Chapter 3
Application of Geoinformatics for the Integrated Watershed Management and Development Planning, Bal Ganga Basin, Tehri Garhwal (Uttarakhand)

Vijendra Kumar Pandey

Abstract The primary issue of the twenty-first century is optimum utilization of natural resources and sustainable development planning in order to accelerate the pace of socioeconomic development. The key issue of the developing countries is how to address the development of backward region and remote hilly areas. They need specific attention of the decision-makers to cater the rapidly, growing population that has created pressure on shrinking natural resources. It is need of the time to prepare development plans considering the optimal use of resources and its sustainability. Despite remarkable advances in agriculture technology, there is prevalence use of conventional methods of cultivation in the various regions. Either it was because of inadequate resources, undulating terrain, or irascible area. The degradation of natural resources was mainly due to the lack of technological and appropriate methodologies to address these issues. Soil degradation and lack of irrigation facility are the primary aspects liable for poor agricultural growth and productivity. Integrated watershed management approach can effectively resolve the issues of natural resource management, livelihood, food security, and environmental issues. In this study, geoinformatics has been used as tools for the resource prioritization, gap analysis, and development planning of the Bal Ganga watershed. This study is an attempt to check the applicability of geoinformatics techniques in the development planning process and resource optimization. Survey of India topographic sheets has been used to digitalize contours and prepare digital elevation model that was used for the physiographic analysis in the ArcGIS software. The watershed is assumed as a hydrologic unit which controls the ecological processes, such as soil and water resources. Bal Ganga Basin has the potential for higher agriculture growth with the optimal use of resources. The watershed is situated in the Lesser Himalayas; there is eminence effect of physiographic control on the land use practices. Thematic layers such as slope condition, aspect, types of soil, and soil depth are the essential

V. K. Pandey (✉)
Center for the Study of Regional Development, School of Social Sciences, Jawaharlal Nehru University, New Delhi, India

P. Kumar et al. (eds.), *Applications and Challenges of Geospatial Technology*,
https://doi.org/10.1007/978-3-319-99882-4_3

parameters that affect crops growth were prepared in the GIS environment and prioritized for the development planning. These independent variables are prepared using ArcGIS 9.3, and land use capability was delineated for the suitable area of cultivation. Demographic data of the villages and socioeconomic variables has been attached, and level of development has been analyzed. As per the analysis of potential resource region, cultivation zone has been identified for comprehensive land use planning.

Keywords Geoinformatics · Integrated watershed development · Land degradation · Resource region · Uttarakhand

3.1 Introduction

The watershed management approach has become an increasingly significant question in the developing countries (Bulkley 1977). This is stimulated by government departments as well as nongovernmental organizations to find out suitable management methodologies for the aggregate productivity of natural resources (Ratna Reddy et al. 2017). The main approaches which are related to watershed management have experienced a paradigm shift during the past few decades. Thoguh, there is no universal methodology that has been developed for attaining watershed management (Nath Roy 2005; Chowdary et al. 2009). The significant advance in the watershed management approach is community participation (Wani and Garg 2008; Thapa 2000; Saravanan 2002; Pirani and Mousavi 2016; Johnson et al. 2001; Batabyal 2002; Arya 2005). Watershed management has gained eminence appreciation in the developing countries for the integrated resource management which will be focused on the livelihood security of the poor. The frequent crops failure due to climatic variability made the situation worse and become difficult to address the situation of large-scale river valley projects forced a paradigm shift from watershed to micro-watershed. It become major concern for the state and community to scripts a new ground for the government towards as a “learning organization” which has thrust to address the changing social order and environmental condition (Eswaran and Samra 1997).

The watershed projects in India have long history implemented during the Vedic period (Bhan 2013). The recent development in the watershed programs in India can be dated back with the implementation of Command Area Development and Water Management (CADWM) program, which initially started during 1974 (NITI Ayog 2015). Further, Drought-Prone Areas Programme (1973–1974) and the Desert Development Programme (1977–1978) were brought into the watershed mode in 1987 (Department of Land Resource, Ministry of Rural Development 2001). The Integrated Wasteland Development Programme (IWDP) was launched in 1989 under the aegis of the National Wasteland Development Board and also aimed the development of wasteland (Department of Land Resource, Ministry of Rural

Development 2003). These three major programs were implemented with watershed development guidelines from 1995 with the National Watershed Development Project in Rainfed Areas (NWDPRA) and the Watershed Development in Shifting Cultivation Areas (WDSCA) (Department of Land Resource, Ministry of Rural Development 2001). The objective of these schemes are to improve the irrigation potential, soil conservation, and utilization and optimize the agricultural production and productivity and promotion of agroforestry through integrated and coordinated approach of efficient watershed management (Department of Land Resource, Ministry of Rural Development 2001; Bhan 2013; Bulkley 1977). Due to the partial success, a new comprehensive scheme "Haryali" was launched during 2003 which has encompassed rainwater harvesting, erosion control, irrigation, and microenterprise as a part of watershed programs (Department of Land Resource, Ministry of Rural Development 2003).

Integrated watershed management (IWM) is considered as optimum approach for improving agricultural productivity in the rain fed or drought-prone regions (Naqvi et al. 2015; Pandey et al. 2007; Pirani and Mousavi 2016; Prasannakumar et al. 2012). It was estimated that India has planned and implemented micro-watershed development programs at large scale (Farrington et al. 1999). The GoI has further implemented Integrated Watershed Management Programme (IWMP) during 2008–2009 (Department of Land Resource, Ministry of Rural Development 2008). The scheme has focused on the selection of micro-watershed and application of *Geoinformatics* for the preparation, implementation, and monitoring of IWMP projects. The objectives of the IWMP are overall development of the micro-watershed and mainly focused on the involvement of community and stakeholders in each stage of the project.

The integrated watershed management programs were strengthened since the 1980s after the successful implementation of Sukhmojari Projects in Haryana (Agarwal and Narain 2010; Arya 2005). It was a an innovative approache to create new functionaries that meant to intensification of community involvement, sustainability of programs, and its impacts on rural livelihood. Many government departments as well as nongovernment organizations have promoted watershed development schemes to address the basic issues with the objectives of soil conservation, soil erosion, water harvesting, afforestation, and encouraging suitable technologies for the resourceful and sustainable use of natural resources. However, many of these watershed projects have not achieved the desired objectives, due to the poor community participation (Johnson et al. 2001; Wani and Garg 2008; Thapa 2000; Village et al. 1990; Wani et al. 2014).

The development of watershed management approach in India has significantly evolved in the last two decades. During the first phase, it was primarily based on the physical parameters and conservation of natural resources. In the late 1990s, there was a significant paradigm shift observed in the watershed management approach. The watershed approaches not only were included in the conservation of natural resources but also focused on the increasing productivity of natural resources and optimum utilization with active people participation (Wani et al. 2014; Tennyson and White 2005). It was also adopted that modern tools and techniques for sustainable utilization and better coordination were found between the government agencies. The development of remote sensing technology and geographic information system (GIS) has added a new dimension to the watershed development planning (Tim and Mallavaram 2003; Pandey et al. 2007; Murty 1998; Khan et al. 2001; Hiese et al. 2011; Gosain and Rao 2004; Abdelrahman et al. 2016). The geoinformatics tools have proved to be a catalyst for the analysis of geophysical parameters such as estimation of soil erosion, water conservation, forest loss, and land use changes in the watershed (Al-Nasrawi et al. 2016; Bhaduri et al. 2000; Gosain and Rao 2004; Naqvi et al. 2015; Prasannakumar et al. 2012; Pandey et al. 2007). The availability of global digital elevation model (GDEMs) and Google Earth images has promoted the use of technology to address the issues and progression toward the development of Civil GIS (Al-Nasrawi et al. 2016; Hiese et al. 2011).

The main issues of the twenty-first century are food security, drinking water, and environmental attributes (Schmidhuber and Tubiello 2007). The technological advances which were made in the agricultural apparatuses, many of the countries around the world are unable to keep up with the fast paced food production and increasing population. Stagnation or deterioration in agricultural production can be due to excess use of fertilizer, degradation of soil and irrigation facility, and lack of knowledge about soil fertility restoration methods. It was required to provide appropriate training and demonstration to the farmers about new farming methods to address the basic issue of resource management and to increase agricultural productivity. The water scarcity is increased in the hilly areas where sufficient precipitation occurs in the form of snowfall and rain. This is because of the lack of water harvesting approach and deterioration of water quality. This also has negative impacts on soils and land resources and potential risks of the enhanced deterioration of the environment (Kukal and Bawa 2013; Khan et al. 2001; Dhruvanarayana and Babu 1983; Nath Roy 2005). The study aims to explore the application areas of geoinformatics technique for the watershed management, prioritization of the issues, and needs and gap analysis for sustainability in the hilly terrain of Uttarakhand.

3.1.1 Why Watershed

Watershed is a well-defined area or catchment, which drains through a common outlet. It is geographically delineated from the interfluve or water divide. Watershed includes detailed characteristics of soils, landforms, vegetation, and land use. Hydrologic processes within the watershed which are infiltration, runoff, subsurface flow, and evapotranspiration are interlinked and can be appropriately assessed. It is a basic hydrologic unit to study biophysical parameters of the region to prepare development plans (Pirani and Mousavi 2016). Each watershed has a unique physical setting which requires specific attention to address the problems. These could be soil erosion processes and transport of nutrients and pollutants by surface and subsurface flow of water within the watershed. The surface runoff is directly related to topography, slope length, and gradient as well as the direction which influences geochemical process (Reddy et al. 2004). The fluvial processes show watershed physical and vegetative characteristics controlling erosion and minimizing land degradation, vegetative loss, and water quality. These issues require a holistic approach to understand the hydrologic processes at watershed level in order to check the process and approaches to manage it. Soil degradation is a physical process that has positive impacts on anthropogenic activity such as land use practices. Deforestation and water scarcity need to be addressed with land degradation to improve the geophysical environment within a watershed. Therefore, the watershed is a basic unit for the sustainable development planning (Pirani and Mousavi 2016; Reddy et al. 2004; Saravanan 2002; Schmidhuber and Tubiello 2007).

3.1.2 Natural Resource Degradation

The degradation of soil and water resources has been very crucial and considered as a global risk (Oldeman 1994). Due to the degradation, lands lost productive capacity. The sources which degraded lands are wind and water. These two account for the 82% (250 out of 305 Mha) of the total degraded area (Oldeman 1994). In order to check the soil erosion, drainage, and slope gradient, relationship-based strategy is required in a catchment area. The watershed management approach in this regard is very useful to effectively address the erosion processes and also restoration of degraded land. A watershed is geographic unit which can be used as an ideal unit to study the degradation process and decreasing productivity of natural resources. The lack of adequate management techniques for the natural resources, which are fragile, can cause deterioration of environments (Saravanan 2002). The quality of life and livelihood of people are strongly interlinked with the natural resources quality and function of the watershed. If the soil resources are good, its productivity is higher which sustains livelihood pattern of people residing in the particular watershed. In India, average soil loss was estimated at 16.5 ton/ha/year (Dhruvanarayana and Babu 1983). Sedimentation rate of reservoirs of Indian subcontinent has been examined to be 2–20 times more than that these were predicted during the design stage (Galay and Evans 1989). The average annual soil loss is calculated ranging from 21 to 555 ton/ha/year for the Asian rivers (Holeman 1968).

3.2 Study Area

The Bal Ganga is a right bank tributary of Bhilangna River which itself is an important tributary of the Bhagirathi River. It originates near a peak (4846 mts) opposite of Shastru Tal in the district of Tehri Garhwal. The geographical location of the watershed is 78° 32′ 37″ E longitude 30° 25’ 42″ N latitude to 78° 49′ 5″ E longitude to 30° 43’ 16″ N latitude (Fig. 3.1). The watershed covers part of Ghansali and Pratap Nagar Tehsil. Bal Ganga is remarkably known for its flat summit surface near Chamiyala which is a town and market of the area. The climate of the area is varied to subtropical in the valley to cold temperate on the upper reaches. January is

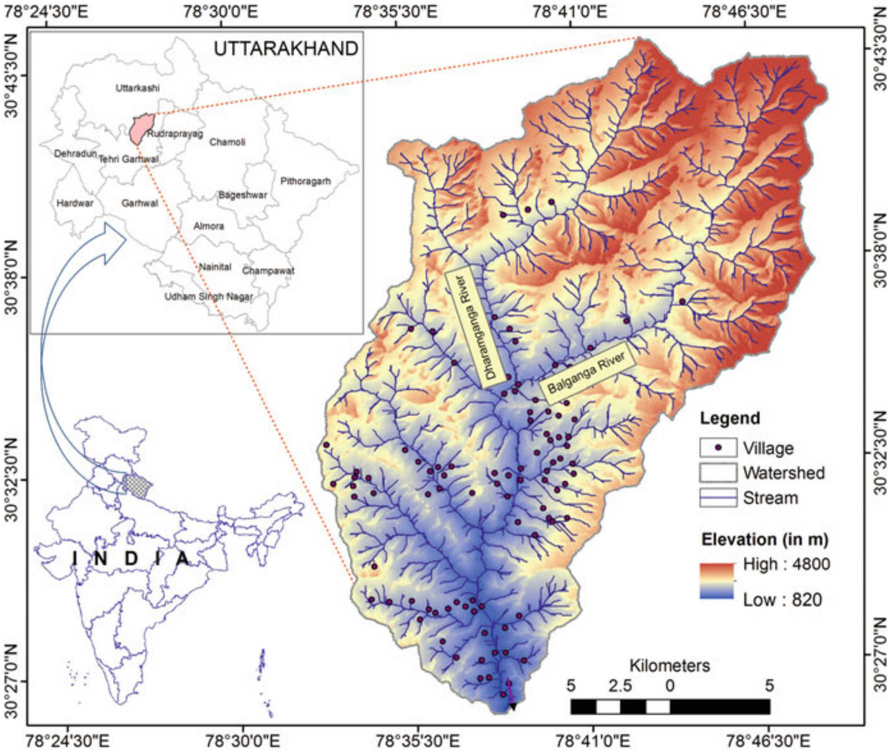

Fig. 3.1 Location map of the Balganga Basin, District Tehri Garhwal (Uttarakhand)

the coldest and June is the warmest month in the area. Mean temperature of the warmest months is recorded 32 °C and coldest months 19.6 °C. Relative humidity touches to 85.6% in the monsoon season. Approximately 85% rainfall is received in monsoon season (July–September) in the study area. Winter rainfall is also associated with the passage of the western disturbances and is in the form of snowfall on higher elevations. The average annual rainfall in the district is 1395 mm which occur in 87 rainy days (Indian Meteorological Department).

In the present study, 96 villages were studied of Pratapnagar Tehsil of Tehri Garhwal district. Total population of the study area is 34,081 persons with a population density of 45 persons/km^2. The number of household resides in these 96 villages is 6250.

3.3 Materials and Method

To achieve the objectives of the present study, it is necessary to choose an appropriate methodology. There are a number of digital elevation models (DEMs) and satellite images that were available in the open-source domain (Table 3.1). In order

Table 3.1 Database and software available for geoinformatics applications

Type of database	Data source	Spatial resolution	Applications	Web links
DEMs	SRTM	90 m	Topographic analysis	https://earthexplorer.usgs.gov
	ASTER	30 m		https://earthexplorer.usgs.gov
	CartoDEM	30 m		http://bhuvan.nrsc.gov.in/data
	GEOTOPO30	30 m		https://earthexplorer.usgs.gov
Satellite image	Landsat 8	30 m (*15* m panchromatic)	Land use/land cover, infrastructures and utilities, etc.	*glovis*.usgs.gov
	Sentinel 2	10 m		https://earthexplorer.usgs.gov
	IRS AWiFS	56 m		http://bhuvan.nrsc.gov.in/data
	IRS LISS-3	23.5 m		http://bhuvan.nrsc.gov.in/data

to prepare physiographic analysis survey of India topographic sheets and SRTM, 1-arc v.3 DEMs (digital elevation models) were used. ArcGIS 10.3 software was used for the DEM processing, and satellite imageries were analyzed using Erdas Imagine 14.0 software. Rainfall and temperature data and other ancillary data have been procured from the various sources of the study area. The base map was prepared on RF 1:12,500 scales. Survey of India topographic sheets was used to digitize contours, drainage, and other infrastructures for the development planning. DEM (digital elevation model) of the area is prepared from contour map and also used for the preparation of slope, aspect, and relief maps. Land use/land cover of the area was extracted using the satellite images. Soil map was prepared from the National Bureau of Soil Survey and Land Use Planning (NBSS&LUP). Google Earth images were used to geo-rectify cadaster map on RF 1:4000 for the IWMP and resource management.

3.3.1 Physiography Variables

Bal Ganga basin lies in the Lesser Himalayan range having rugged topography. Minimum elevation of the watershed is 820 m at the confluence with Bhilangana River, and the highest elevation is 4780 m at the peak summit which separates the watershed (Fig. 3.2a). It has unique topography as high undulating peak, wide flat surface in the middle of the watershed, and narrow outlet. In the middle part of the basin, there is wide and flat river terrace deposited by fluvial processes.

Slope gradient is an important factor which controls human interface to the environment. According to the s Slope inclination, controls the human activity and reaching a particular point, it seeded. Average slope inclination of the area is varying from 10 to 30° which are categorized at moderate slope category. Low slope angle covers around 3% area (Fig. 3.2b). The total area of low and moderately inclined slope accounts 63% area of the watershed. Particularly, this slope category is used for plantation and growing crops. Subsequently, moderate-high slope covers 31% area and high slope angle which is 40–60° inclination covers around 5% area of watershed (Table 3.2).

Aspect is a very important physical factor which regulates geo-environmental process in the hilly area (Fig. 3.2c). It is slope direction toward the sun. This gives details about the average sunshine hours to the slope and also one of the important agents that control physical weathering process. This is also important for the growing crops in the hill tract.

Geomorphology is confined to the process that is operating on the surface of the area. It could be fluvial, glacial, and aeolian in the hilly area. Most of the terrain of the watershed is moderately dissected followed by very highly dissected according to the coverage of the area. Highly dissected slope shows high land degradation and covered by exposed rocky surface often sometime by sparse vegetation. River terrace is best used for growing crops in the area. Rice cultivation is done on the floodplain and terraces.

3.3.2 Soil

The soil is basic element for the development of a watershed. The soil of Bal Ganga watershed has been classified as per multiple criteria such as soil depth; soil texture; sand, silt, and clay composition; and soil structures (Fig. 3.2d). This has also included soil fertility. The soil of valley floor is more fertile and has good depth. The soil of upper slope has low soil depth and poor textures.

3.3.3 Land Use/Land Cover

Land use/land cover of the watershed has been changed significantly over a period of time. The land use map prepared using topographic map being prepared by Survey of India, surveyed during 1962–1963, has shown some contrasting result in comparison to the satellite imagery dated 16 April 2006 IRS LISS III, path 046, row 097. Table 3.2 shows that cultivated land has been decreased around 2.5%, and further decreases have been noticed in the forest area near about 4% (Table 3.3). These changes have been directly related to land degradation as the area under barren land

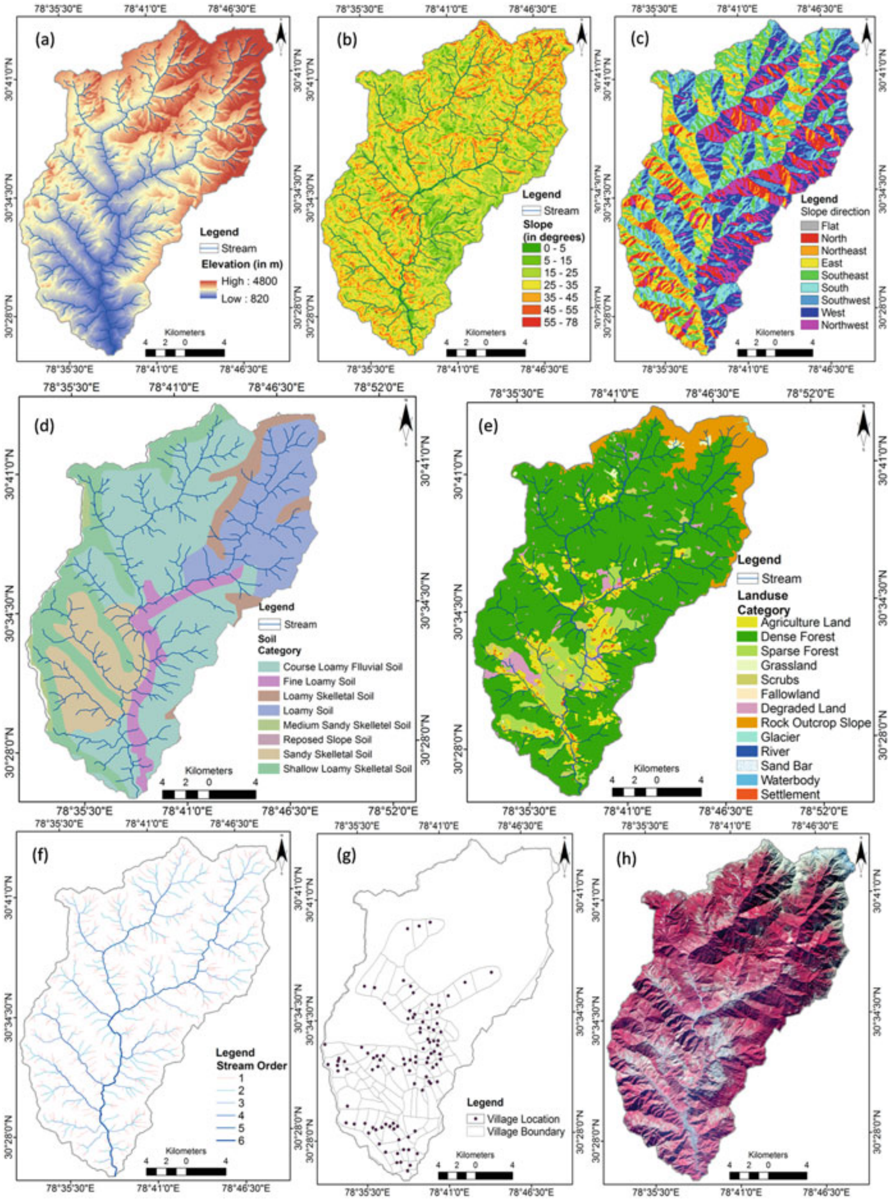

Fig. 3.2 Physiographic variables of the study area: (**a**) physiography; (**b**) slope; (**c**) aspect; (**d**) soil; (**e**) land use and land cover; (**f**) drainage network; (**g**) village boundary and location of settlement; and (**h**) false color composite (FCC) satellite imagery showing vegetation cover

Table 3.2 Slope distribution of the Bal Ganga watershed

S. No.	Slope category	Description	Area (km^2)	% Area
1	< 10	Gentle	19.15	3.93
2	10–20	Moderate	101.82	20.88
3	20–30		190.88	39.14
4	30–40	Moderately high	150.53	30.87
5	40–50	High	23.93	4.91
6	50–60		1.24	0.26
7	> 60	Very high	0.11	0.02
Total			487.66	100.00

Table 3.3 Land use changes in Bal Ganga watershed

Land use based on topographic sheet (1962–1963)			Land use based on imagery (2006)		
Class name	Area (km^2)	% area	Class name	Area (km^2)	% area
River	1.63	0.33	Waterbodies	0.82	0.17
Inland water	0.04	0.01			
Open area	54.83	11.27	Open area	40.34	8.27
Quasi open	17.95	3.69			
Alpine grasses	2.22	0.46	Scrubs	28.57	5.86
Forest	314.94	64.72	Forest	335.14	68.72
Dense forest	17.87	3.67			
Cultivated land	62.98	12.94	Cultivated land	76.91	15.77
Settlement	1.38	0.28	Settlement	4.74	0.97
Landslides	3.27	0.67	Rocky slope	1.16	0.24
Glaciers/snow covered	10.42	2.14			
Total	487.53	100.00	Total	487.67	100.00

(open area) has increased 8.27–11.27% (Fig. 3.2e). Those areas have been classified as scrubs in 1962–1963 presently classified as separating alpine grasses and scrubs. Some new category has also been introduced to improve the classification processes.

3.3.4 Drainage Network

Dendritic drainage pattern is observed in the watershed (Fig. 3.2f). It shows uniform lithology and bedding plane. The major right bank tributary is Dharamganga, Medh Gad, Gangadd Gad, and Argad Gad. Left bank streams are Jandria and Ghatu Gad which pours water into the Bal Ganga.

3.3.5 Villages

In the Bal Ganga watershed, villages are located in two major clusters. First, villages are situated along the river valley, terraces, and moderately sloping surfaces which are suitable for cultivation and construction of houses and road networks. Approximately, 97 villages are located in the watershed, which is found in a clusters (Fig. 3.2g). The first is located between Chakrushera village and Jyondana village, and the second cluster is located between Gajwan Gaon village and Koti village. The average village population size is 350 people.

3.3.6 Road Network

Villages of the watershed are connected with pucca road categorized as district and link road. These roads run along the Bal Ganga River starting from Ghansali town to Budha Kedar village (confluence at Bal Ganga and Dharamganga River). Other villages have recently connected with road constructed under Pradhan Mantri Gram Sadak Yojana (PMGSY). These roads are constructed by local PWD divisions. The major roads run through the valley can be seen in the satellite images (Fig. 3.2h).

3.4 Integrated Resource Planning

The approaches of integrated watershed studies have gained momentum because it evolves multiple problem solution environments within a catchment. It was observed that natural processes are interlinked together and need a comprehensive approach to address the issues. It was noted in the study area that in upper catchment area due to the steep slope and denudation, land degradation is prevalent. Mass movements induced by the torrential streams devastate forest, soil, and economic resources. In the river valley, scarcity of water for irrigation has persisted. Land degradation is directly related to soil erosion, high-velocity surface runoff, and vegetation damage, particularly on the upper reaches. On the other side, these are related to slope inclination, forest species composition, and institutional frameworks regulating use of the natural resources. The barren slope which is exposed to the natural process of denudation is most vulnerable to land degradation rather than the vegetated surface. The main forces in mountain area of the land surface transformation processes are physiography and climate. These forces influence works differently and sometimes individually or in combinations to the biophysical environment of the watershed. In this regard, a combined approach has been required to solve the problems (Fig. 3.3).

The effective implementation of watershed plans and management strategies depends on the efficiency of institutions and community participation. Comprehensive development plans have been prepared for the study area using problem solution

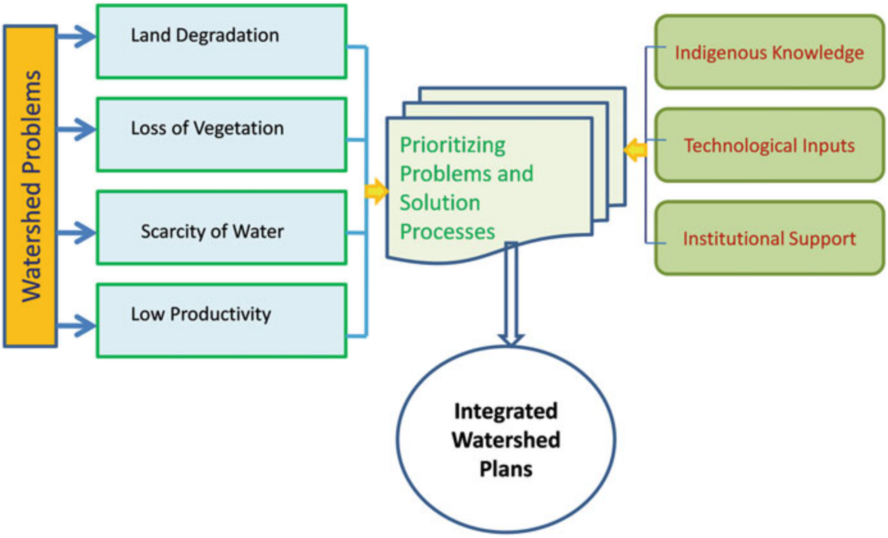

Fig. 3.3 Flowchart for the integrated watershed management planning and resource prioritization

matrix. Land capability classes have been prepared for the area to identify a suitable area of cultivation. It was also analyzed to prepare development according to the feasibility and level of economic development. Community participation was ensured to study the local issues, their priorities, and indigenous knowledge to tackle the issues with the sustainability of the project (Fig. 3.4). In this study, physiographic variables such as physiography, slope, aspect, soil, and drainage were analyzed to prepare land capability classification of the area using geoinformatics techniques. Land use/land cover map was prepared to understand the present scenario of primary activities in the area, influencing the environment. GIS techniques prove a panacea for the integrated watershed management. Topographic analysis, cadaster map digitalization, and preparation of development to implementation of land management as well as monitoring using the satellite imagery can be effectively done. All the biophysical layers and resource prioritization were overlaid in the GIS environment, and optimum regions were identified for the development planning.

The Bal Ganga watershed was divided into three principle zones based on the resource prioritization and identification of the main problems and suggests effective measures (Fig. 3.5). During the field visits, it was assessed that due to the topographic constraints, upper reaches were barren land and fallow land. Mostly, community grasslands were found on the upper reaches slope that were used for the fodder. In the discussions with the community, it was noted that these areas were earlier used for agriculture, but due to drying up of springs and streams, scarcity of water for irrigation facility turned these areas into fallow lands. If the irrigation facility is available, these areas can be used for cropping. Forest on the lower slope covered the first zone, and upper reaches are barren land (Fig. 3.6). These areas have vast potential for off-season vegetables and herbals and aromatic plants. Villagers

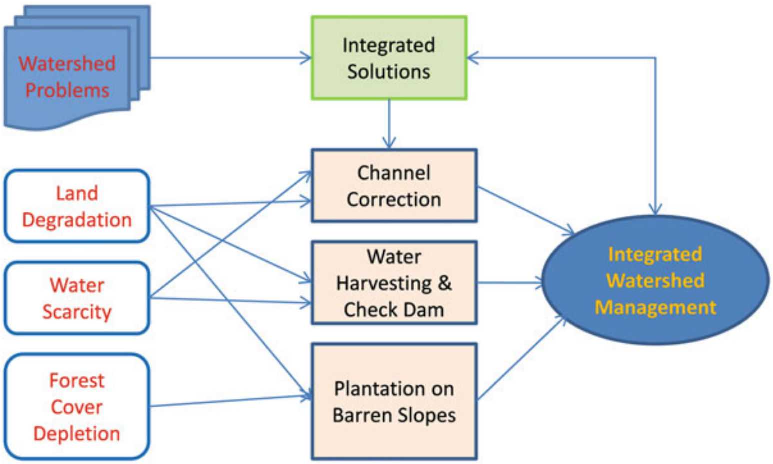

Fig. 3.4 Watershed issues and challenges and approaches to address the problems for the sustainable development planning

Fig. 3.5 (**a**) Broad Bal Ganga valley used for intensive cultivation; (**b**) debris fall damaging forests; (**c**) high-tech nursery promoting community as well as departmental afforestation program; and (**d**) Boorha Kedar temple situated at the confluence of Bal Ganga and Dharamganga river

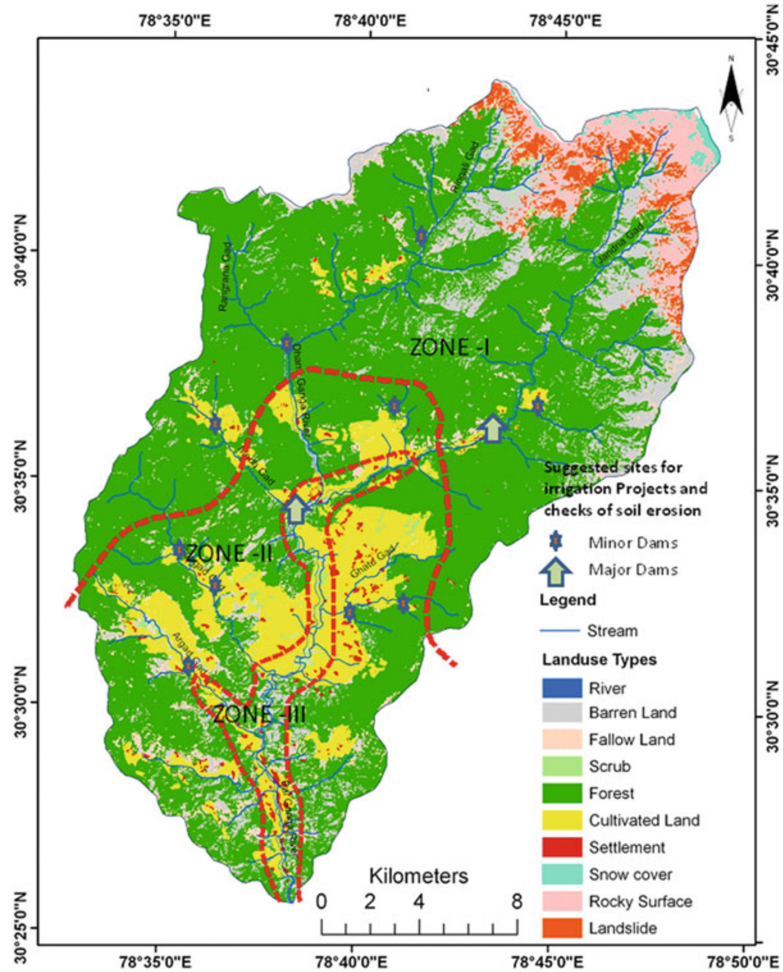

Fig. 3.6 Resource planning and development zones prepared for the IWMP

were very keen if the government agency will help them for the water resource conservation using check dams and small ponds. This water can be used for irrigation of crops and drinking water. Some villagers have told that during pre-monsoon months, they face acute shortage of drinking water. These barren lands are the source of land degradation during the monsoon season. This causes havoc on the lower slopes and in the river valleys. Slope failures, soil erosion, and vegetation loss are the main issues in this zone. In order to minimize the effect of channel correction and plantation, check dams have been suggested.

Second zones have major problems of soil erosion, land degradation, forest loss, etc. These have economic values and very important for the prosperity of the watershed. It requires a scientific approach to agriculture practices, community plantation, and awareness among individuals about social forestry on the barren and fallow land. Third zones witness severe flash floods during monsoon season due to sudden catastrophic rainfall. The area also witness landsliding that dispalce slope materials and causes debris deposits is other issues which are being a concern as it helps to floods and erodes fertile soil of the valleys.

3.5 Conclusions

This paper is an attempt to raise the issues, challenges, and potentialities of the watershed development planning which could be studied and managed in an efficient way using the geoinformatics technique. Land degradation, soil erosion, and scarcity of water and forest damages are interlinked in such a way that a holistic approach is needed to solve these issues. Land degradation is not only deteriorating the soil and decreasing the farm production but also overall natural resource productivity which could lead a region toward prosperity. How the topographic variable influences the approaches to implement integrated watershed management within a watershed can be prioritized using the GIS techniques. Physiography, slope, soil, forest, and drainages can be integrated to prepare development plans for the watershed level. In order to implement any project successfully, community participations and change of approaches in both the community and institution are required working together in coordination to sustain ecology and natural resources. Community participation and institutional cooperation has been highlighted to effectively manage the natural resources. Considering the step-by-step approaches to study different stages of watershed planning and implementation, geoinformatics techniques can play a crucial role, particularly in the hilly areas. The paper explains key challenges which are needed to be addressed and methods to be applied for the community participation and institutional integration.

Acknowledgment I would like to thank the District Administration, Tehri Garhwal, for their kind support during the field visits and providing the required data. The author also acknowledges the USGS for the SRTM DEM and Landsat L8 satellite images were downloaded from https://earthexplorer.usgs.gov/.

References

Abdelrahman MAE, Natarajan A, Hegde R (2016) Assessment of land suitability and capability by integrating remote sensing and GIS for agriculture in Chamarajanagar district, Karnataka, India. Egypt J Remote Sens Space Sci 19(1):125–141. https://doi.org/10.1016/j.ejrs.2016.02.001

Agarwal A, Narain S (2010) Equitable sharing of benefits in Sukhomajri. GIST, pp 1–4

Al-Nasrawi AKM et al (2016) Civil-GIS incorporated approach for water resource management in a developed catchment for urban-geomorphic sustainability: Tallowa dam, southeastern

Australia. Int Soil Water Conserv Res 4(4):304–313. https://doi.org/10.1016/j.iswcr.2016.11.001

Arya SL (2005) Participatory integrated watershed management a success story of “Sukhomajri Project” (Haryana), India

Batabyal AA (2002) Participatory watershed development: challenges for the twenty-first century by JohnFarrington; Cathryn Turton; A. J James J Asian Stud 61(4):1407–1408 http://www.jstor.org/stable/3096502

Bhaduri B et al (2000) Assessing watershed-scale, long-term hydrologic impacts of land-use change using a GIS-NPS model. Environ Manag 26(6):643–658

Bhan S (2013) Land degradation and integrated watershed management in India. Int Soil Water Conserv Res 1(1):49–57. https://doi.org/10.1016/S2095-6339(15)30049-6

Bulkley JW (1977). Integrated watershed management: past, present, and future, p 18

Chowdary VM et al (2009) Integrated water resource development plan for sustainable management of mayurakshi watershed, India using remote sensing and GIS. Water Resour Manag 23 (8):1581–1602

Department of Land Resource, Ministry of Rural Development, Govt. of India (2001) Guidelines for Watershed Development (Revised-2001). Available at: http://dolr.nic.in/dolr/guidewd.asp

Department of Land Resource, Ministry of Rural Development, Govt. of India (2003) Guidelines for Haryali, 2003. Available at: http://dolr.nic.in/HariyaliGuidelines.htm

Department of Land Resource, Ministry of Rural Development, Govt. of India (2008) Common guidelines for watershed development projects

Dhruvanarayana VV, Babu R (1983) Estimation of soil Erosion in India. J Irrig Drain Eng 109 (4):419–434 Available at: http://ascelibrary.org/doi/10.1061/%28ASCE%290733-9437%281983%29109%3A4%28419%29

Eswaran H, Samra JS (1997) Challenges in ecosystem management in a management in a watershed context in Asia. In: Lal R (ed) Integrated watershed management in the global ecosystem. CPC Press, Boca Raton, pp 19–32

Farrington et al (1999) Participatory watershed management. Oxford University Press, Oxford

Galay VJ, Evans R (1989) Sediment transport modeling. In: Proceedings of the international symposium, New Orleans, American Society of Civil Engineers, New York, pp 1–12

Gosain AK, Rao S (2004) GIS-based technologies for watershed management. Curr Sci 87 (7):948–952

Hiese N et al (2011) Application of geoinformatics in land resource management at micro-watershed level for sustainable development of Sanis, Wokha District, Nagaland. In: Dimensions and Directions of Geospatial Industry, Hyderabad, pp 1–10

Holeman JN (1968) The sediment yield of major rivers of the world. Water Resour Res 4 (4):737–747

Johnson N et al (2001) User participation in watershed management and research. Water Policy 3:507–520. Available at: http://www.sciencedirect.com/science/article/pii/S1366701702000144

Khan MA, Gupta VP, Moharana PC (2001) Watershed prioritization using remote sensing and geographical information system: a case study from Guhiya. India J Arid Environ 49 (3):465–475

Kukal SS, Bawa SS (2013) Temporal variations in runoff and soil loss in relation to soil conservation practices in catchments in Shiwaliks of lower Himalayas. Int Soil Water Conserv Res 1 (2):19–25. https://doi.org/10.1016/S2095-6339(15)30036-8

Murty JVS (1998) Watershed management. New Age International, New Delhi

Naqvi HR et al (2015) Soil erosion planning using sediment yield index method in the Nun Nadi watershed. India Int Soil Water Conserv Res 3(2):86–96 Available at: http://linkinghub.elsevier.com/retrieve/pii/S2095633915300836

Nath Roy U (2005) Sustainability of watershed projects: a case of Punjab Shivalik, India Available at: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.738.5673&rep=rep1&type=pdf

NITI Ayog (2015) Selected best practices in water management, New Delhi

Oldeman L (1994) Global extent of soil degradation. Soil resilience and sustainable land use, pp 19–36. Available at: http://library.wur.nl/isric/fulltext/isricu_i26803_001.pdf

Pandey A, Chowdary VM, Mal BC (2007) Identification of critical erosion prone areas in the small agricultural watershed using USLE, GIS and remote sensing. Water Resour Manag 21 (4):729–746

Pirani FJ, Mousavi SA (2016) Integrating socio-economic and biophysical data to enhance watershed management and planning. J Hydrol 540:727–735. https://doi.org/10.1016/j.jhydrol.2016.05.072

Prasannakumar V et al (2012) Estimation of soil erosion risk within a small mountainous sub-watershed in Kerala, India, using revised universal soil loss equation (RUSLE) and geo-information technology. Geosci Front 3(2):209–215. https://doi.org/10.1016/j.gsf.2011.11.003

Ratna Reddy V, Saharawat YS, George B (2017) Watershed management in South Asia: a synoptic review. J Hydrol 551:4–13. Available at. https://doi.org/10.1016/j.jhydrol.2017.05.043

Reddy VR et al (2004) Participatory watershed development in India: can it sustain rural livelihood? Dev Change 35(2):297–326. Available at: http://eds.b.ebscohost.com/eds/pdfviewer/pdfviewer?vid=5&sid=6e200a5d-df28-4002-b9e0-b1d8112672a6@sessionmgr112&hid=121

Saravanan VS (2002) Institutionalising community-based watershed management in India: elements of institutional sustainability. Water Sci Technol 45(11):113–124

Schmidhuber J, Tubiello FN (2007). Global food security under climate change. Proc Natl Acad Sci USA 104(50):19703–19708. Available at: http://www.pnas.org/content/104/50/19703.short

Tennyson L, White R (2005) Preparing for the next generation of watershed management programmes and projects. In: Proceedings of the Asian regional workshop, p 163

Thapa GB (2000) Integrated watershed management: basic concepts and issues. Hum Settlement Dev II:12–23

Tim US, Mallavaram S (2003) Application of GIS technology in watershed-based management and decision making. Watershed Update 1(5):1–6

Village S, Shiwalik H, Soil C (1990) Forest and watershed protection in India. In: World pp 1–4

Wani SP, Garg KK (2008) Community watersheds for improved livelihoods through consortium approach in drought prone rain-fed areas. J Hydrol Res Dev 23:55–77

Wani SP, Chander G, Sahrawat KL (2014) Science-led interventions in integrated watersheds to improve smallholders' livelihoods. NJAS – Wageningen J Life Sci 70–71:71–77. https://doi.org/10.1016/j.njas.2014.07.001