# Database creation using high resolution IRS PAN + LISS III satellite data for ecological modelling of Himalayas under GIS environment – a study in Shiwalik range, Himachal Pradesh, India

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**This work reports an attempt to make use of the indigenously developed high resolution IRS-1C satellite imagery to generate a database, including expertize from different organizations involved in floral, soil, microbial, hydro, socio-economic and geological fields. In the absence of large scale topographic maps, high resolution precision geocoded PAN + LISS-III imageries at 1 : 12,500 were used. This final database was subsequently integrated in the geographic information system environment[1] and was used to address queries of the user organization pertaining to area statistics, location, water potential, soil suitability, agricultural suitability according the prevailing ecological conditions, etc.**

**Keywords:** Everest datum, geographic information system, global positioning system, minimum sampling unit, polyconic projection.

GENERATION of Bio-Geo database on natural resources is aimed at providing information on natural resources regarding land, water, flora, soils and socio-economic information and infrastructure. The integration of these sets assists the decision making process for systematic resources utilization and also aids sustainable development.

The study area of Mandhala Watershed falls in the foothill zone of Himalaya, in the southernmost part of Solan district in the state of Himachal Pradesh. The satellite image of the study area is given in Figure 1. The non-standard definitions and classification system adopted by different organizations for preparing an inventory of watersheds have resulted in varying statistical estimates. Therefore, there was a need for the standard definitions and classification system for mapping micro-watersheds using high resolution remotely sensed satellite imageries together with the ground-based information.

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## Methodology

### *Base map generation*

Drainage maps were generated from the published Forest Survey of India (SOI) maps at 1 : 15,000 scale. These

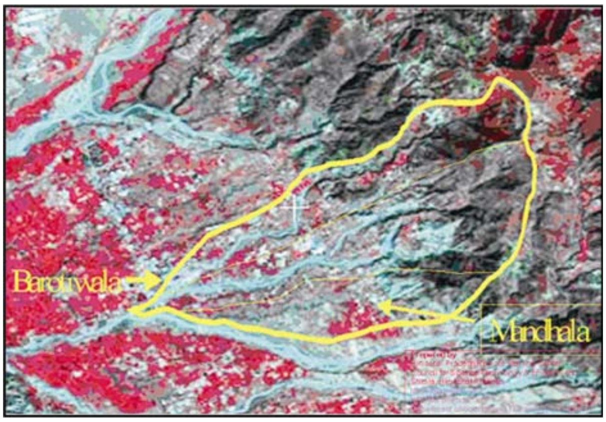


**Figure 1.** IRS-1C LISS-III satellite image of Mandhala Watershed in Solan district, Himachal Pradesh, India.

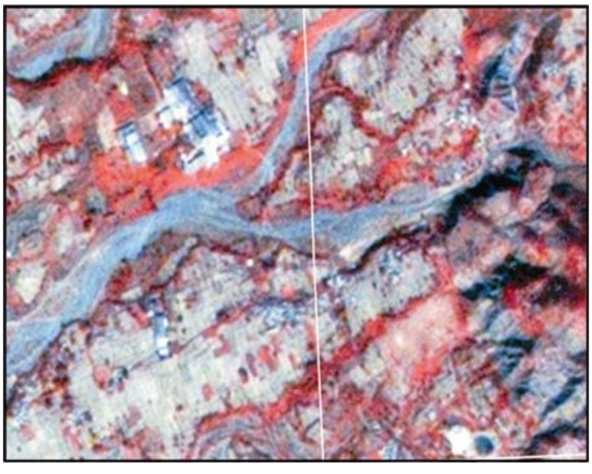

**Figure 2.** IRS-1C PAN + LISS-III satellite image of a part of the study area, Mandhala Watershed in Solan district, Himachal Pradesh, India.

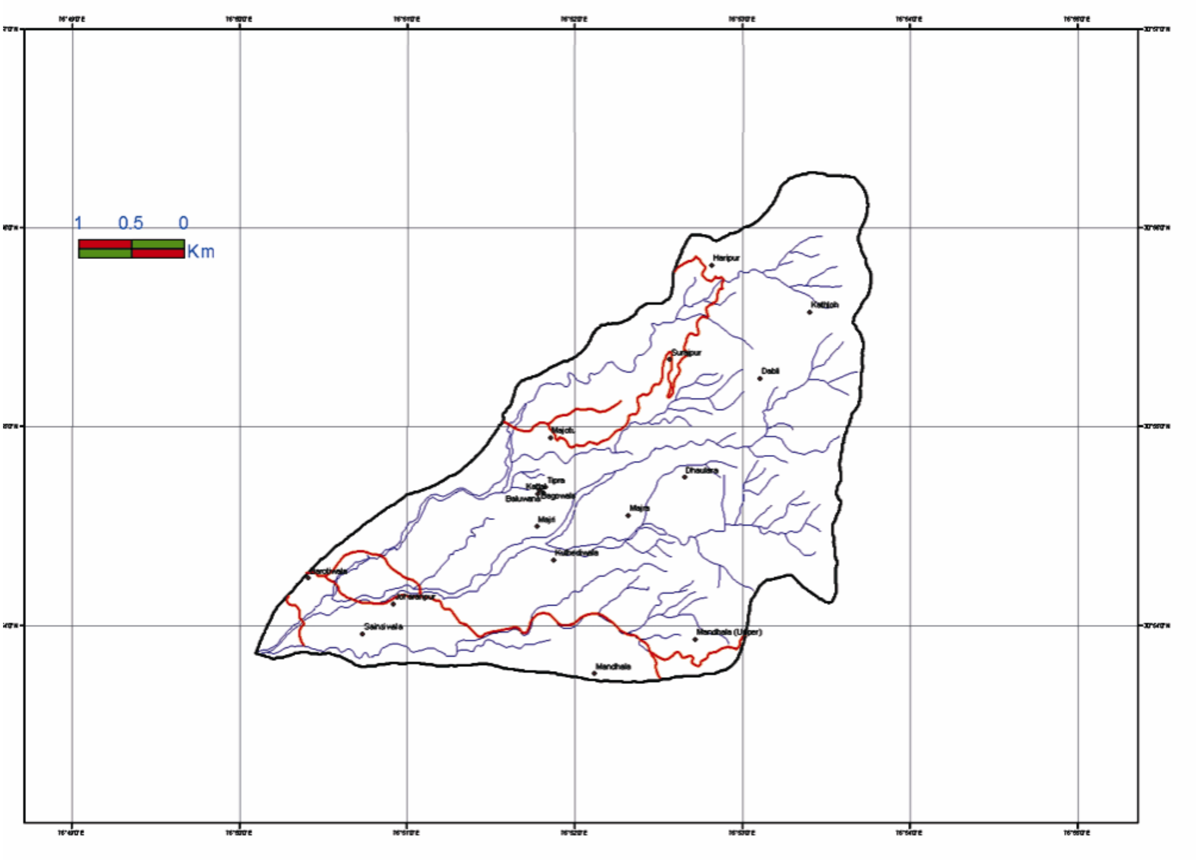


**Figure 3.** Base map representing the drainage network, prominent village locations and the road network connections in Mandhala Watershed.

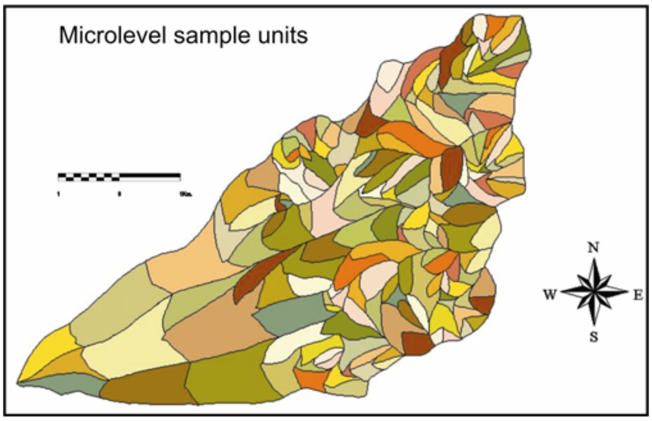


**Figure 4.** Microlevel sampling units representing the microlevel watersheds based primarily on the first order drainage pattern mapped at the scale of 1 : 12,500 scale by using the hybrid approach of contour and PAN + LISS-III satellite data and limited ground verifications in Mandhala Watershed in Solan district, Himachal Pradesh.

maps were enlarged up to 1 : 12,500 scale and overlaid with the interpreted satellite data[2] at 1 : 12,500 scale. The drainage data available at 1 : 15,000 scale from the Forest SOI maps and the SOI maps were limited. Therefore the information derived from the Forest Survey of India maps was updated using high resolution geocoded PAN + LISS-III (Figure 2) satellite data. This process facilitated identification of all the major and minor details of the drainage[3] which was otherwise not possible to extract from any other survey maps (Figure 3). On the basis of this detailed drainage map[4] the minimum sampling unit (MSU) was generated for field study.

Using a 1 : 15,000 scale Forest SOI map, it was only possible to map the actual 2nd and 3rd order drainages. However, using the PAN + LISS-III data it was possible to delineate all the 1st and 2nd order drainages as on the ground. On the basis of this drainage map, an MSU was generated for field study. This MSU becomes a complete hydrological unit[5] and the basic component for gathering information from the smallest to larger organisms.

The map projection used was preferably Everest Datum and Polyconic Projection[6]. The planimetric accuracy w.r.t. the control points on Survey of India toposheet at 1 : 15,000 scale is 15 m but at 1 : 12,500 scale using Pan + LISS-III it is higher at 3.75 m. The thematic accuracy for the MSU is 2500 sq. m and the mapping accuracy is 90/90 according to the sample check in the field.

Thematic maps were scanned and digitized in the GIS environment with the help of ARC/INFO software[7] and generated information regarding the natural resources, vegetation, habitation, flora and fauna. The integration of

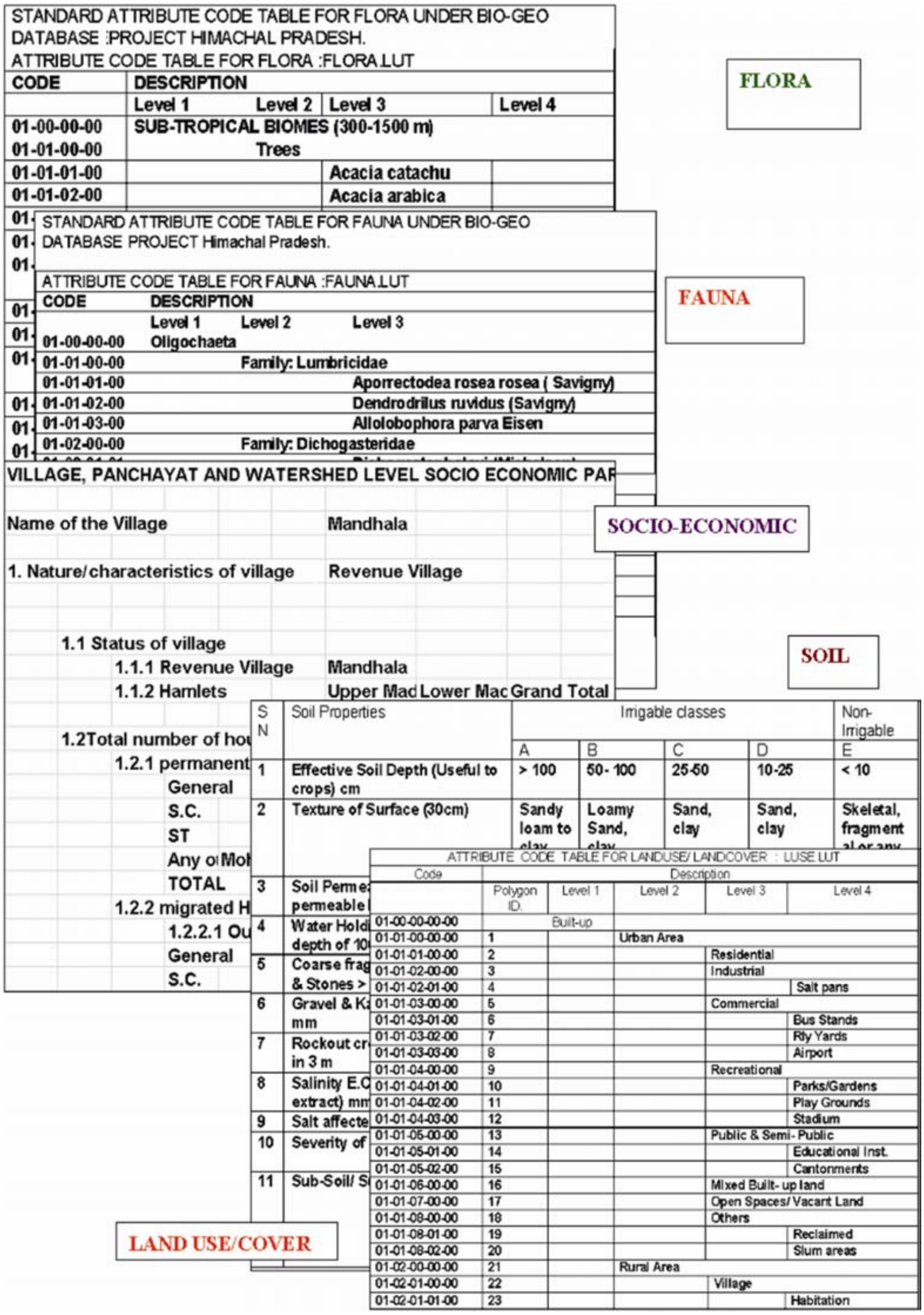


**Figure 5.** Standard codes on faunal, floral, soils, socio-economic, landuse, land cover, etc. prepared specifically for higher resolution satellite based thematic land parcels.

spatial and non-spatial data set was carried out to arrive at local specific action plan. GIS-based query shell was utilized to retrieve the land resources information and also to generate the action plans for each landuse parcel. Multi-temporal and multi-spectral IRS satellite images were used to map the natural resources along with the field surveys with respect to the available land use, flora and fauna in the watershed[8]. High resolution IRS PAN and LISS-III merged satellite data was used to extract information on land use/cover, drainage, lineament, geomorphology, lithology base map, etc. The spatial information of thematic maps was then transferred in a GIS environment using the ARC/INFO software[9]. The non-spatial information in the form of attribute data (socio-economic) was integrated with the spatial information in the GIS environment. Finally, the land resources action plan was generated with the available spatial and non-spatial statistics along with the user queries for the Mandhala Watershed[10].

### *Microlevel sampling unit*

According to the norms of the All India Soil and Land Use Survey, the watersheds were delineated according to their size; these watersheds were further subdivided into sub-watersheds, mini-watersheds and micro-watersheds based on the individual hydrological unit sizes 30–50, 10–30 and 5–10 sq. km respectively as per the codification of the Integrated Mission for Sustainable Development Project of the Department of Space, Government of India.

For this study, delineation of the MSU involving the first order drainages and its drain orders with their individual hydrological entity was taken into consideration as microsampling unit (Figure 4).

### *Ground truth surveys*

Ground truth survey was undertaken according to the season and date of satellite passing over the study area[11]. Emphasis was made to coincide the satellite passes with the date ground truth survey, so as to obtain the actual ground truth conditions with respect to seasonal variations. All the doubtful units encountered during pre-field interpretations was verified and correctly incorporated on the final map. During the ground truth survey, effort was made to check all the major land use and land cover features according to the existing satellite images to enhance the map interpretation accuracy.

High resolution IRS-1C PAN + LISS-III merged satellite data at 1 : 12,500 scale (published Forest Survey of India maps at 1 : 15,000 scale) was further enlarged up to 1 : 12,500 scale and aerial photographs at 1 : 50,000 scale were used to generate the thematic layers. The precision geo-coded satellite data was visually interpreted and all the land use–land cover categories were delineated using the standard codes[12,13]. After the pre-field visual interpretation was over, output was generated for the actual ground verification. Ground truth survey was undertaken according to the season and date of satellite passes over the study area. All the samples during pre-field interpretations were verified using GPS (global positioning system) and correctly incorporated in the final map after the final ground truth surveys.

The use of high resolution satellite data required new land use codes and the same was generated up to the 4th level of classification in terms of hierarchy (e.g. built-up > urban area > recreational > parks), similarly (forest > evergreen > willow > open) soil down to the phase level, flora down to species level, microbes based on smallest land use/cover parcel, socio-economic information at the household level, etc. (Figure 5).

For the preparation of a uniform database for all watersheds a working manual had to be devised. For this purpose, the participating institutions collectively prepared the working manual for the Himalayan region across the Himalayan transact from south to north[14]. Using the final, updated and corrected maps at 1 : 12,500 scale and through the process of map scanning, digitization, geo-referencing and map projection various thematic maps were created using Arc Info software. Some of the themes prepared under the project for data integration and analysis are land use, land cover, soil, flora, geomorphology, contour, lithology, lineament, geology, socio-economic and microbial diversity; other derived maps include the digital elevation model (DEM), slope, aspect, hydrogeomorphology[15], etc. One of the derived layers, e.g. DEM is represented in Figure 6.

The final database was integrated in the GIS environment. Here the users' queries relating to area statistics,

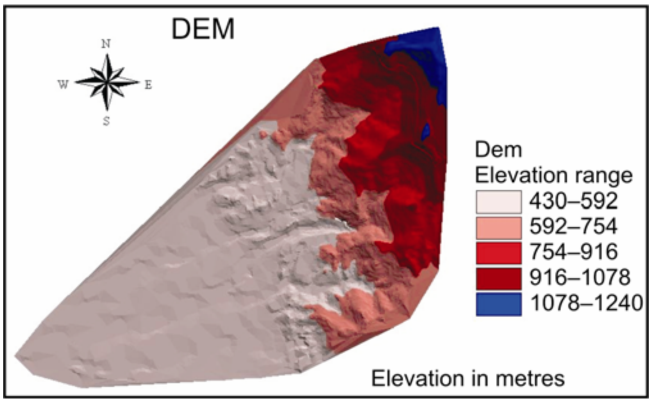


**Figure 6.** Digital elevation model derived from the contours at 1 : 15,000 scale and contour interval of 10 m for Mandhala Watershed.


**Figure 7.** Microsampling units suitable for capsicum cultivation based on the analysis of the integrated thematic maps in Mandhala Watershed.

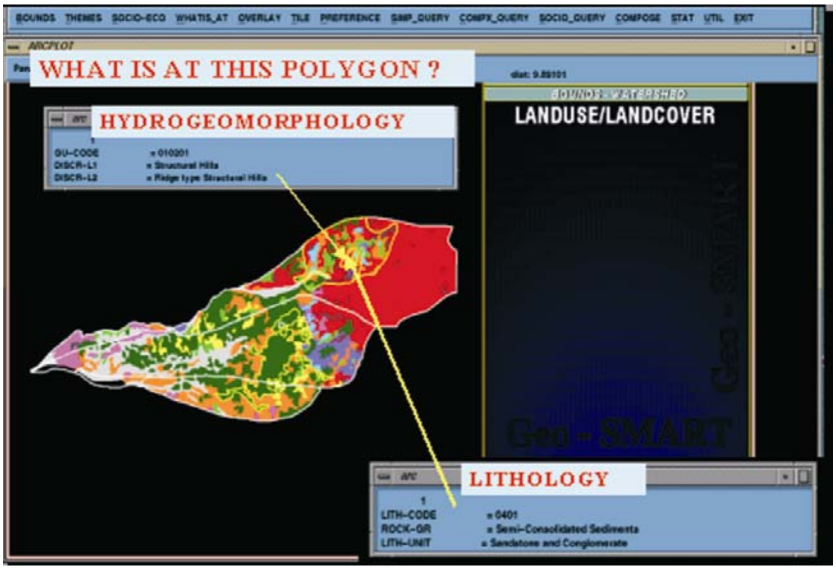


**Figure 8.** User-based query interface.

location, water potential, soil suitability, faunal availability were analysed and the suitable locations identified for the user communities within the micro-watershed were addressed by the decision support system[16] (Figures 7 and 8). These user queries are based on the report prepared by the independent nongovernmental organization in consultation with the line departments to identify the intrinsic problems within the study area.

## Results

According to the user need reports, the database so created has been validated and created in the user friendly software where queries are addressed by the software. Here queries relating to area statistics, location, water potential, soil suitability, faunal availability, etc. were analysed and suitable recommendation was specified. Under this pilot study involving high resolution satellite imageries, the following objectives were accomplished and generated specific standard codes, guidelines and working manuals for other users to follow while designing the database in the specific agro-ecological transact in the Himalayan region or any other similar ecological region elsewhere.

The Bio-Geo database project addresses most of the users' immediate requirements with respect to land, such as the requirements of the total area in a specific watershed or its sub-unit, area under agriculture, area under horticulture, statistics for irrigated land, different types of crops, land use pattern in the area and types of the soil in a watershed. It addresses the requirements with respect to water such as total number of streams in a watershed or its sub-units, sources of water and its distance, availability of drinking water, potential ground water region, total stream discharge on daily or monthly or seasonal basis, potential area for irrigation, silt load, data on rainfall, temperature, humidity, etc. It also addresses requirements for biological information such as the requirements for total area under forest (trees, herbs and shrubs), their types, size, availability of the species with respect to trees, shrubs and herbs (including medicinal and aromatic).

It addresses the requirements with respect to the socio-economic aspects up to the household level such as the population characteristics, livelihood distribution, inventory of community resources, availability of arable land, data on irrigated and un-irrigated area and category-wise land holdings, pastureland, data on cattle, poultry, etc. An important aspect of this study was the integrated approach of high resolution remote sensing satellite-based information and expertise of the scientists of varied fields including biologists, zoologists, agriculture scientists, hydrologists and socio-economists to understand the user's immediate requirement within the microwatershed thereby generating the existing database so as to provide a scientific solution to their problems in order to improve the overall quality of life.

1. Lillesand, T. M. and Kiefer, R. W., *Remote Sensing and Image Interpretation*, John Wiley, New York, 1994, p. 750.
2. Legg, C., *Remote Sensing and Geographic Information System – Geological Mapping and Image Interpretation*, John Wiley, New York, 1994, p. 750.
3. Mehta, N. S., Bhatt, N., Thapa, R. S., Sood, R. K. and Panigrahi, S., Evaluation of IRS LISS III data for Apple orchard inventory – a case study covering Jubbal–Kotkhai block of Shimla district, ISRS Symposium, Kanpur, 2000.
4. Thapa, R., Mid-term evaluation report on micro watershed projects under IWDP-II in district Mandi, HP, India. Watershed Evaluation Report on Physical, and Financial achievements Sub-

mitted to Department of Rural Development Agency, Shimla, 2003.
5. NRSA, Integrated Mission for Sustainable Development. Technical Guidelines – National Remote Sensing Agency, Department of Space, Hyderabad, 1995, p. 205.
6. Thapa, R. S., Deol, S. S. and Chawdhary, M. S., Study of environment impact assessment of the proposed limestone mining area using remote sensing techniques and GIS applications near village Shind, distt. Chamba, HP. National Seminar Mining Technology of New Millennium, Shimla, Himachal Pradesh, India, 2000, pp. 200–204.
7. Kalubarme, M. H., Dutta, S., Thapa, R. and Sood, R. K., Wheat acreage estimation for Himachal Pradesh using remote sensing techniques, National Symposium of Indian Society of Remote Sensing, Guwahati, Assam, India, 1993, pp. 145–162.
8. Thapa, R. S. and Sood, R. K., Application of Remote sensing techniques in monitoring mining activity – a case study of Khaniara slate mines, District Kangra, Himachal Pradesh. National Seminar on Eco-friendly mining in the hilly region and its socio-economic impacts. Mining Engineers Association of India, Shimla, India, 1997, pp. 96–100.
9. Chawdhary, M. S., Deol, S. S. and Thapa, R. S., Application of remote sensing technology in EIA-EMP studies in mining – a case study of limestone mining in Sirmour. National Seminar Mining Technology of New Millennium, Shimla, Himachal Pradesh, India, 2000, pp. 6–11.
10. NRSA, Manual nationwide land use/land cover mapping using satellite imagery. National Remote Sensing Agency, Hyderabad, 1989.
11. Kimothi, M. M., Kalubarme, M. H., Dutta, S., Thapa, R. S. and Sood, R. K., Remote sensing of horticultural plantations in Kumarsain Tehsil (Shimla District), Himachal Pradesh, India. *Indian Soc. Remote Sensing J.*, 1997, **25**, 18–26.
12. Department of Space/ISRO, Manual for National (Natural) Resources Information System, Technical Guidelines National Remote Sensing Agency, Department of Space, Hyderabad, 1988, p. 125.
13. SAC, National (Natural) Resources Information System (NRIS) – Node Design and Standards. Space Applications Centre Document No. SAC/RSA/NRIS-SIP/SD-01/97, 1997.
14. Thapa, R. S., Sood, R. K., Deol, S. S. and Tanwar, H., Bio-Geo data base creation and sustainable micro-watershed development planning using remote sensing and geographic information. A Scientific Document for the Department of Science and Technology, New Delhi, 2004, p. 99.
15. ISRO, Manual for hydro-geomorphological mapping for drinking water mission, Department of Space, Bangalore, 1988.
16. Thapa, R., Morphotectonics and hydrogeology of catchment of Lower Jalal-Giri, Upper Markanda and Bata river, Sirmour District, Himachal Pradesh, India, Ph D thesis, Panjab University, Centre of Advanced Study, Chandigarh, India, 2007, p. 205.

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