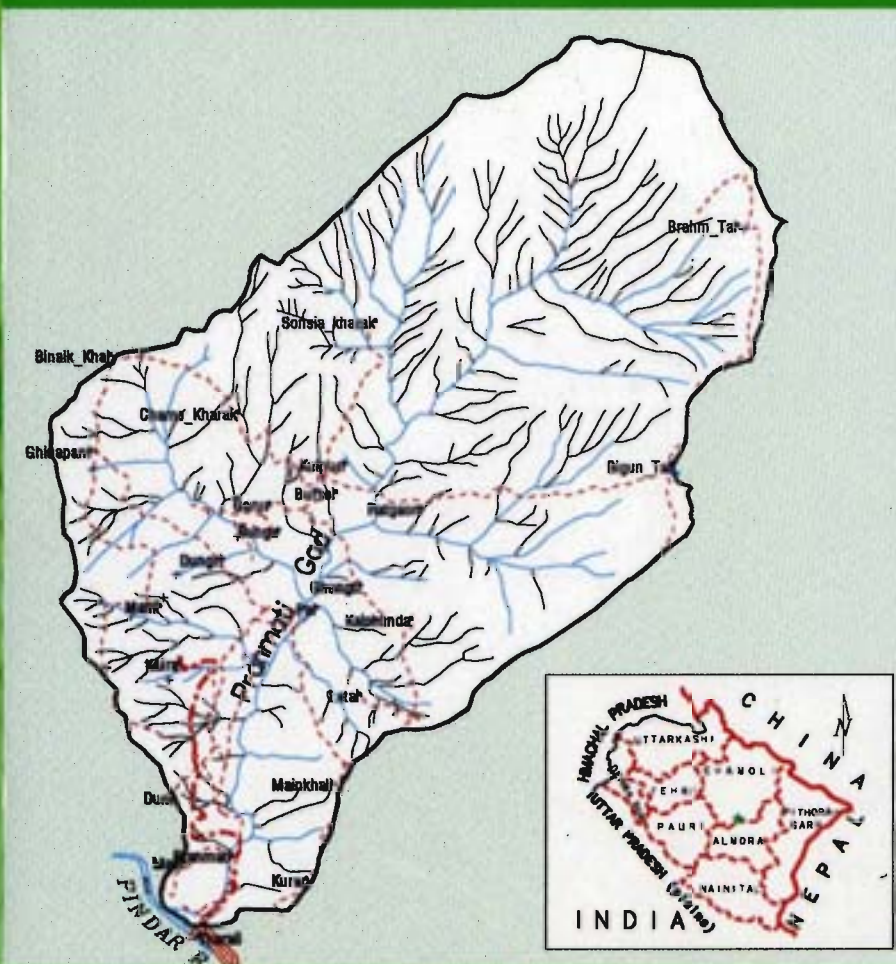


# MENRIS CASE STUDY SERIES

## No. 5

GIS Applications to Natural Resource Management and  
Development Planning in a Rural Area -  
Pranmati Watershed Garhwal Himalayas, India



**International Centre for Integrated Mountain Development**

Mountain Environment and Natural Resources' Information Service (MENRIS)

Kathmandu

July 1997

Copyright © 1997

International Centre for Integrated Mountain Development

All rights reserved

Cover photo: Map of Pranmati Watershed

Inset: IRS - 1B Satellite Image of Pranmati Watershed

**Published by**

International Centre for Integrated Mountain Development  
G.P.O. Box 3226  
Kathmandu, Nepal

**ISSN 1021 - 6529**

**Typesetting at** ICIMOD Publications' Unit

The views and interpretations in this paper are those of the author(s). They are not attributable to the International Centre for Integrated Mountain Development (ICIMOD) and do not imply the expression of any opinion concerning the legal status of any country, territory, city or area of its authorities, or concerning the delimitation of its frontiers or boundaries.

# **MENRIS CASE STUDY SERIES No. 5**

## **GIS Applications to Natural Resource Management and Development Planning in a Rural Area — Pranmati Watershed Garhwal Himalayas, India**

PREPARED by

**Ghosh, S., SEN, K.K., RANA, U., RAO, K.S., AND SAXENA, K.G.**

**International Centre for Integrated Mountain Development (ICIMOD)  
Mountain Environment and Natural Resources' Information Service (MENRIS)**

**Kathmandu  
July 1997**

## FOREWORD

In the complex mountain environment of the Hindu Kush-Himalayas, development planning and decision-making for watersheds needs an integrated method of collecting, storing, and using information which is both concomitant and discrete.

Geographic Information Systems and Remote Sensing (GIS/RS) technologies are powerful tools that can improve the information base essential for sustainable mountain development. The strength of GIS/RS lies in their ability to integrate data and information on different subjects and from different sources using a common geographical reference. Since 1989, ICIMOD has developed a strong capability in the fields of GIS/RS through its Mountain Environment and Natural Resources' Information Service (MENRIS). Since the establishment of MENRIS, the G.B. Pant Institute of Himalayan Environment and Development (GBPIHED) has been a major partner in disseminating GIS/RS technologies in the Indian HKH region. The present case study provides a good example of application of GIS and Remote Sensing technologies for watershed development planning. The study demonstrates the power of such a technology to integrate and assimilate data from various sources, e.g., satellite images, census data, and field observations.

In the present study, the Pranmati Watershed, a representative micro-watershed, has been selected to depict the GIS/RS applications in natural resource management for watershed development planning. The Pranmati Watershed is based in the Ganges' system in Chamoli District of Uttar Pradesh in the Garhwal Himalayas. The text describes different aspects of GIS applications to natural resources' management and development planning. These applications are developed mainly for watersheds and village-level planning but could also be extended to any other unit.

This study is the result of a joint effort of the Norwegian Agency for Development Cooperation (NORAD), the Norwegian Agency for International Agricultural Development (NORAGRIC), the GBPIHED, the United Nations Environment Programme-Environment Assessment Programme-Asia and Pacific (UNEP-EAP-AP), and ICIMOD.

We express our sincere gratitude to NORAD, NORAGRIC, GBPIHED and UNEP-EAP-AP for infrastructural and financial support to this study. We wish to acknowledge the support extended by these and various other organisations whose officials and individuals have been of great assistance in the completion of this work.

Prior to this case study, ICIMOD published 'Applications of GIS for Natural Resource Management in Dhading District, Nepal' in 1992. It illustrated basic concepts and the use of GIS to demonstrate how data integration enables decision-makers and development planners to improve the management of natural resources. The second case study 'Application of GIS to Rural Development Planning in Nepal' was published in 1994. The illustrations presented both basic and advanced use of GIS and Remote Sensing applications in several districts of Nepal. The third case study was published in 1995, namely, 'Application of GIS for Planning Agricultural Development in Gorkha District of Nepal'. This study illustrated how decision-makers can (a) arrive at improved depictions of existing natural resources and infrastructure, (b) integrate natural science and socioeconomic data, and (3) use the information thus gained for improved area-specific planning and programme monitoring. The fourth case study 'Lamjung District Information System for Local Planning and Assessment of Natural Resources Using GIS and RS Technology' was published in 1996 and provides an extension to GIS knowledge and applications achieved in the previous three case studies. This fifth case study is the first depicting such applications in the Indian context.

Ghosh, S., Sen, K.K., Rana, U., Rao, K.S., and Saxena, K.G. from the G.B. Pant Institute of Himalayan Environment and Development (GBPIHED) are the primary authors of this study and have made an excellent contribution in preparing the final report. From MENRIS, Basanta Shrestha, Birendra Bajracharya, Govinda Joshi, and Mona Thapa provided assistance and support. Professor A.N. Purohit, ICIMOD Board Member and Ex-Director of GBPIHED, and Dr. L.M.S. Palni, Director of the GBPIHED, have been key mentors for this work. On behalf of ICIMOD we would like to thank them all for their contributions and the people of the Pranmati Watershed Area and various government/non-government officials for their cooperation. We would also like to express our sincere appreciation of the efforts made by Greta Rana and her editorial staff in preparing this document for publication.

Pramod Pradhan  
Head  
MENRIS/ICIMOD

Egbert Pelinck  
Director General  
ICIMOD

# CONTENTS

|  |           |
|--|-----------|
| <b>CHAPTER 1: MANAGEMENT AND RURAL DEVELOPMENT OF PRANMATI WATERSHED</b>                       | <b>1</b>  |
| 1.1 Introduction   | 1         |
| 1.2 Description of the Study Area  | 1         |
| 1.3 Approach   | 2         |
| <b>CHAPTER 2: DATABASE DEVELOPMENT AND MANAGEMENT FOR MICRO-LEVEL DEVELOPMENT PLANNING</b>     | <b>3</b>  |
| 2.1 Introduction   | 3         |
| 2.2 Methodology  | 3         |
| 2.3 Results  | 4         |
| 2.4 Conclusions  | 7         |
| <b>CHAPTER 3: GIS APPLICATIONS IN MONITORING LAND-COVER / LAND-USE CHANGES</b>                 | <b>9</b>  |
| 3.1 Introduction   | 9         |
| 3.2 Methodology  | 9         |
| 3.2.1 Building the Database  | 9         |
| 3.2.2 Data Processing and Information Input  | 10        |
| 3.2.3 Methods of Analysis  | 10        |
| 3.3 Results  | 10        |
| 3.4 Conclusions  | 12        |
| <b>CHAPTER 4: APPLICATION OF GIS AND REMOTE-SENSING TECHNOLOGIES TO FOREST MANAGEMENT</b>      | <b>13</b> |
| 4.1 Introduction   | 13        |
| 4.2 Methodology  | 14        |
| 4.3 Results  | 15        |
| 4.4 Conclusions  | 16        |
| <b>CHAPTER 5: APPLICATION OF GIS FOR AGRICULTURAL DEVELOPMENT</b>                              | <b>17</b> |
| 5.1 Introduction   | 17        |
| 5.2 Methodology  | 18        |
| 5.3 Results  | 18        |
| 5.4 Conclusions  | 21        |
| <b>CHAPTER 6: POTENTIAL OF GIS TECHNOLOGY FOR MONITORING IMPACTS OF DEVELOPMENT ACTIVITIES</b> | <b>23</b> |
| 6.1 Introduction   | 23        |
| 6.2 Methodology  | 24        |
| <i>Methods of Soil Mapping</i>   | 24        |
| <i>Soil Erosion</i>  | 24        |
| <i>Areas Viable to Agricultural Extension</i>  | 24        |
| <i>Erosional Impact of Agricultural Practices</i>  | 25        |
| <i>Micro-hydel Proposal</i>  | 25        |
| <i>Road Feasibility Study</i>  | 26        |
| 6.3 Results  | 26        |
| <i>Micro-hydels and Water Mills</i>  | 26        |
| <i>Road Construction</i>   | 26        |

|  |           |
|--|-----------|
| <i>Food Processing</i>                     | 27        |
| <i>Agroforestry, Fodder, Fuelwood</i>      | 27        |
| <i>Support Services and Infrastructure</i> | 27        |
| <b>6.4 Conclusions</b>                     | <b>27</b> |
| <b>Bibliography</b>                        | <b>29</b> |

**LIST OF MAPS** **31**

|    |  |           |
|----|--|-----------|
| 1  | <b>General Features and Location (inset)</b>                           | <b>33</b> |
| 2  | <b>Altitudinal Zones</b>   | <b>35</b> |
| 3  | <b>Average Slope Classes</b>   | <b>37</b> |
| 4  | <b>Topographic Aspect</b>  | <b>39</b> |
| 5  | <b>Population Density (1991)</b>                                       | <b>41</b> |
| 6  | <b>Population Growth (1981-91)</b>                                     | <b>43</b> |
| 7  | <b>Land Use and Land Cover (1963)</b>                                  | <b>45</b> |
| 8  | <b>Major Land-use Changes (1963-93)</b>                                | <b>47</b> |
| 9  | <b>Land Vulnerable to Accelerated Erosion</b>                          | <b>49</b> |
| 10 | <b>Land-use Changes in the Buffer Zone of Settlements (1963-93)</b>    | <b>51</b> |
| 11 | <b>Biotic Niches</b>   | <b>53</b> |
| 12 | <b>Vegetation Types and Land Use (1993)</b>                            | <b>55</b> |
| 13 | <b>Forest Classes</b>  | <b>57</b> |
| 14 | <b>Degraded Forests</b>  | <b>59</b> |
| 15 | <b>Crop Rotation Zones</b>   | <b>61</b> |
| 16 | <b>Agricultural Land in Different Slope Classes (1993)</b>             | <b>63</b> |
| 17 | <b>Agricultural Land in Different Slope Aspects (1993)</b>             | <b>65</b> |
| 18 | <b>Extension of Agriculture in Different Slope Classes (1963-93)</b>   | <b>67</b> |
| 19 | <b>Extension of Agriculture in Different Slope Aspects (1963-93)</b>   | <b>69</b> |
| 20 | <b>Agricultural Extension in Different Bioclimatic Zones (1963-93)</b> | <b>71</b> |
| 21 | <b>Suitability Classification of Agricultural Land</b>                 | <b>73</b> |
| 22 | <b>Soil Types in Agricultural Land</b>                                 | <b>75</b> |
| 23 | <b>Areas Viable to Agricultural Extension</b>                          | <b>77</b> |
| 24 | <b>Proposed and Operational Micro-hydel and Water Mills</b>            | <b>79</b> |
| 25 | <b>Erosional Impact of Proposed Motor Roads</b>                        | <b>81</b> |
| 26 | <b>Schools and Hospitals (1993)</b>                                    | <b>83</b> |

**LIST OF TABLES**

|     |   |           |
|-----|---|-----------|
| 1.  | <b>Distribution of Watershed Area in Different Average Slope Classes</b>  | <b>5</b>  |
| 2.  | <b>Distribution of Watershed Area in Different Slope Aspects</b>  | <b>5</b>  |
| 3.  | <b>Land-use / Land-cover in 1963</b>  | <b>11</b> |
| 4.  | <b>Land-use / Land-cover in 1993</b>  | <b>11</b> |
| 5.  | <b>Land-use and Land-cover Changes 1963-93</b>  | <b>11</b> |
| 6.  | <b>Extent of Deforestation (1963-93)</b>  | <b>15</b> |
| 7.  | <b>Vegetation Types Interpreted through Visual Interpretation of an RS Image from 1993 - Supported by Field Study</b>   | <b>15</b> |
| 8.  | <b>Extent of Forest Regeneration (1963-93)</b>  | <b>16</b> |
| 9.  | <b>Distribution of Land Use and Vegetation Types in the Different Forest Classes (Based on 1993 RS Interpreted Vegetation Distribution and FD boundaries)</b> | <b>16</b> |
| 10. | <b>Distribution of Agricultural Land in Different Elevation Zones 1993</b>  | <b>18</b> |

|  |    |
|--|----|
| 11. Distribution of Agricultural Land in Different Average Slope Classes in 1993 | 19 |
| 12. Distribution of Agricultural Land in Different Topographic Aspects 1993      | 19 |
| 13. Extension of Agricultural Land in Different Elevation Zones (1963-93)        | 19 |
| 14. Extension of Agricultural Land in Different Average Slope Classes (1963-93)  | 19 |
| 15. Extension of Agricultural Land in Different Topographic Aspects (1963-93)    | 19 |

#### LIST OF PLATES

|   |    |
|---|----|
| 1. A general view of the watershed landscape of Pranmati at mid-elevations  | 1  |
| 2. A household in the watershed — the residential quarters are on the first floor and the ground floor is used as a store and cattleshed  | 2  |
| 3. Erosion threatening agricultural activities  | 11 |
| 4. There is plenty of fuelwood, but market forces encourage harvesting for export of even unsplit larger branches/logs  | 13 |
| 5. Export of fuelwood to an urban market  | 13 |
| 6. Trees are lopped excessively to meet the fuel and fodder requirements  | 14 |
| 7. Agricultural fields in broader and gently sloping areas of the watershed after the millet/cereal cropping. The terraces are almost flat here   | 17 |
| 8. Leaf litter from forest floors used as bedding material is removed from cattlesheds and put into the manure pit. It will be used on the agricultural fields eventually.  | 18 |
| 9. Encroachment of open patches in the forests for potato cultivation at higher elevations. The stone wall demarcates the extent of individual encroachments and within are small patches of potatoes.                  | 19 |
| 10. Agricultural fields in narrow and steeply sloping areas of the watershed during millet/cereal cropping. Note that the terraces are outwardly sloping and narrow.  | 25 |
| 11. A micro-hydel introduced by the GPIHED is operated by one of the villagers who has received a significant amount of training. The unit is still functioning.<br>without any support even after two and a half years | 25 |
| 12. Light has brought cheer to this woman and reduced her drudgery. We expect the introduction, of electricity will reduce the pressure on forests and allow their regeneration   | 26 |
| 13. The recent landslide which the proposed road is to pass through. Mules and men face these hurdles to survive.   | 26 |

#### LIST OF FIGURES

|  |    |
|--|----|
| 1. Longitudinal Profile of Pranmati <i>Gad</i> (Stream)          | 5  |
| 2. Area (%) under Crops (above 2,200m)                           | 20 |
| 3. Area (%) under Crops (below 2,200m)                           | 20 |
| 4. Field Soil Loss (kg/ha-1) - Indifferent terrace slope classes | 24 |



## GLOSSARY OF RELEVANT INDIAN AND LOCAL TERMS

|                           |  |
|---------------------------|--|
| <b>Aloo:</b>              | Potato ( <i>Solanum tuberosum</i> ),   |
| <b>Anganbari:</b>         | Kindergarten and mother and child health care centre   |
| <b>Ayurvedic :</b>        | Based on traditional Indian herbal medical science   |
| <b>Banj:</b>              | Oak ( <i>Quercus incana</i> ), ( <i>Quercus dialata</i> / <i>Q. semecarpifolia</i> )   |
| <b>Bhaikal:</b>           | <i>Princepia utilis</i> - an oil-yielding seed   |
| <b>Bhat:</b>              | Beans ( <i>Glycine max</i> )   |
| <b>Bugyal:</b>            | Alpine meadow  |
| <b>Burans:</b>            | Rhododendron ( <i>Rhododendron arboreum</i> )  |
| <b>Chir:</b>              | Pine ( <i>Pinus roxburghii</i> )   |
| <b>Chiradh:</b>           | <i>Litseolea consimilis</i> - an oil-yielding seed   |
| <b>Chua / Ramdana:</b>    | Amaranth ( <i>Amaranthus paniculatus</i> )   |
| <b>Chuli:</b>             | <i>Prunus americana</i> - an oil-yielding seed   |
| <b>Development Block:</b> | Smallest planning unit   |
| <b>Gad:</b>               | Stream or river  |
| <b>Garhwal:</b>           | Western section of the Himalayan region falling within the Uttar Pradesh State in India, its boundary being demarcated by the district boundaries. The region is also populated by <i>Garhwali</i> speaking people.  |
| <b>Gehu:</b>              | Wheat ( <i>Triticum aestivum</i> )   |
| <b>Gram Sabha:</b>        | Village council  |
| <b>Harijan:</b>           | the lowest social caste among Hindus enlisted among the Scheduled Castes by the Government of India  |
| <b>Jau:</b>               | Barley ( <i>Hordeum vulgare</i> )  |
| <b>Jhangora:</b>          | Millet ( <i>Echinicloa colunum</i> )   |
| <b>Lisa:</b>              | Pine resin (commercially tapped)   |
| <b>Mandua:</b>            | Finger millet ( <i>Elusine corcana</i> )   |
| <b>Owa:</b>               | Barley ( <i>Hordeum spp</i> )  |
| <b>Dhan / satti:</b>      | Paddy ( <i>Oryza sativa</i> )  |
| <b>Panchayat:</b>         | Elected body of the Village Council  |
| <b>Panchayat Forest :</b> | Community Forest under the control of the village council ( <i>Gram Sabha</i> ), managed by people's representatives to cater to people's needs. The Forest Department carries the responsibility for providing technical inputs under the administrative control of the Revenue Department. |
| <b>Protected Forest :</b> | A class of forests set apart for environmental considerations.   |
| <b>Rajma:</b>             | Kidney beans ( <i>Phaseolus lunetus</i> )  |
| <b>Reserved Forest:</b>   | Under the control of the Forest Department, which is also in-charge of earning revenue from commercial forests (Class II) and maintaining them to regulate the hydrological balance (Class I).   |
| <b>Ringal :</b>           | Temperate bamboo ( <i>Thamnocalamus spathiflora</i> )  |
| <b>Van Panchayat :</b>    | Forest council consisting of elected members.  |

## ABBREVIATIONS

|             |  |
|-------------|--|
| DBH         | Diameter at breast height (1.52 m)                                     |
| ESRI        | Environmental Systems' Research Institute                              |
| FCC         | False Colour Composite (of image)                                      |
| FSI         | Forest Survey of India   |
| FYM         | Farmyard manure  |
| GBPIHED     | Govind Ballabh Pant Institute of Himalayan Environment and Development |
| GIS         | Geographic Information Systems   |
| ha          | hectares   |
| ICIMOD      | International Centre for Integrated Mountain Development               |
| ID          | Identification number for a specific spatial feature                   |
| IRS         | Indian Remote Sensing Satellite  |
| MENRIS      | Mountain Environment and Natural Resources' Information Service        |
| NGO         | Non-government Organisation  |
| NORAD       | Norwegian Agency for Development Cooperation                           |
| NORAGRIC    | Norwegian Agency for International Agricultural Development            |
| NRSA        | National Remote Sensing Agency   |
| PC          | Personal Computer  |
| RF          | Representative Fraction (scale of map)                                 |
| RMS         | Root Mean Square (error)   |
| RS          | Remote Sensing   |
| SoI         | Survey of India  |
| SML         | Simple Macro Language (of Arc/Info)                                    |
| spp         | Species  |
| TMU         | Terrain Mapping Unit   |
| <i>masl</i> | metres above (mean) sea level  |

N.B. Abbreviated forms of standard units of measurement are not given in the above list.

## DATA SOURCES

- \* Topographical Maps, 1963. Survey of India, Dehradun, India.
- \* FCC IRS-1B L2B 2 MAP-ID: 53N12. NRSA, Hyderabad, India.
- \* Primary Census Abstract, Chamoli District, 1981.
- \* Primary Census Abstract, Chamoli District, 1991.
- \* Rangers' Office, Department of Forests, Tharali, U.P.
- \* Public Works' Department Office, Tharali, U.P.
- \* Primary Data Survey by GBPIHED Team Members (1993-95).