Chapter 2
Watershed Management and Development

Abstract In this chapter the watershed as a hydrogeological drainage feature that typically utilizes land and water assets is discussed. India's central government and the Maharashtra state government are introducing various water boundary improvement programs, which require a systematic methodology for sustainable watershed development and soil-related resources. Remote sensing (RS) and geographical information (GIS) systems may be used for effective control of the whole field of groundwater properties. Watershed development treatments include essential activities such as rainwater production, soil management, and water management to estimate natural protection measures. Two areas within Akola and Buldhana districts have been studied for this research. For two seasons, SOI toposheets and village maps have been completed. Supplementary information was gathered using GPS and remote sensing, including soil rates, agriculture, population, and socio-economic information. Maps including SOI toposheets and satellite images provided basic contour, drainage, soil, geomorphology, slope, and land-use information. All maps were reviewed for the design and creation of soil and water conservation assets and the sustainable development and management of water resources.

Keywords Watershed · GIS · RS · Toposheets · Natural resources

2.1 Introduction

The management of environmental resources involves various hydrology, physical-organic, socio-economic, and political dimensions. Soil and vegetation are key to the essential assets of land and water. Water is a powerful natural management tool, but also a complex one. Watersheds have critical functions affecting plants, animals, and human communities, including water supply, water quality, streams, storm runoff water, and water rights, and watershed management. Landowners, land-use organizations, conservation consultants, ecological researchers, water-use inspectors, and the public are all concerned with groundwater and surface water production and planning and the implementation of relevant projects and activities. Lectures have been

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given covering key capability issues and the use of sustainable water technologies (Pande et al. 2019a, b; Moharir et al. 2019).

The consequences of rainfall are determined by moisture conditions and the prevailing atmosphere at the time. Therefore, due to changes in the climate as well as the spatial variability of the landmass, watershed response is non-linear. In India, the management of ecological resources in the watershed is undertaken at village level. These partnerships at the local level must be improved by management devices that are easy to understand, use integrated watershed management tools and provide information to make correct choices (Moharir et al. 2017a, b; Murthy 1998).

This chapter considers the key characteristics of a healthy watershed. It also examines the use of remote sensing and GIS technologies to build outline models for local-level planning and to establish the features of watershed sustainability. Well managed large, medium-sized, and minor irrigation projects have been an important factor in semi-arid production in India over the last 50 years. Key irrigation systems cover a large number of hectares of land, and small tanks can be used to meet the requirements of village-level communities (Khadri and Pande 2016; Khadri and Moharir 2016). Different examples have been found to account for the existence of ecological problems when such projects are applied. While an integrated watershed management approach is the best for sustainable environmental resource planning, it is rarely implemented because of its perceived lack of relevance to the production of the watershed system. Correct maintenance procedures can be overlooked (Fig. 2.1).

2.2 Integrated Watershed Management Philosophy

This chapter describes a comprehensive watershed management methodology, using a case study to assess the priority of the watershed. It explores integrated watershed management as well as the multifunctional management and planning process undertaken with a watershed investor. A team strategy is used to identify the resource challenges and concerns of the watershed, promoting and implementing the watershed development strategy with results that are ecologically, informally, and financially sustainable.

IMM has been active in India since 1970. Over the years, there have been many different implementation strategies. In 1995 the government of India, the World Bank Group, and a group of universities formally initiated sustainable, multi-spectrum watershed planning and development programs with specific targets. Following a 1999 review by the Ministry for Rural Development and the Ministry of Agriculture, a set of working approaches, priorities, plans, and regular disbursements were established in 2001, including the DPAP (Drought-Prone Area Programme), DDP (Desert Development Programme), and IWDP (Integrated Watershed Development Programme). These strategies promote the involvement of NGOs, semi-governmental organizations, private enterprises, universities, and development organizations in watersheds. These numerous projects continue to rely on groundwater production and rainwater collection methods for sustainable development (Wani et al.

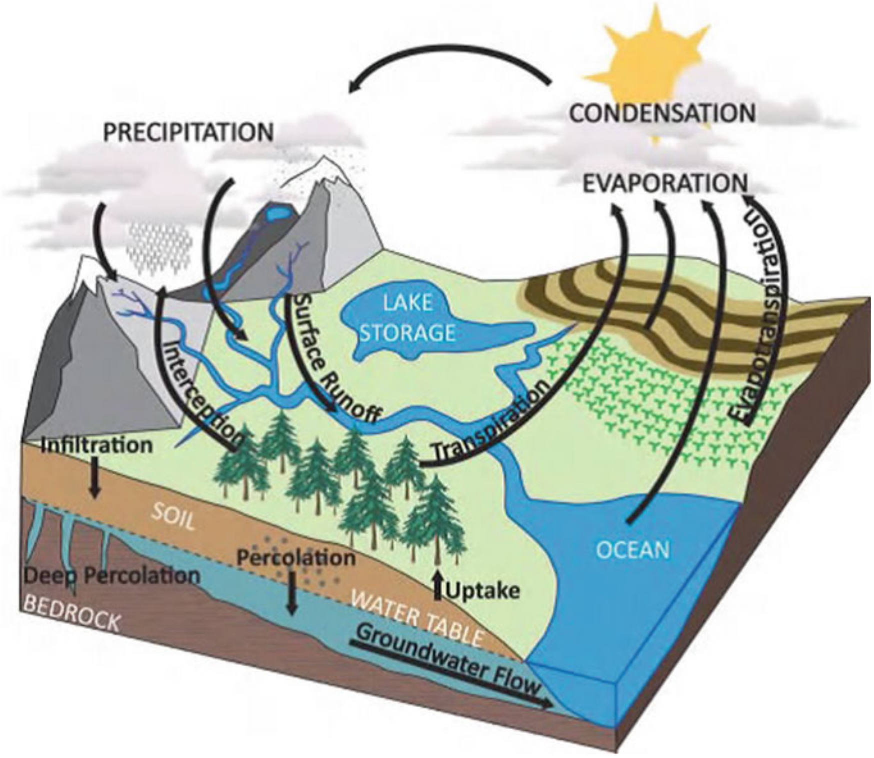

Fig. 2.1 The hydrologic cycle

2008). In order to determine the logical sequence of the proposed operations, analysis of all relevant data is necessary.

Water change is the least effective dimension in which an assessment of human effects is possible based on ecological resources. Thus, while the *Panchayat* remains the most favored part of the implementation, it is the watershed that should be used to determine results. To quantify the effects of activities carried out at the Panchayat/watershed level at a higher point in the drainage basin, a framework that maps these parts and how they are connected at Panchayat and watershed levels is required. This structure may be used by all line offices and updated by the key divisions to which ward areas are allocated in the information area. Full replication of the program will be required. This system would be feasible at local, state and national level, as well as at the river, sub-lake, and lake level (Arnold et al. 1990).

A method that meets the fundamental requirement of integrated watershed management is hydrological simulation modeling. This simulates the level in the sub-watersheds of a water and groundwater region, modeling land utilization and land cover to detect changes. The model provides a complete record of the quantity of water given to the land as a result of precipitation. The watershed is divided into separate sub-watersheds for modeling purposes. Input data are collected on individual sections of soil and land for each sub-water shaft, and these are referred to as hydrologic response units (HRUs). The process of these HRUs is identical to the precipitation inputs. The model includes all the water balance components at each sub-watershed level at monthly or annual intervals per day (Wani et al. 2003).

This present project, which used GIS-based technology to combine with and improve existing methods and technologies for village-level development planning, was funded by the Department of Science and Technology in New Delhi (UNDP). Water science researchers and NGOs were responsible for reporting the technologies presented here during the UNDP project.

2.3 Watershed Management

Watershed management is defined as the appropriate use of all ecosystem resources, including land, water, and air, to ideally establish current demands and minimize ecosystem degradation. Civil servants, environmental scientists and financial planners are all involved in watershed management. The philosophy of watershed management researches cultural, financial, and official issues both within and beyond the watershed to establish reasonable use of land and water resources. It is a multilevel method enabling resource analysis to establish the tolerance limits of potential resource exploitation, ensuring its physical sustainability and economic viability. Watershed management combines instruments and methods for soil, hydrological, biotic, and vegetative resource enhancement within the ecological environment of a stream basin to meet people's sustainable development needs. Watershed planning is a modern approach to managing soil and humidity analysis for an enhanced farm perspective similar to land use according to capacity (Murthy 2000).

The main goal of sustainable planning and growth is soil and water conservation; in this context the history of soil and water and their value must be established. A supportive structure that recognizes the role of the past within the present is needed. The decision-making process also needs to balance financial support with other operating costs, and to socialize the existing dynamics of the market and the expectations of long-term ecosystem sustainability. Sustainable manufacturing focused on health, energy, and hygiene are essential components for soil and water operations. Consequently, land and water planning and development are based on the scientific use of natural resources. The perfect geographical unit is the development of rain and land communication in the watershed area (Pande et al. 2018b).

2.4 What is a Watershed?

A watershed is a 'natural hydrologic element' draining towards specific rivers at a particular point under the earth's surface. The term 'watershed' is used synonymously with catchment area and drainage pipe. A water change region is called a separate drain. A change is a land area that can be reached at a particular point along a lake. A riverbank area is distinguished by the highest rises surrounding the river. A drop of water from the area can drain to another water bay. The watershed is also a valuable unit for economic analysis and the consideration of various physical changes related to asset use and growth. Hydrologic units are appropriate to evaluate available resources and to plan and use various development programs (Dwivedi et al. 1988).

A significant proportion of the watershed is used by people and livestock. A watershed is not defined simply by the element of water but is also a social-political object and an environmental object that plays a crucial role in defining food, social, and economic safety and in providing the human community with life-support facilities (Wani et al. 2008).

2.5 Watersheds and Stream Orders

Watersheds and stream networks are defined by the whole of the landscape. There is a specific terminology for streams (Horton 1945). First-order streams are defined as unbranched stream networks (Fig. 2.2). A second-order stream is one with two or more streams of the first order and the third-order stream has two or more streams of the second order. The water source that the drainage system uses takes on the same stream order. Although there is no evidence that streamflow and watershed characteristics are defined by stream orders, the terminology helps to position a

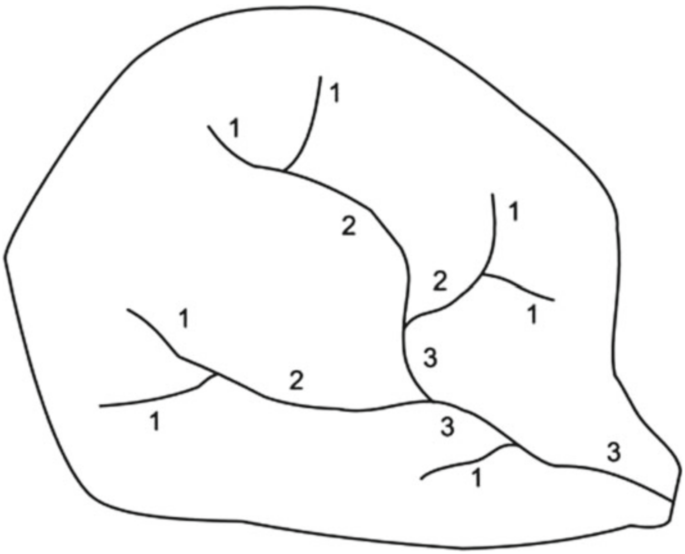

Fig. 2.2 Stream order

stream channel or a bay in a whole river basin water drainage system. Watersheds and their environment, where they are present, determine the nature and routes of water flows. In addition, watershed hierarchies in a river system typically influence water flow scales (Pande and Moharir 2018).

2.6 Watershed Assessment

The hydrological system (see Fig. 2.1) responds to climate change and land-use change. It is essential to examine watershed boundaries and to evaluate several watershed metrics, including human activity. Physical parameters need to be established, such as the basin length, stream length, water field, river slope, slope, water drainage order, and drainage density. More detailed and accurate data for the creation of the vegetative cover, geology, and soil map are obtained using GIS and remote sensing data (Pande et al. 2019a, b). Hydrological unit codes (HUCs), based on work in the United States, are used to identify watersheds. The four stages of hydrology are identified, beginning with 21 main geographical areas. This includes one of the major river basins in a particular region with another river basin chain. The key areas are divided into 221 subregions of 378 components; the final number of components is 2264. HUCs are used in thematic mapping to define watersheds or other features of the land and related characteristics such as climate, vegetation, geology, soils, land use, and topography. The hydrology properties of HUCs can be predicted based on various characteristics of similar HUCs. For the specific applications covered in this book, these techniques and methods of assessing watershed characteristics are required.

2.7 Sustainable Use and Development of Natural Resources

There are several ways in which climate changes need to be better and more sustainably managed to conserve natural assets and meet existing and potential water needs. The use of assets is not based strictly on the physical and natural characteristics of waterways. Institutional, socioeconomic, and social considerations should be fully integrated into structures in order to achieve human, economic, and social goals, such as the social base of rural communities and the concept of governance. Specific examples can show how these variables relate to each other (Pande et al. 2017).

The world's increasing population is making land and water increasingly scarce resources.. Human reactions to these deficiencies are difficult to change and can have real environmental effects. The increasing demand for water induced by the expansion of populations and by the increase of monetary growth will continue to pose prominent questions (Vorosmarty et al. 2000).The changing climate and climatic conditions create uncertainty for the management of land and water assets. The extent to which freshwater sources will change with environmental and climate change, and the location of such changes, is uncertain.

2.7.1 Land Scarcity

In many developing countries, land scarcity has been exacerbated by rural poverty. Forests are cleared to grow crops, steep highland areas are cultivated, and fragile fields overgrazed to satisfy the need for food and natural resources. Watersheds also cause erosion and further rising land productivity which in turn leads to wider and more intensive land use. In other situations, unacceptable irrigation practices to improve agricultural productivity have resulted in a reduction of land productivity due to salinization. People in both uplands and downstream areas are affected by the decline of wetlands. The depletion of agricultural land production suggests that land usage of 8.7 billion ha worldwide is unsustainable. Almost 25% of the soil, forests, forests, and grasslands have been degraded since mid-1900, with 3.5% of the 8.7 billion ha worldwide, almost 25% being degraded (Khadri and Pande 2014a, b).

2.7.2 Water Scarcity

One of the biggest environmental challenge facing the world in the twenty-first century is recognized as water scarcity. In March 2001, when the United Nations celebrated the World Day for Water, water speakers argued that demand for sustainable groundwater with surface water was 15–20% higher than the world's available surface water and that two-thirds of the world's population will experience serious water shortages in the next 25 years. Even the 9000–14,000 km^3 of freshwater worldwide required in the near future to allow people to develop, will be insufficient in the world's semi-arid region (Rosegrant et al. 2002; Khadri et al. 2013a, b).

2.8 Remote Sensing and GIS for Integrated Watershed Management

Remote sensing (RS) and GIS technologies are a collection of non-spatial and spatial data-mingling techniques and decision-support systems that can analyze, manipulate, and display geographical data. They represent methods for designing and managing large-scale spatially wide data frames, with all the benefits of the CPU environment: precision, consistency, and lack of computational errors. The long-term objective of RS and GIS applications to watersheds is to understand a novel development strategy (Khadri and Pande 2014a, b). Initial analysis is carried out based on data collected and categorized on slope, soil erosion, surface topography, and aquifers, and hydro-meteorological information (Moharir et al. 2017a, b). The latest tools and technologies such as groundwater flow modeling, aquifer mapping, land-use modifying software, and hydrological modeling with satellite data represent a rapid, cost-effective analysis that can be used to produce plans relating to sustainable watershed growth and management (Fig. 2.3).

Innovations in space-borne remote sensing have created tools to provide convincing spatial, multi-spectral planning data. GIS information can be used in connection with standard range description, classification, priority assessment, identifiable facts, potential, and management assessment. For example, remote sensing and GIS has been used by specialists in groundwater management activities for rainwater harvest (Anbazhagan and Ramasamy 2006). Remote sensing data combined with field analysis knowledge provides an ideal one-of-a-kind hybrid database for watershed managers (Solanke et al. 2005). The successful use of spatial remote sensing information properly combined with other financial insurance information under GIS conditions will indicate clear local sustainable development solutions.

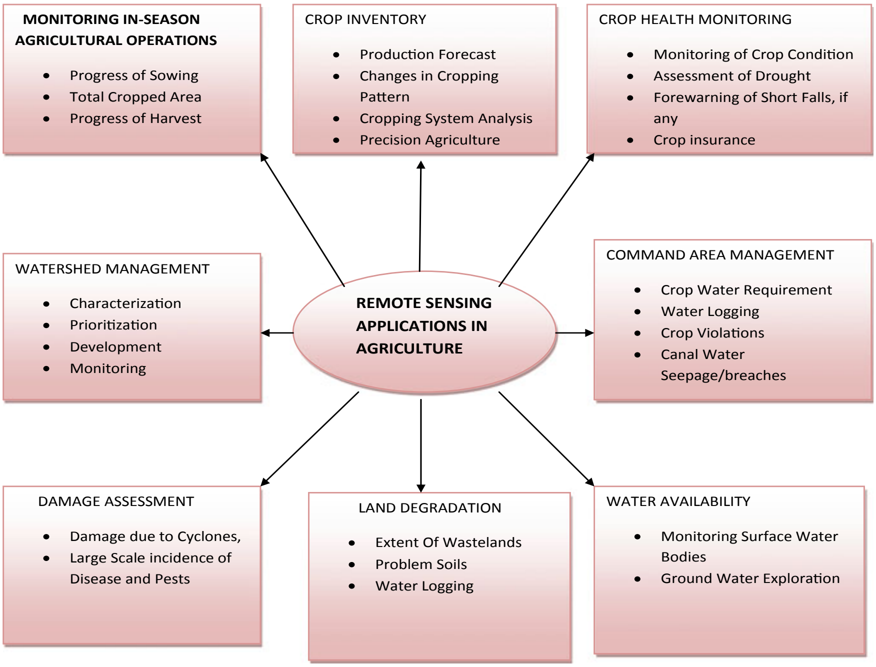

Fig. 2.3 Watershed management systems

2.9 Types of Watershed

Watersheds are categorized according to scale, presence, shape, drainage density, geology, slopes, drainage type, and land-use pattern (Pande 2014).

a. Macro watershed (>50,000 ha)
b. Sub-watershed (10,000–50,000 ha)
c. Milli-watershed (1000–10,000 ha)
d. Micro-watershed (100–1000 ha)
e. Mini-watershed (1–100 ha).

2.10 Mini-watershed Concept

A mini-watershed is a homogeneous geo-hydrological unit covering 50–2500 ha or 5–25 m^2. A mini-watershed can include up to four villages. Surface water, groundwater, and water conservation techniques should be planned in the mini-water unit to improve consumption of water-irrigated crops with *gram sabha* approval. Only then can the watershed improvement plan be presented and implemented.

2.11 Objectives of Sustainable Watershed Management

The objectives and priorities of sustainable watershed creation and planning programs are:

a. To control and preserve soil and water from harmful runoff and degradation.
b. The beneficial use and management of runoff water.
c. To preserve, maintain, and enhance watershed land to increase production efficiency and sustainability.
d. To protect and enhance water resources from the basin.
e. To control soil erosion and reduce the effects of sediment.
f. To rehabilitate deteriorating land.
g. To moderate flood peaks in downstream areas.
h. To increase rainwater infiltration.
i. To improve and increase the production of timber, feedstock, and wildlife resources.
j. To enhance groundwater recharge, wherever applicable.

2.12 Factors Affecting Watershed Management

Size and shape, topography, soils, and relief are among the factors affecting planning and management of the watershed. Precipitation, and rainfall rate and volume are the climatic characteristics. Land-use patterns include type and density of vegetation. Issues of social status and weak watershed management will also play an important role (Khadri and Moharir 2013; Khadri et al. 2013a, b).

2.13 Watershed Management Practices

Science plays a vital role in the effective conservation and management of accessible water supplies. Prominent watershed practices include infiltration expansion, water-holding volume extension, prevention of soil erosion, and recharging strategies. Control measures include strip cropping, pasture cropping, and the use of grasslands and woodlands for agriculture. Engineering solutions such as contour bunding, terracing, earth embankment, check dams, farm ponds, gully-monitoring structures, and rock dams, complement the effect of soil conservation measures and vegetation cover on erosion, surface runoff, and nutrient losses. Watershed characteristics that organizations seek to manipulate are water quality, drainage, stormwater flow, and water rights. Systematic methods that require a responsive mix of conventional land measurement and remote sensing technologies pave the way for primary water supply projects to be planned and run (Moharir et al. 2017a, b). Human involvement in watershed management builds an autonomous, effective system that is indispensable for sustainability. In this semi-arid region, reliable spatial and non-spatial information is vital for study of the characteristics of a watershed intended for sustainable ecological supply (Pande et al. 2018a, b).

Watershed management seeks to halt deterioration in the links between the watershed's natural resources. Exceptional use of resources in a previous area undermines the sustainability of watershed connections. Management of groundwater bodies in the micro-watershed, with their associated water supply potential, has not been systematically evaluated. Rural planning historically concerned dams, reservoirs for irrigation, and domestic control of land runoff requiring minor irrigation tanks. The majority of the tanks, however, are historical and their storage capacity has decreased. Cultivation in the control area, on the other hand, has become more time-consuming and multiple cropping has been introduced. There are two restorative approaches to preserve correct current land-use practices. The surface storage (percolation tanks) system is being installed in some places to replenish an aquifer which is under stress. Longer storage of groundwater increases the possibility of filtration. It is expected that water storage leads to percolation, filling the aquifers. Check dams typically built to protect soil conservation can be used as mini or micro percolation tanks depending on their storage capacity. A water catchment tank has a region that is opened and also a control area. The impact of a percolation tank can also correspond to the irrigation tank's control area. The absence of a sluice in a percolation tank is a major difference between the two structures. Water is no longer drawn for irrigation immediately, but may percolate the surface strata and thereby increase groundwater (Khadri et al. 2013a, b; Khadri and Pande 2015).

2.14 Capacity Building

Capacity building to boost resources for village populations, and specifically for farmers, plays an important role in the development of watershed areas in semi-arid regions, linking all stakeholders from farmers to service managers. Capacity building is a program that is not mandatory or customer oriented and that seeks to improve people's abilities to achieve their own goals on a sustainable basis (Wani et al. 2008). Lack of awareness and information on goals, strategies, and behavior of the parties involved affect the catchment's overall performance. Stakeholders are aware of the importance of numerous and varied activities. Capacity-building software focuses on the development of cost-effective rainwater harvesting approaches, conservation, the creation and use of bio-fertilizers and bio-pesticides, income-generation measures, action-based livestock, land reclamation, and key stakeholders' bazaar association.

2.15 Watershed Management Approaches

2.15.1 Integrated Approach

This approach applies combined sciences to the natural limitations of a stream location in order to achieve top-quality expansion of land, water, and plant resources to sustainably meet the basic requirements of people and animals. It seeks to enhance people's living standards by growing farmers' production capability to reach the desired income. Combined watershed planning recommends the following rainwater and soil preservation practices for the development of a sustainable watershed: soil and water harvesting activities, such as farm ponds; the artificial renewal of groundwater to increase water sources; crop diversification; use of an extended range of seeds; built-in nutrient management; and built-in pest management practices (Pande et al. 2015).

2.15.2 Group Approach

A group strategy emphasizes collective activity and participation by principal stakeholders, government and non-government organizations, and different institutions. Watershed planning should therefore involve multidisciplinary abilities and competencies. Such a system can drive remarkable change by providing timely advice to farmers, increasing their awareness and their ability to seek advice from professionals when troubles arise. Multidisciplinary skills are required in the areas of engineering, soil, water, remote sensing, GIS, geology, hydrology, botany, horticulture, animal husbandry, entomology, social science, economics, and marketing. While it is not always feasible to gather all the required aid and skill sets within a single organization, the group method provides the advantage of specialist know-how to supplement the activities of many watershed initiatives and interventions (Singh et al. 2008).

2.16 The Importance of Land-Use Planning in Watershed Development

The unequal distribution of various natural assets and the interdependence of social, animal, and human life, call for effective preparation in the production, management, and use of semi-arid land resources. Adinarayana (2008) developed a watershed management system in which agroecological characteristics were determined using the most relevant data, assessing soil erosion, and managing conservation elements (Patode et al. 2017). Data from several sources such as the NBSSLUP, remote sensing, irrigation, agriculture, forestry, rural enhancement departments, and markets were combined with geographical data structures (GIS), simulation models, and bio-econometric models to improve water policy and rainfall planning. This concept is appropriate to a variety of watersheds (Pande et al. 2018a; Wani et al. 2008).

2.17 Conclusion and Recommendation

A participatory policy for the sustainable use of natural resources to improve agricultural productivity and reduce rural poverty proposes the preparation of a small catchment or watershed. This approach, a sustainable alternative to a pure hydrduological facility, is a collaborative land and water planning method helping to enhance livelihoods in synchronization with the local environment. Sustainable and scientific use of soil-based and water-related production taking account of the interdependence of people and animals must be codified in compliance with national and scientific standards to give priority to developing-country watersheds. Over the past 30 years, India's watershed system has established a central, integrated, community-based approach to rural livelihoods through sustainable management of natural resources. The pinnacle of this strategy consists of soil and water conservation. Integrated watershed management (IWM) programs enable soil, water, and biodiversity conservation, improved production, increased family incomes, development of community resources, and the potential resilience to cope with changes including those related to local weather and globalization. The IWM system will become a growth engine for the sustainable development of dryland tropical areas.

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