Application of Vegetation Indices for Forest Degradation Using Landsat TM Data

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Abstract

This paper demonstrates that it is feasible to evaluate forest degradation and to detect deforestation in the 8156㎢ study area affected by expand farming using vegetation indices derived from Landsat TM data.

The NDVI-growing stock relation was applied on th Landsat TM data and a 3 second grid DEM, whose coverages could improve the assessment of forest degradation and also estimate the rate of change of forest cover area depending on elevation intervals. The strength of the relationship between the ratio of the greenness and brightness indices and forest degradation conditions would have been more interesting in the deforested areas which were converted to crop farming land.

1. INTRODUCTION

It has become very important to monitor forest cover in North Korea, whose western part got damaged by an unprecedented rainfall disaster from July to August 1995. The disastrous flood was enhanced by landslides in mountainous areas and soil erosion in surrounding hillsides resulting from a deforestation. The cause of deforestation was primarily the clearcuts in the lower regions of mountain forest to increase crop production due to a chronic grain shortage of North Korea and forest degradation occurred mainly in the lower elevation of mountains and hills for fuelwood use by rural households. Lack of information outside North Korea makes it difficult to examine deforestation and forest degradation assessment, which is essential to mitigate natural hazards. To collect the data of changes of forest cover area, which are inaccessible on the ground, we need to use the satellite remote sensing

In this study, a high resolution digital elevation model(DEM) data together with Landsat TM data has been used to investigate the plausible explanation of the destruction of forests. The primary goal of the study is to estimate the gradual reduction of biomass according to stratifying the elevation corresponding to the range of forest degradation, derived from over-exploitation for fuelwood.

The approach demonstrated here adopts the derivative vegetation indices from the Landsat TM data for estimation of biomass.

For explicit formulations, the link between biomass and vegetation indices of

Hawanghaepukto Province of North Korea can be compared with the relation between growing stock and vegetation indices of the forest stands by the Kwangnung Experiment Forest basis, South Korea, because the TM data covers both of the areas.

2. MATERIALS AND METHODS

Study Area

The test site is located in Hwanghaepukto province which is one of the most intensively cultivated provinces in North Korea.

The coordinates of the site(Changpung & Paekhakdong), which exhibits a moderately high mountainous tract, are defined as : (127° 00′E, 38° 10′N), (126° 59′E, 38° 00′N), (126° 29′E, 38° 00′N) and (126° 30′E, 38° 10′N).

The Kwangnung Experiment Forest which is useful for the ground reference information for image analysis, is situated at 37° 45′ latitude North and 127° 10′ longitude West. It includes a variety of species and different classes depending these stands. Five stands of the forest were selected because their growing stocks are well known, related to the vegetation indices within the TM scene.

Data Sources

Landsat TM data acquired on 31 May 1991 were geometrically corrected for integration into the elevation data(a 3 second grid DEM). The use of the high resolution DEM coverages can improve the interpretability of the deforestation and the forest degradation associated with the two vegetation index values.

Methods

It has long been recognized that the normalized difference vegetation index (NDVI) is basically a measure of biomass and vegetation dynamics because it is simple in calculation and produces high degree of standardization (Curran, 1980 ; Jackson et al., 1983 ; John et al., 1998).

For this study, average NDVI values were calculated, depending on elevation levels which may be correlated with a gradual reduction of biomass(or growing stack) in the forest areas of the site. To avoid miss-registration pixels based on atmospheric effects in the image analysis, NDVI values of clouds, less than zero, were subtracted from the original bands.

Transformation techniques such as the Gramm-Schmidt transformation are also useful for monitoring the forest degradation conditions (Collins and Woodcock, 1994 ; Cohen et al. , 1998).

Thus, the TM data were transformed into Tasseled Cap greenness, brightness, and wetness indices (Crist, 1985), because change in brightness and greenness transforms can provide reliable information on the detailed vegetation condition in the test site.

3. RESULTS AND DISCUSSION

After resampling both the vegetation indices imagery and the grid-based DEM to the

1:50,000 scale topographic maps, the vegetation indices values of the Changpung & Paekhakdong areas were assessed for deforestation and forest degradation depending on elevation intervals.

Unlike forest degradation, deforestation is defined as a phenomenon in a geographic area associated with a change of land use from forest to non-forest category (Singh et al. , 1991), so that the change rate of the forest cover area only by the Landsat TM data without multitemporal data images can be achieved through comparing the 3 classified(forest, non-forest, and water) image using maximum-likelihood classifier and the areal extraction from 813 sample points on two 1:50,000-scale maps featuring between 1979 and 1981.

There is the noteworthy change in the forest cover areas between Table 1 and Table 2. Through the period of 10 years, 34.4 percent of the total area of the forests decreased and the areal loss amounted to 280,772ha in the test site. Within 200m above sea level, more than 10 percent of the forested area in each elevation interval was changed into non-forest category during the time period(Figure 1).

Figure 2 indicates that the non-forested areas increase along with decreasing of the forested areas, specifically those under 100m elevation along with the increase of 17.37 percent.

The areas of the water body in 1991 were less than those between 1979 and 1981. As the previously mentioned in the Methods, areal change of the water body depending on period could be neglected during elimination of cloud effects. Table 3 demonstrates the trend of forest degradation and the estimation of growing stock in the mountainous forests of the test site by comparing with the known Kwangnung Experiment Forest base which belongs to South Korea.

It should be noted that in this relationship of NDVI change according to varying biomass(or timber volume), the remaining forests have an impressive growing stock or a high crown density, because the average NDVI value of each elevation interval is higher than that of the stand No. 58 in Kwangnung Experiment Forest.

Table 1. Results of the classified land cover types depending on elevation intervals, extracted from the Landsat TM bands(2, 3, and 4) and checked with a 75-m resolution grid DEM

Range of Elevation (m)	Total		Forest		Non-forest		Water body	
	Pixels(#)	Area(%)	Pixels(#)	Area(%)	Pixels(#)	Area(%)	Pixels(#)	Area(%)
≤100	367464	45.80	119768	14.93	244975	30.53	2721	0.34
101-150	195146	24.32	86905	10.83	108149	13.48	92	0.01
151-200	101567	12.66	55715	6.94	45851	5.71	1	0.00
201-300	78628	9.80	57874	7.21	20754	2.59	-	-
301-400	30102	3.75	27616	3.44	2486	0.31	-	-
401-500	15671	1.95	15063	1.88	608	0.08	-	-
501-600	9775	1.22	9556	1.19	219	0.03	-	-
601≤	4007	0.50	3904	0.49	103	0.01	-	-
Totals	802360	100.00	376401	46.91	423145	52.74	2814	0.35

Table 2. Numbers of observation points and their corresponding area percent depending on elevation interval for each class and total, determined from systematic sampling

Range of Elevation (m)	Total		Forest		Non-forest		Water body	
	Points(#)	Area(%)	Points(#)	Area(%)	Points(#)	Area(%)	Points(#)	Area(%)
≤100	351	43.17	233	28.66	107	13.16	11	1.35
101-150	175	21.53	145	17.84	30	3.69	-	-
151-200	134	16.48	131	16.11	3	0.37	-	-
201-300	78	9.59	77	9.47	1	0.12	-	-
301-400	41	5.04	41	5.04	-	-	-	-
401-500	17	2.10	17	2.10	-	-	-	-
501-600	8	0.98	8	0.98	-	-	-	-
601≤	9	1.11	9	1.11	-	-	-	-
Totals	813	100.00	661	81.31	141	17.34	11	1.35

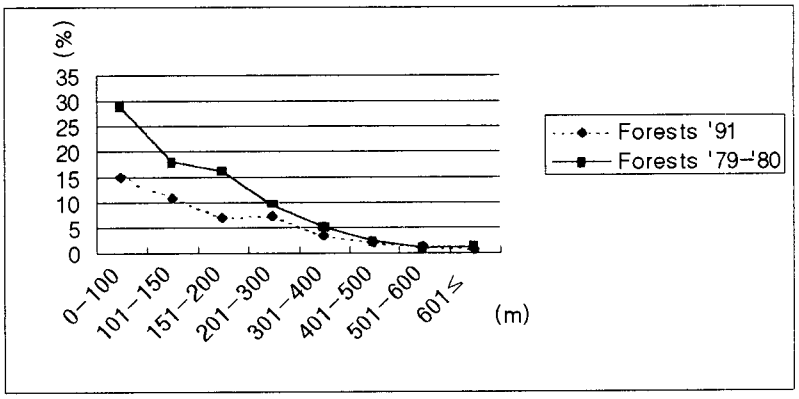

Figure 1. Comparison of the forested areas(%) in 1991 with those(%) between 1979 and 1981 depending on elevation interval

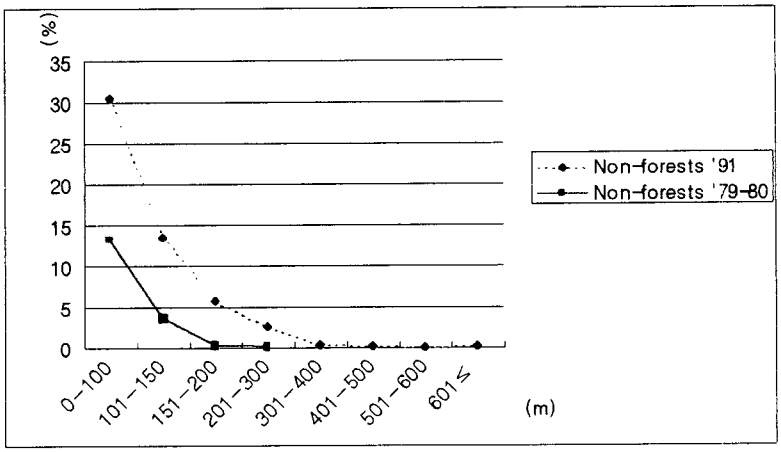

Figure 2. Percents of the non-forested areas depending on time period and also elevation interval

Table 3. Classification results and vegetation indices values derived from Landsat TM data

Test Site Forests (Changpung & Paekhkdong)					Kwangnung Experiment Forest		
Elevation Range(m)	Pixels(#)	NDVI (mean)	Greenness (mean)	Brightness (mean)	Satnd(#)	Growing Stock (m³/ha)	NDVI (mean)
≤100	119768	0.5456	48.909	196.0290	58	120	0.5373
101-150	86905	0.5512	51.571	200.4038	59	110.6	0.5457
151-200	55715	0.5575	52.501	199.6608	43	131.3	0.5582
201-300	57874	0.5705	51.801	191.4316	47	142.6	0.5745
301-400	27616	0.5895	52.774	183.7030	42	181.8	0.6023
401-500	15063	0.6045	54.916	180.5217			
501-600	9556	0.6075	54.364	177.7447			
601≤	3904	0.6076	52.964	174.6428			

As NDVI could not be differentiated solely by the biophysical properties (e.g. the amount of growing stock) due to topographic effects(Kim, 1996), the ratio of the greenness and brightness indices from the Tasseled Cap transformation was used to evaluate forest degradation depending on elevation intervals.

Figure 3. illustrates the relationship between the ratio and the forest degradation

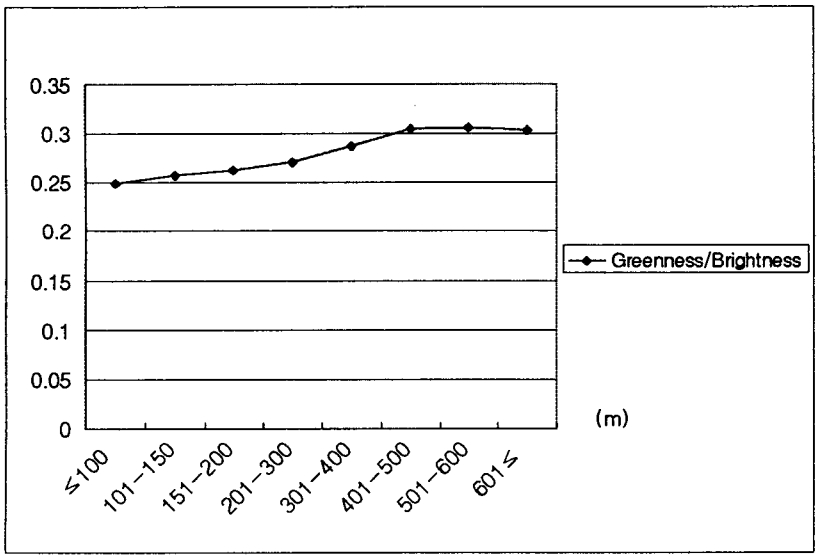

Figure 3. The ratio (Greenness/Brightness indices) associated to the foret degradation depending on elevation intervals

According to evaluating the relationship based on the Kwangnung Experiment Forest data, the values of the ratio increase with increasing of elevation intervals with exception of over 601m.

The analogous linear shape of the ratio values suggests that this ratio parameter is also less sensitive to topographic effects and really is a good non-dimensional variable for estimating forest degradation.

4. CONCLUSIONS

The results extracted from the Landsat TM data combined with the 3 second grid-based DEM provide that the deforestation area, i.e. the transformation of the forested areas into agricultural areas to increase crop production in Changpung & Paekhakdong of North Korea expanded to 300m above sea level during more than 10 year time period of observation.

The ratio of the greenness and brightness indices has been shown to be a reliable parameter for monitoring of a gradual loss of growing stock in the mountain forests.

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