MAPPING POTENTIAL LAND DEGRADATION IN BHUTAN

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ABSTRACT

This study attempted to map potential land degradation area based on existing degraded areas at Lumang and Thrimshring Geogs in Bhutan through integration of Geospatial Information. Existing land degradation areas are mapped through field mapping. Moreover, 9 factors of land degradation such as drainage density, water flow accumulation, distance from drainage, water flow direction, slope, aspect, geology, land use & cover and distance from road are considered for mapping potential land degradation areas. These factors are also found out through field observation. This study demonstrated how to create factor maps while accessing very limited available Geospatial Information. This study also demonstrated how to integrate Geospatial information through weighted factor combination model to create seven levels of land degradation risk map using hydrological model and spatial analyses.

1. INTRODUCTION

Bhutan is mountainous Himalayan Country. The landscape of Bhutan is characterized by an accentuated topography and steep gradients between the valley floors and the mountain peaks. The land degradation is caused by gravity-driven natural processes such as Geomorphology, steep slopes and anthropogenic phenomena such as road construction in Bhutan. The study area, Lumang and Thrimshing Geogs are located in eastern Bhutan

Therefore, 'insight study' into the probable factors of land degradation would potentially be of considerable benefits for potential land degradation mapping and spatial planning at the different spatial scale.

T. Wangchuk and F.Turkelboom, (1999) reported land degradation of upper catchments of Radhi Geog in relation to Geology.

Thinley (2004) investigated land degradation of Tshogompa, Lumang Geog in relation to Geology.

Previous land degradation studies have largely concentrated on field visit and reporting the findings qualitatively as the field reports, and focused on Geology types.

There is reason to believe that land degradations in Bhutan occurred not only by the geological factors but also other factors such as grazing, slopes, and nearness to the drainages etc.

The primary focus of this paper is to find out the potential land degradation areas based on the probable factors of land degradation at Lumang and Thrimshring Geogs in Eastern Bhutan.

2. METHODS AND PROCEDURES

2.1 Field mapping of existing land degraded areas

The 30-meter resolution of satellite imagery does not permit to map existing land degraded areas. Moreover, new land degraded areas occurred after the date of satellite imagery. Therefore, the team documented existing land degraded sites on the enlarged topographic sheet and field map sheets through field observation and visit to these sites. The polygons of existing land-degraded areas are drawn, by referencing the landscape and topographic features such as drainages, ridges and peaks.

It is dangerous and impractical to walk along the perimeter of land-degraded areas with GPS. Therefore, point locations of land-degraded areas were located to reference spatially and for quality control.

Land Degradation Area Field Map well represents existing land degraded areas spatially although the boundary of each degraded area may not be spatially precise. The existing degraded areas are digitized to create the digital version of Field Map (Figure-1 Existing Land Degradation Map).

2.2 Factors probably contributing to land degradation through field observation

During the field mapping, the following factors that probably contributing to land degradation are observed.

1. Drainage density
2. Water Flow Accumulation
3. Distance from the drainages
4. Water Flow Direction
5. Slope
6. Aspect
7. Geology or Mineral Types
8. Land use and land cover
9. Distance from the Road

2.3 Creation of Factor Maps

2.3.1 Digital Elevation Model (DEM)

A DEM (digital elevation model) is digital representation of topographic surface with the elevation or ground height above any geodetic datum (Murai, 1997).

In order to derive slope, aspect, water flow direction and water flow accumulation, the DEM is required.

Although, the DEM can be generated from various methods and technologies such as LIDAR, digital photogrammetry, radar interferometry and radarmetry, due to the cost constraints, DEM was generated through interpolation of digitized elevation points or contour lines from the topographic sheet.

The elevation points are digitized along the contour lines and at peaks within and outside the study area boundary.

Elevation points are interpolated with the Spline method at 10-meter resolution grid to create DEM. The Spline method fits a minimum-curvature surface through the input points. It fits a mathematical function (a minimum curvature, two-dimension, thin plate) to a specific number of the nearest input points while passing through all input points (Booth, B. (2000)). In order to control the DEM quality, the contour lines are derived from the DEM and compare with the contour lines of georeferenced scanned topographic sheets through out the study area. Generated contour lines fit well to the contour lines of georeferenced scan topographic sheet.

2.3.2 Digital Terrain Model (DTM)

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 (Murai, 1997).

Slope in degree grid and **Aspect** grid, are generated based on the DEM using the procedure of Burrough P.A (1986).

The **Flow Direction and Flow Accumulation Grids** were generated according to the procedures of ArcHydro, (Maidment, 2002).

The streamlines are generated through the use of a threshold flow accumulation value based on the flow accumulation grid. These streamlines are compared with the streams digitized from georeferenced scanned topographic sheets for the quality control purpose and in order to make sure water in the model and water in the reality are flowing similar way or not. Both streams fit well.

2.3.3 Drainage Density Factor Map

The drainage density map is calculated based on 50 Meter vector cells.

Existing drainage lines are digitized from the georeferenced scanned topographic sheets. The 50 Meter vector cells are created for the whole study area. The total length of drainage segments to each 50 Meter vector cell is calculated. The Drainage Density Factor Map represents total length of drainage in integer value in meter with 50 M by 50 M vector cells.

2.3.4 Nearness to the Drainage factor map

The land degradation is associated to the drainages in the study area. Therefore, the Euclidian distance from the drainage is calculated.

2.3.5 Nearness to the Road factor map

Some areas of land degradation are associated to the highway and feeder road. Therefore, the Euclidian distance from the road is calculated until 1 KM from the road in order to create Nearness to the Road Factor Map. Based on the field observation, the cause of land degradation is not related to the road construction if it is occurred beyond 1 KM from the road.

2.3.6 Land cover and land use factor map

The existing land use map is further updated based on the satellite image and intensive field observation in order to produce the Land Cover and Land Use Factor Map. Minor imperfections of land use map was improved especially detail forest types and agriculture types.

2.3.7 Geology or Mineral Types Factor Map

The Department of Geology and Mine of Bhutan provided the general mineral types as part of the National Geology Map. The map is clipped according to the study area boundary to produce Mineral Types Factor Map. Mineral types are useful for the analyses.

2.4 Criteria Weight Determination

Each Factor Map is intersected with the existing land degradation area. The frequency of each class or each value is generated and analyzed carefully. Then weight of each class or each value or range of values is assigned as the weight.

Weight value of each class (Table-1 through Table-9) for each factor map is discussed in the discussion section.

2.5 Weighted Factor Maps

Each factor map is classified according to the weight value of each class to produce the weighted factor maps. Then, the weight value of each factor map is scaled to 100.

2.6. Potential Land Degradation Map

All the weighted factor maps are integrated by summing the raster grids in Map Algebra in order to produce the quantitative sum of weighted map (Figure-2 Quantitative Potential Land Degradation Map). Higher the value, more contributing the factors for land degradation and higher potential for land degradation.

The quantitative Potential Land Degradation map was reclassified based on the thorough field validation into seven levels of land degradation risk (Figure-3 Land Degradation Risk Map).

3. RESULTS

Figure-1 illustrates the existing land degradation areas based on though field mapping. Most of the land degradation occurred along the drainages and intersections of road and drainages. The existing land degradation polygons are samples sites in order to find out the thematic spatial characteristics of probable contributing factors.

Table-1 shows the weighted value of each drainage density class in the study area. The unit of drainage density is length in meter per 50 M square. Drainage density class 2, 3 and 4 has significantly higher weight value.

Table-2 provides the weighted value of each flow accumulation class in the study area. The unit of flow accumulation is number of cells. Flow accumulation class 1 has significantly higher weight value. It indicates that land degradation is not necessarily to be associated with high flow accumulation in the study area.

Table-3 gives the weighted values of distance from the drainages. The table suggests that the distance within 10 meter, 20 meter and 40 meter from the drainages has significantly higher weight value.

Table-4 illustrates the weight values of flow direction associated to the existing land degradation. The table provides NW, W, N, SE and SW flow direction has significantly higher weight value.

Table-5 provides the weighted value of slope associated to the existing land degradation. The table suggests that slope class 24-33 degree, 20-23 degree and 34-38 degree have significantly higher weight value.

Table-6 shows the weighted value of aspect associated to the existing land degradation. The table illustrates that N, NE, SW, W and NW facing slopes have the higher weight value.

Table-7 provides the weight value of geology mineral types associated to the existing land degradation. It illustrates the phyllite, green micaceous quartzite and thin marble band and variegated phyllite and quartzite have the significantly higher weight value.

Table-8 gives the weight value of land use and land cover associated to the existing land degradation. The table provides the dry land agriculture and broadly forest has significantly higher weight value.

Table-9 illustrates the weight value of distance from the road within 1 KM. The table suggests that the distance classes within 50 M, 100 M and 150 M from the road have significantly higher weight value.

Figure-2 provides the quantitative sum of weighted factor maps. The minimum value is 77 and the maximum value is 393. Higher the value, more contributing the factors for land degradation and higher potential for land degradation.

Figure-3 provides Land Degradation Risk Map, which illustrates seven levels of land degradation risks. Most of the existing land degraded areas fall within risk level 5,6 and 7. Field validation suggests that risk level 5,6, and 7 are critical areas for land degradation. Total 9100 Acres of study area is under the risk level 5,6 and 7.

4. DISCUSSION

The former studies of land degradation in Bhutan focused Geology associated to land degradation, reporting as the field trip reports.

The findings of this study goes beyond the focus of Geology. Other factors such as slope, drainage density, nearness to the drainages, nearness to the road, land use and land cover, aspect, flow accumulation and flow direction has considerable impact on land degradation. One possible conclusion is that road and drainage intersections have significant association to the land degradation especially upper catchments is covered with broadleaved forest. Another possible conclusion is that the slope and land cover quality also have significant association to the land degradation.

This study has taken a step in the direction of considering probable factors based on existing land-degraded areas. Existing land degradation areas are mapped based on the field observation. Existing land degradation areas could be mapped more accurately if 5-meter resolution or better resolution satellite images are available.

It is possible that other study areas with different spatial characteristics may produce entirely different result. More factors such as quality of the forest cover, elevation, nearness to the pasture and nearness to the irrigation channels could contribute to refine the result.

Although weight for classes of factor map was calculated, weight for each factor map is assumed equal in this study. Further improvement could be made by developing a method to calculate the weight for each factor map.

The approach outlined in this study should be replicated in other areas of Bhutan considering more factors and, calculating weight of each factor and weight of classes of each factor map in order to create the potential land degradation risk map.

TABLES

Table-1: Weight of drainage density classes

Drainage Density Value	Class	Weight
0	1	0
1-50	2	23
51-100	3	25
101-150	4	46
151-200	5	5
201-250	6	1

Table-2: Weight of flow accumulation classes

Flow Accumulation Value	Class	Weight
0-1405	1	96
1405-5830	2	2
5830-13167	3	1
13167-239500	4	1
239500-2025585	5	0

Table-3: Weight of Distance from the drainage values

Distance from drainages values	Weight
10	31
0	22
20	16
40,22,50	13
28,26	9
30,31,40,41,44,60,70,80	6
42,53,56,58,63,64,67,72,76,78,82,84,85,86,89,90,100,102,104,106,107,110,111,113,114,116,120,125,130,134,136,140,141,143,148,150,152,161,170,180	3
Other	0

Table-4: Weight of flow direction classes

Flow Direction Class Name	Flow Direction Class Code	Weight
E	1	11
SE	2	6
S	4	10
SW	8	16
W and N	16, 64	19
NW	32	21
SE	128	18

Table-5: Weight of slope classes

Slope in Degree classes	Weight
0-8	0
9-15 and 43-50	10
16-19 and 39-42	20
20-23 and 34-38	30
24-33	40
51-76	0
Other	0

Table-6: Weight of Aspect classes

Aspect Class Name	Aspect Class Code	Weight
N, W	1, 7	21
NE	2	17
E	3	8
SE	4	7
S	5	10
SW	6	14
NW	8	23
Flat	9	0

Table-7: Weight for Geology Classes

Geological Types	Weight
Phyllite, green micaceous quartzite and thin marble bands	41
Variegated phyllite and quartzite	55
Grey tilliod boulder slates and carbonaceous slates	4

Table-8: Weight for the land use and land cover classes

Land use and land cover name	Class code	Weight
Dry land agriculture	AD	33
Mixed Agriculture	AM	5
Tseri and Scrub Forest	AT and FS	4
Broadleaved Forest	FB	57
Mixed Confer Forest, Natural Pasture	Fcm and PN	1
Open land	OL	0

Table-9 Weight for the distance from the Road within 1 KM classes

Distance zone class	Distance zone code	Weight
0-50	1	23
50-100	2	19
100-150, 150-200	3,4	16
200-250, 250-300, 300-350, 350-400	5, 6, 7, 8	14
400-450, 450-500	9, 10	12
500-550, 550-600, 600-650, 750-800	11, 12, 13, 16	9
650-700, 700-750, 800-850, 850-900, 900-950, 950-1000	14, 15, 17, 18, 19, 20	7

FIGURES

Figure-1 Existing land degradation map

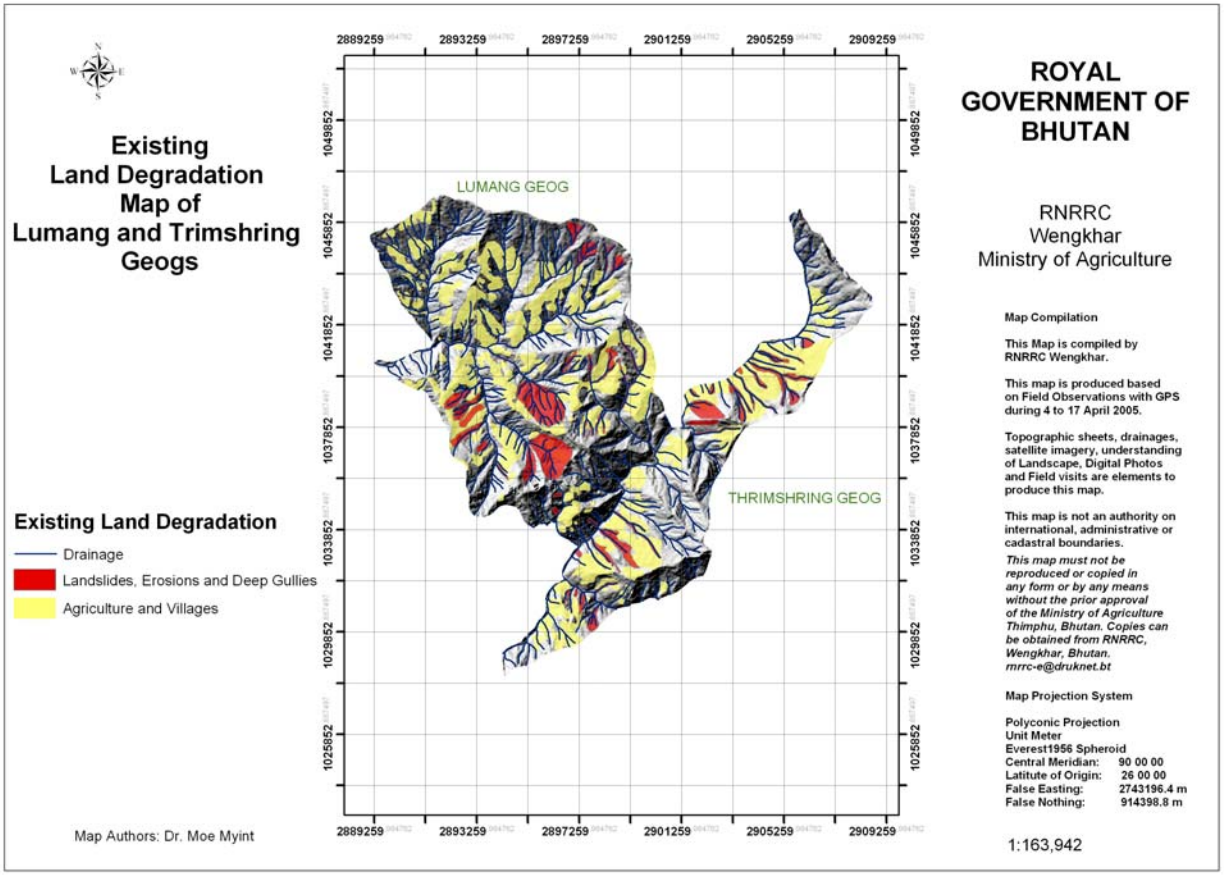


Figure-2 Quantitative Potential Land Degradation Map

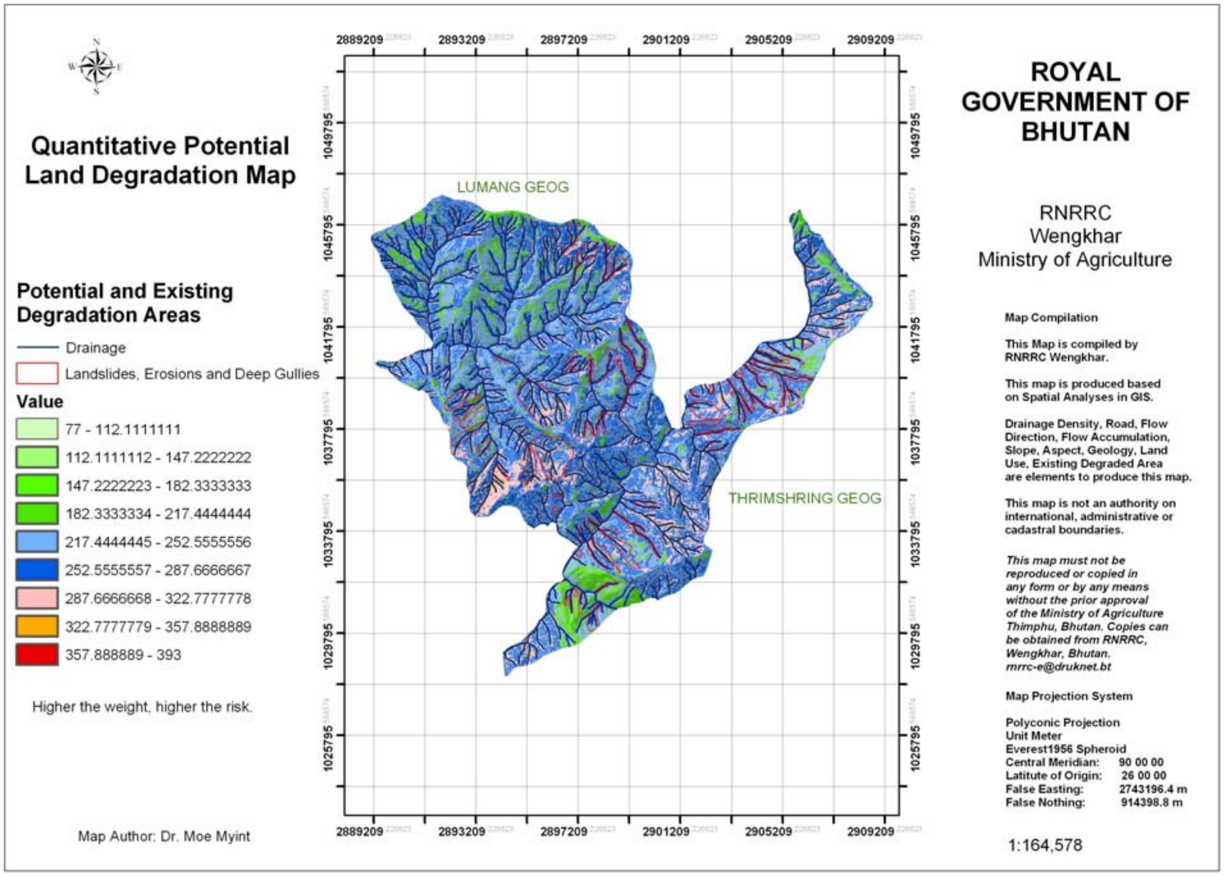
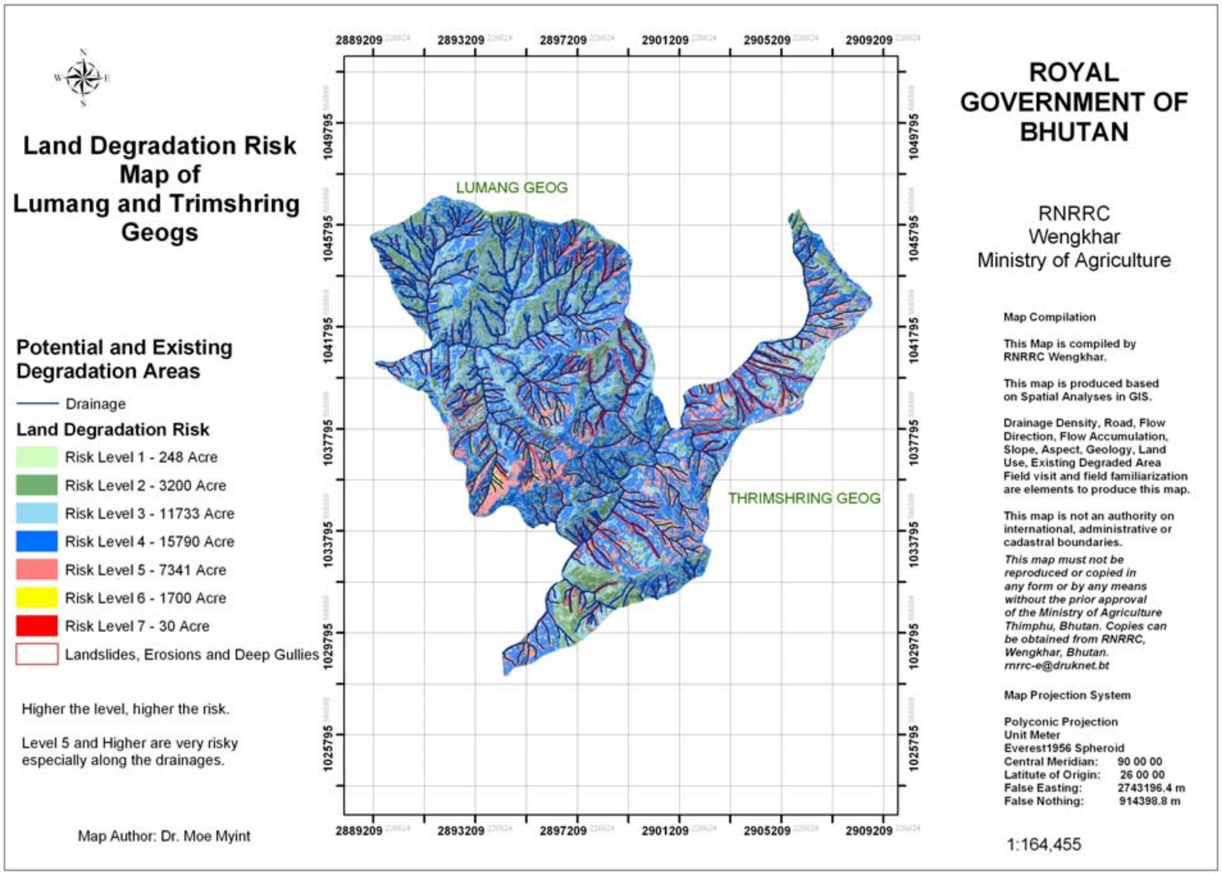


Figure-3 Land Degradation Risk Map



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