Asian Journal of Environment and Disaster Management
Vol. 6, No. 1 (2014) 83–93

doi:10.3850/S1793924014001424

Implications of Rapid Land Use/Land Cover Changes upon the Environment of the Area Around Nainital in Uttarakhand, India

Piyoosh Rautela[a], Sushil Khanduri[b], Bhupendra Bhaisora[c], K. N. Pande[d], Suman Ghildiyal[e], Chanderkala[f], Sunil Badoni[g] and Ashish Rawat[h]

Disaster Mitigation and Management Centre, Department of Disaster Management, Government of Uttarakhand, Uttrakhand Secretariat, Rajpur Road, Dehradun – 248 001, Uttarakhand, India.
E-mail: [a]piyooshrautela@gmail.com, [b]Sushil.khanduri@gmail.com, [c]bhupendra_b1@rediffmail.com, [d]knpande@rediffmail.com, [e]suman.ghildiyal.7@gmail.com, [f]chanderkala.sweet.18@gmail.com, [g]sunilbadonidmmc@gmail.com, [h]ashishrawat_27ddun@gmail.com

Unplanned anthropogenic intervention in the area around the lake city of Nainital in Uttarakhand is observed to have adverse impact upon the environmental stability. Effects of this are clearly visible in the land use/land cover change that the area has undergone in the previous six years alone. Vegetation cover around the lake is observed to be dwindling and most of these changes are driven largely by infrastructure development to sustain the growth of tourism and these have not even spared the recharge zone of the lake. The changes introduced by the anthropogenic intervention have already started to have adverse impact upon the recharge of the lake and pose the threat of mass movement in many areas.

1. Introduction

Nainital is a famous tourist destination of Uttarakhand Himalaya in India located in Lesser Himalaya in close proximity of Main Boundary Thrust that is a northeast dipping regional tectonic boundary bringing the Lesser Himalayan rocks in juxtaposition with the sedimentary sequence of the Siwaliks [1, 2]. The area around Nainital has rugged topography and high relative relief. The vegetation around Nainital comprises of mostly conifers and oak. Present population of Nainital is 41,461 [3].

Habitation in Nainital started towards the end of the first half of the nineteenth century and since then the town has been repeatedly affected by slope instability. Major landslides around the town occurred in 1867, 1880, 1893, 1898, 1924, 1989 and 1998 [4, 5, 6, 7]. Landslides of 1880 and 1898 look toll of 151 and 28 human lives respectively [8].

Studies carried out on the aftermath of cited lack of surface drainage and unplanned anthropogenic intervention as the reasons for slope the instability [9]. Detailed network of surface drains was thus put in place and human intervention

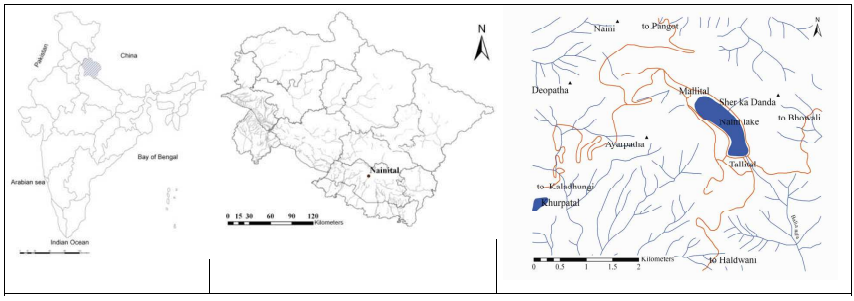

Figure 1 Location map of the area. In the left location of the State of Uttarakhand is shown while the figure in the middle shows the drainage network and district boundaries together with the location of Nainital while that on the right shows the area around Naini lake.

in many vulnerable slopes were banned. The Bye Law of 1930 laid down provisions for regulating anthropogenic activities in three areas around the lake (Sher ka Danda, Ayarpatha and beyond the lake basin system) that were classified as being Prohibited areas.

In the recent past the issue of environmental instability around Nainital has been raised by various civil society groups as well. The apex court of the country (Supreme Court of India) in Ajay Singh Rawat v/s Union of India has also advised against undertaking construction on the vulnerable slopes around the lake.

In the present study geomorphic setup of the area around the Naini lake has been studied (Figure. 1) together with the land use/land cover changes. The nature of anthropogenic pressure upon the environment has also been investigated and attempt has been made to correlate the same with the observed physical parameters.

2. Geomorphic Set Up

The area around Nainital is observed to be dissected by several ridges and the ground elevations vary between 1694 to 2611.5 meters above mean sea level (msl). Naini peak with height of 2611.5 meters above msl is the highest point of the area while Sher ka Danda, Deopatha and Ayarpatha respectively measure 2402, 2435.1 and 2352 meters above msl. Naini lake has elevation of 1935.5 meters above msl. The area is prone to landslides due to high relief, presence of overburden and high precipitation.

Digital elevation model (DEM) and slope map of the area have been prepared using the Survey of India (SOI) toposheet. The surface slope in the area; particularly in the catchment of Naini lake is observed to be gentle to moderately steep. Large areas with gentle slope occur along the northwestern and southeastern extremities of the lake. Small areas running almost parallel to both eastern and western portions of the Naini lake however show steep slope. The hill slopes in the

area around the Naini lake are generally observed to comprise of rocky outcrops, rocky cliffs and mantle of colluviums. The geomorphic processes operative in the area include laminar flow, freezing and thawing, mass wasting and solution action. Southwesterly aspect is observed to dominate the area around the Naini lake.

Fed by the discharge of the Naini lake, Balia nala is the major stream of the area. Balia nala, as also some of its tributaries have carved out more or less linear valleys that are indicative of distinct structural control. The tributary valleys are observed to be deep, narrow and steep with high channel gradient. These streams are observed to undergo rapid down cutting and have rocky channel with channel material comprising mostly of debris and fine sediments. The catchment of the Naini lake is however devoid of any significant surface drainage line. The catastrophe of 1880 asserted the importance of having a drainage system in the town for safe disposal of the excess precipitation. In the course of time a number of surface drains were planned and put in place on both eastern and western hill slopes around the lake so as to dispose the rainwater into the lake.

The area around Nainital, particularly to the south and west of the Naini lake comprises largely of calcareous rocks. Action of subterranean water has carved out cavities and caves in this terrain. Preponderance of faults and shears in the area has accelerated this process. Existence of a number of sink holes of diverse sizes is thus a distinctive feature of this area. Prominent sink holes are observed at Sukhatal, Sleepy Hollow, Ayarpatha, Narayan Nagar and Golf Course. The former three play a major role in the recharge of the Naini lake and water from these sink holes used to replenish the lake after the withdrawal of SW monsoon.

A number of active landslides are observed in the area around Nainital in Golf Course, Lands End, Naina peak, Ayarpatta, Harinagar - Baliya Nala section, Krishnapur and Hanumangarhi areas. The condition of the landslides in Golf Course and Harinagar - Baliya Nala section is observed to be critical and in both these areas impressions of ongoing sliding are clearly observed. In the Golf Course area a series of wide open (with opening up to 35 cm) NW – SE trending transverse cracks with down throw as large as 2 meters are observed. Crown cracks are also observed in the area. Seepage of water is observed in the landslide scar at lower elevations and displacement of fines from the sediments due to piping action of water seeping in from Sherwood – Golf Course area is perceived to be the main cause of accelerated pace of mass movement in this area.

The rocks in the area are highly weathered and have low cohesive strength. Creation of subsurface cavities due to the action of water and eventual collapse of the overlying rocks together with the dilation of the pre-existing fractures due to diurnal temperature fluctuations (heating and thawing) have carved out wide open joints and fractures in the overlying slumped rock mass. At many places this rock mass is observed to be in critical state of equilibrium and even a slight disturbance can trigger massive rock fall. The situation could well be serious in case of violent earthquake shaking. Areas susceptible to rock fall include

southwestern portion of the Naini lake near Pashan Devi, Slopes below All Saints – Geology Department and Narayan Nagar – Barah Pathar. Some significant old slide zones are also observed on the hill slope along the eastern extremity of the Naini lake.

Many incidences of creep were recorded during the course of fieldwork in Nainital, particularly in the slopes to the east of the lake. These are observed to be reflected in the tilting / bending of trees, bulging of the retaining walls and cracks in the structures.

3. Land Use/Land Cover

Land use/land cover characteristics and changes therein reflect the influence of a number of internal and external factors that shape and decide the distribution of various parameters in space and time. As commonly understood it is not always the anthropogenic pressure that shapes the land use/land cover characteristics of an area. Geomorphic processes together with climatic variability also have a major role to play in this.

Satellite data is universally accepted as being a powerful tool for delineating land use/land cover characteristics of an area in a cost effective manner. In the present study multispectral 8 band WorldView-2 satellite imagery (50 cm resolution) of December 2010 and QuickBird PAN satellite imagery (60 cm resolution) of January 2005 have been used for delineating the land use/land cover features around Nainital in Uttarakhand state of India as also the changes therein in the previous six years.

The following seven land use/land cover classes have been delineated for the area around Nainital after detailed study of the satellite data along with limited ground truth collection:

(1) Dense forest
(2) Open forest
(3) Trees out of forest
(4) Water bodies
(5) Open area
(6) Agriculture
(7) Urban/built up area

The present land use/land cover map of the area around Nainital shows that most area around the lake has appreciable vegetal cover significant portion of which is observed to fall under dense forest class. The built up area around the Naini lake is observed to be restricted to the northern and southern fringes of the lake as also in the vicinity of the Mall road that runs along the eastern fringe of the lake.

Table 1 Variation of land use/land cover with surface slope in the area around Nainital.

	Area (in percent)				
	Gentle (0 – 15°)	Moderate (15 – 25°)	Moderately steep (25 – 35°)	Steep (35 – 50°)	Escarpment (> 50°)
Dense forest	21.08	25.38	32.46	20.29	0.78
Open forest	10.47	24.24	37.58	25.22	2.48
Trees out of forest	29.75	34.50	25.44	10.31	0.00
Built up area	45.34	29.12	18.57	6.95	0.02
Open area	54.48	21.98	11.28	11.90	0.36
Agriculture	47.74	35.84	10.16	6.26	0.00

Table 2 Variation of land use/land cover with slope aspect in the area around Nainital.

	Area (in percent)							
	N	NE	E	SE	S	SW	W	NW
Dense forest	11.43	13.36	13.42	13.50	14.44	18.00	9.17	6.68
Open forest	0.32	0.99	11.32	20.88	28.59	24.09	12.49	1.32
Trees out of forest	1.03	8.83	12.59	12.21	18.18	33.24	13.55	0.37
Built up area	4.00	9.59	18.97	16.63	19.42	20.72	9.73	0.95
Open area	7.37	7.33	19.24	28.42	10.86	13.48	10.03	3.28
Agriculture	0.11	0.34	8.05	15.60	25.90	35.99	12.41	1.61

Correlation of the land use/land cover characteristics of the area around Nainital with various slope classes shows that the moderately steep slope class $(25 - 35°)$ has maximum vegetation cover and the built up area shows a diminishing trend with increasing slope characteristics (Table 1). This leads to the corollary that gentles slopes being preferred by humans for habitation are bereft of significant vegetal cover.

The correlation of the land use/land cover characteristics of the area around Nainital with the slope aspect shows that the southerly slope aspects (SW, S and SE) have the maximum vegetation cover and these are also the slope aspects preferred for construction (Table 2). Northwesterly and northerly slope aspects have minimal vegetation cover as also constructed area.

Land use/land cover map of 2010 has been correlated with the one prepared for the year 2005 from QuickBird PAN satellite imagery (Figure. 2). It is important to

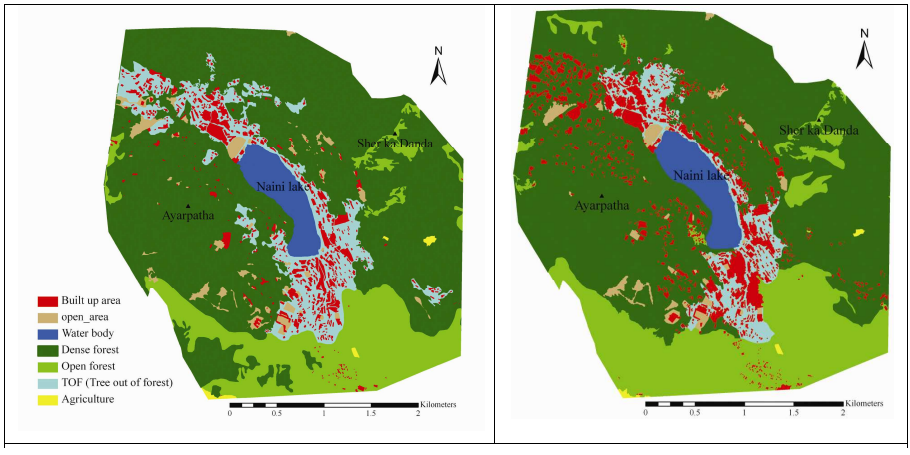

Figure 2 Map depicting land use/land cover characteristics around Nainital in 2005 (left) and in 2010 (right).

note that the land use/land cover change related details have been delineated from satellite imageries of comparable resolutions and these are expected to present fair idea of the changes that have come in the previous six years.

Correlation of the land use/land cover maps for 2005 and 2010 show that the forest area around the lake is shrinking at the cost of built up area that has increased by more than 2,13,609 square meters in the previous six years (Table 3). It

Table 3 Statistical details of the changing land use/land cover characteristics of the area around Nainital.

Land use / Land cover class	Area (in square meters)			
	QuickBird (5th January, 2005)	WV 2 (24th December, 2010)	Change in area (WV2 - QB)	Percent change
Built up area	6,30,498.18	8,44,108.12	2,13,609.94	33.88
Open area	3,45,878.41	2,08,344.41	-1,37,534.00	-39.76
Trees out of forest	12,42,649.75	6,99,390.98	-5,43,258.77	-43.72
Open Forest	21,43,476.85	26,61,936.97	5,18,460.12	24.19
Dense Forest	77,89,118.89	77,46,524.83	-42,594.06	-0.55
Agriculture	34,849.72	24,333.99	-10,515.74	-30.17
Water bodies	4,41,331.48	4,43,164.00	1,832.52	0.42
Total	1,26,27,803.29	1,26,27,803.29	-	-

can thus be concluded that on an average 42,722 square meters of area under other land use classes is being encroached upon by various anthropogenic interventions every year.

The data indicates that large tracts of hitherto open areas and agricultural lands around Naini lake have vanished in the previous six years and the annual rate of shrinkage of open areas alone is around 27,507 square meters. The dense forest around Naini lake is also shrinking at an average rate of 7,089 square meters per year while 42,722 square meters of built up area is being added annually.

Municipal Ward wise changes in land use/land cover were also studied. It is observed that all the wards have appreciable vegetal cover but the same is observed to be dwindling except in Ward numbers 4, 5 and 7. Some Wards however show increase in the area under dense forest cover which is an encouraging sign. Ward numbers 1 and 3 show the fastest pace of depletion of forest cover while Ward numbers 4, 5 and 7 have recorded increase in vegetal cover in the period 2005 – 10. Despite reduced vegetation cover it is encouraging to note that all the Municipal Wards except Ward numbers 1, 3, 5, 9 and 12 show increase in the area under dense forest cover. Built up area in all the Wards has however undergone a positive change and Ward numbers 10 and 3 have registered the maximum growth.

4. Anthropogenic and Other Forcing Factors

Land use/land cover change data of the previous six years shows decreasing vegetation cover trend in the area around Nainital. Dwindling forest cover and denudation of dense forest at a fast pace suggests onset of ecological imbalance.

Figure 3 Disposal of excavated debris along the hill slope in Nainital. Obliteration of surface drains by site development works for construction.

Figure 4 Disposal of excavated debris along the hill slope in Nainital. Obliteration of surface drains by site development works for construction.

The Bye Law of 1930 laid down provisions for regulating anthropogenic activities in three areas around the lake (Sher ka Danda, Ayarpatha and beyond the lake basin system). Land use/land cover changes in these three areas therefore deserve special attention. The study brings forth the fact that the built up area has significantly increased in all the three areas identified as being Prohibited areas by the Bye Law of 1930. In the previous six years the built up area in these areas has increased by almost 50 percent that is well above the average built up area increase of 34 percent. The growth of built up area has been particularly high in

Table 4 Data depicting changes in the built up area in the three areas classified as Prohibited Areas in the Bye Law of 1930.

Prohibited areas according to Bye Law of 1930	Area in square meters			Percent change
	QuickBird (5^{th} January, 2005)	WV 2 (24^{th} December, 2010)	Change in area (WV2 - QB)	
Sher ka Danda (1)	62203.4	97359.3	35155.9	56.5
Ayarpatha (2)	31797.5	48853.3	17055.8	53.6
Beyond the lake basin (3)	57155.2	82266.3	25111.1	43.9
Total	151156.1	228478.9	77322.7	51.2

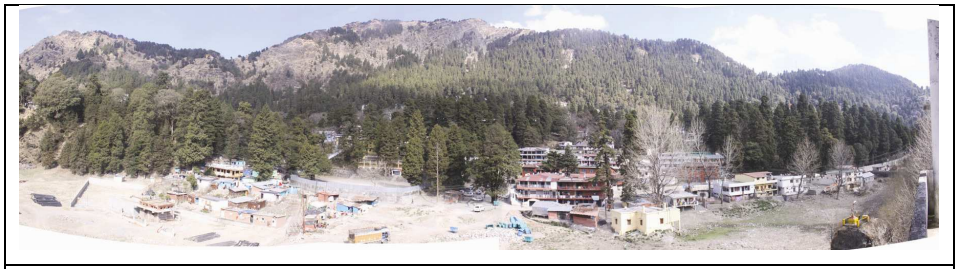

Figure 5 Disposal of excavated debris along the hill slope in Nainital.

Sher ka Danda Prohibited area where it has increased by more than 56 percent (Table 4).

As is expected from the expansion of the built up area, the tree cover in all three Prohibited areas has dwindled in the previous five years. The Prohibited area of Sher ka Danda has witnessed the maximum loss of vegetal cover (10.5 percent) and it is important to note that this area has witnessed up to 24 percent decrease in the dense forest class area.

It was observed during the field work in the area that steep slopes in many areas are presently being leveled for various construction related initiatives and excavated debris is being disposed off along the hill slopes as also along the surface drains (Figure. 3). At a number of places in the town the drainage network is observed to be encroached, blocked and obliterated (Figure. 4). Anthropogenic activities in the township have not spared even the recharge zones of the lake (Figure. 5) and these are sure to have irreversible adverse impact upon the very existence of the Naini lake.

The area around Nainital has not witnessed any major seismic activity for a long time but the township falls in Zone IV of Seismic Zoning Map of India [10] and probability of the area being jolted by a major earthquake cannot be ruled out. It was observed during the fieldwork that constructions around Nainital are not complying with seismic safety provisions and adequate attention is not being paid even for siting the house over a firm foundation.

5. Discussion and Conclusion

Hydrological characteristics of any area play an important role in deciding its ecological health but the state of surface drainage in Nainital was observed to be in highly neglected state. It is observed to be the main reason for a number of other problems that the town faces.

Surface drains were designed and developed in Nainital for safe disposal of the atmospheric precipitation. Obliteration and blockade of the surface drains as has been observed during the course of fieldwork is sure to interfere with the pore

Table 5 Level of the Naini lake on 15th March between 2003 and 2011.

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011
Lake level (in feet)	9.26	6.45	7.77	6.40	6.85	7.00	6.20	5.52	3.95

water pressure regime that might trigger mass movement along the vulnerable slopes around the lake. Slopes to the east of the lake show evidences of creep movement and enhanced pore water pressure might result in major devastation.

Moreover the entire economy of Nainital revolves round the lake and sustaining the recharge during the lean rainfall and high water demand period is a major challenge. During the course of fieldwork anthropogenic encroachments were observed in the recharge zone of the Naini lake in Sukhatal and Ayarpatha areas. It is important to note that the clay and silt layer deposited and consolidated at the bottom of the depressions and sink holes formed in the limestone country around Nainital facilitate delayed and slow discharge from these reserves and ensures steady recharge of the lake during the lean period. Any disturbance of this layer is sure to be detrimental to their storage capacity and would lead to depletion in the recharge of the Naini lake.

Analysis of the land use/land cover change data for the area around Nainital brings out the fact that the built up area is expanding largely at the cost of trees out of forest class that accounts for almost 85 percent of the increase in the built up area. Only 11 percent of the hitherto open areas have been converted into built up area in the previous six years. It also brings forth important fact that large tracts of hitherto dense forest are being denuded and being converted to open forest. This is a cause of grave concern.

Observed changes in the land use/land cover of the area around Nainital together with anthropogenic intervention in the recharge zone of the lake is reflected in depleted replenishment of the lake during the lean rainfall period. This is testified by the record of the lake level during the previous some years (Table 5). It may be noted that despite abnormally high precipitation during the monsoon season of 2010 the lake has been depleted to the level of 3.95 meters as on 15th March, 2011.

Every care therefore needs to be taken to ensure that the recharge zone of the lake in Nainital be kept free of anthropogenic intervention. At the same time it is required that a debris disposal policy be formulated and sites for safe disposal of the debris be identified and the same not be allowed to be disposed off irresponsibly. At the same time adequate arrangements are required to be made for proper maintenance of the surface drains and their blockade and obliteration not be allowed. Vegetation cover as also the open areas play an important role in stabilizing the hydrological regime of an area and therefore these should necessarily be kept free of anthropogenic intervention of any kind.

The geo – environment of the area around Nainital is clear witness to the conflict of commercial interests and environmental conservation. Nainital faces the challenge of catering to the needs of the fast growing tourist traffic and satisfying economic interests of the people. It is therefore urgently required that all developmental initiatives be objectively weighed in the light of their long term geo- environmental consequences.

Acknowledgements

Authors are thankful to Shri Bhaskaranand, Additional Secretary, Disaster Management, Government of Uttarakhand for guidance, support and encouragement. Special thanks are owed to Shri J. Radhakrishnan, Shri G. Padmanabhan, Ms Abha Mishra, Ms Ranjini Mukarjee and Shri Ashok Malhotra of UNDP, India for facilitating the study. Partial financial support from Disaster Risk Reduction (DRR) Programme of the Government of India and United Nations Development Programme (UNDP), India is acknowledged.

References

1. Valdiya, K. S., Geology of Kumaun Lesser Himalaya, 291 (Wadia Instituite of Himalayan Geology, Dehradun, India, 1980.)
2. Valdiya, K. S., Geology and natural environment of Nainital hills, 160 (Kumaun Himalaya, Gyanodaya Prakashan, Nainital, India, 1988).
3. Census of India, 2001, Population profiles (India, States and Union Territories), 2004, Office of the Registrar General, India, New Delhi.
4. Oldham, R. D., Note on the Nainital landslip, Records of the Geological Survey of India, **13**(4), (Geological Survey of India, Calcutta, 1880).
5. Atkinson, E. T., The Himalayan districts of the North West Province of India (forming volume XII of the Gazetteer NWP, Allahabad), Reprint 1996, The Himalayan Gazetteer, (Natraj Publishers, Dehradun, India, 1886).
6. Middlemiss, C. S., Report on Kailakhan landslip near Nainital of 17th August, 1898, (Government Press, Calcutta, 1898).
7. Auden, J. B. Geological report on the hill side of Nainital, (Geological Survey of India, unpublished report, 1942).
8. Clay, J. M., Nainital: A historical and descriptive account, 122 (Government Press, United Provinces, Allahabad, 1928).
9. Coulson, A. L., Report on the safety of certain areas in Nainital, (Government Branch Press, Lucknow, 1939).
10. Indian Standard (IS):1893, Part 1, 2002, Criteria for earthquake resistant design of structures, Bureau of Indian Standards, New Delhi.