingredient that is fundamental for supporting terrestrial and aquatic life system, as well as the fundamental natural resources constraint for socio–economic development and the resulting improvement of human livelihoods.

Most of the developing countries are rapidly coming to the recognition that land degradation is reaching serious problems, causing damage to the national economy and lowering living standards. The consequence of inappropriate cultivation practices and other exploitative forms of land use are becoming evident in the form of deep erosion gullies, bare and eroded grazing lands, over-clearing of vegetation, rising water tables, saline soils and the movement and accumulation of sediment and erosion debris in stream/river channels.

The impact of land degradation is cumulative and far-reaching. Reduced agricultural productivity is often associated with the decrease in availability of water resource both in terms of water quantity as well as quality. Land restoration measures, involving soil erosion control, enhanced vegetative cover and water run-off management will help preserve the remaining soil and vegetation resources. Natural resources should be effectively managed to meet social, economic, environmental and other community goals.

1.1. Geographic Information System in Watershed Management

"A geographic information system is a system for collecting, inputting, checking, processing, integrating, analyzing, modeling and reporting information related to a land surface" (Tin Tin Aye, 1999). It is a key technology for the automated capture, structure, management, analysis and presentation of location-references data all over the world (ibid). It can also perform to rotate, zoom in and out of the images, on the screen (ibid). Visualization in itself is a unique contribution of GIS concept, comprising a database with a verity of spatial data, and suitable software to access the database and to perform logical, statistical and cartographic operations with the data.

A Digital Elevation Model (DEM) of a watershed can be generated with a triangular network (TIN) model in a vector GIS by using a network of irregularly spaced, randomly selected elevation points. More sample elevation points can be selected in the area of rough terrain and fewer in smooth terrain to obtain location specific information. Alternatively, in a raster GIS a DEM can be generated based on digitized elevation points by using interpolation algorithms. Using stereo aerial photography and stereo space images, automated DEM can be generated applying algorithms based stereo-image matching. Topographic features such as slope, aspect, drainage, network and elevation contours can be generated in vector or raster GIS based on the digital elevation model. A rainfall map or temperature map can be generated by using thickness polygons and by interpolation based on the location and temperature and rainfall data from meteorological stations.

1.2. The Role of Remote Sensing and its Data Products

Remote sensing is defined as the art and science of obtaining information, without physical contact, from the object under consideration (Lillesand & Kiefer, 1994). Human eye can be considered a device in obtaining information of his environment. Our eyes detect the reflectance coming from the objects and our mind will interpret data as recognized objects. For earth scientists however, remote sensing can be defined as comprising measurement and recording of electromagnetic energy reflected from or emitted by the earth's surface. Such measurements can relate to the nature and properties of surface materials (Dhurba P. Shrestha, 1992). It also provides multi-spectral, multi-resolution, multi-temporal and multi-sensor imagery of the latest conditions of an area.

Various techniques exist for analyzing remote sensing data which can be used for watershed related studies, such as landcover/landuse, soil, geomorphology, hydrology, etc. Depending on the data types, the techniques used in watershed surveys can be performed by visual interpretation of aerial photos using stereoscopes or monoscopic interpretation of processed images. If the data are in digital form, the computer techniques can be applied. These techniques make use of computer hardware and software for manipulating and transforming the data into useful information; these techniques are commonly known as Digital Image Processing. Nevertheless, before going in to any detail concerning image processing techniques, it is important to realize the characteristics of spectral reflectance of the major cover types of the earth surface.

1.3. Integrating GIS and Remote Sensing

Data obtaining through satellite images differ from other geographic data in their consistency, positional accuracy, spatial, and temporal resolution and levels of human abstraction or interpretation. To be able to process such data, GIS required capabilities to store and analyze large volume of these data with minimum loss of resolution or radiometric precision. To make use of relevant map data (e.g. polygon, lines, and points), GIS requires vector capabilities also. Therefore, the integration of GIS's with Remote Sensing data structures and software that supports a range of spatial queries (Tin Tin, Aye, 1999). Data derived from remote sensing are increasingly being utilized as a data source in Geographic Information Systems (GIS).

In short, remote sensing can provide information on current and changed landcover/landuse where as a GIS can provide an essential Expert Knowledge Base to help automate the technically demanding aspects of remote sensing for change analysis (ibid). GIS can be used to enhance standard image processing functions like geometric correction, image classification and masking operations. Remotely sensed data can also be used for image-map backdrop and database update (ibid). Although remote sensing is an important source of data for planning (e.g., monitoring and mapping), it needs to be linked to other data sets to arrive at meaningful information for decision making.

2. LITERATURE REVIEW

It is increasingly recognized that the state of the world conservation has continued to deteriorate, despite efforts to improve the situation "Application of Geographic Information System (GIS) for Watershed Surveys and Planning; Watershed Management Training in ASIA (GCP/ RAS/ 129/Net) Kathmandu" (FAO, 1992). Many environmentalists, scientists, planners and researchers are concerned about population growth and degradation of the environment (Aye, Tin Tin, 1999) and to verify to their adverse affect on the socio-economic conditions of the population, especially the rural population.

2.1. The Role of the Watershed Management

In this respect, the role of the watershed management plays a very important role in Myanmar due to its many mountainous regions with elevations ranging from a few hundred meters up to more than 5700 meters above sea level. Due to the wide latitudinal and longitudinal range, a broad spectrum of bio-physical and agro-ecological settings occur resulting in a diversified agriculture, the main livelihood for the majority of its people and the backbone of its national economy. (Sit Bo, 1999). To Support this, the Government of the Union of Myanmar has constructed and renovated many dams and reservoirs through out the country. For maintaining the expected life span of these dams and reservoirs, prudent management of their watershed is required. Sustainable development of agriculture also depend on the country's environmental and ecological stability, which is, in turn influenced by how well its watershed are managed. Therefore, effective conservation of the watershed resources through their appropriate management is of paramount importance.

2.2. Watershed Degradation

343,587 sq. km (52.3% of total area of Myanmar) is still covered by forest in 1998. However, the annual deforestation rate as per 1975-1989 data, is alarmingly high 218.800 sq. km/year. (0.68% of total area of natural forest). Due to sloping mountainous regions which predominates in North, West and East of the country, deterioration of the watershed is fast and widespread due to natural and man-made factors. Some of the man-made causes are illicit logging, short fallow cycle shifting cultivation, excessive cutting and marketing of firewood and charcoal due to the fuelwood crisis, degradation of forests and croplands, encroachments, improper land use and inappropriate farming practices (Keh, K, 1996). All these are closely related to abject poverty and to the migration of the rural population, the majority of which are dependent on the forests and their products, for their livelihood from a depleting forest resources area to a more remunerative forest resource area. (Keh, K 1996 and Aye, Tin Tin, 1999).

2.3. Combating the Watershed Degradation

Participation of the local people, especially those villagers living in villages adjoining the forest, is central to effective watershed management.

The rural population had been managing their watershed in their traditional forms for centuries. There was little or no problem when the population is sparse and watershed areas, plentiful for them to practice their shifting cultivation. However, this become a problem, when conditions changes drastically with the increase in the rural population and the drastic decrease and degradation of the watershed area. However, the Government interventions started to evolve in Shan State in the last century only, where the situation and conditions were becoming acute. Only during the outset of the present century, serious recognition of the menace of resources degradation and the need for arresting it seems to have taken its root. The Forest Department is responsible for overall watershed management, while the Agriculture Department focuses only on conservation of permanent agricultural lands. With the establishment of the Soil Conservation Unit in 1930 under the Forest Department, watershed management and soil conservation activities were then gradually accelerated.

However, these efforts are mainly concentrated on soil conservation with little emphasis on the need for the welfare of the inhabitants or land users. Only in 1990, the Government of Myanmar started to focus on the welfare of the local population in natural resource management. Socio-economic development of mountain areas also received attention upon signature on ICIMOD charter. The government is driving at full power with vast inputs for the development of the border mountain areas. In 1994, a project “the Watershed Management of Three Critical Areas (MYA/93/005) was launched as a component of a holistic program called the Human Development Initiatives (HDI) and the Myanmar Government. As it now stands, a participatory approach to watershed management has been extensively tried in Myanmar. Several local institutions such as Farmers’ Income Generation Group (FIGG), Women’s Income Generating Groups (WIGG), Village Forest Conservation Committee (VFCC) etc, were organized for self-reliant community development with a view to obtaining more sustainable watershed management program.

A Training Manual for Watershed Management was published by U Sit Bo (1991), sponsored by the Watershed Management Division, Forest Department, in cooperation with, ASIAN WATANET, Participatory Watershed Management Training in ASIA (PWMTA) program, GCP/RAS/161/NET, Netherlands/FA)(UN), Kathmandu, Nepal, 1991.

2.4. Review of the Past and Present Land, Socio and Economic Conditions of the Yezin Dam Watershed Area

The area under study had been classified as good Moist Upper Mixed Deciduous Forest in the Topographic Map drawn by the survey of India over 50 years ago.

As far back as 30 years ago, the forest situation was still in good conditions and the population was still sparse and their socio-economic conditions were also good.

However, around 1975, the forest situation and the environment gradually started to deteriorate with the sudden influx of large population which might be 20 times greater than the normal population of Paukkone and Yezin Village due to the con-current establishment of Yezin Dam, Institute of Agriculture, Institute of Forestry, Institute of Animal Husbandry, Public Construction Department, Irrigation Department, Forest Research Institute and Central Agriculture Research Institute and No.2 Military Recruiting and Training Camp.

Consequently, the supply of the household commodities cannot keep up with the demand of the ever growing population resulting in the growing price hike. As an example, a bag of charcoal in 1985cost only Ks 10 while it now cost Ks 300 per bag which exerted a social and economic stress on all the population, especially the rural population who are heavily dependent on the forests for their subsistence. The villagers in the 5 villages in the Watershed Area also suffered the same fate as the growing stock of the Watershed area also declined.

This is compounded by the migration of some rural people from other economically highly stressed area to the Yezin Watershed Area which comparably is much better than their old habitat. Annual repeated forest fires also enhance the rate of forest decline. The rate of sedimentation in the dam had also alarmingly accelerated, shown by the formation of sand bars at the incoming terminals of the in-flowing streams into the dam.

It is therefore considered most appropriate to redress this degradation of resources and soil by the applications of data available from the remote sensing and GIS for assessment and monitoring and also evolve some form of appropriate participatory watershed management system and soil management fitted to present social and environmental conditions in some future project (Guidelines and Manual on Landuse Planning and practices in Watershed Management and Disaster Reduction, Economic and Social Commission for Asia and the Pacific. UN, 1997)

3. DESCRIPTION OF THE STUDY AREA

3.1. Location, Area and Legal Status

The Yezin watershed area is located at about 12 miles from Pyinmana, in the Yamethin District. Yezin Watershed is situated between Latitudes 19 50' 22” N and 19 57’ 54” N and Longitudes 96 16' 04” E and 96 22' 40” E. It covers an area of 36 sq miles including the five major villages namely; Chon, Shanywa, Chaungbya, Ngokchaung and Suboktaung.

Table (1) Lists of Reserve Forests and Protected Public Forests in the Pyinmana Township

No.	Reserve/ Protected Public Forest/ Nature Conservation Area	Area (sq. km)	Notification No. and Date	Remarks
(1)	(2)	(3)	(4)	(5)
Reserve Forest				
1	Yezin	22.94	58/31.3.1913 222/15.9.1931 189/25.61932	Reservation Deleted 0.81 sq.km Define the Boundary
Public Protected Forest (PPF)				
1	Yezin	13.44	58/24.3.1969	

Source: Working Plans and District Forest Department, Yamethin District.

3.2. Topography

On the eastern side of the Yezin Watershed Area is the high mountain ranges of the Shan Plateau going from north to south. The highest mountain in the Watershed Area is the Shautpintaung with a height of (4000) feet above sea level. The surrounding mountaintops average about 3000 feet.

3.3. Geology and Soils

Table (2) The soil types found in the Pyinmana Township

No	Township	Reserve	Soil Types		Remark
			Myanmar Name	Landuse nomenclature	
(1)	(2)	(3)	(4)	(5)	(6)
1	Pyinmana	Yezin	Sane land & Thewon Land at mountain Range, Sane Land at Low, flat area	Compact & Catena of Savanna Soils on slopes & compact soils in Depressions	

Source: Pyinmana District Working Plan Year, 1996.

Limestone as raw materials is extracted by the Watana Company at Bawdimyaing Camp, north of Yezin Dam, in the Pyinmana Township.

3.4. Climate

The highest temperature in the District is (32.2) centigrade and the Lowest is (18.2) centigrade. The average annual rainfall is (980.04) millimetre. The average monthly rainfall, the average monthly temperature, the highest monthly temperature and the lowest monthly temperature are shown in Table (3). The monthly average temperature and the monthly average rainfall are shown in histograms respectively.

Table (3) Monthly Data pertaining to Climate in the District Location of Weather Centre: Pyinmana (1987 to 1996)

Month	Average Rainfall (mm)	Average Temperature (Centigrade)	Highest Temperature (Centigrade)	Lowest Temperature (Centigrade)	Humidity %
(1)	(2)	(3)	(4)	(5)	(6)
January	1.3	21.43	23.6	19.0	
February	4.1	23.60	26.5	20.3	
March	6.2	27.92	30.3	24.8	
April	30.2	29.67	32.2	26.5	
May	114.4	29.41	31.8	26.7	
June	150.8	26.39	29.5	24.3	
July	170.0	25.14	27.5	22.1	
August	180.5	25.18	26.5	23.6	
September	140.0	25.42	27.4	23.9	
October	128.7	24.71	26.4	20.8	
November	53.2	21.21	25.4	21.4	
December	2.7	18.55	23.7	18.2	

Source: Meteorology and Hydrology Department, Myanmar

Monthly Average Temperature (1987 – 1996)

Table Showing Monthly Average Temperature in Pyinmana (1987 – 1996)

Figure(1)

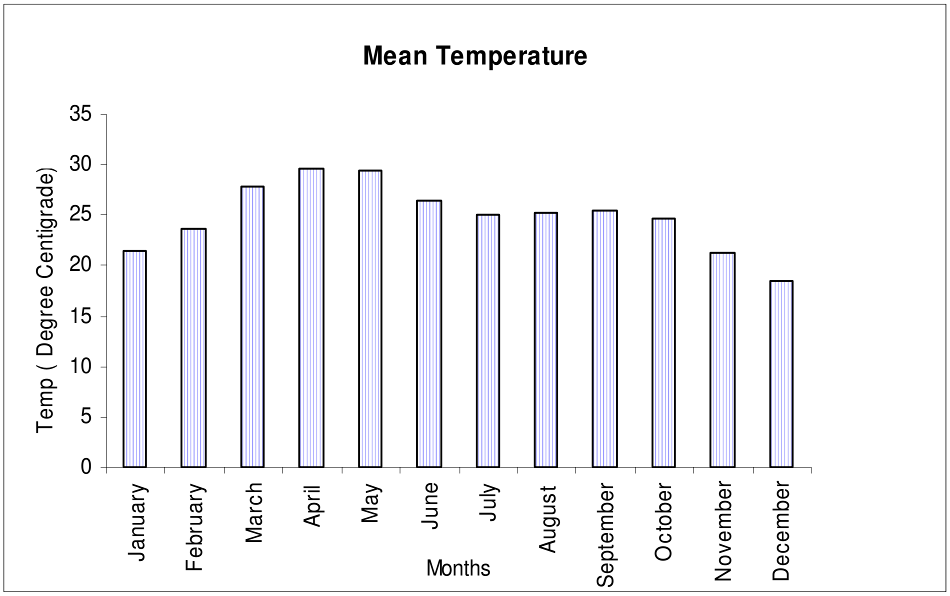
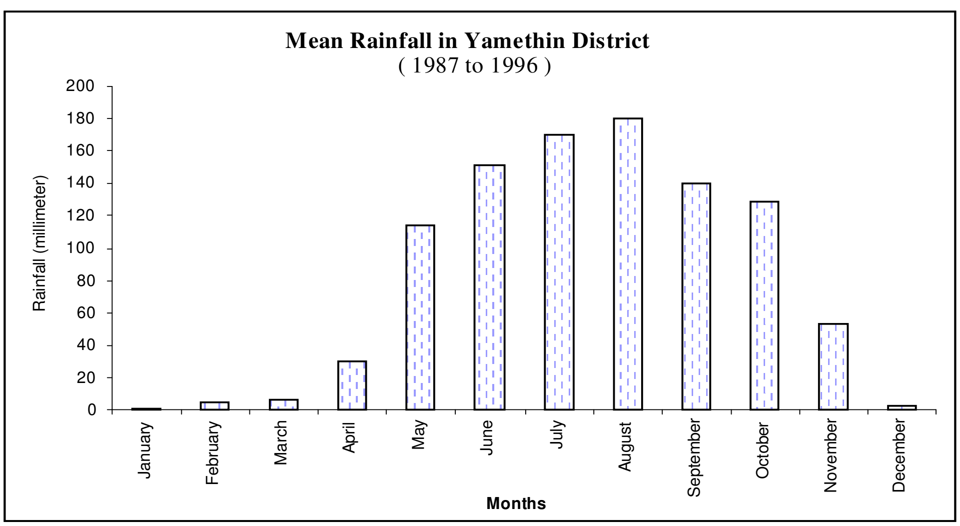


Table Showing Monthly Average Rainfall in Pyinmana

Figure(2)



3.5. Hydrology, Drainage and Water Supply

The Yezin chaung has its source in the watershed area of Yezin Reserve and flows across the Yezin Reserve from north to south direction.

The Yezin chaung is never short of water even during the hot summer season. Villages on either side of these chaung thrive well in agricultural vegetables and fruits crops.

3.6. Socio-economic Conditions

The Yezin watershed area was covered by mainly Chon, Shanywa, Chaungbya, Ngokchaung and Suboktaung villages and the total area were 36 sq miles. The total households are 215 (6 persons per households), 60% of population are ethnic Kayin Phyu and the remaining are Burmese people.

The average size of a holding is 0.002 sq. km per family. Landlessness and tenancy are not widespread. Main crop grown beside paddy are banana, maize, peanut, various vegetable, sugar-cane, papaya, Chile, lime juice, danyin and jack fruit. Major socio-economic problems are ;

(1) efficiency particularly among the upland population
(2) insufficient of health facilities, commonly malaria is prevalent
(3) insufficient of transportation facilities and difficult road conditions, again particularly for the upland people, who live in remote areas far away from Yangon and Mandalay main road.
(4) access to market facilities are difficult
(5) lack of proper educational facilities

Most of the children cannot afford to attend school regularly even at the primary level education. Eventually, their drop-out rate is fairly high in primary and middle school, even for the few that can afford to attend school. The economic conditions of the people can be said to be slowly declining while their social condition can be said to be move vibrant as they have to mix with the migrating rural people from un-remunerative areas.

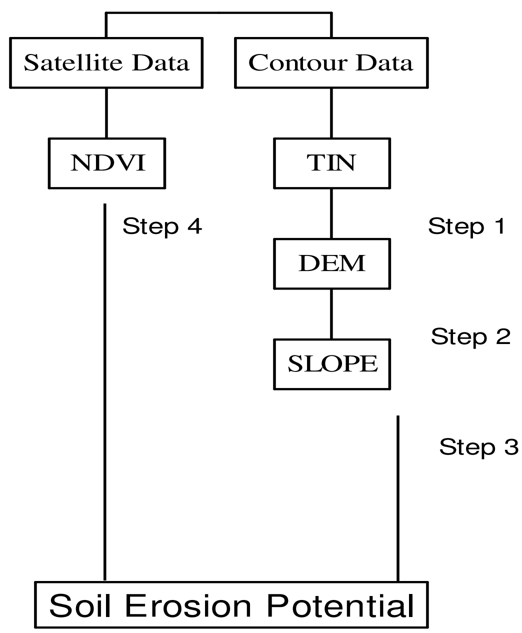
Due to the degradation of the soil and declining growing stock of the forest, due to overexploitation, recurring annual forest fires, indiscriminate cutting and marketing of fuelwood and charcoal and illegal extraction and marketing timber, the crop production and growing stock in the forest have declined. The economic decline of the villagers cannot be assessed in monetary form as they are very conservative and secretive and will not divulged their monetary status when the economic and social survey was carried out.

4. MATERIALS AND METHODS

4.1. Flow Chart of Calculating Annual Soil Erosion Potential for Yezin Watershed Area

Input data set:
- Contour
- Watershed Boundary
- Satellite data (95opsb2 & 95opsb3)
- Reserve Boundary

Steps



TIN = Triangular Irregular Network
DEM = Digital Elevation Model

4.2. Calculating Soil Erosion Potential

Step (1)

Topographic maps were listed then prepared for the study area.

Step (2)

Topographic maps were scanned using scanner which produced raster (.tif) format. Topographic maps were used to know the watershed area, contour, stream, township boundary and village location, etc.

Step (3)

Contour (lines), stream (lines) and village (points) information were put into GIS with screen digitization. Rectification is done in Indian Grid IIB, of landsat Continual Conic Projection System.

Step (4)

Create the DEM (Digital Elevation Model) layer from the assigned elevation contours. DEM layer was made to obtain the slope and elevation of Yezin watershed area.

Step (5)

Create the slope layer from DEM layer than using SML (Spatial Manipulation Language) which was converted into FAO format, and slope layer which is divided into (6) classes.

Step (6)

Calculate the NDVI (Normalized Difference Vegetation Index) layer using the SML to know the situation of vegetation cover in the watershed area, NDVI was used.

Step (7)

Create the land cover map, which was used to know the forest cover in Yezin watershed area by digital classification.

Step (8)

To calculate the erosion potential, E30 layer has to be made using SML

Step (9)

Erosion Potential was calculated by using the SML to know the condition of erosion in Yezin watershed area.

Step (10)

Erosion Potential which is divided into (3) classes using SML.

5. ANALYSIS

5.1. Problems in Erosion Potential Calculation (S)

Following factors govern the erosion potential of a watershed.

(a) Land Cover
(b) Geology
(c) Soil
(d) Rainfall
(e) Topography

All these factors are used in calculation of the famous Universal Soil Loss Equation.

However for Myanmar it is very difficult to obtain all data pertaining to watershed management. Especially soil, geology and rainfall data cannot be compiled in the standards needed for calculating soil loss equation. The need for GIS type calculation is much more impossible to obtain.

For example the weather stations are not very well distributed in Myanmar and rain fall data although present in some cases are almost useless. Soil maps in micro level scales are almost non-existent. Existing soil maps are classified very broadly.

Even landcover data has been unavailable until very recently till Landsat TM imageries are introduced. However landuse classifications are still not standardized and very careful conversion parameters have to be formulated when using landcover maps produced by various agencies. However with the help of remote sensing and satellite images this problem has been solved.

One other factor capable of producing within reach is topography. Here also, slope map production has been very difficult in the past until the introducing of GIS systems. The current topographic maps in use can satisfy the contour interval required by the regional watershed modeling. Therefore these two parameters namely land cover and topography will be used for calculation of erosion potential in this work.

5.2. E30 Model

E30 model developed by AIT needs only two inputs for calculation namely NDVI (Normalised Difference Vegetation Index) and Slope Digital Terrain Model (Slope DTM). NDVI is calculated from Landsat 5 TM data and Slope DTM is produced from DEM (Digital Elevation Model) derived of Topographic Maps.

$$E = E30\ (S/S_{30})^{0.9}$$

Where	**E30**	**=**	**Annual Rate of Soil Erosion at 30° slope**
	S	=	Gradient of point under consideration
	S30	=	Tan 30°

Tangent 30° is considered as the critical value where soil erosion and particle movements are significant. E30 is calculated from the formula:

$$E\ 30 = [\{(\log 0.132 - \log 17.12)/(NDVI_{max} - NDVI_{min})\} x \{NDVI_{max} - NDVI_{min}\} - \{\log 17.12\}]$$

5.3. Normalised Difference Vegetation Index (NDVI)

Amount and presence of green vegetation is a direct index of landcover. One of the outstanding merits of remote sensing procedures relates to the spatially comprehensive overview of vegetation that it provides.

The most commonly used technique by vegetation analysis is computation of ratio images using landsat data in near infrared (NIR) and visible bands of the electromagnetic spectrum. In this study the first spectral band is (0.62 – 0.68 µm) where chlorophyll causes considerable absorption of incoming radiation and second spectral band is in a region (0.77 – 0.86 µm) where spongy mesophyll leaf structure leads to considerable reflectance.

Taking advantages of spectral behavior of these regions, very good correlation has been derived, which gives a clear indication of the photosynthetic activity and vigour in green biomass. Spectral response characteristics of healthy vegetation, and dead or senescent vegetation can easily be identified in the different parts of the electronic spectrum. Healthy vegetation reflects 40 to 50 percent of the incident NIR energy and 8 to 0 percent of the incident energy in the visible band.

Various mathematical combinations of these two bands have been generated for vegetation indices. This contrast between NIR and visible can be conveniently shown by ratio transforms i.e. dividing one band by the other. Several ratio transforms (called band rationing in RS terminology) have been proposed for studying different land surfaces. Two such indices normally used for vegetation are simple vegetation index (VI) and normalised difference vegetation index (NDVI).

Formula for NDVI is:

NDVI = (Band4-Band3)/(Band4+Band3) or

NDVI = (NIR-RED)/(NIR+RED)

Where,

NIR = amount of reflection of the incident Near Infrared electromagnetic spectrum, and

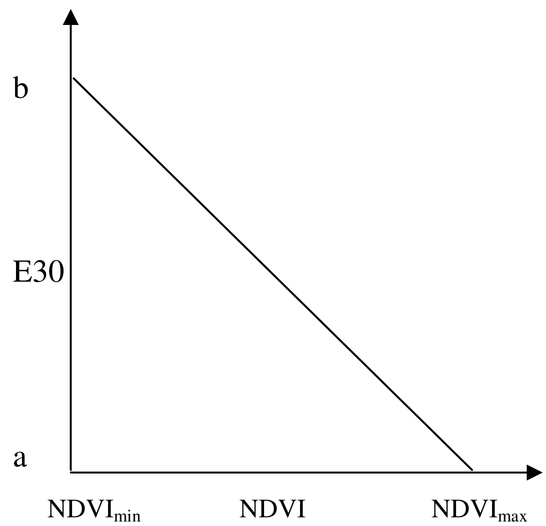
RED = amount of reflection of the incident in Natural Red electromagnetic spectrum

NDVI has been shown to be highly correlated with vegetation parameters such as green-leaf biomass and green-leaf areas and hence is of considerable value for vegetation discrimination. In addition, a ratio between bands is of considerable use in reducing variations due to surface topography.

Vegetated areas will have generally high value index because of their relatively result high near-infrared reflectance and low visible reflectance. In contrast, cloud, water, and snow have larger visible reflectance than near-infrared reflectance. Thus these features result in negative index values. Rock and bare soil areas have similar reflectance in the two bands and result in vegetation indices near zero.

The constant values of log 0.132 and log 17.12 are empirical values derived from erosion rate studies of various countries and watersheds of South Asia and South East Asia regions.

Constants log 0.132 and log 17.12 have been modified by Dr. Honda of AIT with practical erosion values as shown in following diagram.



Relationship between NDVI and erosion potential at 30 degree slope

The relationship between is developed using few known points of E30 values and their corresponding NDVI values. Using this relationship, it is possible to estimate E30 of each and every pixels of the watershed.

$E30 = [\{(a-b)/(NDVI_{max} - NDVI_{min})\} * (NDVI_{max} - NDVI)] + b$

Erosion potential at densely forest area (30 degree slope), a = 0.2 mm/year

[4]Erosion potential at bare land area (30 degree slope), b – 20 mm/year

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[4] See Postscript

5.4. Gradient of Points under Consideration (S)

The watershed area has been considered as summation of pixel points as a raster slope map. The Slope DTM is produced from DEM.

A DEM (digital elevation model) is digital representation of topographic surface with the elevation or ground height above any geodetic datum.

A DTM (digital terrain model) is digital representation of terrain features including elevation, slope, aspect, drainage, and other terrain attributes. Usually a DTM is derived from a DEM or elevation data.

6. ESULTS AND DISCUSSIONS

Map (3) is the final result, showing the "Erosion Susceptibility Map" . This data is divided into simple three classes namely, minimal, moderate and critical.

The accuracy of the E30 model is checked against the algorithms in use by the Forest Department in its Erosion Susceptibly Mappings.

Forest Department in the Dry Zone Mapping surveys generate following databases.

Table (4) (1) Slope Map in six classes

Class 1	Gently sloping	<5°
Class 2	Moderately sloping	5-15 °
Class 3	Moderately steep	15-20 °
Class 4	Gently steep	20-25 °
Class 5	Steep	25-30 °
Class 6	Very steep	>30 °

(2) Land Cover map, which is combined into (6) classes

(1) Good Forest
(2) Degraded Forest
(3) Agriculture
(4) Shifting Cultivation
(5) Bamboo Forest and
(6) Water

Algorithm used is steep slopes covered with good vegetation cover are not susceptible to erosion and vice versa gentle slopes although devoid of vegetation cover are also have minimal erosion impact. Some vegetation type like bamboo break are good soil cover.

Table (5) Gradient of Points Under Consideration is the test of E30 Erosion Map using the above algorithm. 30 points are randomly selected to cover all land use classes GIS overlays are used to generate this table.

It can be seen in the table that all 25 points satisfy the algorithm tested.

The NDVI layer is well represented with the vegetation classes and erosion susceptibly easily calculated using the E30 formula.

Table (5) Gradient of Points Under Consideration (S)

Point	Slope Class	E30 Class	NDVI Value	Forest Type	Remark
1	2	1	92	Agriculture	True
2	1	1	92	Agriculture	True
3	2	1	95	Scrub/Grass Land	True
4	2	2	93	Scrub/Grass Land	True
5	2	1	125	Degraded Forest	True
6	6	2	132	Degraded Forest	True
8	4	1	153	Bamboo	True
9	4	1	151	Good Forest	True
11	2	1	91	Agriculture	True
12	6	3	101	Agriculture	True
13	3	3	101	Scrub/Grass Land	True
14	3	2	110	Scrub/Grass Land	True
15	2	1	128	Degraded Forest	True
16	6	2	135	Degraded Forest	True
17	3	1	154	Bamboo	True
18	3	1	159	Bamboo	True
19	1	1	104	Agriculture	True
20	1	1	95	Agriculture	True
21	2	1	103	Scrub/Grass Land	True
22	6	3	100	Scrub/Grass Land	True
23	6	2	124	Degraded Forest	True
24	6	2	130	Degraded Forest	True
25	3	1	153	Bamboo	True
26	3	1	151	Bamboo	True
27	4	2	130	Good Forest	True
28	2	1	148	Good Forest	True
29	6	1	144	Good Forest	True
30	6	1	155	Bamboo	True
31	4	2	121	Good Forest	True
32	3	1	124	Good Forest	True

7. RECOMMENDATIONS

After a thorough analysis from the acquired data and maps had been carried out the following pertinent conclusions and recommendations are presented as follows;

(1) It is urgently need to conserve the watershed areas of important dams and reservoirs in Myanmar because of the watershed management is very important to secure good quality of water and to maintain the expected life span of these dams; and reservoirs.

(2) Selecting priority area for rehabilitation of watershed is an important process in watershed management.

(3) Conventional watershed assessment tools like Universal Soil Loss Equation (USLE) need a lot of inputs like soil moisture, soil type, geology etc which are hard to compile in Myanmar at present.

(4) E30 modeling is an appropriate tool for assessing watershed quality, within the technology research of Myanmar.

(5) This paper has clearly shown the usefulness of Remote Sensing & GIS via E30 modeling for priority area selection in watershed rehabilitation programs.

(6) The whole technology can be and should be instantly applied by the Watershed Management Division of Forest Department.

(7) Further RS/GIS application in watershed management application should be developed and practiced.

8. CONCLUSION

In the case of watershed management, there is needed to take consideration of the estimation of soil erosion potential. If there is unable to get the information of soil, rainfall, geology or there is the data about slope and vegetation cover, it is learnt to find out the estimation potential of soil erosion by using RS/ GIS with E30 equation for calculating of NDVI.

It is clearly shown that the erosion potential is dependent upon the density of vegetation cover. Although the slope is high, the land cannot be affected by soil erosion where the forested or vegetated area is dense. Likewise, the slope is medium and the vegetation cover is few, the rate of soil erosion can be increased. In addition, the slope level is low and the land cover is bare, it is surely that this land is affected by soil erosion.

So it has been graphically shown that density of vegetation cover is most important in controlling soil erosion in watershed management activities.

*** Postscript**

Pertaining to the parameter of soil erosion between dense forest area and bare land in Thailand at 30% slope is found to be approximately 100 times greater in the area with no vegetation (i.e. bare land).

At the time of the preparation of this paper, the data pertaining to the parameter of erosion potential from the Chindwin area was non-available due to the fact that in Chindwin data pertaining to the erosion potential is available only in 2004 through the Ph.D thesis presented by the researcher Daw Nila Aye from Mandalay University.

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