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Desertification Change Analysis Study Using Multi-Temporal Awifs Data: Uttarakhand State

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Abstract:

The ecosystem in arid, semi-arid, dry sub-humid region appears to be undergoing degradation processes generally described as desertification. The Himalayan region in India is most susceptible to the processes of desertification due to its very fragile and sensitive ecosystem. Change detection study on desertification was conducted on 1:0.5 million scale using IRS-IC and Resourcesat-2 multi-temporal data for the years 2003-2005 to 2011-2013. It was found that there was an increase of 1.25 percent in the desertification area in the state during the study period. A significant increase was observed in vegetation degradation i.e. from 10.20 percent to 11.30 percent. The degradation under settlement also increased from 0.19 percent to 0.30 percent during 2003 to 2013, respectively. The results show that highest vegetal degradation was observed in scrub lands i.e. 1.01 percent followed by 0.14 percent in the forest class. It was also observed that area affected by water erosion and frost shattering show no change during the study period.

Keywords: Desertification, Change Analysis, Erosion, frost, Uttarakhand

1.0 Introduction:

The complex phenomenon of desertification is a resulting from factors of physical, biological, socio-economic, political and cultural nature. Desertification is not restricted to the desert areas or to the arid region but relates to land degradation in about two-thirds of the country's geographical area falling within the semi-arid, arid and dry sub-humid regions. Desertification describes circumstances of land degradation in arid, semi-arid and dry sub-humid ecosystems resulting from the climatic and human activities (Elhag, 2006). Monitoring and assessment involve data acquisition through available records ,field surveys and remote sensing (Baartman *et al*., 2007;Vogt *et al*., 2014). Desertification has been defined as land degradation in drylands resulting from various factors including climatic variation and human activities (UNCED, 1992). Similarly, the human activities like unscientific land use, deforestation resulted in climate change and leading to accelerated soil erosion by wind and water leads to deterioration of physical, chemical, biological, economical properties of soil and long-term loss of natural vegetation. Land degradation has a direct impact on land and other natural resources which cause loss of biodiversity and vegetative cover, the decline in groundwater and availability of water in the affected region (United Nation, 1994).

The desertification status mapping using remote sensing has an important role in recent years as it has greatly contributed to the knowledge of the environment and also helps in understanding the economic dynamics of dry lands by exploring the environmental hazards related to desertification. The advent of remote sensing has helped the scientific communities to study the process at various scales and analyse the interaction between various elements of environments in relation to the dynamics of soil, vegetation and human activity. This tool offers excellent possibilities of collecting vital data. This is because the technology has capable of data acquisition at global and regional scales rapidly , with low cost and high accuracy, repetitively and

in digital format (Kachhwala, 1985, Costantini *et al*., 2004. In desertification status mapping, interpretation of satellite data helped to differentiate different degradation processes active in study area essentially required for designing mitigation measure (Arya *et al*., 2014). Similarly geographic information system provides suitable platform for data analysis, update and retrieval in organize formats (Chilar, 2000, Li Cui, 2008). Four broad geographical areas of India's mainland comprises: the Northern Mountains which has the great Himalayas and the vast Indo-Gangetic plains. The Himalayas as the world's biggest and largest mountain range which form an unconquerable physical barrier. The Himalayan valleys also contain the cold arid deserts and fertile valleys. The ecosystem in the Himalayan region appears to be undergoing degradation process commonly called as desertification.

The human population pressure is the most crucial indicator for inducing desertification in India (Ministry of Environment and Forests, 2001). Out of total geographical area (TGA) of India the 32.75 % is affected by various forms and degree of desertification (Ministry of Environment and Forests, 2006 & 2008). The desertification scenario more severe making this due to the adversely changing rainfall pattern and rising trends in temperature.

The present study undertaken to asses desertification using AWiFs data at 1 : 0.5 million scale and geographic information system. The mapping of vegetation degradation, soil erosion and frost shattering with low and high severity types under different land use classes carried out to generate desertification status map of Uttarakhand state using multi temporal data (year 2003-05 and 2011-13) to analyze and for comparing the spatio-temporal change in desertification status in the state.

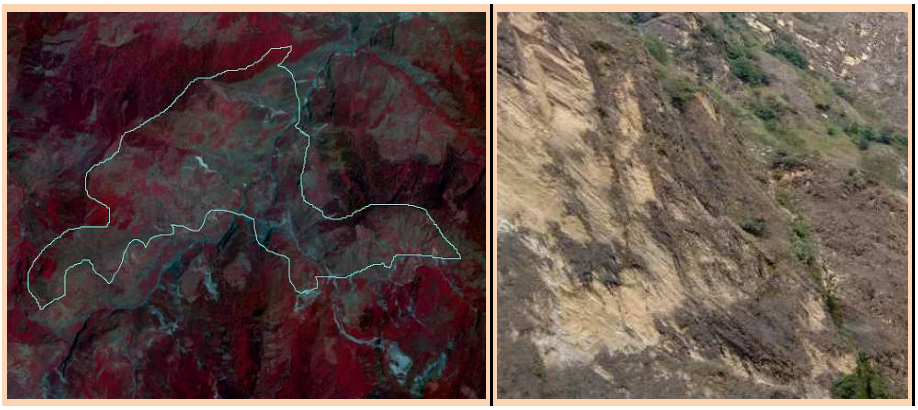

Fig. 1: AWiFS image showing the vegetal degradation as seen in field (Uttarakhand)

Fig. 2 : Frost-shattering in cold desert as seen in the field (Uttarakhand)

2.0 Materials and Methods:

2.1 Description of the Study Area:

The Himalayan state of Uttarakhand is located between 28° 43' - 31° 27' N latitude and 77° 34' - 81° 02' E longitude. It includes 320 km long mountains stretch between the Kali River forming the Indo-Nepal border in the east and the eastern border of Himachal Pradesh in the west forming Tons-Pabar valleys. Geographically area of the state is 53,483 sq. km (93% is mountainous and 64% is covered by Forest). The Uttarakhand is located in the northern part of India bordering with China and Nepal. Most of the northern parts of the state are the part of Greater Himalaya ranges with Nanda Devi (7816 m) as the highest peak, covered by the high Himalayan peaks and glaciers, while the lower foothills were densely forested. Two of the India's powerful rivers, The Gangaes and the Yamuna originates in the glaciers of Uttarakhand, namely Gangotri and Yamunotri respectively(Watershed Management Directorate, 2010). The climate of Uttarakhand is of humid subtropical with cool summer and very cold winter. The northern parts of the state experience heavy snowfall in winter seasons. The state is blessed with a rare and wide range of flora and founa. In all major climatic zones it has production capacity to a variety of commercial agriculture ,floriculture and horticulture production. The State is rich in mineral deposits like copper,dolomite ,gypsum, limestone ,magnesite , marble, rock phosphate etc. The State is also bestowed with a relatively high average annual rainfall of 1229 mm. The temperatures in winter can be very cold going below 5°C. The lowest temperature recorded is -5 to -7°C and highest is between 40 to 45°C (Watershed Management Directorate, 2010).

The State geomorphology is completely defined by the Himalayas, being completely landlocked. The State has a wide range of geomorphic features like rocky slopes ,cliffs, waterfalls, river valleys with uplifted river tarrces, highly dissected denudation mountain, moderate and low dissected denudation mountain, river terraces and various fluvial geomorphic features like, point bar, meandering scars and natural levees. The state is completely affixed by the complex geological setting. A large variety of rocks are developed in this area, the central crystalline complex of the Greater Himalayas and as well as the sub-Himalayas and Lesser Himalayas,. The area is very sensitive towards the mass wasting process. The State has 2 Divisions i.e**.** Kumaun and Garhwal. It has 13 Districts and Dehradun is the capital city. Uttarakhand consists of 13 districts i.e., Almora, Bageshwar, Chamoli , Champawat, Dehradun,Pauri Garhwal, Tehri Garhwal, Haridwar, Nainital, Udham Singh Nagar, Uttarkashi, Pithoragarh and Rudraprayag.

2.2 ***Data and Material Used*****:**

The Indian Remote Sensing Satellite data (IRS-P6) AWiFS was used for the study area. Satellite sensor and acquisition dates of the data used for the analysis are given in Table 1.

Table1: Satellite Data Used

S. No.	**Satellite**	**Sensor**		**Date of acquisition**
1	IRS1C-1D	AWiFS		2003-2005
2	IRS-P6	AWiFS		2011-2013
Satellite Data	**(2011-2013 & 2003-2005)**	**Ancillary**	**Data**	
Season	**Timeframe**	**Layer**	**Source**	
Kharif	September-November	**Forest Boundary**	Forest Survey of India	
Rabi	December- March	**Water body, Rivers**	Natural Resources Data Base	
Summer	April – June	**Road and railway network**	SAC National Wetland Inventory & Assessment	

2.3 *Survey of India Topographical Sheets used:*
Study area is covered by Survey of India toposheets no.53/E,F,G,I,J,K,M,N,O,P and 62/B,C,D on 1:2, 50,000 scale.

2.4 *Software*:
ERDAS IMAGINE 9.3 and ARC/MAP 10.2.

2.5 *Methodology*:
In the present study land use /land cover maps were prepared on 1:2,50,000 scales using Survey of India toposheet to monitor the desertification changes during the year 2003-05 to 2011-13 using IRS-P6 (Resourcesat) geo-coded False Colour Composite (FCC) AWiFS data were analysed by onscreen visual interpretation techniques to generate DSM on 1: 500,000 scale. The National Classification System for desertification status identification and mapping (DSM) as evolved at the Space Application Centre (SAC), Ahmadabad, all the line departments and common for both hot and cold areas of the country was used in the study (Anonymous, 2003) and is given Table 2. Level-1 comprises land use categories; level-2 depicted the process of degradation and level-3 deals with the severity of degradation. An attempt was also made to assess the severity of these processes as low and high. The study was made using remotely sensed spatial-temporal data obtained from geocoded false colour composites of IRS-Resourecsat-2 AWiFS digital data of three different seasons viz. summer, kharif and rabi will be used for mapping at 1:500,000 scale. Codification of classification system is given as Table 3.

The methodology details are described in the Fig. 3. Base maps prepared using the Survey of India topographical maps on 1: 250,000 scale.The satellite images were used while analysing satellite data information. Base features like drainage, habitation, rail and road were taken from satellite imagery, whereas forest boundaries were taken from Forest Survey of India for preparing base maps. Ground truth data collected from various places well spread throughout the state to assess the spatial distribution of vegetation cover and other land degradation processes were checked with respect to the captured satellite data in the field and the accuracy of the of the field check was evaluated by visual interpretation used to finalize the maps. This system considers the land use at the highest level as a result of the recognition of the fact that land utilization has a greater role to play in the desertification process as it enforces a shift from the delicate, naturally established equilibrium to the man-made one. An initial field traverse was made of the state to identify the land use categories and significant degradation processes vis-à-vis the general mapping legend. In each land use type, the land degradation is classified according to the degradation processes that are basically climatic and land processes. The vegetation, though depending on land and climate, show degradation processes that are mostly depend on human use. The degradation processes are considered at the second level and their severity at the third level of mapping.

Table 2: Classification Scheme

LEVEL	Class	Symbol /code
LEVEL 1: *Land use/land cover*	Unirrigated agriculture	D
	Forest/Plantation	F
	Land with scrub	S
	Periglacial	L
	Settlement	S
	Water body/Drainage	W
LEVEL 2: *Processes of Degradation*	Vegetal degradation	V
	Water erosion	w
	Frost shattering	f
LEVEL 3: *Severity of Degradation*	Low	1
	High	2

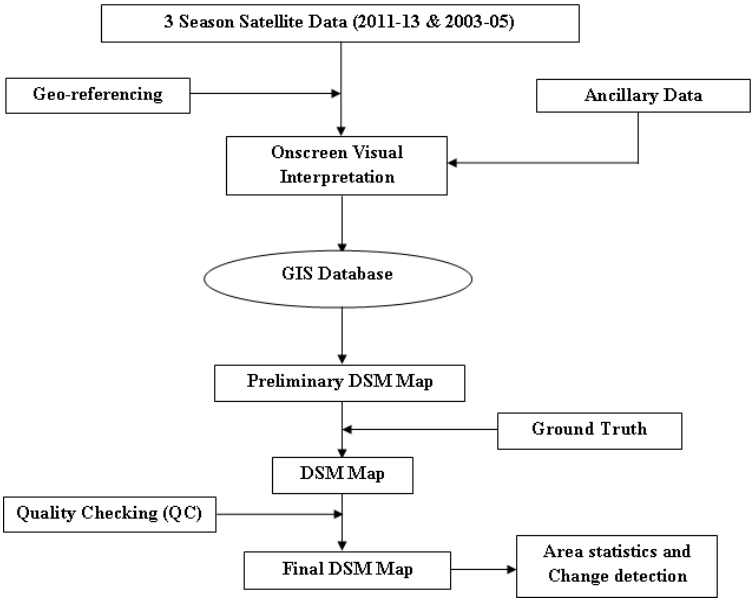

Fig. 3: Details of the methodology

3.0 Results and Discussion:

On 1:5, 00,000 scale the desertification change status maps were prepared for the years 2003-05 and 2011-13, according to the legend suggested by the National Classification System the image interpretation and ground truth are done in the area under investigation. Study area has the total geographical area is 5048.30 sq.km. Different processes of land desertification appear particularly on satellite imagery as an example the satellite image showing desertification process such as vegetation degradation, water erosion, frost shattering land with scrub and water erosion. The results study for desertification status mapping are presented in Table 4 and Fig. 4 show desertification status on observed in agricultural lands (unirrigated), forest, scrublands and Periglacial. The different forms of degradation from vegetation loss, water erosion, settlements and frost shattering under different land use/land cover were observed. During the period 2003-05 to 2011-13, total area is 4738.94 sq. km reported under No apparent degradation (NAD) category was decreased to 4667.75 sq.km. Major losses in vegetation were noted in the state. These changes can be ascribed to effect of climate change and human impact in combination.

The largest category is vegetation degradation with low severity in scrublands (Sv1), in the year 2003-2005, the area under this category was 7.34 percent of TGA and in the 2011-2013, it increased to 8.08 percent of TGA of the state. Similarly under forest, with low vegetation degradation (Fv1) increased from 2.59 percent in the 1st cycle to 2.79 percent in 2011-2013. Whereas under land with scrub, high severity vegetation degradation (Sv2) increased from 0.27 percent to 0.54 percent of TGA in 2011-2013 .

In respect of desertification in settlement (S) was increased from 0.19 percent to 0.30 percent of TGA of state in 2nd cycle. However, the desertification status under agriculture (unirrigated), low severity water erosion (Dw1), periglacial, high severity frost shattering (Lf2) which was found to be 0.22 percent and 0.26 percent respectively, remained constant during 1st and 2003-05 to 2011-13. The results of the study are given in table 3.

Table 3 : The distribution of area in various desertification classes and severity under different land use during 2003-05 and 2011-13

SrNo	Classification	Desertification/ Land Degradation Classes	2011-13		2003-05		Change (ha)
	Code	Description (Land cover, Process, Severity)	Area (ha)	%	Area (ha)	%	(2011-13)-(2003-05)
1	Fv1	Forest, vegetation degradation, Low	145902.79	2.73	138612.53	2.59	7290.26
2	Sv1	Land with Scrub, vegetation degradation, Low	432038.22	8.08	392529.83	7.34	39508.39
3	Sv2	Land with Scrub, vegetation degradation, High	28675.41	0.54	14467.28	0.27	14208.13
4	Dw1	Agriculture Unirrigated, water erosion, Low	11942.59	0.22	11942.59	0.22	0.00
5	Lf2	Periglacial, frost shattering, High	13785.97	0.26	13785.97	0.26	0.00
6	S	Settlement	15907.60	0.30	9903.27	0.19	6004.33
		Total area under Desertification/ Land Degradation	**648252.58**	**12.12**	**581241.48**	**10.87**	**67011.10**
7	W	Water body/ Drainage	32297.04	0.60	28122.83	0.53	4174.21
8	NAD	No Apparent Degradation	4667750.37	87.28	4738935.69	88.61	-71185.31
		Total Geographic Area (ha)	**5348300.00**	**100.00**	**5348300.00**	**100.00**	

The spatial distribution of land degradation under different land use/land cover classes for the Uttarakhand State (2003-2005 & 2011-13) are depicted in Fig. 4 The legends including the symbols and colour notation prepared for land use and land degradation process are also given in Fig. 4 and area distribution under land degradation in state is given in Table 3. The study also shows status of land-usewise severity under varoius processes of land degradation, the most of the desertification taking place in lower Himalayan region (<1500 meters above MSL) mapped under vegetal degradation due to large scale deforestation/grazing of lands and this also resulted in an increase of area by about 1.25 percent of TGA under all degradation processes since 2003-2005.

3.1 *Spatial Change Analysis*:

The change detection technique was adopted to map and analyze the spatial location, extent, and direction of change in the context of desertification processes. The results of the change detection method shows that most significant process of Desertification / land degradation in the state was found to be vegetation degradation (11.34% in 2011-13 and 10.20% in 2003-05) which shows an increase of 1.14 % during the study period between 1st and 2nd mapping cycle, followed by under settlements which show 0.19% area in 2003-2005 were increased to 0.30% in the year 2011-2013 shows an increase of 0.11 % during the period, similar findings were reported by Amin et al. (2012), Rawat *et al., 2014* who found that built up area has sharply increased due to construction of new buildings in agricultural and vegetation lands in the state.whereas area affected due to frost shattering

and water erosion did not show any increase or decrease during the period.

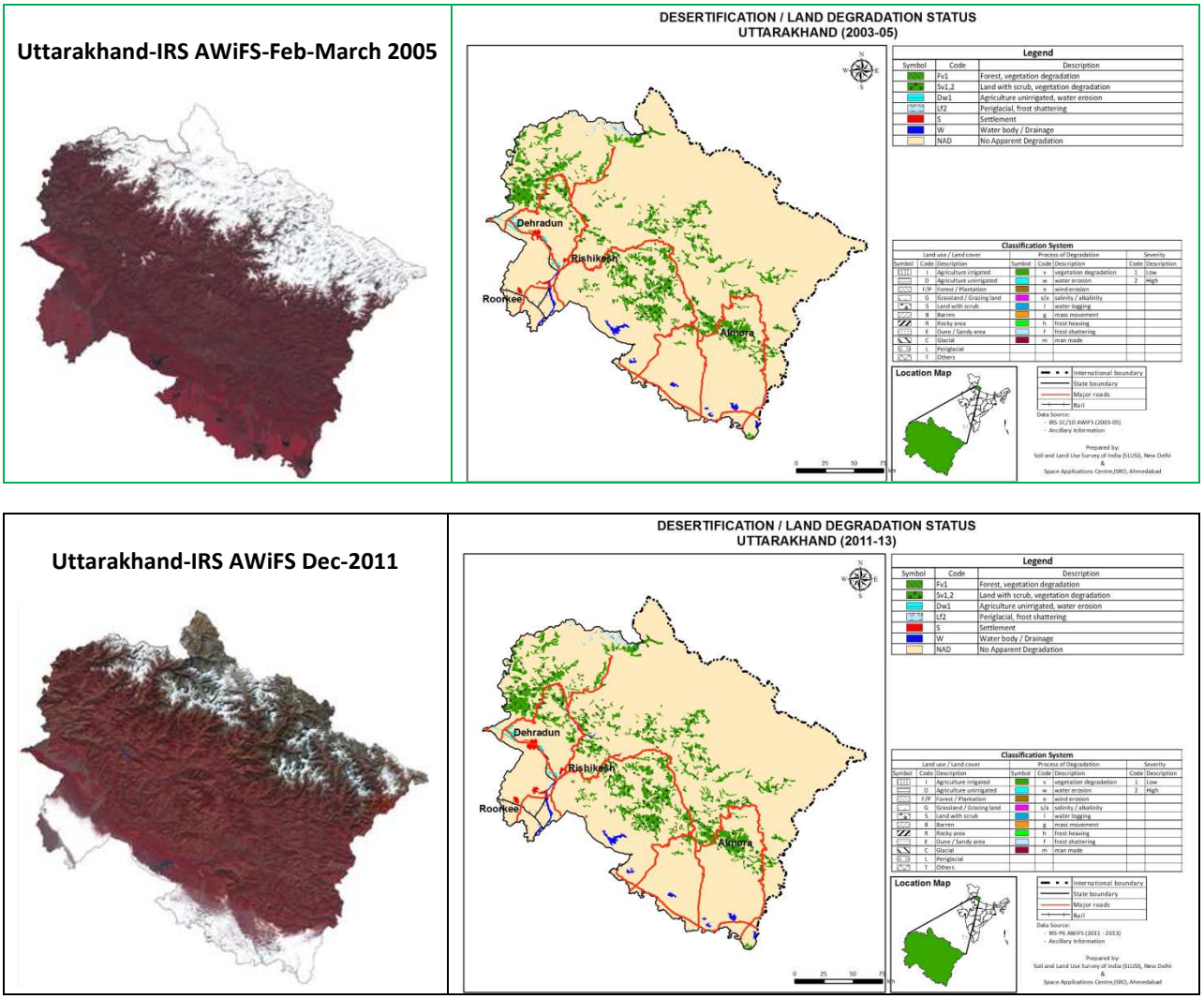

Fig 4 : The Desertification status map of Uttarakhand state during 2003-2005and 2011-2013

Table 4 : The desertification change status under different degradation process during 2003-05 to 2011-13

Process of Desertification/Land Degradation	2011-13 (2nd cycle)		2003-05 (1st cycle)		Change Area(ha)
	Area (ha)	%	Area (ha)	%	(2011-13)-(2003-05)
Vegetation Degradation	606616.42	11.34	545609.65	10.20	61006.78
Water Erosion	11942.59	0.22	11942.59	0.22	0.00
Frost Shattering	13785.97	0.26	13785.97	0.26	0.00
Settlement	15907.60	0.30	9903.27	0.19	6004.33
Total Area Under Desertification	**648252.58**	**12.12**	**581241.48**	**10.87**	**67011.10**
No Apparent Degradation	4667750.37	87.28	4738935.69	88.61	-71185.31

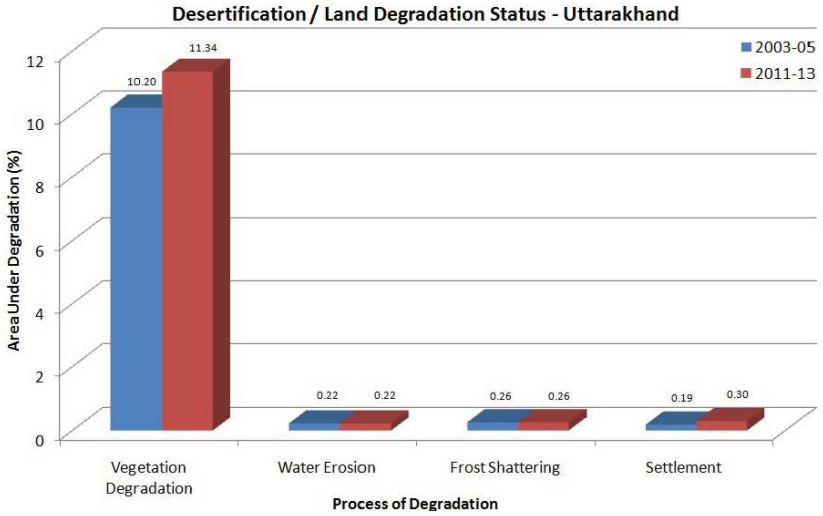

Fig. 5 : Process-wise change status under degradation during 2003-05 to 2011-13 under desertification status mapping in Uttarakhand

The severity wise degradation of high severity vegetation degradation was observed in around 0.54 percent TGA of state under the open scrubland use in 2011-2013which has increased from 0.27 percent in 2003-05. The increase in area under high severity was found to be 0.27 percent during the period. The results indicate desertification is apparent and show the increasing trend in the 2nd cycle as compares to 1st cycle in vegetation degradation. The results od spatial change analysis are presented in Table 4 and the spatial distribution of changes from the (2003-05) and (2011-13) illustrated in graphics in Fig. 5.

4.0 Conclusions:

The objective of this paper study is to address the issue of ecological change, locating and identifying the land degradation processes and to monitor the spatial-temporal changes in desertification status through spatial change analysis on multi time frame AWiFS data ,which influence the characteristic elements of the environment, human exercises and settlements shows that the area of desertified land has increased during the study period and the increase is profound. In areas of the Lower Himalayan region (<1500 mts) of the state shows drastic changes in vegetation cover which are found mostly in the middle of the study area whereas the vegetation around the upper Himalayan region and Siwalik range is comparatively more stable. These changes were due to land use changes, over-grazing, an increase in crop area and an increase in deforestation for fuel, furniture, and general household demands. This serves as a useful tool to guide policy makers identify urgent areas to intervene in land management.

5.0 Acknowledgment:

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