NATURALISTACAMPANO
ISSN:1827-7160
Volume 28 Issue 1, 2024

Assessment of Forest Canopy Density in the Siwaliks of Panchkula District, India

Sandeep Gupta[1*], Anuradha[2], Shant Kumar[3]

[1,2,3]Institute of Environmental Studies, Kurukshetra University Kurukshetra.

Email: [2]annu.evs0@gmail.com, [3]shantthakur45@gmail.com
[*]Corresponding Email: [1]drsandeep.gupta@kuk.ac.in

Abstract: This work analyzes the current status of forest canopy density (FCD) in the Siwalik region of the Panchkula district, North-Western part of India. The study area includes the lower and upper part of the Siwalik region of India and is around 34.93% of the total geographical region of the district. This study uses the recent satellite data from Operational Land Imager (OLI) and Thermal IR sensors (TIRS-2) of Landsat 9 acquired on 15 December 2022 and algorithm from Rikimaru's FCD model to estimate the canopy density. The result shows that 89% of the Siwalik forest of the district is covered with canopy of different density categories. The FCD classification further indicate: i) 3.07% of the forest is covered with moderately dense canopy of density 10-40%, ii) 82.28% area is dense forest with canopy density 40-70% and iii) 3.7% area is very dense forest covered with canopy of density more than 70%. The ground truthing shows that the study area is rich in Pine, Tendu, Shisham and other important tree species of commercial and medicinal importance. The result indicates that the emphasis is to be given in increasing forest biodiversity and in afforestation activities.

Keywords: Remote Sensing, Landsat 9, FCD Model, Forest Cover, Human Interventions.

1. Introduction

Siwalikregion is relatively fragile mountain region having bouldery soil frequently dissected by overland flow from hills through networks of small streams, choes, gullies etc. and is sandwiched between Himalayan ecosystem and Indo-Gangetic plains in north-western India (Yadav et al. 2015). The Siwalik is considered synonymous to lower or outer Himalayas and extends in the States of Uttarakhand, Haryana, Himachal Pradesh, Punjab and Jammu & Kashmir in north-western India (Panwar et al. 2012). In Haryana, the Siwalik passes through its Yamunanagar, Ambala and Panchkula districts (Yadav et al. 2015).
Forest cover is one of the essential resources for regulating the terrestrial ecosystem. The anthropogenic activities leading to forest degradation, deforestation and removal of indigenous tree species with commercial ones (Haddad et al. 2015). Haryana is among the Indian State/UT where it has the second lowest fraction (3.63%), after Ladakh, of recorded covered forest area (1603 sq. Km.) to its total geographical area (44212 sq. Km.) (ISFR 2021). According to Champion and Seth (1968) classification of India’s forests, the forests of Panchkula district are occupied with lower or Siwalik Chir Pine forests, dry mixed deciduous forests with patches of dry bamboo brakes. Most of the dense forest of Haryana is located on its northern territory in the upper Siwalik range in the Panchkula and Yamunanagar district. However, ground survey shows that anthropogenic activities such as residential and industrial development is constantly encroaching the outer periphery forest land apart from the illegal logging (Anuradha and Gupta 2022).
The canopy cover density is one of the indicators that reflects forest growth (Rikimaru 1996). The canopy density of forest cover is uninterruptedly declining both due to natural as well as anthropogenic activities (Bandyopadhyay et al. 2017). Therefore, canopy density is one of the tools for forest planners to design an effective plantation plan that can yield a valid growth of trees and its density. In the development and accomplishment of forest analysis programs FCD is an important parameter (Rikimaru et al. 1999, 2002; Roy 1999). The satellite image-based approach is considered as the most efficient, scientifically proven and cost-effective method to quantify crown canopy of forests (Rikimaru 1996, Falensky et al. 2020). The repetitive coverage of satellite remote sensing with various spatio-temporal scales is an added advantage that offers the cost-effective means of assessing the environmental parameters and impact of the developmental processes (Adjovu 2023). The FCD model computes the values of several indices from the moderate resolution multi-spectral satellite images (Rikimaru et al. l999, Azizia et al. 2008, Falensky et al. 2020, Medhe and Badhe 2023). Thus, quantification of FCD is adopted in many studies for monitoring and assessing forest health (Biradar et al.

2005; Mon et al. 2012). In literature we do not find any study that has assessed the FCD in the Siwaliks of the study area by incorporating a semi-expert model. Therefore, distribution of forest areas having different canopy densities was studied in the Siwaliks of Panchkula district of north-western part of India incorporating FCD model and satellite image as an input.

2. Materials and Methodology

2.1 Study Area

Panchkula district is a north-eastern part of Haryana State of India. It lies from 30^0 28’10’’ to 30^0 55’05’’North latitude and from $76^0$46’33’’ to $77^0$10’30’’ East longitudes covering an area of 898 sq. Km. and occupying a total population of 561293 individuals (Directorate of Census Operations, Haryana 2015). The area is transitional between the Outer Himalayas and the Ghaggar Yamuna Upland Plain and has a subtropical/monsoon climate. The district has sharp rising Siwalik hills and foothill rolling plains in the north and north-east. The continuity of the Siwalik range further east is broken by the transcurrent fault of Panchkula. The district is dissected by the Ghaggar river and its tributaries, nadis, nalas and choes (Directorate of Census Operations, Haryana 2015). The district is covered by reserved, protected and unclassed forests with a total forest cover of 392.10 sq. Km. (ISFR 2021). The study area is located in the Siwaliks of Panchkula district of Haryana State of north-west India (Figure 1).

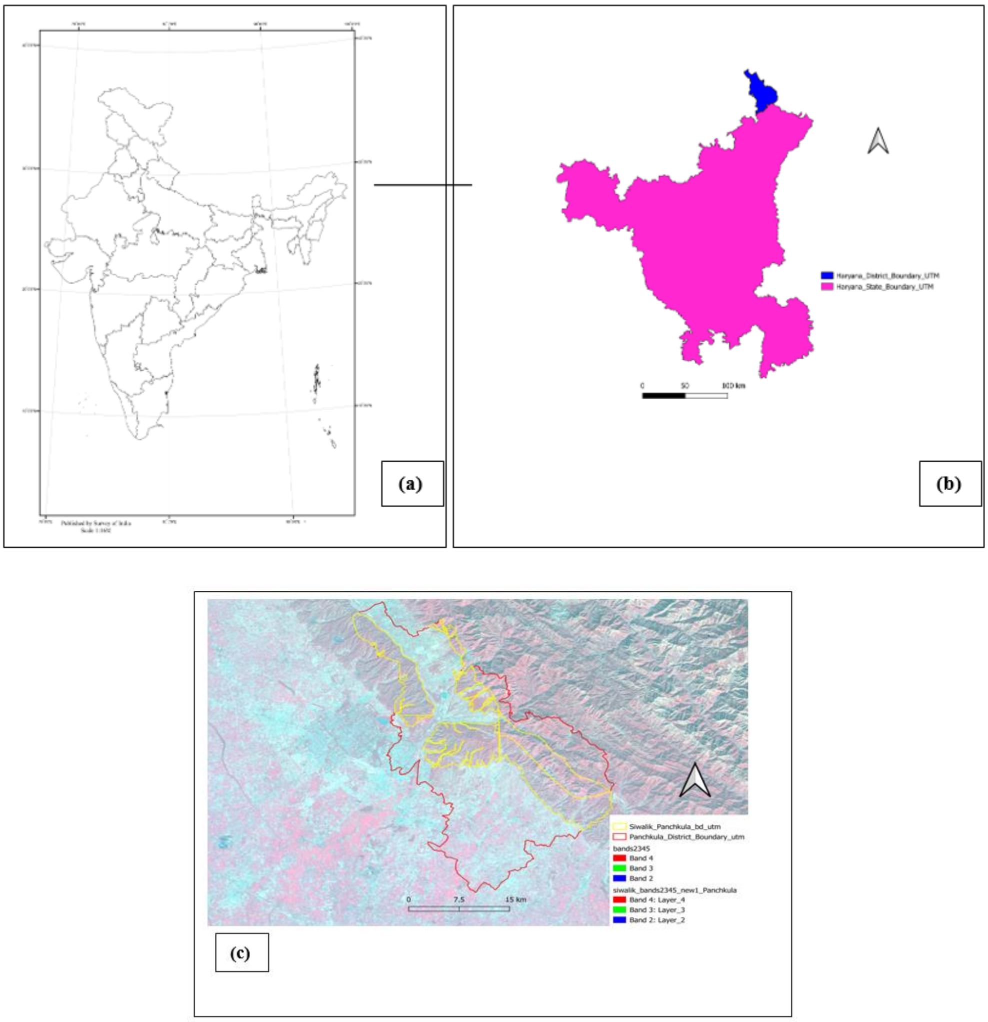

Figure 1. Location map of the study area: (a) *Outline Map of India with State Boundary; (b) Panchkula District (in blue color) highlighted on the *Boundary Map Haryana State (in magenta color); (c) A Satellite View depicting **Boundary of Siwaliks (in yellow color) of Panchkula District (with boundary in red color) of north-

west India overlaid on Landsat 9 OLI False Color Composite (FCC) satellite image of path/row - 147/39 acquired on 15 December 2022.
*Downloaded and used from Survey of India, Govt. of India (SOI 2024).
**Downloaded and used from Geological Survey of India, Govt. of India Bhukosh platform (GSI 2024).

2.2 Satellite Images

The cloud-free Landsat 9 OLI and TIRS-2 satellite image of path and row, 147 and 39, respectively, and acquired on 15 December 2022 is downloaded from USGS Earth explorer online platform and used. TIRS-2 includes two sensors, each in band 10 and band 11. In FCD estimation band 10 (TIRS 1) is used. The satellite image after download is subset using the boundary map of Siwaliks of Panchkula district of north-west India in QGIS software (QGIS 2024) and further used. All the image processing and GIS analysis was performed in QGIS.

2.3 The Indices and Algorithms

In this study, five OLI bands and one TIRS-2 band (TIRS 1 or band 10) and semi-expert FCD mapping model is used to calculate FCD. The semi-expert FCD mapping model, which is based on four biophysical indices namely the Advance Vegetation Index (AVI), Shadow Index (SI), Bare Soil Index (BI) and Thermal Index (TI), is very effective for detecting and estimating the density of canopy over a large forest area with satellite images because it reduces the effect of biases like effect of atmospheric noise on vegetation (Rikimaru 2002). In this study, different indices such as the AVI, SI, BI and NDVI have been utilized to present the spatial pattern of FCD using OLI and TIRS-2 at 30m pixel resolution.

Table 1. Indices to Calculate FCD using Landsat 9 OLI and TIRS 2

Indices to Calculate FCD	**Formula**
Advanced Vegetation Index (AVI)	$(NIR+1)X(65536-R)X(NIR-R)^{1/3}$
Bare Soil index (BI)	$(((SWIR1+R)-(NIR+B))/((SWIR1+R)+(NIR+B))\times100)+100$
Shadow Index (SI)	$((65536-B)X(65536-G)X(65536-R))^{1/3}$
[1]Thermal Index (TI)	$K2/(\ln(K1/L_{\lambda}+1))$
FCD	$(SSI \times VD+1)^{1/2} - 1$

Where as, NIR = pixel values in near-infra wavelength band (band 5); R = pixel values in red wavelength band (band 4); B = pixel values in blue wavelength band (band 2); G = pixel values in green wavelength band (band 3); SWIR = pixel values in SWIR1 (band 6); K1, K2 = calibration coefficients of band 10 (TIRS 1); L_{λ}= spectral radiance value, L_{λ}= Bias + (Gain × Band 10). *SSI = Scaled Shadow Index; **VD = Vegetation Density (VD).
[1]Thermal Index (TI) calculate the surface temperature (in Kelvin) in two stages: first is changing pixel value of thermal channel (band 10) in to spectral radiance a the sensor's aperture, and second is the calculation of radian temperature of the ground surface in degree Kelvin.
*SSI is derived through integration by applying Principal Component Analysis (PCA) between SI and TI. The first PC image is then normalized to produce a SSI image where the value of SSI ranges from 0-100%.
**VD is derived through integration by applying PCA between AVI and BI. The first PC image is then normalized to produce a VD image where the value of VD ranges between 0-100%.

2.4 Characteristics of FCD indices

The measurement of FCD is a function of a complex combination of different indices. For example, the temperature data (TI) used to separate a soil and a non-tree shadow. Higher is the TI, higher is ground surface temperature. Since higher TI is related to lower AVI, therefore the soil is exposed to higher amounts of radiation and thereby causing higher BI value. Thus, lower is AVI, higher is the BI which in turn allows higher amounts of solar radiation reaching the ground thereby warming the soil more, and therefore soil becomes more dry. Similarly, the young, even aged forest will have lower canopy shadow when we compare it to a matured natural forest of different tier level. Thus, higher is the AVI, higher is the SI. When, both AVI and SI is higher, lower is the TI and lower is the BI.

2.5 FCD classes

Depending on the % of canopy density, ISFR (2021) has categorised forest in to following canopy density classes (Table 2). Our results also follow the same % canopy density class after estimating the FCD.

Table 2. FCD classes

FCD Class	% of Canopy Density
Moderately Dense	10-40%
Dense	40-70%
Very Dense	>70%

The canopy density 5-10% represents shrubs and 0-5% as scrub land which has not been considered in this study.

2.6 Methodology to estimate FCD

This has been shown in diagrammatically below.

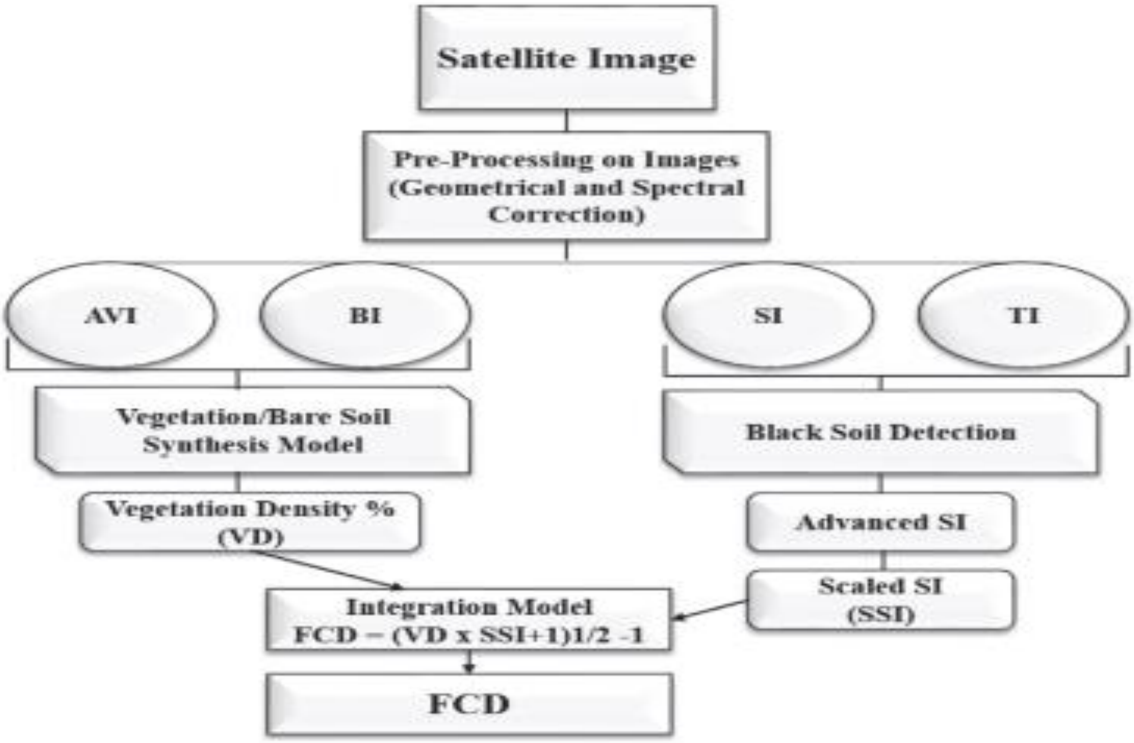

Figure 2. Methodological Framework to estimate FCD.

3. Results and Discussion

The total geographical area (TGA) of the Panchkula district is 89800 ha. The Siwalik boundary downloaded from Bhokosh platform shows that the total Siwalik area of the district is 31364 ha which around 34.93% of the TGA is. After executing the FDP model, the result shows the area distributed in different canopy density classes. The area is separated based on different canopy density classes as shown in table 2. The result is shown in table 3.

Table 3. FCD area distribution in the Siwaliks of Panchula district, Haryana

FCD Class	% FCD	Area (ha)	% of Total Siwalik Area
Moderately Dense	10-40%	962.82	3.07
Dense	40-70%	25807.23	82.28
Very Dense	Above 70%	1159.56	3.7
Total Area		27929.61	89.05

FCD model is one of the best and proven methods of canopy density estimation from forest areas using satellite images (Medhe and Badhe2023). The result of FDP mapping reveals the fact that a total of 27930 ha area is covered with forest canopy of different density classes. Thus, the FCD area estimated is 3.11% of the total TGA and is 89% of the total Siwalik area of the district. According to the ISFR (2021) report, the total area covered under different density classes of forests in Panchkula district is 39210 ha. Thus, in reference to ISFR (2021) report, the Siwalik occupies 71.23% of the total area covered under forest of the Panchkula district. The table 3 shows that most of the forest is covered with canopy having 40% to 70% density. This shows that the area has a fair growth of mature tree species. The field work revealed that the Chir Pine forest is distributed, typically at a higher altitude of the region. The presence mixed deciduous tree species such as Neem (*Azadirachta indica*), Dhak (*Butea monosperma*), Tendu (*Diospyros malabarica*), Shisham (*Dalbergia sissoo*) is also observed in the field. On the other hand, forest with very dense canopy is only 3.7%. The loss of forest cover reported here is not new but it has been expressed as an important problem at global level, with implications for biodiversity and global climate change (Pokhriyal et al. 2020). Though, forest department is making efforts to increase forest cover, still low lying fragile areas of Siwalik require intensive implementation of afforestation and reforestation programs throughout the year. Further, encroachment of forest areas for building construction projects is seen as a cause of concern by many ecologists. Human interference in forest leads to its fragmentation and degradation (Schmierer et al. 2004). The ground survey in the study area shows that construction development in forest patches at the periphery of urban boundaries has begun. This needs a change at policy level to prohibit such activities. Also, plantation by the Forest Department and other afforestation agencies along the periphery of forest can lead to increase in forest cover along edges. The field survey showed that stress on commercially important tree species and illegal timber cutting is also a cause of concern. In consonance the FCD model may be utilized as a significant planning tool for monitoring the status of forest cover.

The quantification of FCD utilizing different FCD indices prepared from available spectral responses of the satellite images from the Earth's surface and semi-expert FCD model is an important cost and time saving approach. The quantity of vegetation has a strong association with the AVI. Its value is high for high forest density and grassland. Our finding shows that there are significant variations in soil index over time. The SI is in charge of the cooling impact within the forest as well as evaporation from the leaf structure. The finding revealed that the percentage of shadow cast by the tree canopy changed dramatically over time. Mature forests have higher value of SI compared to the new forest areas. In forest areas that have tall and dense trees, will cause high AVI and SI values, otherwise there are low values for BI and TI. Likewise, forest areas that are already open where the presence of the trees are relatively poor will result in an increase in the value of BI and TI and decrease in the value of AVI and SI (Rikimaru & Miyatake, 1997; Roy, et al. 1997).

4. Conclusions

The research presented a FCD model in analysing the recent status of forest density in the Siwaliks of Panchkula district. The FCD model can provide a broader map of forest canopy density from a local to a global scale, and they can be implemented in different forest ecological systems for sustainable management of forest cover, protection and restoration. In our study area a minor quantity of very dense canopy forest indicates the need for an increase in effective forest management practices. The FCD model, thus, is an important development tool for policy planning, examining spatial forest health conditions and can be replicated in other forest ecosystems for sustainable management of forest cover.

The estimation of different indices and their relationship helps in understanding the forest condition, the cooling and the warming effect. Another conclusion from this understanding is that conservation of natural forests is more important than felling it and planting again on the same land. This, in turn, will yield the growth of even-aged trees and create many more losses in terms of warming effect, soil erosion, soil fertility etc. Thus, FCD monitoring and analysis is not only related to green growth, but can also reveal other facts.

5. Acknowledgements

The authors are grateful to the Kurukshetra University, Kurukshetra for providing the financial support under the Kurukshetra University Seed Money Grant (2022-23, extended to 2023-24) that led to the project completed successfully.
We acknowledge Survey of India, Govt. of India for free access to Outline Map of India with State boundary and District boundaries on its online platform for download and use in this study.
We acknowledge Geological Survey of India, Govt. of India for freely availing boundary of Siwaliks through its online Bhukosh platform and used in this study.
We acknowledge United State Geological Survey (USGS) for availing Landsat 9 satellite image at no cost through its Earth explorer online platform and used in this study.

Conflict of interest

The authors declare no competing interests.

6. References

1. Adjovu, G. E., Stephen, H., James, D., Ahmad, S. (2023). Overview of the Application of Remote Sensing in Effective Monitoring of Water Quality Parameters. Remote Sensing, 15, 1938.
2. Anuradha & Gupta, S. (2022). AHP-based Multi-Criteria Decision-Making for Forest Sustainability of Lower Himalayan Foothills in Northern Circle, India - A Case Study. Environmental Monitoring and Assessment, 194(12), 849.
3. Azizia, Z., Najafi, A., Sohrabia, H. (2008). Forest Canopy Density Estimating, Using Satellite Images. In: The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. Vol XXXVII, Part B8, Beijing.
4. Bandyopadhyay, R., Kaplan, P. O., Araujo, R., Dodder, R., Smith, E. R. (2017). FREIDA (framework of resources for modeling energy/ environmental/economic impacts of development and advancements) in ports: A portfolio of interactive information resources, and an illustrative energy sector analysis. In: 2017 IEEE Global Humanitarian Technology Conference, October, 1-9.
5. Biradar, C. M., Saran, S., Raju, P. L. N., Roy, P. S. (2005) Forest Canopy Density Stratification: How Relevant is Biophysical Spectral Response Modelling Approach?.Geocarto International, 20(1), 1–7.
6. Champion, H. G., Seth, S. K. (1968). A Revised Survey of Forest Types of India, Govt. of India Press, New Delhi pp. 404.
7. Directorate of Census Operations, Haryana. (2015). Census of India 2011 - Haryana - Series 07 - Part XII A - District Census Handbook, Panchkula. Retrieved March 10, 2024, https://censusindia.gov.in/ nada/index.php/catalog/428/download/1360/DH_2011_0601_PART_A_DCHB_PANCHKULA.pdf
8. Falensky, M. A., Sulti, A. L., Putra, R. D., Marko, K. (2020). Application of forest canopy density (FCD) model for the hotspot monitoring of crown fire in Tebo, Jambi Province. Jurnal Geografi Lingkungan Tropik, 4(1), 59-67.
9. GSI. (2024). Lithology map of India, Geological Survey of India, Government of India, Kolkata, India. Retrieved March 10, 2024, https://bhukosh.gsi.gov.in/Bhukosh/Public.
10. Haddad, N. M., Brudvig, L. A., Clobert, J., Davies, K. F., Gonzalez, A., Holt, R. D., Lovejoy, T. E., Sexton, J. O., Austin, M. P., Collins, C. D., Cook, W. M., Damschen, E. I., Ewers, R. M., Foster, B. L., Jenkins, C.N., King, A. J., Laurance, W. F., Levey, D. J., Margules, C. R., Melbourne, B. A., Nicholls, AO., Orrock, J. L., Song, Dan-Xia., Townshend, J. R. (2015). Habitat fragmentation and its lasting impact on Earth’s ecosystems. Science advances, 1(2).
11. ISFR (2021) India State of Forest Report 2021, Forest Survey of India, Dehradun, Ministry of Environment and Forests & Climate Change, Government of India. Retrieved March 22, 2024, at https://fsi.nic.in/forest-report-2021
12. Medhe, R. S. and Badhe, Y. P. (2023). Forest Canopy Density Monitoring by Using Geospatial Techniques: A Study of Gadchiroli District, Maharashtra, India. Current World Environment, 18(3).
13. Mon, M. S., Mizoue, N., Htun, N. Z., Kajisa, T., Yoshida, S. (2012). Estimating Forest canopy density of tropical mixed deciduous vegetation using Landsat data: a comparison of three classification approaches. International Journal of Remote Sensing, 33(4): 1042–1057.
14. QGIS. (2024). QGIS Geographic Information System. QGIS Association. Retrieved January 22, 2023, http://www.qgis.org

15. Panwar, P., Tiwari, A. K., Dadhwal, K. S. (2012). Agroforestry systems for resource conservation and livelihood security in lower Himalayas. New India Publishing Agency, New Delhi, 302p.
16. Pokhriyal, P., Rehman, S., Areendran, G., Raj, K., Pandey, R., Kumar, M., Sahana, M., and Sajjad, H. (2020). Assessing forest cover vulnerability in Uttarakhand, India using analytical hierarchy process. Modeling Earth Systems and Environment, 6(2), 821–831.
17. Rikimaru, A. (1996). LAMDSAT TM data processing guide for forest canopy density mapping and monitoring model. In: ITTO workshop on Utilization of Remote Sensing in Site Assessment and Planning for Rehabilitation of Logged-over Forest. July 30-August 1, Bangkok, Thailand.
18. Rikimaru, A., Miyatake, S., & Dugan, P. (1999). Sky is the limit for forest management tool. ITTO Tropical Forest Update, 9(3), 6–9.
19. Rikimaru, A., Roy, P. S., Miyatake, S. (2002). Tropical forest cover density mapping. Tropical Ecology,43(1), 39–47.
20. Roy, P. S. (1999). Space remote sensing for forest management. India Institute of Remote Sensing (National Remote Sensing Agency).
21. Schmierer, Jr. J. M., Mroz, G. D., Noble, S. D. (2004). The FERM: Forest and environmental resource management. Natural Resources and Environmental Issues, 12(1), 49.
22. SOI (2024). Open series map. Retrieved March 15, 2024. https://onlinemaps.surveyofindia.gov.in.
23. Yadav, R. P., Panwar, P., Arya, S. L., Mishra, P. K. (2015). Revisit of Shivalik Region in Different States of Northwestern India. Journal Geological Society of India, 86(3), 351–60.