SUMMARY AND CONCLUSIONS
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From the beginning of human civilization, mankind has lived in a competitive relationship with nature. While man’s interdependence on environment is greater than that of any other organism, his restless pursuit of progress, comfort and security has resulted in increased stress on the environment. The environmental impacts of many developmental activities are costly and results may be negative. The negative impacts can manifest in a variety of ways, such as, green house effect, floods, soil erosion, desertification, habitat destruction, deforestation loss of bio-diversity and ecosystem unstability. The growing awareness on the ranges and significance of environmental threats has forced people all over the world to concern for save the deterioration of environment. It is in this context, sustainable development is relevant. This calls for the holistic approach towards the development and environmental management plans based on intrinsic potential of the entire area, i.e., on terrain conditions, natural resources and environmental opportunities and constraints, which can possibly avoid this ecological crisis and improve the quality and rational growth of the human habitat.

There is need to have thorough geo-scientific database in respect of natural resources for generation of development plans for optimal and better use of potential resources eliminating the problems involved in development activities with minimising the environmental degradation. Also one of the basic requirements towards the development of any area is information at a single source. While it is difficult to make all information relating to environmental procedure available at one place, the present report attempts to give a clear evaluation of natural resources of a part of Son river watershed, Shahdol district, Madhya Pradesh.
To achieve above, a systematic approach of understanding the terrain characteristics at the regional level and then going for detailed mapping has been adopted which helps in improving the quality of information / output and saves considerably time, cost and manpower. Gorna and Baghari Subwatershed of Son river watershed have been selected for the detailed study. In this context, remote sensing and geographic information system technology is used here which has emerged as the most optimal means for monitoring and management of natural resources on global, regional and local scales. Remote sensing by its synoptic coverage, repetivity and availability offers an effective first hand tool in mapping and monitoring resources within a reasonably short time frame.

The present research work has been carried out with the main objective, to prepare a geo-scientific dataset of lithology, landforms, land use / land cover, soils, slopes, drainage, forest types, watershed map, road / settlement location map etc. and to develop methodology for ground water prospect mapping and forest fire risk zone mapping. Towards this, a phase-wise research work has been carried out as thematic mapping using visual and digital satellite data interpretation and ground truth information; inputting ancillary information of contours and drainage; transfer of thematic maps into ARC/INFO – GIS attribute data creation; derivation of secondary maps of ground water prospect and forest fire risk zoning.

Data identified and used for the present investigation are ground surveys, reports, IRS 1C & 1D LISS III FCC, IRS 1D LISS III and PAN digital data, SOI toposheets (64E, E/6, E/7, E/10), forest stock maps etc. The data collected from different sources have been used as ground truth information for the preparation of various thematic maps because the information collected from different sources do not have consistent accurate cartographic base and
different co-ordinate system. Various digitally enhanced products viz., contrast enhancements, ratio images, principle component, HIS and filtered images has been also used for the present study.

The study was carried out in two steps. Initially, the study of regional set up was done. Towards this, regional geological and physiographical map on 1:250,000 scale using IRS LISS III standard FCC (64E) and digital data has been prepared. In this second step, two test sites, which are subwatersheds of Son river, have been chosen in such a way that they represent a different environmental framework for detailed analysis of resource potentials and problems.

The regional study area is geologically represented by sandstone, shale, limestone, coal seams, basalt, dolerite, conglomerate etc. (Figure 4.4). Different rock types present in the area has been categorised into Bijawar Group, Vindhyan Supergroup, Gondwana Supergroup, Lameta beds and Deccan Trap. The present study has brought out the refinement of the Deccan Trap, Supra Barakar Group, Damuda Group, Semri Group and Bijawar Group clearly in terms of their boundaries due to their characteristic tone and textural variations in the study area. While the satellite images could help to map the different rock units, the images could not resolve the some rock units, such as Talchir Group and Unclassified Granites & Gneiss. The physiographic units in the area of study have been delineated with the help of visual interpretation of FCC 2, 3, 4 and edge enhanced FCC (Sobel filter) along with geological map prepared. Areas of study has been classified into five distinct physiographic units viz. Plains area with black soil, Plains area with vegetation, Hills with vegetation, Undulating terrain with thick vegetation and Undulating terrain without vegetation (Figure 4.5). A reservoir constructed recently across the Son river in the southern west part of the
study area has been mapped in the satellite image due to its distinct image characteristics. It can be noted that the occurrence of this reservoir is not shown in SOI topographical sheet prepared in 1975. This illustrates that change in land use pattern could be monitored from the multi-temporal satellite data.

In the second step, two test sites viz., (i) Gorna Subwatershed and (ii) Baghari Subwatershed studied in terms of lithology, landform, land use / land cover, forest types, slope, drainage morphometry, soils etc. In order to extract the maximum details available for remotely sensed data, different digital enhancement techniques were performed using ERDAS Imagine (ver 8.0.3) digital image processing software. Arc/Info (ver 7.02) GIS software has been used for getting derived output of ground water prospect and forest fire risk zoning. The following observations has been made for Gorna and Baghari Subwatersheds:

Land use / land cover maps has been prepared by creating classification scheme and interpretation based on field observations (Figure 5.10). FCC formed by hue, intensity and saturation is able to map the whole forest including burnt area, which is visible as dark patches in other images and difficult to do interpretation in such areas. Among the different land use / land cover, forest occupies largest geographical area (63.5%), followed by cropland (28.5%) in Gorna Subwatershed. Baghari Subwatershed is dominated by cropland (57%) followed by forestland (24.5%) (Table 5.5).

Vigorous field work and NDVI images has made possible to discriminate and map the different forest types of the study subwatersheds (Figure 5.6 & 5.7). While mapping the forest type, density, composition of species and location of the forest has played the important role. Eight-forest type has
been identified in the forestland viz. Sal, Sal and Bamboo mix, Dry mix, Moist mix, Bamboo mix, Degraded bamboo, Forest plantation and Forest blank. Sal and Bamboo dominate forests of both the subwatersheds (Figure 5.11).

A correlative approach involving image elements and the physiographic units has been adopted for soil resource mapping. While making the soil maps, FCC formed by PC2, PC1 & PC3 was found useful after knowing the tentative soil classes (Figure 5.4). Eleven soil type classes has been delineated successfully based on its morphological characteristics (Figure 5.12). Gorna Subwatershed is characterised by Moderate to deep, gravely sandy loam to sandy clay loam soils. Baghari Subwatershed’s soils are deep to very deep, clay to sandy clay loam.

The landform units in the area of study have been delineated and demarcated with the help of visual interpretation of FCC 432 and FCC of LISS III – PAN merged along with variations in lithology and various geotechnical elements. Broadly there are four landform units viz. Valley fills, Buried pediplains, denudational hills and ridges. Gorna subwatershed is dominated by Buried pediplains (moderate) and denudational hills. Baghari subwatershed is dominated by Buried pediplains (moderate) and Buried pediplains covered with black soils (Figure 5.13).

Lithology has been mapped using standard FCC, PAN and geological map published by GSI. Study watershed has been divided into four lithological classes viz., Basalt, Dolerite, Sandstone intermixed with clay and Sandstone intermixed with shale. It has been found that Gorna Subwatershed is dominated by Sandstone intermixed with clay and Baghari Subwatershed is made up of Basalt and Sandstone intermixed with shale(Figure 5.14).
A lineament map of the study watershed has been made by visual interpretation of FCC. Most of the streams of the area are controlled by lineament having NE-SW & NW-SE trends. Survey of India (SOI) toposheets on 1:50,000 scale with 20m contour interval was used for delineating different slope categories. This has been classified into six slope categories, viz., 0-3%, 3-5%, 5-10%, 10-15%, 15-35% and more than 35%. The field characteristics falling under different slope categories have been observed in the study subwatersheds (Figure 5.18). Major portion of both the subwatersheds falls under very gently sloping class. Gorna Subwatershed is dominated by hills, having high relief. Settlement location and road network maps has been made using toposheet and FCC.

Drainage maps have been prepared with the help of SOI toposheet on 1:50000 scale along with the satellite data. The quantitative morphometric analysis for linear, areal and basin parameter has been carried out from drainage networks extracted from the Survey of India topographical maps on 1:50,000 scale for both the drainage basins using the system of Strahler (1964). Based on the quantitative morphometric analysis, a comparative evaluation has also been carried out to understand the relationship between drainage development and geologic formations.

Both the subwatersheds have developed fifth order streams indicating similar level of dissection of the area and maturity attained. The stream number and bifurcation ratio is significant in deciphering the erosional activity of the basin (Table 5.12 to 5.14). The cumulative stream length of Baghari Subwatershed is lesser than the Gorna Subwatershed. While the Gorna Subwatershed drainage basin is represented topographically by highly undulating mountainous terrain dominated by hillocks, dykes and narrow
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valleys suggesting high relief, the Baghari Subwatershed is represented by moderate relief. Since the bifurcation ratio of the streams indicates how the bifurcation of the streams is proceeding within the basin, an attempt has been made to study the same. The bifurcation ratio of first to second order stream is more in the case of Gorna Subwatershed suggesting that the headward erosion is stronger in Gorna Subwatershed than that of Baghari Subwatershed. The average bifurcation ratio also supports this inference. Similarly the mean stream length of Gorna Subwatershed (0.66) is less than Baghari Subwatershed (0.69) suggesting that the headward erosion is more and this sub basin is less stabilized when compared to Baghari Subwatershed. This is corroborated by the presence of landforms in both the drainage basins. The length of overland flow measure suggests that surface run-off on Gorna Subwatershed drainage basin will reach the streams quicker than Baghari Subwatershed drainage basins.

The drainage density measures worked out for both the drainage basins indicates that the Baghari Subwatershed drainage basin is characterised by highly permeable sub soil material unlike Gorna Subwatershed drainage basin which exhibits impermeable subsurface material. These observations are confirmed by the presence of landforms and vegetative cover in the drainage basins. The lower value of constant of channel maintenance obtained for the Gorna Subwatershed drainage basin confirms the presence of structurally controlled stream segments within the basin. The basin shape measures have also been worked out for both the basins.

Though the ground water movement and localisation is a subsurface phenomenon, the surfacial expressions especially hydrogeomorphological details act as valuable indicators in understanding ground water characteristics. In this context, the interpretation of remotely sensed data
becomes an effective tool in identifying and mapping these parameters. Ground water occurrence and movement in an area is governed by several factors such as lithology, geological structure, landforms, terrain slope, soils, drainage basin characteristics and land use / land cover and interrelationship between these factors. So for delineation of ground water prospects zones, it is therefore, necessary to integrate the data on these terrain characteristics using GIS. The GIS based ground water demarcation has been developed here with the relevant logical conditions and reasoning which can be used with appropriate modifications elsewhere (Table 6.3 & 6.4). The ground water prospect map in GIS has been derived by integrating various thematic maps. The output of ground water prospect map for both the subwatersheds using the same criteria shows four classes, viz., Excellent, Good, Moderate and Poor (Figure 6.2 & 6.3). The ground water prospect zone map generated through this model for Gorna Subwatershed was verified with the ground reality to ascertain the validity of the model developed. The methodology was trialled initially in Gorna Subwatershed. For testing and evaluation of the methodology, the Baghari Subwatershed, which is having different terrain characteristics has been taken. Village wise ground water prospect map for Gorna Subwatershed has been also prepared which will be helpful for the authorities in ground water development, suggesting the site for bore well locations etc.

A watershed is a manageable independent hydrological unit, which can be taken as the basic unit of development planning. Now a day, all the planning for natural resource management is done on a watershed basis. The present study has been carried out on watershed basis. Hence, it will be helpful in suggestion of the management measures in future.
The annual incidence of forest fire often causes irreversible damage to the environment, loss of regeneration status and even at times total loss of the vegetation cover along with the increase in the rate of soil erosion. It is therefore imperative to keep regular record of all the important factors influencing the forest fire in order to enable planners to draw up protection programs. The approach to this is to prepare fire-prone zone maps of the study area, which would indicate the probability of the fire incidence and extent of its spread. An attempt has been made to map the fire risk areas of a forested region of Gorna Subwatershed. The various factors, such as vegetation type, vicinity to settlements, distances from roads and the slope / aspect etc. has been considered for the forest fire risk modelling. All these parameters having direct / indirect influence over the occurrence of fire were integrated using GIS and weightage index model to derive fire-risk zone map (Figure 7.7). Finally the fire risk zone map was compared with the actual sites disturbed by the fire. It was interesting to note that most points representing the history of past fires (LISS III of May, 1996 and May, 1999) occurred on the very high and high-risk zones predicted from the model. The risk areas and the actual affected sites were assumed to be a major test for the reliability of the present approach. It has been suggested that the area falling under very high and high risk zones should be initially monitored and strategic plan should be made to minimise biotic interference through fencing etc. There should be redeployment of fire fighting manpower and machinery on the basis of fire prone area map. The resultant risk map would help authorities in taking remedial measures against fire incidence.

Various thematic maps generated, analysed and synthesised in the previous chapters and also summerised earlier in this chapter helps not only to make broad generalisation but also to draw specific conclusions of the study.
• The study has clearly demonstrated the usefulness/application potentials of remote sensing techniques in assessing the natural resources through preparation of thematic maps, viz., land use/land cover, landforms, lithology, lineament, soils etc. The study has also highlighted the need to perform selective digital enhancement techniques for extracting all the information details of interest.

• The present study illustrates the efficiency of remote sensing and GIS analysis in ground water exploration activities. The methodology attempted for integration of various data sets through computer based GIS techniques can be successfully used elsewhere with appropriate modifications.

• The present approach combining field observations, remote sensing and GIS is reliable and satisfactory for fire risk zone mapping.