INTEGRATED WATERSHED MANAGEMENT FOR SUSTAINABLE DEVELOPMENT OF WESTERN HIMALAYAS- A STUDY OF LIDDER CATCHMENT

THESIS

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DECLARATION

I hereby declare that this thesis, submitted for the degree of Doctor of Philosophy (Ph.D) is the result of my own research work and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree or diploma at this University or any other institution, except where due acknowledgement has been made in the thesis.

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CERTIFICATE

This is to certify that the thesis entitled **"Integrated Watershed Management for Sustainable Development of Western Himalayas- A Study of Lidder Catchment"**, is a bonafide record of the research work carried out by Mr. Mohammad Imran Malik, for the degree of **Doctor of Philosophy (Ph.D)** of the University of Kashmir, Srinagar. The thesis is worth submitting for the degree of Doctor of Philosophy (Ph.D) in Geography.

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Dedicated to all the parents who sacrifice their present for the prosperous future of their children

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I have accumulated a large number of debts in preparing this work. While a brief acknowledgement here in no way writes them off, it is a small courtesy whose sentiments are sincere.

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Mohammad Imran Malik

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CHAPTER - 1

INTRODUCTION

1.1. INTRODUCTION

The degradation of the natural environment is intrinsically linked with the development process. Industrial and agricultural development has created many environmental problems largely due to the mismanaged and improper use of technology (Singh and Mishra, 1998). New technologies will certainly increase the carrying capacity of the earth for humans, but, a paradox of our time is the mixed blessing of almost every technological development (Gray, 1989). It is possible that life as we know it on this earth is not sustainable if we continue to live as we do (Wilbanks, 1994). The emphasis of sustainable development is to carry developmental achievements into the future in such a way that future generations are not left worse off (Pearce et al., 1990; World Commission on Environment and Development, 1987). Development must be guided by ecological understanding if degradation of natural system is to be avoided. It should not be regarded and treated as a technical engineering exercise and more attention should be paid to historical, cultural, social, economic and political realities (Stiefel and Wolfe, 1994; Berkes et al., 1998).

Mountain and upland watersheds constitute 25 percent of the earth's land surface. They in fact provide direct life support for about 10 per cent of the world's population and indirectly to half, principally because they are the source region for many of the world's major river systems (Beniston, 2000). However, little understanding of mountain specificity by planners and policy-makers and the inability of development efforts to harness local niches have aggravated economic woes and threatened prospects for mountain development. It is indeed paradoxical that the mountains which metamorphically denote strength, stability and resilience are indeed the exact opposite (Pandey et al., 1998). Increased accessibility, population pressure, economic development and the excessive utilization of the region's resources for grazing, firewood and timber extraction has resulted in a threat to the health of this mountain ecosystem and its inhabitation (Gupta, 1978) which has led to a number of environmental problems including gradual increase in volume of run-off and hence soil erosion (Yadav, 1984). The population in the mountain areas is comparatively more backward and underdeveloped. Recently, the sustainability issues in these areas are getting more attention because of poor development in the mountain areas.

The Himalayas have been the cradle of everything precious and beautiful in India's heritage (Madan and Rawat, 2000). These constitute 16.2 per cent of India's total geographical area and 3.2 per cent of the total population of the country (Census of India, 2001). Over one hundred million people in the Himalayas directly depend on forests and over 80 per cent of the population depends either on full or part time farming for their livelihoods (Xu, 2008). Thus, despite the abundance of natural resources, most of its people are marginalized and still live on subsistence level (Singh, 2006). The Himalayan region is characterized not only by ecological fragility but also by a deep and historical geopolitical sensitivity (Stone, 1992). The pace, magnitude and spatial reach of human alterations of the Himalayan region are unprecedented (Ivas and Messerli, 1989). Development priorities for the Himalayan region must focus on improving the life quality of mountain people and also to persuade the people of the plains that the future of the mountains cannot be isolated from their own (Eckholm, 1975). Protection of interests of indigenous population, therefore, must assume the focus as well as priority for interventions aimed for sustainable development in the Himalayan region. Present levels of appropriate technological knowledge as well as capacity to put the existing knowledge in to practice in the Himalayan Region need dramatic improvements for the wellbeing of the people settled in the region and many more settled in the adjoining low lands.

The forests shape our natural environment in various ways as these not only influence micro-climate, soil environment, flood conditions, erosion and human health (Dwivedi, 1980) but also provide shelter for wildlife and play an important role in the ecology of watersheds (Bhati and zingel, 1997). Preserving forests thus contribute to both climate stability and biodiversity goals (World Resources Institute, 1992). Degradation of natural forests is a global problem (Guppy, 1984; Sayer and Whitmore, 1991). Mankind has been destroying forests for millennia ever since agriculture was discovered (William, 1989). In the Himalayan Region deforestation has a long history, being well established in late eighteenth century (Mahat et al., 1986). Forest degradation is a primary problem which gives way to a variety of problems by accelerating many environmental degradation processes. Expansion of agriculture on marginal land and declining crop yields are considered to be major unsustainable trends in the Himalaya (Eckholm, 1979; Ives and Messerli, 1989; Jodha, 1990).

Land use land cover (LULC) studies are of interest to a wide range of social and environmental scientists because land is a key factor in social relationships and resource use. Land use studies provide a powerful rationale for maintaining land. Changing LULC is a fundamental driver of global change (Fischer and O'Neill, 2005) and direct reflections of human activity and impacts (Jolly and Torrey, 1993). Understanding past and present impacts of LULC change is very important to the study of human-driven environmental change (Liu and Chen, 2006). Intensification and diversification of land use, together with advances in technology, have led to rapid changes in the global cycles of carbon, nitrogen and other critical elements (Melillo, Field and Moldan, 2002) which is responsible for a significant proportion of the phenomenon of global climatic change (National Research Council, 1992). By the early 1990's, human influences on the natural environment were understood to occur through two main processes: change in land cover and land use and "industrial metabolism," that is, the transformation of materials and energy for industrial production and economic consumption (National Research Council, 1990). In the conceptual framework developed for the Millennium Ecosystem Assessment, changes in LULC figure among the "direct drivers" affecting ecosystem services while demographic factors among the “indirect drivers” (Alcamo, Bennett and the Millennium Ecosystem Assessment Project, 2003).

Watersheds are ubiquitous units that can be seen as the physical foundation of the nation. They have long been recognized as desirable units for planning and implementing developmental programmes (Brooks et al., 1991, FAO, 1985; 1987; Honore, 1999; Khan, 1999). Different approaches to planning or management of the environment related human activities have been adopted and practiced. Earlier approaches have been and in many cases still are issue based and political area based. Linkages between different subsystems have been ignored or not properly understood and the political areas used as planning units are often not spatially integrated. Drainage basins, catchments, sub-catchments and the watersheds are identified as fundamental development units for planning (Moore et al., 1994) in which all the natural resources like soil, water, vegetation, geomorphology and land use are in harmony thereby facilitating adoption of holistic approach for sustainable development and management of natural resources (Gosain et al., 2004). This kind of planning or management attempts to avoid such activities that lead to negative effects of the environment (Marh, 1998). The river basin can be considered to be functional ecosystem characterized by direct feedbacks from human actions and understood as a naturally evolving complex of environmental components, linked by pathways of energy flows (Pantulu, 1981).

The utilization of the watershed area beyond its carrying capacity has resulted in its deterioration in most parts of the world (Food and Agriculture Organization, 1985) resulting into deforestation and soil erosion increment (Kelly, 1983). Being an integral part, the natural resources and the socio-economic status of a watershed should be paid equal attention (Erickson, 1995). Watershed assessment needs an approach that can handle complex problems but is easy to implement, that is flexible but consistent, that can be applied at different spatial scales, and that can readily be translated into easily communicated descriptions related to management decisions (Shukla et al., 1990). In an operational context, this would mean integrating different uses and management of resources, different departments through an inter-disciplinary approach, and towards alleviation of poverty (Mollinga, 2000). All collective efforts are designed through institutions, and without institutional change we will not move purposefully towards sustainability (Dovers, 2001). Because of the highly complex nature of human and natural systems, the ability to understand them and project future conditions using a watershed approach has increasingly taken a geographic dimension. Geographical Information System (GIS) technology has played critical roles in all aspects of watershed management, from assessing watershed conditions through modeling impacts of human activities on watersheds to visualizing impacts of alternative management scenarios. The integrated and holistic approach of watershed development has been focused for sustainable development of the society. The planners, academicians, development professionals, NGO activists, and national and international funding agencies like Government of India and World Bank have led a major emphasis on development through watershed management approach with people's participation as a key to sustainable watershed development.

Over the past two decades, there have been numerous applications of integrated watershed management worldwide. For example, integrated watershed management approaches have been recently used for combating drought in the Jhabua watershed in India (Singh et al. 2002), assessing and managing water resources in the upper Chao Phraya in Thailand (Padma et al. 2001), assessing and managing agricultural phosphorus pollution on the Chesapeake Bay (Sharpley 2000), tackling the problem of land degradation in Australia (Ewing 1999), and managing the Truckee River in Nevada (Cobourn 1999). Also, in the United States, the USEPA has been quite instrumental in promoting the integrated watershed approach to management (National Research Council 1999). The lessons learned from these and other initiatives indicate that in order to succeed, integrated watershed management must be participatory, adaptive and experimental, integrating all the relevant scientific knowledge and user-supplied information regarding the social, economic and environmental processes affecting natural resources at the watershed level.

The present study focuses on research in which LULC change is a key mediator of human-environment interactions, in which demographic variables figure prominently among the driving forces investigated, and in which efforts are made to investigate the causal mechanisms by which human population changes affect land use and environmental outcomes at the watershed level. The watershed prioritization is carried out by integrating various socio-economic and bio-physical indicators for the management of the natural resources of the Lidder catchment in order to achieve sustainable development. Besides, the catchment being one of the important tourist destinations of Kashmir valley receiving more than 50 percent of the tourists to Kashmir valley, it was imperative to evaluate the tourist carrying capacity and demarcate different tourist potential regions of the catchment for sustainable tourism development of the region.

1.2. CONCEPT OF WATERSHED

Watershed is an independent (Maitra, 2001) geo-hydrological unit demarcated through water divide lines separating one drainage basin from another. A watershed is defined as a topographically delineated geographical area in which the entire run-off tends to coverage, through the existing drainage system, to the common outlet of the area for sub-sequent disposal (Corn, 1993; Swallow et al., 2001). One watershed is separated from another by a natural boundary known as the water divide or the ridge line. It is a land area that captures rainfall and conveys the overland flow and runoff to an outlet in the main flow channel. Essentially watershed is all land and water which contributes water to a common point. Watershed is defined as a geographic area drained by stream or a system of connecting streams such that all surface runoff originating due to the precipitation in this area leaves the area in a concentrated flow through a single outlet (Singh, 2000). While a simple or a first-order watershed comprises a single stream, a multi-order watershed comprises several such single-order watersheds. The entire drainage area of a major river system is referred to commonly as a river basin, which in fact comprises a large number of watersheds. Thus a watershed is an area from which all water drains to a common point, making it an attractive unit for technical efforts to manage water and conserve soil for improving production and conservation.

A watershed has a third dimension- height (or depth). The depth of a watershed may extend from the top of the vegetation to the confining geological strata beneath. Every watershed in the world is as unique as a fingerprint. No two watersheds are exactly same. A watershed in alpine region would be very different from dry and dusty watershed of an arid region. Two contiguous watersheds, lying side by side, are actually different in detail, even though they may look alike. The watershed above any point on a defined drainage channel can easily be identified. Hence it comprises of a catchment area (recharge zone), a command area (transition zone) and a delta area (discharge zone). Therefore, watershed is the area encompassing the catchment, command and delta of a stream. Hydrologically the shape of the watershed is important because it controls the time taken for the run-off to concentrate at the outlet. Watersheds may also be categorized as hill or flat watersheds; humid or arid watersheds; red soil watershed or black soil watershed based on criteria like soil, slope, climate etc.

The above definitions are mostly postulated by the hydrologists depicting watershed as a hydrological unit. But it is beyond doubt that watershed is more complex; in fact it is a physical, biological, economic and social system bounded vertically by the area influenced by human activities and horizontally by the water that drains into a point in this channel. It has a profound influence on forestry, agriculture and other aspects of ecology, economic and social aspect. It is a resource region where the ecosystem is closely interconnected around basic resource i.e. water. Watershed controls the rainfall and climate, soil development, ecosystem and thus environment. The watershed is therefore an ideal spatial management unit for integrated development of its resource potentialities.

1.3. INTEGRATED WATERSHED MANAGEMENT

During the last few decades, degraded watersheds have posed serious problems to environment and people, both upstream and downstream (Mountain, 2002). It was realized that land degradation was a serious threat to the environment and to the well being of millions of people (Ives and Messerli, 1989; Oldeman, 1994; Jodha, 1995; Lal, 1998). As it is often the result of human activities, it can therefore, be prevented or controlled by human efforts. One such effort is the management of natural resources at watershed level. Originating from the science of hydrology, the term watershed management has over the years acquired much wider implications. The term is now used for a variety of development projects involving natural resources management. In the early days watershed management had a narrow focus primarily for controlling erosion, floods and maintaining sustainability of useable water yield (Ozyuvaci et al., 1997). However, in the present context, watershed management is not only for managing or conserving natural resources in a holistic manner, but also to involve local people for betterment of their lives (Mountain, 2002). Thus, modern watershed management is more people oriented and process based to fit into the farmers' lifestyles rather than merely fulfilling the purposes of donors, governments or non-government agencies (Sen et al., 1997). The implications of watershed degradation and its management are understood differently by different persons. The conceptual differences arise primarily due to the adoption of different thrust areas. Soil, water and vegetation are the main important and vital natural resources and watershed affects all of them. Judicious and efficient management of these resources in the watershed can ensure the sustained productivity of food, fuel, fodder, forage, fiber, fruits and timber. However watershed planning can be difficult because of the complex array of interactive physical and social forces (National Research Council, 1999a).

Watershed management can be regarded as both a science and an art (Swallow et al., 2001). Broadly, it is the process of guiding and organizing land and other resource use in a watershed to provide desired goods and services without adversely affecting land resources. It integrates various aspects of hydrology, ecology, soils, physical climatology and other sciences to provide guidelines for choosing acceptable management alternatives within the socio-economic context taking into consideration the interactions and implications among land resources and the linkages between uplands and downstream areas (Brooks et al., 1991; Sen et al., 1997). Watershed Management provides direction to human activities in the protection and rehabilitation of water and associated aquatic and terrestrial resources within the watershed while recognizing the benefits of orderly growth and development. The goal is to contribute to the environmental, social and economic well being of the area on a sustainable basis. Watershed Management is a tool to aid land and water use decision makers. Water is the most critical resource as the efficient utilization of other resources is dependent upon its spatio-temporal availability. Thus, efficient and economic use of water becomes an important factor in improving the livelihood of the watershed inhabitants. Watershed management develops a holistic perspective on the local ecosystem and its stressors, "Emphasizing the importance of the whole and the interdependence of its parts" (Webster's II, 1995), by compiling and analyzing environmental data along with other natural, cultural, and historical information.

Integrated watershed management (IWM) is the process of managing human activities and natural resources in an area defined by watershed boundaries. It is an evolving and continuous process through which decisions are made for the sustainable use, development, restoration and protection of ecosystem features, functions and linkages. IWM allows us to address multiple issues and objectives; and enables us to plan within a very complex and uncertain environment. It is based on the perception of water as an integral part of the ecosystem, a natural resource and social and economic good. The emergence of IWM in several countries throughout the world reflects a growing recognition of the multiple—often competing—uses of water, and the increased awareness of the interrelationships of water systems with other physical and socioeconomic systems. IWM is a holistic area-based planning process that extends the government's policy on sustainable natural resources management and development activities. It has emerged as a new paradigm for planning, development and management of land, water and vegetation resources with a focus on social and institutional aspects apart from bio-physical aspects following a participatory 'bottom up' approach. Sustainability and replicability of the watershed management programmes call upon people's participation in the planning, implementation, management and equitable sharing of benefits and responsibilities (Aplet et al., 1993).

The watershed management approach has been highly recommended by the Indian Council for South Asian Cooperation (ICSAC) for the purpose of environmental protection and sustainable development (Burman and Jaual, 1989). The basic idea in watershed management is to conserve the vegetation cover in the upper part of the watershed and to regulate land use through the rest of the watershed in order to protect the downstream areas (Berkes et al., 1998). In India, the IWM efforts go back to 1970. There have been many changes in the implementation strategies during the following years. Until 1995, watershed development projects were officially coordinated by multi-sectoral programmes (with different objectives) launched by the Government of India. After review in 1999 by the Ministry of Rural Development and Ministry of Agriculture, a common set of operational guidelines, objectives, strategies and expenditure norms were established for watershed development programmes in 2001. These are implemented through programmes such as Drought-Prone Area Programme (DPAP), Desert Development Programme (DDP) and Integrated Watershed Development Programme (IWDP). The guidelines encourage the active involvement of non-governmental organizations, semi-governmental institutions and private enterprises, universities and training institutions. However concerns are being raised that emphasis in watershed development programme is still firmly based on the belief that water is an infinite resource, through development of groundwater extraction and water harvesting techniques (Gosain et al., 2004).

1.4. SUSTAINABLE DEVELOPMENT

The concept of sustainable development integrates environment and development in the long term. Although many discussions about the definition and components of sustainability have been held in the world, it is generally agreed that economy, environment and social equity are three foremost values in sustainability concept. The work program of the 1992 United Nations Conference on Environment and Development in Rio de Janeiro provided a political foundation and action items to facilitate the global transition towards sustainable development. Sustainable development implies a dynamic balance between maintenance (sustainability) and transformation (development) functions both directed towards human needs (Robinson et al., 1990). Sustainable development requires pragmatic management of natural resources through positive and realistic planning that balances human expectations with the ecosystem's carrying capacity. It aims not only at environmental harmony, but also at long term sustainability of the natural resource base with economic efficiency in the utilization of non-renewable resources and structural shifts to renewable resource utilization in economic processes.

The definition of sustainable development was given by World Commission on Environment and Development (WCED) as ‘‘a development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs’’ (WCED, 1987). This definition concisely conveys a long term future orientation (Smith, 1993) and acknowledges an ethical intergenerational obligation towards the satisfaction of human needs. However, this definition provides an incomplete representation of the sustainability concept. Any characterization of sustainability forms, whether economic, social, or ecological (Goodland, 1994) reflects the dynamic nature of sustainability (Niu et al., 1993) and acknowledges that sustainability will vary by context (Shearman, 1990) and will take many forms (Robinson et al., 1990). Moreover, this definition is also unclear for operational purpose and ordinary in nature due to three reasons: firstly, it does not specify human needs, secondly, it does not clarify the timeframe for the analysis of future generations needs, and thirdly it does not mention the environment as a key concern in sustainability (Bartelmus, 1997). According to Bartelmus (1997) sustainable development is defined as “the set of development programs that meets the target of human needs satisfaction without violating long-term natural resource capacities and standards of environmental quality and social equity.”

Sustainable development “should be economically viable, socially just, and environmentally appropriate” (Payne and Raiborn, 2001). Harris and Goodwin explain that in the extensive discussion and application of the concept of sustainable development which has taken place since its inception, three essential themes (fig. 1.1) have been recognized (Harris and Goodwin, 2001):

Economic: An economically sustainable system must be able to produce goods and services on a continuing basis, to maintain manageable levels of government and external debt, and to avoid extreme sectoral imbalances that damage agricultural or industrial production.

Environmental: An environmentally sustainable system must maintain a stable resource base, avoiding overexploitation of renewable resource systems or environmental sink functions and depleting nonrenewable resources only to the extent that investments are made in adequate substitutes. This includes maintenance of biodiversity, atmospheric stability, and other ecosystem functions.

Social: A socially sustainable system must achieve fairness in distribution and opportunity, adequate provision of social services, including health and education, gender equity, and political accountability and participation.

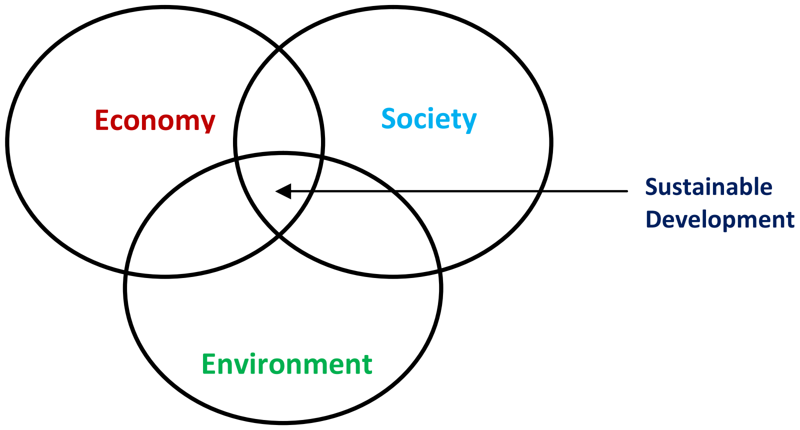


Fig. 1.1: Themes of Sustainable Development

Sustainable development principles have been introduced in existing national frameworks, such as conservation strategies, environmental plans, national vision statements, and national Agenda 21 initiatives. The implementation of Agenda 21 has been slow (United Nations, 2002**)** but the collection, analysis, and use of geographic information offers a starting point on the path to sustainable development (Brooner, 2002). Geographic data and information have the potential to play a role in the planning, implementation, and monitoring of many of Agenda 21's action items. The use of geographic data and related technologies will help overcome a number of implementation challenges, in particular the traditional fragmented approach toward sustainable development. Sustainable development is therefore a set of guiding principles whose implementation is reflected in a variety of action programs, of which Agenda 21 is the most prominent.

1.5. WATERSHED AS A SPATIAL UNIT FOR SUSTAINABLE DEVELOPMENT

In any watershed natural and human resources are inter-dependent. Hence, the land and water resources in conjunction with the socioeconomic data serve as a tool for watershed management which ultimately leads to sustainable development of the region. The IWM attempts to enrich the life of the people and improve its quality at gross root level. The introduction of detailed socioeconomic aspects generate public interest, the objectives of which provide protection, development and management of the land and water resources to maximize the economic returns. Hence, watersheds are increasingly recognized as the most applicable spatial units at which the management of natural resources should occur (Davenport, 2003). Watershed level planning is identified as an important tool for sustainable development (Rhoades, 2000; DeBarry, 2004). The importance of ecosystem thinking as a key way to approach watershed planning is stressed by several researchers (Soloway and the Township of Mono, 1991). The ecosystems approach involves several core principles: everything is connected to everything else, humans are a part of nature, we are responsible for our own actions, and economic and environmental health are not mutually exclusive, rather, they are mutually dependent (Soloway and the Township of Mono, 1991).

IWM has come to be recognized internationally as an important holistic approach to natural resources management, which seeks to promote the concept of sustainable development. Such an integrated approach has been recommended in Agenda 21 for all sectors dealing with the development and management of water resources. Given the diversity in physical and socioeconomic environments and the spatial variations in the type and severity of resource degradation in the Himalayas, any effort at conservation needs to be site specific. The physically appropriate spatial units for research on resource conservation issues are watersheds (Gregersen et al., 1996; Brooks et al., 1997). The watershed context provides the natural framework for investigating into the complex and reciprocal linkage among land use, soil and water resources, and the interdependence of people in their resource use practices. Because of this physical significance, watersheds are also considered to be the logical spatial constructs for the sustainable and integrated management of the resources with the direct involvement of local population (Brooks et al., 1997; Sharma, 1999; Rhoades, 2000).

Managing watersheds for sustainable rural development in developing countries is a relatively new concept. It is concerned not only with stabilizing soil, water and vegetation, but also with enhancing the productivity of resources in ways that are ecologically and institutionally sustainable (Farrington et al., 1999). Watershed management is practiced as a means to increase rain fed agricultural production, conserve natural resources and reduce poverty in the semi-arid tropical regions of South Asia and Sub–Saharan Africa, which are characterized by low agricultural productivity, severe natural resource degradation and high level of poverty (Kerr, 2002). A holistic approach converging the activities, which could improve livelihoods of rural people including landless dependent on natural resources, is adopted which is critical for sustainable development (Wani et al., 2003; Ramakrishna and Osman, 2004). Watershed management projects begin with the proposition that some natural resources are best managed on a watershed basis. They commonly involve multiple scales and a mix of physical and social dimensions that require an interdisciplinary approach. Watersheds are considered useful units of analysis and action because of several physical and social characteristics (Schreier et al., 2003; Vernooy, 1999). Upper catchments are endowed with rich natural resources and characterized with great physical and cultural diversity where environmental changes are often coupled with severe socio-economic consequences. Conservation of natural resources in these mountainous areas is of utmost concern for sustainable development and improving livelihood securities. Blending of remote sensing and GIS technologies has proved to be an efficient tool and have been successfully used by various investigators (Chalam et al., 1996; Chaudhary and Sharma, 1998; Kumar et al., 2001; Ali and Singh, 2002; Singh et al., 2003; Pandey et al., 2004; Suresh et al., 2004) for water resources development and management projects as well as for watershed characterization and prioritization. Thus, it is generally accepted that sustainable land and water management must be approached by taking watershed as the basic management unit.

1.6. SIGNIFICANCE OF THE STUDY

The mountainous areas are experiencing the triple revolution of industrial, transportation and tourism revolution, which has created havoc with the ecological setting of these regions. Successful intervention to halt the spiralling process of population growth, environmental degradation and poverty in mountain regions of the developing world requires an understanding of the reciprocal relationship between environment and development in mountain areas (Karan, 1989). Sustainable development of natural resources of the Himalayas has acquired added importance with the deepening anxiety at the disruption of the ecological balance in the mountains and its attendant deleterious effects on the environment. With the rapid increase in population during the recent years, the demand for food, fuel, fodder and grazing land has increased considerably, putting increased biotic stress on the critical environmental components, like land, water and forests. Consequently, the human transformation process of bio-physical components has brought about drastic changes in the resource use practices and land use pattern of the region (Tiwari, 1997). Agriculture is being pushed to forests, marginal and sub-marginal areas and areas with very steep slopes, without taking into consideration the suitability of these lands for crop farming.

LULC studies have been designed to improve understanding of the human and biophysical forces that shape LULC change. Thus, linking human behavior and social structures to biophysical attributes of the land is a fundamental aspect of LULC change research. Knowledge of the nature of LULC change and their configuration across spatial and temporal scales is consequently indispensable for sustainable environmental management and development (Turner et al., 1994). Cumulative watershed effects are the response to multiple land use activities that are caused by, or result in, altered watershed function (Reid, 1993). The spatial information on LULC and their pattern of change is essential for planning, utilization and management of the natural resources. LULC inventories are extremely important in the various resource sectors like agricultural planning, settlement and cadastral surveys, environmental studies and operational planning. Information on LULC permits a better understanding of the land utilization aspects on cropping pattern, fallow land, forest and grazing land, waste land, surface water bodies etc, which is very vital for sustainable developmental planning.

Advancement in science and technology together with restructuring of institutional mechanisms for implementation of development activities is needed for enhancing the element of sustainability in Himalayan scenario. Multiple facets of problems and potentials in Himalaya demand integrated approaches. Environmental issues should be dealt together. Isolated measures to cope with one of them can sometimes make others worse (Tickell, 1993). The overall land and resource use system is an integrated system because of the interdependence of forest, pasture and farmland. An understanding of the system would not be complete without a proper understanding of the component subsystem. Since the system we are trying to handle and modify is integrated and spatial in nature, the method of its management should also be integrative (all encompassing) and spatial (Geographic). Such a method of management and planning is provided by the watershed management approach. The area of the catchment forms a viable unit for planning as all the settlements located in the area are interlinked and interconnected physically, socially and economically more closely than their connections with those located out of the catchment area (Marh, 1998).

The watershed is the smallest unit where the evaluation of human induced impacts upon natural resources becomes possible. Watershed prioritization is an important aspect of planning for implementation of the watershed management programme (Gosain and Rao, 2004). Change detection in watersheds help in enhancing the capacity of local governments to implement sound environmental management (Prenzel et al., 2004). In this regard, Geographical Information System (GIS) holds great promise with a provision to handle spatial and temporal data and aid as an integrative planning tool for watershed management. During the past decades, more and more of the complex environmental challenges have been addressed by using a watershed approach. According to the U.S. Environmental Protection Agency (EPA), environmental management using a watershed approach constitutes “a coordinating framework for environmental management that focuses public and private sector efforts to address the highest priority problems within hydrologically defined geographic areas”.

In the present study watershed prioritization is carried out by integrating various bio-physical and socio-economic characteristics of different watersheds which would certainly help to address the current environmental problems of the catchment. The study also identifies the major contributing factors which are responsible for the environmental degradation in different watersheds of the catchment. The study site is a reflection of watershed degradation in many ways and studies made in this site may have wider application not only to other catchments of Kashmir valley but to the entire Himalayan Region. The evaluation of tourism carrying capacity is very important to achieve sustainable tourism development. In fact it stresses on the maximum number of tourists who could visit a tourist destination without creating any environmental problems.

1.7. OBJECTIVES

The study aims to accomplish the following objectives:

i. To assess the socio-economic character of Lidder catchment.
ii. To evaluate the geo-physical environment of Lidder catchment.
iii. To analyse the dynamics of land use land cover change in Lidder catchment.
iv. To devise management plan by evaluating tourist carrying capacity and watershed prioritization for sustainable development of Lidder catchment.

1.8. REVIEW OF LITERATURE

Most literature dealing with the Himalayan environmental change can be divided into three categories by the supported theories of different researches: Catastrophic, Normal process and Greening trends. The picture of the Himalaya presented by several authors (Eckholm, 1975; Claire, 1976; Moddie, 1981; Reiger, 1981; World Bank,1984; Messerschmidt, 1987) supported the theory of catastrophic degradation indicate among several explanations the eastward movement of the mountain deserts of the western Himalayas. The authors indicate the possibility of catastrophic degradation based on their observations of rapidly rising population, limits of forest resources and agricultural extension, soil loss and the loss of soil fertility and increasing natural disasters in the region (Smith, 1988). Several researchers challenge the "Theory of Himalayan Degradation" described above (Bajracharya, 1983; Bruijnzeel and Bremmer, 1989; Gilmour, 1991; Ives and Messerli, 1989; Kattlemann, 1990). They argue that the human influence in the Himalayas is insignificant compared to the scale of natural processes. Most reasons behind the contrasting theories of the Himalayan environment can either be due to inadequate information on environmental assessment in the region or the lack of synthesis of available information.

The Himalayan environmental problems, their causes and consequences have been studied by several researchers in order to address these problems. But the study area (Lidder catchment) has been ignored to a large extent. Gupta (1978) analyzed the impact of humans in terms of agriculture, forest fires and overgrazing on the vegetation of western Himalayas. Bishop (1978) and Masri (1995) highlights the human impact in terms of soil, air and water pollution and the loss of species and forest cover due to increasing human population and urbanization. They came to the conclusion that fertile lands are quickly disappearing due to urbanization. Karan and Lijima (1985) divided the Himalaya region into various geo-ecological zones and studied their environment problems. Ahmad, Rawat and Rai (1990) have classified the Himalayan environmental problems into physical, biological and socio-economic and have presented a detailed management plan for all the three components to achieve sustainable development. Singh and Singh (1986), Tucker (1987), Dewan (1987) and Kant (1998) are of the opinion that the environmental problems in the Himalaya are increasing because of growing population, economic changes like tourism, construction of roads, execution of river valley projects and extension of agriculture into steep slopes, forest fires, overgrazing etc. They concluded that the ecological problems have been aggravated under the impact of modern development process. Chadha (1990) discussed various environmental problems emerging in Kashmir Himalayas due to growing human interferences as air pollution, water pollution, problem of landslides, deforestation etc.

Pant (2003) suggested that all development efforts for the Himalayan region should be made according to demographic traits and needs, and keeping in mind the availability of the resources and ecologically fragile and geologically sensitive nature of the Himalayan environment. A separate population policy should be framed for the Himalayas. Any approach adopted for planning in this region must consider the aspects of man and his environment. The Asian Development Bank/ICIMOD (2006) estimated that while 47 percent of the denudation and landslides are of natural causes while the remaining 53 percent are manmade. Joshi et al. (2006) observed that soil loss and surface flow is very low under forest cover while the human disturbed slope (agricultural land) is leading in soil loss. Sati (2006) concludes that Rapid growth in the population of the Uttaranchal Himalaya has had a negative impact on the sustainability of the environment and economy.

The analysis of LULC change, its driving forces, techniques of analysis and its impact on the natural environment has been thoroughly analyzed in the past three decades especially after the introduction of remote sensing technology (for example Hamilton 1987; Hrabovszky et al., 1987; Turner et al., 1994; Ruiz et al., 1996; Dale et al., 1998; Berkes et al., 1998; Walsh et al., 1999; Meyer and Turner, 1994; Lambin et al., 1999; Wickham et al., 2000; Mather and Needle, 2000; Burgi and Turner, 2001; Hietel et al., 2005; Jingan et al., 2005; Ojima, Galvin and Turner-II, 2008). Much attention has been paid to the issues of human induced LULC change within the last few decades as evidenced by such multi-disciplinary, multi-national programs as NASA's Land Cover Land Use Change (LCLUC) programs or the International Geosphere Biosphere Programmes. Since LULC change is regarded as an important indicator of environmental change (Turner et al., 1994), these studies have acquired significance in the Himalayan region as well. Rawat et al. (1996) and Singh (2006) are of the opinion that rapid population growth is the main driver of land use change. Singh (1998) attributed the expansion of agricultural land to population growth and urbanization to tourism. Ahmad (1998) discussed various environmental components under stress in the Himalayas. Singh and Tingal (1998) studied various interactions of physical and socio-economic factors and found that natural hazards are increasing because of human interventions like tourism and agriculture and critical environmental zone is expanding. Tiwari (2000) argued that irrational land transformation process has not only disturbed the ecological balance is Himalayan watersheds but has also aversively affected the ecology and economy of the indo-gangetic plain region by recurrent floods and decreased irrigation potential. Singh et al. (2005) in their work have assessed the forest resources using remote sensing and GIS techniques and have established the socio-economic factors responsible for deforestation. Pandit et al. (2007) in their work reported an alarming rate of deforestation using remote sensing and GIS. They concluded that Western Himalayan region is expected to suffer high losses in forest cover than the Eastern Himalayan region because of higher human population densities in the Western Himalayan provinces. Munsi et al. (2009) found that anthropogenic disturbances are the main drivers of land use change in the form of increased agricultural activities and human settlements. Kasereka et al. (2010) used remote sensing and GIS to infer LULC change and argued that such kind of research will benefit society through the creation of reliable land cover information for better decision making. They concluded that the integration of visual interpretation and digital classification lead to significant improvement in overall accuracy.

Concern over the ecological effects of tourism started to mount during the 1960’s and 1970’s, through the realization that the industry has had the capability of either moderately altering or completely transformation destination regions in adverse ways. Crittendon (1975) illustrates that while tourism has transformed much of the world’s natural beauty into gold, the industry may have planted the seeds of its own destruction. The studies on the environmental impact of tourism in Kashmir valley carried out by Bhat (1992) emphasized a three-tier strategy blending economy, society and ecology harmoniously for sustainable tourism development in Kashmir valley. Kanth and Bhat (1997) compared the tourist flow and chemical characteristics of water in Dal lake. Dutta (1992) suggested that tourism activities in each season must be regulated and spread over the whole year, so that the pressure during summer and autumn is eased. Karan and Mather (1985), Chadha (1990), Forsyth (1991) and Savage (1993) have discussed tourism related environmental problems attributed to large number of visitors, use of fire wood, trekking and tourist related sewage and waste disposal. They are of the opinion that the income from the tourism and trekking rarely reaches the bulk of the local population, but they do receive the negative side effects like trailside litter and erosion. Cater (1995) concluded that given the multitude of interests involved in environment and tourism development completely sustainable outcome is likely to remain more of an ideal than a reality. Sharma (1998) stated that the environmental impact of tourism depends pretty much on the type of tourism being promoted, the magnitude or scale of tourism prevalent, seasonality of the activity, extent of concentration in particular areas, and the monitoring and management regime in place. Tosun (2001) identified the main challenges to sustainable tourism development and concluded that environmental codes should be developed and enforced to protect unique and fragile natural resources and cultural heritage. Parizzi et al. (2001) concluded that the risk of water contamination has increased, caused by the increase of tourist activities.

Since the focus of geography is on man environment relationship, geographers have provided new approaches to the practice of natural resource management. They have identified natural resources management as a method both for assessing resource potential and planning resource use (Burton, 1961; Burton and Kates, 1964; Burton, Kates and White, 1963, 1997; Kates, 1962). Because natural resources management also focuses on people environment interactions, it shares a concern with this geographical tradition. Much work in resource management by geographers emerged with the behavioral revolution in the discipline in the 1960s. For example, White (1963) maintained that the study of resources was fundamental to the geographic tradition. He opined that it is important to recognize the intellectual problems which call for solution and which, because of their relation to spatial distributions and human adjustment to differences in the physical environment, are of interest to geographers.

The acceptance of watershed as a natural hydrologic unit for multi-resources development planning stems from the fact that sustainability of development based on soil and land use depends on their interaction with water in all the activities that takes place throughout the watershed. The watershed development approach in India was first adopted in 1974 when the Government of India enforced the scheme for 'Soil Conservation in the watershed of river valley projects". In 1982 Government of India launched another ambitious programme for the development of dry land Agriculture on watershed basis under which 47 Model watersheds were identified under different Agro-climatic zones all over the country.

Many agencies, natural resource managers and academicians have supported planning and managing water and related land resources on a watershed basis and the approach is now being widely adopted (Anonymous, 1997; Batchelor, 1999; Bellamy et al., 1999; Born and Margerum, 1995; Born and Sonzogni, 1995; Burton, J. 1986; Downs et al., 1991; Environmental Protection Agency, 1993; Gonzales and Arias, 2001; Heathcote, 1998; Hooper and Margerum, 2000; Jonch-Clausen and Fugl, 2001; Margerum and Born, 2000; Mitchell and Hollick, 1993; Rogers; 1993; White, 1997). The conceptual development of IWM was extended recently by the Global Water Partnership (Global Water Partnership, 2000; Jonch-Clausen and Fugl, 2001). Moreover, international endorsement of the concept has now been seen at the highest levels, including the 2003 Summit on Sustainable Development in Johannesburg, South Africa as well as the Second (2000) and Third (2003) World Water Forums in Kyoto, Japan. At the latter, “IWRM and the Basin Management Theme” was issued. Band, 1986; Moore et al., 1988; Famiglietti and Wood, 1994 developed spatially distributed models of watershed hydrological processes to incorporate the spatial patterns of terrain, soils and vegetation as estimated with the use of remote sensing and GIS.

Nataraj et al. (1988); Srinivasa (1988); Ingle and Wayazade (1989) and Agnihotri et al. (1989) analyzed different watershed development projects along the Shiwalik foot hills for increasing agricultural production, economic development, rehabilitating and found that the watershed approach was economically feasible. Singh et al. (1991) revealed that the forestry, animal husbandry, soil conservation and horticultural components of the integrated watershed development project in the Kandi tract of the Punjab were economically viable. Rajput (1991) analyzed the differences in the output of soybean, sorghum, wheat and gram between watershed and non-watershed areas in the Indore district of Madhya Pradesh. The paper suggested increased access of technology and education while infrastructure development and price policies needed to be pursued more actively.

Singh (1993) analyzed that lack of adequate information, absence of people's participation, subsidies, inadequate supply of modern inputs, lack of group action, poor marketing and processing facilities of new products, inadequate price incentives, lack of timely and adequate credit facilities were the constraints that plague watershed technological adoption. Dhyani et al. (1993) studied the various soil and water conservation measures undertaken in the Bhaintan watershed at Fakot in Tehri Garhwal of Uttar Pradesh. The study revealed that the rehabilitation of the Himalaya region with soil and water conservation technologies on a watershed basis was economically beneficial. They also concluded that adoption of soil and water conservation technology on farmer's fields on watershed basis in the outer Himalayan region was economical as benefit cost ratio was higher than unity (1.93).

Rajput et al. (1994) studied the impact of watershed development programme in western Madhya Pradesh. The study revealed that the productivity levels were higher in watershed development area over non-watershed development area. The watershed development programme played a significant role in accelerating agricultural production and bringing about change in the cropping pattern in favour of remunerative crops. Swarnalatha et al. (1994) reported that in the Aravali foot hills of watershed project of Haryana reported that agriculture, animal husbandry and horticultural components of the watershed project were economically viable. Moreover the land use pattern revealed a decline in the area under wastelands while increase in the area under irrigated agriculture, forestry and horticulture.

Jally et al. (1995) studied the impact of watershed development at Nartora watershed, Madhya Pradesh and reported that yield of groundnut, paddy and wheat increased by 30, 25 and 10 per cent respectively during the post-project period, compared to the pre- project period. Sharma (1995) while studying the elements of the successful implementation of watershed management at Falkot watershed observed that, non-agricultural land brought under horticulture, agro-forestry, forestry and grasses resulted in an increase in their productivity by 200 to 800 per cent. Singh et al. (1995) studied soil conservation and management of marginal lands of Mahi ravines and found that the programme not only helped to overcome the problem of soil and water conservation on marginal lands of Mahi ravines but also increased and stabilized the productivity and net returns.

Krishna (l996) discussed the usefulness of remotely sensing data for watershed management in the Sikkim Himalaya. The bio-physical conditions were assessed based on field experience while LULC categories as well as physiographic unit's were identified from the satellite imagery. Shah and Patel (1996) studied the impact of watershed development project in Kaira district of Gujarat and found that the watershed project contributed positively in enhancing agriculture productivity, moisture retention capacity of the soil, recharging of ground water, crop income and employment generation. It also improved the environment and prevented degradation of soil. Rajput et al. (1996) based on their study on economic evaluation of watershed programme on crop yields in Madhya Pradesh reported that the crop yields with in watershed area were higher as compared to non-watershed area.

Pendke et al. (1998) in their study on Wagarwadi watershed of Parbhani district in Maharashtra found an increase in educational status by 20 per cent after the implementation of watershed development project. The cultivated area increased by 24 per cent in addition to the increase in agricultural production which resulted in the higher standard of living of the local population. Moreover, the livestock population increased by 30 per cent after post implementation stage of watershed. Nag (1998) carried out Morphometric analysis of Chakra-river basin of West Bengal using satellite data and delineated different hydro-geomorphological units. The parameters worked out in the study included bifurcation ratio, stream length, form factor, circulatory ratio and drainage density. The study suggests that the area is covered by fractured, resistant, permeable rocks and the drainage network is not so much affected by tectonic disturbances. Kumar and Tomar (1998) carried out a study on the ground water assessment in Godavan Sub watershed Bihar using remote sensing and GIS. Correlation between different hydro-geomorphic units and top soil resistivity were attempted which has helped in better understanding the surface resistivity pattern. Arun Kumar (1998) found that the implementation of watershed development project resulted in the employment generation as an additional employment of 46,550 man days was generated by the watershed project at Kuthanagere in four years.

Biswas et a1. (1999) carried out the prioritization of sub-watersheds based on morphometric analysis of drainage basin by using remote sensing and GIS. The prioritization was carried out on the basis of stream length, bifurcation ratio, drainage density, stream frequency, texture ratio, form factor, circulatory ratio and elongation ratio. Babu et al. (1999) suggested a catchment treatment plan by multi-thematic analysis based on different physical parameters of slope, LULC, drainage, relative relief and soil using remote sensing and GIS. Nalini et al. (1999) studied the Aril watershed in Bareilly district of Uttar Pradesh and found that the land use pattern revealed a decline in the area under wasteland while there was increase in the area under irrigated agriculture, forestry and horticulture. Singh (1999) studied the Chajawa watershed and adjacent villages of Baren district of Rajasthan. The study revealed that family income inside the watershed was 21.5 per cent higher as compared to those outside the watershed.

The expert group statement on Integrated River Basin Management for the Second World Water Forum and Ministerial Conference in Hague, 2000, maintained that sustainable river basin management required proper study, understanding, and effective management within the context of social, economic and environmental resources.

Ramanna and Chandrakanth (2000) while studying the watershed programme implemented by the government, reported that lack of knowledge of programme, uneven distribution of incentives, supply of poor inputs and materials, favoritism and politics at village level, poor quality of work by implementing agency, improper location of soil and water conservation structures as major problems/constraints of implementation in the watershed project as expressed by beneficiary farmers. Pal (2000) Evaluated the water discharge and sediment budget in the lesser Himalaya based on the morphometric analysis. Drainage pattern in three catchments was mapped through the interpretation of aerial photographs. The study concluded that most of the suspended load was transported between June and September and during rest of the year the concentration of sediment load was close to zero. Pratap et a1. (2000) studied the groundwater prospect in Uttar Pradesh. Thematic maps in respect of geology, geomorphology, slope, drainage, LULC and lineament were prepared by remote sensing and GIS. Each theme was assigned a weightage depending on its influence on the movement and storage of groundwater and hence the ground water potential map was prepared.

Sarkar et a1. (2001) emphasized the role of various parameters namely, drainage, lineaments, lithology, slope and land use for delineation of groundwater potential zones. The resultant map indicates a high groundwater potentiality in the flood plains, river terraces and river channels. Carios et a1. (2001) carried out the erosion risk zonation in a river basin using remote sensing data, GIS and Universal Soil Loss Equation. Soil and water conservation practices are developed especially for the areas of highest erosion risk. Chakrabarthy and Datta (2001) observed the land use pattern of watershed in arid region, Western Rajasthan using remote sensing and GIS and concluded that the vegetation and biomass has been deteriorated over the years. Durbude and Purandara (2001) estimated the runoff potential under geomorphic set-up. After the analysis of satellite imagery, topographical maps, ground truth data verification and runoff calculation, different water harvesting as well as storage structures are proposed. Rao and Pant (2001) have employed remote sensing and GIS to quantify LULC change in a central Himalayan watershed. The study has revealed that the forest cover has substantially reduced in the 33 years of study period due to increase in population pressure and wood extraction. Khan et al. (2001)

prioritized the different watersheds of Guhai catchment on the basis of sediment yield index using remote sensing and GIS.

Tripati et al. (2002) conducted a study for the Nagwan watershed of the Damodar valley Corporation, Bihar to prepare Runoff modeling. The model is helpful in the designing of conservation structures and evaluating the effect on these structures. Sen et al. (2002) studied the patterns and implications of LULC in a Himalayan watershed from 1963 to 1993 using satellite data and archival records. They found that agriculture has increased by more than 4 percent and more than 50 percent of the agricultural expansion was on community forests. Srinivas et a1. (2002) estimated soil erosion by USLE method using remote sensing and GIS in Nagapur district, Maharastra for prioritization and delineation of conservation units. The study revealed that the implementation of Universal Soil Loss Equation using integration procedures of GIS enabled the prediction of potential and actual conditions respectively. Suitable agronomic and mechanical measures are suggested for soil conservation.

Zacharias et al. (2004) demonstrated that land use alterations have significant impact on the hydrology of catchments and remote sensing and GIS has proved to be very useful to analyze this phenomenon. Singh and Jain (2004) while studying the Kandi Watershed and Area Development Project (KWADP) of Punjab observed that the cultivated area, cropping intensity and the productivity of maize, wheat and milk increased from 1979-80 to 2000-01. Joshi and Gairola (2004) have studied LULC dynamics is a micro-watershed of Garhwal Himalayas with reference to topography and concluded that the slope and altitude is not a major determining factor of LULC change as is the aspect of the land because of sun illumination. Gosain and Roa (2004) put forward a scientific approach to handle integrated watershed management strategy through a case study implemented to demonstrate the watershed prioritization exercise. Watershed prioritization approach is advocated in order to manage the deteriorating environmental quality of Himalayan region in a sustainable manner.

Shetty et al. (2005) demonstrated that how satellite data can be displayed and manipulated using digital technology in a rugged forested watershed. A detailed account of methodology for supervised classification is also provided while classifying the watershed in different LULC classes. Saha et al. (2005) classified satellite data using maximum livelihood classified in a rugged Himalayan terrain. The study demonstrated that use of Digital Elevation Model (DEM) as ancillary data significantly improved the accuracy of image classification. Mishra (2005) is of the opinion that watershed management involves the management of all the natural resources including human beings by ensuring their complete participation. Without people’s participation the watershed management objectives are unachievable. He suggests that we should try our best to work to minimizing the adverse effects simultaneously ensuring the higher productivity and sustainability of the natural resources. Joshi et al. (2005) observed that the forests, grazing lands and grasslands in Himalayan region are facing immense biotic pressure, because of removal of higher rate of biomass and timber. They suggested that the grass production at agriculture terrace risers might be encouraged to maintain the fertility of the agricultural land and reducing the pressure in grazing and over-grazed patches within the watershed. O'Neill (2005) states that successful watershed management depends on local socio-political conditions and support. Thus, watershed planning requires an integration of sound scientific and social processes in order to be successful.

Singh et al. (2006) are of the opinion that proper land use in conjunction with mechanical soil conservation measures when adopted within the boundary of watershed can enhance sustainability of the production system in the region. Mottet et al. (2006) studied the role of various bio-physical and socio-economic factors in LULC change in a mountain landscape of Pyrenees. Jasrotia and Singh (2006) in their work estimated soil loss and prioritized the watershed area. They compared soil loss with LULC and found that highest soil loss is from barren land and open forests. Katiyar et al. (2006) divided Ramganga reservoir into nine sub-watersheds to determine the sub-watershed most prone to soil erosion using remote sensing and GIS software for the assessment of reservoir sedimentation. An approach, based on land surface factors mainly responsible for erosion, which include slope, land use, brightness and greenness are used in the study. The integrated effect of all the parameters is evaluated to find sedimentation rate in the reservoir.

Vittala et al. (2008) integrated various physical and socio-economic variables for watershed prioritization using remote sensing and GIS. Chowdary et al. (2008) advocate the role of remote sensing and GIS for integrated watershed management and sustainable development. They argue that integrated watershed management requires a host of interrelated information to be generated and studied in relation to each other. Calder et al. (2008) concluded that intensification of water retention and use within watershed areas can lead to downstream water shortages. They argued that planning methodologies and approaches which were appropriate 20 years ago for planning water harvesting within watershed development projects are no longer appropriate today.

Ma et al. (2010) simulated the coupled effect of land use and climate change on hydrology of a Himalayan watershed and the study revealed the likelihood of increase in vulnerability of mountain watershed to anthropogenic land use and climate change.

Very few studies relevant to the present study were carried out on the Lidder catchment. Ahmad and Hashimi (1974) provided a detailed account of the historical dynamics of Kolahoi glacier and concluded that in the Pleistocene there were three advances of Kolahoi glacier and the last advance was the major one when the glacier extended as far as Pahalgam. They estimated the length of glacier as 5 kilometers and total area of 35 km^2. Wani (2004) opined that deforestation, unplanned construction and neglect about the maintenance of rivers, lakes and streams are responsible for water and air pollution. The waste generated at tourist places lead to the spread of vital diseases like jaundice and other disorders at Salar, Kular and Kangan villages in Lidder and Sind valleys. Sherring et al. (2009) used stochastic time series model for catchment and concluded that the autoregressive modal can be used to estimate the rainfall and runoff of the catchment. Jeelani et al. (2010) studied the relation between stream discharge, temperature perception and δ^{18}O isotope in Lidder catchment. Kanth et al. (2011) studied the receding trend of Kolhoi glacier using Survey of India toposheets and land set data and estimated that the glacier is receding at a rate of 0.07 km^2 per year. A brief account of various geomorphologic features of the glacier is also presented. Sheikh et al. (2011) used USLE integrated into GIS to estimate the soil loss in one of the watersheds of Lidder catchment and concluded that the soil loss is highest in agricultural regions (26 tons/hectare/year) and was lowest in forest areas (0.99 tons/hectare/year).

1.9. ORGANIZATIONAL FRAMEWORK

The present study has been organized in nine chapters. The first chapter is devoted to the introduction and the significance, major objectives and review of the existing literature. The second chapter deals with the description of the study area. A brief account of physiographic divisions with climate and soil characteristics is followed by major drainage and vegetation types. At the end of the chapter an account of the human habitation with major economic activity is provided. The third chapter discusses in detail the methodology used in the present study. The first part of the chapter is devoted to the type, source and characteristics of the various data sets used and the sample frame for the present study. The second part discusses the various methodological steps, different indicators and the formulas used for various calculations. The fourth chapter provides the geo-physical profile of the catchment which includes the description of the geology and geomorphological features, slope and altitude analysis with drainage morphometry. A detailed account of various climatic and hydrological characteristics of the catchment is also presented. The fifth chapter provides description about the socio-economic and demographic characteristics of the study area. Chapter sixth is devoted to the analysis of tourism development in the catchment. The delineation of different tourist potential regions and the tourist carrying capacity is also evaluated. The seventh chapter provides spatio-temporal analysis of LULC change. In the eighth chapter watershed prioritization based on different socio-economic and bio-physical indicators has been devised. The conclusion of the study is given in the ninth chapter along with major findings and suggestions. The references cited in the text are provided in a separate section at the end of the report.

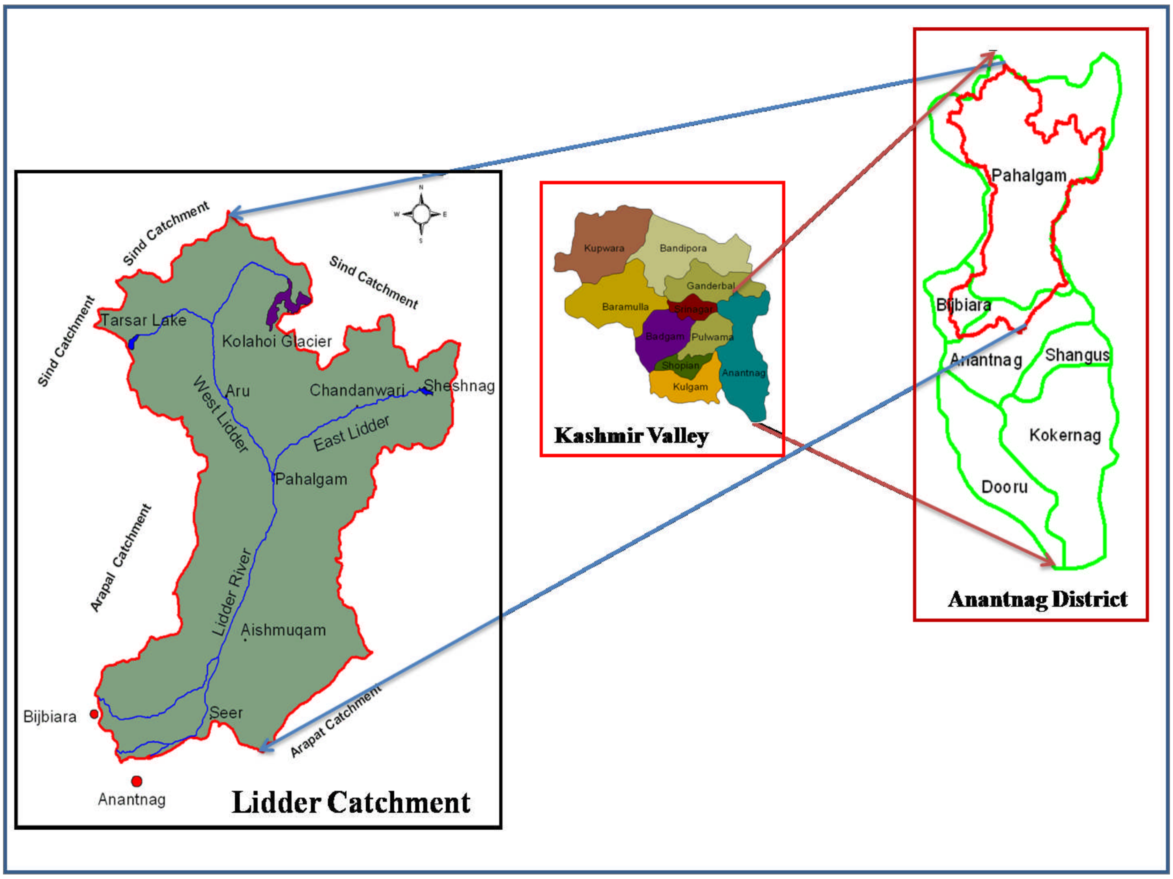
CHAPTER - 2

STUDY AREA

2.1. SPATIAL FRAMEWORK

The Valley of Kashmir situated in northwestern Himalayas is drained by river Jhelum and its seventeen tributaries. Each tributary forms a catchment of Jhelum basin. The Lidder catchment occupies the southeastern part of the Kashmir valley (fig. 2.1) and is situated between 33º 45' 01″ N - 34º 15' 35″ N and 75º 06' 00″ E – 75º 32' 29″ E. It has a catchment area of 1159.38 km^2 which constitute about 10 per cent of the total catchment area of river Jhelum. It is surrounded by Arapat catchment in the southeast, Arapal catchment in the southwest and Sind catchment on north, northeast and northwest. The Lidder valley forms the part of the middle Himalayas and lies between the Pir Panjal range in the south and southeast, the north Kashmir range of the main Himalayan range in the northeast and Zanskar range in the southwest. The area gradually rises in elevation from south (1570 meters) to north (5425 meters).

LIDDER CATCHMENT
LOCATION MAP



Source: Generated from survey of India toposheets, 1961

Fig. 2.1

2.2. PHYSIOGRAPHY AND RELIEF

The Lidder catchment can be divided into three physiographic divisions (Lidder floodplain, Karewa lands and Mountains) on the basis of relief. The Lidder floodplain marks the southern boundary of the catchment and is densely populated. The floodplain is characterized by a dense network of artificial streams and is under paddy cultivation. In between the plain and mountains there exists the Karewa belt of Lidder catchment. This belt is in fact the apple orchard belt of Lidder valley and is also densely populated. The mountainous region, which covers the catchment on all sides except south, is the largest physiographic division and is very sparsely populated in the lower altitudes. Though there are scattered settlements in the side valleys, higher reaches are devoted to animal rearing (grazing) in the summer months. The West and East Lidder streams are fed by a number of tributaries which flow between a complex network of ridges carving out their valleys which are mostly inaccessible in the north. The important side valleys of West Lidder are Basmi Nar, Sosirwen Nar, Zaymarg Nar, Armiun Nar, Gandpath Nar and Chhumanai Nar. The important side valleys of the East Lidder stream are Sarankut Nar, Potsar Nar, Razdan Nar, Wokhbal Nar and Zamtir Nar. The Lidder valley is girdled on three sides by lofty ridges; the Saribal katsal ridge (4800 meters) on the east, the Wokhbal (4200 meters) on the west and Basmai-Kazimpathlin bal (4800 meters) in the north. The interior of the northern part of the Lidder valley has a concentration of high mountain ridges like Dadwar (3560 meters), Goucher (4000 meters) and Tramakzan (4200 meters) which run parallel to the course of streams. The extremes of the catchment are characterized by barren lands and remain under snow cover for most part of the year.

2.3. CLIMATE

The Lidder catchment possesses distinctive climatic characteristics. This is related to its location at higher altitudes and its physical setting. The valley being enclosed on all sides by mountain ranges, experiences a sub-Mediterranean type of climate with nearly 70 per cent of its annual precipitation concentrated in winter and spring months (Meher, 1971). The temperature regimes are marked by significant variations. The variations within the minimum temperature are very large within the high mountain areas (Penck, 1973). The temperature variations suggest marked seasonality in the weather with a long cold season lasting for nearly seven months and a short summer season. This variation is mainly due to the local topography of the catchment resulting in profound seasonal variations throughout the year. The seasonal pattern of weather in Lidder valley could clearly be understood by dividing it into the following seasons.

Winter season: The winter season is very long. The average minimum temperature remains below freezing point for five months (November to March) in Pahalgam with the lowest minimum temperature of -6.7 °C recorded for January (plate 2.1). The average maximum temperature of 13.1 °C is recorded for November. The winter precipitation is mostly received in the form of snowfall caused by the western disturbances. The pattern of snowfall varies with the altitude. It ranges between 1 to 4 meters from Pahalgam (2200 masl) to Kolahoi- Shishram areas (3800 masl) respectively.

Plate 2.1: A view of winter snow covered residential houses near Pahalgam

Summer season: The summer season commences from June and terminates in October. The temperature curves (fig. 2.2) show that the mean monthly maximum temperature is 23.6 ^{o}C with the highest mean maximum temperature recorded for July and August (25.5^{o}C and 25.4 ^{o}C respectively). The mean minimum temperature is 9.4 ^{o}C with the lowest (5.6 ^{o}C) recorded for the month of May. The precipitation is in the form of rainfall and afternoon showers are very frequent due to orographic effect.

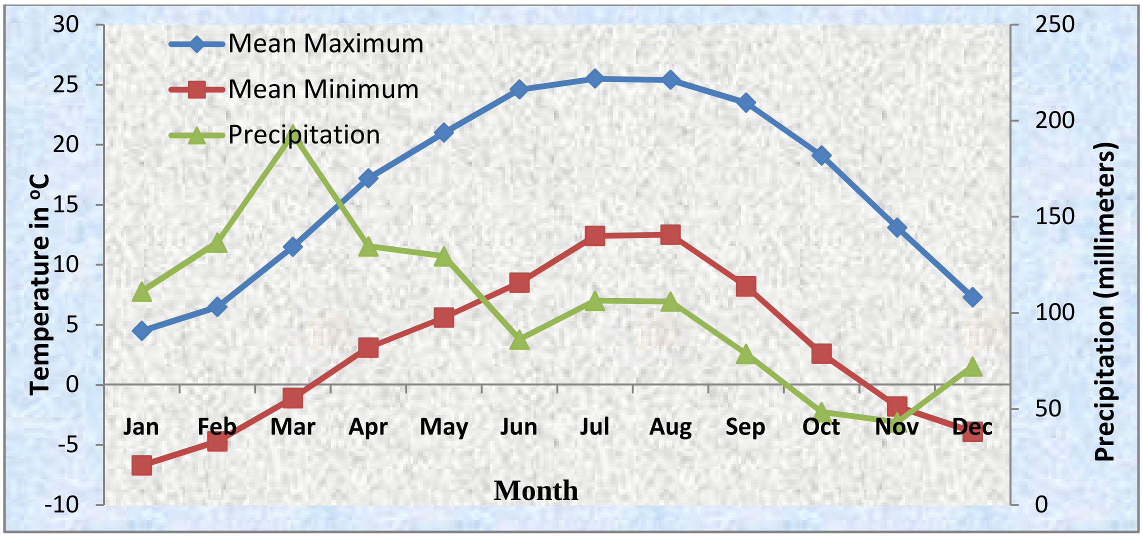
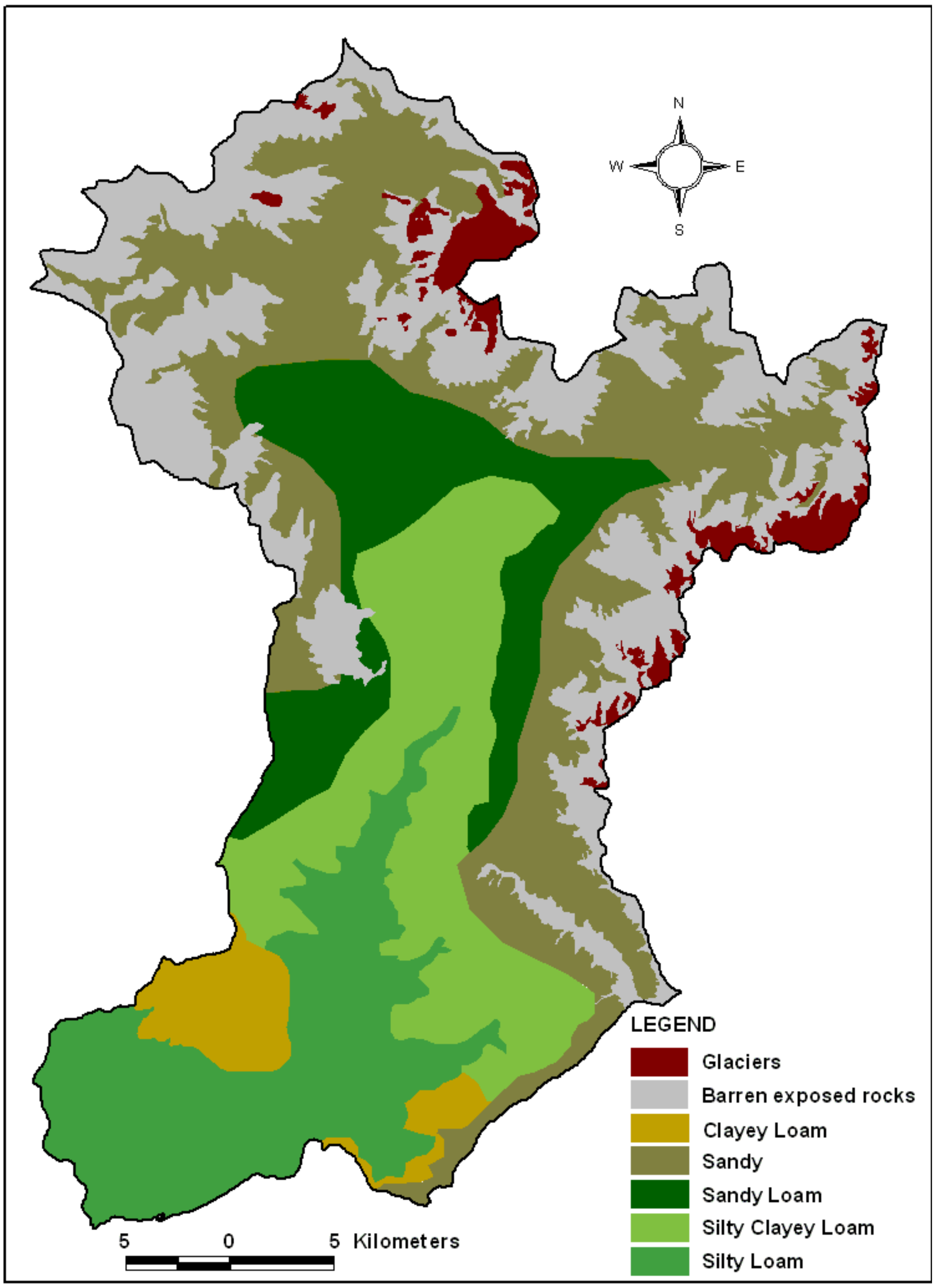


Fig. 2.2: Mean monthly minimum and maximum temperatures and precipitation at Pahalgam

2.4. SOILS

The loose material consisting of small particles and humus which can support the growth of plants is known as soil. Soil is made up of four elements i.e. minerals or inorganic matter, organic matter, water and air. The soils in Kashmir valley have been divided into four types related to different altitudinal zones (Raza et al., 1978). These are; Gurti (clayey), Bahil (ill drained, rich loam), Dazanland (poor loam, saline) and Surzamin (silty soil). These soils vary in colour, structure and texture. Lidder catchment being mostly a mountainous area is dominated by mountainous soils, which are shallow, immature and highly susceptible to erosion. These soils are acidic in character, deficient in potash and phosphoric acid. The humus content in these soils varies from place to place. The low altitude soils in the southwest are ideal for the cultivation of maize, wheat, pulses, fodder, paddy and oil seeds. While as the high ground areas are reserved as Alpine forests, where Gujjars and Bakarwal rare their flock during summer season.

LIDDER CATCHMENT
DISTRIBUTION OF SOILS



Source: Generated from land use map 2010 and field survey 2010

Fig. 2.3

Table 2.1: Distribution of soils in Lidder catchment

S. No.	Soil class	Area (km^2)	Area (Per cent)
1	Sandy	294.83	25.4
2	Sandy loam	145.48	12.5
3	Silty clayey loam	182.01	15.7
4	Clayey loam	46.23	4.0
5	Silty loam	181.61	15.7
6	Barren exposed rocks	278.87	24.1
7	Glaciers	30.35	2.6
Total		**1159.38**	**100.0**

Source: Computed from land use map 2010 and field survey 2010

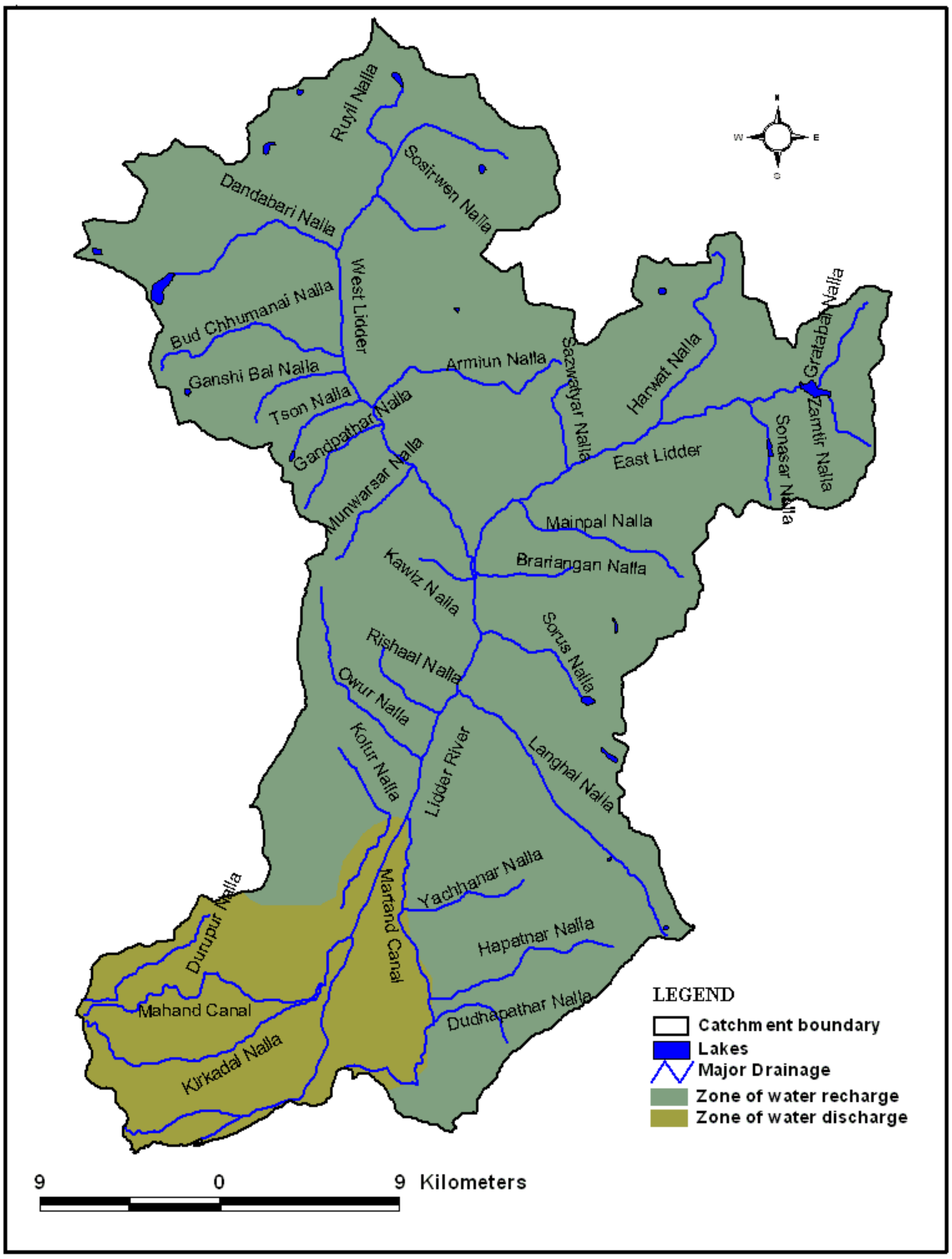
Five soil types (table 2.1) have been identified covering 73.3 percent of the total catchment area while the remaining 26.7 percent of the total area is under barren exposed rocks and glaciers. Sandy soils cover 25.4 percent of the total catchment area in the relatively higher altitudes where the glacier and river erosion has brought down the unconsolidated weathered material. Silty clayey loam is the next dominant soil type which is mostly under dense forests in the mid-altitude zone of the catchment. The silty clayey loam soils and silty soils covering equal area (15.7 percent each) are most important so far as the agriculture is concerned. These soils have supported not only the paddy cultivation in Lidder flood plain but also the high income generating apple orchard cultivation in karewa belt of the catchment. The spatial distribution of soils (fig. 2.3) has shown that Lidder flood plain is dominated by silty loam while Karewas are covered by clayey loam soils. The mountainous areas are dominated by sandy soils while as the middle altitudes of the catchment are characterized by silty clayey loams.

2.5. DRAINAGE SYSTEM

The Lidder or the “Yellow” river is formed by two mountainous torrents (East Lidder and West Lidder), which after flowing from the northwest and northeast unite at Pahalgam. The eastern branch trickles from the snow on the southern slope of the Panjtarni mountains and flows into the Sheshnag, which is connected by another small lake, called Zamti. Leaving the Sheshnag, the stream flows in the westerly direction for about 24 kilometers before merging with western branch. The western branch rises from Kolahoi glacier in the northern slopes of Kolahoi mountain and is joined by a stream flowing from the Tarsar and Chandasar.

After the junction of these torrents at Pahalgam, the river flows in the form of a rapid and un-navigable stream in a southwesterly direction. The channel is narrow and studded with massive boulders, till it debouches into a wide alluvial fan near Aishmuqam where its load gets deposited and the stream bifurcates into a number of channels. In its passage through the lower part of the valley, the river is divided into a number of distributaries, which fan out to form a wide alluvial plain. The Lidder river merges with Jhelum at four places of Khanabal, Gur, Adar and Katriteng, contributing it a volume of water slightly less than that of the Jhelum itself. In altitude the Lidder falls from 2129 meters at Pahalgam to 1591 meters at Gur just in a distance of about 38 kms. Thus the fall is 14 meters in 1 km. However, from the source of west Lidder to Gur, the fall is 49 meters in 1 km or 1 in 20 (Raza et al., 1978).

LIDDER CATCHMENT DRAINAGE NETWORK



Source: Generated from survey of India toposheets, 1961 and satellite data, 2010

Fig. 2.4

The East and West Lidder rivers are fed by numerous tributaries before they join at Pahalgam (fig. 2.4). The important tributaries of West Lidder stream are Dandaberi Nalla, Ganshibal Nalla, Tson Nalla and Armiun Nalla. The important tributaries of East Lidder stream are Sonasar Nalla, Harwat Nalla and Manpal Nalla. Many important tributaries join Lidder river below Pahalgam among which Sorus Nalla, Owur Nalla and Langhai Nalla are important. In addition to the natural drainage the river is molded into a number of streams in the lower parts of the catchment for irrigation purposes among which Martand canal and Mahand canal are most important. Martand canal is one of the oldest canals of the state of Jammu and Kashmir which was constructed in 8th century AD by the king Lalitadatya. This canal has received its name from the Martand Karewa which it irrigates with 38 km^2 under its command (Husain, 2006). It was raised from Lidder river at village Ganishpora and terminates in the Karewa of Martand with a total length of 50 kms. In addition to this a large number of small streams are diverted from Lidder river to irrigate paddy fields and hence a dense network of artificial streams is found in the Lidder flood plain. The water recharge zone covering 84.89 percent of the total catchment area is fed by a dense network of tributaries in the north, east and west while the zone of water discharge covering 15.11 percent of the total area of the catchment is characterized by various artificial canals used for irrigation purposes in the Lidder flood plain (fig. 2.4).

2.6. VEGETATION

The type of vegetation in a particular area depends on its climatic conditions, altitude, aspect, topography, soils, etc. The Himalayan mountains have rich forests comprising over a thousand species of trees, shrubs, herbs and climbers. The western Himalayan forests are diverse both in content and composition (Dhar et al., 1997). The state of Jammu and Kashmir is well endowed with forest resources. Its natural vegetation has great diversity in flora, ranging from the lush green *Margs* (Alpine pastures) to evergreen conifers on the gentle slopes of high altitudes and from scrub jungles of the foothills to the deciduous forests on the southern slopes of the Shiwaliks and Pir Panjal range. The vegetation of the study region displays characteristic mixture of temperate and alpine flora. The phytogeographic composition of plant communities is different at different elevations due to differential microclimatic, biotic and other environmental conditions.

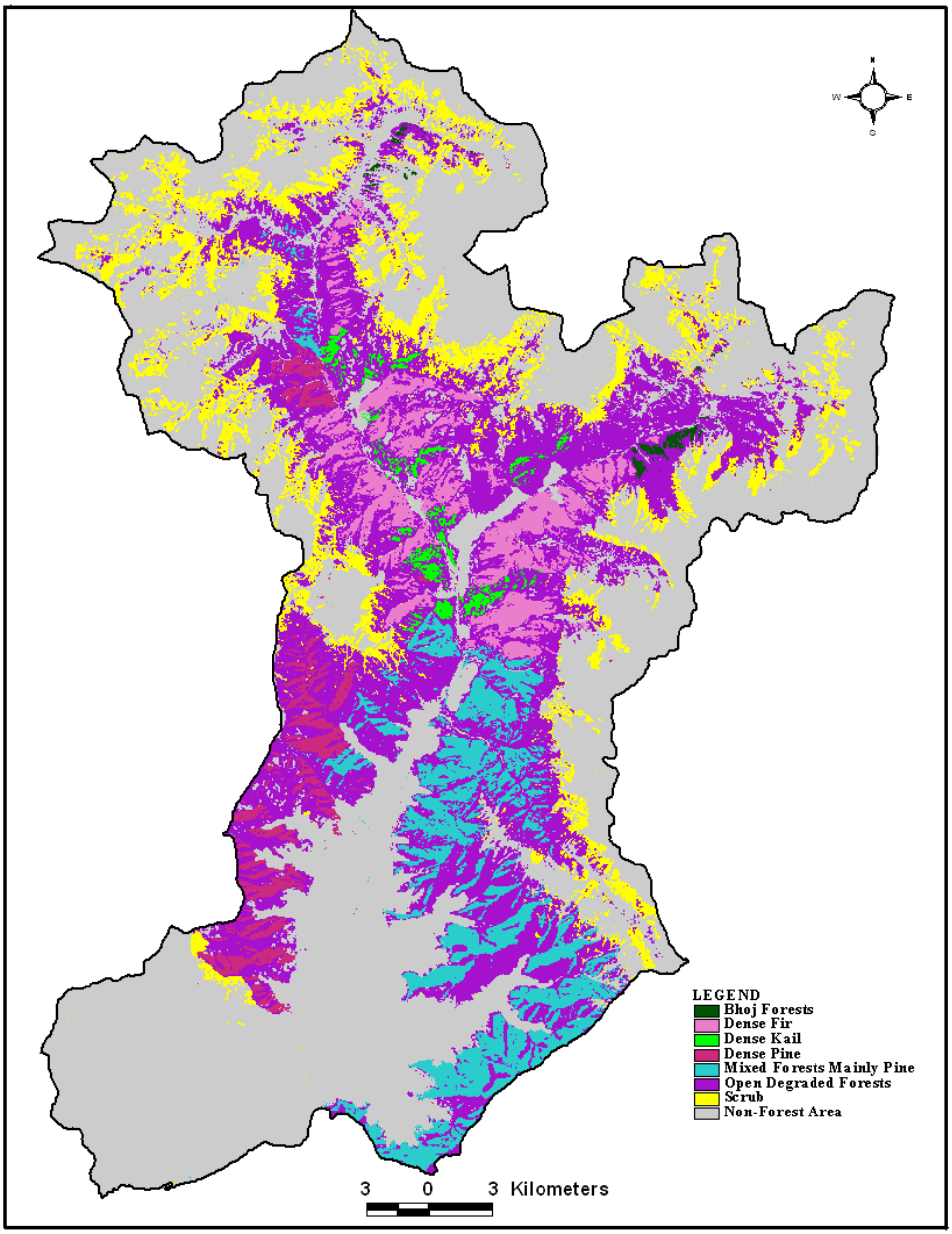
The following vegetation zones have been identified (Kachroo, 1985) in Lidder catchment;

Upper conifer herbaceous zone: The dominant arboreal vegetation of this zone includes *pinus wallichiana*, *picea smithiana*, *Abies pindrow* and several other evergreen species. This zone extends from Pahalgam (2200 meters) to Pissu Ghati and Liddarwat (3000 meters).

White birch zone: The vegetation of this zone is observed from Zaijpal to Sheshnag in the East Lidder and from Lidderwat to Satlanjan in the West Lidder valley. The dominant vegetation of this zone is *Betula bhojpatra*.

Alpine shrubs and meadow zone: This zone of vegetation is observed above 3500 meters altitude and is mainly localized near Sheshnag and Kolahoi valley head. The extreme cold climate helps in the growth of bushy vegetation of *juniperus communis* and *Rhododendron anthopogen*.

LIDDER CATCHMENT
DISTRIBUTION OF VEGETATION



Source: Generated from survey of India toposheets, 1961 and Satellite data, 2010

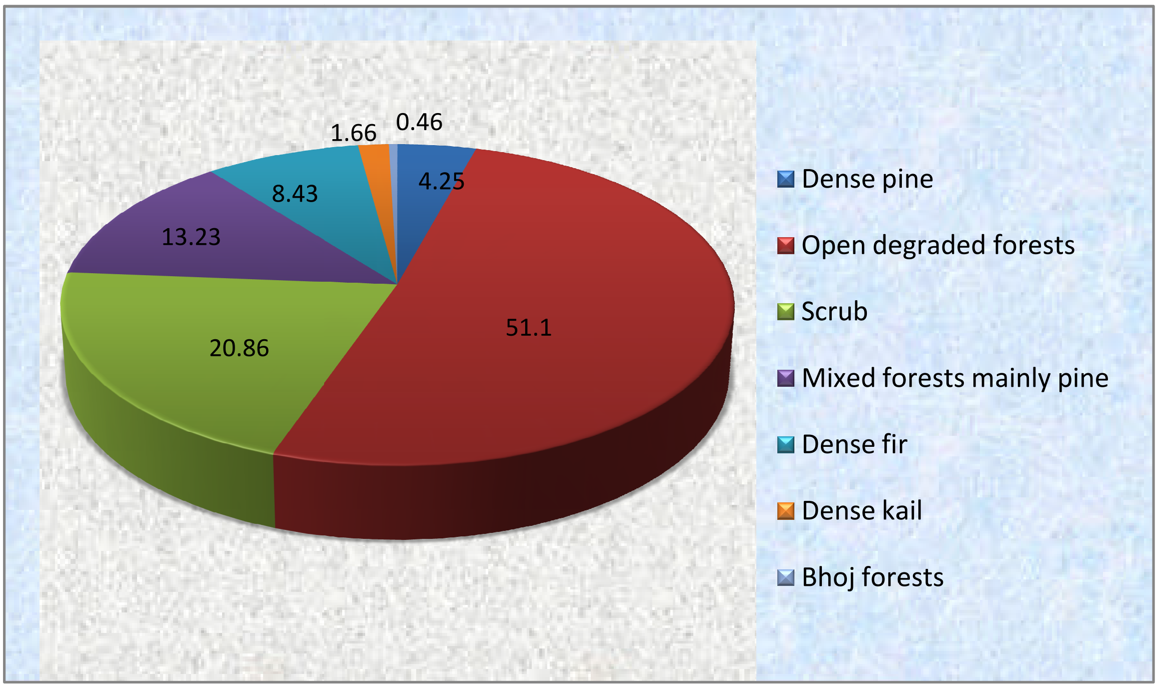
Fig. 2.5

The total area of forests including scrubs is 552.55 km^2 (47.66 percent) in lidder catchment. Open degraded forest is the dominant category comprising more than 51 percent of the total forest area (table 2.2). These forests are under tremendous human impact. The other dominant category is scrubs (20.86 percent) which occupy the outer limits of the catchment below snow line and are dotted among the barren rocky outcrops of the catchment on all sides except south. Mixed dense forests with the dominance of pine occupying 13.23 percent of the total forest area occupy the middle altitudes especially in the southeastern portion of the catchment (fig. 2.5). Dense fir covering 8.43 percent is concentrated on both sides of East Lidder and West lidder streams in a belt stretching from Pahalgam to Aru and Pahalgam to Chandanwari. Dense pine forests are found in the southwest of the catchment with a total percentage share of 4.25 percent. Dense Kail forests are found on the south and west of Pahalgam town and on the north and east of Aru. These forests cover 1.66 percent (fig 2.6) while Bhoj forests covering only 0.46 percent are found along the left bank of Kolhoi stream and Chandanwari forests. The Bhoj forests comprise of short trees developed on higher altitudes due to cold climate.

Table 2.2: Vegetation types in Lidder catchment

S.No.	Vegetation type	Area	
		Absolute (km^2)	Percentage
1	Dense pine	23.47	4.25
2	Open degraded forests	282.38	51.10
3	Scrub	115.26	20.86
4	Mixed forests mainly pine	73.11	13.23
5	Dense fir	46.59	8.43
6	Dense kail	9.18	1.66
7	Bhoj forests	2.56	0.46
Total		**552.55**	**100**

Source: Computed from survey of India toposheets, 1961 and Satellite data, 2010.



Source: Computed from survey of India toposheets, 1961 and Satellite data, 2010

Fig. 2.6: Composition of vegetation in Lidder catchment

2.7. GLACIERS

The glaciers in Lidder catchment are presently confined to the northern limits of the East and the West Lidder valley. The West Lidder glaciers are also called as the Kolahoi group because Kolahoi is the largest glacier. The other important glaciers are Hoksar glacier and Musa Sabin Qabr glacier. The important East Lidder glaciers are Shishram glacier, Wokhbal Glacier and Sonsar glacier.

2.8. HUMAN HABITATION

The Lidder catchment is inhibited by 120 rural settlements and three urban centers of Pahalgam, Aishmuqam and Seer Kanaligund belonging to three tehsils of Anantnag, Pahalgam and Bijbiara of Anantnag district (table 2.3). The whole Lidder catchment was falling under the administrative jurisdiction of tehsil Anantnag in 1961. However, in 1971, Anantnag tehsil was bifurcated into three separate tehsils of Anantnag, Pahalgam and Bijbiara and presently the Lidder catchment is spread over these three tehsils (fig. 2.7). Pahalgam tehsil covers the maximum area (86.1 percent) while Bijbiara and Anantnag tehsils cover only 6.6 percent and 7.3 percent of the total area respectively. All the 66 revenue villages of Pahalgam tehsil fall in Lidder catchment with 1.11 lac persons constituting 47.6 percent of the total population of the catchment.

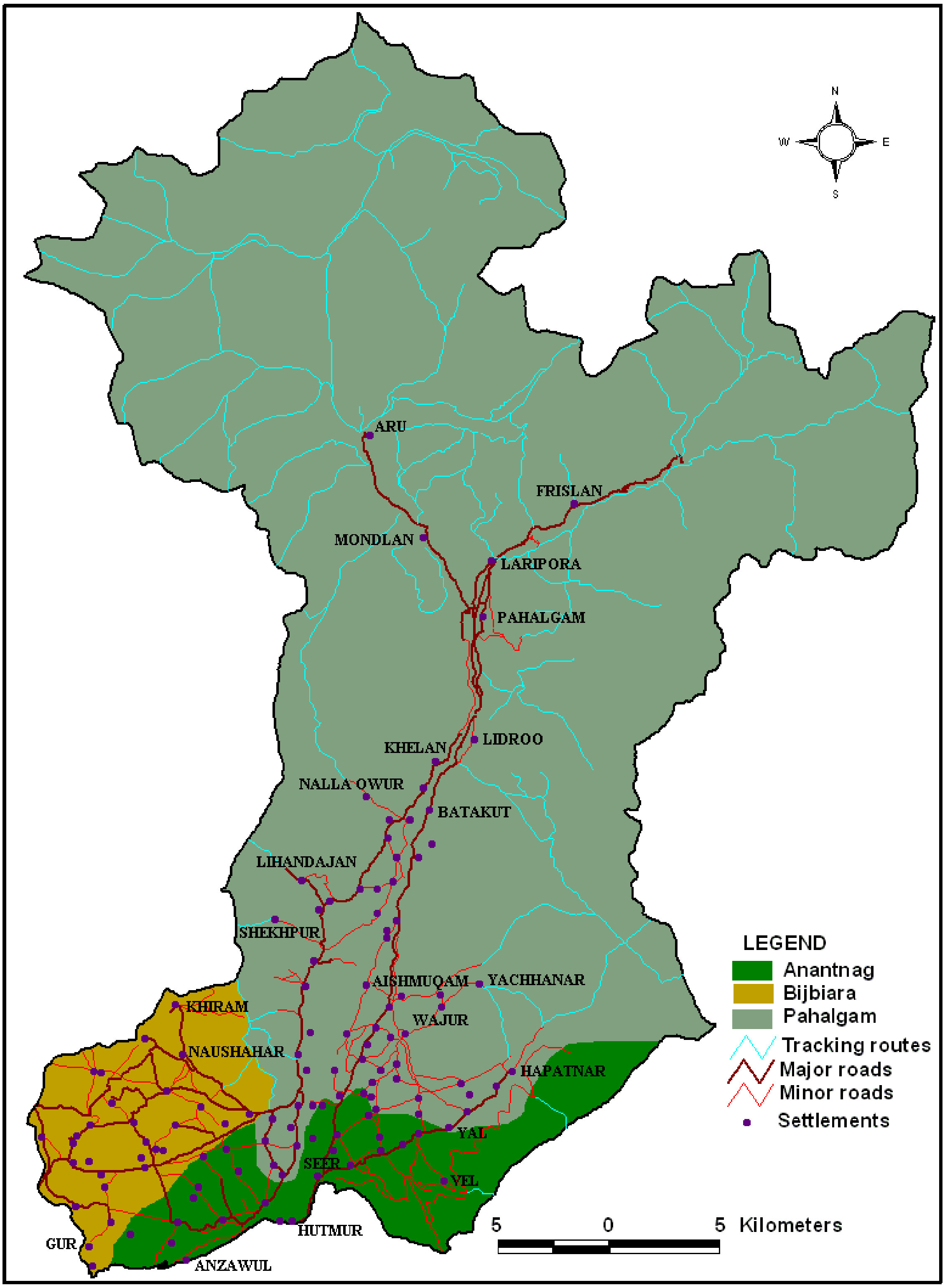
Table 2.3: Tehsil wise distribution of revenue villages and population in Lidder catchment, 2011

S. No.	Tehsil	Number of revenue villages	Area		Population		
			Absolute (Km^2)	Percentage	Absolute (Persons)	Percentage	Population density (Persons/km^2)
1	**Pahalgam**	68	997.65	86.1	111273	47.6	111.5
2	**Bijbiara**	29	76.55	6.6	58888	25.2	769.3
3	**Anantnag**	26	85.18	7.3	63503	27.2	745.5
Lidder Catchment		**123**	**1159.38**	**100**	**233664**	**100**	**201.5**

Source: Computed from Survey of India toposheets 1961 and Census of India, 2011

Bijbiara tehsil covers 29 villages with 25.2 percent of the total population while Anantnag tehsil constitutes 26 villages with 27.2 percent of the total population of the catchment (fig. 2.8). The density of population is highest in Bijbiara tehsil (769.3 persons/km^2) where 25.2 percent of the total population of the catchment is concentrated in only 6.6 percent of the total catchment area. This is because of the fact that Bijbiara tehsil constitutes the Lidder flood plain which is characterized by fertile soils, gentle slope and a dense network of roads which have resulted in high concentration of population in this area. On the other hand Pahalgam tehsil records lowest population density (111.5 persons/km^2) where 47.6 percent of the total population of the catchment is spread over 86.1 percent of total area of the catchment. This could be attributed to the fact that the tehsil is a mountainous one with rugged terrain, steep slopes and inaccessibility which has resulted into population concentration at few favorable spots especially in the lower altitudes along the banks of Lidder river.

LIDDER CATCHMENT
DISTRIBUTION OF REVENUE VILLAGES



Source: Generated from survey of India toposheets, 1961 and Census data, 2011

Fig. 2.7

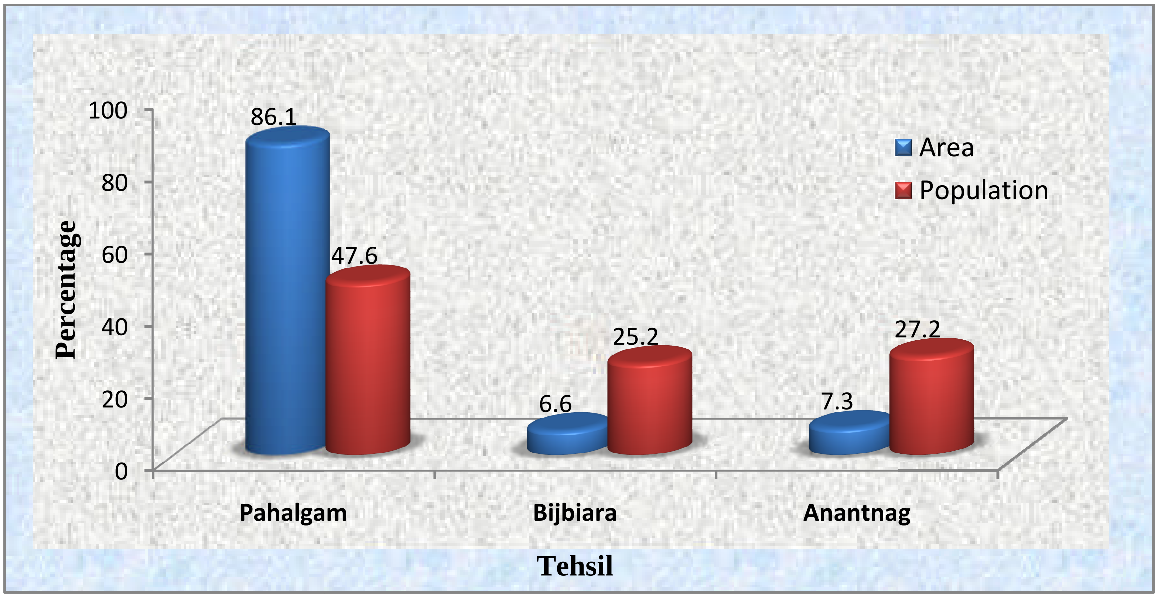


Fig. 2.8: Tehsil wise distribution of area and population in Lidder catchment, 2011

2.9. ECONOMY

Tourism and agriculture are the two major contributors of the regional economy of Lidder catchment. Tourism is a dominant source of income in Pahalgam tehsil especially for the revenue villages surrounding Pahalgam town. Agriculture is the dominant economic activity in the Lidder flood plain where agriculture is practiced mostly on subsistence basis. The northern portion of Bijbiara tehsil and southern portion of Pahalgam is devoted to apple orchards which is high income generating agricultural activity as compared to other crops. Animal rearing has always played an important role as Pahalgam is often translated as the village of shepherds. The presence of meadows has facilitated the people to rear a good number of livestock population. It is because of this fact that the livestock population has outnumbered human population in the catchment.

CHAPTER - 3

DATABASE AND METHODOLOGY

A comprehensive methodological framework has been adopted for the present study. Since the main purpose of the study was to prioritize different watersheds on the basis of various geo-physical and socio-economic indicators, various data sets were generated to serve the purpose. An outline of the methodology used is presented in this chapter as discussed below.

3.1. DATA SETS USED

As the nature of the study was very diverse, the data base required was also comprehensive. The various data layers were collected and generated from different sources with diverse nature and characteristics as given in table 3.1.

Table 3.1: Type and sources of data sets used

S. No	Data set	Source	Date of acquisition
1	Topographic maps	Survey of India	1961
2	LANDSAT 7 ETM	NRSC, India	September, 1992
3	LANDSAT 7 ETM^+	NRSC, India	September, 2001
4	IRS P6 LISS III	NRSC, India	September, 2010
5	Primary data	Ground Truthing/Field survey/sample survey	2010, 2011
6	Secondary data	Government departments; Published sources; etc	1961- 2011

3.1.1. Survey of India Toposheets

The Survey of India topographic maps of the year 1961 on 1:50,000 scale were used to delineate and to demarcate different watersheds of Lidder catchment. Seven toposheets (43 N/4; 43 N/7; 43 N/8; 43 N/12; 43 O/1; 43 O/2; 43 O/5) were used and their arrangement is given in figure 3.1. These toposheets were geo-referenced and a mosaic of toposheets was prepared. These toposheets were used to generate various data layers such as LULC map of 1961, drainage map, contour map, settlement distribution map and map showing major roads and tracking routes etc. The mosaic of toposheets was also used for the identification of various sample sites, ground truthing points and also for the demarcation of different tourist potential regions. Moreover the other satellite data was geo-referenced with reference to this toposheet mosaic.

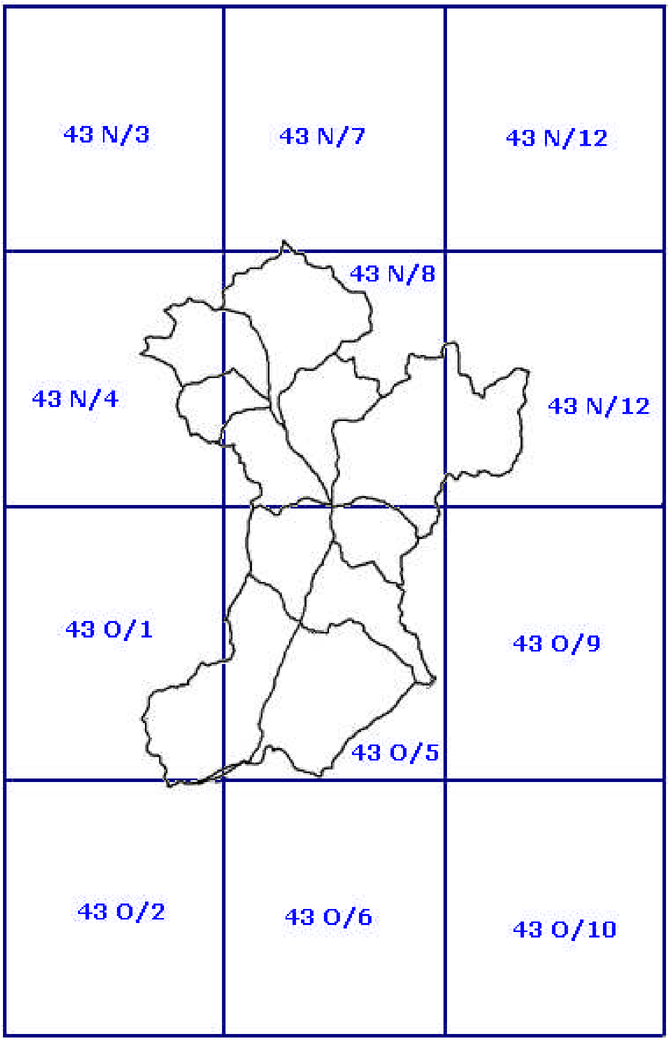


Fig. 3.1: Number and arrangement of toposheets covering Lidder catchment

3.1.2. Satellite Data

Satellite data served as one of the important data source for the present study. Satellite images for three time periods (1992, 2001 and 2010) were used to compare LULC change in Lidder catchment **(**table 3.2). This data was obtained from National Remote Sensing Agency (NRSA), Hyderabad.

Table 3.2: Satellite data used and their characteristics

Satellite	**Sensor**	**Spatial resolution (meters)**
LANDSAT 7	ETM	28 m
LANDSAT 7	ETM^+	23 m
IRS P6	LISS III	23 m

3.1.3. Sample Survey / Field Survey

Sample survey was conducted in order to collect the data regarding different social, economic and demographic variables. The survey was covered in four phases.

The first one covered the survey of households to obtain information on various demographic variables. For the generation of the socio-economic data, a stratified sample of 50 villages from all watersheds constituting 41 per cent of the total villages was taken (fig. 3.2). From every village twenty households were surveyed at random (table 3.3**)** which amounts to the total survey of 1000 households in the catchment. In the watersheds of 1E7A2, 1E7A7, 1E7B1 and 1E7B3, the number of revenue villages is small and hence all the villages were surveyed. The location of all the sample villages was recorded using portable GPS **(**table 3.4**)**. Pahalgam, the tourist town was surveyed separately. A structured schedule (Annexure- I) was used as a tool for primary data collection.

Table 3.3: Sample frame of the study

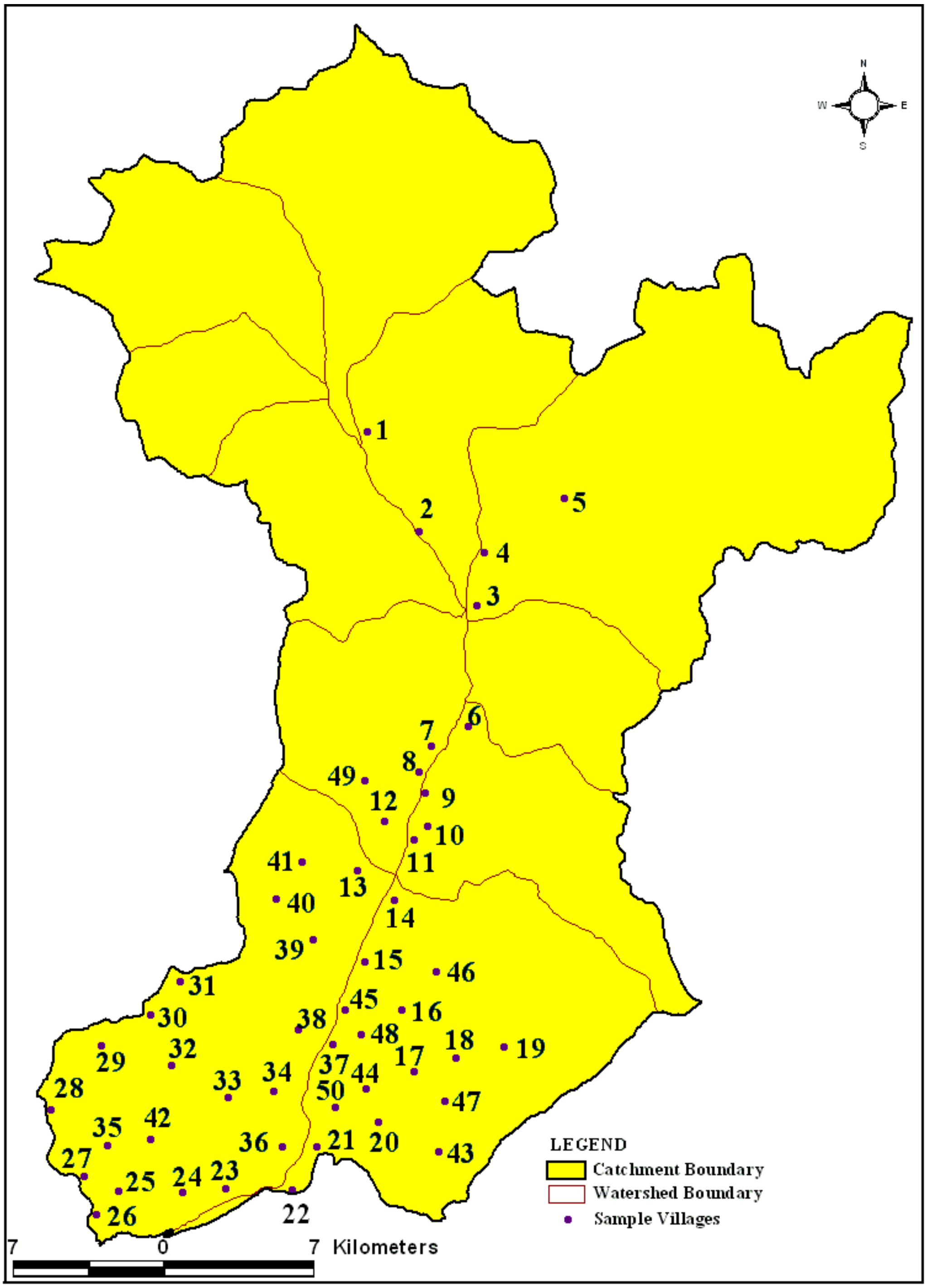
Watershed	Total area (km^2)	Revenue villages			Number of households	
		Total	Sample	Percentage of sample to total villages	Total	Sample
1E7A1	173.24	58	20	34	19024	400
1E7A2	73.14	8	4	50	1364	80
1E7A3	65.08	Uninhabited				
1E7A4	40.46	Uninhabited				
1E7A5	78.07	Uninhabited				
1E7A6	129.36	Uninhabited				
1E7A7	77.19	2	2	100	180	40
1E7B1	228.52	3	3	100	1254	60
1E7B2	53.49	Uninhabited				
1E7B3	78.36	4	4	100	1066	80
1E7B4	162.47	48	17	35	12871	340
Lidder catchment	**1159.38**	**123**	**50**	**41**	**35759**	**1000**

Source: Computed from Survey of India toposheets 1961 and Census of India, 1961 and 2011

In the second survey the data regarding various attributes of tourists and yatries was generated and the survey was conducted in three phases i.e. before yatra, during yatra and after yatra. One thousand tourists and one thousand yatries were interviewed using a structured schedule (Annexure- II). The third survey was conducted in order to analyze the existing tourist infrastructure in terms of accommodation and amenities in Pahalgam valley. All the hotels and dhabas were completely surveyed while as fifty percent of the total guest households were surveyed (Annexure- III). The information regarding the solid waste generation and its composition was generated through direct measurement and also supplemented by the stratified sample survey of different categories of hotels and guest houses by using the structured questionnaire given in annexure- IV. The necessary information regarding the flow of transport vehicles was obtained from the sumo stands and pony stands of Pahalgam. The fourth survey was conducted to validate the LULC map generated from satellite data for the year 2010 by way of Ground truth survey for selected LULC categories in different watersheds.

LIDDER CATCHMENT

DISTRIBUTION OF SAMPLE VILLAGES



Source: Generated from SOI toposheets 1961 and Census data 2010

Fig. 3.2

Table 3.4: Location of sample villages in Lidder catchment

S. No.*	Village	Latitude	Longitude	Altitude (masl)	S. No.	Village	Latitude	Longitude	Altitude (masl)
1	**Aru**	34^{0} 05'22″	75 16' 01″	2640	**26**	**Gur**	33^{0} 45' 45″	75 07' 47″	1570
2	**Mondlan**	34^{0} 02' 53″	75^{0} 17' 34″	2260	**27**	**Krendigom**	33^{0} 46' 45″	75^{0} 07' 29″	1570
3	**Pahalgam**	34^{0} 00' 59″	75^{0} 19' 18″	2235	**28**	**Katriteng**	33^{0} 48' 25″	75^{0} 06' 28″	1570
4	**Laripora**	34^{0} 02' 21″	75^{0} 19' 30″	2240	**29**	**Shalagam**	33^{0} 50' 02″	75^{0} 08' 01″	1620
5	**Frislan**	34^{0} 03' 43″	75^{0} 21' 56″	2470	**30**	**Srihom**	33^{0} 50' 48″	75^{0} 09' 27″	1740
6	**Lidroo**	33^{0} 58' 02″	75^{0} 19' 00″	2155	**31**	**Kheram**	33^{0} 51' 37″	75^{0} 10' 23″	1750
7	**Khelan**	33^{0} 57' 30″	75^{0} 17' 53″	2160	**32**	**Mahand**	33^{0} 49' 34″	75^{0} 10' 08″	1730
8	**Virsaran**	33^{0} 56' 51″	75^{0} 17' 34″	2020	**33**	**Darigund**	33^{0} 48' 45″	75^{0} 11' 51″	1620
9	**Batkut**	33^{0} 56' 20″	75^{0} 17' 42″	1995	**34**	**Sirigofwara**	33^{0} 48' 53″	75^{0} 13' 14″	1690
10	**Batkut Gujaran**	33^{0} 55' 31″	75^{0} 17' 47″	2110	**35**	**Thajwor**	33^{0} 47' 32″	75^{0} 08' 13″	1600
11	**Sruchan**	33^{0} 55' 10″	75^{0} 17' 24″	2000	**36**	**Peth-Nambal**	33^{0} 47' 29″	75^{0} 13' 29″	1650
12	**Dahwot**	33^{0} 55' 38″	75^{0} 16' 33″	1980	**37**	**Srangus**	33^{0} 50' 04″	75^{0} 15' 01″	1690
13	**Kular**	33^{0} 54' 26″	75^{0} 15' 45″	1920	**38**	**Bodur**	33^{0} 50' 26″	75^{0} 13' 59″	1680
14	**Ganishpora**	33^{0} 53' 40″	75^{0} 16' 48″	1925	**39**	**Salar**	33^{0} 52' 42″	75^{0} 14' 27″	1830
15	**Amar**	33^{0} 52' 07″	75^{0} 13' 54″	1820	**40**	**Shekhpur**	33^{0} 53' 43″	75^{0} 13' 19″	2010
16	**Logripora**	33^{0} 50' 54″	75^{0} 17' 01″	1850	**41**	**Lihandajan**	33^{0} 54' 39″	75^{0} 14' 07″	2040
17	**Hassannoor**	33^{0} 49' 20″	75^{0} 17' 22″	1810	**42**	**Kanyalwan**	33^{0} 47' 41″	75^{0} 09' 30″	1630
18	**Shumahal**	33^{0} 49' 42″	75^{0} 18' 36″	1940	**43**	**Vel**	33^{0} 47' 19″	75^{0} 18' 07″	2040
19	**Hapatnar**	33^{0} 49' 59″	75^{0} 20' 05″	2070	**44**	**Palapur**	33^{0} 48' 55″	75^{0} 15' 56″	1780
20	**Sali**	33^{0} 48' 05″	75^{0} 16' 18″	1750	**45**	**Karshangom**	33^{0} 50' 56″	75^{0} 15' 18″	1780
21	**Seer**	33^{0} 47' 28″	75^{0} 14' 26″	1780	**46**	**Ayun**	33^{0} 51' 50″	75^{0} 18' 02″	2020
22	**Hutmor**	33^{0} 46' 22″	75^{0} 13' 43″	1740	**47**	**Yal**	33^{0} 48' 38″	75^{0} 18' 14″	1900
23	**Akura**	33^{0} 46' 25″	75^{0} 11' 41″	1730	**48**	**Malikgund**	33^{0} 50' 18″	75^{0} 15' 48″	1760
24	**Nanyil**	33^{0} 46' 20″	75^{0} 10' 22″	1640	**49**	**Nalla Owur**	33^{0} 56' 39″	75^{0} 15' 55″	2120
25	**Veer**	33^{0} 46' 20″	75^{0} 08' 27″	1595	**50**	**Akad**	33^{0} 48' 29″	75^{0} 15' 04″	1700

Source: Sample survey, 2011

***Note:** The serial number in the table corresponds to the number given in figure 3.2

3.1.4. Secondary Data

Ancillary data comprising reports and publications relevant to the present study were obtained from different sources. The data pertaining to the number of revenue villages and their population in different watersheds for 1961, 1971, 1981 and 2001 were obtained from the district censes hand books of the respective years prepared by the Department of censes Jammu and Kashmir. However the census data for 2011 was obtained from the tehsil offices of Pahalgam, Anantnag and Bijbiara. The data pertaining to tourist flow was obtained from department of tourism Jammu and Kashmir; Department of tourism, Pahalgam; State road transport corporation, Pahalgam; Pahalgam Development Authority, Pahalgam and Joint Police Control Room (JPCR), Pahalgam.

The data regarding river discharge was obtained from Department of Flood Control, Planning and Designing Division, Srinagar for all the four Gauging stations which are installed at the four respective places where Lidder river Joins Jhelum river. The meteorological data was obtained from the regional meteorological centre, Rambagh, Srinagar.

3.2. METHODS USED

The above mentioned data sets were analyzed in the light of the various objectives of the study. A broad outline of the various methodological steps is provided in figure 3.3 for which a brief description is produced as under.

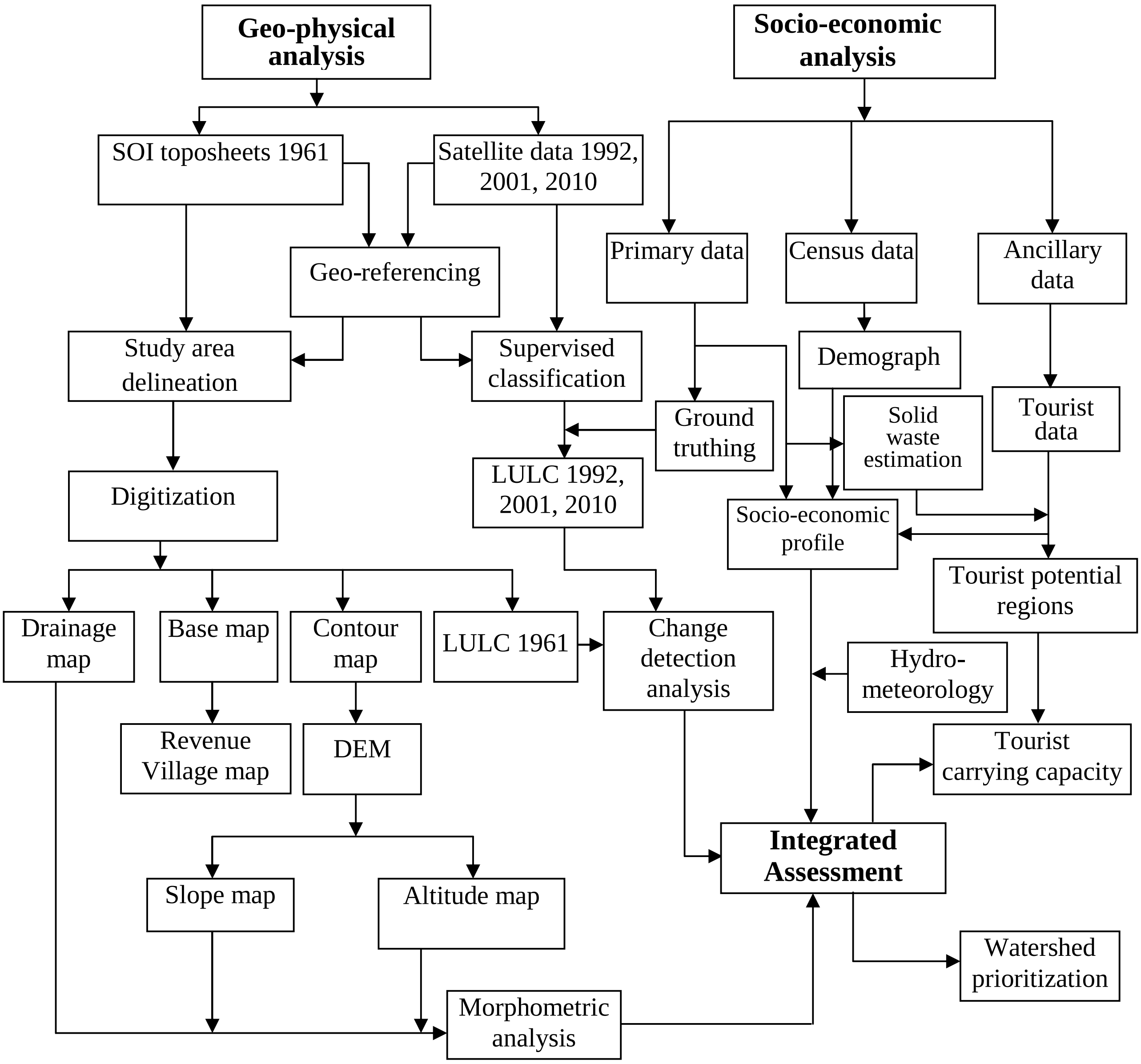


Fig. 3.3: Flow chart showing methodological framework of the study

3.2.1. Geo-referencing

All the hard copy topographic maps and other related maps were scanned and geo-referenced in a common frame to make them compatible for the subsequent analysis. Accurate geometric registration of images is a pre-requisite to perform a multi-source classification. The method of image registration or "geo-referencing" can be divided into two types: "image-to-image-registration" and "image-to-map registration". First of all the toposheets were individually geo-referenced to a common projection (UTM, Zone 43 North, WGS 84) using 16 well distributed ground control points for each toposheet with the help of the coordinate system already available on the toposheets and a mosaic was prepared. This mosaic was defined as the master image for subsequent registration of the satellite images and other scanned maps using image to image registration. Due to non-existence of sharp, well defined, stable and prominent features in the image, the Ground Control Points (GCPs) were acquired mainly from the intersection of the drainage lines. Owing to the steep topography and narrow valleys in the upper parts of the catchment, it was assumed that there was no change in drainage network between the year of topographic map generation and the date of acquisition of satellite image. However in the southern parts of the catchment, the intersection of transport lines especially bridges on the Lidder river and the confluence of Lidder river with Jhelum river were used as important GCP's. Accurate geometric rectification is essential for change detection, since the potential exists for registration errors to be interpreted as land use change, leading to an overestimation of actual change (Stow, 1999). Change detection analysis is performed on a pixel-by-pixel basis; therefore, any miss-registration greater than one pixel will provide an anomalous result of that pixel. All images were rectified to UTM Zone 43 N, WGS 1984 using at least 25 well distributed GCP's. After registering all the maps to a common coordinate system a precise ground validation was carried out using a differential global positioning system to reduce the margin of error to sub-pixel level.

3.2.2. Extraction of Study Area

From the geo-referenced mosaic of toposheets, the catchment area of Lidder river was delineated on the basis of drainage and contour lines. The study area was further divided into two sub-catchments of West Lidder and East Lidder. Eleven watersheds (fig.3.4) were delineated from these two sub-catchments (seven from the West Lidder sub-catchment and four from the East Lidder sub-catchment). The boundary of Lidder catchment and its watersheds was digitized and was used to subset other images and maps of the study area to keep the overall area of the catchment constant and also to facilitate a perfect overlay analysis in GIS. This was substantiated by an automated extraction of Lidder catchment and its watersheds from DEM through advanced geospatial techniques. A close comparison was found between the two.

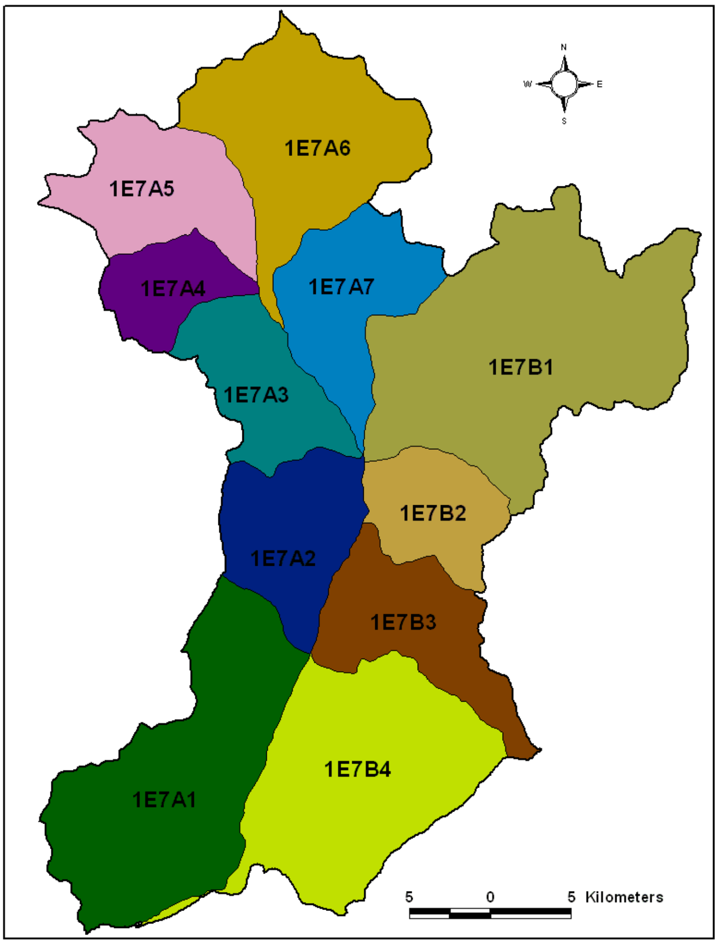
Table 3.5: Watershed codification scheme

Hydrological unit	Code
Water Resource Region	1,2,3,4,5,6.
River Basins	A,B,C,D,E, …
Catchments	1, 2, 3, 4, 5, 6, 7, …
Sub- catchments	A, B, C…
Watersheds	1, 2, 3…

Source: All India Soil and Land use Survey, Ministry of Agriculture, New Delhi

These watersheds are assigned specific systematic codes (table 3.5) according to the codification system devised by All India Soil and Land use Survey (Gautuam and Krishna, 2005). The codification includes five letters. The codes for eleven watersheds are; 1E7A1, 1E7A2, 1E7A3, 1E7A4, 1E7A5, 1E7A6, 1E7A7, 1E7B1, 1E7B2, 1E7B3 and 1E7B4. Thus for watershed 1E7A1, the first Arabic letter 1 represents resource region i.e. Indus. The second place letter E represents the basin i.e. Jhelum basin. Again the Arabic numerical 7 at the third place refers to the catchment i.e. Lidder catchment and the fourth letter A refers to sub-catchment i.e. West Lidder sub-catchment. The fifth place Arabic numerical 1 indicates a particular watershed.

LIDDER CATCHMENT
DISTRIBUTION OF WATERSHEDS



Source: Generated from Survey of India toposheets, 1961

Fig. 3.4

3.2.3. Generation of Digital Elevation Model (DEM) and Its Derivatives

A DEM is a regular array of terrain elevations normally obtained in a grid or generated using; (a) ground survey data, (b) cartographic digitization of contour data, and/or (c) photogrammetric measurements. Existing topographic maps contain a wealth of terrain data that may be used for digital terrain modeling. For the generation of DEM, contour lines were digitized from the already geo-referenced mosaic of toposheets. These contours were labeled with their respective elevation values. The contour map was then processed in the ERDAS Imagine software to create a continuous raster surface by interpolating the elevation values. In the data preparation module of ERDAS Imagine software, the surfacing was done and the 40 meter spatial resolution DEM of the study area was obtained and was used for topographic analysis of the area.

DEMs along with their derivatives such as slope and aspect provide the basis for LULC classification (Jones et al., 1988; Frank, 1988; Janssen et al., 1990). These are very helpful especially in mountain watersheds with high altitudes and rugged terrain to eliminate the shadow effect of mountains and contribute to the overall accuracy of the land use classification. A major variation in the brightness values of pixels can be found due the presence of shadows. This may lead to erroneous classification. Therefore, the DEM was used as ancillary data in the classification process primarily to reduce misclassification of shadowed areas to water bodies or dense forests. Moreover, the elevation information from DEM may also act as a logical rule to eliminate the presence or absence of certain classes in some elevation zones. For example, agriculture land is not expected to exist at higher elevations that are covered with snow since climatic conditions do not allow for any agricultural activity at such high elevations. These areas should be categorized as barren land. Therefore, any presence of fallow land in the neighborhood of snow-covered areas may represent a misclassification, which can be reduced by including a DEM in the remote sensing classification process.

3.2.4. Morphometric Analysis

Morphometric analysis is one of the important components to determine the overall hydrological behaviour of a catchment. Delineation of all the existing streams in a drainage basin is prerequisite for drainage morphometric analysis. The stream delineation was done digitally in GIS (Arc view, 3.2a) system. The tributaries of different extents and patterns were digitized from the geo-referenced mosaic of Survey of India toposheets (1: 50000 scale). The different morphometric parameters have been determined as shown in table 3.6. The validation of Horton’s law of stream numbers and stream lengths was also carried out for Lidder catchment.

Table 3.6: Morphometric parameters

S.No.	Morphometric parameter	Formula	Reference
1	Stream order	Hierarchical rank	Strahler (1964)
2	Stream length (Lμ)	Length of the stream	Horton (1945)
3	Mean stream length (Lsm)	Lsm = Lμ/Nμ Where, Lμ = total stream length of order 'μ' Nμ = total no. of stream segments of order 'μ'	Strahler (1964)
4	Bifurcation ratio (Rb)	Rb = Nμ / Nμ +1 Where, Rb = Bifurcation ratio, Nμ = No. of stream segments of a given order and Nμ +1= No. of stream segments of next higher order.	Schumn (1956)
5	Mean bifurcation ratio (Rbm)	Rbm = Average of bifurcation ratios of all orders	Strahler (1957)
6	Drainage density (Dd)	Dd = Lμ/A Where, Dd = Drainage density. Lμ = Total stream length of all orders and A = Area of the basin (km^2).	Horton (1932)
7	Drainage frequency (Fs)	Fs = Nμ/A Where, Fs = Drainage frequency. Lμ = Total no. of streams of all orders and A = Area of the basin (km^2).	Horton (1932)

3.2.5. Socio-economic Analysis

The analysis of the socio-economic characteristics includes the calculation and comparison of absolute population, population density, population growth, sex ratio, literacy, work force, occupational structure, dependency ratio, work participation rate, age structure, livestock population and energy consumption in different watersheds. These characteristics were calculated and compared between watersheds as they serve as important indicators of man-land relationship and anthropogenic impact on the environment.

3.2.6. Delineation of Tourist Potential Regions

The tourist potential regions of the Lidder valley have been identified on the basis of the selected indicators (index of natural beauty, index of adventure and spots and index of games and infrastructure) and ranked on the basis of composite scores. The presence or absence of any indicator at a particular site was assigned a value of 4 and 0 respectively.

1. **Index of natural beauty**

   i. presence of forests
   ii. presence of springs

iii. presence of pastures and meadows
iv. presence of glaciers
v. presence of high altitude lakes
vi. presence of flowing water

2. Index of adventures and sports

i. Ice skiing
ii. Water skiing
iii. Heli skiing
iv. River rafting
v. Mountaineering and trekking
vi. Hiking and rock climbing
vii. Boating and swimming

3. Index of games and infrastructure

i. Presence of shooting and fishing beats
ii. Presence of accommodation
iii. Presence of hotels and shops
iv. Transport and communication
v. Other civic infrastructure

3.2.7. Generation of Land Use Land Cover Maps

A series of LULC maps were prepared for all the eleven watersheds of Lidder catchment for 1961, 1992, 2001 and 2010. Different methods were used because of their different nature and sources. On-screen visual interpretation and digitization was done at a constant scale of 1:10000 in order to prepare the LULC map for 1961 from mosaic of toposheets using Arc view 3.2a. The LULC maps for 1992, 2001 and 2010 were prepared using maximum livelihood classifier of supervised classification.

3.2.7.1. Classification scheme

A preliminary component of mapping LULC is to develop or adopt a LULC classification system. The present study incorporated the modified form of the classification scheme set by Gautam and Krishna (2005). The majority of the classes (table 3.7) were from level I and II (table 6.2). The only exception was that of Dense and Sparse Forest, Which belonged to level III, but were included in the classification scheme due to their clear and vivid spectral response.

Table 3.7: Land use land cover classification for Lidder catchment

S. No.	LULC Category	Description
1	**Built-up**	*It is defined as an area of human habitation developed due to non-agricultural use and that which has a cover of buildings, transport and communication, utilities in association with water, vegetation and vacant lands. All manmade constructions covering the land surface are included under this category.*
2	**Agricultural land**	*It is defined as the land primarily used for farming and for the production of food, fiber and other commercial crops. It includes land under crops (irrigated and un-irrigated) and fallow lands.*
3	**Horticulture/ Plantation**	*It is the area devoted to horticulture crops with the dominance of apple orchards. It also includes the area under willow and popular trees.*
4	**Dense forest**	*It is an area bearing an association predominantly of trees and other vegetation types capable of producing timber and other forest produce. Forests, where the vegetation density (crown cover) is 40 per cent or above, are classified a dense or closed forest.*
5	**Sparse forest**	*Forests, where the vegetation density is between 10 to 40 per cent are classified sparse forest and/or open degraded forest.*
6	**Waste lands**	*Waste lands are described as degraded lands and lands which are deteriorating due to lack of appropriate water and soil management or on account of natural causes. Gullied/ravenous lands and barren rocky/stony waste are taken as waste lands. The waste lands in the study area are mostly rocky barren lands.*
7	**Scrub lands**	*The area covered with mixture of short scrub and bushes with little useful wood is classified under this category.*
8	**Water Bodies**	*This class comprises area of surface water either impounded in the form of pounds, lakes and reservoirs or flowing as rivers, streams, canals etc.*
9	**Glaciers**	*Areas of perpetual snow cover come under this category. When a mass of snow and ice deforms under its own weight and starts flowing, it is termed as glacier.*
10	**Rangelands/ Meadows**	*These are areas where natural vegetation is dominated by grasses or grass like plants and non-grass like herbs. Lands exclusively used for farming grasses are called meadows and pastures.*

Source: Modified after Gautam and Krishna, 2005

3.2.7.2. Image classification

Land cover classes are typically mapped from digital remotely sensed data through digital image classification and interpretation. The overall objective of the image classification procedure is to automatically categorize all pixels in an image into land cover classes or themes (Lillisand et al., 2008). Image classification procedures are used to classify multispectral pixels into different land cover classes. The input for the classification is multispectral bands and textural patterns computed from the multispectral data. Primary methods are supervised classification and unsupervised classification. Several variations of these methods exist; each process uses multiple bands of the images to isolate unique spectral classes. No definite advice can be made about which classifier is best in all circumstances (Townshend, 1992). The digital image classification as such seems to be a simple process but in reality there are complications that limit the accuracy of land cover classification. These may arise partly due to the characteristics of the remote sensing images and assumptions underlying the techniques employed in the classification process (Mather, 1999).

In the unsupervised approach, pixels are grouped into different spectral classes by clustering algorithms without using prior information (Jenson, 1996). Unsupervised classification algorithms only have a secondary role in remote sensing. Supervised classification begins with ground observations at particular points in the study area. In supervised classification, the analyst supervises the pixel categorization process by specifying the computer algorithm of the statistical parameters, viz. mean vector and variance-covariance matrix of various thematic classes present in the scene. In order to achieve this objective, representative training sets were developed after analysis of various visual (colour, tone, texture, shape, size, association, etc.) and statistical (mean, standard deviation, etc.) characteristics of the data. A representative training data for each of the predefined number of classes was selected. The training sets were taken from homogeneous cover types. The supervised classification was carried out by the flowing three steps:

1) The number and nature of the information classes was defined. Sufficient and representative training data for each class was collected.
2) Required statistical parameters were recorded for the training sets, and finally
3) An appropriate decision rule (maximum likelihood algorithm) was used.

A combination of more approaches in mapping provides better results than just using a single approach (Kuemmerle et al., 2006; Lo and Choi, 2004). In mountain area, especially in Himalayas due to the terrain complexity, the spectral signature is influenced by elevation, aspect and slope. The same objects may show different reflectance or the different objects may have the same reflectance. In this situation, having the intensive ground truth, onscreen visual interpretation is employed. The automated Supervised Classification had many errors of misclassification, particularly in the shadow regions giving a poor accuracy report. Therefore a GIS post-processing approach has been followed that combines the advantages of both unsupervised and supervised approaches to produce an improved LULC map. Morerover, the post classification smoothing in order to remove the local variability (salt and pepper appearance) was applied and thus both the appearance and reliability of the maps was improved.

For the present work homogenous sample pixels were identified as training sets in the image and were used as representative samples for each LULC category to train the algorithm to locate similar pixels in the image. For each LULC type five to ten areas of interest were prepared as the signature of training sample to ensure that the spectral properties of each category are represented sufficiently. The training areas were created in order to discriminate the individual classes. The spectral reflectance characteristics and textural patterns and various other interpretation keys employed in the present study are elaborated in table. 3.8.

Table 3.8: Interpretation keys for different LULC Classes

LULC category	Interpretation Keys (FCC)
Dense forest	Dark/Deep reddish tone, smooth to medium texture and irregular pattern.
Spare Forest	Red tonal variation from bright red to blackish red medium texture,
Meadow	Bright red patches specifically located in high altitudes. Smooth texture associated with forests and water bodies.
Barren land	Brownish to yellow in color , irregular to discontinuous shape
Water bodies	Blue to dark blue, black or cyan with well defined shapes (linear- river/ round-pond etc)
Scrub land	Light yellow to brown to greenish blue appearing in small to medium size depending on surface moisture cover and vary in size from small to large having either contiguous or dispersed pattern, with moderate slopes in plains and foothills and are generally surrounded by agricultural lands..
Built up	Bluish green, blue mixed with red and white irregular outline and varying size, fine texure (high density builtup land). Medium texure (low density to medium density builtup land)
Agriculture	Dark grey to Blue, with varying size, rectangular shape and contiguous pattern. Medium texture and mostly associated with drainage.
Glacier/snow	Bright white to white in color irregular with a contagious pattern located in mountain peaks and slope with a linear to dispersed pattern located on mountain peaks or river mouths
Horticultural Plantation	Tone ranges from orange red to bright red with uniform size, rectangular shape and medium to fine texture. Pattern is generally contagious.

Source: National Remote Sensing Agency (NRSA) 2006

3.2.7.3. Ground Truthing

In present study, Ground truthing was conducted both in pre-classification as well as post-classification stage. The pre-classification field study was conducted to prepare a preliminary legend which was later corroborated with the spectral characteristics of images and with standard classification scheme. The post-classification ground truthing was essential in assessing accuracy and classifying some unclassified pixels and shadow regions. The field verification process was preceded by selecting the ground truthing points and their coordinates were taken from geo-referenced images and were located on toposheets. On ground these points/patches were identified with the help of DGPS. The field information was collected on ground verification Performa. The sample information collected from the ground is given in table 3.9 and their spatial distribution is presented in figure 3.5.

LIDDER CATCHMENT
GROUND TRUTHING LOCATIONS

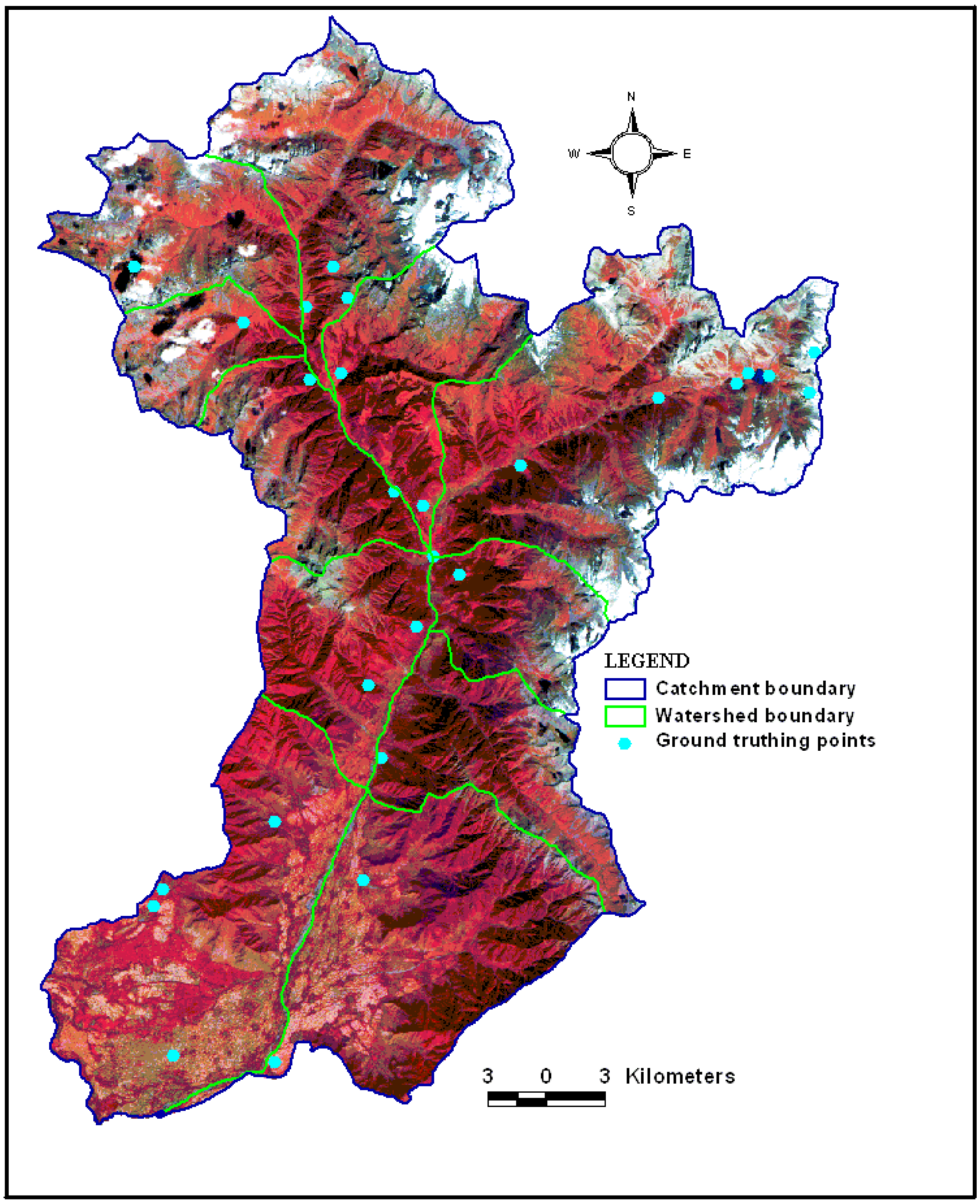


Fig. 3.5

Table 3.9: Field Verification Information

S.No.	Watershed	Nearest Village	Latitude (N)	Longitude (E)	Elevation (masl)	LULC subunit	Major Category	Dominant Slope	Remarks
1	1E7A1	Magrepur	33^0 46' 56″	75^0 10' 25″	1630	Paddy field	Agriculture	Gentle	Vast agricultural area dotted by willow trees on the individual field boundaries.
2	1E7A1	Srihom	33^0 51' 05″	75^0 09' 46″	1780	Apple orchards	Horticulture	Gentle	Dense patch of Apple gardens
3	1E7A1	Kheram	33^0 51' 30″	75^0 10' 05″	1810	Residential area	Built-up	Gentle	Built-up area of village Kheram surrounded by Apple orchards
4	1E7A1	Salar	33^0 53' 25″	75^0 13' 48″	1900	Dense pine	Dense forest	Gentle to moderate	Dense patch of Pine forests in Salar forest area
5	1E7A2	Virsaran	33^0 57' 10″	75^0 16' 51″	2320	Dense Pine	Dense forest	Gentle to moderate	Dense mixed jungle in Virsaran forests mainly Pine trees
6	1E7A2	Sarbal ziarat	33^0 58' 47″	75^0 18' 32″	2400	Degraded forest	Sparse forest	Moderate to steep	Degraded Pine forests
7	1E7A3	Mondlan	34^0 02' 32″	75^0 17' 43″	2200	Degraded forests	Sparse forests	Moderate to steep	Degraded Kail forest on the right bank of west Lidder surrounded by dense kail Forests of their west
8	1E7A3	Aru	34^0 05' 36″	75^0 15' 01″	2600	Dense Fir	Dense forest	Moderate to steep	Dense fir forests on the right bank of west Lidder above Aru village
9	1E7A4	Nandaran area	34^0 07' 10″	75^0 12' 48″	3170	Grass lands	Meadow	Steep	Grass lands dotted with small trees
10	1E7A5	Tarsar lake	34^0 08' 25″	75^0 08' 46″	4000	Lake	Water bodies	Gentle	Tarsar lake is an alpine lake located at northwestern edge of Lidder catchment
11	1E7A6	Aru	34^0 07' 36″	75^0 14' 51″	2600	Open forest	Sparse forests	steep	Vast patch of sparse forests surrounded by dense fir forests
12	1E7A6	Aru	34^0 07' 50″	75^0 16' 14″	4000	Rocky outcrop	Waste lands	Very steep	These are the barren rocky outcrops
13	1E7A6	Aru	34^0 08' 44″	75^0 15' 48″	3720	Short bushes	scrubs	Steep slope	These are the bushes with small trees
14	1E7A7	Aru	34^0 05'47″	75^0 16' 02″	2480	Grass land	Meadow	Gentle to moderate	The famous meadow of Aru surrounded by dense forests on its west and north while by village Aru on its south
15	1E7A7	Pahalgam	34^0 02' 04″	75^0 18' 49″	2310	Maize fields	Agriculture	Gentle to moderate	Dry croplands surrounded on one side by mountain with coniferous trees and other by sparse village settlement
16	1E7B1	Pahalgam	34^0 00' 42″	75^0 19' 07″	2160	Commercial area	Built-up	Gentle	Main market area of Pahalgam town with a dense concentration of hotels and shops
17	1E7B1	Frislan	34^0 03' 12″	75^0 21' 57″	2400	Betab valley	Meadow	Gentle	A beautiful meadow on Sheshnag Nalla surrounded by dense forests on east and dense willow on west
18	1E7B1	Chandanwari	34^0 05' 03″	75^0 26' 34″	3200	Sparse forests	Sparse forests	Steep	Area covered with sparse forests on the left bank of Sheshnag Nalla and by meadows on the right bank.
19	1E7B1	Near Sheshnag lake	34^0 05' 27″	75^0 29' 09″	3600	Barren exposed rocks	Waste lands	Very steep	These are the barren exposed rocks of the western mountain range which runs in the west of Sheshnag lake
20	1E7B1	Sheshnag lake	34^0 05' 42″	75^0 29' 29″	3580	Sheshnag lake	Water bodies	Gentle	This is one of the famous alpine lakes of Kashmir

21	1E7B1	Sheshnag lake	34^{0} 05' 40″	75^{0} 30' 12″	3590	Bushes	Scrubs	Gentle to moderate	These are the bushes just on the west of Sheshnag lake
22	1E7B1	Sheshnag lake	34^{0} 05' 11″	75^{0} 31' 33″	4300	Glacier	Glacier	Very steep	This is the glacier area surrounded by barren exposed rocks
23	1E7B1	Gulal Ghati	34^{0} 06' 20″	75^{0} 31' 48″	4440	Glacier	Glacier	Very steep	This is the glacier area surrounded by barren exposed rocks
24	1E7B2	Baisaran	34^{0} 00' 12″	75^{0} 19' 56″	2430	Sar	Meadow	Gentle to moderate	This is a grassland in the middest of dense forests popularly known as baisarn
25	1E7B3	Sruchin	33^{0} 55' 07″	75^{0} 17' 21″	1980	Potato fields	Agriculture	Gentle to moderate	Cultivation of potato is carried away on the moderate slopes which depend on natural rainfall as there are no irrigation facilities
26	1E7B4	Aishmuqam	33^{0} 51' 46″	75^{0} 16' 45″	1880	Residential area	Built-up	Gentle to moderate	Built-up area of Aishmuqam town on the left bank of Martand canal
27	1E7B4	Hutmur	33^{0} 46' 47″	75^{0} 13' 50″	1750	Paddy field	Agriculture	Gentle	Vast area under agriculture as this area forms the part of Lidder flood plain

Source: Field Survey, 2010

3.2.7.4. Accuracy Assessment

The accuracy of thematic maps derived by image classification analysis is often compared in remote sensing studies. Accuracy assessment is a general term for comparing predicted (classified) results to geographical reference data that are assumed to be true (Lillesand et al., 2004; Richards and Jia, 1999). This could also be done through the verification of different LULC categories generated from the image with the field observations. A set of reference pixels representing geographic points on the classified image is required for the accuracy assessment. Randomly selected reference pixels lessen or eliminate the possibility of bias (Congalton, 1991). In the present study a random stratified sampling method was used to prepare the ground reference data. This sampling method allocates the sample size for each land use based on its spatial extant (Shalaby and Tateishi, 2007). A total of 120 reference pixels were identified and verified/crosschecked in the ground. The minimum threshold for each LULC class was set to five verification points. Subsequently the required, post-field modifications were made through Signature editing, reclassification and required onscreen digitization.

3.2.8. Land Use Land Cover Change Detection Analysis

To draw a comparative picture and quantify the magnitude of change in various LULC categories of the catchment a change detection analysis of time series LULC maps was been carried out. LULC change information can be obtained by either image-to-image comparison or map-to-map comparison (Green et al., 1994). The image-to-image comparison involves subtracting two images. It does not give detailed information of the how changes in particular LULC category is taking place. In map-to-map comparison, first images are to be classified and map is to be generated to compare. These types of classifications generally work well for spectrally homogeneous areas like forest. The LULC change detection analysis was done in terms of the calculation of the area in square kilometers of all the LULC categories for each watershed. The comparison of the LULC statistics assisted in identifying the percentage change between different time periods.

The degree of success depends upon the reliability of the maps made by image classification. The comparison of the LULC statistics assisted in identifying the percentage change, trend and rate of change between 1961 and 2010. In achieving this goal, the first task was to develop the figures showing the area in km^2 determining the percentage change for each year (1961, 1992, 2001 and 2010) measured against each LULC type for all watersheds.

The rate or degree of LULC change is quantified (Modified after Wang, 2000 and Kasereka et al., 2010) by using the following formula:

DLC = (Lb- La) /La * 1/T *100…………………….. (1), Where,

DLC = Degree of LULC change;La = Amount of the particular LULC in the year a,

Lb = Amount of the particular LULC in the year b;T = Length of time between the year a and b.

3.2.9. User Density and Carrying Capacity Evaluation

The monthly user density was calculated by using the following equation:

UD = (Pt+ Pr + Ps)/AD……………………. **(2),** Where,

UD = user density; Pt = tourist population; Pr = resident population (locals); Ps = seasonal population under tourist service and Ad = area at disposal.

The carrying capacity was calculated by using equation 3, 4 and 5 (modified after Zacarias et al. 2011) as discussed below.

PCC = (A/Au) x 100………………………… **(3),** Where,

PCC is the physical carrying capacity, A is the size of the study/visited area or the area available for recreation, Au is the area available per user or the minimum area per tourist so that the tourist does not feel uncomfortable or crowding and Rf is the rotation factor.

ERCC = PCC X (cf1 x cf2 x cf3 x…………………..x cfn)………………. **(4),** Where

ERCC is the effective real carrying capacity, PCC is the physical carrying capacity and cf1…..cfn are the correction factors determined using the equation 5.

Cfx = 1- (Lmx/Tmx) ………………………………… **(5),** Where,

Cfx is the correction factor of variable x, Lmx is the limiting magnitude of variable x and Tmx is the total magnitude of variable x. Considering that tourism is dependent upon environmental attributes, six correction factors were considered for this study because of their limiting power in the tourism activity, facility of analysis and because of enabling the measurement of the sustainability level of a tourist destination. These limiting factors are climatic limiting factors in terms of temperature and rainfall, infrastructure limiting factor, transport limiting factor, management limiting factor and perception limiting factor.

3.2.10. Measurement of Solid Waste

The direct waste analysis (Hoang, 2005), which is one of the most commonly used methods, involving direct examination of the waste characteristics (weight and composition) has been used for the present analysis. A total of 20 hotels and 20 guest houses were purposefully identified to categorize and measure the solid waste generated from them. The sample hotels and guest houses were provided plastic bags of 50 kg capacity to collect the daily waste generated which was subsequently weighed and segregated to analyze the composition of the waste. Daily room occupancy of each category of tourist accommodation facility has been used to determine the waste generated per tourist as well as per room.

3.2.11. Watershed Prioritization

The prioritization was done on the basis of the various socio-economic and geo-physical indicators of human impact on the natural environment. Twenty two indicators were used for prioritization of watersheds. The socio-economic indicators include total population, density of population, population growth, magnitude of energy consumption, livestock population, literacy, dependency ratio and physiological density. Existing LULC was taken as the physical indicator along with the slope, altitude, drainage density and stream frequency. Tourism was taken as an indicator of anthropogenic impact along with LULC change. Prioritization was done by ranking method. Ranks were assigned from 1-11 to all the watersheds. The watershed with highest rank is of low priority while the watershed with the lowest rank is of high priority.

3.3. HARDWARE AND SOFTWARE USED

The scanning of different data sets and their analysis was made possible by using a number of hardware equipments and different remote sensing software's which are listed in table 3.10. However the statistical analysis was carried out by using SPSS software.

Table 3.10: Hardware and software used

S. No.	Hardware/Software	Purpose
1	Scanner, A0 – VIDAR Surveyor 600	Scanning of hardcopy maps and SOI toposheets
2	Plotter A0 – HP Designjet Z 6200	Printing of LULC maps for ground validation
3	Differential Global Positioning System (DGPS) – Leica GS 05	Ground truthing and location of sample villages
4	Digital Camera – Sony	Photography
5	Erdas Imagine 8.4, 9.2	Digital Image processing
6	Arc GIS – Arc view 3.2a	Geospatial data base creation and spatial analysis
7	Statistical Package for the Social Sciences (SPSS) software 16.0	Statistical analysis
8	MS Office 2007, 2010	Typing and formatting

CHAPTER - 4

GEO-PHYSICAL SETUP

The geo-physical setup plays an important role in determining the environmental quality of a region. The physical setting of Lidder catchment is governed by its mountain topography. Being predominantly a mountainous one, the region is dominated by steep slopes, rugged terrain, immature soils and hence limited availability of productive arable land which is confined to the Lidder flood plain. The precipitation is mostly in the form of snow during winter while as afternoon showers are very common during summer. The presence of a number of glaciers supplemented by winter and summer precipitation have resulted into perennial flow of river lidder which not only provides beautiful view in the higher reaches but is also utilized for irrigation and domestic purposes in its lower course. All these factors have helped Pahalgam to emerge as one of the most beautiful tourist destination of the world where the tourist related infrastructure is expanding very fast.

4.1. GEOLOGY

The preliminary geological and physiographic investigations in Lidder valley were carried out by Lyddeker in 1883. He described various rock formations and structures of a number of sections from Anantnag to Amarnath and from Pahalgam to Sind valley. Latter, Middlemiss (1910) gave a detailed account of the area and divided the Silurian-Triassic sequence into two main groups. He was the first to prepare a systematic geological map of the area. Since the pioneering work of Middlemiss, many geologists have investigated the rocks of the Lidder valley and made revisions in respect of litho-stratigraphy and nomenclature in the Middlemiss classification. Gupta and Sahni (1964) classified the stratigraphic sequence of rocks of the area on the basis of fossils. They reported for the first time graptolites from Silurian shale and fossils in Muth Quartzite. The sections in eastern Kashmir are important because they contain more or less complete and mostly fossiliferous sequence. The rocks are exposed in a series of anticlines chiefly Kotsu anticline and Kolahoi-Basmai anticline. In none of these anticlines are the Precambrian rocks exposed (Shah, 1978). The succession has been discussed by a number of workers especially Middlemiss (1910), Gupta (1969), Fuchs and Gupta (1971), Shah (1972), Fuchs (1975), Wadia (1975) and Kaul (1976).

The Palaeozoic formation is exposed in the denuded anticlinal flexure of Lidder valley. The Cambrian and Ordovician, lying in the central parts of this anticline are flanked by successively thinner bands of younger formations till rocks of Triassic age. Outcrops of the Lower Palaeozoic rocks are scanty and are generally capped by thick soil cover (Kaul, 1976). The sequence is fossiliferous from Middle Ordovician onwards (Gupta, 1969; Shah, 1972). Devonian-Carboniferous sequence, Consisting of Muth Quartzite-Syringothyris Limestone-Fenestella Shale, is well exposed in the Kotsu anticline and fairly developed in the Kolahoi-Basmai section (headwater region). It may be, however, mentioned that the thickness of these rock formations is highly variable and are either partially or completely absent in certain sections. This, however, applies generally to the Carboniferous formations, viz, Syrngothyris Limestone and Fenstella Shale. In the southwestern limb of the Kotsu anticline the two formations pinch out gradually when followed along southeast and die out completely in Haribal valley beyond which Muth Quartzite is directly overlain by Agglomeratic Slate, as is the case with northwestern Kashmir (Shah, 1978). The quartzite and limestone with moderate to high dips constitute the steep sloping conical hills. The isolated hill near Kotsu on the western bank of Lidder forms a prominent landmark in an otherwise plain country covered by alluvium. Steep mountain ranges accompanied by deep narrow gorges are the most striking features especially in the upper Lidder catchment (Kaul, 1976). The geological succession as observed in the Lidder valley is given in the table 4.1.

Table 4.1: Geological succession and rock formation in Lidder catchment

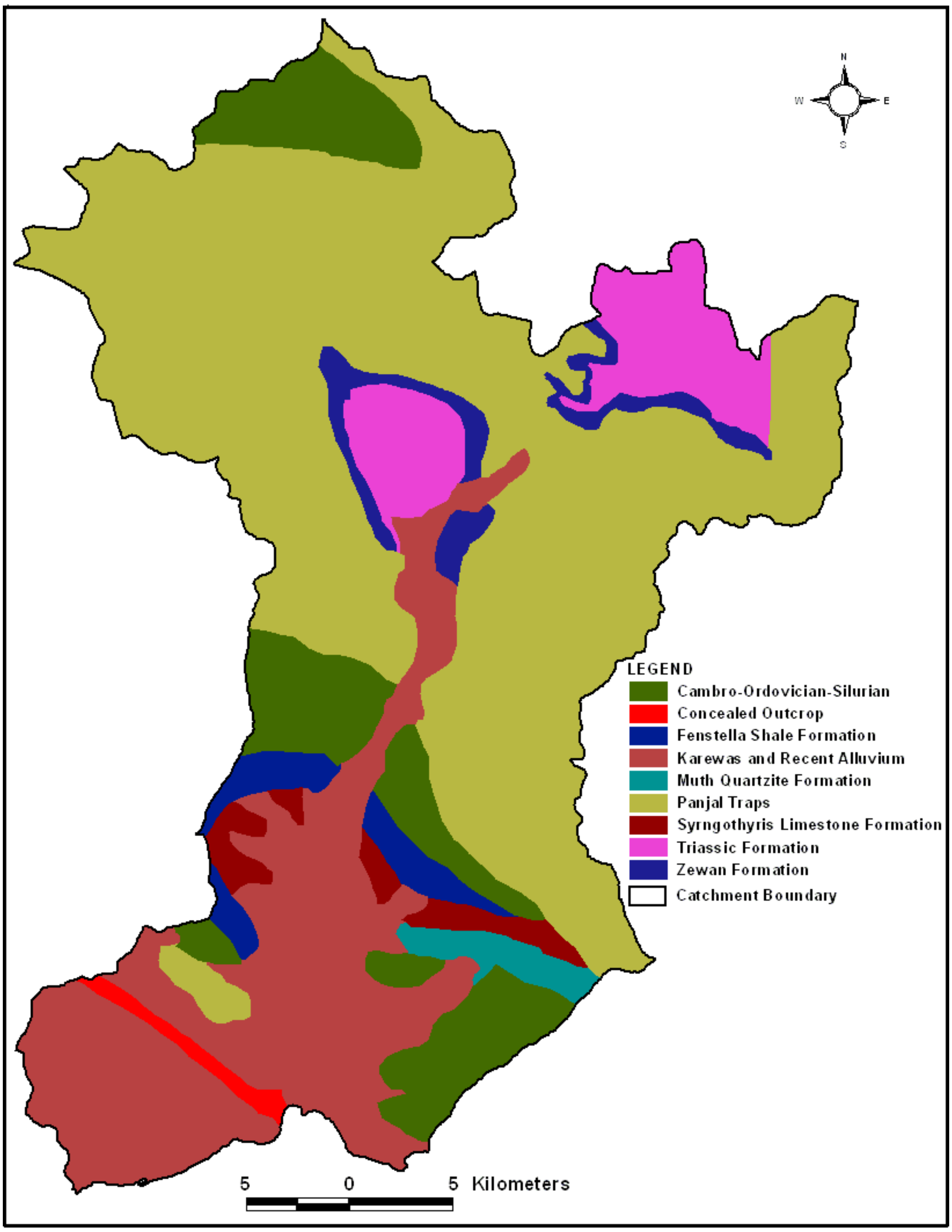
Era	**Period /epoch**		**Rock formation**
Cenozoic	Quaternary	Recent to sub-recent	Soil and Alluvium
Mesozoic	Triassic	Upper Middle Lower	Limestone
Paleozoic	Permian	Upper-most Part of upper Middle Lower	Grey and Purple Shale Panjal Trap
	Carboniferous	Upper Carboniferous Middle Carboniferous Lower Carboniferous	Agglomeratic Slate Fenestella Shale Syringothyris Limestone
	Devonian		Muth Quartzite
	Silurian		Silurian Shale
	Cambro-Silurian		Silt and Argillaceous Mudstone, Shale and Greywacke
Precambrian	……………. Not exposed ……………….		

Source: After Middlemiss, 1910; Gupta, 1969; Kaul, 1976; Bhat and Zainudin, 1979

The detailed grouping of the rock sequence has been made on the basis of the principal rocks with reference to the specific rock formation proposed by Middlemiss and others (fig. 4.1). Each group has a distinctive depositional environment in the vertical sequence and ultimately suggests the evolution of the valley basin in which these rocks were deposited and their relative competence for erosion. This helps in the reconstruction of paleogeography. A brief summary of the lithological succession identified in the Lidder valley is given as under:

LIDDER CATCHMENT

GEOLOGICAL MAP



Source: After Middlemiss, 1910; Gupta, 1969; Kaul, 1976; Bhat and Zainudin, 1979

Fig. 4.1

i. Cambro-Silurian: This sequence contains comparatively less resistant rocks deposited during Lower Silurian and Cambrian. Gupta (1969), on the basis of the fossils, placed it in Cambro-Silurian. Srikantia and Bhargava (1983) dated it to Cambrian-Devonian. This is the oldest formation in the region and occupies considerable part of the localities of Chaturgul, Gaurav, and Hapatnar, of the extreme southeastern part of Lidder valley. The most common rocks of the group are greywacke. The Shale-

Greywacke formation is overlain by pale, pink/grayish coloured quartzite near the localities of Hapatnar, Shumahal and Riatang.

ii. Upper Silurian Shale: The rock is dark, medium-grained, thinly laminated sandy-shale. It is at places intercalated with thin calcareous bands. The exposures are very scanty except at Wajru where it forms major hillocks and is conformably overlain by Muth Quartzite (Kaul, 1976).

iii. Muth Quartzite: The rock is massive, milky white to dirty white in colour and has a granular texture. It is characterized by the presence of patches or thin spots of yellow coloured ferruginous material probably limonite. It is well exposed in roughly E-W trending bend between Ayun to Aishmuqam (Zainshah Sahib Ziarat) and further westwards it is concealed under alluvium, but again seen as a small exposure near Kotsu on the western bank of Lidder river (fig.4.1). The rock in the region is devoid of fossils. The age of Muth Quartzite is believed to be as Devonian (table 4.1).

iv. Syrngothyris Limestone: The limestone is dirty grey to light pink, massive, well jointed and lies conformably over Muth Quartzite. The exposures are well seen near Kotsu and between Goas and Reshkulbal. Minor bands of quartzite are associated with it in the upper parts whereas thinly laminated shale is seen in the lower part. Several sills, probably of Panjal Trap, are disposed within it towards east of Aishmuqam (Kaul, 1976). In the Kotsu hill the Syrngothyris Limestone conformably overlies the Muth Quartzite. In the Lower part limestone contains thin interbeds of shale with fossils predominantly of Rhynconellida family. In the middle it is dominantly limestone with large and well preserved fossils of Syrngothyris cuspidata and other brachiopods, and some sills of Panjal Trap. In the upper part limestone is unfossiliferous and carries within it intercalations of quartzite and trap material. Syrngothyris Limestone belongs to Lower Carboniferous (table 4.1).

v. Fenstella Shale: The series comprises sandstone, quartzite and shale and conformably overlies the Syrngothyris Limestone in the Grind Nar. Exposures are also seen near Sruchin and Ladwan on the eastern side of the Lidder river. The shale, east of Yanar, is abundantly fossiliferous. Occasionally thin intercalations of black shale are noticed within the sandstone. In the upper parts of the sequence near Sruchin shale is succeeded by quartzite with minor intercalations of shale and contains a few branched bryozoans. Hence Fenstella Series underlies Agglomeratic Slate (Kaul, 1976).

On the western side of Lidder river, prominent exposures are seen near Kullar, Sallar, WSW of Lidder**,** Kotsu and Chutros Bodur (fig. 4.1) while the contact between the Fenstella series and the underlying rocks is largely concealed. The exposures

WSW of Lidder and Kotsu clearly indicate that Fenstella-quartzite overlies the Syrngothyris Limestone. Near Chutrosbdhur and Kullar, Agglomeratic Slate overlies the Fenstella quartzite and the outcrop trends in NW-SE direction. The outcrops of Fenstella quartzite and the Agglomerate Slate between these two places are fairly extensive and continuous which indicate a broad ‘U’ shaped pattern with outward dips suggesting a northwesterly plunging anticline (Wadia, 1975; Kaul, 1976; Shah, 1978). A fine-grained green sill of trap rock is seen near Yinar and Kullar on either sides of the Lidder valley. According to Middlemiss (1910), quartzite intercalated with thin shaley bands over the Syrngothyris Limestone, referred to as ‘Passage beds’ forms a part of Fenstella Series as the contact between them is clear and distinct. While the quartzite intercalations within the Syrngothyris Limestone are grey, practically devoid of micaceous material, the younger quartzite over the Syrngothyris Limestone is pink to purple and micaceous. The Fenstella Shale belongs to the Middle Carboniferous.

vi. Agglomeratic Slate: The orthoquartzite-carbonate group is conformably overlain by a set of rocks having a complex petrological character. They are pyroclastic in nature and are named as Agglomeratic Slates. The exposures form a horse-shoe pattern, covering the outer margins of Fenstella Series (Fig. 4.1). Its contact with Fenstella Series on the eastern bank is seen near Sruchin and on the western bank near Kullar and Chitrosbdhur. The rock is dark grey, fine grained with euhedral grains of quartz and angular fragments of slate and limestone. At places it is vesicular. The rocks show a NW-SE strike trend and dip 30^o-40^o towards NE. The Agglomeratic Slate forms the lower part of the Panjal Volcanic Series (Wadia, 1975; Kaul, 1976; Bhat and Zainudin, 1979). This formation is well preserved in the localities of Batakot, Kullar, Nobug, Kolahoi-Basmai anticline**.** These rocks belong to Upper Carboniferous.

vii. Panjal Trap: Agglomeratic Slate is overlain by a thick homogeneous mass of lava, known as Panjal Trap/Panjal Volcanics. The rocks are green in colour, medium-fine grained and compact in nature, covering a major part of the northern portion of the Lidder valley (upper catchment area) and form towering cliffs in the area. Rocks are very hard, thickly bedded and massive in nature and are moderately to highly jointed with prominent joint patterns. The Panjal Volcanics cover the high mountain ridges and valley walls of the East and West Lidder valley (Bhat and Zainudin, 1979). The lower contact of the volcanic is observed near Pahalgam while the upper contact of the rocks with the Zewan Series is seen near Pissu Ghatti. The beds strike in NW-SE direction with the dip of about 30^o-60^o towards NE. The majority of the glacial-erosional-landform features have been carved in Panjal Volcanics as the rocks are very hard. Near Ganashbal and Pahalgam narrow gorges have developed in the volcanic rocks on the Lidder river. The age of Panjal Volcanics is Permo-Carboniferous and the most wide spread covering more than 52 percent of the total catchment area (table 4.2).

viii. Permian Series/ Sandstone-Shale Group: The volcanic group is conformably overlain by complex set of rocks being composed of sandstone, siliceous limestone and Shale. The rocks belonging to this group are also known as 'Zewan Series'. The sandstone and limestone are massive and tough while Shale is soft and highly cleaved. The formation generally occurs along the flanks of the Valley (fig.4.1). The exposures are observed along channel sites. They stretch from S-N along West and East Lidder streams from Mammal to Lidderwat, and Pahalgam to Chandanwari respectively (Kaul, 1976). In the localities of Burzulpatharnar and Minmaragnar, the formation consists of grey Shale. The thick outcrops of Shale and sandstone are also exposed in Athnar and Barzulpathar areas.

ix. Triassic Limestone: The next succeeding rock formation overlying the sandstone and shale in the northern part of the Lidder valley is the Triassic Limestone (fig. 4.1). It comprises massive limestone, thinly bedded limestone, greyish shales, slate and thin limestone covering 6.74 percent of the total catchment area. These beds have been dated to lower, middle, and upper Triassic age. The rocks trend NE 65^{o} SW. At the top of the Zewan Series a 100m thick bed of Limestone and Shale is conformably located (Wadia, 1975; Shah, 1978). These rocks are exposed nearly 3 km north of Pahalgam near Dadwar Mountain, Mundane and Poruspat Ridge. On the top of the Poruspat ridge in the East Lidder the lower Triassic rocks are overlain by 90 m thick bed black limestone with intercalation of Shaley layers. The formation constitutes a minor syncline. In the west Lidder about 350 m thick hard, grey limestone with Shaley intercalation are overlying Lower Triassic sequence near Mondlan. The rock outcrops plunge 25^{o} NE in the East Lidder and 35^{o} NW in the West Lidder.

x. Recent Alluvium: These represent the detrital sediments or deposits which occur in the form of older and newer alluvium covering 20.20 percent of the total catchment area (fig. 4.2). The older alluvium is deposited in the form of moraines, kames and scree. The older alluvium overlies the older rock groups from Sheshnag to Ganashbal, and Kolahoi to Pahalgam along the valley sections of the east and west Lidder respectively. The older alluvium is subsequent in age. The recent alluvium or soil (fluvial deposits) brought from the East and West Lidder streams has been deposited along the stream beds and banks in the form of boulders, gravel, pebble, sand and silt. Thin blanket of clay is also deposited on the top of these coarser sediments, forming a thin veneer of soil.

Table 4.2: Area under different geological formations in Lidder catchment

S. No.	Geological formation	Area	
		Absolute (km^2)	Percentage
1	Concealed Outcrop	8.68	0.75
2	Muth Quartzite Formation	14.86	1.28
3	Fenstella Shale Formation	26.74	2.31
4	Triassic Formation	78.14	6.74
5	Syrngothyris Limestone Formation	22.96	1.98
6	Zewan Formation	32.37	2.79
7	Panjal Traps	608.47	52.48
8	Cambro-Ordovician-Silurian	133.02	11.47
9	Karewas and Recent Alluvium	234.14	20.20
Total		**1159.38**	**100**

Source: After Middlemiss, 1910; Gupta, 1969; Kaul, 1976; Bhat and Zainudin, 1979

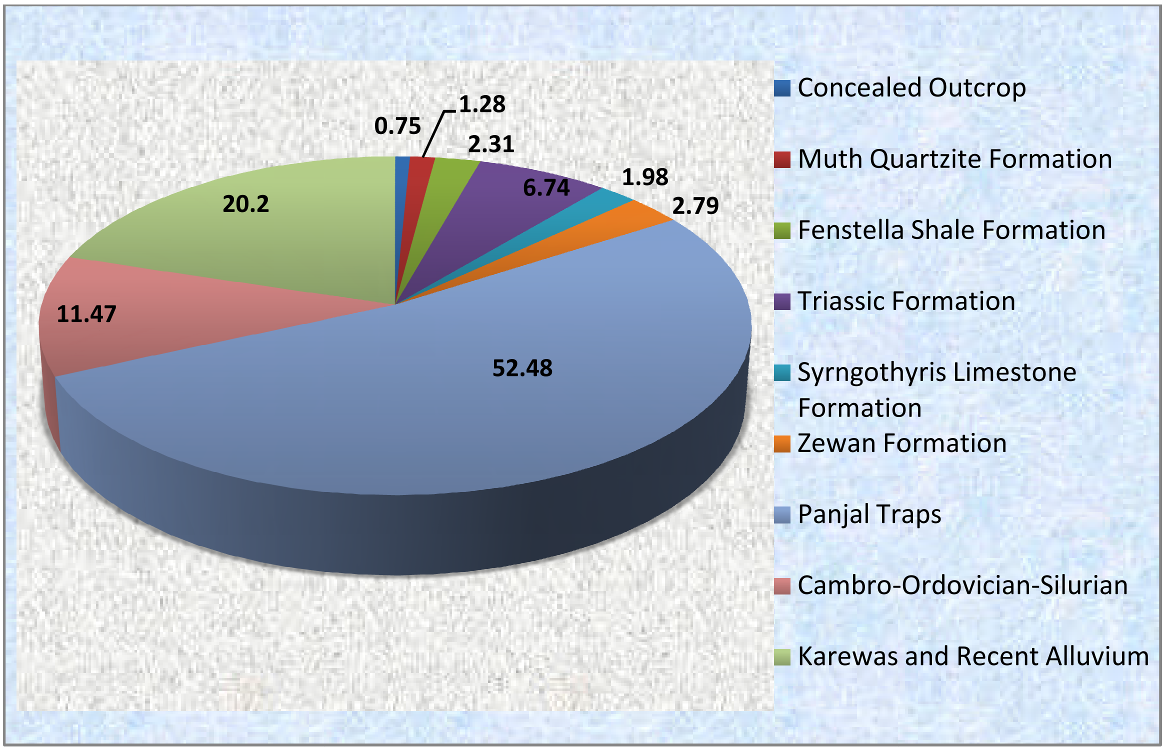


Fig. 4.2: Percentage area under different geological formations

4.1.1 Geological Structures in Lidder Valley

The lithological formations in Lidder valley had gone through severe deformation in the geologic past, which is conspicuous in the form of folds, systematic joints and faults. Following is the brief account of major geological structures imprinted on the lithology of Lidder valley.

i. **Anticlinal folds:** The major rock formations of Lidder valley are folded into anticlines and synclines. The syncline axis passes near Pahalgam whereas the corresponding anticlines in the north and south of Pahalgam. The beds on both the limbs dip in the opposite directions. The central part (core) of this structure has been considerably denuded (Wadia, 1975). As a result of this, a large part of rocks have been exposed. On the eastern side of the Lidder river the uninterrupted sequence of sedimentaries broadly strike NW-SE and dip at 35^o- 45^o NE. At places the beds dip at steeper angles. In the southeast part of the area the beds strike WNW-ESE which dips up to 60^o towards NNE. On the western side of the Lidder river, the beds show considerable variation in the strike direction. While the regional strike is NW-SE, the beds trend at places to NE-SW and even ENE-WSW and rarely E-W. In the southwestern part of the area, the beds dip southwesterly, and in the western part around Sheikhpur beds dip towards WNW and further northwards the dip is towards NE. The variation in the strike direction of 'S' forming a broad 'U' shaped outcrop pattern is indicative of an anticlinal structure with a gentle plunge towards NW (Kaul, 1976). The beds exposed on the southwestern limb of the anticline have moderate to steep dips whereas the beds on the NE limb have moderate dips. At Sheikhpur, near the axis of the fold the beds dip at low angles.

ii. **Faults:** The disposition of the outcrop of Fenstella Shale reveals the existence of a dip-fault traversing it along the Lidder basin. The effect of fault upon the outcrop on the two banks of the river is quite illustrative. The exposure on the left bank lies much higher up the river than the right bank outcrop. This is in consequence of a lateral shift (heave) produced by a fault cutting across the strike of the beds. This major fault in the area roughly trend in NNE-SSW direction and runs roughly south of Pahalgam, near and almost parallel to Lidder river (Wadia, 1975). The contact between Fenstella Shale and Agglomeratic Slate on either sides of the Lidder river appears to be displaced, suggesting its faulted nature (Kaul, 1976). The river has a remarkably straight course in NNE-SSW in this area and appears to have been controlled by this major fault. It is significant to mention the disposition of a number of springs at Kotsu, Goas in NNE-SSW direction parallel to the faulting in the area. Near Yinar on the eastern bank of the river, a crushed clayey material (fault gouge) of about a meter width and over 20 m in length also trends in NNE-SSW direction. Besides, considerable crushing of rocks has been noted near Ganishpora in Kotsu. However, no effect is seen on the other side of the river near Salar and also SE near

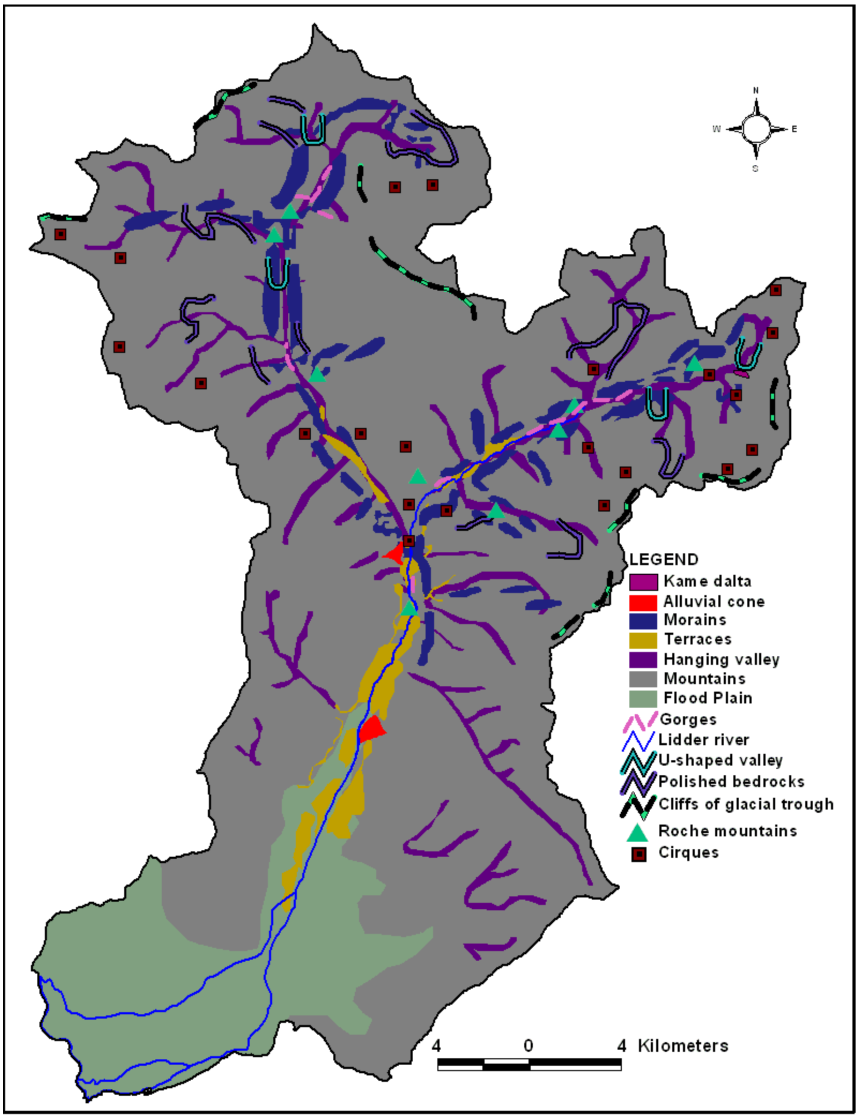
Logripora, and later is not clear in view of the large alluvial and soil cover present in the area. The fault appears to be of pre-Panjal Trap age, as the trap sill noticed on either sides of the river near Yinar and Kullar has not been affected by the fault. Several cross faults have also been noticed in the region. One of them trending N80^{o}E – S80^{o}W seen near Kanjdori on the Kotsu hill is evidenced by fault scarp, sudden variation in strike and minor fault breccia. Whereas another trending N80^{o}W – S80^{o}E noticed on the same hill is indicated by intense crushing of the surrounding rock, fault gouge and sudden abutting on the trap intrusive. This fault may be of post-Panjal Trap in age (Kaul, 1976).

iii. **Joints:** The joints noticed in the lower Lidder valley are mostly observed in Fenstella-Quartzite and Syrngothyris Limestone. They are spaced at intervals of a few centimeters to several meters. Some joints continue for a length of over 25m. In relation to the disposition of lithological units these joints can be grouped as strike joints, dip joints and oblique joints. The average disposition of joints in Fenstella-Quartzite and Syrngothyris Limestone is in NW-SE and NE-SW direction with steep to vertical dips (Kaul, 1976). One set of joints trend in N50^{o}E – S50^{o}W and is nearly perpendicular to the fold axis, whereas another set is more or less parallel to the same. The joints appear to be genetically related to the folding. Prominent joints have also been observed in the northern parts of the Lidder valley along the Panjal Volcanics and Sandstone-Shale group of rocks.

4.1.2 Geomorphic Features

The landscape of Lidder catchment has been denuded from the ancient past mainly by the combined action of glaciers and Lidder river. The entire process of the formation of boulder-beds, screes, alluvial cones and clay and sand beds was generally influenced by fluvial action intensified by heavy precipitation, the steep gradient of the valleys and contemporary tectonic activity. Glaciers were wide spread in the Pleistocene and three major advances of Kolhoi glacier have been recorded by the geologists. The last advance was as far as Pahalgam which resulted into the formation of cirque which is presently used as golf course. Cirques are well distributed throughout the north of the catchment. The moraines are deposited throughout the north, northwest and northeast of lidder catchment (fig. 4.3) especially along the banks of East Lidder and West Lidder streams. The glaciers have carved out numerous U-shaped valleys in the upper reaches of the catchment. A kame delta has developed at Sheshnag where a stream horridly rushing from a glacier enters into a leveled plain near Sheshnag lake and deposits its load and hence kame delta gets formed. Roche mountains are also dotted along the moraine deposits. All the major tributaries of Lidder river have developed hanging valleys along their respective courses with occasional gorges at many places.

LIDDER CATCHMENT
GEOMORPHIC MAP



Source: After Koal, 1992 and Field Survey, 2011

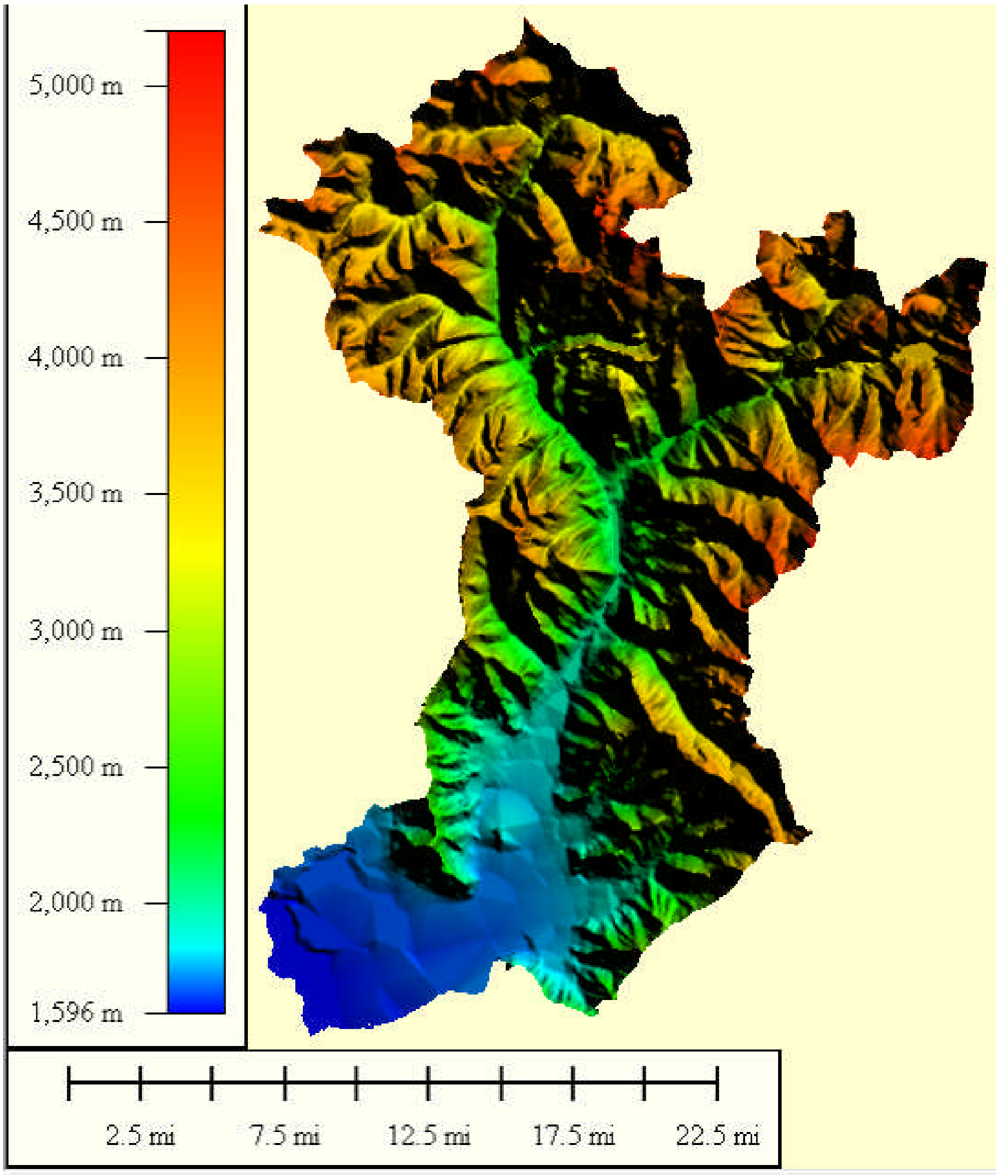
Fig. 4.3

The middle valley covers the Pahalgam area and extends as far as Batkut. In this tract massive deposits of boulder clay of both glacial and fluvio-glacial origin are deposited. All along the road from Batkut to Pahalgam, high cliff sections in the road cuttings on both banks can be seen displaying massive boulder deposits. Between Nunwan and Batkut the river passes through a narrow gorge exposing the basement rock overlaid with boulder deposits. The maximum estimated thickness of this deposit at the gorge would be 50 meter. Two important alluvial cones were formed by Prangamnar Nalla and Kawiznar Nalla. Mamal is situated on one cone while the two revenue villages of Batkut Gujaran and sruchhin are situated on the other cone, which has subsequently been cut into a terrace. The southern part of the catchment has developed as the Lidder flood plain while rest of the catchment is predominantly a mountainous one.

4.2 DIGITAL ELEVATION MODEL (DEM) OF LIDDER CATCHMENT

The 40 meter spatial resolution Digital Elevation Model (DEM) of the study area was generated from the contour map digitized from Survey of India toposheets on 1:50000 scale. This DEM (fig. 4.4) was used for topographic analysis of the area. All the watersheds were divided into different elevation zones using GIS and the slope map for every watershed was also prepared.

LIDDER CATCHMENT
DIGITAL ELEVATION MODEL



Source: Generated from contour map of Lidder catchment

Fig.4.4

4.2.1 Relief Characteristics

Lidder catchment is predominantly a mountainous catchment surrounded by mountains on all sides except southwest. It is surrounded by Pir Panjal range in the south and southeast, the greater Himalayan range in the north and northeast and zanskar range in the West and northwest. The Lidder valley is girdled on three sides by lofty ridges; the Saribal katsal ridge (4800 meters) on the east, the Wokhbal (4200 meters) on the west and Basmai-kazimpathlin bal (4800 meters) in the north. The interior of the northern part of the Lidder valley has a concentration of high mountain ridges like Dadwar (3560 meters), Goucher (4000 meters) and Tramakzan (4200 meters) which run parallel to the course of rivers. The general elevation ranges from 1596 meters (near Gur village) to 5425 meters (Kolahoi peak) with the average altitude of 3510 meters. The other important peaks are Sheshnag (5096 meters) and Kotsal Saribal (4882 meters). Higher elevations (more than 3600 meters) are noted towards the outer limits of the catchment which are characterized by rock outcrops and snow fields with very steep slope (more than 30 degree). The heights decrease towards the centre where the Lidder river flows and towards the outlet of the basin in the southwest.

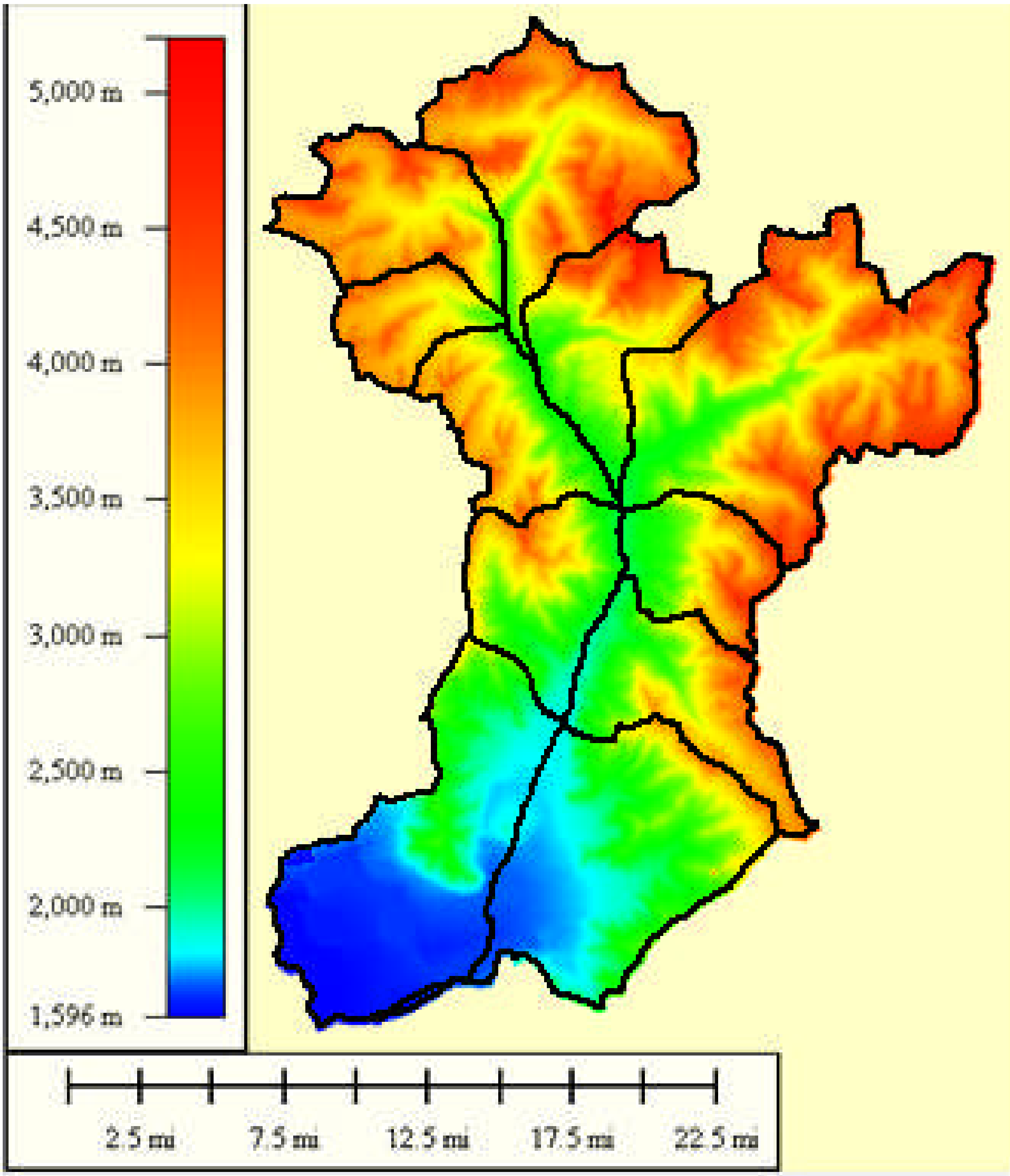
Table 4.3: Altitude zonation of Lidder catchment

Watershed	Area (km^2)	Altitude (meters above sea level)						
		Below 2000	2000-2500	2500-3000	3000-3500	3500-4000	4000-4500	4500 & above
1E7A1	173.24 (100)	131.25 (75.8)	31.96 (18.4)	8.76 (5.1)	1.27 (0.7)	0 0	0 0	0 0
1E7A2	73.14 (100)	5.23 (7.2)	19.46 (26.6)	18.45 (25.2)	16.76 (22.9)	11.26 (15.4)	1.98 (2.7)	0 0
1E7A3	65.08 (100)	0 0	7.25 (11.1)	12.28 (18.9)	14.38 (22.1)	26.88 (41.3)	4.29 (6.6)	0 0
1E7A4	40.46 (100)	0 0	0 0	2.36 (5.8)	7.89 (19.6)	22.93 (56.7)	7.26 (17.9)	0 0
1E7A5	78.07 (100)	0 0	0 0	4.59 (5.9)	12.6 (16.1)	39.56 (50.7)	20.57 (26.3)	0.75 (1.0)
1E7A6	129.36 (100)	0 0	0.7 (0.5)	6.51 (5.2)	21.26 (16.4)	48.83 (37.7)	45.19 (34.9)	6.87 (5.3)
1E7A7	77.19 (100)	0 0	8.01 (10.4)	16.59 (21.5)	20.49 (26.5)	12.99 (16.9)	13.76 (17.8)	5.35 (6.9)
1E7B1	228.52 (100)	0 0	10.2 (4.5)	22.75 (10.0)	38.03 (16.6)	61.2 (26.8)	78.66 (34.4)	17.68 (7.7)
1E7B2	53.49 (100)	0 0	9.06 (16.9)	10.24 (19.1)	8.91 (16.7)	11.43 (21.4)	10.44 (19.5)	3.41 (6.4)
1E7B3	78.36 (100)	2.28 (2.9)	14.72 (18.8)	13.56 (17.3)	14.28 (18.2)	21.99 (28.1)	11.15 (14.2)	0.38 (0.5)
1E7B4	162.47 (100)	68.4 (42.1)	41.94 (25.8)	28.74 (17.7)	13.96 (8.6)	8.07 (5.0)	1.36 (0.8)	0 0
Lidder Catchment	**1159.38 (100)**	**207.16 (17.9)**	**143.3 (12.4)**	**144.83 (12.5)**	**169.83 (14.6)**	**265.14 (22.9)**	**194.64 (16.7)**	**34.48 (3.0)**

Source: Compiled from the Digital Elevation Model

Note: Figures in parenthesis indicate percentage

LIDDER CATCHMENT
ALTITUDE MAP



Source: Generated from Digital Elevation Model

Fig. 4.5

The watersheds of Lidder catchment are divided in seven elevation zones (table 4.3). The analysis has revealed that 17.9 per cent of the area lies in the altitude zone of below 2000 meter which is a plan area and is devoted to paddy cultivation and settlements. The altitudinal zones of 2000-2500 meters and 2500-3000 meters cover almost equal area (12.5 per cent each) devoted to maize cultivation, orchards and dense vegetation. About 14.6 per cent of the area lies in the altitude zone of 3000-3500 meters which is the vegetation zone (both dense and sparse) in Lidder catchment. The elevation zone of 3500-4000 meters covers 22.8 percent of the total catchment area characterized by a mixed land cover of pastures and scrub lands. The elevation zone of 4000-4500 meters covering 16.8 percent of the total catchment area is mostly barren with very sparse patches of grass. Mostly covered by outcrops and rock debris, this area is also dotted by many small and few large glaciers. The remaining 3 per cent of the area lies above 4500 meters which constitutes the barren peaks of the mountains. The higher elevations are noted towards the outer limits of the basin in the north, east and west from where the heights decrease towards the trunk stream and the outlet of the basin in the southwest (fig. 4.5). The hypsometric curve (fig. 4.6) has revealed that 20 percent of the total catchment area is above 4500 meters of elevation while 50 percent of the total catchment area lies above 4000 meters.

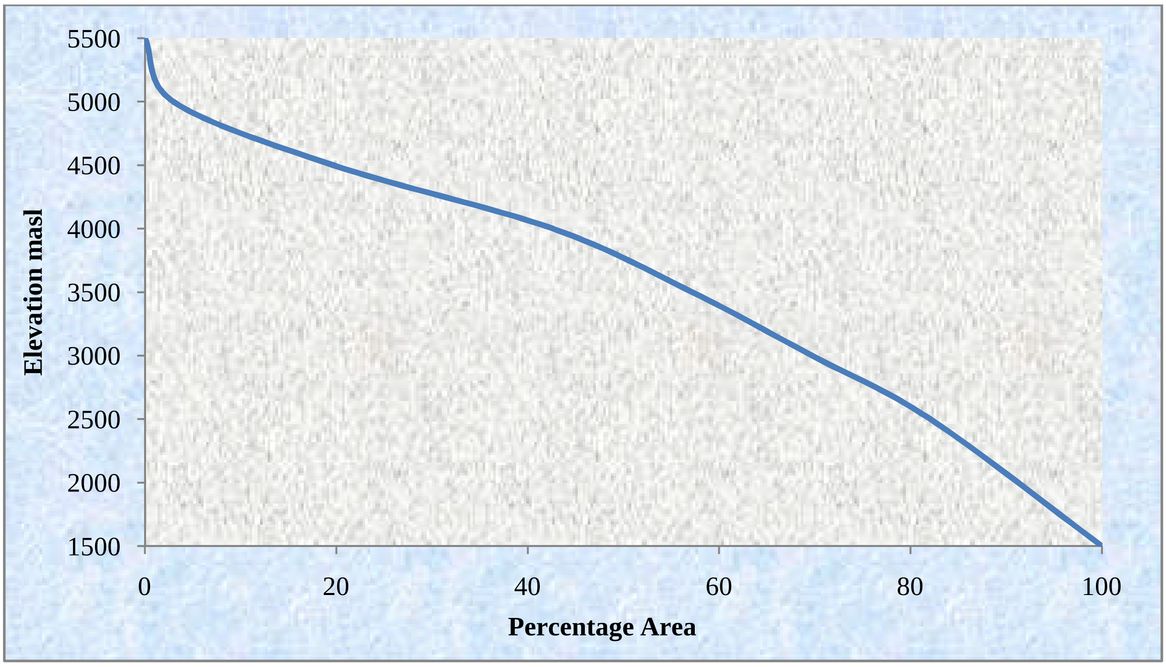


Fig. 4.6: Hypsometric curve of Lidder catchment

The watershed wise analysis has revealed that the watershed 1E7A1 is a comparatively low altitude watershed with the maximum elevation of not more than 3500 meters and 75.8 percent of the total area below 2000 meters. The other low elevation watershed is 1E7B4 with its 42.1 percent of the area below 2000 meters and 68 percent of the area below 2500 meters and no area above 4500 meters (fig. 4.7). The other watershed having area below 2000 meters (2.9 percent) is 1E7B3 with its maximum area in the elevation zone of 3500-4000 meters (28.1 percent). This is the only watershed with shares its area in all the elevation zones. The watersheds of 1E7A4 and 1E7A5 are located in the higher reaches of the catchment with more than 50 percent of their total area in the altitude zone of 3500-4000 meters. The highest point (Kolahoi peak) is located in watershed 1E7A6 with 5.3 percent of the total watershed area above 4500 meters. The highest percentage of 7.7 (17.68 km^2) located above 4500 meters is found in watershed 1E7B1 with its maximum watershed area (34.4 percent) in the elevation category of 4000-4500 meters.

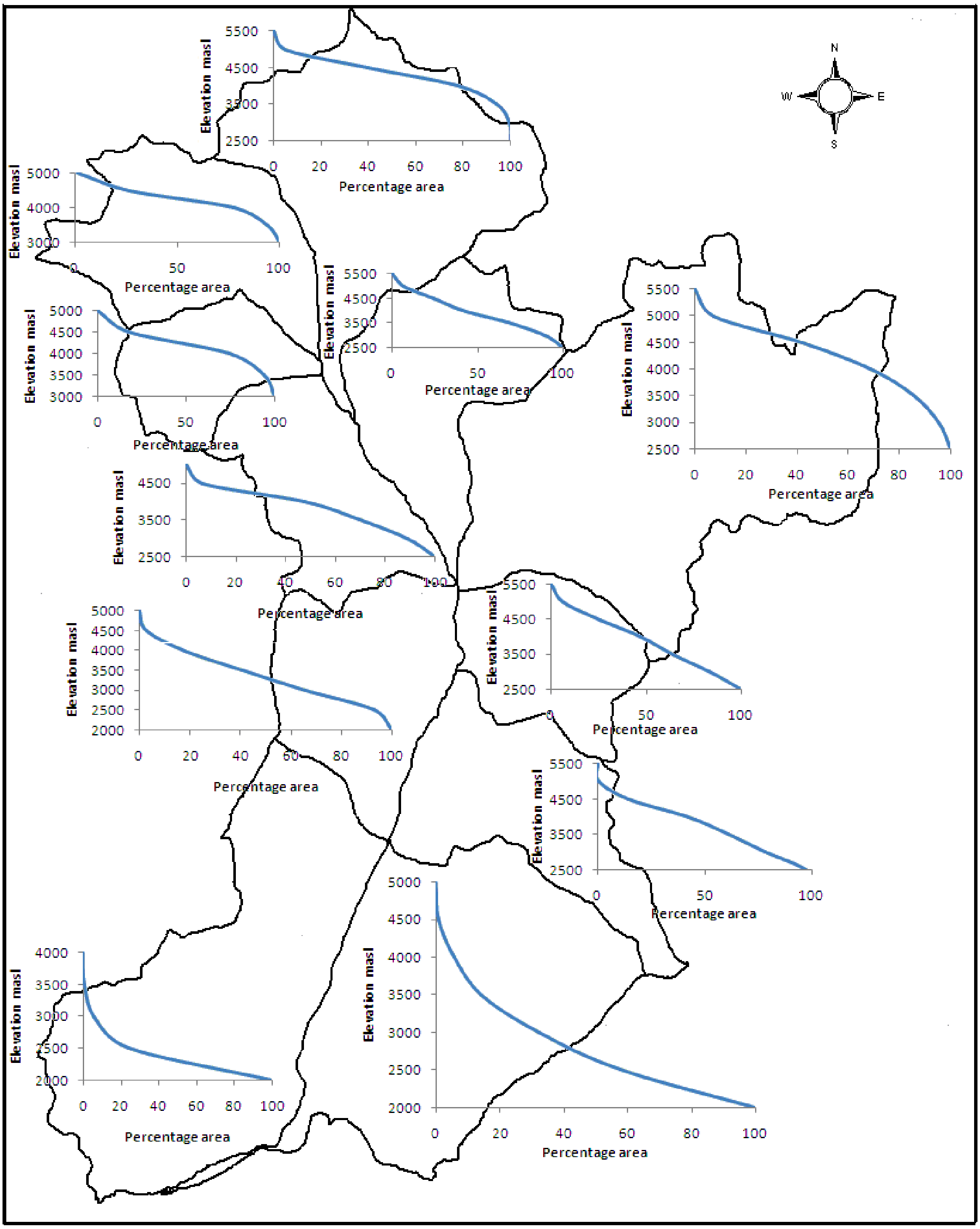


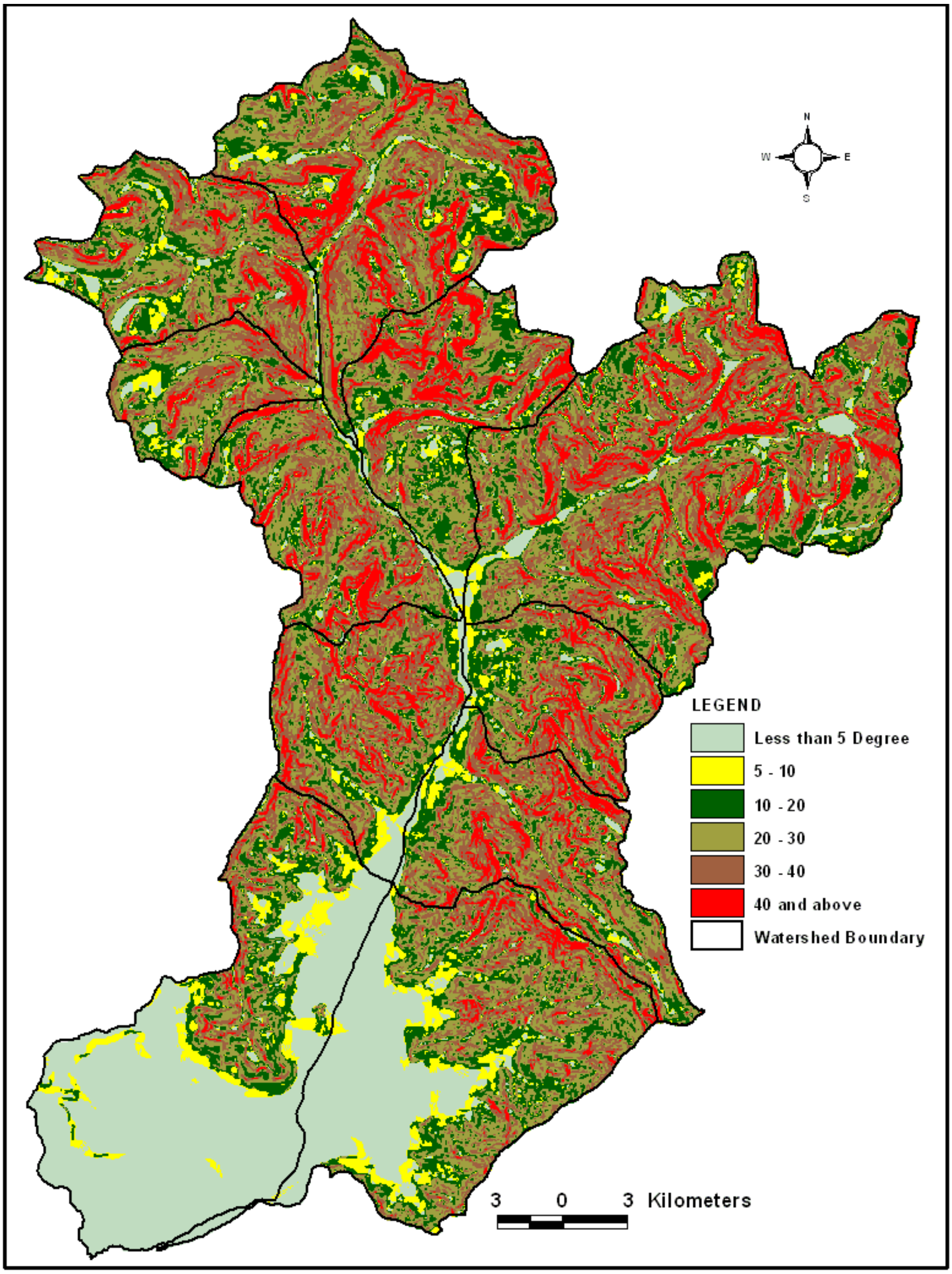
Fig. 4.7: Watershed wise area under different altitude zones in Lidder catchment

4.2.2 Slope Characteristics

Slope is defined by a plane tangent to a topographic surface as modeled by the DEM at a point (Burrough, 1986). The slope shows the inclination of the surface from the horizontal. It is the measurement of the steepness of terrain, the ratio of vertical rise to horizontal run expressed as percentage or degrees of angle. In the present study the slope is expressed in degrees of angle. In the Lidder catchment six slope categories were identified from DEM by using Arc view GIS software.

LIDDER CATCHMENT

SLOPE MAP



Source: Generated from Digital Elevation Model

Fig. 4.8

Table 4.4: Slope categories of Lidder catchment

Watershed	Area (km^2)	Area (km^2) in each Slope category (in degrees)					
		Below 5	5-10	10-20	20-30	30-40	40 and above
1E7A1	173.24 (100)	110.8 (64.0)	13.91 (8.0)	18.84 (10.9)	16.21 (9.4)	10.23 (5.9)	3.25 (1.9)
1E7A2	73.14 (100)	5.38 (7.4)	3.06 (4.2)	11.45 (15.7)	20.24 (27.7)	23 (31.4)	10.01 (13.7)
1E7A3	65.08 (100)	2.58 (4.0)	1.58 (2.4)	10.19 (15.7)	21.36 (32.8)	19.12 (29.4)	10.25 (15.7)
1E7A4	40.46 (100)	1.52 (3.8)	2.33 (5.8)	7.43 (18.4)	14.03 (34.7)	11.01 (27.2)	4.14 (10.2)
1E7A5	78.07 (100)	4.15 (5.3)	3.9 (5.0)	15.41 (19.7)	25.74 (33.0)	19.63 (25.1)	9.24 (11.8)
1E7A6	129.36 (100)	4.06 (3.1)	5.51 (4.3)	23.8 (18.4)	39.13 (30.2)	36.15 (27.9)	20.71 (16.0)
1E7A7	77.19 (100)	3.75 (4.9)	3.83 (5.0)	18.54 (24.0)	22.46 (29.1)	16.32 (21.1)	12.29 (15.9)
1E7B1	228.52 (100)	9.77 (4.3)	7.29 (3.2)	40.5 (17.7)	67.25 (29.4)	66.67 (29.2)	37.04 (16.2)
1E7B2	53.49 (100)	1.99 (3.7)	2.36 (4.4)	10.47 (19.6)	14.18 (26.5)	16.32 (30.5)	8.17 (15.3)
1E7B3	78.36 (100)	3.52 (4.5)	3.82 (4.9)	14.21 (18.1)	23.79 (30.4)	22.43 (28.6)	10.59 (13.5)
1E7B4	162.47 (100)	51.65 (31.8)	12.44 (7.7)	27.09 (16.7)	39.71 (24.4)	24.97 (15.4)	6.61 (4.1)
Lidder catchment	**1159.38 (100)**	**199.17 (17.2)**	**60.03 (5.2)**	**197.93 (17.1)**	**304.1 (26.2)**	**265.85 (22.9)**	**132.3 (11.4)**

Source: Compiled from the slope map
Note: Figures in parenthesis indicate percentage

The analysis of table 4.2 reveals that the highest percentage of Lidder catchment (26.2) falls in the slope category of 20-30 degrees. The slope category of less than 10 degree constitutes 22.4 percent of the total catchment area while 5.2 percent lies in the slope category of less than 5 degree characterizing the flood plain of Lidder river in the southern and southwestern part of the Lidder catchment. This area is quite suitable for agriculture and is densely populated. However the lakes of Sheshnag, Tarsar and others situated in the northern portion of the catchment also show a slope of less than 10 degree. A significant percentage (22.9) of Lidder catchment falls in the slope category of 30-40 degrees (steep slope) while 11.4 percent of the total catchment area falls in the slope category of more than 40 degree (very steep slope) which is the area of barren mountain peaks. Thus, an area of less than 39 per cent of the total area is suitable for agriculture and cultivation (fig 4.8). The area of moderate slope is associated with the upper valley slopes on both sides of Lidder river in the south used for dry land agriculture, horticulture and is under dense vegetation. However, small patches of moderate slope are also found in northwest of Lidder catchment around Tarsar and Chanda sar lakes. Moderate to steep slope is associated with mountainous uplands, crests of ranges, low elevation spurs, intermediate parts of mountain ranges and outer margins of uplands. Very steep slopes characterize the primary and secondary divides of the basin.

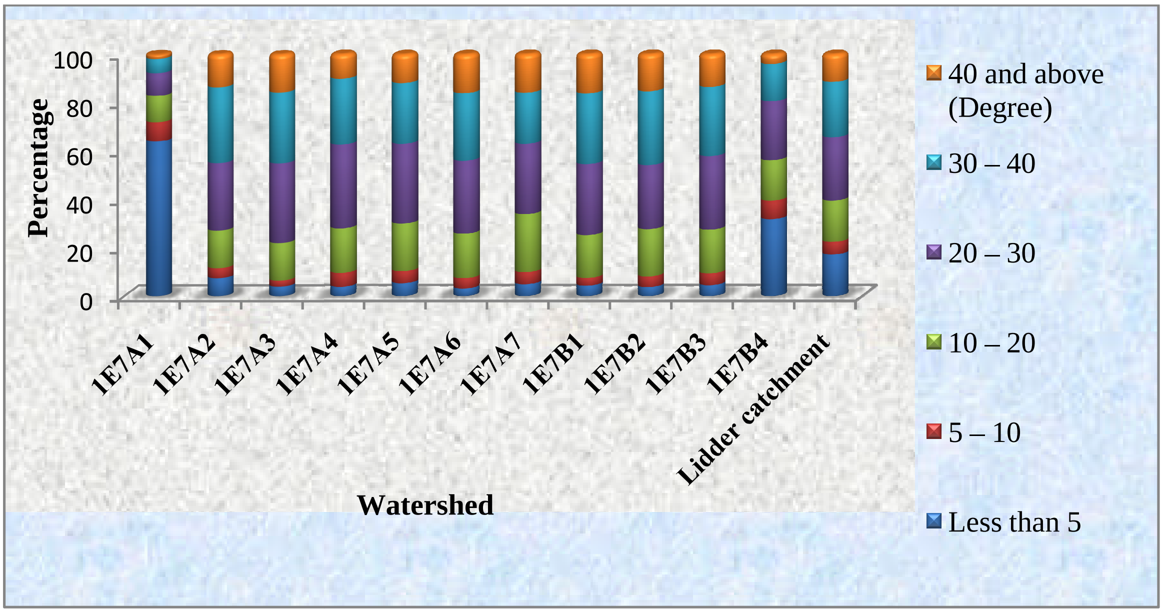


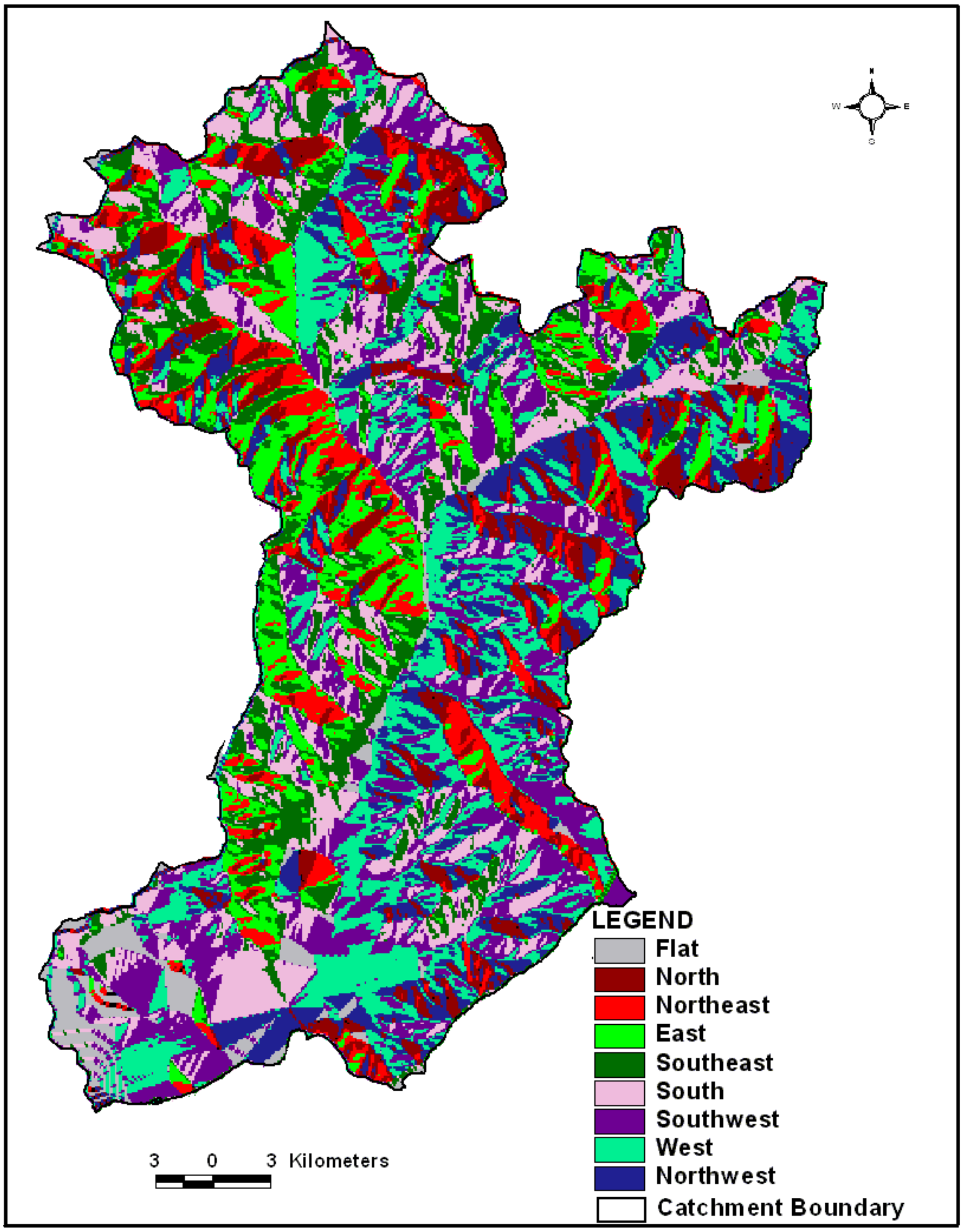
Fig. 4.9: Watershed wise slope categories in Lidder catchment

The watershed wise analysis (table 4.4) has revealed that 64 percent area in watershed 1E7A1 is below 5 degrees of slope with only 1.9 percent of its total area above 40 degree of slope. In the watershed 1E7B4, 31.8 percent of the total area is below 5 degrees of slope, the other dominant slope category (24.4 percent) being 20-30 degrees. These two watersheds are densely populated and agriculture is the dominant land use. In the watersheds of 1E7A6 and 1E7B4, more than 16 percent of the area is under the slope category of more than 40 degrees (fig. 4.9). The slope category of 20-30 degrees is the dominant category with 34.7 percent, 33 percent, 32.8 percent and 30.4 percent of the total area of watersheds 1E7A4, 1E7A5, IE7A3 and 1E7B3 respectively.

4.2.3. Aspect

Aspect generally refers to the horizontal direction to which a mountain slope faces. Aspect can be very influencing on temperature. In the Himalayas, this effect can be seen to an extreme degree, with south-facing slopes being warm, wet and forested, and north-facing slopes cold, dry but much more heavily glaciated. Aspect is one of the three main topographic factors (the other two being slope and altitude) that control the distribution and patterns of vegetation in mountain areas (Titshall et al., 2000) as they determine the microclimate and thus large-scale spatial distribution and patterns of vegetation (Geiger 1966; Day and Monk 1974; Johnson 1981; Marks and Harcombe 1981; Allen and Peet, 1990; Busing et al., 1992). The aspect map (fig. 4.10) derived through digital terrain modeling has revealed that the East Lidder sub-catchment predominantly has west and south west facing slopes while West Lidder has East and northeast facing slopes.

LIDDER CATCHMENT
ASPECT MAP



Source: Generated through digital terrain modeling

Fig. 4.10

The analysis (table 4.5) has revealed that southern aspect is the most dominant in the catchment which constitutes 17.6 percent of the total catchment area. The slopes facing southwest and west are also dominating with 15.89 percent and 15.02 percent of the total catchment area. The flat area in the extreme south of the catchment constitutes only 2.68 percent of the total catchment area (fig. 4.11). The flat area is found in the Lidder flood plain covering the southern part of the catchment. However flat aspect also covers the area covered by lakes in the north.

Table 4.5: Area under different aspects in Lidder catchment

S. No.	Aspect	Area	
		Absolute (km^2)	percentage
1	Flat	31.09	2.68
2	North	104.31	9.00
3	Northeast	97.14	8.38
4	East	108.06	9.32
5	Southeast	125.09	10.79
6	South	204.08	17.60
7	Southwest	184.17	15.89
8	West	174.17	15.02
9	Northwest	131.27	11.32
Total		**1159.38**	**100.00**

Source: Compiled from the aspect map

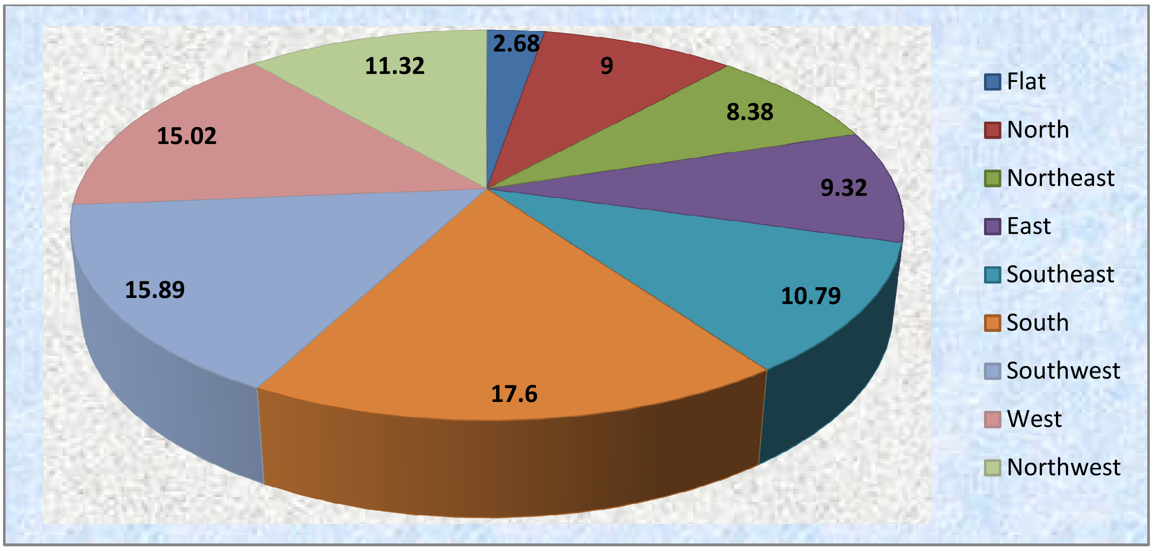


Fig. 4.11: Percentage area facing different aspects in Lidder catchment

4.3. DRAINAGE MORPHOMETRY

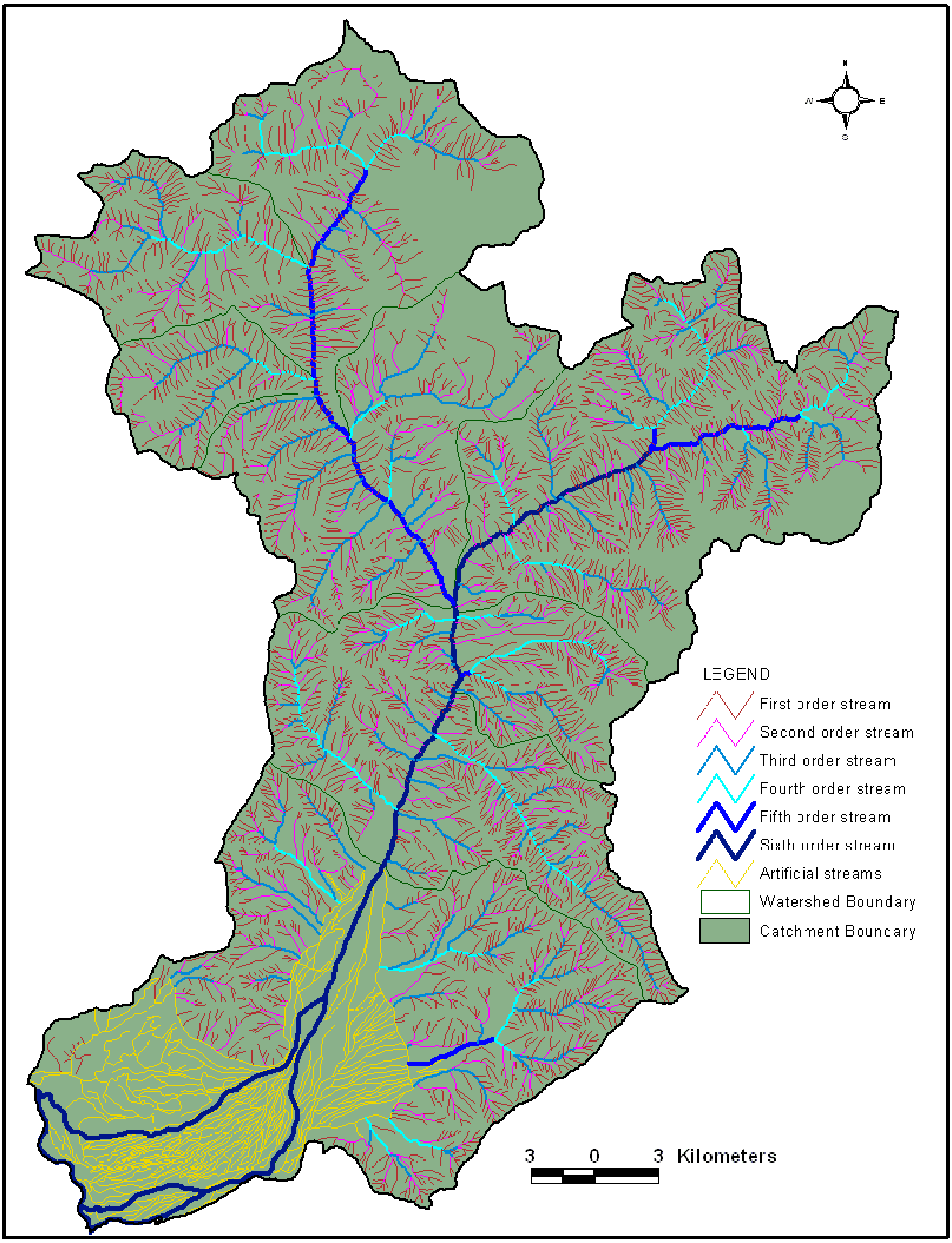
Morphometry is the measurement and mathematical analysis of the configuration of the earth's surface, shape and dimension of its landforms (Agarwal, 1998; Obi Reddy et al., 2002). A major emphasis in geomorphology over the past several decades has been on the development of quantitative physiographic methods to describe the evolution and behavior of surface drainage networks (Horton, 1945; Leopold and Maddock, 1953; Abrahams, 1984). Most previous morphometric analyses were based on arbitrary areas or individual channel segments. Using watershed as a basic unit in morphometric analysis is the most logical choice. A watershed is the surface area drained by a part or the totality of one or several given water courses and can be taken as a basic erosional landscape element where land and water resources interact in a perceptible manner. In fact, they are the fundamental units of the fluvial landscape and a great amount of research has focused on their geometric characteristics, including the topology of the stream networks and quantitative description of drainage texture, pattern and shape (Abrahams, 1984). The morphometric characteristics at the watershed scale may contain important information regarding its formation and development because all hydrologic and geomorphic processes occur within the watershed (Singh, 1992).

The quantitative analysis of morphometric parameters is found to be of immense utility in river basin evaluation, watershed prioritization for soil and water conservation and natural resources management at watershed level. Morphometric analysis of a watershed provides a quantitative description of the drainage system which is an important aspect of the characterization of watersheds (Strahler, 1964). The influence of drainage morphometry is very significant in understanding the landform processes, soil physical properties and erosional characteristics. Drainage characteristics of many river basins and sub basins in different parts of the globe have been studied using conventional methods (Horton, 1945; Strahler, 1957, 1964; Krishnamurthy et al., 1996). Geographical Information System (GIS) techniques are used for assessing various terrain and morphometric parameters of the drainage basins and watersheds, as they provide a flexible environment and a powerful tool for the manipulation and analysis of spatial information. In the present study stream number, order, frequency, density and bifurcation ratio are derived and tabulated on the basis of areal and linear properties of drainage channels using GIS based on drainage lines as represented over the Survey of India topographical maps (scale 1:50,000).

4.3.1. Stream Ordering

The designation of stream order is the first step in the drainage basin analysis. It is defined as a measure of the position of a stream in the hierarchy of tributaries (Leopord, Wolman and Miller, 1969). There are 3858 streams linked with 6 orders of streams (fig. 4.12) sprawled over an area of 1159.38 km^2. A perusal of table 4.6 indicates that the Lidder river which is the trunk stream in Lidder catchment is of the sixth order. Out of the eleven watersheds, one watershed (1E7A3) is of third order, five watersheds (1E7A1, 1E7A2, 1E7A4, 1E7A5 and 1E7B3) are of fourth order, four watersheds (1E7A6, 1E7A7, 1E7B2 and 1E7B4) are of fifth order and one watershed (1E7B1) is of sixth order. The highest number of stream segments is found in watershed 1E7B1 (958 stream segments) followed by watershed 1E7B4 (460 stream segments) while the lowest number of stream segments is found in watershed 1E7A4 (137). It is observed that there is a decrease in stream frequency as the stream order increases. First order streams constitute 80.19 per cent while second order streams constitute 15.70 per cent of the total number of streams. Third and fourth order streams constitute 3.29 per cent and 0.64 per cent of the total number of streams respectively while fifth and sixth order streams together constitute only 0.18 per cent of the total number of streams. Thus the law of lower the order higher the number of streams is implied throughout the catchment.

LIDDER CATCHMENT
STREAM ORDERING



Source: Generated from Survey of India toposheets, 1961and satellite data, 2010

Fig. 4.12

Table 4.6: Order wise stream number and stream length in Lidder catchment

Watershed Code	Area (km^2)	1st order		2nd order		3rd order		4th order		5th order		6th order		Total	
		No.	Length	No.	Length	No.	Length	No.	Length	No.	Length	No.	Length	No.	Length
1E7A1	173.24	247	135.03	59	59.59	10	23.81	1	4.30	-	-	1	50.16	318	262.79
1E7A2	73.14	287	156.30	67	47.29	16	19.62	2	12.50	-	-	1	13.34	373	249.05
1E7A3	65.08	194	129.59	33	31.87	6	23.32	-	-	-	-	-	-	233	184.78
1E7A4	40.46	117	84.55	17	17.39	2	10.48	1	3.32	-	-	-	-	137	115.74
1E7A5	78.07	216	155.87	30	30.47	6	15.72	1	8.49	-	-	-	-	253	210.55
1E7A6	129.36	246	171.9	47	43.50	10	14.42	2	10.20	1	14.19	-	-	306	254.21
1E7A7	77.19	136	86.10	30	37.12	7	20.82	2	4.64	1	9.45	-	-	176	158.13
1E7B1	228.52	769	485.97	152	119.26	27	47.88	7	21.92	2	9.06	1	13.12	958	697.21
1E7B2	53.49	191	122.96	33	32.43	7	11.54	3	11.64	1	0.51	-	-	235	179.08
1E7B3	78.36	335	191.27	62	46.61	14	27.20	1	10.53	-	-	-	-	412	275.61
1E7B4	162.47	356	235.02	76	68.88	22	38.36	5	15.64	1	4.24	-	-	460	362.14
Lidder Catchment	**1159.38**	3094	1954.56	606	524.31	127	253.17	25	103.18	5	37.45	1	76.62	3858	2949.29

4.3.2. Stream Number

The number of stream segments in each order is known as stream number. Horton (1945) gave the law of stream numbers which states that the number of stream segments of successively lower orders in a given basin tend to form a geometric series beginning with the single segment of the highest order and increasing according to constant bifurcation ratio. In other words “the number of streams of different orders in a given drainage basin tend closely to approximate an inverse geometric series in which the first term is unity and the ratio is bifurcation ratio”. It is expressed in the form of negative exponential function as:

$$N\mu = Rb^{(K-\mu)} \ldots\ldots\ldots\ldots\ldots \text{(i)}$$

Also, the total number of stream segments of the catchment can be calculated as:

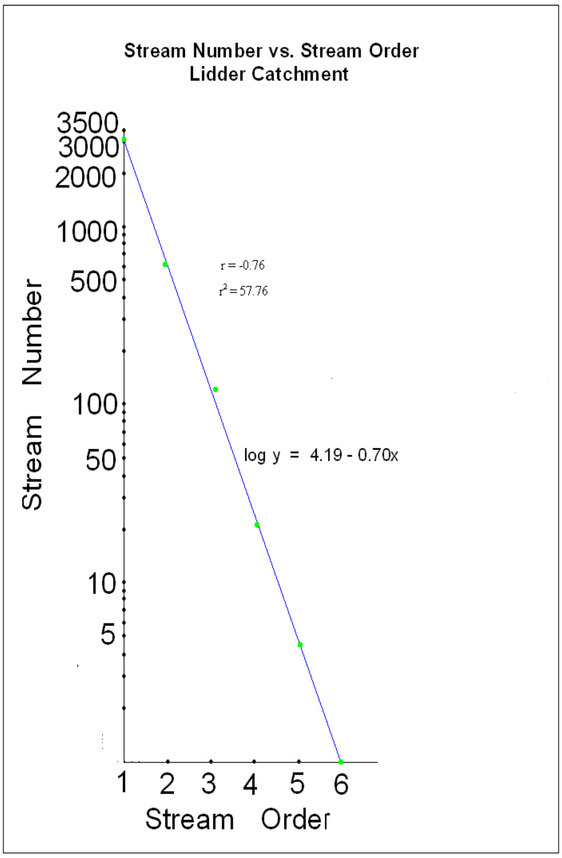
$$\Sigma\mu = Rb^{K}-1/ Rb-1 \ldots\ldots\ldots\ldots\ldots \text{(ii)},$$ Where,

$N\mu$ = Number of stream segments of a given order; Rb = Constant Bifurcation ratio; μ = Basin order and K = Highest order of the basin.

Table 4.7: Order wise actual and calculated number of streams in Lidder catchment

Stream Order	Number of streams		Mean stream length		Calculated cumulative mean stream length
	Actual	Calculated	Actual	Cumulative	
1st order	3094	1845.28	0.63	0.63	0.63
2nd order	606	410.06	0.86	1.49	2.24
3rd order	127	91.12	1.99	3.48	7.98
4th order	25	20.25	4.12	7.60	28.42
5th order	5	4.5	7.49	15.09	101.20
6th order	1	1	76.62	91.71	360.24
Total	**3858**	**2372.5**			

It is clear from table 4.7 that the computed values of stream numbers do not match with the actual values of stream numbers. However the deviations decrease from lower to higher orders. The regression line plotted on semi log graph (fig. 4.13) almost validates the Horton's law of stream number as the coefficient of correlation is -0.76 and the percentage variance explained is 57.76 per cent.



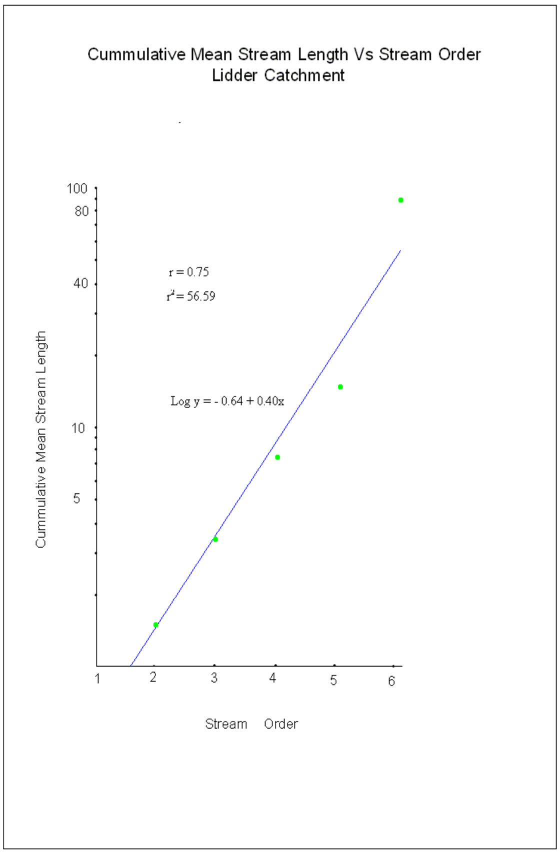


Fig. 4.13: Relation between stream order, stream number and mean stream length

4.3.3. Stream Length

Stream length is indicative of chronological developments of the stream segments including interlude tectonic disturbances. Mean stream length reveals the characteristic size of components of a drainage network and its contributing surfaces (Strahler, 1964).

Table 4.8: Order wise mean stream length in different watersheds of Lidder catchment

Watershed code	Mean stream length in kilometers					
	1st order	2nd order	3rd order	4th order	5th order	6th order
1E7A1	0.55 (51.38)	0.84 (18.83)	2.38 (9.06)	4.30 (1.64)	-	50.16 (19.09)
1E7A2	0.54 (62.76)	0.70 (18.99)	1.23 (7.88)	6.25 (5.02)	-	13.34 (5.35)
1E7A3	0.67 (70.13)	0.96 (17.25)	3.89 (12.62)	-	-	-
1E7A4	0.72 (73.05)	1.02 (15.02)	5.24 (9.05)	3.32 (2.88)	-	-
1E7A5	0.72 (74.03)	1.01 (14.47)	2.62 (7.47)	8.49 (4.03)	-	-
1E7A6	0.70 (67.62)	0.92 (17.11)	1.44 (5.67)	5.10 (4.01)	14.19 (5.59)	-
1E7A7	0.63 (54.45)	1.24 (23.47)	2.97 (13.17)	2.32 (2.93)	9.45 (5.98)	-
1E7B1	0.63 (69.70)	0.78 (17.10)	1.77 (6.87)	3.13 (3.14)	4.53 (1.30)	13.12 (1.89)
1E7B2	0.64 (68.38)	0.98 (18.20)	1.65 (6.54)	3.88 (6.60)	0.51 (0.28)	-
1E7B3	0.57 (69.40)	0.75 (16.91)	1.94 (9.87)	10.53 (3.82)	-	-
1E7B4	0.66 (64.90)	0.90 (19.02)	1.74 (10.59)	3.13 (4.32)	4.24 (1.17)	-
Lidder Catchment	**0.63 (66.27)**	**0.86 (17.78)**	**1.99 (8.58)**	**4.12 (3.50)**	**7.49 (1.27)**	**76.62 (2.60)**
Cumulative mean stream length	**0.63**	**1.49**	**3.48**	**7.6**	**15.09**	**91.71**

Note: Figures in parenthesis show percentage stream length contributed by different stream orders

From table 4.8 it is evident that the length of first order streams constitute 66.27 per cent of the total stream length with second order (17.78 per cent), third order (8.58 per cent), fourth order (3.50 per cent), fifth order (1.27per cent) and the sixth order (2.60 per cent). The total length of 1st and 2nd order streams constitutes 84.04 per cent of the total stream length. It can be inferred that the total length of stream segments is maximum in first order streams and decreases as the stream order increases. However sixth order is an exception where the total stream length (76.62 kms) is more than that of the fifth order (37.45 kms). This anomaly is also found in watersheds 1E7A1 (between fourth and sixth orders), 1E7A2 (between fourth and sixth orders), 1E7A6 (between fourth and fifth orders), 1E7A7 (between fourth and fifth orders) and 1E7B1 (between fifth and sixth orders) where the total length of the lower order streams is less than that of the total length of their respective higher orders. Generally higher the order, longer the length of streams is noticed in nature. This is also true for Lidder catchment as well as for all the eleven watersheds (table 4.8). But the watershed 1E7B2 is an exception where the mean stream length of fourth order (11.64 kms) is much higher than that of the fifth order (0.51 kms). These variations from general observation may be due to flowing of streams from high altitude, change in rock type and variation in slope and topography (Singh and Singh, 1997; Vittala et al., 2004).

4.3.4. Horton's Law of Stream Lengths

Horton (1945) in his law of stream lengths stated that the cumulative mean lengths of stream segments of each of the successive orders in a basin tend closely to approximate a direct geometric series in which the first term is the mean length of streams of the first order. He suggested the fallowing positive exponential function model of stream lengths**.**

$L\mu = L1\ RL^{(\mu - 1)}$………….. (iii), Where,

$L\mu$ = Cumulative Mean Length of the given order; L1 = Mean Length of the first order; RL = Constant length ratio and μ = Given order.

The regression line plotted on semi log graph (fig. 4.13) tends to validate Horton's Law of stream lengths as the coefficient of correlation is 0.75 and the percentage variance is 56.59. However the values obtained (table 4.7) by using equation (iii) does not match with the actual values. This is because of the fact that in nature constant mean stream length between different orders does not exist.

4.3.5. Bifurcation Ratio (Rb)

Bifurcation ratio is related to the branching pattern of a drainage network and is defined as the ratio between the total number of stream segments of one order to that of the next higher order in a drainage basin (Schumn, 1956). It is a dimensionless property and shows the degree of integration prevailing between streams of various orders in a drainage basin. Horton (1945) considered Rb as an index of relief and dissection while Strahler (1957) demonstrated that Rb shows only a small variation for different regions with different environments except where powerful geological control dominates.

A perusal of table 4.9 shows that the Rb between different successive orders is almost constant for Lidder catchment ranging from 4.77 to 5.08 with the mean bifurcation ratio of 5. This is because of the homogeneous geological and lithological development of the catchment. The highest Rb (14.00) is found between 3rd and 4th order in watershed 1E7B3 which indicates corresponding highest overland flow and discharge due to hilly metamorphic formation associated with high slope configuration.

The lowest Rb is found between 4th and 5th orders in watersheds 1E7A6 and 1E7A7 and between 5th and 6th orders in watershed 1E7B1. The higher values of Rb indicate strong structural control in the drainage pattern whereas the lower values indicate that the watersheds are less affected by structural disturbances (Strahler, 1964; Nag, 1998; Vittala et al., 2004). The mean bifurcation ratio is highest in watershed 1E7B3 (7.94) while it is lowest in watershed 1E7A7 (3.58).

Table 4.9: Watershed wise stream frequency, drainage density and bifurcation ratio between different orders in Lidder catchment

Watershed	Drainage frequency	Drainage density	Bifurcation ratio between different orders					
			1st & 2nd	2nd & 3rd	3rd & 4th	4th & 5th	5th & 6th	Mean bifurcation ratio
1E7A1	1.84	1.52	4.19	5.90	10.00	-	-	**6.70**
1E7A2	5.10	3.40	4.28	4.18	8.00	-	-	**5.49**
1E7A3	3.58	2.84	5.88	5.50	-	-	-	**5.69**
1E7A4	3.39	2.86	6.88	8.50	2.00	-	-	**5.79**
1E7A5	3.24	2.70	7.20	5.00	6.00	-	-	**6.06**
1E7A6	2.36	1.96	5.23	4.70	5.00	2.00	-	**4.23**
1E7A7	2.28	2.04	4.53	4.29	3.50	2.00	-	**3.58**
1E7B1	4.19	3.05	5.06	5.63	3.86	3.50	2.00	**4.01**
1E7B2	4.39	3.35	5.79	4.71	2.33	3.00	-	**3.96**
1E7B3	5.26	3.52	5.40	4.43	14.00	-	-	**7.94**
1E7B4	2.83	2.23	4.68	3.45	4.40	5.00	-	**4.38**
Lidder Catchment	**3.33**	**2.54**	**5.10**	**4.77**	**5.08**	**5.00**	**5.00**	**5.00**

4.3.6. Drainage Frequency or Stream Frequency (Fs)

It is defined as the total number of stream segments of all orders per unit area (Horton, 1932). It is an index of the various stages of landscape evolution. The occurrence of stream segments depends on the nature and structure of rocks, vegetation cover, nature and amount of rainfall and soil permeability. The Fs in Lidder catchment is 3.33 stream segments per km^2. It varies from 1.84 stream segments per km^2 in watershed 1E7A1 to 5.26 stream segments per km^2 in watershed 1E7B3. Thus it has been possible to identify four categories of Fs; poor (below 2.5/km^2), Moderate (2.5-3.5/km^2), High (3.5-4.5/km^2) and Very High (Above 4.5/km^2) as shown in fig. 4.14. The analysis has revealed that 32.76 per cent of the total catchment area of Lidder has poor Fs, while 24.23 per cent has moderate, 29.94 per cent has high and only 13.07 per cent has very high Fs.

The poor to moderate Fs in the watersheds of 1E7A1 and 1E7B4 is attributed to agricultural land use (54.23 per cent) with the consequent development of artificial drainage which is not considered here. Poor Fs in the watersheds of 1E7A6 and 1E7A7 could be attributed to rugged topography and steep barren slopes. The highest Fs in watershed 1E7B3 is because of the fact that it falls in the zone of fluvial channels and the presence of ridges on both sides of the valley which results in elongated drainage with highest Fs. The Fs decreases as we move to higher altitudes from south to north of the catchment. The watersheds falling in the zone of fluvial channels (Kaul, 1990) have highest Fs as compared to the watersheds in the zone of melt water channels.

LIDDER CATCHMENT
DISTRIBUTION OF DRAINAGE DENSITY AND STREAM FREQUENCY

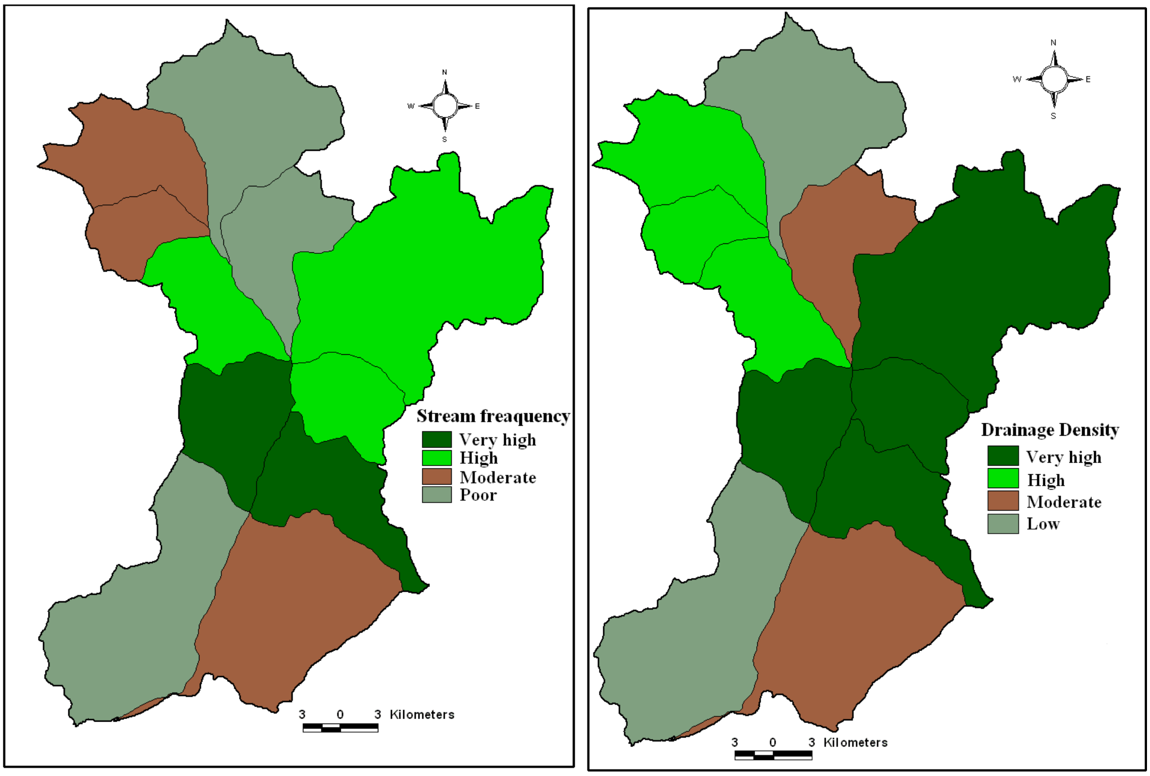


Fig. 4.14: Distribution of stream frequency (left) and drainage density (right) in Lidder catchment

4.3.7. Drainage Density (Dd)

The measurement of Dd is a useful numerical measure of landscape dissection and runoff potential (Chorley, 1969). On the one hand, the Dd is a result of interacting factors controlling the surface runoff; on the other hand, it is itself influencing the output of water and sediment from the drainage basin (Ozdemir and Bird, 2009). Dd is known to vary with climate and vegetation (Moglen et al., 1998), soil and rock properties (Kelson and Wells, 1989), relief (Oguchi, 1997) and landscape evolution processes. The Dd of the Lidder catchment is 2.54 kms/km^2. It varies from 1.52 kms/km^2 in watershed 1E7A1 to 3.52 kms/km^2 in watershed 1E7B3.

The watersheds can be grouped into four categories on the basis of Dd as Low (below 2.0kms/km^2), Moderate (2.0-2.5kms/km^2), High (2.5-3.0kms/km^2) and Very High (Above 3.0kms/km^2) as shown in fig. 4.14. The analysis of the table 4.9 reveals that in Lidder catchment 26.10 per cent of the area has low Dd, 20.67 per cent has moderate Dd, 15.83 per cent has high while 37.39 has very high Dd. It is found that the watersheds of

East Lidder sub-catchment have higher Dd as compared to the watersheds of West Lidder sub-catchment. The analysis has further shown that the Dd values of the different watersheds exhibit high degree of positive correlation (0.97) with the Fs suggesting that there is an increase in stream population with respect to increasing Dd and vice versa.

4.4. CLIMATIC CHARACTERISTICS

Climate is an important factor in the physical environment of a region. It has a profound influence on the human welfare ranging from the immediate effects of weather elements to complex responses associated with climate change. The study of climatic variability in the catchment would serve as a vital input in the eco-environmental planning processes. The meteorological station at Pahalgam was established by Indian Meteorological Department in 1978. Rainfall and temperature variability has been thoroughly investigated from 1980 to 2010 as these two are most influential and determining factors of the climate around which several other factors revolve to make a composite and complex climatic region. The variation in humidity is also analyzed from 1995 to 2010 because the data regarding relative humidity is available after the year 1995.

The Lidder catchment being a mountainous region is characterized by delicate ecological framework endowed with rich biodiversity and presence of various freshwater high altitude lakes and numerous mountain and valley glaciers. The climate of Lidder catchment is governed by altitude, insulation and amount of rainfall received. The valley has an average altitude of 3510 masl and experiences temperatures varying from as low as -9.8°C in the winter to as high as 27°C in summer. Winters are generally severe while the month of July is the warmest. The catchment receives 124 cm of average annual precipitation with its considerable share in the form of winter snowfall. The catchment has experienced rapid development in the tourism sector mainly because of its pleasant climate and any climatic fluctuation could retard the very base on which tourism is dependent. Excessive increase in temperature could neutralize the advantage of the region being known for its pleasant summers and thus will not only affect the tourism industry but also other sectors of the regional economy.

4.4.1. Temperature Analysis

The analysis of climatic record of last three decades (table 4.10) reveals that overall mean maximum temperature of the catchment is 16.5°C and mean minimum temperature is 2.9°C. The year 2001 has been the warmest year with mean maximum temperature of 18.2°C which is 1.7°C higher than the average temperature of 16.5°C. However the highest mean minimum temperature was recorded for the year 2008 (3.9°C) which is 1°C higher than the average mean minimum temperature of 2.9°C. The year 1989 has been the coldest year with the mean maximum temperature of 14.4°C which is 2.1°C lower than normal and mean minimum temperature of 1.1°C which is 1.8°C lower than the average temperature.

Table 4.10: Decadal analysis of temperature at Pahalgam, (1981 - 2010)

Month	1981 – 1990		1991 – 2000		2001 – 2010		1981 – 2010	
	Max. °C	Min. °C	Max. °C	Min. °C	Max. °C	Min. °C	Max. °C	Min. °C
January	4.2	-7.3	3.4	-7.8	5.8	-5.4	**4.5**	**-6.7**
February	5.9	-5.8	6.1	-5	7.5	-3.2	**6.5**	**-4.7**
March	10.1	-2.4	10.8	-1	13.7	0	**11.5**	**-1.1**
April	16.4	2.8	17.2	3.1	18.1	3.7	**17.2**	**3.1**
May	19.9	5.4	21.6	5.5	21.7	5.8	**21.0**	**5.6**
June	24.3	8.1	25.6	8.2	24.0	9.2	**24.6**	**8.5**
July	25.1	11.8	25.9	12.4	25.5	12.9	**25.5**	**12.4**
August	25.5	12.1	25.1	12.2	25.4	13.1	**25.4**	**12.5**
September	23.5	8.4	23.4	8.6	23.6	8.5	**23.5**	**8.2**
October	17.6	2.5	19.6	2.7	20.0	2.8	**19.1**	**2.6**
November	12.3	-2.2	13.2	-1.8	13.6	-1.6	**13.1**	**-1.8**
December	6.3	-4.2	7.9	-3.5	7.8	-3.8	**7.3**	**-3.9**
Mean	**15.9**	**2.4**	**16.7**	**2.7**	**17.0**	**3.5**	**16.5**	**2.9**

Source: Compiled from meteorological data

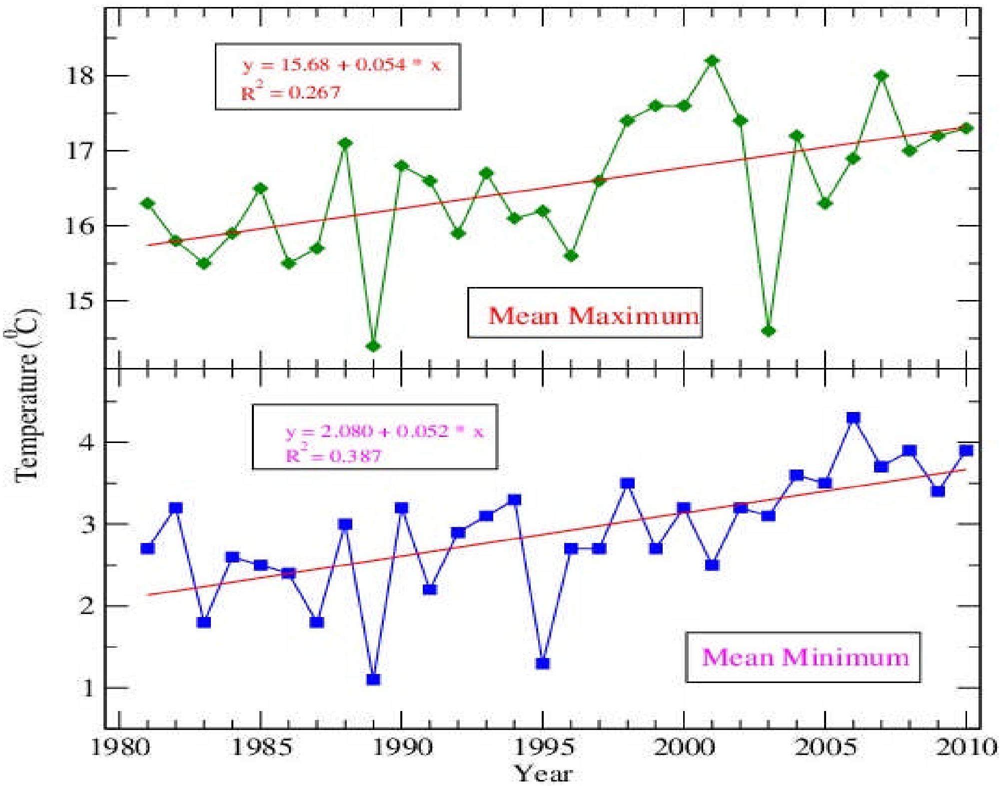


Fig 4.15: Time series analysis of temperature at Pahalgam

The decadal analysis (table 4.10) reveals that the mean maximum temperature at Pahalgam during 1981-1990 was 15.9°C and mean minimum temperature was 2.4°C. The decade of 1991-2000 was considerably warmer with a mean maximum of 16.7°C and mean minimum of 2.7°C. The decade of 2001-2010 was the warmest with the mean maximum temperature of 17°C and mean minimum temperature of 3.5°C. The mean minimum as well as the mean maximum temperatures have increased considerably (1.1°C each) during the last three decades (fig. 4.15).

Monthly analysis of temperature (fig. 4.16) has revealed that July is the warmest month with mean maximum temperature of 25.5°C and mean minimum 12.4°C. August is the second hottest month with a mean maximum of 25.4°C and 12.5°C followed by June with mean maximum of 24.6°C and mean minimum of 8.5°C. January is the coldest month with a mean maximum temperature of 4.5°C and mean minimum temperature of -6.7°C followed by February (mean maximum of 6.5°C and mean minimum of -4.7°C) and December (mean maximum of 8.2°C and mean minimum of -3.9°C). However the highest mean monthly temperature of 27°C was recorded for the month of July in 1990 while the lowest mean minimum temperature of -9.8°C was recorded for the month of January in 1987. The analysis (fig. 4.15) has revealed that the temperature in Pahalgam has experienced a moderate increasing trend during the last thirty years (1980 - 2010).

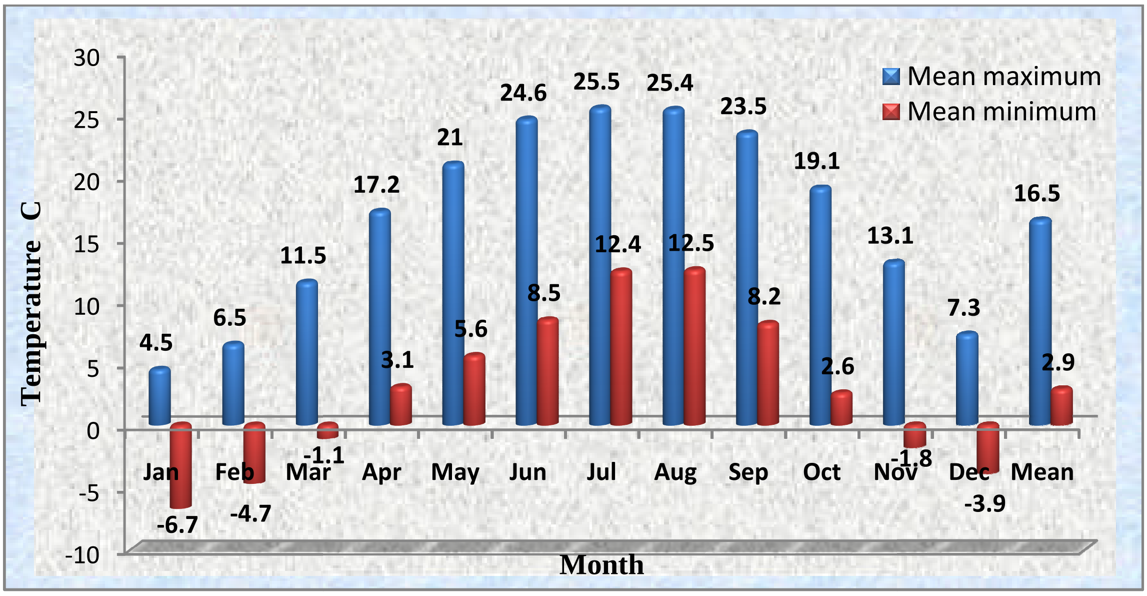


Fig. 4.16: Monthly analysis of temperature at Pahalgam

4.4.2. Precipitation Analysis

The precipitation at Pahalgam occurs as rain in summer and in the form of snowfall in winter. In the present study the snow fall is converted into rain for comparative analysis. The characteristic feature of precipitation in Pahalgam is the mode of occurrence and its frequency. Pahalgam receives frequent showers which makes precipitation effective. The study reveals that the average rainfall at Pahalgam is 124 cm in 117 rainy days per year. The year 1996 has been the rainiest year with an annual rainfall of 163 cm in 126 rainy days. Year 2007 has been the driest year with an average rainfall of 92 cm in 110 rainy days.

Table 4.11: Decadal analysis of precipitation at Pahalgam, (1981 - 2010)

Month	1981 – 1990		1991 – 2000		2001 – 2010		1981 – 2010	
	Rainfall (mm)	Rainy days	Rainfall (mm)	Rainy days	Rainfall (mm)	Rainy days	Rainfall (mm)	Rainy days
January	88.3	9.1	120.0	10.7	125.0	11.2	**111.1**	**10.3**
February	145.0	11.3	107.9	10.9	156.9	12.4	**136.6**	**11.5**
March	246.0	14.5	192.2	14.5	140.7	12.2	**193.0**	**13.7**
April	149.3	12.6	131.3	12.4	123.3	11.1	**134.6**	**12.0**
May	126.4	11.7	143.7	13.1	118.4	10.4	**129.5**	**11.7**
June	89.8	12.5	79.0	9.7	89.4	10.2	**86.1**	**10.8**
July	96.6	13.1	116.5	11.5	105.7	10.5	**106.3**	**11.7**
August	92.6	11.5	119.5	12.5	105.6	11.6	**105.9**	**11.9**
September	60.8	7.3	85.7	8.4	89.5	7.8	**78.7**	**7.8**
October	65.5	5.7	43.1	4.8	36.3	4.6	**48.3**	**5.0**
November	39.0	3.6	45.4	4.0	44.6	3.8	**43.0**	**3.8**
December	113.7	8.5	45.6	5.2	57.2	6.2	**72.1**	**6.6**
Total	**1313.1**	**121.4**	**1230**	**118**	**1192.5**	**112**	**1245.1**	**117.1**

Source: Compiled from meteorological data

Monthly analysis of precipitation reveals that March is the wettest month with an average rainfall of 19.3 cm and 13.7 rainy days followed by February with 13.7 cm of average rainfall and 11.5 rainy days. It is also evident that November is the driest month with only 4.3 cm of average rainfall and 3.8 rainy days followed by October with 4.8 cm of average rainfall and 5 rainy days. The decadal analysis of rainfall (table 4.11) has shown a marked decrease not only in the annual precipitation (from 131 cm in 1981-1990 to 123 cm in 1991-2000 to 119 cm in 2001 to 2010) but also in the number of rainy days (from 121.4 in 1981-1990 to 118 in 1991-2000 to 112 in 2001-2010). The average rainfall has decreased by 12 cm in the last thirty years with the average loss of 4 cm of rainfall every decade. The number of rainy days has decreased by 9 days with the average decrease of 3 days per decade. Though the precipitation has considerably reduced in Pahalgam, there are large variations in the monthly dynamics. The worst affected has been the month of March which alone has suffered the loss of 10 cm of rainfall out of the total loss of 12 cm in the last thirty years. The other months which have registered significant decrease in precipitation are December and October. The month of January has registered a considerable increase in precipitation (3.7 cm) in the last thirty years with the average increase of 1.2 cm of rainfall per decade. The analysis revealed a decline of 8 rainy days associated with a decline of 12cms in rainfall as indicated by the trend line in fig. 4.17. The time series analysis indicated that prevalence of a warming associated with a decline in rainfall is experienced in Pahalgam thus exhibiting a negative correlation between temperature and rainfall (fig. 4.18).

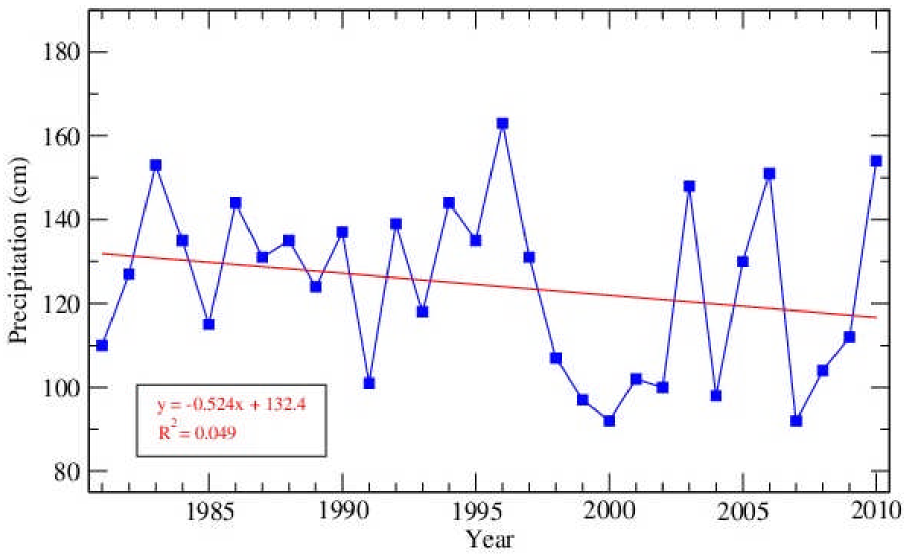


Fig. 4.17: Time series analysis of Precipitation at Pahalgam

Pahalgam has witnessed a steep hike in temperature during the last 30 years. Increase in temperature was associated with a drastic decline in precipitation. The characteristic feature of microclimate of Pahalgam is frequent showers which modifies the temperature considerably. During the last two decades especially the last decade of 20th century there was a drastic decline of rainfall along with the number of rainy days per year. This decline allowed the temperature to shoot up, which ultimately resulted in overall increase of temperature. This is the main reason that Pahalgam experienced an increase of 1.1°C in mean maximum as well as mean minimum temperature. There exists a negative correlation of r = -0.61 between temperature and rainfall at Pahalgam. Regression analysis with the help of trend line clearly reflects the nature and magnitude of correlation between temperature and precipitation in Pahalgam (fig. 4.18).

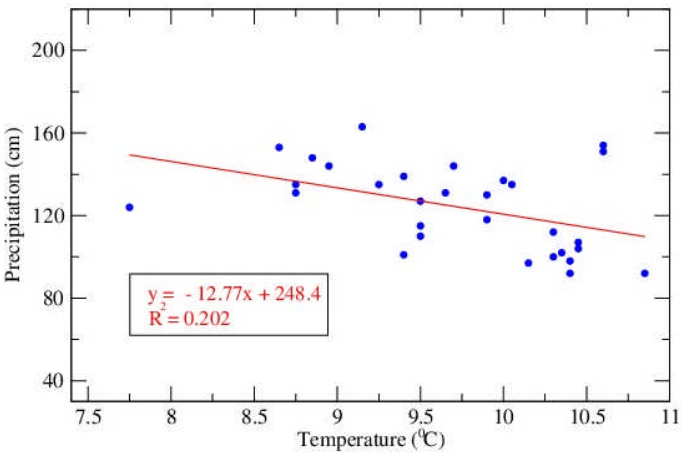


Fig. 4.18: Regression analysis of temperature and precipitation at Pahalgam

4.4.3. Relative Humidity

The relative humidity at Pahalgam is recorded at 8:30 am and 5:30 pm every day. The average relative humidity of Pahalgam is 84 percent and 81 percent for morning and evening time respectively. The analysis of five year average of relative humidity (table 4.12) has revealed that the morning time relative humidity has remained constant from 1995 to 2004 while it has decreased by 3 percent from 2005-2010. However the evening time relative humidity has decreased considerably from 87 percent during 1995-1999 to 75 percent during 2000-2004 with the decrease of 12 percent. However, it has again increased to 82 percent during 2005- 2010. Thus the morning time relative humidity has decreased by one percent during the last 16 years while the evening time relative humidity has decreased by six percent during the last 16 years (fig. 4.19). The monthly analysis has revealed that the relative humidity is maximum in January (92 percent and 81 percent for morning and evening respectively). The lowest relative humidity is recorded for the month of May (70 percent and 59 percent for morning and evening respectively).

Table 4.12: Relative humidity at Pahalgam, (1995 - 2010)

Month	Five yearly average relative humidity (percent)							
	1995 - 1999		2000 – 2004		2005 – 2010		1995 – 2010	
	(8:30am)	(5:30pm)	(8:30am)	(5:30pm)	(8:30am)	(5:30pm)	(8:30am)	(5:30pm)
January	92	87	93	75	91	81	92	81
February	92	79	93	73	90	80	92	77
March	88	72	87	63	84	65	86	66
April	73	60	79	64	69	56	73	60
May	72	62	67	54	71	60	70	59
June	75	58	72	58	73	59	73	59
July	85	64	81	63	83	65	83	64
August	91	73	90	67	87	67	89	69
September	86	68	91	66	84	53	87	61
October	87	67	87	56	82	55	85	59
November	87	72	88	64	81	67	85	68
December	90	77	92	77	88	75	90	76
Mean	**85**	**87**	**85**	**75**	**82**	**81**	**84**	**81**

Source: Compiled from meteorological data

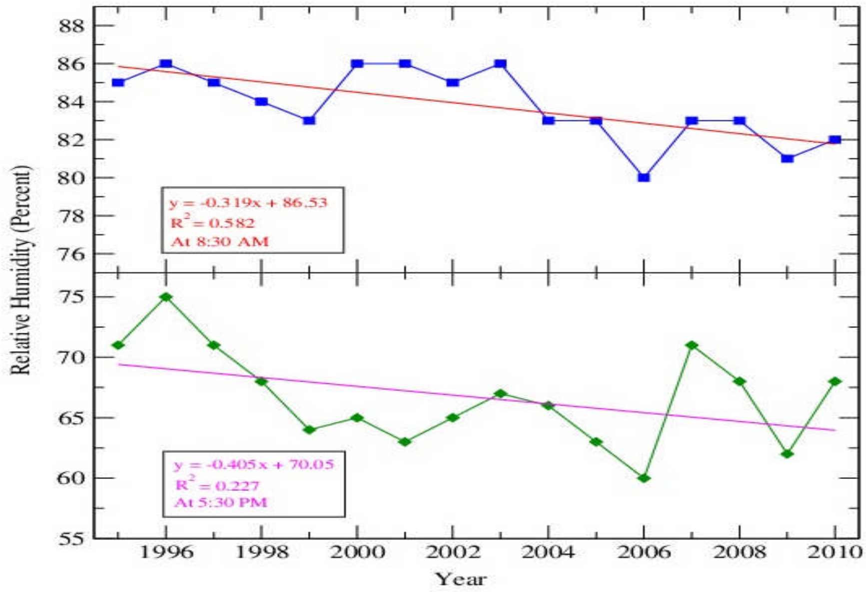


Fig. 4.19: Time series analysis of Relative Humidity

4.5. HYDROLOGICAL CHARACTERISTICS

The study of river discharge is of paramount importance in order to assess the water resource potential of Lidder catchment. The water discharge of Lidder river is largely governed by the spatio-temporal variability in precipitation which is in the form of snow in winter and rainfall in summer. The temperature, form of precipitation and its temporal distribution are the key factors which determine the magnitude and variability of water discharge throughout the year.

Table 4.13: Decadal analysis of average monthly discharge of Lidder river, (1961 - 2010)

Month	Average discharge in cusec					
	1961-70	1971-80	1981-90	1991-2000	2001-2010	1961-2010
January	180	222	381	313	284	**276**
February	230	291	433	382	371	**341**
March	618	690	863	735	754	**732**
April	1397	1455	1386	1159	1433	**1366**
May	1518	2004	1828	1431	1886	**1733**
June	2040	2201	1621	1517	1268	**1729**
July	1507	1887	1641	1292	1174	**1500**
August	1151	1482	1449	1101	1019	**1241**
September	1000	852	839	873	834	**879**
October	498	437	699	556	407	**519**
November	305	336	503	380	297	**364**
December	239	273	381	272	282	**292**
Average	**890**	**1010**	**970**	**834**	**834**	**914**

Source: Compiled from records of Flood Department, Planning and Designing Division, Srinagar

The Lidder catchment receives a considerable amount of precipitation in winter season (table 4.11) but river discharge (table 4.13) is very low as the snow remains frozen because of low temperatures. In the summer season as the temperatures rise above 20 °C, the snow (which had actually fallen in winter), melts and hence the discharge is maximum in summer season (figure 4.20). The Lidder river is braided into four main branches before it joins Jhelum river and hence discharge is measured at four stations of Gur, Khanabal, Adar and Kirkadal. In the present study the discharge record of all these four stations is added up in order to analyze the total discharge of Lidder river.

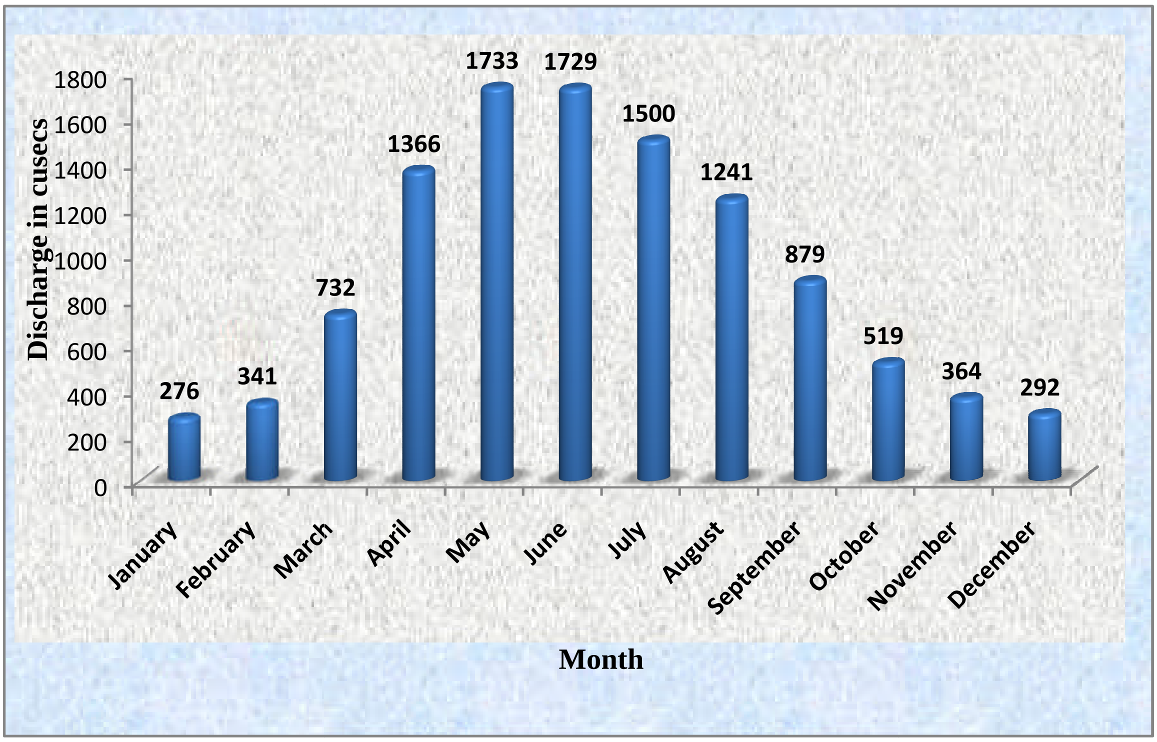


Fig. 4.20: Monthly analysis of average (1961-2010) water discharge in Lidder river

The analysis (table 4.13) has revealed that the average annual discharge of Lidder river is 914 cusecs with the highest discharge recorded for the months of May and June (1733 cusecs and 1729 cusecs respectively). These are the months when the rainfall is considerable and the snow melt is at its peak because of relatively higher temperatures. The lowest discharge is recorded for the month of January (276 cusecs) followed by February (341 cusecs) because in these two months almost all the precipitation is in the form of snow fall and snow melt is negligible because of low temperatures. The decadal analysis has revealed that the average annual river discharge has decreased by 55 cusecs from 890 cusecs in the decade 1961-70 to 834 cusecs in 2001-2010. The discharge has initially increased by 120 cusecs from 890 in the decade 1961-70 to 1010 cusecs in 1971-81. It is further evident that the discharge has shown a decreasing trend from 1971-81 to 1981-90 where it has decreased by 40 cusecs (fig. 4.21). However, it has remained constant (834 cusecs) from the last two decades.

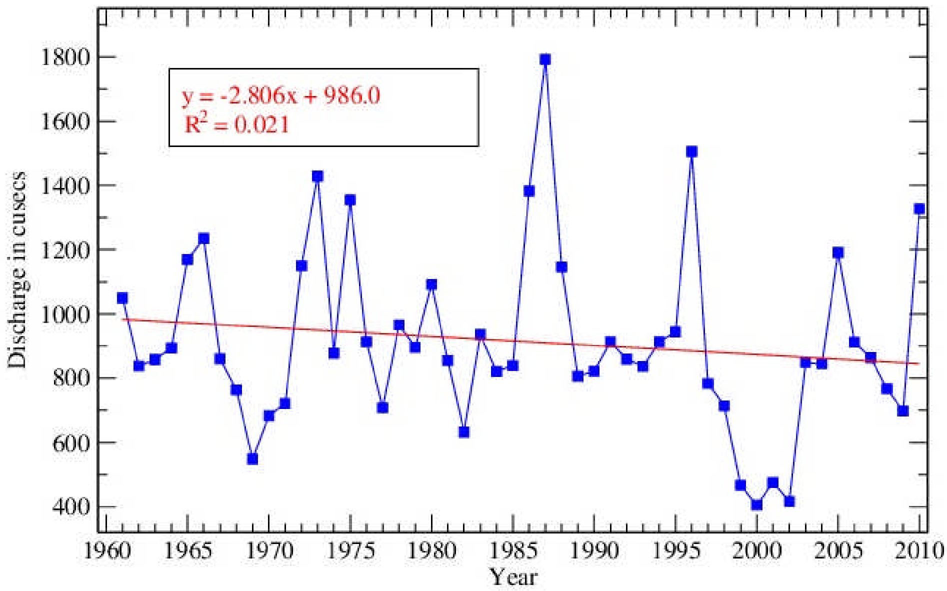


Fig. 4.21: Time series analysis of water discharge of Lidder river

It is interesting to note here that the discharge has decreased for only those months which experience relatively higher temperature (June to November) with the highest decrease of 772 cusecs recorded for June while it has increased in the months which have relatively low temperatures (December to May) with the highest increase of 368 cusecs recorded for the month of May. The decrease in the discharge in summer months could be attributed to the considerable decrease in magnitude and extant of glaciers and hence reduced melt water in summer season. More over it is also clear from figure 4.22 that the discharge for the months of January to March and October to December is well below the annual average while the average discharge for the period of July to September and April to June is well above the annual average. The average discharge is highest for the period from April to June throughout the last half century.

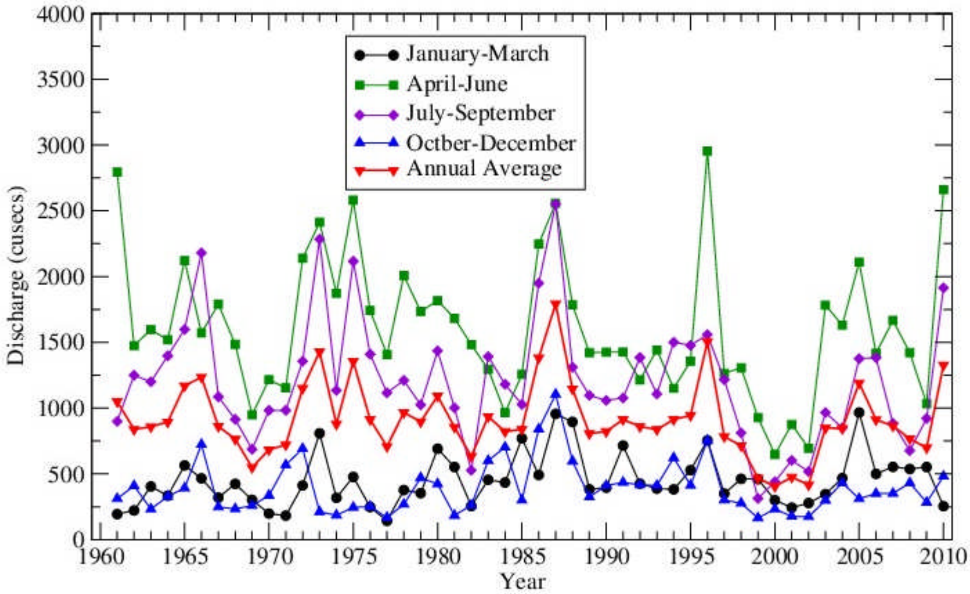


Fig. 4.22: Seasonal variations in water discharge in Lidder river.

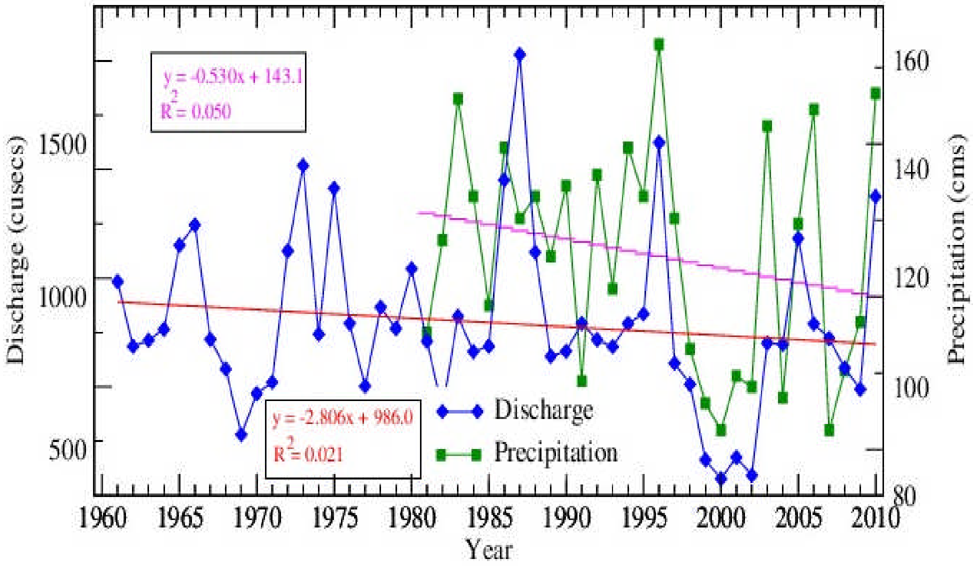


Fig. 4.23: Trend analysis of precipitation and water discharge.

The discharge in Lidder river largely corresponds to precipitation in the catchment. The trend analysis (fig 4.23) of precipitation and discharge has revealed that both have shown a decreasing trend in the catchment. The scatter diagram (fig. 4.24) has shown a positive correlation (r^2= 0.27) between precipitation and discharge.

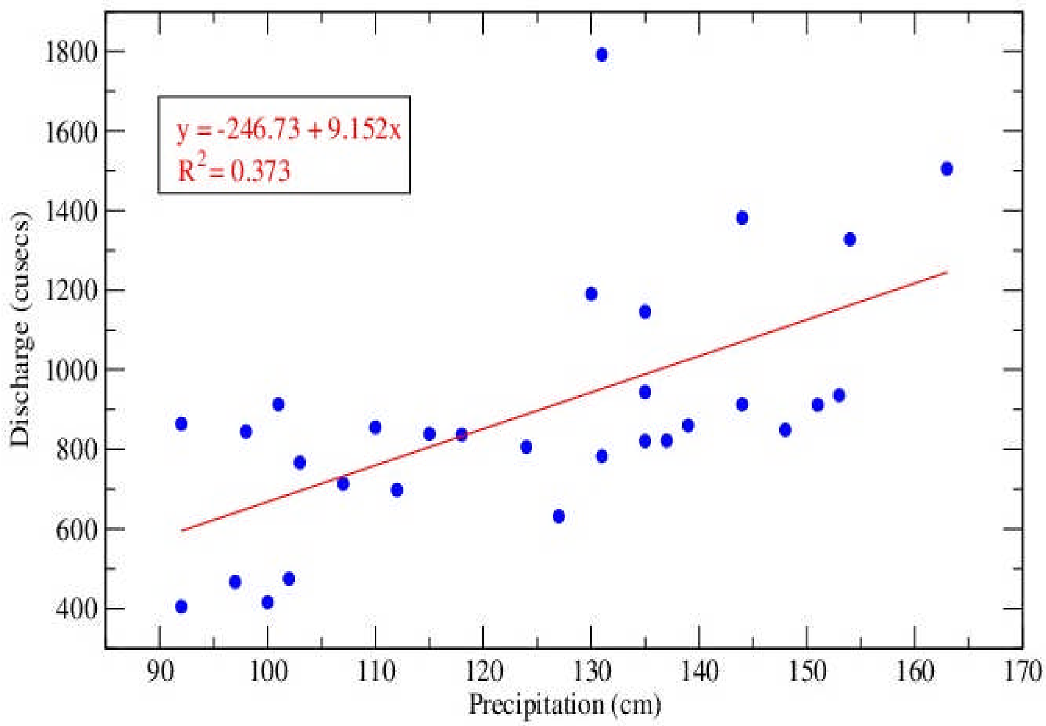


Fig. 4.24: Scatter diagram of Precipitation and water discharge.

CHAPTER - 5

SOCIO-ECONOMIC PROFILE

The socio-economic variables are considered significant factors influencing the environmental quality of a particular region in terms of extraction of various natural resources and altering LULC pattern. The socio-economic structure determines the overall anthropogenic impact as expressed (I = PAT; where I = Impact on environment; P = Population; A = Affluence and T = Technology) by Ehrlich and Ehrlich (1970). Therefore the evaluation of socio-economic structure must receive the top priority so far as the management of natural resources is concerned. The level of socio-economic development of Lidder catchment is very low. Being a remote mountainous area, the people are backward with low levels of education and low literacy rate. The population is growing very fast which has not only resulted in low per capita land availability but also into higher rates of unemployment. This has resulted into low per capita income and low standard of living of the inhabitants. Agriculture is the dominant economic activity in the Lidder flood plain where as tourist related activities dominate in and around Pahalgam town.

5.1. POPULATION DISTRIBUTION

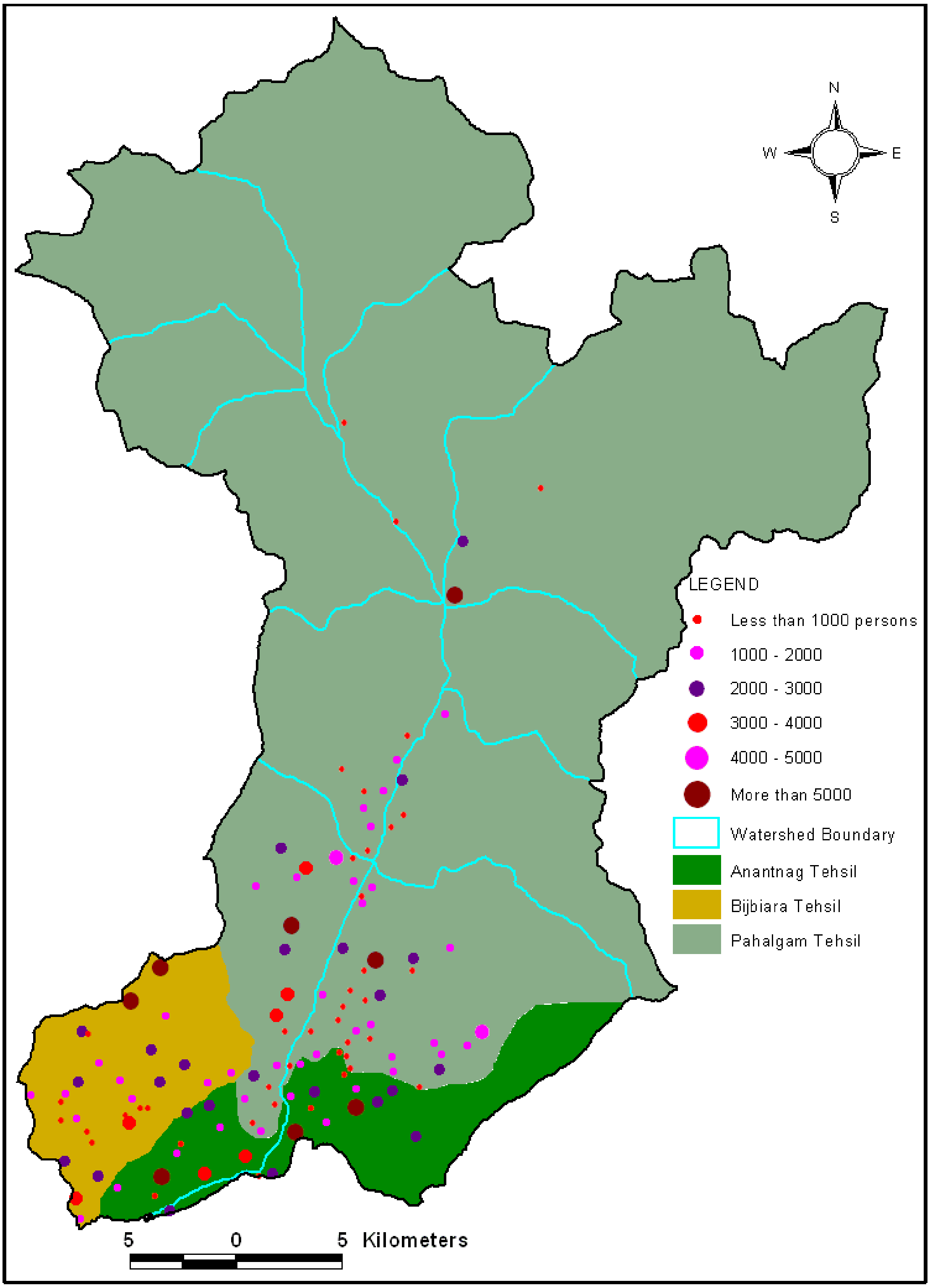
The Lidder catchment comprises of eleven watersheds among which six watersheds are inhabited by 120 rural settlements and three urban centers of Pahalgam, Aishmuqam and Seer Kanaligund while five watersheds are uninhabited. The total area of Lidder catchment is 1159.38 km^2. The watershed 1E7B1 is biggest in size with an area of 228.52 km^2 while the watershed 1E7A4 is smallest in size with the total area of 40.46 km^2 (table 5.1). The total population of Lidder catchment is 2.34 lac persons (Census of India, 2011) distributed in 35.8 thousand households (fig. 5.2) with the average household size of 6.5 persons per household. The average household size is lowest in watershed 1E7A7 (5.2 persons per household) while it is highest in watershed 1E7B1 (8.3 persons per household).

Table 5.1: Population distribution and density of Lidder catchment, 2011

Watershed	Total area (km^2)	Revenue villages (number)	Net sown area (km^2)	Population (persons)	Households (number)	Average household size (persons)	Population density (persons/km^2)	Physiological density (persons/km^2 of net sown area)
1E7A1	173.24	58	86.90	127158	19024	6.7	734	1463
1E7A2	73.14	8	5.79	8037	1364	5.9	110	1388
1E7A3	65.08	Uninhabited						
1E7A4	40.46	Uninhabited						
1E7A5	78.07	Uninhabited						
1E7A6	129.36	Uninhabited						
1E7A7	77.19	2	0.76	931	180	5.2	12	1225
1E7B1	228.52	3	2.99	10388	1254	8.3	45	3474
1E7B2	53.49	Uninhabited						
1E7B3	78.36	4	2.51	6005	1066	5.6	77	2392
1E7B4	162.47	48	47.37	81145	12871	6.3	499	1713
Lidder catchment	**1159.38**	**123**	**146.33**	**233664**	**35759**	**6.5**	**201**	**1597**

Source: Compiled from census of India, Jammu and Kashmir, 2011

LIDDER CATCHMENT
SIZE CLASS DISTRIBUTION OF REVENUE VILLAGES



Source: Survey of India toposheets, 1961 and Census of India, 2011

Fig. 5.1

The most striking feature of population in Lidder catchment is its uneven distribution as only 20.55 per cent of the total area is inhabited while the remaining

79.45 per cent of the total area is uninhabited (fig. 5.1). The highest size of population (1.27 lac) along with the highest number of households (19 thousand) is found in watershed 1E7A1 followed by watershed 1E7B4 with the population of 81 thousand persons distributed among 12 thousand households. These two watersheds (1E7A1 and 1E7B4) constitute 89 per cent of the total population while the remaining 11 per cent of the population is distributed among the other four inhabited watersheds. The lowest number of households (180) with the population of 931 persons is found in watershed 1E7A7 which comprises the village settlements of Aru and Mondlan. The marked difference in the distribution of population among different watersheds is largely because of the variation in physiography especially relief, slope, soil, drainage and the micro-climatic characteristics.

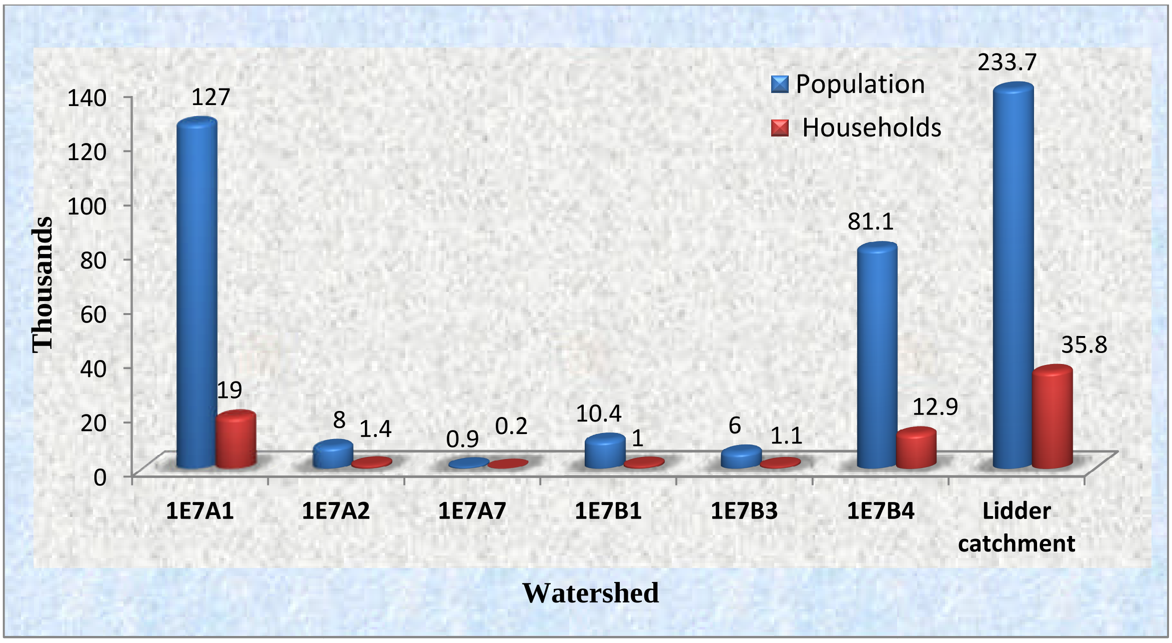


Fig. 5.2: Distribution of population and household in Lidder catchment, 2011

5.2. POPULATION DENSITY

The crudest measure of the relationship between population and land is simple population density which measures the human pressure on the total land of a region. The extent of ecosystem loss and alteration is closely related to population density, which is very uneven across the planet. Today, one half of the human population lives on less than 10 per cent of the Earth's land, and three quarters on only 20 percent. The average population density of Lidder catchment is 201 persons/km^2 (table 5.1) which is much higher not only than the state average of 124 persons/km^2 (census of India, 2011) but also than that of Indian Himalayan Region as a whole (74 persons per square kilometer). The highest population density of 734 persons/km^2 is found in watershed 1E7A1 followed by watershed 1E7B4 (499 persons/km^2) while the lowest density of population is found in watershed 1E7A7 (12 persons/km^2). The Lidder catchment has been divided into four categories of low, medium, high and very high population density (fig. 5.3).

LIDDER CATCHMENT
DISTRIBUTION OF ARITHMETIC AND PHYSIOLOGICAL DENSITY

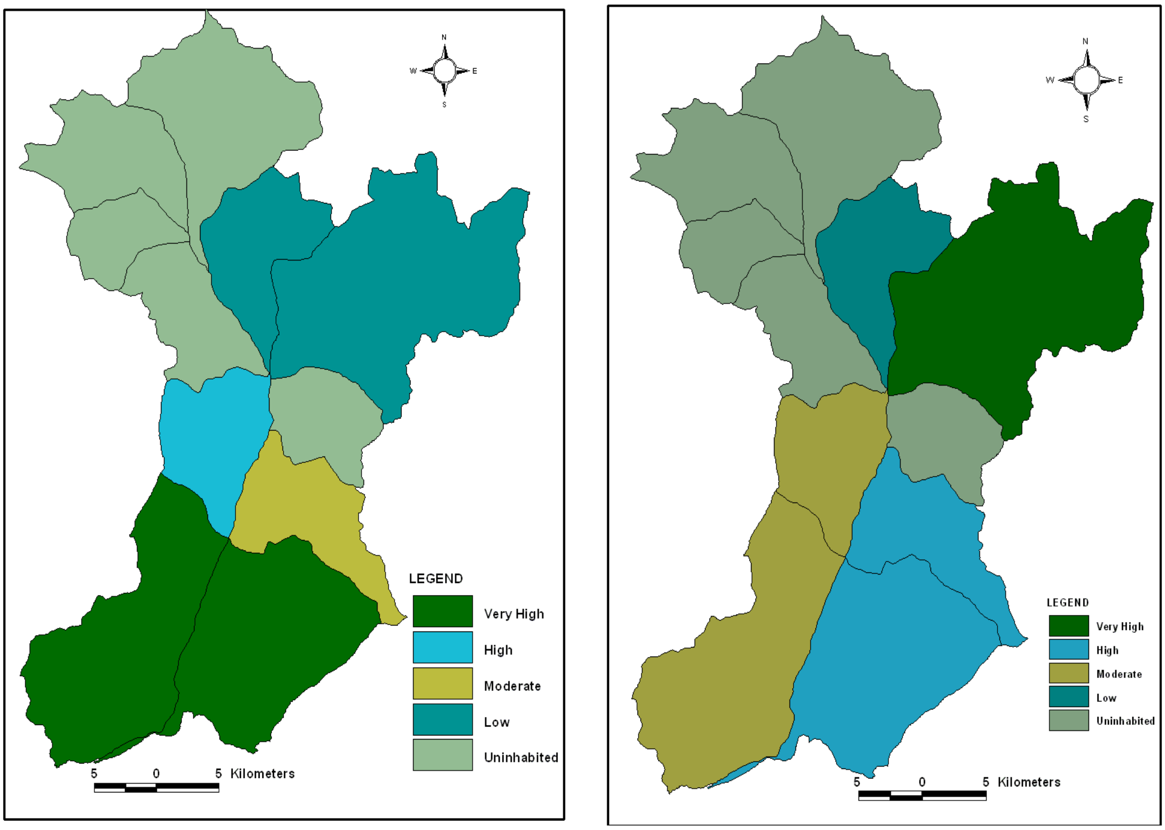


Fig. 5.3: Arithmetic (left) and physiological density (right) in Lidder catchment, 2011

5.3. PHYSIOLOGICAL DENSITY

Physiological density is a more meaningful population measure especially for rural areas where the inhabitants are dependent mainly on agriculture. The higher physiological density of a region indicates higher pressure on cultivated area to feed more people. The physiological density is very high in Lidder catchment (1597 persons/ km^2 of net sown area) with the highest physiological density (3474 persons/ km^2 of net sown area) found in watershed 1E7B1 followed by watershed 1E7B3 (2392 persons/ km^2 of net sown area) while the lowest physiological density is found in watershed 1E7A7 (1225 persons/ km^2 of net sown area). The higher physiological density in different watersheds of Lidder catchment (table 5.1) could be attributed to the fact that the region is a mountainous one with the slope in most parts ranging from moderately steep to very steep which limits the area available for cultivation. It is further explained by the fact that the population has registered higher growth rates in these watersheds which has further increased the physiological density. The catchment has been divided into four categories on the basis of physiological density (fig. 5.3).

5.4. SEX-RATIO

According to the definition adopted by the Indian census department, sex ratio is the number of females per thousand males. Sex ratio influences the socio-cultural milieu of a region. The active work force in economic pursuits is directly affected by the sex ratio as the workers are easily available if the proportion of males exceeds that of females. The sex ratio is mainly the outcome of the interplay of sex differentials in mortality, selective migration and sex differential in population enumeration. Changes in sex composition largely reflect the underlying socio-economic and cultural pattern of a society. The analysis of table 5.2 reveals that in Lidder catchment sex ratio is 947 females/thousand males which is higher than the sex ratio of 883 females/thousand males for the state of Jammu and Kashmir and 914 females/thousand males for the country as a whole (Census of India, 2011). The highest sex ratio (fig. 5.4) is found in watershed 1E7B1 (1007 females/thousand males) followed by the watershed 1E7A7 (972 females/thousand males) while it is lowest in watershed 1E7B4 (907 females/thousand males).

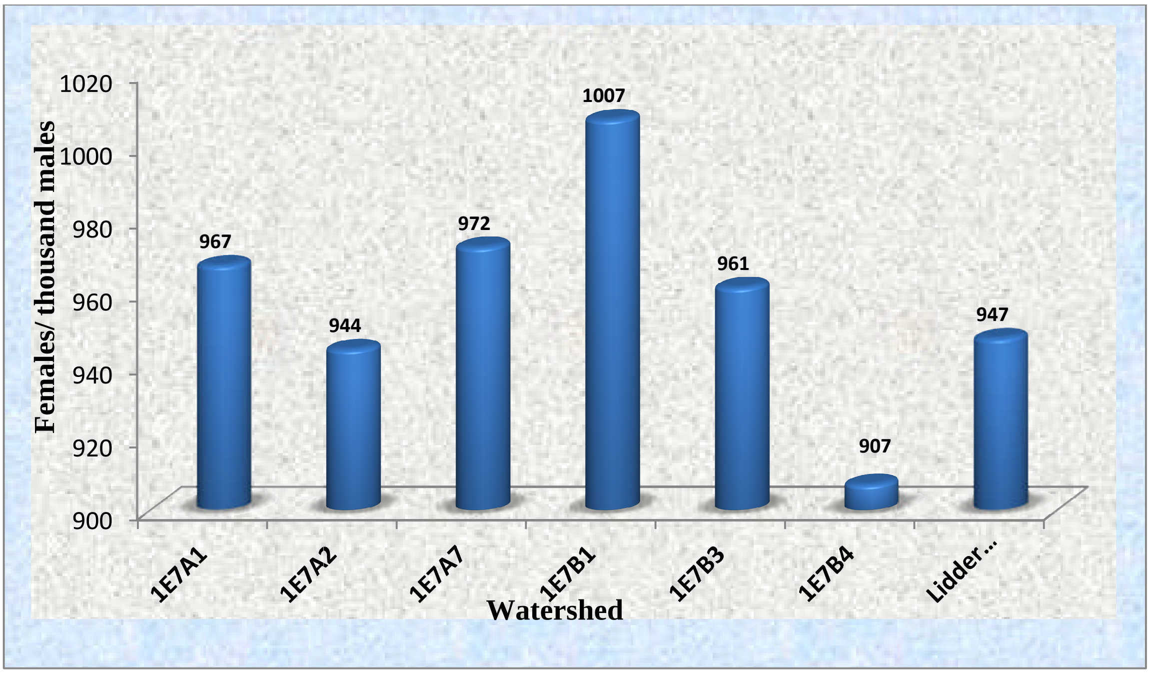


Fig. 5.4: Distribution of sex-ratio in Lidder catchment, 2011

5.5. AGE STRUCTURE

Age structure is an important characteristic of a population in terms of social milieu and stage of development. Age structure has direct impact on dependency ratio and occupational structure. The analysis of table 5.2 reveals that 25.4 per cent of the population belongs to the age-group of less than 14 years where as 6.3 per cent is in the age group of 60 years and more. The economically productive population in the age group of 15 to 59 years age constitutes 68.3 per cent of the total population (fig. 5.5). The lowest percentage of population in the age-group of 0 to 14 years is in the watershed 1E7A1 (23.96 per cent) while it is highest in the watershed 1E7B3 (39.34 per cent). The lowest percentage of population in the age-group of 15 to 59 years is in the watershed 1E7B3 (55.75 per cent) while it is highest in the watershed 1E7A1 (69.67 per cent). The highest percentage of old age people is in the watershed 1E7B4 (6.77 per cent) while it is lowest in the watershed 1E7B1 (2.85 per cent).

Table 5.2: Age structure of population in Lidder catchment, 2011

Watershed	Population			Sex-ratio (females/thousand of males)	Age structure (persons)		
	Persons	Male	Female		0 – 14 (years)	15 – 59 (years)	60 + (years)
1E7A1	127158	64650	62508	967	30467 (23.96)	88591 (69.67)	8100 (6.37)
1E7A2	8037	4134	3903	944	2866 (35.66)	4778 (59.45)	393 (4.89)
1E7A3	Uninhabited						
1E7A4	Uninhabited						
1E7A5	Uninhabited						
1E7A6	Uninhabited						
1E7A7	931	472	459	972	274 (29.41)	594 (63.87)	63 (6.72)
1E7B1	10388	5177	5211	1007	3264 (31.42)	6828 (65.73)	296 (2.85)
1E7B2	Uninhabited						
1E7B3	6005	3062	2943	961	2362 (39.34)	3348 (55.75)	295 (4.91)
1E7B4	81145	42545	38600	907	20286 (25.00)	55365 (68.23)	5494 (6.77)
Lidder catchment	**233664**	**120040**	**113624**	**947**	**59519 (25.4)**	**159504 (68.3)**	**14641 (6.3)**

Source: Sample survey, 2011
Note: Figures in parenthesis represent percentage

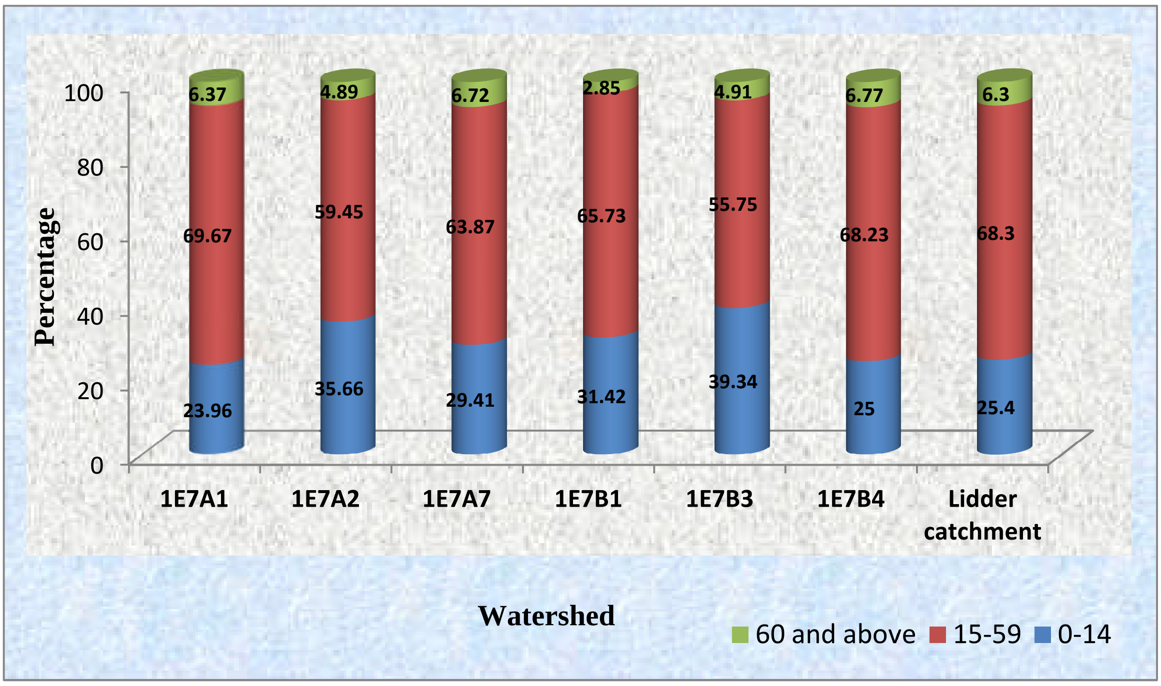


Fig. 5.5: Distribution of age structure in Lidder catchment, 2011

5.6. LITERACY

Literacy rate is the number of literate persons for each hundred people and is expressed in percentages. Literacy rate is a vital parameter to gauge the socio-economic transformation of the population. The process of education in terms of improved qualification and skills would help in the formation of human capital stock which has an overwhelming influence on the socio-economic development of a region as it determines the rate and pattern of resource utilization. An educated population not only accepts the scientific temperament but also very easily learns the know-how from others. Thus the improvement in literacy is an important index of social and cultural advancement and economic transformation.

Table 5.3: Sex-ratio and literacy of population in Lidder catchment, 2011

Watershed	Population (persons)	Literacy		
		Total	Male	Female
1E7A1	127158	67139 (50.0)	41441 (64.8)	25698 (41.2)
1E7A2	8037	3882 (48.3)	2414 (58.4)	1468 (37.6)
1E7A3	Uninhabited			
1E7A4	Uninhabited			
1E7A5	Uninhabited			
1E7A6	Uninhabited			
1E7A7	931	403 (43.3)	263 (55.7)	140 (30.5)
1E7B1	10388	5701 (54.9)	3400 (65.7)	2301 (42.2)
1E7B2	Uninhabited			
1E7B3	6005	2672 (44.5)	1641 (53.6)	1031 (35.0)
1E7B4	81145	44782 (55.2)	27952 (65.7)	16830 (43.6)
Lidder catchment	**233664**	**124579 (53.3)**	**77111 (64.2)**	**47468 (41.8)**

Source: Sample survey, 2011
Note: Figures in parenthesis indicate percentage

The analysis of the table 5.3 indicates that the literacy rate of Lidder catchment is 53.3 per cent with the male literacy rate of 64.2 per cent and female literacy rate of 41.8 per cent against the literacy rate of 68.74 per cent for the Jammu and Kashmir state with the male literacy rate of 78.26 per cent and female literacy rate of 58.01 per cent (Census of India, 2011). The total literacy rate is highest in watershed 1E7B4 (55.2 per cent) followed by watershed 1E7B1 (54.9 percent) while it is lowest in watershed 1E7A7 (43.3 per cent). The male literacy rate is highest in watershed 1E7B1 and watershed 1E7B4 (65.7 per cent each) while it is lowest in watershed 1E7B3 (53.6 per cent). Further it is evident from figure 5.6 that the female literacy rate is highest in watershed 1E7B4 (43.6 per cent) while it is lowest in watershed 1E7A7 (30.5 per cent). It was also found during the survey that the literacy of household heads was poor but they were sending their children to school.

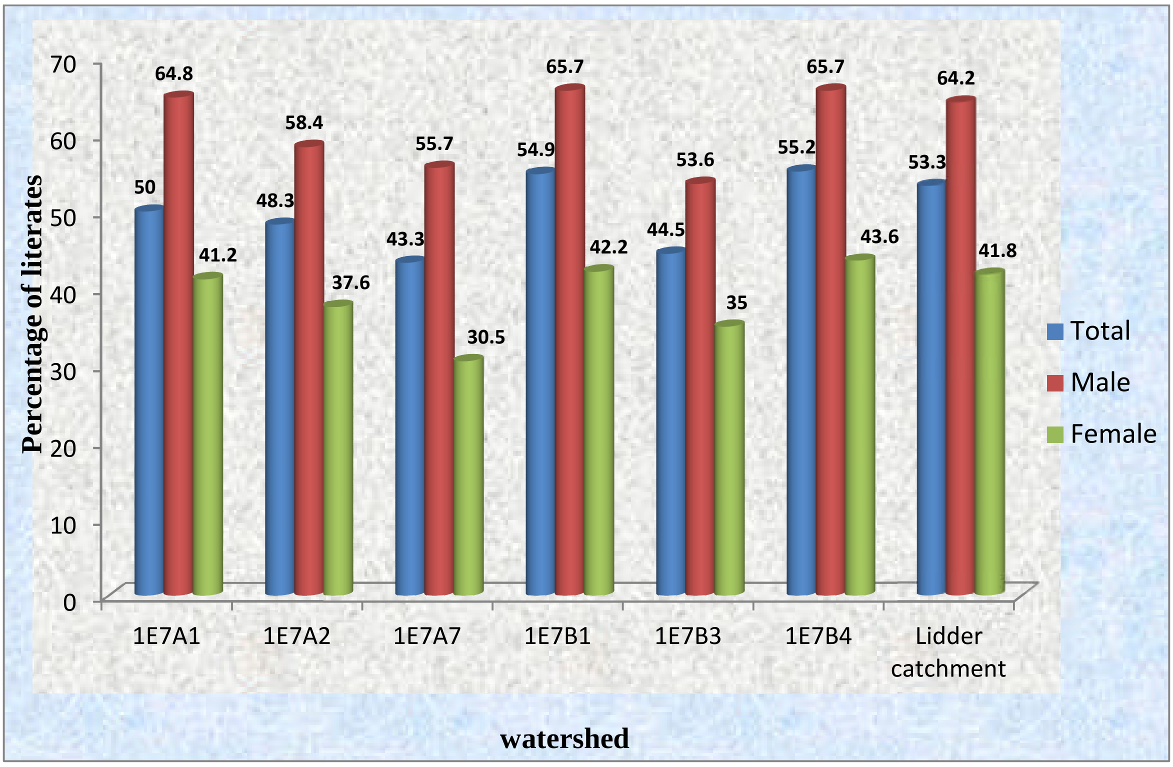


Fig. 5.6: Distribution of literacy in Lidder catchment, 2011

5.7. OCCUPATIONAL CHARACTERISTICS

The analysis of occupational structure serves a vital clue about the structural position of an economy. If the occupational structure is dominated by secondary and tertiary sectors, the prospects of growth are very high as these sectors have relatively better growth potential as compared to agricultural sector. The analysis of table 5.4 has revealed that 44.7 per cent of the working population is engaged in service sector which comprises of government employees, business men and the people engaged with tourist activity. The service sector is predominant in watersheds 1E7A7 (81.4 per cent) and 1E7B1 (78.9 per cent) because the employment opportunities are provided by tourism sector as these watersheds are inhabited by Pahalgam, Aru and Frislan villages where high concentration of tourist activities are prevailing. It is also because of the non-availability of agricultural land as the slopes are steep and soils are immature.

It has been inferred from table 5.4 that 45.7 per cent of the working population of Lidder catchment is engaged in agriculture and allied sectors. The dominance of primary sector is found in watershed 1E7A1 (48 per cent) and 1E7B4 (45.8 per cent) where large tracts of agricultural land are available. It could be further inferred from figure 5.7 that the secondary sector is quite insignificant in the region as only 9.6 per cent of the working population is engaged in small scale household industrial sector. The highest percentage of workers in secondary sector is found in watershed 1E7A1 (11 percent) while the lowest percentage is found in watershed 1E7A2 and 1E7B3 (3.8 percent each). The region is having a low level of resource utilization and availability.

Table 5.4: Occupational structure of population in Lidder catchment, 2011

Watershed	Population (persons)	Total workers	Primary sector	Secondary sector	Tertiary sector	Potential work force	Participation rate (percent)	Dependency ratio	Average monthly income (INR)
1E7A1	127158	54169 (42.6)	26001 (48.00)	5959 (11.00)	22209 (41.00)	88591 (69.67)	61.1	0.44	8000
1E7A2	8037	3113 (38.7)	1136 (36.5)	119 (3.8)	1858 (59.7)	4778 (59.45)	65.2	0.68	7200
1E7A3	Uninhabited								
1E7A4	Uninhabited								
1E7A5	Uninhabited								
1E7A6	Uninhabited								
1E7A7	931	306 (32.9)	34 (11.1)	23 (7.5)	249 (81.4)	594 (63.87)	51.5	0.57	6500
1E7B1	10388	2686 (25.9)	385 (14.3)	181 (6.7)	2120 (78.9)	6828 (65.73)	39.3	0.52	7300
1E7B2	Uninhabited								
1E7B3	6005	1558 (25.9)	688 (44.1)	59 (3.8)	811 (52.1)	3348 (55.75)	46.5	0.79	7000
1E7B4	81145	35866 (44.2)	16427 (45.8)	3084 (8.6)	16355 (54.19)	55365 (68.23)	64.8	0.47	7500
Lidder catchment	**233664**	**97698 (41.8)**	**44671 (45.7)**	**9425 (9.6)**	**43602 (44.7)**	**159504 (68.3)**	**61.3**	**0.46**	**7250**

Source: Sample survey, 2011
Note: Figures in parenthesis indicate percentage

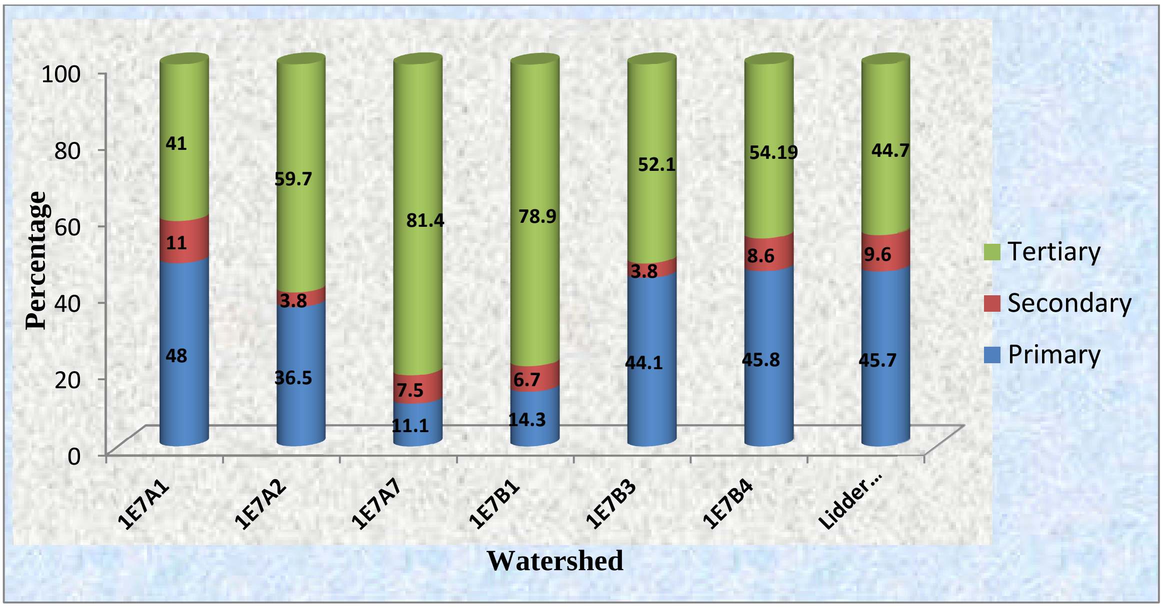


Fig. 5.7: Occupational structure of different watersheds in Lidder catchment, 2011

5.8. WORK FORCE

The magnitude of work force or the productive population forms a basic parameter to examine the status of economic development. The working age group (15 –

59 years) is considered to be the backbone of labor economy. The analysis of table 5.4 reveals that the Lidder catchment has 68.3 per cent productive population that could be fully utilized as a human resource. The highest percentage of potential workforce is found in watershed 1E7A1 (69.67) followed by watershed 1E7B4 (68.23) while it is lowest in watershed 1E7B3 (55.75). The percentage of actual workers is 41.8 percent in Lidder catchment with the highest percentage in watershed 1E7B4 (44.2 per cent) while it is lowest in watershed 1E7B1 and 1E7B3 (25.9 per cent each). The proportion of actual workers to total population depicts the rate of economic productivity on one hand and simultaneously the rate of unemployment on the other. The difference between the potential work force and the actual work force represents the employment gap which is 26.5 per cent in case of Lidder catchment, the highest being in watershed 1E7B1 (39.83 per cent) and the lowest in watershed 1E7A2 (20.75 per cent).

5.9. PARTICIPATION RATE

Participation rate signifies the rate of employment of the population who actually work in various sectors of the economy, captured as the percentage proportion of actual workers to total productive population mainly in the age-group of 15 to 59 years. The participation rate of workers in Lidder catchment is 61.3 per cent against the availability of 68.3 per cent work force (table 5.4). The situation corresponds to the non-availability of job opportunities for the potential work force. The participation rate is highest in the watershed 1E7A2 (65.2 per cent) followed by the watershed 1E7A2 (40.00 per cent) while it is lowest in watershed 1E7B1 (39.3 per cent).

5.10. DEPENDENCY RATIO

The dependency ratio of population indicates the proportion of population which is dependent on the potential work force or in other words it is the ratio of unproductive population to productive population. The larger the percentage of dependents, the greater the financial burden on the working population. The analysis of table 5.4 reveals that Lidder catchment has an average dependency ratio of 0.46 which means that 54 per cent of the population is presently productive population. The dependency ratio is highest in watershed 1E7B3 (0.79) where as it is lowest in watershed 1E7A1 (0.44).

5.11. HOUSEHOLD INCOME

Total income of a household is a combination of various income generating activities such as crop cultivation, business, labour, tourism, income from livestock and other sources. The average household income of Lidder catchment is 7250 rupees/month (table 5.4). It is highest in watershed 1E7A1 (8000 rupees/month) followed by watershed 1E7B4 (7500 rupees/month) while it is lowest in watershed 1E7A7 (6500 rupees/month). This disparity in the average monthly household income (fig. 5.8) is attributed to the fact that the people living in 1E7A1 and 1E7B4 watersheds have comparatively more agricultural land which is devoted to rice cultivation and more importantly to apple orchards which is more revenue generating. On the other hand inhabitants of watershed 1E7A7 depend mostly on tourism activity which is characterized by its seasonality. The seasonal character of tourism is heavily impacting on the household income.

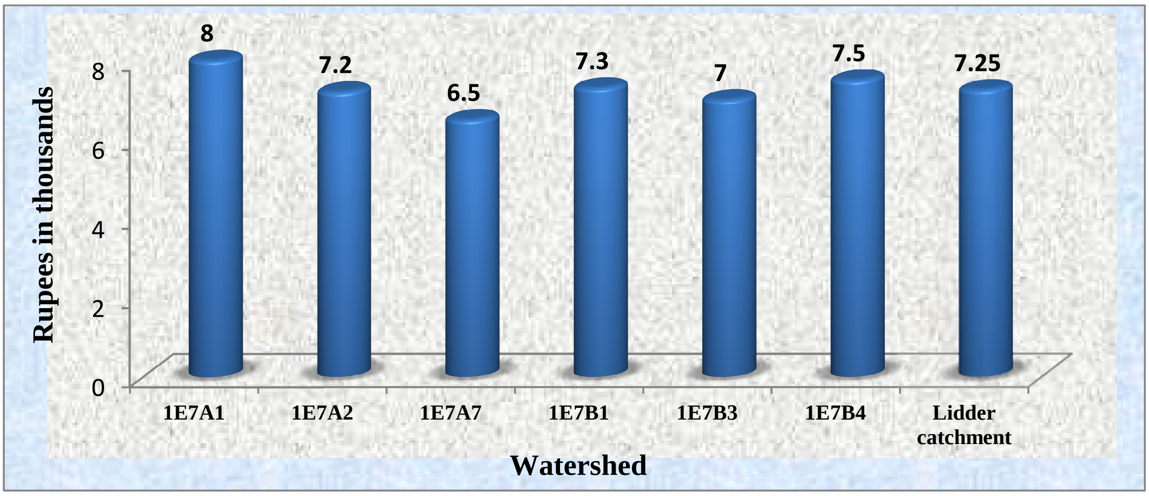


Fig. 5.8: Average monthly household income in Lidder catchment, 2011

5.12. GROWTH OF POPULATION AND HOUSEHOLDS

The population of Lidder catchment has increased more than 3.3 fold from 69.3 thousand persons in 1961 to 2.34 lac persons in 2011 (table 5.5). The analysis of table 5.6 brings to light the fact that there has been 237.2 per cent growth of population in Lidder catchment during the last fifty year period (1961 to 2011) with the average growth rate of 47.5 percent per decade. The highest growth rate of population was recorded for watershed 1E7B1 (373.7 percent from 1961 to 2011) mainly due to tourism as Pahalgam town is located in this watershed while the lowest growth was recorded for watershed 1E7B3 (216.6 percent from 1961 to 2011). The population of watershed 1E7A1 (fig. 5.9) has increased from 37.6 thousand in 1961 to 1.27 lac in 2011 registering a growth of 237.8 percent from 1961 to 2011.

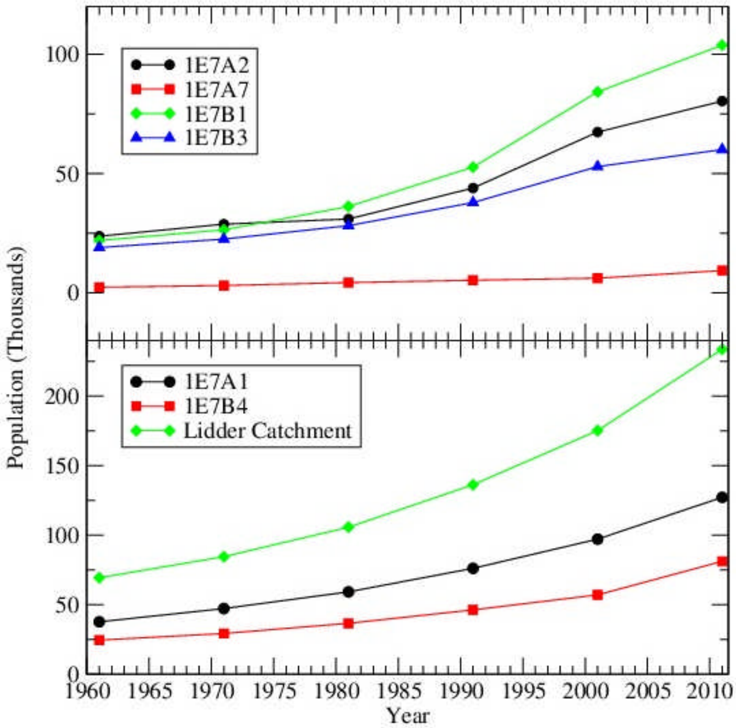


Fig. 5.9: Watershed wise distribution of population in Lidder catchment, (1961-2011)

Table 5.5: Decadal analysis of population and households in Lidder catchment, (1961-2011)

Watershed	1961		1971		1981		1991		2001		2011	
	Population	Households	Population	Households	Population	Households	Population	Households	Population	Households	Population	Households
1E7A1	37642	6445	47188	7303	59180	8732	76057	11222	97101	13315	127158	19024
1E7A2	2372	492	2876	503	3093	494	4391	701	6739	906	8037	1364
1E7A3	Uninhabited											
1E7A4	Uninhabited											
1E7A5	Uninhabited											
1E7A6	Uninhabited											
1E7A7	231	41	303	54	424	59	523	73	610	101	931	180
1E7B1	2193	404	2636	443	3617	562	5270	819	8422	1104	10388	1254
1E7B2	Uninhabited											
1E7B3	1897	320	2249	398	2811	500	3781	673	5289	756	6005	1066
1E7B4	24494	4240	29236	4897	36522	5871	46206	7428	56998	8861	81145	12871
Lidder catchment	**69299**	**12028**	**84488**	**13598**	**105647**	**16218**	**136228**	**20916**	**175159**	**25043**	**233664**	**35759**

Source: Compiled from census of India, Jammu and Kashmir, 1961, 1971, 1981, 2001 and 2011

The decadal analysis of population growth (table 5.6) shows that the growth of population from 1961 to 1971 was only 21.9 per cent followed by 25 per cent in 1971 to 1981, 28.9 percent from 1981 to 1991 and 33.4 percent from 2001 to 2011. Thus the population has been growing at an increasing rate in Lidder catchment from 1961 to 2011 and shows no signs of any population control. Regarding the population growth of different watersheds, the lowest growth rate was found in watershed 1E7A2 from 1971 to 1981 (7.54 per cent) because Nalla Ower, one of the villages in this watershed was depopulated almost completely. The highest growth rate (59.8 percent) was recorded for watershed 1E7B1 from 1991 to 2001 when the tourism sector once again started expanding after the stagnation due to political instability in the region. The other important reason being the fact that the watershed is inhabited by the urban centre of Pahalgam where population growth accelerated due to urbanization.

Table 5.6: Decadal growth of population and households in Lidder catchment, (1961-2011)

Watershed	Absolute Change											
	1961-1971		1971-1981		1981-1991		1991-2001		2001-2011		1961-2011	
	Population	Households	Population	Households	Population	Households	Population	Households	Population	Households	Population	Households
1E7A1	9546 (25.4)	858 (13.3)	11992 (25.4)	1429 (19.6)	16877 (28.5)	2490 (28.5)	21044 (27.7)	2093 (18.7)	30057 (31.0)	5709 (42.9)	89516 (237.8)	12579 (195.2)
1E7A2	504 (21.2)	11 (2.2)	217 (7.5)	-9 (-1.8)	1298 (42.0)	207 (41.9)	2348 (53.5)	205 (29.2)	1298 (19.3)	458 (50.6)	5665 (238.8)	872 (177.2)
1E7A3	Uninhabited											
1E7A4	Uninhabited											
1E7A5	Uninhabited											
1E7A6	Uninhabited											
1E7A7	72 (31.2)	13 (31.7)	121 (39.9)	5 (9.3)	99 (23.3)	14 (23.7)	87 (16.6)	28 (38.4)	321 (52.6)	79 (78.2)	700 (303.0)	139 (339.0)
1E7B1	443 (20.2)	39 (9.7)	981 (37.2)	119 (26.9)	1653 (45.7)	257 (45.7)	3152 (59.8)	285 (34.8)	1966 (23.3)	150 (13.6)	8195 (373.7)	850 (210.4)
1E7B2	Uninhabited											
1E7B3	352 (18.6)	78 (24.4)	562 (25.0)	102 (25.6)	970 (34.5)	173 (34.6)	1508 (39.9)	83 (12.3)	716 (13.5)	310 (41.0)	4108 (216.6)	746 (233.1)
1E7B4	4742 (19.4)	657 (15.5)	7286 (24.9)	974 (19.9)	9684 (26.5)	1557 (26.5)	10792 (23.4)	1433 (19.3)	24147 (42.4)	4010 (45.3)	56651 (231.3)	8631 (203.6)
Lidder catchment	**15189 (21.9)**	**1570 (13.1)**	**21159 (25.0)**	**2620 (19.3)**	**30581 (28.9)**	**4698 (29.0)**	**38931 (28.6)**	**4127 (19.7)**	**58505 (33.4)**	**10716 (42.8)**	**164365 (237.2)**	**23731 (197.3)**

Source: Compiled from census of India, Jammu and Kashmir, 1961, 1971, 1981, 2001 and 2011
Note: Figures in parenthesis indicate percentage

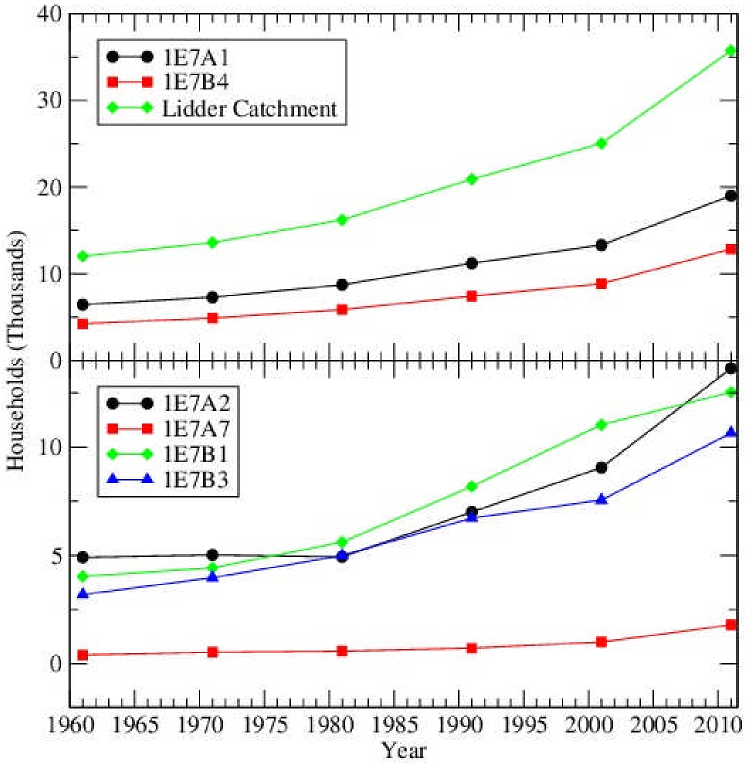


Fig. 5.10: Watershed wise distribution of households in Lidder catchment, (1961-2011)

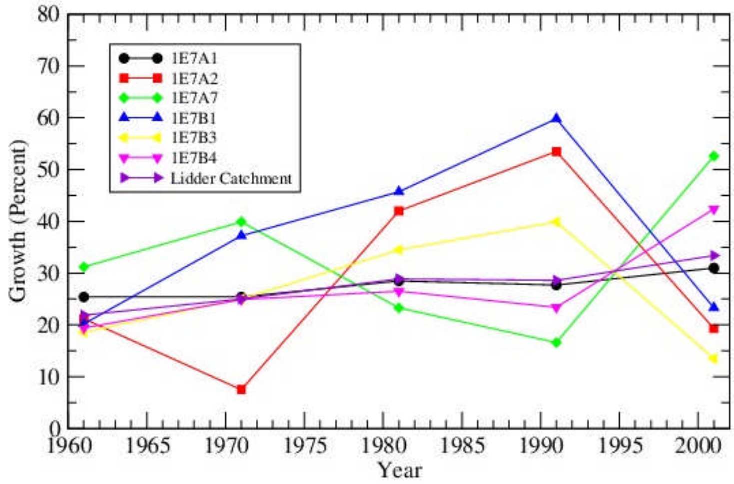


Fig. 5.11: Decadal growth of population in different watersheds of Lidder catchment, (1961-2011)

The average household size has increased from 5.8 persons in 1961 to 6.5 persons in 2011 registering an average increase of 0.7 persons in the average household size in the last fifty years. The number of households has registered a growth of 197.3 per cent from 1961 to 2011 (table 5.6) with the household growth of 39.5 percent per decade. The household growth is increasing at an escalating rate since 1961 except from 1991 to 2001 where it increasing by 19.7 percent as compared to the growth of 29 percent for 1981 to 1991 (fig. 5.12). However, the highest growth in households (42.8 percent) was recorded for the decade 2001 to 2011. Among the watersheds, the watershed 1E7A7 has registered the highest household growth (339 percent) where the households have increased from 41 in 1961 to 180 in 2011 (table 5.5). The lowest household growth of 177.2 percent was recorded for watershed 1E7A2. The decadal analysis has revealed that the watershed 1E7A7 has recorded the highest household growth (78.2 percent) for the decade 2001-2011 while the negative growth of 1.8 percent was recorded for the decade 1971-1981 in watershed 1E7A2 (fig. 5.12).

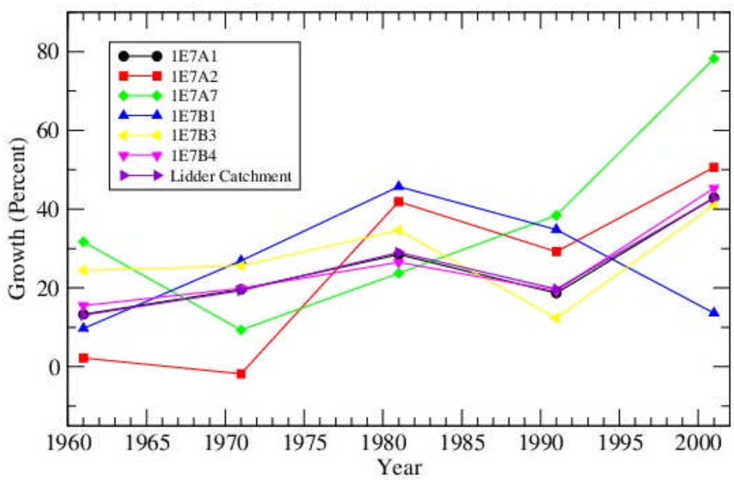


Fig. 5.12: Decadal growth of households in different watersheds of Lidder catchment, (1961-2011)

The increasing growth trends of population parameters indicate the growing demographic pressure on the various resource potentialities of Lidder catchment especially land, vegetation and water resources. The density of population in the state of

Jammu and Kashmir has increased from 99 persons per km^2 in 2001 to 124 persons per km^2 in 2011 while the population density of Lidder catchment has increased from 151 persons per km^2 in 2001 to 201.5 persons per km^2 in 2011. The population density in Lidder catchment is increasing at an alarming rate (fig. 5.13). It has increased by 142 persons per km^2 during the last fifty years. Such an alarming population concentration in this Himalayan catchment has imposed serious implications on the natural resources of the catchment. The watershed wise analysis (table 5.7) has revealed that in watershed 1E7A1 the density of population has increased by 517 persons per km^2 followed by watershed 1E7B4 where the population density has increased by 349 persons per km^2. The lowest population density of 12 persons per km^2 is found in watershed 1E7A7 along with the lowest growth of 9 persons per km^2 from 1961 when the density of population was only 3 persons per km^2. The increase in population density has aggravated the physiological density, which has increased from 627 persons per km^2 of net sown area in 1971 to 1597 persons per km^2 of net sown area in 2011.

Table 5.7: Decadal analysis of population density in Lidder catchment, (1961-2011)

Watershed	Persons per km^2						Increase by persons (1961-2011)
	1961	1971	1981	1991	2001	2011	
1E7A1	217.3	272.4	341.6	439.0	560.5	734.0	**517**
1E7A2	32.4	39.3	42.3	60.0	92.1	109.9	**78**
1E7A3	Uninhabited						
1E7A4	Uninhabited						
1E7A5	Uninhabited						
1E7A6	Uninhabited						
1E7A7	3.0	3.9	5.5	6.8	7.9	12.1	**9**
1E7B1	9.6	11.5	15.8	23.1	36.9	45.5	**36**
1E7B2	Uninhabited						
1E7B3	24.2	28.7	35.9	48.3	67.5	76.6	**52**
1E7B4	150.8	179.9	224.8	284.4	350.8	499.4	**349**
Lidder catchment	**59.4**	**72.9**	**91.1**	**117.5**	**151.1**	**201.5**	**142**

Source: Compiled from census of India, Jammu and Kashmir, 1961, 1971, 1981, 2001 and 2011

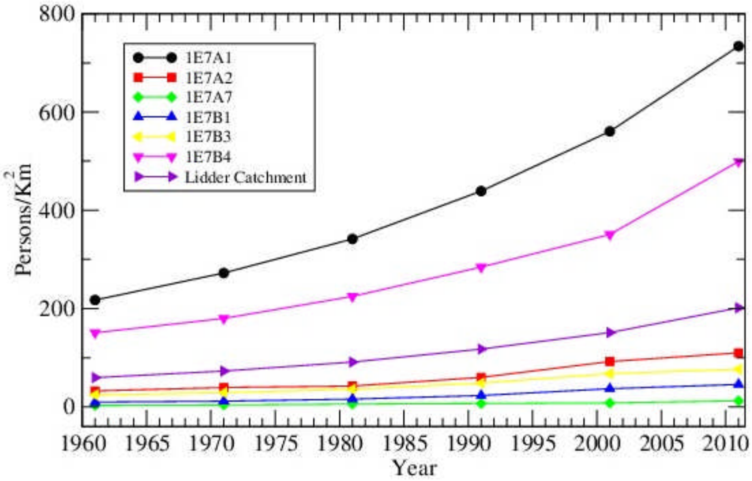


Fig. 5.13: Decadal growth in population density in different watersheds of lidder catchment, (1961-2011)

5.13. GROWTH OF URBAN POPULATION

Though the Lidder catchment has a low level of urban population, its steady growth and skewed concentration in a few watersheds has a marked influence on the environment of Lidder catchment. There are three urban centers (Pahalgam, Aishmuqam and Seer Kanaligund) in the catchment with the total population of 22655 persons which constitutes 9.7 percent of the total population of the catchment. There was only one urban centre of Pahalgam in 1961 with the total urban population of 1920 persons and the density of only 93 persons/km^2 (Census of India, 1961) and was given the status of a statutory town because of its tourist importance.

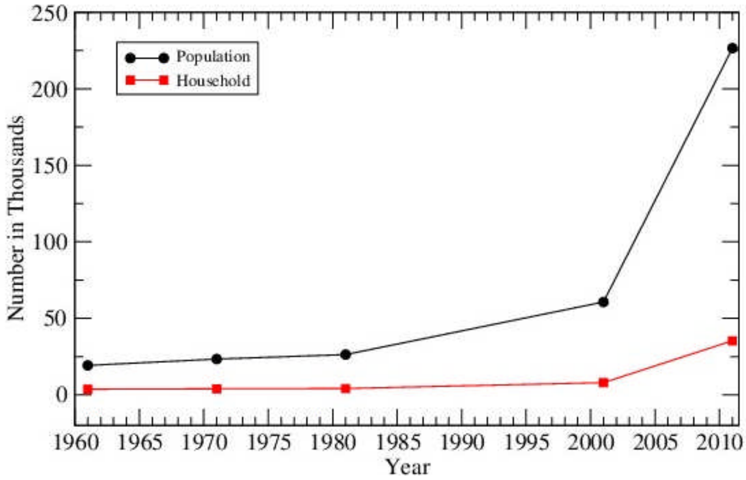


Fig. 5.14: Growth of urban population in Lidder catchment, (1961-2011)

The total urban growth of population from 1961 to 2011 was 1080 percent and the household growth was 876 percent (table 5.8). The urban population has increased from 1920 persons in 1961 to 22655 persons in 2011 (fig. 5.14). This is mainly because of the fact that two new urban centers of Aishmuqam and Seer Kanaligund have been classified as towns for the first time in 2011. All these three urban centers are more or less of the same size. Pahalgam and Aishmuqam contribute 32.5 percent and 31.2 percent of the urban population respectively while Seer Kanaligund is the biggest of all in terms of population contributing 36.4 percent of the total urban population (Census of India, 2011).

Table 5.8: Growth of urban population in Lidder catchment, (1961-2011)

Year	Number of urban centers	Area (km^2)	Population (persons)	Number of households	Household size (persons/ household)	Population density (persons/km^2)	Population growth (per cent)	Household growth (per cent)
1961	1	20.72	1920	362	5.3	93	-	-
1971	1	20.72	2335	390	6.0	113	21.6	7.7
1981	1	18.02	2626	414	6.3	146	12.5	6.2
2001	1	18.00	6066	793	7.6	337	131.0	91.5
2011	3	23.5	22655	3533	6.4	964	273.5	345.5
1961 - 2011	-	-	-	-	-	-	1080.0	876.0

Source: Compiled from census of India, Jammu and Kashmir, 1961, 1971, 1981, 2001 and 2011

Though the process of urbanization has been slow in Lidder catchment, it has gained momentum now mainly because of the growth in tourism activities and development of road transport infrastructure. Among the three urban centers, Pahalgam town has grown mainly on account of tourism as it is one of the leading tourist nodes where both recreational as well as pilgrim tourism is quite significant. Pahalgam town falls in the watershed 1E7B1 while Aishmuqam and Seer Kanaligund fall in watershed 1E7B4. The remaining watersheds are completely rural with no urban population.

5.14. LIVESTOCK POPULATION

The animal husbandry sector constitutes one of the vital allied activities of the primary sector of a rural economy. The prosperity of the rural economy largely hinges on the availability of land resources and the abundance of livestock population. The animal husbandry sector serves not only as one of the important sources of productive asset generation but also makes useful contribution towards the augmentation of level of income for rural households. But at the same time in the absence of scientific management the livestock sector can have adverse impact on the ecological status of the area. It has been observed that some uncultivated lands in the rural areas have suffered from intensive grazing (Polunin and Stainton, 1984).

Table 5.9: Livestock population in Lidder catchment, 2011

Watershed	Households (number)	Population (persons)	Livestock population					Average livestock units/household
			Cattle	Horses	Sheep/Goat	Chicken	Total	
1E7A1	19024	127158	34651	5775	34311	82551	157288	8
1E7A2	1364	8037	2221	243	3262	7115	12842	9
1E7A3	Uninhabited							
1E7A4	Uninhabited							
1E7A5	Uninhabited							
1E7A6	Uninhabited							
1E7A7	180	931	331	214	442	440	1427	8
1E7B1	1254	10388	2641	1123	3460	4875	12099	9.6
1E7B2	Uninhabited							
1E7B3	1066	6005	1336	188	2501	3689	7714	7.2
1E7B4	12871	81145	29509	1884	23545	59332	114269	9
Lidder catchment	**35759**	**233664**	**70689**	**9427**	**67521**	**158002**	**305639**	**8.5**

Source: Sample survey, 2011

Livestock plays an important role in Lidder catchment where mixed agricultural production system is practiced by the farmers with both crop and livestock husbandry as the important components where land holdings are small and fragmented with wide variations in topography. The Lidder catchment is endowed with rich grazing lands, grassy forest slopes and meadows which provide necessary infrastructure for the development of animal husbandry sector in the region. Besides this, the local people collect various types of grasses, sedges, herbs, shrubs and twigs from trees in summer and autumn for the fodder requirement in winter.

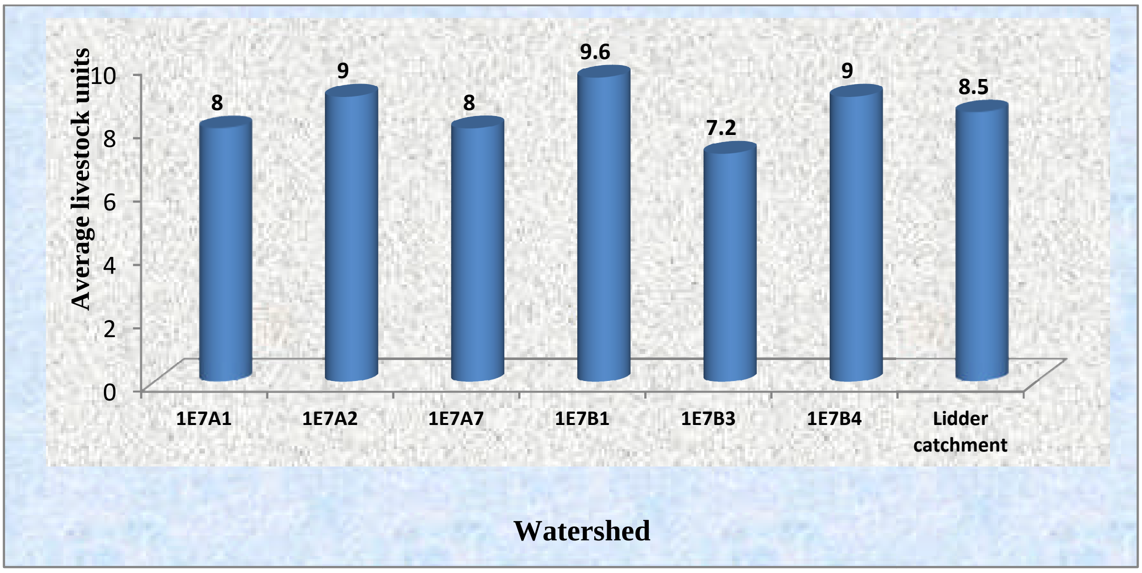


Fig. 5.15: Watershed wise average livestock units in Lidder catchment, 2011

The total livestock population of the catchment is 3.05 lac units **(table 5.9)** with the highest number found in watershed 1E7A1 (1.6 lac) because it covers more than 48 per cent of the total villages of Lidder catchment. The average number of livestock units per household is 8.5 in Lidder catchment (fig. 5.15) with the highest average found in watershed 1E7B1 (9.6) because this watershed is having plenty of grassy slopes and meadows where fodder is easily available as Pahalgam– the village of shepherds, falls in this watershed which has a long tradition of animal rearing followed by watershed 1E7B4 and 1E7A2 (9 each). The lowest number of livestock units per household is found in watershed 1E7B3 (7.2 units). The analysis has revealed that the pastoral activities have a significant role in sustaining the economic life of the people of Lidder catchment.

5.15. AGRICULTURE PRACTICES AND CROPPING PATTERN

The agriculture practices and cropping pattern of a region is decided by and large, by a number of soil and climatic parameters which determine overall agro-ecological setting for nourishment and appropriateness of a crop or set of crops for cultivation. Nevertheless, at farmer’s level, potential productivity and monetary benefits act as guiding principles while opting for a particular crop/cropping system. These decisions with respect to choice of crops and cropping systems are further narrowed down under influence of several other forces related to infrastructure facilities, socio-economic factors and technological developments, all operating interactively at micro-level. The Lidder catchment is dominated by subsistence agriculture and its allied sectors. It is characterized by mono-crop cultivation with paddy as dominant crop with its cultivation confined to alluvial fans along terraced slopes of river Lidder. The upper slopes are devoted to the cultivation of maize and potatoes.

Table 5.10: Per capita land availability and cropping pattern in Lidder catchment

Watershed	Total land (kanals)	Per capita land (kanals/household)	Irrigated (percent)	Un-irrigated (percent)	Cropping pattern (percent)			
					Maize	Potato	Rice	Others
1E7A1	117949	6.2	85	15	5	4	80	11
1E7A2	5865	4.3	30	70	47	13	30	10
1E7A3	Uninhabited							
1E7A4	Uninhabited							
1E7A5	Uninhabited							
1E7A6	Uninhabited							
1E7A7	414	2.3	5	95	51	36	0	13
1E7B1	3260	2.6	8	92	80	5	0	16
1E7B2	Uninhabited							
1E7B3	3624	3.4	25	75	38	46	0	16
1E7B4	65642	5.1	93	7	3	2	85	10
Lidder catchment	**196755**	**5.5**	**83**	**17**	**7.5**	**4.5**	**77.2**	**10.8**

Source: Computed from census of India, 2011 and sample survey, 2011

The total cultivated land is 1.96 lac kanals with the per capita availability of 5.5 kanals per household (table 5.10). The highest cultivable land is found in watershed 1E7A1 (1.18 lac kanals) with the highest per capita land availability of 6.2 kanals per household. The lowest available cultivable land is found in watershed 1E7A7 (414 kanals) with the lowest per capita land availability of 2.3 kanals per household. Irrigation facilities are very poor in the upper watersheds of the catchment where less than 30 percent of the total cultivable area is irrigated. However in the Lidder flood plain the irrigation facilities are well developed with a dense network of artificial streams. In the upper reaches of the watersheds where slopes are relatively higher and irrigation facilities are poor, maize and potato are grown along with the fodder crops. In the watersheds of 1E7A1 and 1E7A4, where Lidder flood plain is located with gentle slope, paddy is the dominant crop along with the vegetable and fodder crops grown for subsistence purposes (fig. 5.16). However, from the last fifteen years, considerable area has been changed to apple cultivation because of its higher economic returns.

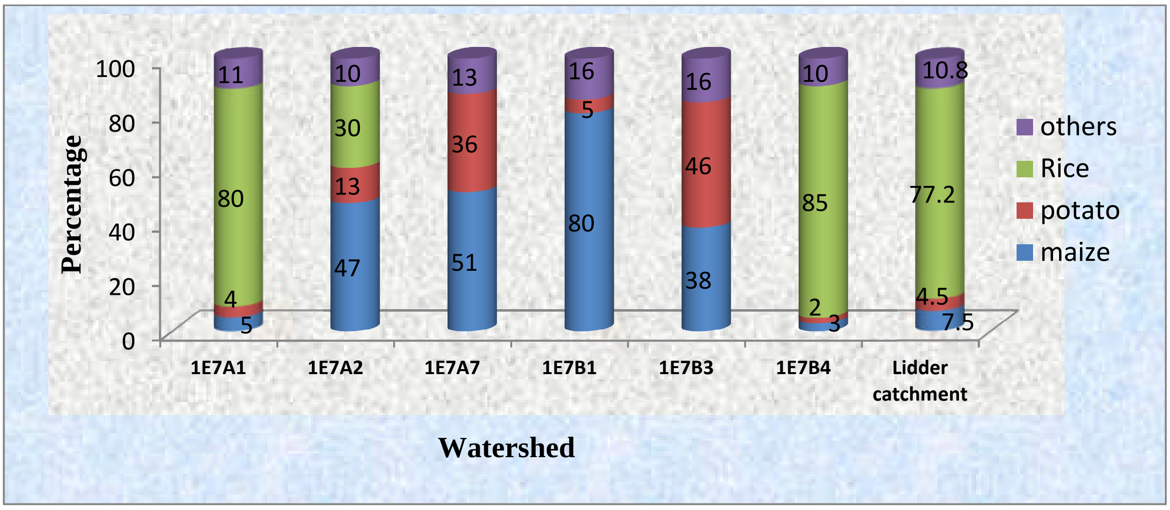


Fig. 5.16: Watershed wise cropping pattern in Lidder catchment, 2011

5.16. MAGNITUDE OF HOUSEHOLD ENERGY CONSUMPTION

The conventional source of energy especially the forest based fuel wood has become a serious environmental concern in the fragile ecosystem of Himalayan region. Rural areas use conventional and non-conventional sources of energy like fuel wood, cow dung and kerosene oil. The forest based fuel wood is one of the leading sources of energy both in commercial and household sectors in Lidder catchment. Low levels of social and economic development manifested in wide spread poverty of native population coupled with high incidence of seasonal unemployment of working population have forced people to have a heavy reliance on fuel wood not only as a source of domestic energy but also to commercialize it in order to augment the household income of the people. The problem is being further accentuated by freezing harsh winters which put severe restrictions on the mobility of the people and accessibility of the area compelling the people to have a huge piling of buffer stocks of fuel wood to confront the vagaries of harsh winter.

The Lidder catchment has rich forest wealth in the relatively higher slopes and vast agricultural fields with horticulture in the relatively plain areas which provide easy access to fuel wood used for heating and domestic cooking purposes. The commercialization of fuel wood through its supply to hoteliers who use it as a cheap alternative source of energy, serve as a lucrative source of household income for a section of population.

The analysis of table 5.11 reveals that firewood is the dominant source of energy (10 kg/day/household) used in Lidder catchment followed by Liquefied petroleum gas (LPG) with the average consumption of 11 L/month/household. The annual firewood consumption is estimated to be 1.51 lac metric tons. Further, it is evident that firewood consumption is highest in watersheds 1E7A7 (13 kg/day) and 1E7B1 (12 kg/day) which are located in forest area where forest wood is easily available and winters are relatively severe (fig. 5.17). The firewood consumption is lowest in watershed 1E7A1 (6 kg/day) and 1E7B4 (7 kg/day) which are plain areas and were forest cover is almost absent. The LPG consumption is highest in watershed 1E7B1 (14 L/month) because of tourist pressure as tourists demand the modern sources of energy. The kerosene consumption is almost uniform (0.156 L/days) throughout Lidder catchment because its distribution is controlled by public distribution system (PDS).

Table 5.11: Magnitude of fuel wood consumption in Lidder catchment, 2011

Watershed	Households (number)	Energy consumption/household		
		Firewood kg/day	LPG L/month	Kerosene L/month
1E7A1	19024	6	11	5
1E7A2	1364	9	9	5
1E7A3	Uninhabited			
1E7A4	Uninhabited			
1E7A5	Uninhabited			
1E7A6	Uninhabited			
1E7A7	180	13	13	5
1E7B1	1254	12	14	5
1E7B2	Uninhabited			
1E7B3	1066	10	8	5
1E7B4	12871	7	10	5
Lidder catchment	**35759**	**10**	**11**	**5**

Source: Sample survey, 2011

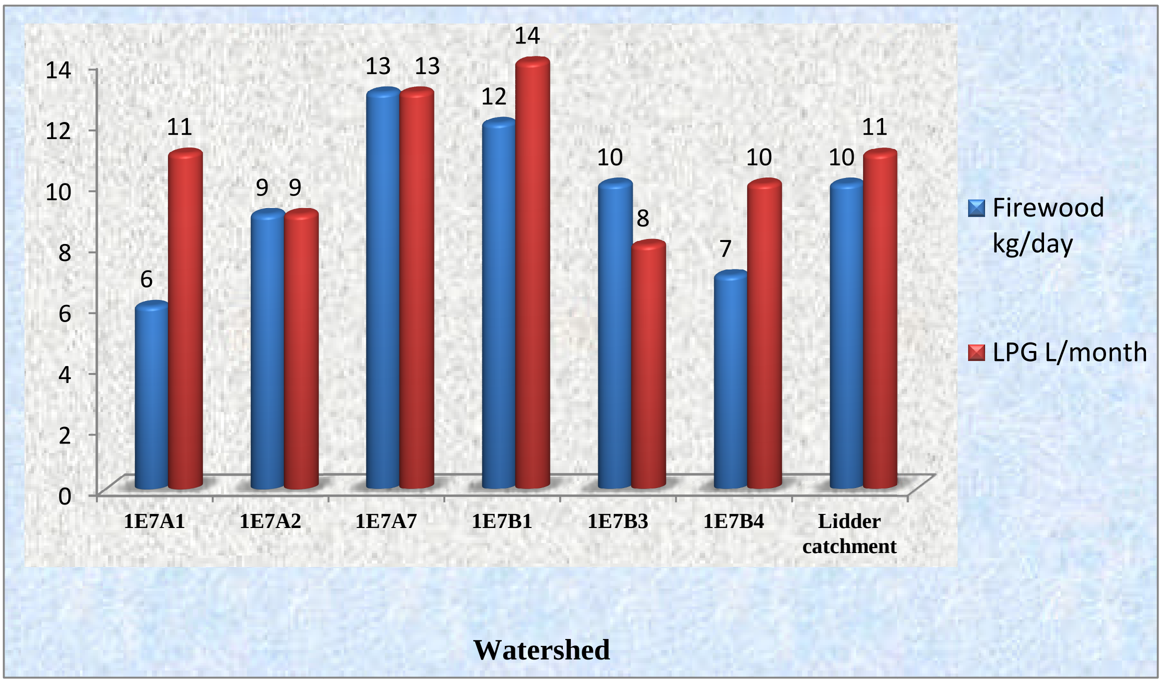


Fig. 5.17: Magnitude of household energy consumption in Lidder catchment, 2011

Thus it could be inferred that the overall energy consumption is highest in upper watersheds of the catchment where most of the tourism activities of the region are concentrated and is also characterized by severe winter conditions lasting about four to five months of the year.

5.17. AMENITIES

Availability of amenities like education, Medicare, water supply, communication, road network, electricity, etc. significantly reflects the level of development of an area. Information on available amenities in the study area is extracted from village amenities directory 2009 of Anantnag district.

5.17.1. Medical Facilities

Medical sub-centers and medical shops are well distributed in all the watersheds. Ananganwari centers are found in 68 percent of the villages to look after the children and their mothers. There are three hospitals in the catchment found at Pahalgam, Hugam and Sali villages. In order to look after the health of livestock population, Animal Husbandry and Sheep Husbandry centers are located in all the watersheds except 1E7A2 where there is no sheep husbandry centre (table 5.12). However there is no private hospital in the catchment. The PHC's are found in watershed 1E7A1 and 1E7B4 (2 each) which fall in Pahalgam and Anantnag tehsils whereas Bijbiara tehsil is devoid of any PHC.

Table 5.12: Distribution of medical facilities in Lidder catchment, 2009

Watershed	Number						
	Hospital	PHC	Medical sub-centre	Medical shop	Anganwadi centre	Animal husbandry centre	Sheep husbandry centre
1E7A1	1	2	9	42	30	12	6
1E7A2	0	0	3	4	1	1	0
1E7A3	Uninhabited						
1E7A4	Uninhabited						
1E7A5	Uninhabited						
1E7A6	Uninhabited						
1E7A7	0	0	2	2	2	2	2
1E7B1	1	0	2	3	3	3	2
1E7B2	Uninhabited						
1E7B3	0	0	2	4	4	2	1
1E7B4	1	2	31	40	43	8	6
Pahalgam tehsil	**1**	**2**	**33**	**51**	**49**	**14**	**10**
Bijbiara tehsil	**0**	**0**	**0**	**21**	**12**	**7**	**2**
Anantnag tehsil	**2**	**2**	**16**	**23**	**22**	**7**	**5**
Lidder catchment	**3**	**4**	**49**	**95**	**83**	**28**	**17**

Source: Village Amenities Directory, Anantnag, 2009

5.17.2. Other Amenities

The public distribution system is well developed in the area as kerocene depot and ration depot is found in all the watersheds. On an average one ration or kerocene depot is shared by 1.4 villages in the catchment. However every forest sale depot is shared by 2 revenue villages in the catchment. There are 71 LPG outlets in the lidder catchment and this facility is extended to far flung areas as well (table 5.13). In the watershed 1E7A1, in which Pahalgam town is located, most of the civic amenities and facilities are provided because the town serves as an important tourist destination. There is a bank branch, Post office, teligraph office, police station and a fire station at Pahalgam.

Table 5.13: Status of amenities in Lidder catchment, 2009

Watershed	Number								
	Forest sale depot	Ration depot	Kerosene oil depot	LPG outlet	Bank branch	Post office	Telegraph office	Police station	Fire station
1E7A1	26	37	41	27	4	9	4	2	1
1E7A2	4	4	3	3	0	0	0	0	0
1E7A3	Uninhabited								
1E7A4	Uninhabited								
1E7A5	Uninhabited								
1E7A6	Uninhabited								
1E7A7	0	2	1	0	0	0	0	0	0
1E7B1	1	3	3	1	1	1	1	1	1
1E7B2	Uninhabited								
1E7B3	1	3	3	3	0	0	0	0	0
1E7B4	26	38	37	37	2	4	6	0	1
Pahalgam tehsil	**33**	**45**	**45**	**38**	**2**	**5**	**2**	**2**	**2**
Bijbiara tehsil	**10**	**21**	**23**	**14**	**1**	**3**	**1**	**1**	**0**
Anantnag tehsil	**15**	**21**	**20**	**19**	**4**	**6**	**8**	**0**	**1**
Lidder catchment	**58**	**87**	**88**	**71**	**7**	**14**	**11**	**3**	**3**

Source: Village Amenities Directory, 2009

The drinking water facilities are provided in all the villages of the catchment. It may be noted that the surface and ground water in the catchment was of very good quality and is under serious degradation due to anthropogenic disturbances. The people in upper parts of the watersheds are still using the stream water for drinking purposes. All the villages in the catchment area are connected with a system of well developed metalled roads. The electricity is available in each and every village and the settlements around Pahalgam are using electricity generated from the Pahalgam Hydroelectric power plant.

5. 17.3. Education Facilities

The education facilities are well distributed in Lidder catchment particularly the primary education with its maximum concentration of 114 primary schools found in watershed 1E7A1. The analysis of table 5.7 has revealed that the number of boys' primary schools (83) is greater than that of the girls' primary schools (67) while the common primary schools are highest in number (96). Moreover the frequency of education institutions decreases from lower to higher order institutions with no government college. The nearest government colleges for boys and Women's college is located outside Lidder catchment in Anantnag town. There are six higher secondary schools for boys and one higher secondary school for girls along with 4 common higher secondary schools (table 5.14). The higher secondary schools are found in watershed 1E7A1 (6) followed by watershed 1E7B4 (5) while other four inhabited watersheds are devoid of any higher secondary school. The reason being the fact that these two watersheds constitute more than 89 percent of the total population of Lidder catchment and are under the urban influence of Anantnag and Bijbiara towns.

The private education institutions are also well distributed in the catchment. There are 67 primary schools, 27 middle schools, 2 high schools and one higher secondary school under private ownership in Lidder catchment. The only private higher secondary school for girls is located in Seer Kanaligund while the only private college is found in Silgam village in the capacity of a private B.Ed. college. The tehsil wise analysis (table 5.14) has revealed that Pahalgam tehsil leads in the frequency of all the education facilities only because of the fact that all the 68 villages of Pahalgam tehsil are located in Lidder catchment. Out of the 11 higher secondary schools 7 are found in Anantnag tehsil while only one higher secondary school is located in Bijbiara tehsil and the remaining three higher secondary schools are located in Pahalgam tehsil. The only private B.Ed. college is found in Pahalgam tehsil while the only private higher secondary school and the two private high schools are found in Anantnag tehsil.

Table 5.14: Distribution of educational facilities in Lidder catchment, 2009

Watershed	Number of institutions																			
	Govt. primary School			Govt. middle School			Govt. high School			Govt. Hr. Sec. School			Govt. college			Private school				Private college
	B	G	C	B	G	C	B	G	C	B	G	C	B	G	C	Primary	Middle	High	Higher secondary	
1E7A1	40	29	45	19	25	25	4	4	11	4	0	2	0	0	0	40	19	1	1	0
1E7A2	5	6	5	3	2	2	2	0	0	0	0	0	0	0	0	2	2	0	0	0
1E7A3	Uninhabited																			
1E7A4	Uninhabited																			
1E7A5	Uninhabited																			
1E7A6	Uninhabited																			
1E7A7	2	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1E7B1	3	3	3	3	1	1	1	1	1	0	0	0	0	0	0	1	1	0	0	0
1E7B2	Uninhabited																			
1E7B3	4	3	4	1	0	0	1	0	1	0	0	0	0	0	0	2	0	0	0	0
1E7B4	29	26	37	21	6	21	7	2	4	2	1	2	0	0	0	22	5	1	0	1
Pahalgam tehsil	**48**	**37**	**50**	**28**	**9**	**25**	**10**	**2**	**4**	**3**	**0**	**0**	**0**	**0**	**0**	**31**	**11**	**0**	**0**	**1**
Bijbiara tehsil	**18**	**16**	**25**	**5**	**15**	**11**	**0**	**3**	**7**	**0**	**0**	**1**	**0**	**0**	**0**	**23**	**9**	**0**	**0**	**0**
Anantnag tehsil	**17**	**14**	**21**	**16**	**10**	**13**	**5**	**2**	**6**	**3**	**1**	**3**	**0**	**0**	**0**	**13**	**7**	**2**	**1**	**0**
Lidder catchment	**83**	**67**	**96**	**49**	**34**	**49**	**15**	**7**	**17**	**6**	**1**	**4**	**0**	**0**	**0**	**67**	**27**	**2**	**1**	**1**

Source: Village Amenities Directory, Anantnag, 2009

Note: B= boys, G=girls, C= common

CHAPTER - 6

TOURISM

Tourism has assumed an overwhelming importance as a component of mountain economies around the world. Though the lowlands remained the major regions of industrial and urban concentration in the past, the mountain regions are now attracting major economic investments for hydro-power and communication routes and above all a number of mountain regions have experienced “tourist revolution” causing substantial economic, social and environmental changes. The natural landscape of Himalayas endowed with rich scenic resources like rolling mountains, pearling torrents, rivers, glaciers, lakes and varied flora and fauna have daunted tourists for long. The Kashmir Himalayas, a segment of western Himalayas has earned world reputation as a famous tourist hill resort. The vast natural green carpets of upland pastures and meadows, dense forests, glistering mountain torrents and placid lakes have made the valley a dreamland indeed the tourist’s paradise.

The snow capped mountains, fast flowing trout streams and vast stretches of green forests and pastoral land represent Pahalgam, one of the most sought-after tourist destinations of Kashmir. The Pahalgam tourist resort, located in the Lidder valley, has assumed additional importance as it stands en route to Shree Amarnath cave which receives huge number of pilgrims from every part of the country and even from abroad. The valley is longitudinal and narrow one with undulating slopes characterized by large meadows, lush green forests and sparkling water streams gushing out of glaciers and high altitude lakes which seem to be crowned in the sky. The important tourist destinations in Pahalgam are Baisaran, Aru, Chandanwari, Mamal, Betab valley, Sheshnag, Lidderwat, Kolahoi glacier, Tarsar and Marsar lakes and Astanmarg.

6.1. TOURIST POTENTIAL REGIONS

Pahalgam valley is the leading tourist destination of Kashmir valley as it receives about 70 per cent of the total tourist flow. The tourist potential regions of Lidder catchment have been identified on the basis of selected indicators and ranked on the basis of composite scores. The existing tourist potential in terms of natural beauty, religious and historical sites, games and sports activities, handicrafts etc. act as the major pull factors. Three broad tourist potential regions with different characteristics have been identified.

i). Pahalgam and Surroundings

This region comprises of Pahalgam and Baisaran with both natural and artificial tourist attraction (fig. 6.1). The essential tourist infrastructure is present only in this region. This region is used as a base camp for trekking and onward journey to Amarnath cave. Pahalgam is guarded by fir covered mountains, flower strewn pastures, beautiful parks (Poshwan Park, Lidder View Park, Amusement park) and white transparent water of Lidder river. The surroundings are ideal and allow for relaxation and leisure in the true spirit of a traditional hill station holiday.

The Pahalgam club: The club has a superb location and is the centre of activity. It is situated on an island surrounded by the branches of the Lidder river. The rapid torrent with its milky glacial-water forming pools and whirls encompasses the place with its cool breeze. The clusters of pine and fir which cover the premises cast a refreshing shade and fill the atmosphere with fragrance which enlivens the body and mind. The island stretches from south to north. There are a number of tanks built for women, children and non-swimmers for bathing purposes.

Mamal: Mamal comprises of two wards of Pahalgam town. It stands across the Kolahoi stream up towards the mountain side. A Shiva temple is situated there, which is considered to be one of the oldest existing temples in Kashmir, dating to the 5th century. There is also a spring beautifully banked with long dressed stones of about 8th century.

Shikargah: Shikargah is another interesting glade to visit. This is a famous wildlife reserve located near the main market area of Pahalgam.

Baisaran: Situated at an elevation of 2438 meters above sea level is a beautiful meadow about 5 km from Pahalgam, with pine and fir trees in its forests and snow on the peaks of its mountains. It offers a charming and commending view of the valley. There is a big rock in the centre of the glade. It is said that saint Zain Shah (Zanak Reshi) meditated 12 years on that stone and finally settled at Aishmuqam where his Ziarat is existing till date.

ii). Middle Meadowland Region

This region comprises of Aru, Chandanwari and Sheshnag. The region is endowed with green carpet like meadows and pastures, forests, springs and lakes. However this region lacks the tourism infrastructure and is also characterized by inadequate accessibility.

Betab Valley: En-route to the Amarnath shrine, this newly developed tourist resort near Pahalgam, is located at an altitude of 2,530 meters above sea level. It derives its name from a bollywood movie 'BETAB' which was shot extensively in this area. A beautiful garden and a bridge to cross the Sheshnag river (East Lidder) has also come up now. Construction activity is in progress and Pahalgam Development Authority proposes to develop this valley as a beautiful holiday spot.

Aru: The word Aru means a sound. The mountain torrent which flows out of the Katri Nag over the Danawat mountains produces noise which probably gave the place its name. The charming meadow of Aru is at a distance of about 11 km from Pahalgam. It is situated at an altitude of 2408 m. It is a rolling meadow of velvety green turf, fringed with fir and pines.

Chandanwari: Tsandanwari or Chhandanwari (Tsandan-pleasure giving coolness, Wari-a farm) is the second stage from Pahalgam on the Amarnath pilgrimage route. It is famous for its snow bridge, situated at an altitude of 2923 meters above sea level, lies at a distance of 16 km from Pahalgam and is a small valley at the junction of two streams i.e., Sheshnag and Astanmarg Nalla.

Sheshnag: Also known as "Wawjan" is situated at an altitude of 3658 meters above sea level. It is at a distance of 12 km away from Chandanwari. The place has derived its name from seven peaks that look like the head of Sheshnag, the sacred snake in the Hindu mythology. The waters of this greenish blue lake are covered with ice till June.

LIDDER CATCHMENT
TOURIST POTENTIAL REGIONS

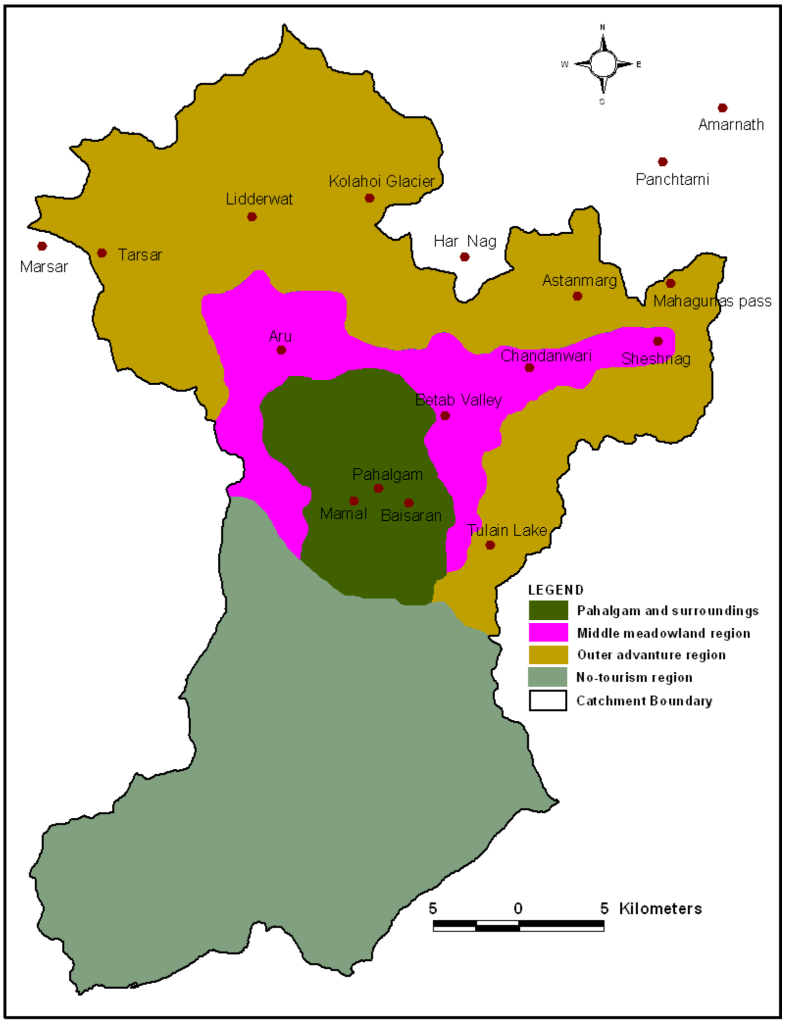


Fig. 6.1

iii). Outer Adventure Region

This region comprises of Tulain lake, Panchtarni, Mahagunas pass, Kolahoi glacier and Lidderwat. Amarnath cave also falls in this region but it does not come under Lidder catchment. The main tourist attractions of this region are glaciers, high altitude lakes, meadows, network of trekking routes and Amarnath cave.

Lidderwat: It is situated at an altitude of 3048 meters above sea level and is about 22 km from Pahalgam and just 11 km from Aru. The green pastures encircled by dense forests offer a delightful sense and site.

Kolahoi Glacier: Kolahoi glacier situated at an altitude of 4267 meters above sea level is the star attraction for tourists who visit Pahalgam. This is the famous glacier of Lidder. Before we enter the Kolahoi valley a torrent from the Sona Sar lake which lies at the foot of Basmai Galli (13,885 ft.) flows over a precipice and is divided into a number of distributaries before it falls into the Lidder. These are called Satalajan (seven branches) which also means streams or Kolhoi and this might be the origin of the name of Kolahoi. Kolahoi peak can be observed from Gulmarg and other high plateaus of the Kashmir valley like a cone of crystal kissing the sapphire cheek of the heavens.

Mahagunas Pass: This is the highest point one has to cross en-route to Amarnath cave. It has an altitude of 4600 meters above sea level. Small lakes are formed during July and August in this area. It is about 32.6 km from Pahalgam and just 5.6 km from Sheshnag.

Panchtarni: It is at a distance of 40 km from Pahalgam and just 6.4 km from Mahagunas pass. It is the confluence of five streams that give Panchtarni its name. A narrow spiraling path from Panchtarni leads to the Amarnath Cave.

Tulain Lake: Situated at an altitude of 3353 meters above sea level is an ice bound lake which is enclosed on three sides by snow clad, steep, overhanging mountain peaks. It is about 16 km from Pahalgam and is a peaceful camping site.

Tarsar and Marsar Lakes: Tarsar lake is at a distance of 34 km from Pahalgam via Aru and Lidderwat situated at an altitude of 3962 meters above sea level. There are delightful camping sites and flower meadows at Sikiwas. It is shaped like an almond. The shores are low and form an excellent camping ground. The mountains are not high but are devoid of trees. They are covered with herbal vegetation and the water is transparent and very sweet. A climb up the Tar Sar pass which is the demarcation line of Dachigam Rakh reveals another beautiful Lake Marsar (Cupid Lake) the waters of which drain the Rakh and skirting the base of mount Mahadiv empty themselves into the Srinagar Reservoir. One has to cross a 243 meter high bridge to reach the Marsar lake.

Amarnath: Amarnath is just 5 km away from Panchtarni. It is situated in narrow gorge outside the Lidder catchment at a height of 3888 meters. It is at a distance of 141 km from Srinagar. The shrine of Amarnath is believed to be the abode of Lord Shiva. Each year in the month of Sawan (July/August) lacs of pilgrims start their journey for the cave to make obeisance on the full moon day. This is the high season of visitors in Pahalgam.

Astanmarg: This is an excellent camping ground where fatigue, boredom and mental worry vanish effortlessly. All nature is astir during the day and at night the moon and star constellations send their rays through pine needles to embrace the beauty of the place. Such is Astanmarg, the home of peace, serenity and sublimity, the restorer of health and vitality.

Har Bhagwan Lake: The Har Bhagwan Ghatti (12,729 ft.) leads to the Har Bhagwan valley. Right at the foot of the pass is the turquoise-green Har Nag (the lake of peace) shining like a glittering eye at the head of an emerald green body. Towards the northeast are the snowy peaks of Baltal with glaciers interspersed among them.

6.2. TOURIST FLOW

Tourist flow to Kashmir valley has increased from 1.85 lac tourists in 1975 to more than 7.3 lac tourists in 2010 at an average growth rate of 8.53 percent per annum. But the tourism industry has received a major setback in 1989-90 due to the political instability in the valley. As the tourist influx has registered a negative annual average growth rate of 19.75 percent (table 6.1). This has affected the economic stability as well as employment opportunities for tourist dependent population. However the tourist influx has again picked up substantially after 1995 onwards achieving significant growth rate (fig. 6.2). This growth is more prominent in the domestic tourist influx than in foreign tourists.

Table: 6.1: Growth of tourist arrivals and percentage share to Pahalgam, (1975-2010)

Year	Kashmir Valley		Pahalgam		Tourist share to Pahalgam (percent)
	Total	Annual change (percent)	Total	Annual change (percent)	
1975	184790	-	63312	-	34.26
1980	595117	+44.41	156312	+29.37	26.26
1985	503614	-3.07	129430	-3.44	25.70
1990	6287	-19.75	5230	-19.19	83.98
1995	8520	+7.10	3109	-8.11	36.49
2000	111920	+242.72	59454	+362.46	53.12
2005	605380	+88.18	442330	+128.79	73.06
2010	736488	+4.33	225320	-9.81	30.59

Source: Compiled from the records of Directorate of Tourism, Srinagar and Department of Tourism, Pahalgam

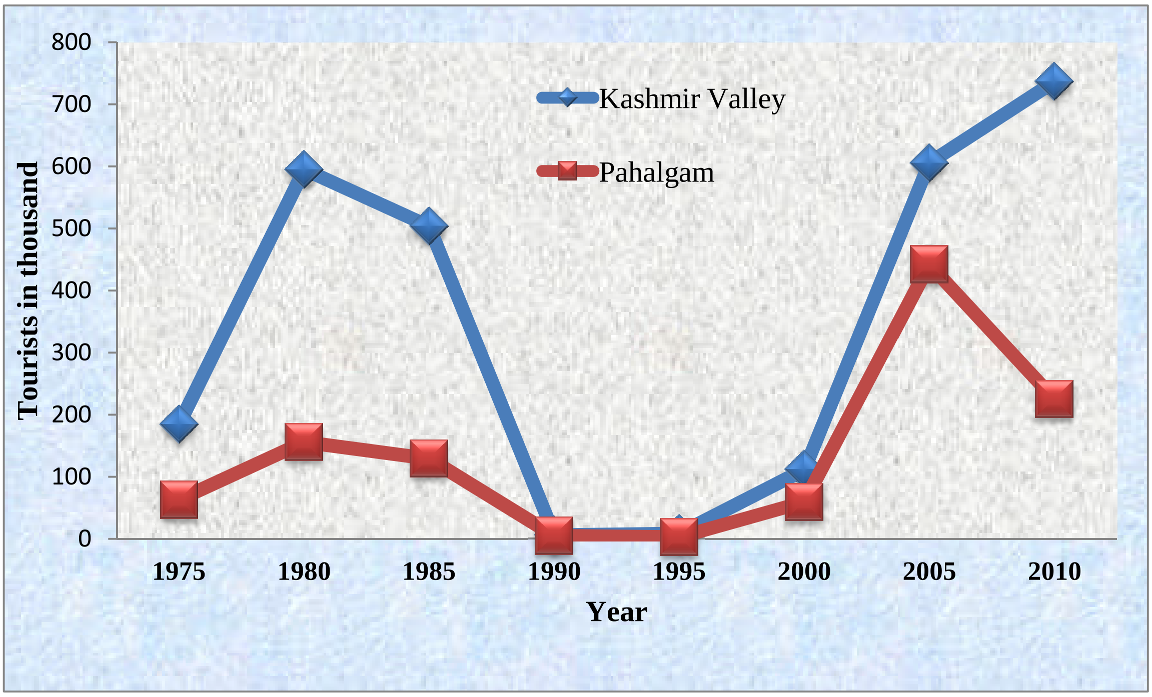


Fig. 6.2: Tourist flow to Kashmir Valley and Pahalgam, (1975 – 2010)

Of all the tourist nodes Pahalgam received the maximum share of tourist arrivals constituting more than 73 percent of total tourist arrival of the Kashmir valley in 2009. However in 2010 because of the political unrest in Kashmir, Pahalgam constituted only 30.59 percent of the total tourists to Kashmir valley. There has been a consistent increase in tourist flow to Lidder valley since 1970s, except in a period of lull experienced during the decade of 1990's (fig 6.3). The tourist arrivals have recorded a growth of 362 percent in Pahalgam valley during the period 1995 to 2000. This huge influx of tourists has encouraged the government as well as local people to develop a large scale infrastructure base in the form of roads, huts, hotels, clubs, parks and other installations of tourist use. This was done with the aim of providing better facilities to the tourists so as to attract more visitors to the place.

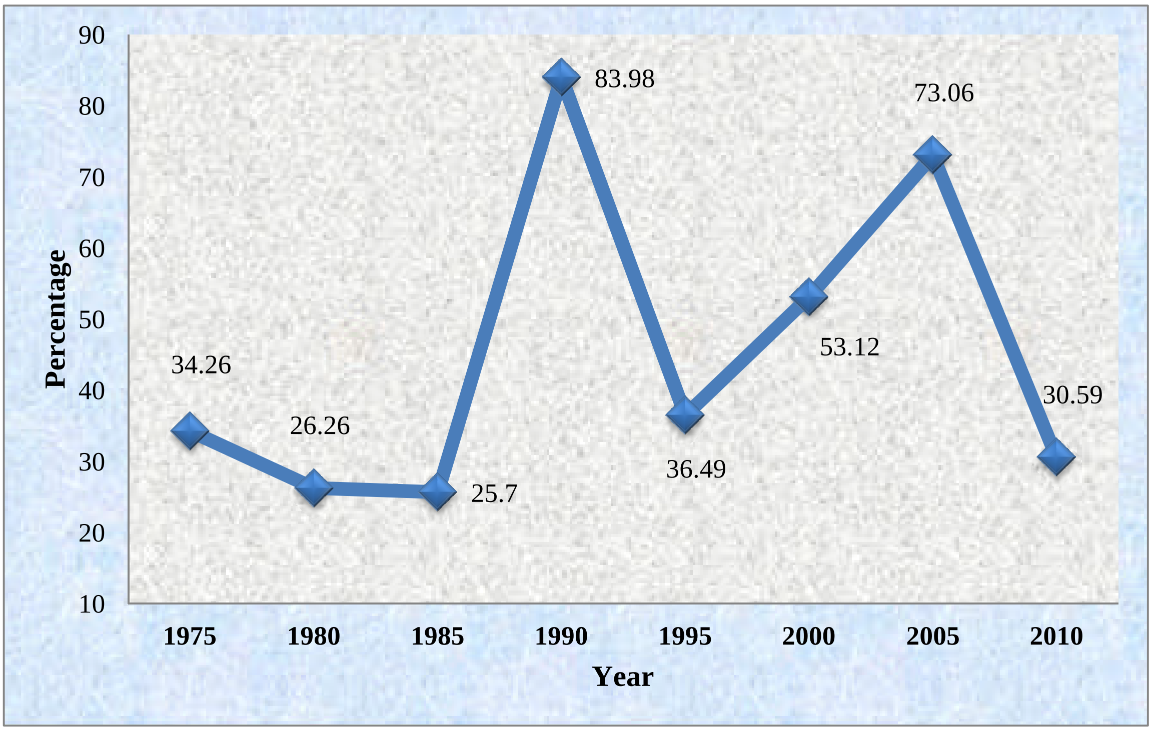


Fig. 6.3: Tourist share to Pahalgam, (1975 – 2010)

There are large variations in the monthly tourist flow to Pahalgam because of the climatic factors. On the one hand summers are very pleasant and winters are harsh at Pahalgam resulting into huge tourist flow in summer months and very low tourist flow during winters. On the other hand winters are very pleasant in rest of the country (excepting Himalayan states) while summers are very hot and humid and summer vacations are at their disposal. This results into the heavy tourist trade during summers in all parts of the country of which Pahalgam receives a considerable share. It is evident from table 6.2 that the tourist flow to Pahalgam increased at an increasing rate and reached its maximum of 2.55 lac in July. From July onwards the tourist flow abruptly decreased till the end of the year (fig. 6.4). It can also be inferred that the three months of May, June and July constitute 83 percent of the total tourist flow to Pahalgam. It is also pertinent to mention here that Yatra is performed in these three months. Thus these three months bare more than eight lac tourists which is certainly beyond the carrying capacity of the region.

Table 6.2: Monthly tourist flow to Pahalgam, 2011

Month	Foreign	Domestic	Local	Total
January	73	998	464	**1535**
February	121	1544	392	**2057**
March	409	6707	1967	**9083**
April	592	14108	5978	**20678**
May	768	51658	47861	**100287**
June	531	82302	146055	**228888**
July	871	53200	201026	**255097**
August	672	14828	7564	**23064**
September	470	13482	1182	**15134**
October	222	24471	5828	**30521**
November	122	10190	2926	**13238**
December	67	4243	1469	**5779**
Total	**4918**	**277731**	**422712**	**705361**

Source: Department of Tourism, Pahalgam

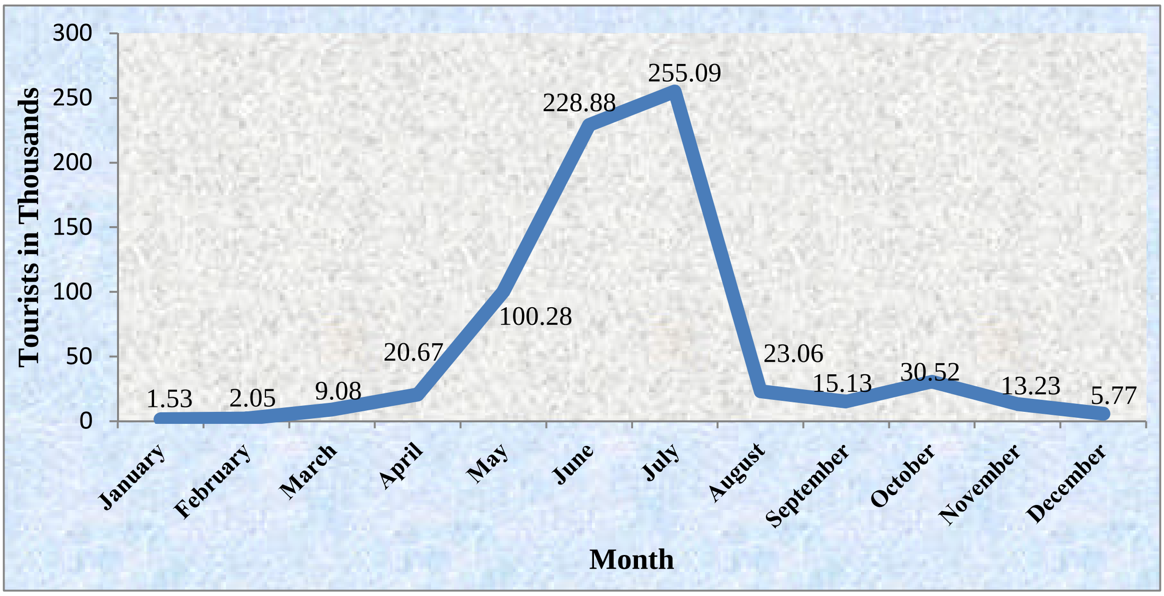


Fig. 6.4: Monthly tourist flow to Pahalgam, 2011

6.3. COMPOSITION OF TOURISTS

Tourist data for the last fifteen years has been analyzed. It has been observed (table 6.3) that the overall tourist scene of Pahalgam is dominated by domestic and local tourists. From 1997 to 2001, domestic tourists constituted more than half of the total tourists visiting Pahalgam valley with their share ranging from 52.7 percent to 64.7 percent. However, from 2002 to 2009, local tourists dominated, with their share ranging between 55.1 percent and 85.9 percent. It was again domestic tourists who substantially contributed (70.9 percent) to the total tourist arrivals in Pahalgam valley in 2010. The number of foreign tourists is very dismal (fig. 6.5) as their contribution to total tourists ranged only between 0.3 percent and 2.4 percent during 1997 to 2010.

Table 6.3: Composition of tourists and yatries to Pahalgam

Year	Non-pilgrim tourists				Pilgrim tourists	Total tourists	Percentage of pilgrims to total tourists
	Domestic	Foreign	Local	Total			
1997	6340 (52.7)	291 (2.4)	5396 (44.9)	12027 (100)	79035	91062	86.8
1998	8340 (55.2)	365 (2.4)	6396 (42.4)	15101 (100)	149000	164101	90.8
1999	58162 (61.1)	673 (0.7)	36322 (38.2)	95157 (100)	114000	209157	54.5
2000	58775 (64.7)	679 (0.7)	31376 (34.5)	90830 (100)	173334	264164	65.6
2001	49744 (62.5)	650 (0.8)	29205 (36.7)	79599 (100)	119037	198636	59.9
2002	11468 (29.1)	378 (1.0)	27533 (69.9)	39379 (100)	110793	150172	73.8
2003	60249 (13.8)	1301 (0.3)	375263 (85.9)	436813 (100)	153314	590127	26.0
2004	158549 (38.3)	3715 (0.9)	251513 (60.8)	413777 (100)	400000	813777	49.2
2005	273121 (38.1)	3899 (0.5)	440649 (61.4)	717669 (100)	388000	1105669	35.1
2006	254590 (36.3)	2975 (0.4)	444604 (63.3)	702169 (100)	265000	967169	27.4
2007	149413 (30.3)	2094 (0.4)	341966 (69.3)	493473 (100)	213565	707038	30.2
2008	131422 (44.2)	2131 (0.7)	163898 (55.1)	297451 (100)	498198	795649	62.6
2009	130675 (22.4)	2106 (0.4)	451546 (77.3)	584327 (100)	373419	957746	39.0
2010	159860 (70.9)	2218 (1.0)	63242 (28.1)	225320 (100)	458212	683532	67.0
2011	277731 (39.3)	4918 (0.7)	422712 (60)	705361 (100)	635000	1340361	47.4

Source: Department of tourism, Pahalgam.
Note: Figures in parenthesis indicate percentage

Pilgrim tourism constitutes one of the important tourist activities in Pahalgam. The share of pilgrim tourists to total tourists is very substantial. The number of yatries has increased from 0.8 lac in 1997 to 6.35 lac in 2011 registering an annual average growth rate of 46.9 percent. However the flow of yatries to Pahalgam has shown a continuously fluctuating trend. It touched the four lac mark in 2004 with the growth of 160.9 percent from the previous year (1.53 lac yatries in 2003). The highest number of yatries as well as other tourists is recorded in 2011 which amounts to the total tourists of more than 13.4 lac. Moreover the share of yatries to total tourists in Pahalgam is very high (fig. 6.6). It was less than 50 percent for six years (table 6.3), ranging between 26 percent and 49.2 percent, while for the remaining nine years it contributed more than half of the total tourists, ranging between 54.5 percent and 90.8 percent.

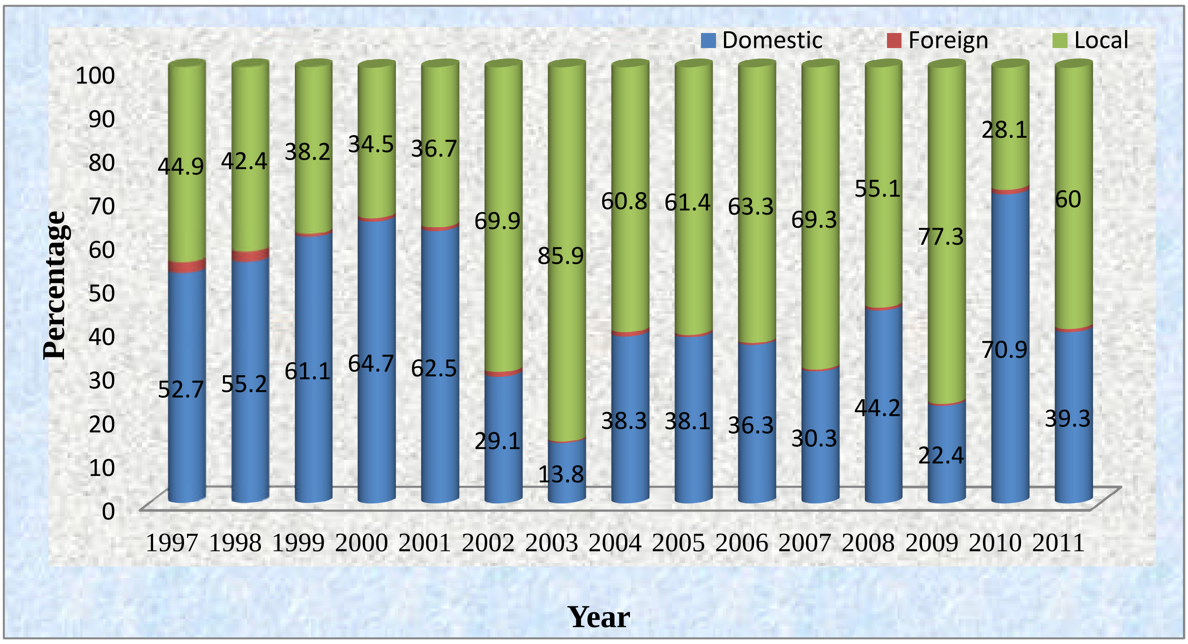


Fig. 6.5: Composition of tourists to Pahalgam

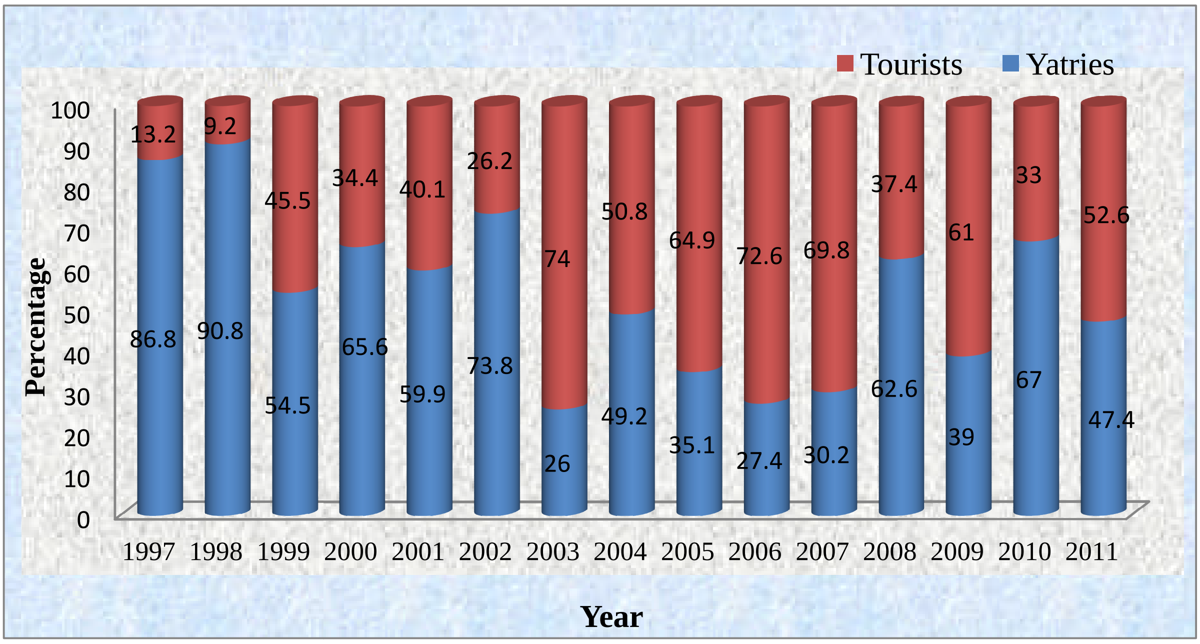


Fig. 6.6: Share of Yatries to total tourists to Pahalgam during 1997 – 2011

6.4. INCOME OF TOURISTS

The income of a tourist is determined by his occupation and status of the job. It has a direct bearing on the total tourist budget and the expenditure pattern. For analysis purposes, the tourists have been divided into five different income groups (table 6.4). It is found that tourists are wealthier than yatries as only 7 percent of the tourists fall in the income group of less than 15000 rupees while 35 percent of the yatries fall in this group.

The highest percentage of tourists (43) fall in the income category of 25-50 thousand rupees while the highest percentage of yatries (37) fall in the income group of 15-25 thousand rupees (fig. 6.7). Moreover 10 percent of the tourists have their income above 75 thousand rupees and none of the yatries fall in this category.

Table 6.4: Distribution of tourists and yatries in different income groups

Income groups (rupees in thousands)	Tourists		Yatries	
	Absolute	Percent	Absolute	Percent
Less than 15	35	7	175	35
15-25	95	19	265	37
25-50	215	43	125	21
50-75	105	21	50	7
Above 75	50	10	0	0
Total	**500**	**100**	**500**	**100**

Source: Sample survey, 2011

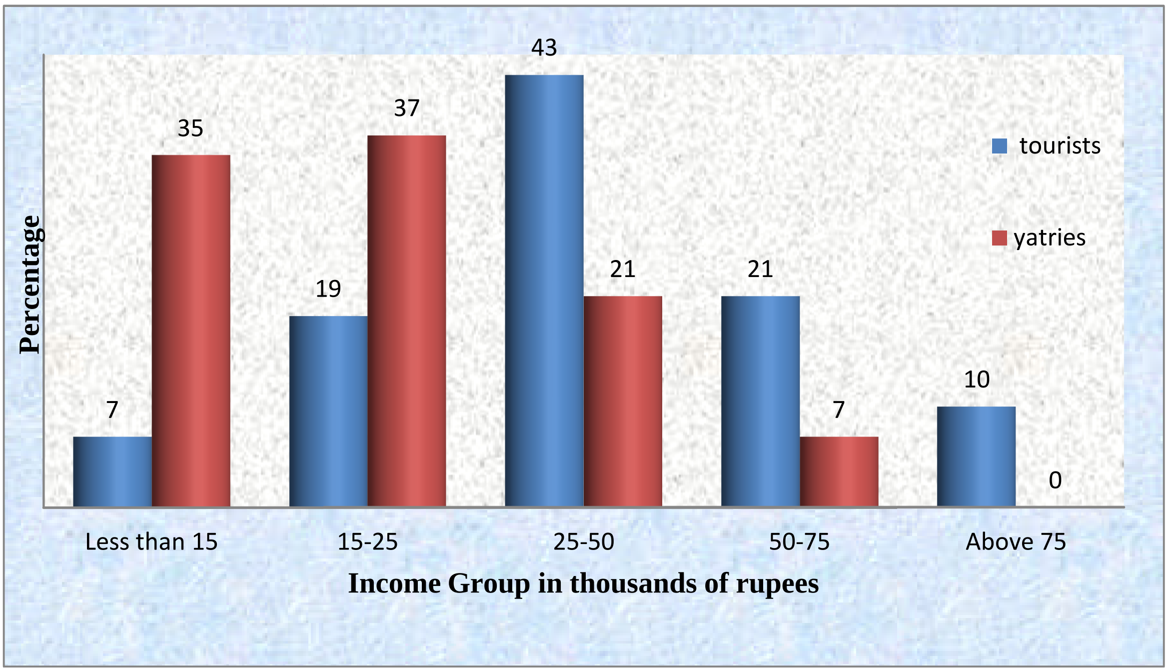


Fig. 6.7: Income Distribution of tourists and yatries to Pahalgam

6.5. PERCEPTION OF TOURISTS

The tourist perception is based on the experiences and observation of the tourists. The ratings given by tourists and yatries vary among different categories (table 6.5). On the one hand 15 percent of the tourists' rate administrative arrangements as poor while on the other hand only 5 percent of the yatries rate it poor. Accommodation is fairly good as only 3 percent of the tourists and 2 percent of the yatries rate it poor. Transport is rated mostly average to good by both tourists and the yatries as only four percent of the tourists and 1 percent of the yatries were dissatisfied with the transport arrangements (fig. 6.8). The behavior and attitude of local Kashmiri people was highly praised by all the tourists and the yatries excepting 1 percent of the tourists and 1 percent of the yatries as they have to face lots of bargaining with pony owners.

Table 6.5: Perception of tourists and yatries to Pahalgam for the year 2011

Category	Perception (percent)							
	Poor		Average		Good		Excellent	
	Tourist	Yatri	Tourist	Yatri	Tourist	Yatri	Tourist	Yatri
Accommodation	3	2	28	35	40	57	29	6
Transport	4	1	27	22	44	69	25	8
Administrative arrangement	15	5	23	3	44	87	18	5
Food quality	1	1	26	3	40	87	33	9
Local population	1	2	0	24	46	65	53	9

Source: Sample survey, 2011

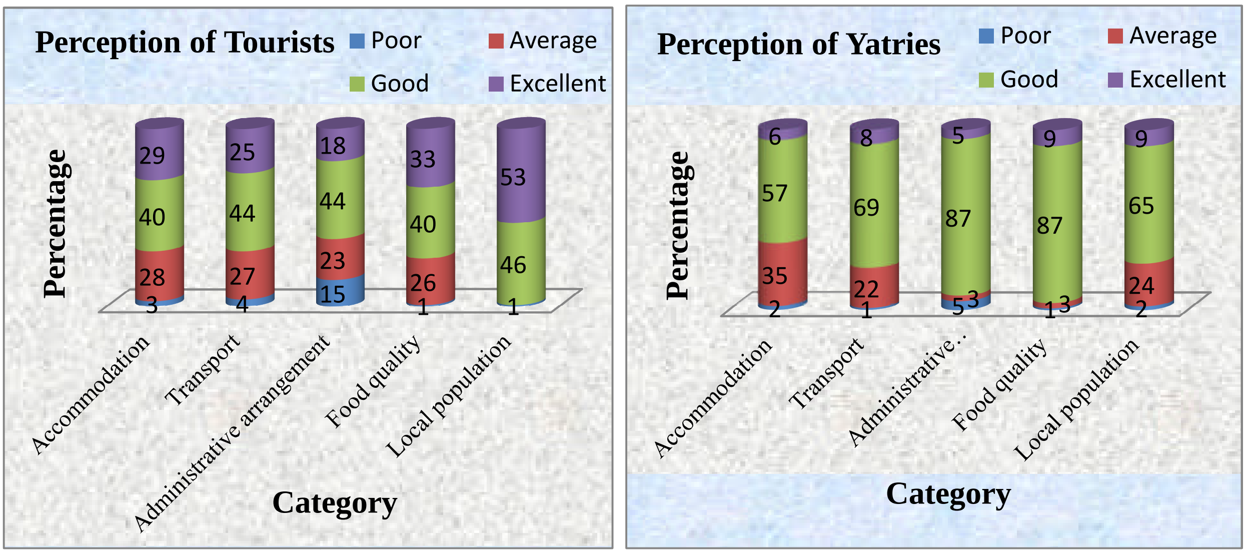


Fig. 6.8: Perception of tourists and yatries to Pahalgam

6.6. TOURIST INFRASTRUCTURE

The development of tourism depends upon the development of an integrated infrastructure of high ways, railways, airports, telecommunication, hotel accommodation, human resources and allied services. In Pahalgam valley there has been a marked increase in the availability of tourist accommodation infrastructure since 1990's onwards. A number of new hotels have been constructed and at the same time a sizeable number of residential housing structures have been converted into guest houses for tourist accommodation purposes while as there have been also considerable expansion of the shopping facilities. The accessibility has improved both in terms of road development and availability of transport facilities.

6.6.1. Accommodation – Hotels and Guest Houses

Accommodation is basic requirement for tourists. Pahalgam has a number of hotels, restaurants and guest houses of various types which are used for accommodation purposes. The tariffs depend on the type of accommodation to be hired. The existing accommodation (table 6.6) has the capacity to cater the needs of accommodation as there are about 231 accommodation units comprising of 84 hotels and 147 guest houses with a total capacity of 5763 beds.

Table 6.6: Number of accommodation units at Pahalgam, 2011

Type	Hotel	Rooms				Beds	
		Single	Double	Total	Average	Total	Average
Hotel	84	21	1745	1766	21	3511	42
Guest house	147	30	1111	1141	7.76	2252	15.3
Total	231	51	2856	2907	11.8	5763	23.4

Source: Sample survey, 2011

There are 2,907 rooms available for accommodation with 51 single bed rooms and 2,856 double bed rooms with the total bed capacity of 5763. Hotels have 1766 rooms comprising of 21 single bed rooms and 1745 double bed rooms with the average of 21 rooms per hotel, while guest houses have 1,141 rooms comprising of 30 single bed rooms and 1,111 double bed rooms with the average of 7.76 rooms per guest house (table 6.6). The average bed capacity of hotels is much higher (42 beds per hotel) as compared to the average bed capacity of guest houses (15.3 beds per guest house). The existing accommodation infrastructure in terms of number of hotels, guest houses and huts is more than the daily average number of tourist flow and existing tourist carrying capacity except for the months of June and July during which the daily average number of tourists especially pilgrimage tourists is higher than the bed capacity which is met through the tented accommodation for pilgrimage tourists.

Table 6.7: Bed capacity and room strength in hotels at Pahalgam for the year 2011

S. No	Hotel category	Rooms				Beds	
		Single bed	Double bed	Total	Average	Total	Average
1	**A**	6	570	576	44	1146	88
2	**B**	4	338	342	21	680	42
3	**C**	11	679	690	15	1369	30
4	**D**	0	158	158	16	316	32
Total		**21**	**1745**	**1766**	**21**	**3511**	**42**

Source: Sample survey, 2011

The category wise breakup of room strength and bed capacity of hotels (table 6.7) reveals that both the bed capacity as well as room strength decreases from A to D category hotels. The average bed capacity is 88, 42, 30 and 32 for A, B, C and D category hotels respectively. The average number of rooms is 44, 21, 15 and 16 for A to D category hotels respectively. The highest number of single bed rooms is found in C category hotels (11) while there is no single bedroom in D category hotels.

6.6.2. Ownership status of Accommodation

Most of the tourist accommodation units belong to the people from Anantnag district particularly Pahalgam tehsil and Srinagar district of Kashmir valley (table 6.8). Pahalgam tehsil own 73 percent of the total guest houses while 7 percent of the guest houses belong to the people from Anantnag district and the remaining 20 percent belong to Srinagar district (fig. 6.9). Out of the total hotels, Pahalgam tehsil own 51 percent while Srinagar and Anantnag districts own 31 percent and 18 percent respectively.

Table 6.8: Ownership of accommodation at Pahalgam

S. No	Type	Pahalgam	Anantnag	Srinagar	Total
1	**Hotel**	43 (51)	15 (18)	26 (31)	84 (100)
2	**Guest house**	107 (73)	10 (7)	30 (20)	147 (100)
Total Accommodation		**150 (64.9)**	**25 (10.8)**	**56 (24.3)**	**231 (100)**

Source: Sample survey, 2011

Note: Figures in parenthesis indicate percentage

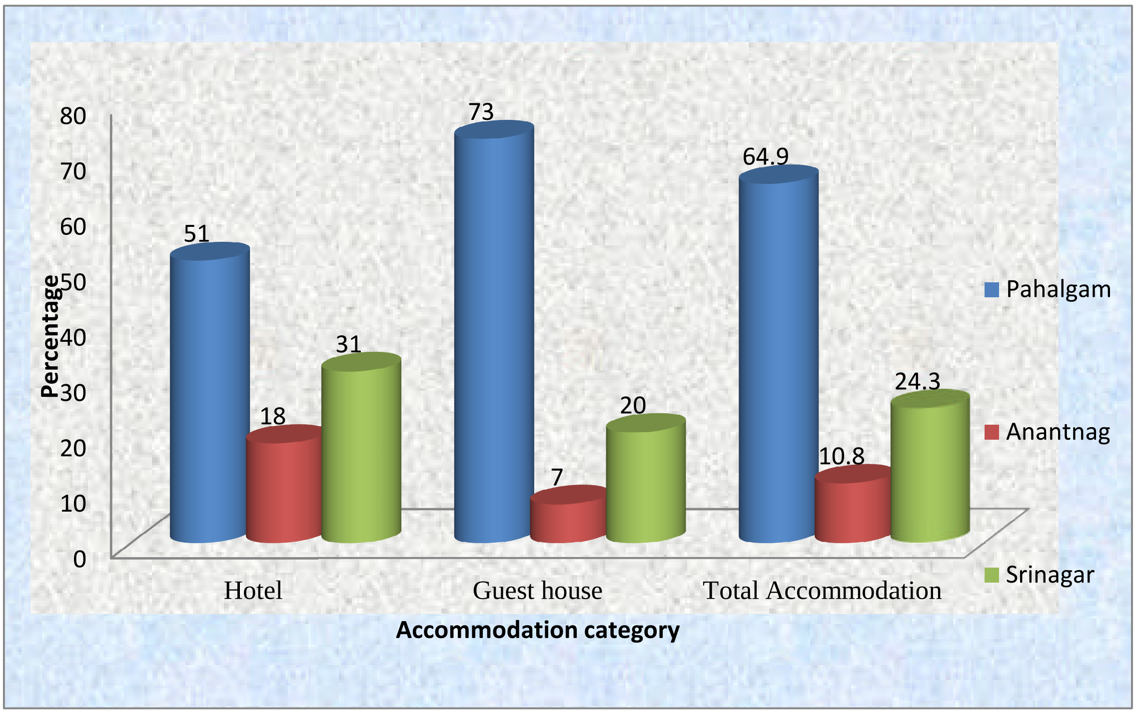


Fig. 6.9: Ownership of accommodation at Pahalgam

The category wise breakup of different hotels (table 6.9) shows that Srinagar district leads in the ownership of A and B category hotels with 62 percent of A category hotels while Anantnag district own 23 percent of the A category hotels and the remaining 15 percent are owned by the people from Pahalgam tehsil. In the B category hotels 50 percent are owned by the people from Pahalgam and Anantnag (38 percent and 12 percent respectively) while the other 50 percent are owned by Srinagar district (fig 6.10). Tehsil Pahalgam leads in the ownership of C and D category hotels (64 percent and 60 percent respectively) while Anantnag and Srinagar districts own 18 percent each in the C category hotels and 20 percent each in the D category hotels.

Table 6.9: Ownership of hotels at Pahalgam for the year 2011

S. No	Hotel category	Ownership			
		Pahalgam	Anantnag	Srinagar	Total
1	**A**	2 (15)	3 (23)	8 (62)	13 (100)
2	**B**	6 (38)	2 (12)	8 (50)	16 (100)
3	**C**	29 (64)	8 (18)	8 (18)	45 (100)
4	**D**	6 (60)	2 (20)	2 (20)	10 (100)
Total		**43 (51)**	**15 (18)**	**26 (31)**	**84 (100)**

Source: Sample survey, 2011
Note: figures in parenthesis indicate percentage

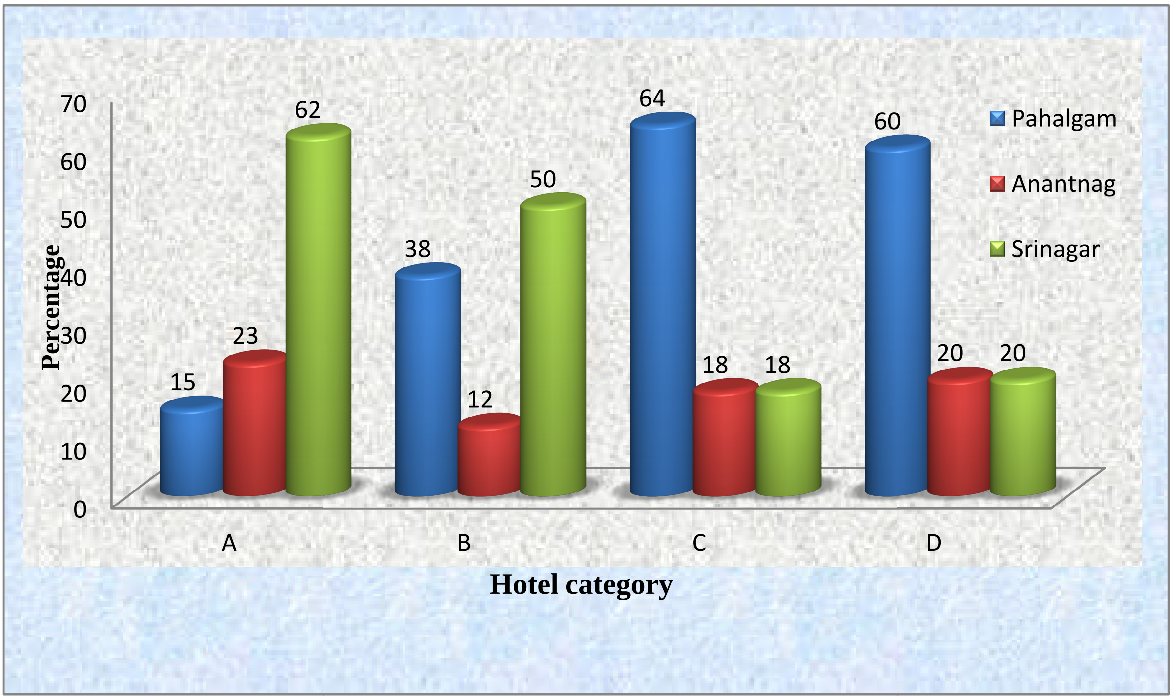


Fig. 6.10: Ownership of hotels at Pahalgam

6.6.3. Base camps

The temporary base camps as tented accommodation is provided to Amarnath Pilgrims at different locations along the route of Yatra. There are such 11 base camps comprising of more than 4500 tents and about 600 shops spread at different locations where accommodation, shopping and medical facilities are available for yatries. These are located at places like; Nunwanan, Chandanwari, Pissu top, Zagibal, Nagakuti, Wakabal, Sheshnag, Ganashtop, posh pathri, Panchtarni and Amarnath cave. Besides this, mobile shopping facilities are also available en-route to Amarnath cave.

The analysis of table 6.10 reveals that 75.2 percent of the tents and 69.6 percent of the shops are from Pahalgam tehsil and 16.8 percent of the tents and 13.7 percent of the shops belong to the people from Anantnag tehsil. Only 1.4 percent of the shops and

0.2 percent of the tents belong to Bijbiara tehsil (fig. 6.11). Thus the major share of the tented accommodation and the shops are from Anantnag district as only 10.5 percent of the tents and 15.4 percent of the shops belong to other districts of Kashmir valley.

Table 6.10: Ownership of tented accommodation and shops during Yatra period

S. No	Tehsil	Tents		Shops	
		Absolute	Percentage	Absolute	Percentage
1	Pahalgam	2212	72.5	402	69.6
2	Bijbiara	7	0.2	8	1.4
3	Anantnag	514	16.8	79	13.7
4	Others	320	10.5	89	15.4
Total		**3053**	**100**	**578**	**100**

Source: Sample survey, 2011

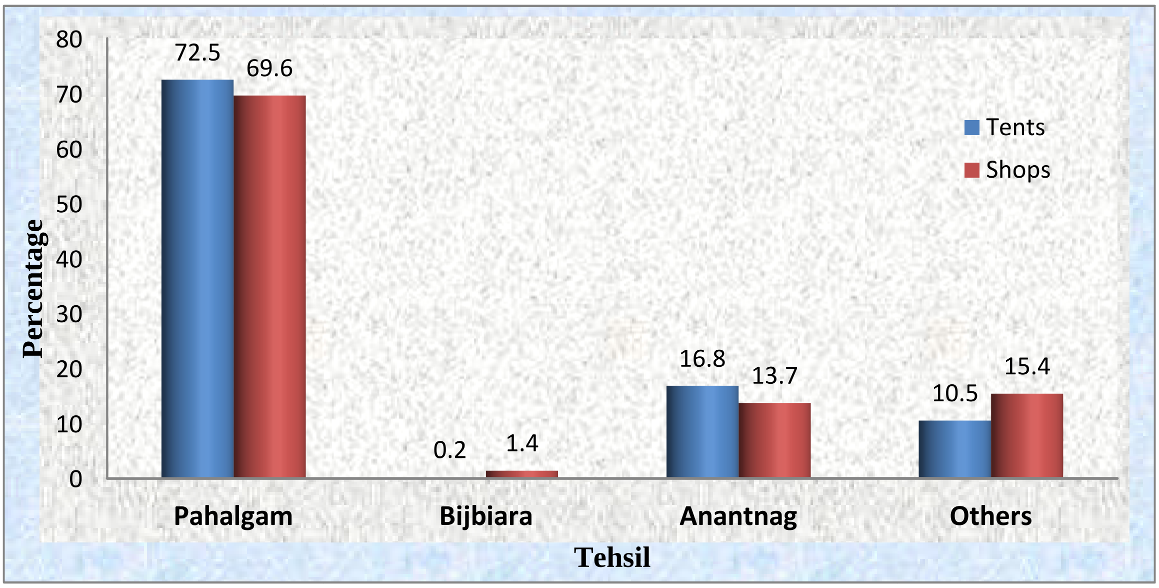


Fig 6.11: Ownership of tented accommodation during yatra period

6.7. ECONOMIC IMPACT OF TOURISM

The economic impacts of tourism can be both direct and indirect. The former relate to the actual expenditure involved in tourism e.g. on transport, boarding, lodging, shopping and services etc. and the later relates to the income generated by industries that provide goods and services as a result of tourist demand. Since there are countervailing forces at play within an economy the costs and benefits accruing from tourism are not immediately quantifiable. The economic value of tourism is often measured by way of estimating its contribution to income, employment and tax revenue. Increased expenditure by the tourist generates more demand for heterogeneous goods and services, which are the product of different economic activities. Tourist expenditure thus has important economic implication as it seeps through various channels of the economy. The economic impact of tourism is directly related to the income of a tourist which in turn determines total available budget, length of stay and the expenditure pattern.

6.7.1. Employment Effect of Tourism

Tourism industry, being mainly a service oriented and a labour-intensive activity is an important source of employment. It employs large number of people and provides a wide range of jobs which extend from the unskilled to the highly specialized. In addition to those involved in management there are large number of specialist personal required such as accountants, house-keepers, cooks and waiters. Tourism thus provides a direct socio-economic benefit through increased employment opportunities to persons whose activity is connected with satisfying the tourist needs. The employment effect of tourism is most prominent in the Pahalgam Development Authority (PDA) area which constitutes all the villages of watershed 1E7A7, 1E7B1, two villages (Virsaran and Khelan) of watershed 1E7A2 and three villages (Batkut, Lidroo and Batkut Gujaran) of watershed 1E7B3.

Table 6.11: Workers associated with tourism in PDA area, 2011

Village	Households	Population	Total workers	Associated with tourism	
				Persons	Percentage
Aru	104	537	171	126	73.7
Frislan	133	812	236	148	62.7
Mondlan	76	394	135	49	36.3
Batkut	481	2870	864	62	7.2
Lidroo	351	1896	373	68	18.2
Mamal	111	720	235	132	56.2
Ganashbal	81	502	126	78	61.9
Pahalgam	661	6138	1424	712	50.0
Laripora	268	2216	665	315	47.4
Virsaran	220	1218	530	118	22.2
Khelan	173	951	310	155	50.0
Total	2659	18254	5069	1963	38.7

Source: Sample survey, 2011

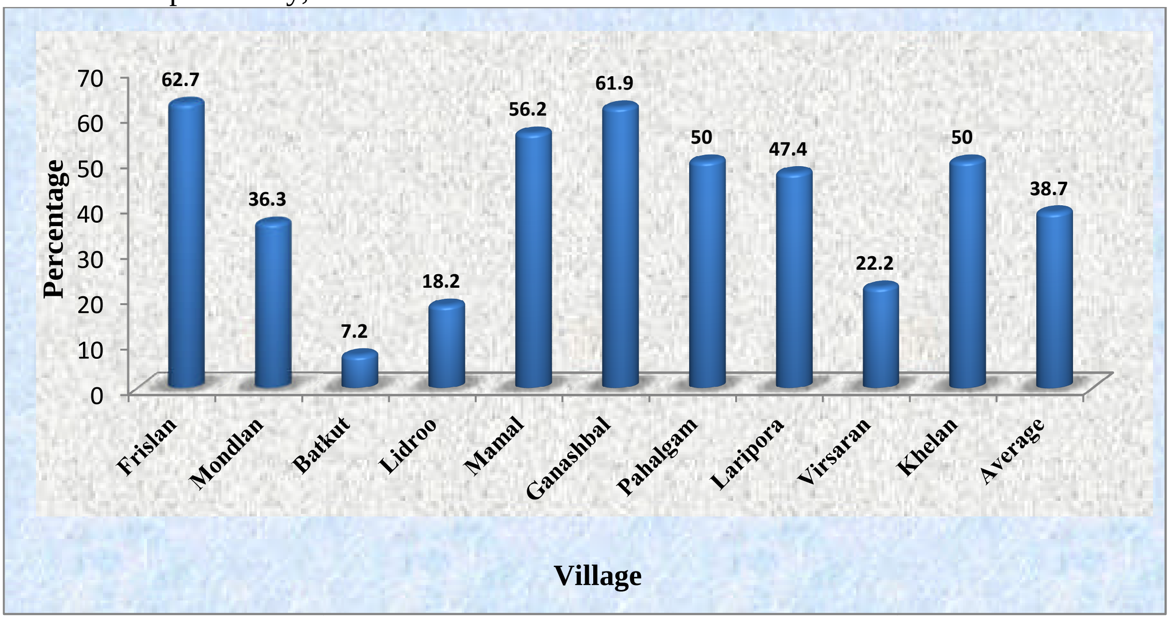


Fig. 6.12: Workers associated with tourism in PDA area, 2011

It is evident from table 6.11 that tourism employs 1963 persons which is 38.7 percent of the total working population of 5069 persons in PDA area. However there are variations in the concentration of people employed with tourism (fig. 6.12). In five villages tourism employs more than half of the total working population with the highest percentage (73.7) employed in Aru. In Pahalgam half of the total working population is associated with tourism while in Batkut only 7.2 percent of the working population is engaged with tourist related activities.

6.7.2. Income Effect of Tourism

The direct income generated by tourism is given by:

$$D = [Pt\ (d + f)\ ls + Pl\ (L)\ ls + Py\ (y)\ ls],$$ Where,

D = Direct Income; Pt = per capita expenditure of tourists, d = domestic tourists, f = foreign tourists, ls= length of stay, Pl = Per capita expenditure of local tourists, L = local tourists Py = Per capita expenditure of yatries, y = yatries.

Thus the total income generated by tourism sector is 84.58 crore rupees.

i. **Income generated by accommodation sector:** The analysis of table 6.12 and table 6.13 has shown that accommodation sector earns a considerable share (46.87 percent) of the total tourist income spent at Pahalgam. The major share (fig. 6.13) goes to hotels (75.77 percent) followed by guest houses (23.14) and dhabas (1.09 percent).

Table 6.12: Income generated by accommodation sector at Pahalgam, 2011

S. No.	Type	Number	Average monthly income (Rs. in lac)	Total monthly income (Rs. in lac)	Annual income (six months tourist season) (Rs. in lac)	Percentage share
1	**Hotel**	84	6.56	500.6	3004	75.77
2	**Guest house**	147	1.04	153	917.3	23.14
3	**Dhaba**	15	0.48	7.2	43.2	1.09
Total accommodation		**246**	**2.68**	**660.74**	**3964.44**	**100**

Source: Sample survey, 2011

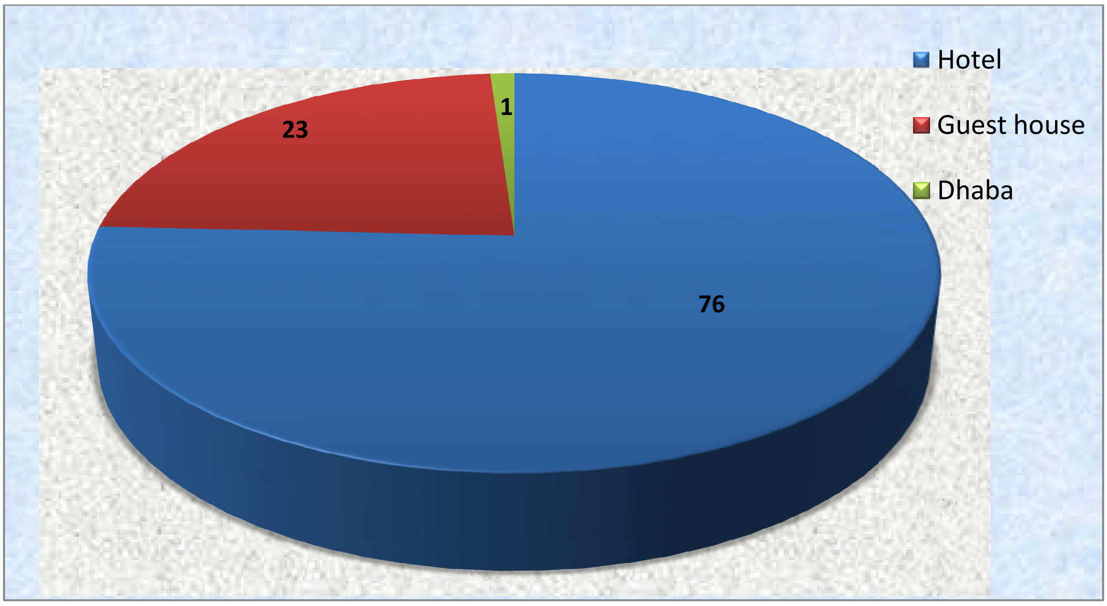


Fig. 6.13: Income generated by accommodation sector at Pahalgam, 2011

ii. **Income generated by sectors other than accommodation:** The analysis of table 6.13 reveals that accommodation sector earns 46.87 percent of the total revenue generated by tourism. Pony owners, tent wallas and shopkeepers are the other important beneficiaries (fig. 6.14) as they earn 15.96 percent, 10.82 percent and 8.19 percent respectively of the total income generated by tourism.

Table 6.13: Income generated by different stake holders from tourism at Pahalgam, 2011

S. No.	Category	Number	Average Monthly income (Rs. in thousand)	Average Seasonal income (Rs. in lac)	Total income (Rs. in lac)	Percentage Share
1	Shopkeeper	578	20	1.20	693	8.19
2	Pony walla	1500*	15	0.90	1350	15.96
3	Tent walla	3053	15	0.30	915	10.82
4	Dandi walla	159	12	0.24	38	0.45
5	Photographer	44	8	0.64	28	0.33
6	Excursion agencies	125	20	0.80	100	1.18
7	Travel agencies	07	90	5.40	37	0.44
8	Tour guides	58	40	2.00	116	1.37
9	Parks	06	230	13.80	82	0.97
10	Accommodation sector	246	268	660.74	3964.44	46.87
11	Others**	-	-	-	1134.56	13.42
Total					**8458**	**100**

Source: Sample survey, 2011

*Though the total number of registered pony wallas in Pahalgam is 4771, but all are not working for the period of six months.

** Includes the income generated by private transport owners and the expenses of the personal transport, various government agencies and the unregistered beneficiaries.

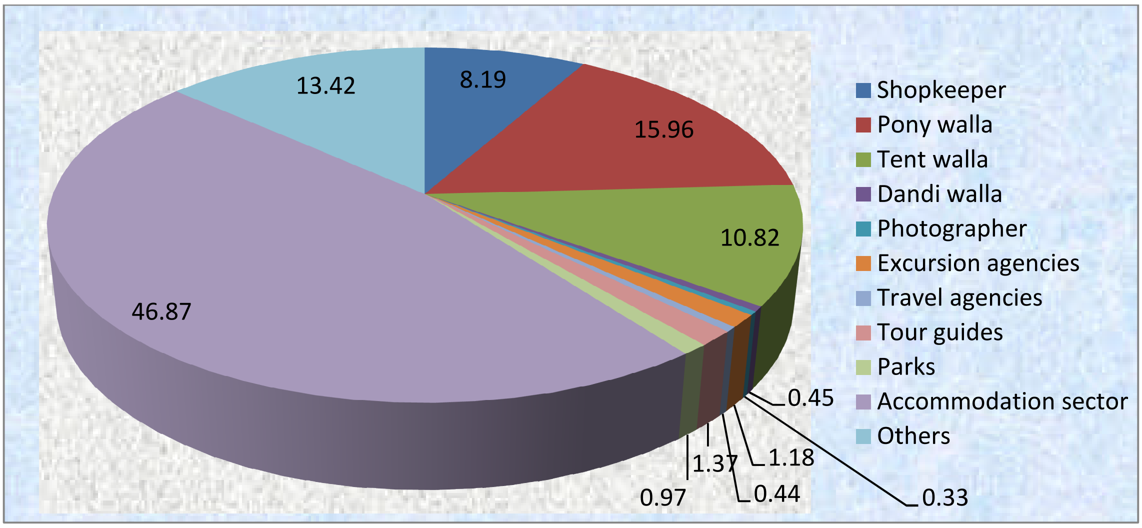


Fig. 6.14: Income generated from tourism at Pahalgam, 2011

6.8. ENERGY CONSUMPTION BY ACCOMMODATION SECTOR

Fuel wood consumption in hotels is imposing major stress on environment in Lidder valley. The pattern of energy consumption is varied among various categories of hotels and guest houses. The average fuel wood consumption was estimated about 2475 kg/hotel/month and 1500 kg/month for guest houses (table 6.14). The category wise breakup of Hotels (Table 6.15) reveals that the average fuel wood consumption decreases from A to D category hotels. It varies from 2000 kg/hotel/month in A category hotels to 1500 kg/hotel/month in D category hotels.

Table 6.14: Energy consumption in accommodation sector at Pahalgam, 2011

S. No	Category	LPG (liters/month)		Kerosene (liters/month)		Firewood (kg/month)	
		Total	Average	Total	Average	Total	Average
1	Hotel	19974	238	14800	176	207900	2475
2	Guest house	9408	64	10290	70	220500	1500
Total Accommodation		**29382**	**127**	**25090**	**109**	**428400**	**1855**

Source: Sample survey, 2011

The average LPG consumption is 127L/month with the highest consumption in hotels where it amounts to 238 L/month and for the guest houses it is 64 L/month. The LPG consumption sharply decreases from A category (818 L/month) to D category hotels (75 L/month) at Pahalgam. Kerosene consumption is also highest in hotels (176 L/month) followed by guest houses (70 L/month). Among the various categories of hotels, kerosene consumption decreases from A category (500) to D category hotels (60). Thus the hotels lead in energy consumption (Fig. 6.15) of all the four types and among the hotels the energy consumption decreases from A category to D category hotels (Fig. 6.16) excepting C category hotel, where the firewood consumption is more than that of B category hotel.

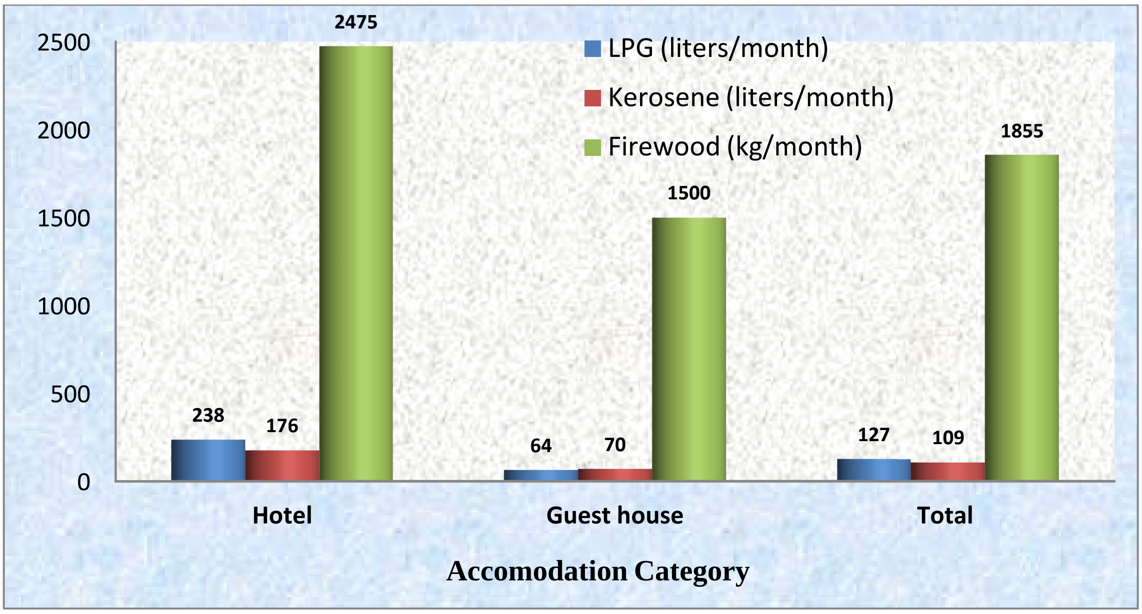


Fig. 6.15: Energy consumption by accommodation sector at Pahalgam, 2011.

Table 6.15: Energy consumption in hotels at Pahalgam, 2011

S. No	Hotel category	LPG (L/month)		Kerosene (L/month)		Firewood (kg/month)	
		Total	Average	Total	Average	Total	Average
1	A	10634	818	6500	500	26000	2000
2	B	4000	250	3200	200	36400	2275
3	C	4590	102	4500	100	130500	2900
4	D	750	75	600	60	15000	1500
Total		**19974**	**238**	**14800**	**176**	**207900**	**2475**

Source: Sample survey, 2011

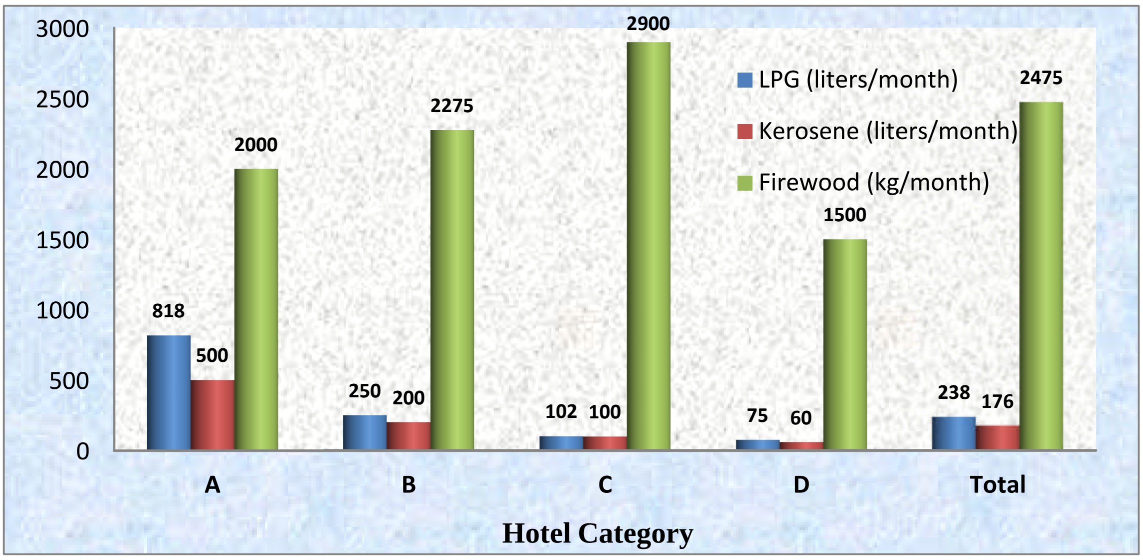


Fig. 6.16: Energy consumption in hotels at Pahalgam, 2011

6.9. TRAFFIC FLOW

The fast growing tourism industry at Pahalgam has resulted into huge demand for different types of transport facilities. The tourists who visit Pahalgam either have their own transport facility or use hired vehicles from different places. The tourists whose first destination is Pahalgam usually hire vehicle from Jammu. However the tourists who first visit other tourist destinations of Kashmir valley hire a vehicle from Srinagar. The foreign tourists hire vehicles from Srinagar airport to different tourist destinations of the valley. Transport facilities are adequate at Pahalgam with two Somo stands, one Bus stand and one mini bus stand. Different types of vehicles are easily available with fixed rates. Tourists hire different vehicles from these vehicle stands to different tourist spots of Pahalgam valley viz. Aru, Chandanwari, Betab valley etc. However the road to Baisaran is closed and only ponies are used to reach the destination.

There is a marked distinction between tourists and yatries so far as the transport used is concerned. The analysis of table 6.16 reveals that the popular mode of transport is the private transport as it is used by 78 percent of the tourists. Moreover 11 percent of the tourists use their own vehicles while another 11 percent use public transport. Most of the yatries (91 percent) prefer to use public transport because of the adequate arrangements made by the government while only 2 percent use their own vehicles and the remaining 7 percent use private transport. It is pertinent to mention here that the shrine board has arranged 150 sumos and 60 minibuses for yatries for their pilgrimage from Nunwanan base camp to Chandanwari in 2011.

Table 6.16: Mode of transport used by tourists and yatries to Pahalgam, 2011

Type of transport	Percentage	
	Tourists	**Yatries**
Public	11	91
Personal	11	2
Private	78	7
Total	**100**	**100**

Source: Sample survey, 2011

It is evident from the data given in table 6.17 and figure 6.17 that the flow of traffic is very high on Saturday and Sunday because of the huge inflow of local tourists as compared to the other days of the week and this situation results in congestion and traffic chaos at Pahalgam. The problem of congestion gets aggravated on the weekends as most of the local school going children are on excursion. The category wise breakup reveals that small vehicles outnumber large vehicles en-route to Pahalgam. It has been found that a considerable proportion (23.9 percent) of all the three categories of vehicles have stayed at Pahalgam on Saturday. These vehicles left Pahalgam on Sunday evening as it is clear that the magnitude of inward flow is less than that of the outward flow except for Buses and minibuses. Though for the lean day the number of buses and minibuses is same as that on Sunday, however the flow of somos and private vehicles is much higher on weekends than that of a lean day (Wednesday).

Table 6.17: Average daily traffic flow to Pahalgam in tourist season

Day	Small vehicles	Large vehicles	Total vehicles
Monday	1035	185	1220
Tuesday	1072	174	1246
Wednesday	1006	162	1168
Thursday	980	155	1135
Friday	845	150	995
Saturday	1440	192	1632
Sunday	1365	233	1598

Source: Sample survey, 2011

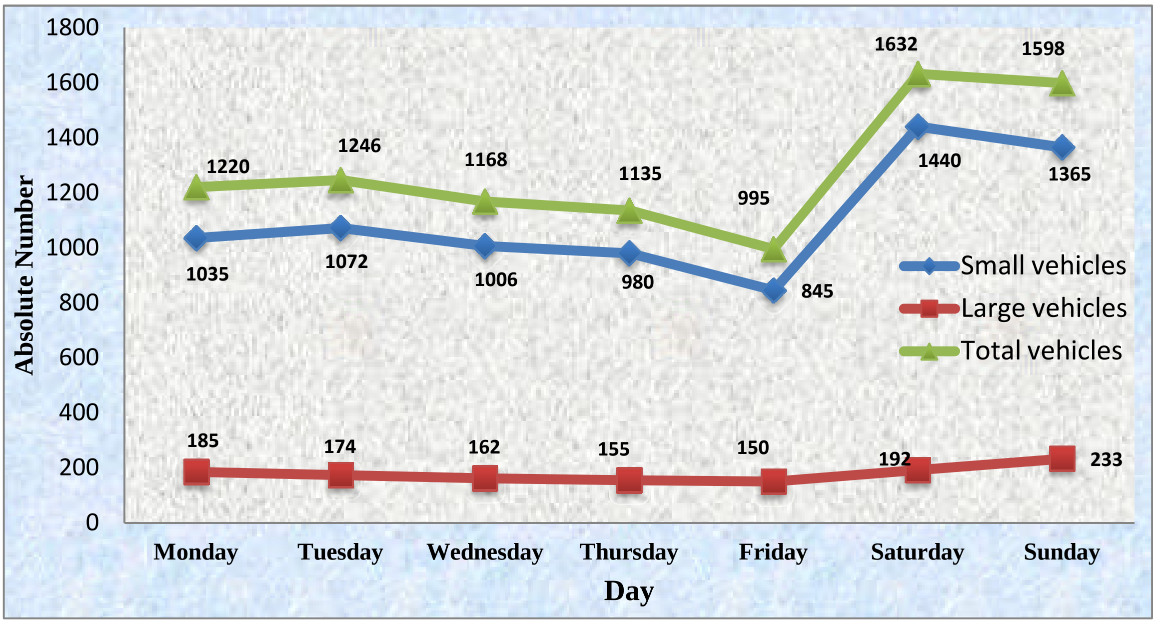


Fig. 6.17: Vehicular flow to Pahalgam during different days of week to Pahalgam

The traffic flow corresponds largely to the flow of tourists to Pahalgam valley. The analysis of table 6.18 reveals that the flow of traffic is dominated by light/small vehicles throughout the year. Small vehicles constitute (93.2 percent) while the large vehicles form only 6.8 percent of the total vehicles (fig. 6.18). The flow of traffic is lowest during winter months and is highest during summer months when the tourism is at peak along with Yatra. During the months of Yatra Pahalgam receives a heavy flow of traffic, which is a great threat to the ecology of Pahalgam. The traffic flow starts increasing with the start of the year and reached its maximum of 69 thousand vehicles in July. From July onwards it decreases sharply to only 1925 vehicles in December.

Table 6.18: Monthly traffic flow to Pahalgam, 2011

Month	Light vehicles	Heavy vehicles	Total
January	1618	490	**2108**
February	1420	350	**1770**
March	3742	779	**4521**
April	14304	803	**15107**
May	36226	997	**37223**
June	63808	2340	**66148**
July	63965	5436	**69401**
August	9038	1325	**10363**
September	11083	1625	**12708**
October	16867	1739	**18606**
November	5371	612	**5983**
December	1710	215	**1925**
Total	**229151**	**16711**	**245862**

Source: Municipal Committee Pahalgam

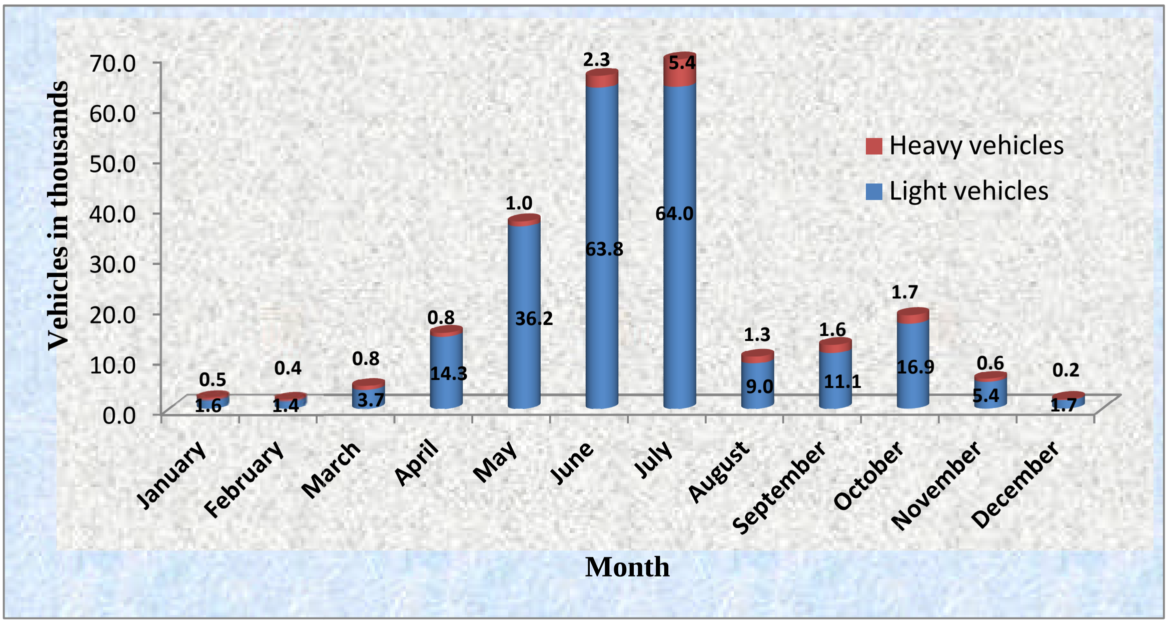


Fig. 6.18: Monthly flow of traffic to Pahalgam, 2011

6.10. WASTE GENERATION BY TOURISM

Solid waste disposal becomes a problem not only in the areas which are densely populated but also in the tourist regions characterized by high flow of tourists. This problem gets aggravated especially in mountainous areas which are very fragile. Solid waste is regarded as one of the most adverse types of pollution. It needs to be managed in a sustainable way to reduce the overall burden on the environment. The International

Hotel Environment Initiative (IHEI, 2002) reported that waste generation is one of the most visible impacts that hotels have on the environment. Unfortunately in many developing countries, the system for managing the waste is primitive and cannot cope with the huge volumes of wastes being generated (Yousfi, 2004, Ahmed and Ali, 2004). In order to understand the challenge of tourism related waste at the global scale, it is useful to evaluate the order of magnitude from the perspective of total weight. Solid waste management thus emerged as an essential, specialized sector for keeping cities healthy and livable (Ahmed and Ali, 2004).

6.10.1. Solid Waste

Solid waste is regarded as one of the most adverse types of pollution. Its management is presently one of the major urban environment challenges for the administrators, engineers and planners. Huge quantities of solid wastes are generated and need to be collected, transported and finally disposed off. These operations have to be carried out speedily and efficiently without incurring excessive cost or damage to environment. Pahalgam being one of the leading tourist destination of Kashmir valley receives more than six lac tourists annually. A huge tourist infrastructure comprising of different categories of hotels, guest houses, tourist huts, shopping complexes and other administrative buildings have been developed to cater the different tourist services. Therefore solid waste and its management is one of the sensitive environmental problems confronted in this tourist town.

The cornerstone of successful planning for a waste management program is the availability of reliable information about the quantity and the type of material being generated and an understanding about how much of that material can be prevented from being generated, and, if generated, how much of it is captured and recycled. The solid waste from the accommodation sector at Pahalgam has three main constituents, i.e., compostable, recyclable and miscellaneous. Out of the total solid waste generated in the accommodation sector at Pahalgam, 59.65 percent is compostable in nature, 17.73 percent contains recyclable material while 22.62 percent includes miscellaneous items (table 6.19). A gradual declining trend was observed in the contribution of compostable material from ‘A’ category to ‘D’ category hotels. Another striking feature is that there is an increasing trend in the generation of miscellaneous wastes from high budget tourist accommodation facilities to low budget accommodation.

The leftover food accounts for a significant part of the compostable waste (table 6.19 and fig. 6.19). Degrading organic waste provides a medium to spread diseases. However organic waste has also a good potential for resource recovery when converted in the form of high quality composting. Among the recyclable material plastic is the most dominant source of waste, which accounts for 8.25 percent. Metal waste includes tin and aluminum containers and other metallic bottles of different consumption items constitute 3.13 percent of the total waste. The plastics, including carry bags, bottles etc., constitute 8.25 percent of the total waste and are most visible sources of environmental pollution in the town. The miscellaneous waste items, including bones, rubber, dirt, sand, cloth, wood pieces, ash, and charcoal, constitute 22.6 percent of the composition of the waste.

Table 6.19: Composition of solid waste from accommodation sector at Pahalgam, 2011

Material category		Tourist accommodation sector: A category hotels	B category hotels	C category hotels	D category hotels	Average percentage composition of hotel waste	Guest houses	Average percentage composition of accommodation sector	
Compostable	**Fruit waste**	20.3 6.52	10.3 9.8	19.57 10.3	2.94 7	53.11 8.18	42.4 13	95.51 9.79	**581.7** **(59.65)**
	Leftover food	145.4 46.59	34 32.38	45.05 23.71	7.56 18	232.01 35.75	58.7 18	290.71 29.81	
	Vegetable waste	78.1 25.04	22.1 21	28.50 15	4.2 10	132.90 20.48	32.6 10	165.50 16.97	
	Garden clippings	7.2 2.3	2.1 1.98	3.55 1.87	13.44 32	26.29 4.05	3.9 1.19	30.19 3.09	
Recyclable	**Metal**	15.9 5.1	2.2 2.11	4.07 2.14	0.84 2	23.01 3.54	7.5 2.3	30.51 3.13	**172.8** **(17.73)**
	Glass	15.6 5	15.6 14.9	7.64 4.02	0.84 2	39.68 6.11	9.8 3	49.48 5.07	
	Recyclable paper	4 1.27	2.5 2.4	2.15 1.13	0.42 1	9.07 1.40	3.3 1	12.37 1.27	
	Recyclable plastics	8.2 2.64	3 2.82	16.42 8.64	3.95 9.4	31.57 4.86	48.9 15	80.47 8.25	
Miscellaneous	**Non-recyclable plastics**	5.1 1.62	1.4 1.38	3.25 1.71	1.05 2.5	10.80 1.66	3.2 0.98	14.00 1.43	**220.5** **(22.62)**
	Non-recyclable paper	4.1 1.3	1 0.99	1.54 0.81	0.84 2	7.48 1.15	3.3 1	10.78 1.11	
	Others	8.2 2.62	10.8 10.24	58.27 30.67	5.92 14.1	83.19 12.81	112.6 34.53	195.79 20.08	
Total		**312** **100**	**105** **100**	**190** **100**	**42** **100**	**649** **100**	**326** **100**	**975** **100**	**975** **100**

Source: Sample survey, 2011

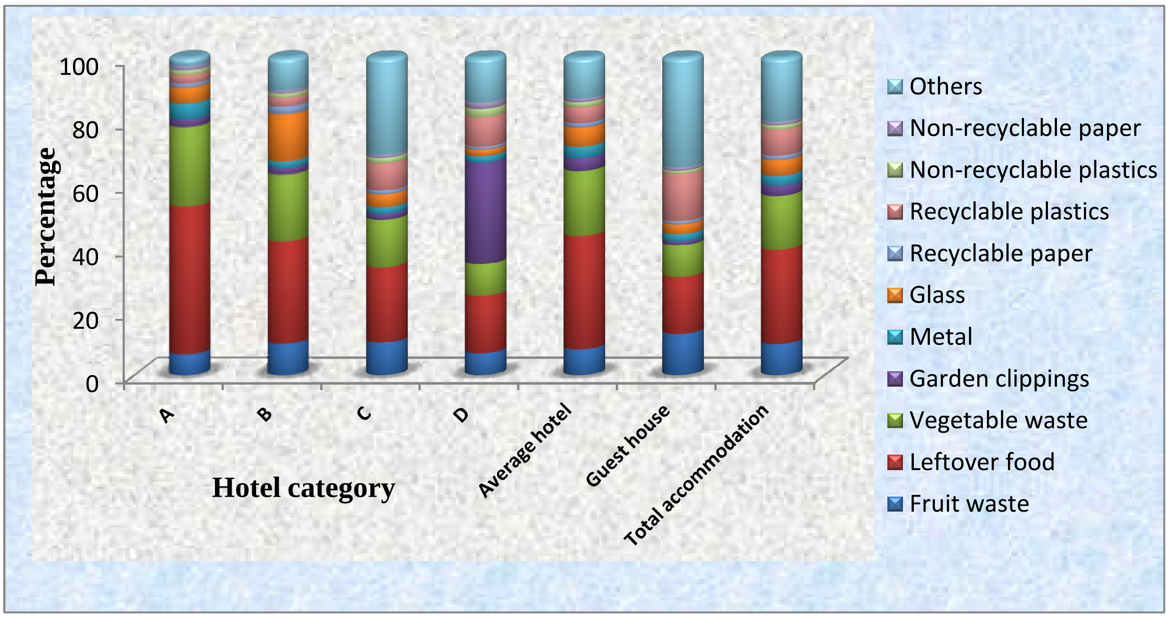


Fig. 6.19: Average composition (percent weight) of solid waste in hotel industry, 2011

It can be noticed from table 6.20 that highest amount of solid waste (326 metric tons) is generated by Guest houses with the lowest per capita generation of 2.2 metric tons per guest house per year because they are highest in number. However A category hotels generate highest per capita of 24 metric tons per hotel per year. This is because of the high standard service offered by these hotels, which results into the generation of huge quantity of solid waste. Besides, they also possess good provisions of restaurants and garden facility. However the other tourist accommodation facilities generate relatively low per capita solid waste. The relatively low per capita waste generation in C and D category hotels is because of the fact that they cater the need of the low income group tourist.

Table 6.20: Monthly solid waste generation in accommodation sector at Pahalgam, 2011

S. No.	Hotel Type	Solid waste in metric tons													Average per hotel per year
		January	February	March	April	May	June	July	August	September	October	November	December	Total	
1	**A**	4.6	7.7	17.1	36.14	46.6	51.7	51.9	51.8	21.2	15.5	4.14	3.62	312	**24.0**
2	**B**	0.6	1.1	5.16	7.4	12.2	22.4	22.4	13.4	10.3	6.9	2.02	1.12	105	**6.6**
3	**C**	2	4.1	6.2	12.8	29.3	31.9	41.4	26.9	15.7	14.4	3.3	2	190	**4.2**
4	**D**	0.36	0.8	1.3	2.2	6.3	6.2	8.64	9	3.6	2.7	0.45	0.45	42	**4.2**
5	**Guest house**	1.47	4.4	23.5	29.4	36	62	73.6	51.5	25.7	11	6.7	0.73	326	**2.2**
Total		**9.03**	**18.1**	**53.26**	**87.94**	**130.4**	**174.2**	**197.94**	**152.6**	**76.5**	**50.5**	**16.61**	**7.92**	**975**	**4.2**

Source: Sample survey, 2011

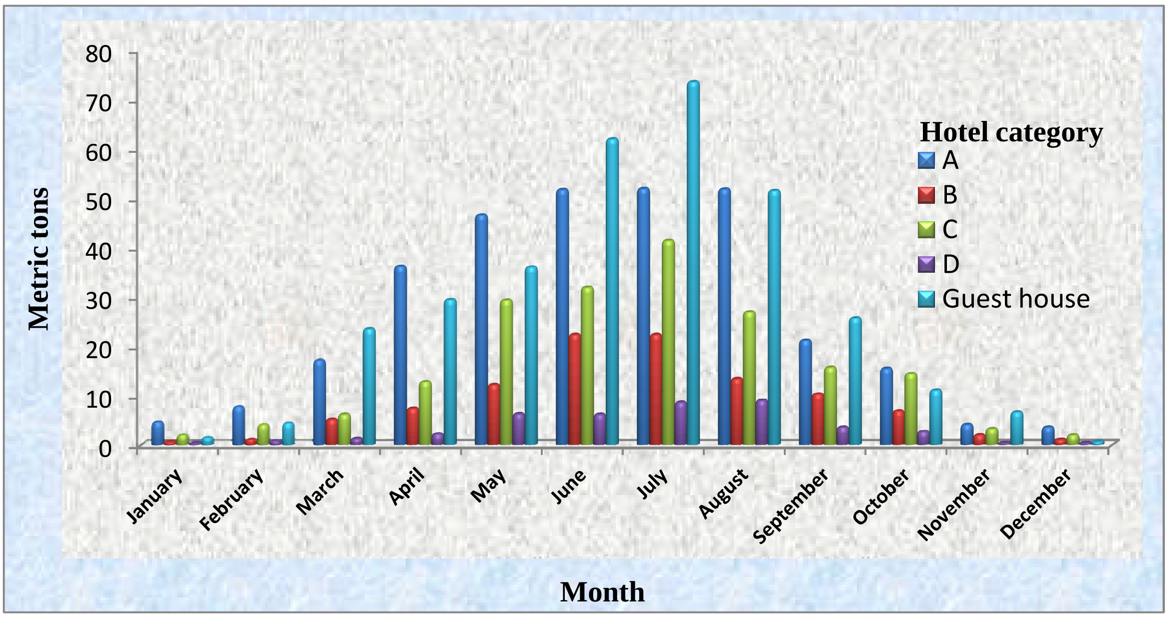


Fig. 6.20: Monthly variation in solid waste generation at Pahalgam, 2011

On an average tourist accommodation sector of Pahalgam generates 975 metric tons of solid waste annually, with the least quantities (7.92 tons) being produced in December and the highest during July (197.9 metric tons) at the peak of the Amarnath yatra. It is important to note that during winter season 'A' category hotels generate the bulk of the waste as the room occupancy is significantly higher in this category of hotels during this period.

6.10.2. Liquid Waste

It is evident from table 6.21 that there is considerable variation in the generation of liquid waste from different accommodation categories. The tourist accommodation sector of Pahalgam generates 339.6 thousand L/hotel/day with the average of 8.8 thousand L/hotel/day (fig. 6.21). The magnitude of liquid waste generation is enormous in A category hotels i.e. 3000 L/hotel/day which amounts to total generation of 39 thousand L/hotel/day. The highest quantity of liquid waste is generated from guest houses i.e. 191.1 thousand L/day, which is due to their large number as compared to hotels. Similarly, there is considerable share of C category hotels to the overall generation of liquid waste. However D category hotels generate only 10 thousand liters of liquid waste/day. Like solid waste generation, the magnitude of liquid waste generation is subjected to the standard of services offered to tourists i.e. higher the stand of services provided, greater is the magnitude of liquid waste generation and vice versa.

Table 6.21: Liquid waste generated from accommodation sector at Pahalgam, 2011

Hotel category	Number	Generation of liquid waste/day (000 Liters)	
		Average	Total
A	13	3	39
B	16	2	32
C	45	1.5	67.5
D	10	1	10
Guest houses	147	1.3	191.1
Total accommodation	**231**	**8.8**	**339.6**

Source: Sample survey, 2011

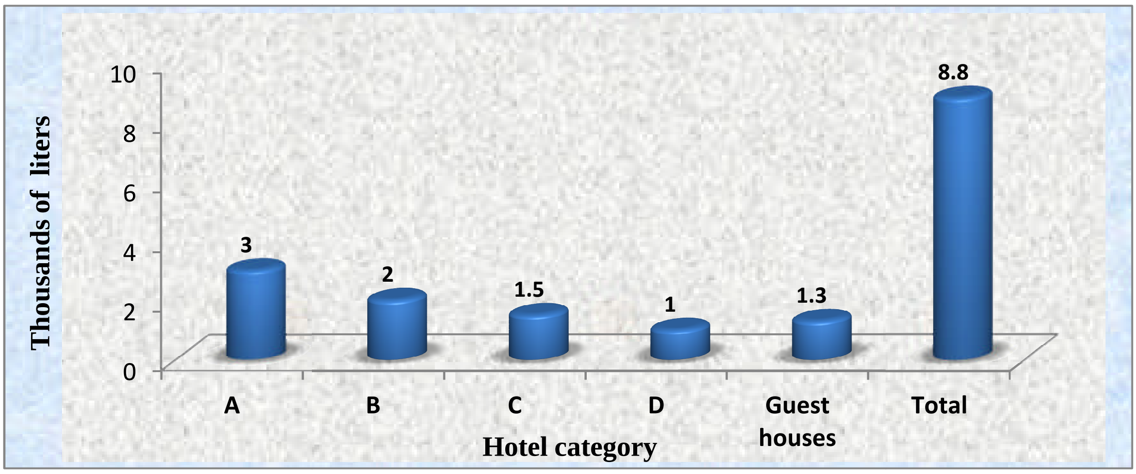


Fig. 6.21: Daily generation of liquid waste by accommodation sector at Pahalgam, 2011

6.10.3. Solid wastes generated during yatra

The data on the composition of solid waste generated by yatries during their stay at the base camp at Pahalgam is presented in table 6.22. The contribution of organic matter was significantly high in the total solid waste, leftover food contributing 38 percent and fruit and vegetable waste forming 27 percent, the two together constituting more than 65 percent of the yatra related solid waste. Recyclable matter constituted 18 percent of the yatra related solid waste (fig. 6.22) in which share of paper including cardboard was very significant. The total solid waste generated by yatra during 2011 was estimated to be 1707 metric tons.

Table 6.22: Composition of solid waste generated during yatra period, 2011

Material category	Weight in Metric tons	Weight in percent
Fruit waste	8.54	0.5
Leftover food	648.66	38
Vegetable waste	460.9	27
Metal	51.21	3
Recyclable paper	170.7	10
Recyclable plastics	85.35	5
Non-recyclable plastics	51.21	3
Non-recyclable paper	3.4	0.2
Others	227	13.3
Total	**1707**	**100**

Source: Sample survey, 2011

It can be concluded from the above analysis that about 2682 metric tons of solid waste is generated annually comprising 975 metric tons from hotels and 1707 metric tons from Yatra base camps. The three months comprising June to August constitute about 83 per cent (2231 metric tons) of total annual generation with an average generation of about 24.77 metric tons/day. The per capita generation of solid waste is about 2.40 kg/day. The existing practice of solid waste disposal of the town is open dumping at Sarbal, a site located on the right bank of a stream flowing into Lidder river which poses a potential threat to pollute the river waters through its leachats especially during the torrential rainfall.

It has been also observed during the field survey that a considerable number of hotels of all categories dump their waste openly in the forest area and alongside the main river front thus exposing the water body to a high level of contamination risk. There are also a number of public sites in the bowl of Pahalgam town and in the vicinity of Mamal and Laripora without any solid waste collection points. The huge quantities of garbage in dispersed form are being disposed near these sites especially in the vicinity of various parking areas like Bus stand, Tata sumo stand, Pony stand and in and outside various public parks, near the sites of public convenience and along the river fronts which remain unattended and finally get their disposal in the main water body.

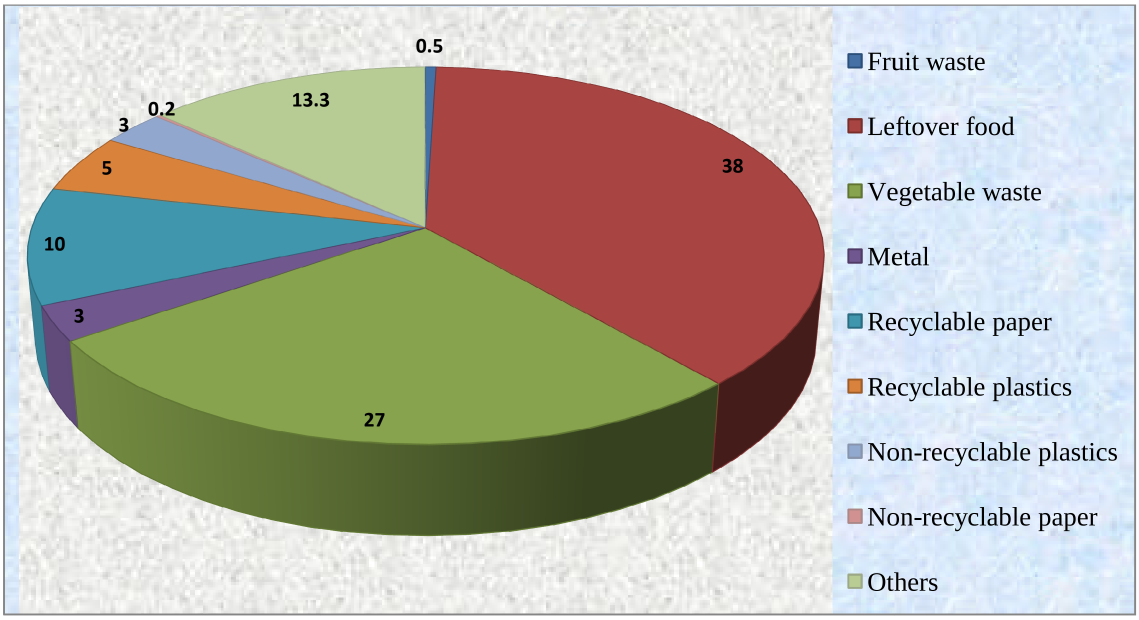


Fig. 6.22: Composition of solid waste generated during Amarnath yatra, 2011

6.11. Tourist Carrying Capacity

In Lidder catchment, Pahalgam valley is the leading tourist destination. Despite the fact that the tourism potential has remained largely underutilized, the highly imbalanced pattern of tourist flow has triggered serious environmental and ecological concerns as the tourism activity has acquired a seasonal character mostly confined to the summer season from June to August. The bulk share of about 83 per cent of the tourist flow is received only during these three months resulting in a soaring tourist user density which is considered exceptionally high as it far exceeds the maximum threshold limits of existing average daily tourist carrying capacity of the area. The tourist destination is confronted with a wide range of planning and management problems which stemmed partly from the flawed master plan that has failed to regulate the growth of Pahalgam Development Authority Area in accordance with a suitable and sustainable developmental model which could properly address the sensitive environmental and ecological concerns of the area. The problem has been further complicated by the non-availability and inadequacy of various civic services especially the management of huge quantities of sewerage and solid wastes during the peak tourist season coupled with the encroachment of river fronts, expansion and construction of hotels in environmentally and ecologically sensitive sites and destabilization of hill slopes. In light of the gravity of problem induced by the seasonally skewed high tourist flow with its likely adverse environmental and ecological impacts, it has become imperative to assess the maximum threshold limits of average daily tourist carrying capacity of the area which could serve as an important input for devising a planning strategy towards the regulation of daily and monthly tourist flow. However the tourist carrying capacity has been assessed only for the months of summer season as the tourist flow during the winter season remains significantly low that needs to be improved in order to make an optimum use of tourism potential of Pahalgam valley. The magnitude and intensity of stress due to tourist flow has been analyzed through tourist user density and daily average carrying capacity considered as complementary measurements which have revealed the following scenario.

6.11.1. User Density

User density is an important indicator of anthropogenic load on the landscape of tourist regions especially in mountainous areas where the tourist population for a particular day exceeds than the total inhabited population. It is defined as the number of users per hectare of available land. The users include the local resident population, tourist population and the seasonal workers associated with tourism. The user density has been worked out for PDA area as it acts as the main tourist bowl for recreation as well as yatra. The available area has been taken as all the PDA area from Batkut to Aru and Laripora to Frislan excluding forest area, Barren lands and Scrub lands. The total available area was calculated as 893 hectares. The monthly user density was calculated by using the following equation:

UD = (Pt+ Pr + Ps)/AD……………………. (1), Where,

UD = user density; Pt = tourist population; Pr = resident population (locals); Ps = seasonal population under tourist service and Ad = area at disposal.

The analysis of table 8.20 has revealed that the user density increases as the year progresses up to July where it touches the highest of 47.4 users per hectare per day and decreases towards the end of the year. The highest user density in July is because of the tremendous yatra flow which is certainly beyond the carrying capacity of the region. The user density also varies greatly within a month. It is found that the tourist flow is highest on weekends when thousands of local tourists visit Pahalgam and disrupt the whole calm, pleasantness and beauty. The user density on weekends goes sometimes above 40 users/hectare and the whole region becomes crowded followed by traffic jams and distasteful experience for the tourists. Thus it is necessary to regulate tourist flow on the daily basis in order to achieve sustainable tourism development.

Table 6.23: User density at Pahalgam, 2011

S. No.	Month	Average Tourist Flow/Day	Local Resident Population	Seasonal Working Population	Area available (hectares)	Users/ha/ day	Users/km^2/day
1	**January**	51	18254	450	893	21.0	2100
2	**February**	69	18254	600	893	21.2	2119
3	**March**	303	18254	2500	893	23.6	2358
4	**April**	689	18254	3800	893	25.5	2547
5	**May**	3343	18254	5100	893	29.9	2990
6	**June**	7630	18254	7267	893	37.1	3712
7	**July**	16000	18254	8053	893	47.4	4738
8	**August**	4700	18254	8000	893	34.7	3466
9	**September**	504	18254	5000	893	26.6	2660
10	**October**	1017	18254	3200	893	25.2	2516
11	**November**	441	18254	797	893	21.8	2183
12	**December**	193	18254	573	893	21.3	2130

Source: Compiled from land use data and tourist flow statistics

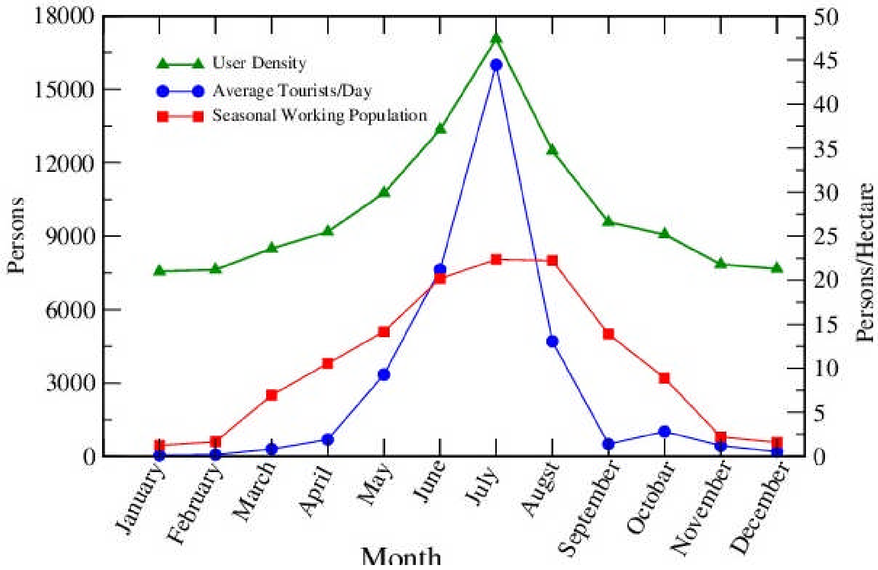


Fig. 6.23: Monthly variation in user density at Pahalgam, 2011

6.11.2. Carrying Capacity

The concept of carrying capacity was initially developed in the fields of range and wildlife management and was based on the notion that an organism can survive only within a limited range of physical conditions (Carey, 1993). Concerns about the ability of parks and protected areas to absorb tourists and their impacts developed initially in the 1930's. Following large increases in visitation to national parks and forests, there were increased calls for managing the apparently crowded conditions in tourist destinations (Clawson, 1963). As knowledge and management experiences grew, definitions of recreational and tourism carrying capacity also evolved, from the initial two primary types (biophysical and social) to include a 'facilities' capacity and others. Recreational carrying capacity came to be defined as the amount of recreational use allowable by an area's management objectives. This definition leads to two fundamental conclusions: (1) there is no such thing as an intrinsic or innate carrying capacity; and (2) an area may have multiple capacities, depending upon what objective is articulated for the area. The assessment of carrying capacity is used as a sign of tourism impact on space and the environment. It represents an important component of planning spatial development in tourism and is one of the mechanisms for establishing standards for sustainable tourism.

Carrying capacity can be defined as a maximum number of tourists that sojourn in a specific area and use its contents in a way that does not induce unacceptable and irreversible change in the environmental, social, cultural and economic structure of the destination nor does it decrease the quality of tourist experience. World Tourism Organization has defined tourism carrying capacity as "the maximum number of persons which could visit a location within a given period, such that local environmental, physical, economic and socio-cultural characteristics are not compromised, and without reducing tourist satisfaction" (World Tourism Organization, 1999). Thus carrying capacity is the threshold of the tourist activity beyond which facilities are saturated (physical capacity), the environment is degraded (environmental capacity) or visitors enjoyment is diminished (perceptual or psychological capacity).

Tourism activities can generate both positive and negative effects on the conditions of the areas where visiting and fruition activities take place; every form of human activity causes changes of environmental conditions; the purpose of the evaluation of carrying capacity of a destination is the measurement of the threshold over which alteration due to human activities becomes unacceptable for the resource recovery. The rapid but unplanned tourism activities at Pahalgam have been creating various social and environmental concerns. If appropriate planning measures are not derived from the consideration of the carrying capacities, it will be overloaded, tourism quality will be degraded and therefore the benefit obtained from tourism activities will be reduced.

The present framework attempts to establish the maximum number of visitors that an area can have based on the physical, biological and management conditions of the area, considering three main levels: the physical carrying capacity (the maximum number of visitors that can physically fit into a defined area over a particular time) and the effective or permissible carrying capacity (the maximum permissible number of visits to a specific site, once correction factors derived from the particular characteristics of the site and the management capacity have been applied to the physical carrying capacity) (Cifuentes et al., 1999). To apply this method, it is important to consider the size of the area, the optimum space available for each tourist to move freely and the visiting time (Cifuentes, 1992).

Based in this model, the physico-ecological carrying capacity was determined by the equation:

PCC = (A/Au) x 100………………………… **(2)**

Where PCC is the physical carrying capacity, A is the size of the study/visited area or the area available for recreation, Au is the area available per user or the minimum area per tourist so that the tourist does not feel uncomfortable or crowding and Rf is the rotation factor.

The total area available for recreation in Pahalgam is 4.4 lac m^2 while the minimum area required for recreation is taken as 20 m^2/tourist. The rotation factor is calculated as the ratio of open hours for recreation and duration of the visit. Since the tourists who visit Pahalgam stay there for a day or more and hence the rotation factor is taken as 1.

ERCC = PCC X (cf1 x cf2 x cf3 x…………………..x cfn)………………. **(3)**

Where ERCC is the effective real carrying capacity, PCC is the physical carrying capacity and cf1…..cfn are the correction factors determined using the Equation

Cfx = 1- (Lmx/Tmx) ………………………………… **(4)**

Where Cfx is the correction factor of variable x, Lmx is the limiting magnitude of variable x and Tmx is the total magnitude of variable x. Considering that tourism is dependent upon environmental attributes, six correction or limiting factors (temperature, Precipitation, infrastructure, transport, management and perception) were considered for this study because of their limiting power in the tourism activity, facility of analysis and because of enabling the measurement of the sustainability level of a tourist destination.

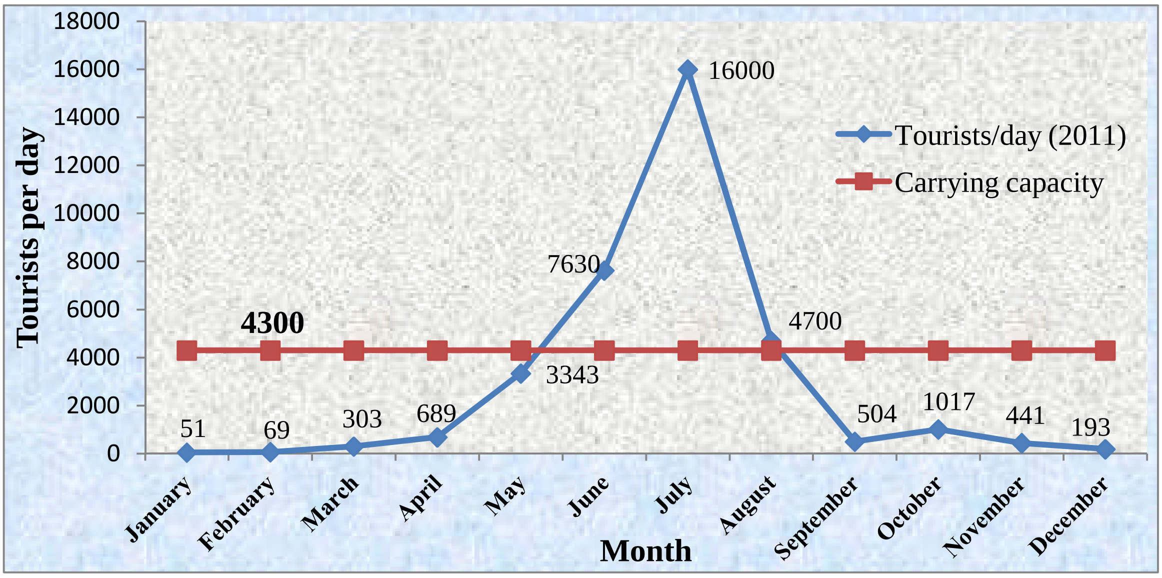


Fig. 6.24: Average daily tourist flow and carrying capacity of Pahalgam, 2011

Using different values of distinct correction factors and parameters in equation 2, 3 and 4, the effective real carrying capacity or the maximum number of people that should be permitted to visit Pahalgam must not exceed 4300 tourists/day. The most important thing is to regulate tourism in a way such that the carrying capacity is not exceeded. There are large variations in the tourist flow to Pahalgam. There are days with a few hundred of tourists visiting Pahalgam and days when we can find thousands of tourists on a single day. The seasonality of tourism at Pahalgam (fig. 6.24) is the main reason for environmental degradation. Thus we must regulate tourist flow on daily basis as per the daily carrying capacity of 4300 tourists/day. The available accommodation at Pahalgam is already more than 5000 beds which mean that we need not to construct any more hotels as the carrying capacity is only 4300 tourists/day. The need of the hour is to manage solid as well as liquid waste scientifically which will not only help in reducing the environmental degradation at Pahalgam but could also help in increasing its carrying capacity.

It is evident from figure 6.24 that the tourist flow to Pahalgam is well below the carrying capacity for most part of the year. The flow considerably exceeds the threshold carrying capacity numbers in the months of June and July which coincides with the timing of Amarnath yatra. Therefore it is imperative to reduce the flow of tourists as per the carrying capacity during these months and develop tourist activities for winter season so that the seasonality of tourism is reduced and the marginality of tourist associated employment is overcome. In summer months the tourist flow must be regulated on daily basis in order to make it compatible with the average daily tourist carrying capacity of the area.

CHAPTER - 7

LAND USE LAND COVER DYNAMICS

Land is one of the most important natural resources. All agricultural, animal and forestry productions depend on the productivity of the land. The entire ecosystem of the land, which comprises of soil, water and plant, meets the community demand for food, energy and other livelihood needs. Land use plays a vital role in the earth system: it links human decision making to the terrestrial environment and is both driver and target of global environmental change. However, decisions about how much land to use, where and for what purpose and the related consequences are still poorly understood. This deficit is in contrast to the fundamental need for future LULC change analysis to answer pressing questions of future food security, biodiversity and climate mitigation and adaptation. The LULC pattern of a region is an outcome of both natural and socio-economic factors and their utilization by man in time and space. Land is the most important natural resources on which all activities are based. Land cover is a fundamental variable that impacts and links many parts of the human and physical environments.

Land use denotes the human employment of the land and is a synthesis of physical, chemical and biological systems and processes on the one hand and human/social processes and behavior on the other (Meyer and Turner, 1994) while land cover denotes the physical and biotic character of the land surface (Turner-II and Meyer, 1991; Lambin et al., 2001). Land use is the intended employment and management strategy placed on the land cover by human agents, or land managers to exploit the land cover and reflects human activities such as industrial zones, residential zones, agricultural fields, grazing, logging and mining among many others. On the other hand, land cover is defined by the attributes of the earth's land surface captured in the distribution of vegetation, water, desert and ice and the immediate subsurface, including biota, soil, topography, surface and groundwater, and it also includes those structures created solely by human activities such as mine exposures and settlement (Lambin et al., 2003; Meyer and Turner, 1994). Land use links land cover to the human activities that transform the land.

7.1. LAND USE LAND COVER ANALYSIS - 1961

The LULC analysis of the study has been carried out for four time periods focusing on the years of 1961, 1992, 2001 and 2010 covering a period of 50 years. The said time periods have been selected keeping in view the temporal coverage representation and the availability of the relevant remote sensing data. The LULC analysis of the study area for the year 1961 revealed nine LULC classes (fig. 7.1). Forest was the dominant land cover type in the catchment with 612.7 km^2 which constituted more than 52 percent of the total catchment area. Dense forests covered 29.71 per cent while sparse forests occupied 23.13 per cent of the total area. Agriculture constituted 16.21 per cent while waste lands accounted for 13.34 per cent of the total catchment area. Glaciers are spread over an area of 3.66 per cent while meadows covered 3.11 per cent of the total area (table 7.1). The area under scrub lands was 8.8 percent while water bodies occupied 1.53 percent of the total catchment area. The area under built-up constituted only 0.5 per cent of the total area (fig. 7.2).

Table 7.1: Watershed wise area under different LULC categories of Lidder catchment, 1961

Watershed	Land use land cover category (Area in km^2)									Total Area
	Built-up	Water bodies	Dense forests	Sparse forests	Agriculture	Waste lands	Meadows	Glacier	Scrub	
1E7A1	2.23 (1.29)	5.41 (3.12)	30.62 (17.67)	14.65 (8.46)	106.4 (61.42)	8.09 (4.67)	2.09 (1.21)	0 0.00	3.75 (2.16)	**173.24 (100.00)**
1E7A2	0.93 (1.27)	0.99 (1.35)	42.13 (57.60)	5.34 (7.30)	10.2 (13.95)	2.91 (3.98)	3.16 (4.32)	0 0.00	7.48 (10.23)	**73.14 (100.00)**
1E7A3	0 0.00	1.74 (2.67)	28.22 (43.36)	13.04 (20.04)	0 0.00	8.94 (13.74)	1.9 (2.92)	0 0.00	11.24 (17.27)	**65.08 (100.00)**
1E7A4	0 0.00	0.26 (0.64)	4.55 (11.25)	12.72 (31.44)	0 0.00	12.76 (31.54)	3.72 (9.19)	0 0.00	6.45 (15.94)	**40.46 (100.00)**
1E7A5	0 0.00	0.99 (1.27)	11.56 (14.81)	32.3 (41.37)	0 0.00	17.55 (22.48)	4.63 (5.93)	0 0.00	11.04 (14.14)	**78.07 (100.00)**
1E7A6	0 0.00	0.58 (0.45)	16.93 (13.09)	39.75 (30.73)	0 0.00	20.76 (16.05)	7.02 (5.43)	13.18 (10.19)	31.14 (24.07)	**129.36 (100.00)**
1E7A7	0.12 (0.16)	0.62 (0.80)	27.36 (35.45)	23.16 (30.00)	0.26 (0.34)	6.63 (8.59)	3.2 (4.15)	5.2 (6.74)	10.64 (13.78)	**77.19 (100.00)**
1E7B1	0.51 (0.22)	2.94 (1.29)	49.63 (21.72)	83.47 (36.53)	1.37 (0.60)	54.31 (23.77)	7.62 (3.33)	21.62 (9.46)	7.05 (3.09)	**228.52 (100.00)**
1E7B2	0 0.00	0.63 (1.18)	25.15 (47.02)	12.28 (22.96)	0.79 (1.48)	6.77 (12.66)	1.26 (2.36)	2.49 (4.66)	4.12 (7.70)	**53.49 (100.00)**
1E7B3	0.42 (0.54)	1.03 (1.31)	34.48 (44.00)	21.93 (27.99)	3.57 (4.56)	8.45 (10.78)	1.45 (1.85)	0 0.00	7.03 (8.97)	**78.36 (100.00)**
1E7B4	1.55 (0.95)	2.57 (1.58)	73.87 (45.47)	9.56 (5.88)	65.31 (40.20)	7.52 (4.63)	0 0.00	0 0.00	2.09 (1.29)	**162.47 (100.00)**
Lidder catchment	**5.76 (0.50)**	**17.76 (1.53)**	**344.5 (29.71)**	**268.2 (23.13)**	**187.9 (16.21)**	**154.69 (13.34)**	**36.05 (3.11)**	**42.49 (3.66)**	**102.03 (8.80)**	**1159.38 (100.00)**

Source: Generated from Survey of India toposheets (1961)
Note: Figures in parenthesis indicate percentage area to total area

The watershed wise analysis (table 7.1) has revealed that in watershed 1E7AI, agriculture constituted the dominant land use covering 61.42 per cent of the total watershed area followed by dense forests (17.67 per cent), sparse forests (8.46 per cent) and waste lands (4.67 per cent). The area under built-up occupied 2.23 km^2 (1.29 per cent) which was the highest land area under built-up category of all the watersheds in the catchment. Water bodies constituted 3.12 per cent which was also highest of all the watersheds in the catchment while meadows constituted only 1.2 per cent (Fig. 4.3). The area under scrub lands was 2.16 percent.

In watershed 1E7A2, dense forests were the dominant land cover type (59.88 per cent) followed by agriculture, scrub and sparse forest with the percentage share of 13.95, 10.23 and 7.3 respectively. Dense forest was the dominant type in this watershed as compared to all other watersheds in the catchment. Water bodies constituted 1.35 per cent while built-up occupied only 1.27 per cent of the total area.

The watershed 1E7A3 was an uninhabited one. The forest cover constituted more than 63 per cent of the total area with dense forest comprising 43.36 per cent and sparse forests covering 20.04 per cent of the total area. Scrub lands also comprised a significant proportion of 17.27 per cent followed by waste lands with 13.74 per cent of the total catchment area. Water bodies and meadows constituted 2.67 per cent and 2.92 per cent of the area respectively with no glaciers.

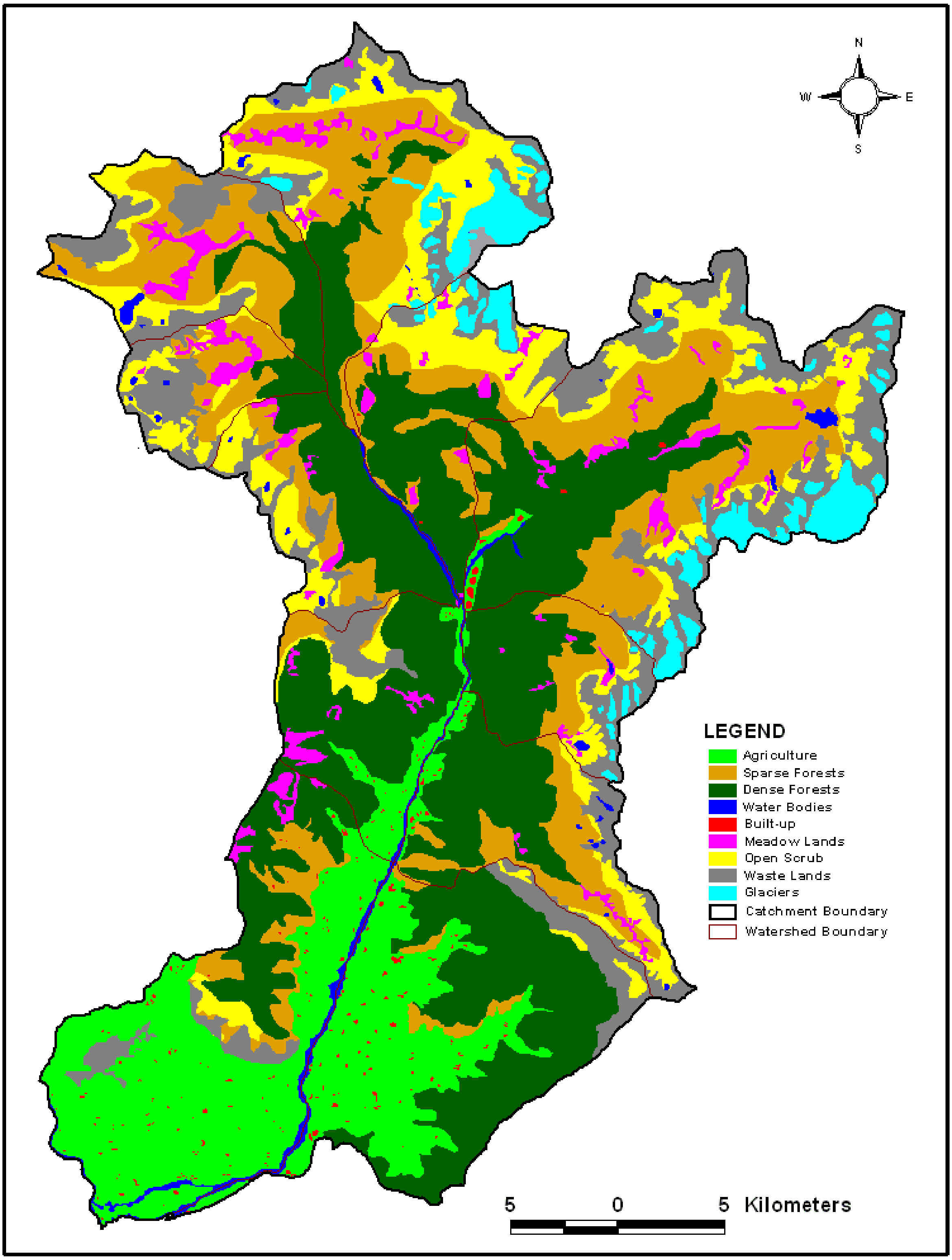
The watershed 1E7A4 was also an uninhabited one with no area under agriculture. The dominant land cover was waste lands followed by sparse forest, scrub and dense forests covering 31.54 per cent, 31.44 per cent, 15.94 percent and 11.25 per cent of the total watershed area respectively. The highest percentage of meadows (9.19 percent) among all the watersheds was found in this watershed. Water bodies constituted only 0.64 per cent while there was no glacier in this watershed.

The watershed 1E7A5 was an uninhabited watershed with no agriculture and glacial area. Sparse forest (41.37 per cent) was the dominant land cover type followed by waste lands (22.48 percent). The dense forests and scrubs covered almost equal percentage area of 14.81 and 14.14 respectively. The area under water bodies was the least land cover type covering only 1.27 per cent while meadows constituted 5.93 percent of the total watershed area.

The watershed 1E7A6 was also an uninhabited watershed with no area under agriculture. Sparse forests (30.73 per cent) and scrub (24.07 per cent) were the dominant land cover type. Waste lands and dense forests also occupied significant proportions of the total watershed area with 16.05 per cent and 13.09 per cent respectively. Meadows constituted 5.43 per cent while water bodies occupied only 0.45 per cent.

The watershed 1E7A7 was a forested watershed where more than 65 percent of the total area was under forests. The dense forests constituted 35.45 percent while sparse forests covered 30 percent of the total watershed area. The other dominant land cover categories were scrub and waste lands which occupied 13.78 percent and 8.59 percent of the total watershed area respectively. Meadows covered 4.15 per cent while the area under built-up was lowest with only 0.12 km^2 (0.16 percent).

LIDDER CATCHMENT
LAND USE LAND COVER (1961)



Source: Generated from Survey of India toposheets, 1961

Fig. 7.1

In the watershed 1E7B1, sparse forests was the dominant land cover type (36.53 per cent) followed by waste lands (23.77 per cent) and dense forests (21.72 per cent). This watershed covered the highest area under glaciers (21.62 km^2) and meadows (7.62 km^2) in Lidder catchment. The area under water bodies constituted 1.29 percent while scrubs constituted 3.09 percent of the total watershed area.

The watershed 1E7B2 was an uninhabited one but agriculture constituted 1.48 per cent of the total area which was practiced by the people living in adjoining watersheds. Dense forest was the dominant land cover type (47.02 per cent) followed by sparse forests (22.96 per cent). Waste lands constituted 12.66 per cent followed by scrub, glacier, meadows covering 7.7 per cent, 4.66 per cent and 2.36 per cent respectively.

In the watershed 1E7B3 about 72 per cent of the area was under forest cover, of which dense forests constituted 44 per cent and sparse forests constituted 27.99 per cent. Waste lands, the third dominant category covered 10.78 per cent followed by scrubs (8.97), agriculture (4.56 per cent), meadows (1.85 per cent), water bodies (1.31 per cent) and built-up (0.54 per cent).

In the watershed 1E7B4, dense forests were the dominant land cover type with 45.47 per cent of the total watershed area. Agriculture accounted for more than 40 per cent of area while sparse forests occupied 5.88 percent followed by waste lands (4.63 per cent), water bodies (1.58 per cent) and built-up (0.95 per cent).

The highest absolute as well as percentage of built-up area 2.23 km^2 (2.5 per cent), water bodies 5.41 km^2 (3.12 per cent) and agriculture 106.4 km^2 (60.20 per cent) was found in the watershed 1E7A1. The highest percentage of dense forests (57.6 per cent) was found in the watershed 1E7A2 while the highest area under dense forests (49.63 km^2) was found in watershed 1E7B1. The highest percentage of sparse forests (41.37 per cent) was found in the watershed 1E7A5 with the highest area under sparse forests 83.47 km^2 in watershed 1E7B1. The highest percentage of meadows (9.19 percent) and wastelands (31.54 percent) was found in water 1E7A4. The watershed 1E7B1 occupied the highest area of five out of nine land cover classes only because of the fact that the watershed is largest in area as compared to other watersheds in the catchment.

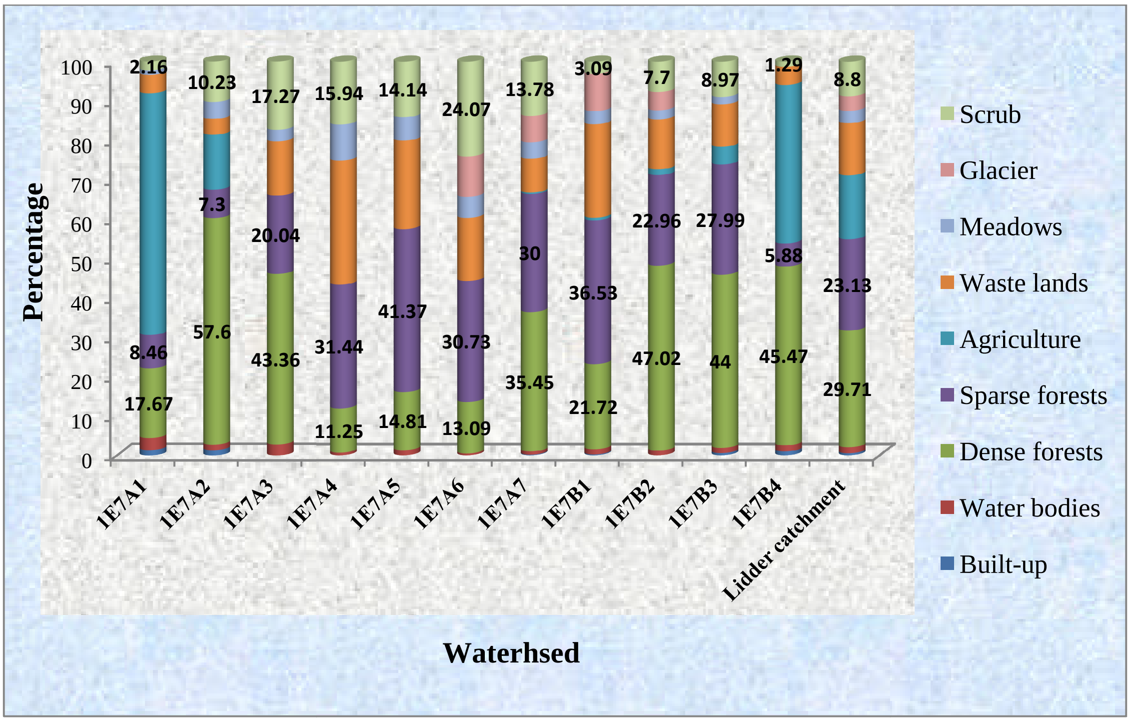


Fig. 7.2: Watershed wise area under different LULC classes in Lidder catchment, 1961.

7.2. LAND USE LAND COVER ANALYSIS - 1992

The LULC classification of the study area for the year 1992 revealed ten LULC classes (fig. 7.3). Forest was the dominant land cover type covering 538.4 km^2 (46.44 per cent) of the total catchment area with sparse forests covering 26.28 per cent and dense forests covering 20.16 per cent. Waste land was the other dominant land cover type with 20.4 per cent of the total catchment area. The area under cultivation was 17.11 percent (198.32 km^2) with agriculture being practiced on 13.95 percent and horticulture on 3.16 percent of the total catchment area (table 7.2). The area under scrub was 95.8 km^2 which constituted 8.26 percent of the total catchment area. Glaciers and meadows respectively occupied 2.78 percent and 2.57 percent while water bodies and built-up covered 1.41 percent and 1.03 percent respectively.

The watershed wise analysis presented in table 7.2 has revealed that in watershed 1E7A1 agriculture was the dominant land use being practiced on 50.46 percent of the total watershed area while horticulture covered 12.86 percent. Thus the cultivated area constituted more than 73 percent of the total watershed area. Sparse forests and dense forests were the other dominant land cover categories covering 13.51 percent and 10.7 percent of the total watershed area. Waste lands covered 3.81 percent while water bodies covered 3.08 percent of the total watershed area. The area under built-up category was significant in this watershed as it covered 3.6 percent of the total watershed area which was the highest percentage of built-up category in any watershed of the catchment.

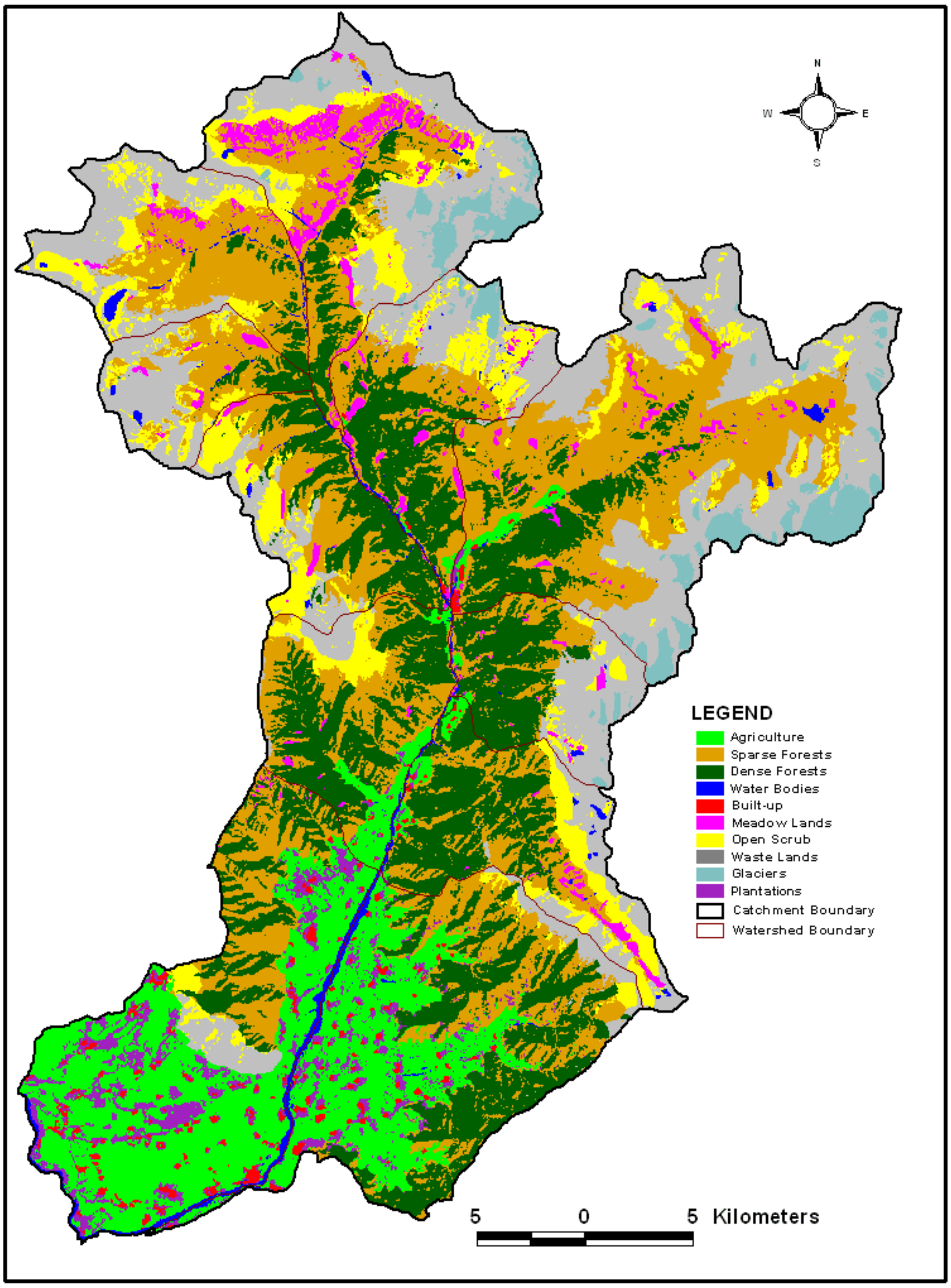
The watershed 1E7A2 was dominated by forests covering more than 67 percent of the total watershed area with dense forests covering 42.08 percent and sparse forests covering 25.16 percent. Agriculture was practiced on 14.19 percent and horticulture covered 2.13 percent (fig. 7.4). Scrub was the other dominant land cover class (7.92 percent) followed by waste lands (5.69 percent). The area under built-up covered 1.64 percent and water bodies covered only 0.53 percent while glaciers were nonexistent.

Table 7.2: Watershed wise area under different LULC categories of Lidder catchment, 1992

Watershed	Land use land cover category (Area in km^2)										Total Area
	Built-up	Water bodies	Dense forests	Sparse forests	Agriculture	Horticulture	Waste lands	Meadows	Glacier	Scrub	
1E7A1	6.24 (3.60)	5.33 (3.08)	18.53 (10.70)	23.40 (13.51)	87.43 (50.46)	22.28 (12.86)	6.61 (3.81)	0.31 (0.18)	0.00 0.00	3.11 (1.80)	173.24 (100)
1E7A2	1.20 (1.64)	0.39 (0.53)	30.78 (42.08)	18.40 (25.16)	10.38 (14.19)	1.56 (2.13)	4.16 (5.69)	0.48 (0.66)	0.00 0.00	5.79 (7.92)	73.14 (100)
1E7A3	0.00 0.00	0.71 (1.09)	20.26 (31.13)	20.43 (31.39)	0.00 0.00	0.00 0.00	10.28 (15.80)	1.35 (2.07)	0.00 0.00	12.05 (18.52)	65.08 (100)
1E7A4	0.00 0.00	0.45 (1.11)	3.52 (8.70)	12.8 (31.64)	0.00 0.00	0.00 0.00	16.65 (41.15)	1.22 (3.02)	0.00 0.00	5.82 (14.38)	40.46 (100)
1E7A5	0.00 0.00	1.52 (1.95)	3.97 (5.09)	31.78 (40.71)	0.00 0.00	0.00 0.00	25.41 (32.54)	2.23 (2.86)	0.00 0.00	13.16 (16.85)	78.07 (100)
1E7A6	0.00 0.00	0.89 (0.69)	10.73 (8.29)	30.1 (23.28)	0.00 0.00	0.00 0.00	46.47 (35.92)	13.42 (10.37)	10.17 (7.86)	17.58 (13.59)	129.36 (100)
1E7A7	0.23 (0.30)	0.98 (1.27)	23.14 (29.97)	20.03 (25.95)	0.49 (0.63)	0.12 (0.16)	16.05 (20.79)	3.34 (4.33)	2.91 (3.77)	9.9 (12.83)	77.19 (100)
1E7B1	0.62 (0.27)	1.18 (0.52)	25.57 (11.19)	87.87 (38.44)	2.71 (1.19)	0.56 (0.25)	74.87 (32.76)	4.17 (1.82)	18.07 (7.91)	12.9 (5.65)	228.52 (100)
1E7B2	0.00 0.00	0.48 (0.90)	21.12 (39.48)	8.98 (16.79)	0.33 (0.62)	0.07 (0.13)	17.68 (33.05)	1.07 (2.00)	1.05 (1.96)	2.71 (5.07)	53.49 (100)
1E7B3	0.44 (0.56)	1.53 (1.95)	29.5 (37.65)	17.42 (22.23)	2.9 (3.70)	0.4 (0.51)	12.4 (15.82)	2.23 (2.85)	0 0.00	11.54 (14.73)	78.36 (100)
1E7B4	3.26 (2.01)	2.87 (1.77)	46.56 (28.66)	33.51 (20.63)	57.48 (35.36)	11.61 (7.15)	5.94 (3.66)	0 0.00	0 0.00	1.24 (0.76)	162.47 (100)
Lidder catchment	**11.99 (1.03)**	**16.33 (1.41)**	**233.68 (20.16)**	**304.72 (26.28)**	**161.72 (13.95)**	**36.60 (3.16)**	**236.52 (20.40)**	**29.82 (2.57)**	**32.20 (2.78)**	**95.80 (8.26)**	**1159.38 (100)**

Source: Computed from Land Sat ETM satellite image, September, 1992
Note: Figures in parenthesis indicate percentage area to total area

LIDDER CATCHMENT
LAND USE LAND COVER (1992)



Source: Generated from Land Sat ETM satellite image, September, 1992

Fig. 7.3

In watershed 1E7A3, the sparse forests and dense forests covered almost equal area of 31.39 percent and 31.13 percent respectively. Scrubs constituted 18.52 percent while waste lands covered 15.80 percent of the watershed area. This is an uninhabited watershed with no built-up, agriculture or horticulture.

The watershed 1E7A4 is an uninhabited watershed with no built-up, agriculture, horticulture and glaciers. Waste lands were the dominant land cover category (41.15) followed by sparse forests (31.64). A significant proportion (14.38 percent) was devoted to scrub lands while dense forests covered 8.7 percent. In the watershed 1E7A5, sparse forests were the dominant land cover category (40.71) followed by waste lands (32.54). Scrub lands covered 16.85 percent while dense forests covered 5.09 percent. This is also an uninhabited watershed with no land use under agriculture, horticulture and glaciers.

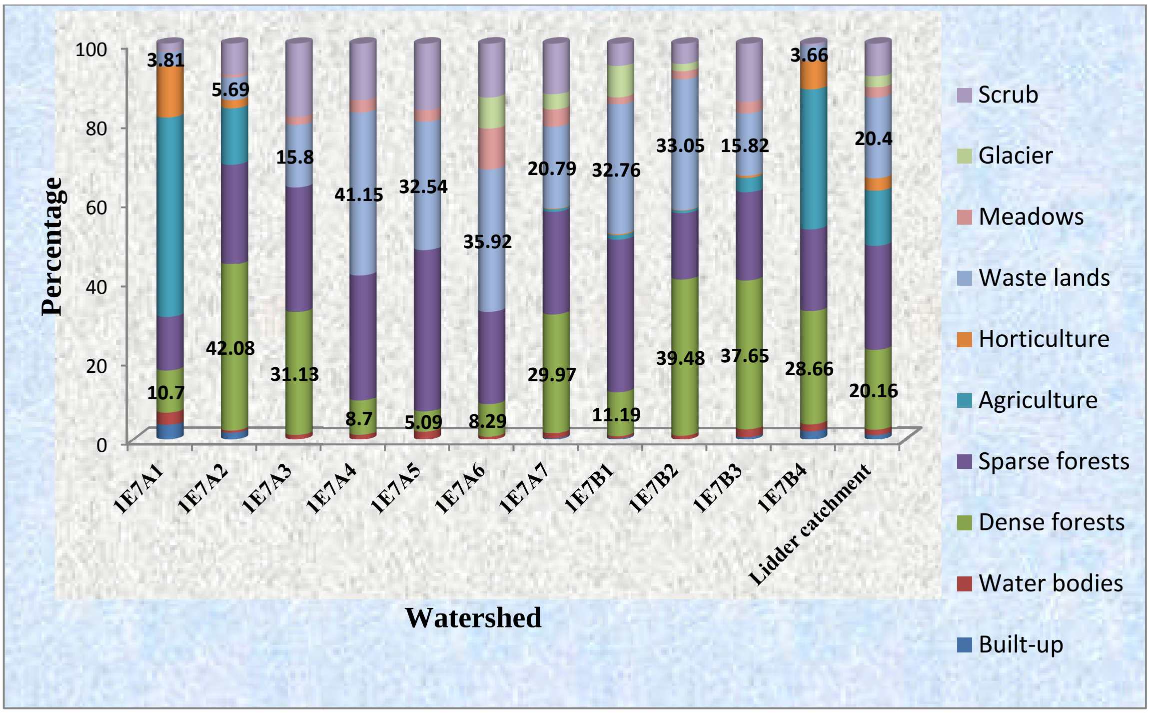


Fig. 7.4: Watershed wise area under different LULC classes in Lidder catchment, 1992.

The watershed 1E7A6 is an uninhabited watershed with the highest percentage of area under wastelands (35.92 percent) followed by sparse forests (23.28 percent) and scrubs (13.59 percent). Glaciers constituted a significant proportion of 7.86 percent while the highest percentage of meadows (10.37 percent) was found in this watershed.

The watershed 1E7A7 was dominated by dense forests (29.97 percent) followed by sparse forests (25.95 percent), wastelands (20.79 percent) and scrub (12.83 percent). Meadows constituted 4.33 percent while glaciers constituted 3.77 percent. Built-up, agriculture and horticulture together constituted slightly more than one percent of the total watershed area.

The watershed 1E7B1 was dominated by sparse forests (38.44 percent) followed by waste lands (32.76 percent) and dense forests (11.19 percent). Glaciers constituted a significant proportion of 7.91 percent while scrubs constituted 5.65 percent. The area under meadows was 1.82 percent while water bodies and built-up together constituted less than one percent of the total watershed area.

The watershed 1E7B2 was an uninhabited watershed dominated by dense forests (39.48 percent) followed by waste lands (33.05 percent) and sparse forests (16.79

percent). However agriculture was being practiced by the people living in adjoining watersheds on 0.62 percent of the total watershed area while horticulture constitutes 0.13 percent. Scrubs covered 5.07 percent while meadows and glaciers covered almost equal proportion of 2 percent and 1.96 percent respectively.

The watershed 1E7B3 was dominated by dense forests (37.65 percent) and sparse forests (22.23 percent) followed by waste lands (15.82 percent) and scrub (14.73 percent). Agriculture was practiced on 3.7 percent and horticulture on 0.51 percent while meadows covered 2.85 percent of the total watershed area.

The watershed 1E7B4 was predominantly an agricultural watershed with 35.36 percent of its area under agriculture and 7.15 percent under horticulture. Dense forests covered 28.66 percent while sparse forests covered 20.63 percent of the total watershed area. Waste lands covered 3.66 percent while scrub lands covered only 0.76 percent with no glaciers and meadows. The area under built up category covered a significant proportion of 2.01 percent.

The highest absolute as well as percentage area of built-up 6.24 km^2 (3.6 percent), water bodies 5.33 km^2 (3.08 percent), agriculture 87.43 km^2 (50.46 percent) and horticulture 22.28 km^2 (12.86 percent) was found in watershed 1E7A1. Dense forests were most widespread (46.56 km^2) in watershed 1E7B4 while their highest concentration was found in watershed 1E7A2 (42.08 percent). Highest area and percentage of sparse forests 87.87 km^2 (38.44 percent) and glaciers 18.07 km^2 (7.91 percent) were found in watershed 1E7B1 with the highest area of waste lands (74.87 km^2). However, the highest percentage of waste lands was found in watershed 1E7A4 (41.15 percent). The highest area of meadows (13.42 km^2) with highest percentage (10.37 percent) and highest scrub area (17.58 km2) was found in watershed 1E7A6 while the highest percentage of scrub (18.52 percent) was found in watershed 1E7A3.

7.3. LAND USE LAND COVER ANALYSIS - 2001

The same LULC classification scheme has been followed for the year 2001 and 2010 as applied for 1992 satellite data in order to facilitate a precise overlay and change detection analysis in the catchment. The LULC classification for 2001 (fig. 7.5) has revealed that forest land continued to be the dominant land cover type covering 42.81 per cent of the total catchment area with sparse forests covering 26.11 per cent and dense forests covering 16.7 per cent. Waste land was the other dominant land cover type with 269.08 km^2 which amounted to 23.21 per cent of the total catchment area. Agriculture was being practiced on 11.34 percent while horticulture constituted 5.93 percent of the total catchment area. Scrubs constituted 8.97 percent while meadows, glaciers and water bodies constituted 2.71 percent, 2.23 percent and 1.36 percent respectively. The area under built-up category was 1.44 percent (16.73 km^2).

Table 7.3: Watershed wise area under different LULC categories of Lidder catchment, 2001

Watershed	Land use land cover category (Area in km^2)										Total Area
	Built-up	Water bodies	Dense forests	Sparse forests	Agriculture	Horticulture	Waste lands	Meadows	Glacier	Scrub	
1E7A1	7.89 (4.55)	3.75 (2.16)	14.06 (8.12)	22.86 (13.20)	69.54 (40.14)	45.01 (25.98)	6.83 (3.94)	0.65 (0.38)	0 0.00	2.65 (1.53)	173.24 (100)
1E7A2	1.51 (2.06)	0.79 (1.08)	24.29 (33.21)	23.88 (32.65)	8.17 (11.17)	0.85 (1.16)	6.28 (8.59)	0.37 (0.51)	0 0.00	7 (9.57)	73.14 (100)
1E7A3	0 0.00	0.49 (0.75)	19.57 (30.07)	16.03 (24.63)	0 0.00	0 0.00	12.87 (19.78)	3.1 (4.76)	0 0.00	13.02 (20.01)	65.08 (100)
1E7A4	0 0.00	0.57 (1.41)	2.12 (5.24)	10.94 (27.04)	0 0.00	0 0.00	17.96 (44.39)	1.96 (4.84)	0 0.00	6.91 (17.08)	40.46 (100)
1E7A5	0 0.00	1.57 (2.01)	1.94 (2.48)	27.94 (35.79)	0 0.00	0 0.00	30.05 (38.49)	2.8 (3.59)	0 0.00	13.77 (17.64)	78.07 (100)
1E7A6	0 0.00	1.09 (0.84)	5.74 (4.44)	34.81 (26.91)	0 0.00	0 0.00	49.6 (38.34)	9.56 (7.39)	8.86 (6.85)	19.7 (15.23)	129.36 (100)
1E7A7	0.37 (0.48)	0.58 (0.75)	21.32 (27.62)	22.76 (29.49)	0.73 (0.95)	0.15 (0.19)	18.57 (24.06)	3.85 (4.99)	2.23 (2.89)	6.63 (8.59)	77.19 (100)
1E7B1	1.13 (0.49)	2.12 (0.93)	16.78 (7.34)	78.57 (34.38)	2.81 (1.23)	0.48 (0.21)	85.73 (37.52)	6.14 (2.69)	13.95 (6.10)	20.81 (9.11)	228.52 (100)
1E7B2	0 0.00	0.9 (1.68)	17.58 (32.87)	12.03 (22.49)	0.61 (1.14)	0.08 (0.15)	18.26 (34.14)	0.96 (1.79)	0.86 (1.61)	2.12 (3.96)	53.49 (100)
1E7B3	0.58 (0.74)	1.26 (1.61)	26.27 (33.52)	18.13 (23.14)	3.12 (3.98)	0.82 (1.05)	16.31 (20.81)	1.94 (2.48)	0 0.00	9.93 (12.67)	78.36 (100)
1E7B4	5.16 (3.18)	2.65 (1.63)	43.98 (27.07)	34.73 (21.38)	46.47 (28.60)	21.4 (13.17)	6.62 (4.07)	0.05 (0.03)	0 0.00	1.41 (0.87)	162.47 (100)
Lidder catchment	**16.73 (1.44)**	**15.77 (1.36)**	**193.65 (16.70)**	**302.68 (26.11)**	**131.45 (11.34)**	**68.79 (5.93)**	**269.08 (23.21)**	**31.38 (2.71)**	**25.9 (2.23)**	**103.95 (8.97)**	**1159.38** (100)

Source: Generated from LANDSAT ETM satellite image, September, 2001
Note: Figures in parenthesis indicate percentage area to total area

The analysis of table 7.3 reveals that in watershed 1E7A1, agriculture was the dominant land use covering 40.14 per cent of the total watershed area followed by horticulture (25.98 percent) and sparse forest (13.2 per cent). Built-up constituted a significant proportion of 4.55 per cent which was highest percentage of built-up area in any watershed of the catchment. Meadows and water bodies constituted only 0.38 per cent and 2.16 per cent respectively where as waste lands constituted 3.98 percent of the total watershed area. The area under scrubs was 1.53 percent while glacier was non-existent (fig.7.6).

In the watershed 1E7A2 forests constituted more than 48 percent of the total catchment area with dense forests covering 33.21 percent and sparse forests covering 32.65 percent. The area under scrubs and wastelands was respectively 9.57 percent and 8.59 percent. Meadows covered only 0.51 per cent while built-up covered 2.06 per cent. Water bodies constituted 1.08 per cent of the total watershed area.

The watershed IE7A3 was an uninhabited watershed. Dense forests have been the dominant land cover type (30.07 percent) followed by sparse forests (24.63 percent), scrubs (20.01 percent) and waste lands (19.78 percent). Meadows covered a significant proportion of 4.76 percent while water bodies covered only 0.75 percent of the total watershed area.

The watershed 1E7A4 was also an uninhabited watershed. Waste lands constitute the greatest percentage of 44.39 percent followed by sparse forests (27.04 per cent). Scrubs also covered a significant proportion of 17.08 percent followed by dense forest (5.24 per cent). Water bodies covered only 1.41 percent of the total watershed area.

The watershed 1E7A5 was an uninhabited one with no agriculture and glaciers. The dominant land cover type was waste lands (38.49 per cent) followed by sparse forests, scrub lands, meadows, dense forests and water bodies covering 35.79 per cent, 17.64 per cent, 3.59 per cent and 2.01 per cent respectively.

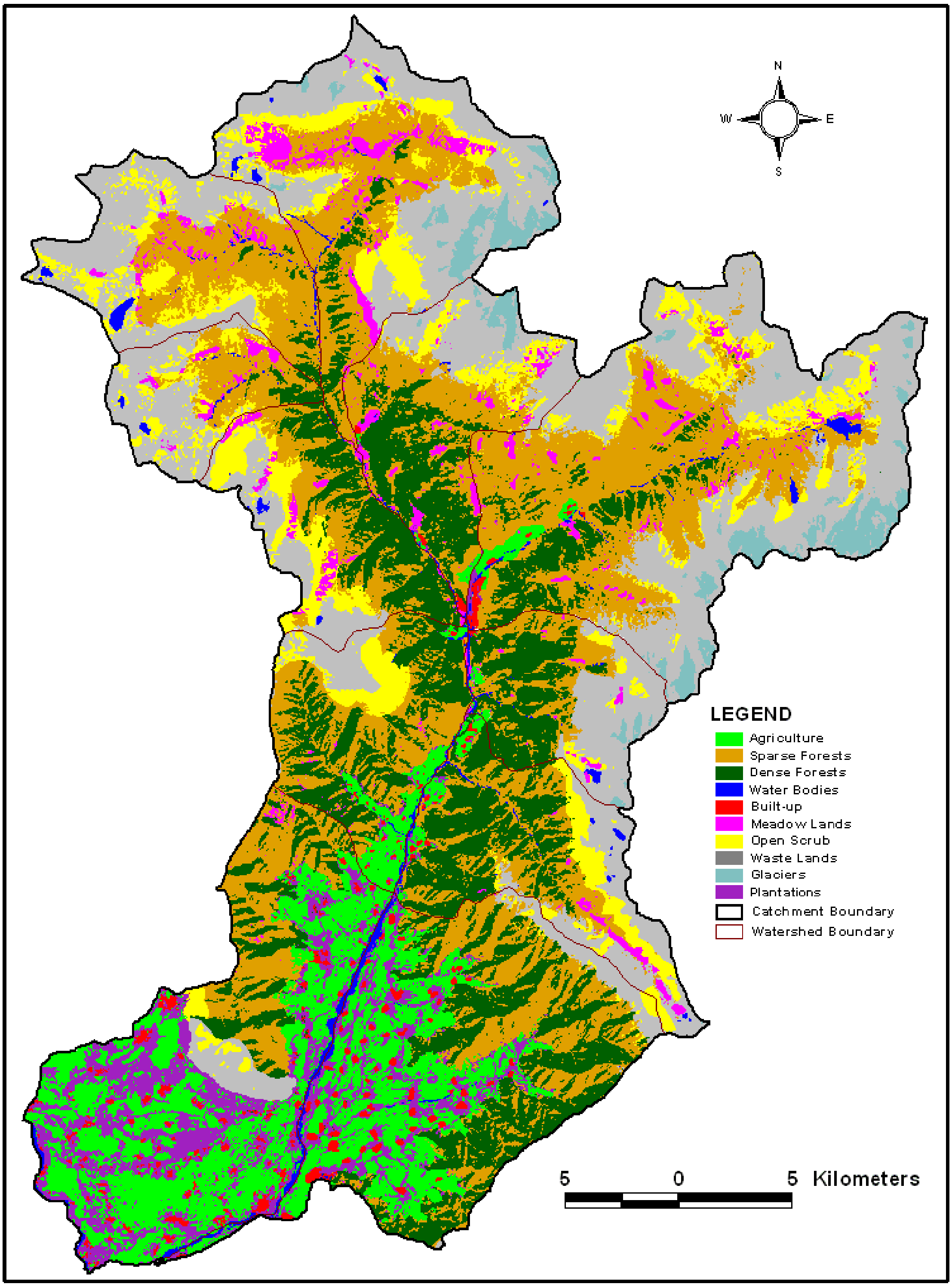
The watershed 1E7A6 is also an uninhabited one with no built-up, agriculture or horticulture. Waste land was the dominant land cover type covering 38.34 per cent followed by sparse forests (26.91 per cent) and scrub lands (15.27 percent). Glaciers covered a significant proportion of 6.85 percent while meadows cover 7.39 percent. The dense forests covered 4.44 percent while water bodies constituted only 0.84 percent of the total watershed area.

In the watershed 1E7A7 sparse forests was the dominant land cover type covering 29.49 per cent of the total watershed area. Dense forests covered 27.62 per cent while waste lands covered 24.06 per cent of the total watershed area. Meadows and glacier also constituted a significant proportion of 4.99 percent and 2.89 percent respectively. Scrubs constituted 8.59 percent while agriculture, horticulture and built-up constituted 0.95 percent, 0.19 percent and 0.48 percent respectively. Water bodies constituted only 0.48 percent of the total watershed area.

The watershed 1E7B1 was dominated by waste lands occupying 37.52 percent of the watershed area followed by sparse forests (34.38 percent) and scrub lands (9.11 percent). Dense forests covered 7.34 percent while glaciers also covered a significant share of 6.1 percent. Agriculture and horticulture constituted 1.23 percent and 0.21 percent respectively while built-up area occupied 0.49 percent.

In the watershed 1E7B2, waste land was a dominant land cover type (34.14 percent) followed by dense forests (32.87 percent) and sparse forests (22.49 per cent). The area under glaciers and water bodies was almost equal with 1.61 per cent and 1.68 percent respectively. The area under scrubs was 3.96 percent while agriculture and horticulture constituted 1.14 percent and 0.15 percent of the total watershed area respectively.

LIDDER CATCHMENT
LAND USE LAND COVER (2001)



Source: Generated from Land Sat ETM satellite image, September, 2001

Fig. 7.5

The watershed 1E7B3 was dominated by dense forests (33.53 percent) followed by sparse forests (23.14 percent) and waste lands (20.81 percent). Scrubs also constituted a significant proportion of 12.67 percent while meadows covered 2.48 percent of the total watershed area. Agriculture was being practiced on 3.98 percent while horticulture covered 1.05 percent. Water bodies covered 1.61 percent while built-up area occupied 0.74 percent of the total watershed area.

The dominant land use type in watershed 1E7B4 was agriculture (28.6 per cent) while horticulture was being practiced on 13.17 percent. Dense forest was the other dominant land cover type covering 27.07 percent followed by sparse forests covering 21.38 percent. The built-up area was significant (3.18 per cent). Waste lands covered 4.07 percent while scrub lands covered only a small percentage of 0.87.

The highest absolute as well as percentage area of built-up (4.55 per cent), water bodies (2.16 per cent), agriculture (40.14 per cent) and horticulture (25.98 percent) were found in watershed 1E7A1. The highest percentage of dense forests (33.52 percent) was found in watershed 1E7B3 while the highest absolute area of dense forests (43.98 km^2) was found in watershed 1E7B4. The highest percentage of sparse forest (35.79 per cent) was found in watershed 1E7A5 while the highest area under sparse forests (78.57 km^2) was in watershed 1E7B1. The highest percentage of glaciers (6.85 per cent) was found in watershed 1E7A6 while the highest glacier area was found in watershed 1E7B1 (13.95 km^2). Waste lands were most widespread (85.73 km^2) in watershed 1E7B1 with the highest percentage found in watershed 1E7A4 (44.39 percent). Scrubs were most dominant in watershed 1E7A3 (20.01 percent) with the highest area in watershed 1E7B1 (20.81 km^2). The highest absolute (9.56 km^2) as well as percentage area under meadows (7.39 percent) was found in watershed 1E7A6.

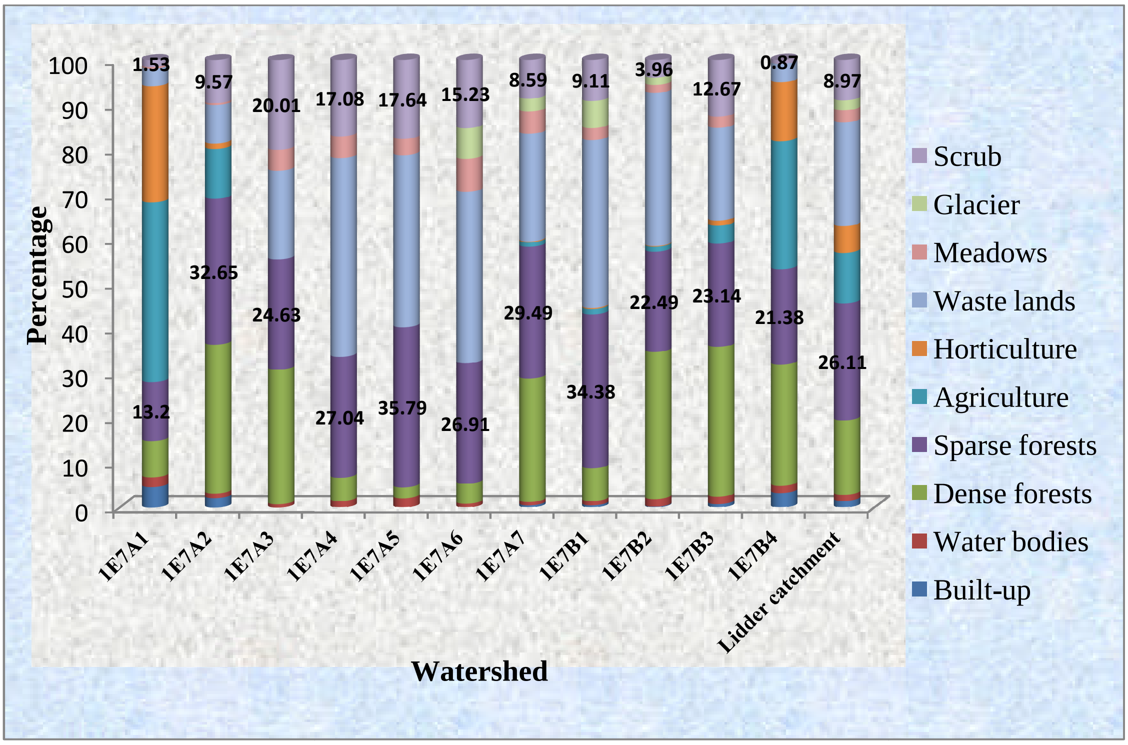


Fig. 7.6: Watershed wise area under different LULC classes in Lidder catchment, 2001

7.4. LAND USE LAND COVER ANALYSIS - 2010

The LULC analysis for the recent period (year 2010) has revealed that Lidder catchment is dominated by forests cover (36.74 percent) with dense forests (plate 7.1) covering 13.19 percent and sparse forests (plate 7.2) covering 23.55 percent. Waste lands (26.5 percent) cover the outer limits of the catchment on north, east and west (fig. 7.7). Agriculture (plate 7.3) is being practiced on 9.77 percent of the total catchment area while horticulture (plate 7.4) covers 7.47 percent of the total catchment area. Scrub lands (plate 7.5) cover 9.94 percent while meadows (plate 7.6) cover 4.2 percent of the total catchment area. The water bodies cover 1.38 percent while 2.22 percent is occupied for residential purposes. Glaciers (plate 7.7) are dotted in the waste lands (plate 7.8) with their maximum concentration towards the north of the catchment.

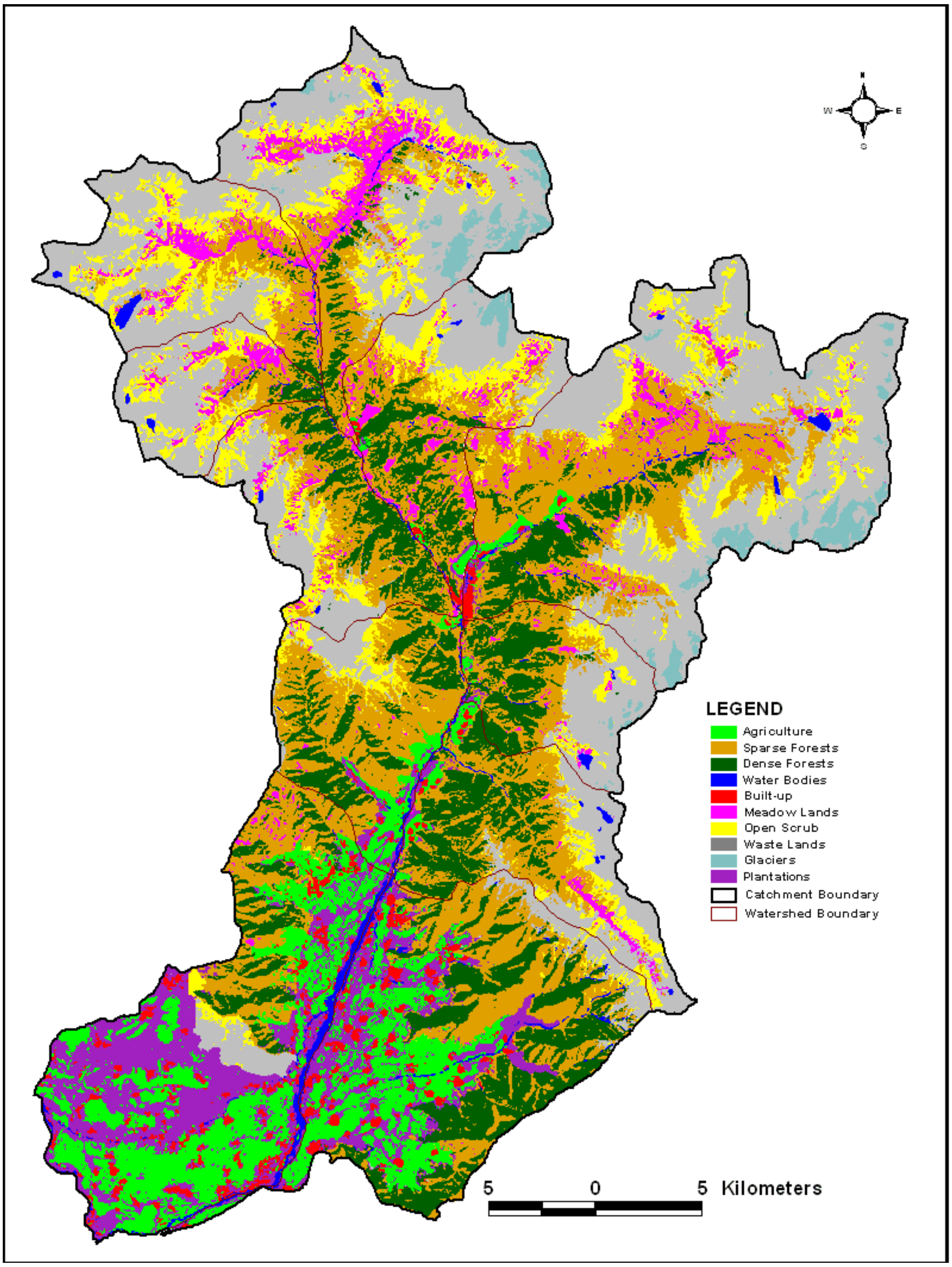
The watershed wise analysis of LULC (table 7.4) has revealed that the watershed 1E7A1 is a human dominated watershed with agriculture being practiced on 35.98 percent and horticulture on 30.95 percent of the watershed area. The area under built-up also occupies a significant proportion (6.56 percent) while water bodies constitute 2.42 percent. Sparse forests and dense forests respectively cover 11.56 percent and 7.11 percent while scrubs and meadows cover 1.17 percent and 0.61 percent respectively.

The watershed 1E7A2 is a forested watershed where 65.78 percent of the total area is under forest cover with dense forests covering 22.08 percent and sparse forests covering 43.7 percent. Waste land is the other dominant land cover category (9.99 percent) followed by scrub lands (7.55 percent) while water bodies cover 1.33 percent. Agriculture is being practiced on 8.31 percent while horticulture area covers 3.94 percent. The area under built-up is also significant covering 2.64 percent of the total watershed area (fig. 7.8).

The watershed 1E7A3 is an uninhabited one and is dominated by sparse forests, waste lands and dense forests cover 30.44 percent, 26.32 percent and 21.85 percent of the total watershed area respectively. Scrub land is the other dominant land cover category covering 15.6 percent while 4.79 percent is under meadows. Exactly one percent of the total area is under water bodies while glaciers are nonexistent.

The watershed 1E7A4 is an uninhabited one dominated by waste lands (48.59 percent) followed by scrubs (20.59 percent) and sparse forests (15.4 percent). Meadows cover 9.37 percent while dense forests cover 4.92 percent of the total watershed area.

LIDDER CATCHMENT
LAND USE LAND COVER (2010)



Source: Generated from IRS P6 LISS III, September, 2010

Fig. 7.7

The watershed 1E7A5 is also an uninhabited watershed with no built-up, agriculture, horticulture and glaciers. It is dominated by waste lands (44.72 percent) followed by scrubs (25.07 percent) and sparse forests (17.36 percent). Dense forests cover the lowest percentage of 2.04 in the catchment while 1.69 percent is covered by water bodies.

Plate 7.1: Dense forests of Lidder catchment

The watershed 1E7A6 is dominated by waste lands (46.34 percent), scrubs (17.34 percent) and sparse forests (15.48 percent). Meadows constitute 10.94 percent which is the highest percentage of meadows in any watershed of the catchment. Dense forests cover only 3.67 percent. Glaciers cover 5.57 percent of the total watershed area while water bodies are spread over only 0.66 percent.

Plate 7.2: Sparse forests of Lidder catchment

The watershed 1E7A7 is dominated by sparse forests (29.81 percent) and waste lands (23.41 percent) while dense forests cover 18.14 percent of the total area. The area under built-up occupies 0.84 percent while agriculture and horticulture respectively cover 1.45 percent and 0.54 percent of the total area. Scrubs constitute a significant share of 15.27 percent while 7.28 percent is under meadows.

The watershed 1E7B1 is dominated by waste lands (43 percent) followed by sparse forests and scrubs which occupy 28.02 percent and 9.95 percent respectively. The area under built-up category occupies 0.85 percent while 1.3 percent and 0.43 percent of the area is devoted to agriculture and horticulture respectively. Sparse forests cover 28.02 percent of the total area while meadows cover 4.56 percent. The area under glaciers is 4.64 percent while only 0.85 percent is under water bodies.

Plate 7.3: Agriculture in Lidder catchment

Plate 7.4: Horticulture in Lidder catchment

The watershed 1E7B2 is dominated by wastelands (34.19 percent) while dense forests and sparse forests cover 26.06 percent and 26.51 percent respectively. Scrub lands cover 6.49 percent of the watershed area while 1.22 percent area is under water bodies and 1.31 percent under glaciers. The area under built-up occupies 0.24 percent of the total area while 1.31 percent and 0.79 percent is devoted to agriculture and horticulture respectively.

Table 7.4: Watershed wise area under different LULC categories of Lidder catchment, 2010

Watershed	Land use land cover category (Area in km^2)										Total Area
	Built-up	Water bodies	Dense forests	Sparse forests	Agriculture	Horticulture	Waste lands	Meadows	Glacier	Scrub	
1E7A1	11.36 (6.56)	4.2 (2.42)	12.31 (7.11)	20.02 (11.56)	62.33 (35.98)	53.61 (30.95)	6.34 (3.66)	1.05 (0.61)	0 0.00	2.02 (1.17)	**173.24 (100)**
1E7A2	1.93 (2.64)	0.97 (1.33)	16.15 (22.08)	31.96 (43.70)	6.08 (8.31)	2.88 (3.94)	7.31 (9.99)	0.34 (0.46)	0 0.00	5.52 (7.55)	**73.14 (100)**
1E7A3	0 0.00	0.65 (1.00)	14.22 (21.85)	19.81 (30.44)	0 0.00	0 0.00	17.13 (26.32)	3.12 (4.79)	0 0.00	10.15 (15.60)	**65.08 (100)**
1E7A4	0 0.00	0.46 (1.14)	1.99 (4.92)	6.23 (15.40)	0 0.00	0 0.00	19.66 (48.59)	3.79 (9.37)	0 0.00	8.33 (20.59)	**40.46 (100)**
1E7A5	0 0.00	1.32 (1.69)	1.59 (2.04)	13.55 (17.36)	0 0.00	0 0.00	34.91 (44.72)	7.13 (9.13)	0 0.00	19.57 (25.07)	**78.07 (100)**
1E7A6	0 0.00	0.86 (0.66)	4.75 (3.67)	20.02 (15.48)	0 0.00	0 0.00	59.95 (46.34)	14.15 (10.94)	7.2 (5.57)	22.43 (17.34)	**129.36 (100)**
1E7A7	0.65 (0.84)	0.43 (0.56)	14 (18.14)	23.01 (29.81)	1.12 (1.45)	0.42 (0.54)	18.07 (23.41)	5.62 (7.28)	2.08 (2.69)	11.79 (15.27)	**77.19 (100)**
1E7B1	1.94 (0.85)	2.21 (0.97)	14.39 (6.30)	64.02 (28.02)	2.96 (1.30)	0.98 (0.43)	98.27 (43.00)	10.41 (4.56)	10.61 (4.64)	22.73 (9.95)	**228.52 (100)**
1E7B2	0 0.00	0.65 (1.22)	13.94 (26.06)	14.31 (26.51)	0.7 (1.31)	0.42 (0.79)	18.29 (34.19)	1.01 (1.89)	0.7 (1.31)	3.47 (6.49)	**53.49 (100)**
1E7B3	0.79 (1.01)	1.02 (1.30)	20.22 (25.80)	22.47 (28.68)	3.75 (4.79)	1.18 (1.51)	19.14 (24.43)	2.1 (2.68)	0 0.00	7.69 (9.81)	**78.36 (100)**
1E7B4	8.95 (5.51)	3.26 (2.01)	39.41 (24.26)	37.77 (23.25)	36.33 (22.36)	27.07 (16.66)	8.13 (5.00)	0 0.00	0 0.00	1.55 (0.95)	**162.47 (100)**
Lidder catchment	**25.75 (2.22)**	**16.03 (1.38)**	**152.97 (13.19)**	**273.04 (23.55)**	**113.27 (9.77)**	**86.56 (7.47)**	**307.2 (26.50)**	**48.72 (4.20)**	**20.59 (1.78)**	**115.25 (9.94)**	**1159.38 (100)**

Source: Computed from IRS P6 LISS III, September, 2010

Note: Figures in parenthesis indicate percentage area to total area

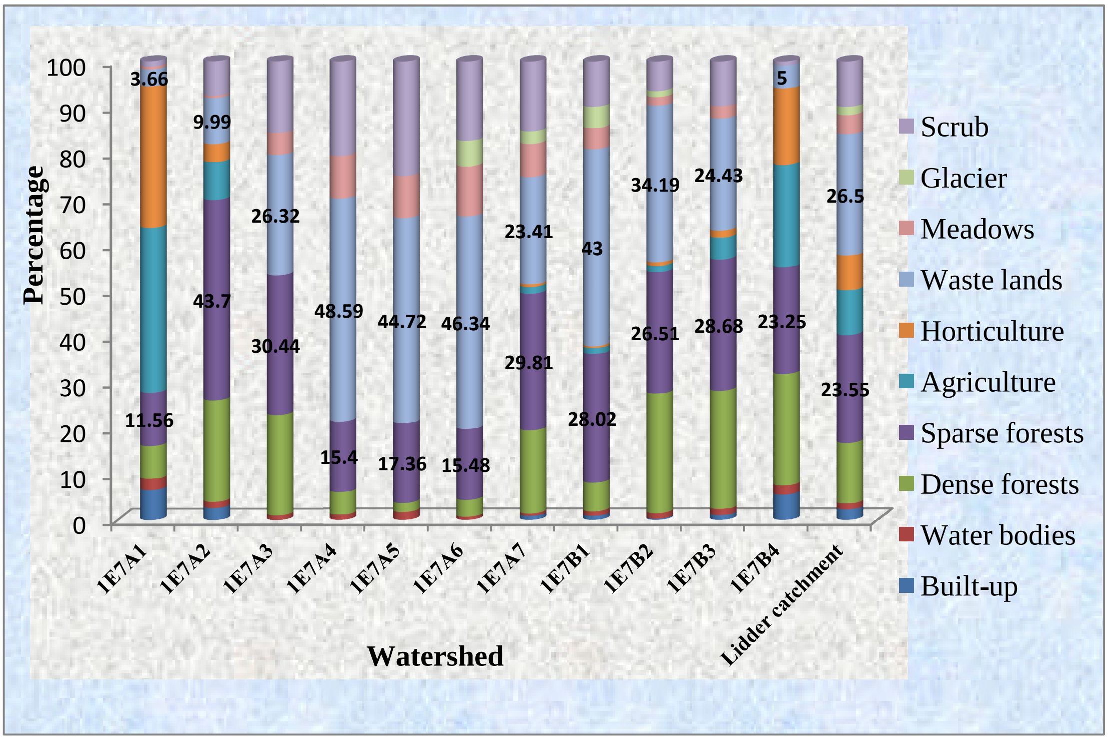


Fig. 7.8: Watershed wise area under different LULC classes in Lidder catchment, 2010

The watershed 1E7B3 is a forested watershed in which more than 54 percent area is under forests with dense forests covering 25.8 percent and sparse forests covering 28.68 percent of the watershed area. Waste lands and scrub lands cover 24.43 percent and 9.18 percent respectively. Meadows cover 2.68 percent while glaciers are nonexistent. About one percent of the total area is occupied by settlements while 1.3 percent is under water bodies.

Plate 7.5: Scrub lands of Lidder catchment

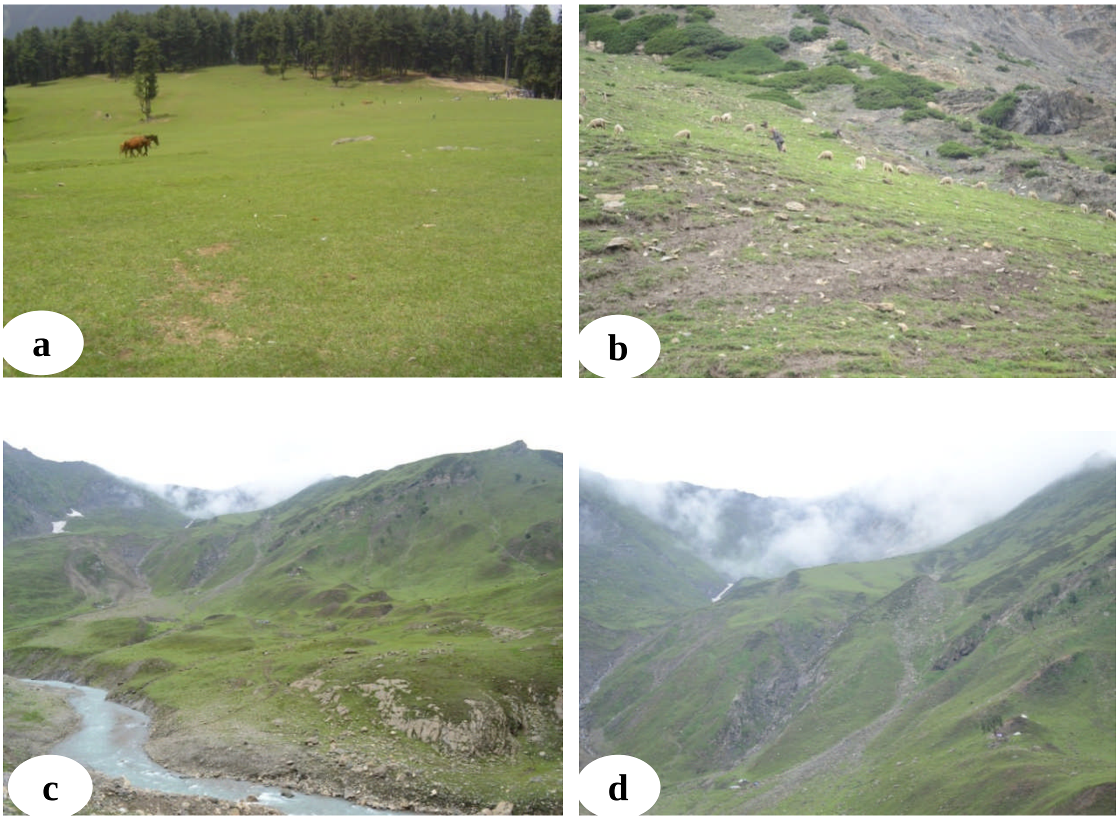


Plate 7.6: Meadows of Lidder catchment in proximity with (a) dense forests (b) Scrub lands (c) Water bodies and (d) waste lands

The watershed 1E7B4 is also a forest dominated watershed where more than 47 percent of the area is under forests of which dense forests account for 24.26 percent and sparse forests constitute 23.25 percent. Agriculture is the dominant human activity and 22.36 percent and 16.66 percent is devoted to agriculture and horticulture respectively. The area under built-up covers a significant proportion of 5.51 percent while only 0.95 percent is under scrubs.

Plate 7.7: Glaciers of Lidder valley

The analysis has further revealed that the watershed 1E7A1 leads in the absolute as well as percentage area of built-up (11.36 km^2 or 6.56 percent), water bodies (4.2 km^2 or 2.42 percent), agriculture (62.33 km^2 or 35.98 percent) and horticulture (53.61 km^2 or 30.95 percent). Dense forests are most widespread in watershed 1E7B4 (39.41 km^2) while the highest concentration is found in watershed 1E7B2 (26.06 percent). The highest area of sparse forests is found in watershed 1E7B1 (64.02 km^2) while their highest percentage is found in watershed 1E7A2 (43.7 percent). The highest area of wastelands (98.27 km^2), glaciers (10.61 km^2) and scrubs (22.73 km^2) is found in watershed 1E7B1 while their highest percentage is found in watershed 1E7A4 (48.59 percent), 1E7A6 (5.57 percent) and 1E7A5 (25.07 percent) respectively. The highest absolute (14.15 km^2) as well as percentage area (10.94 percent) of meadows is found in watershed 1E7A6.

Plate 7.8: Waste lands of Lidder catchment

7.5. LAND USE LAND COVER CHANGE

LULC change is a dynamic, widespread, continuous and accelerating process driven by natural phenomena and anthropogenic activities (Sarma et al., 2008) which in turn impel changes that would impact natural ecosystems (Moshen, 1999; Luna and Robles, 2003). The environmental monitoring of such systems includes the diagnosis and prognosis of LULC changes in a holistic manner at various spatial and temporal scales. Land cover changes take two forms: conversion from one category of land cover to another and modification of condition within a category (Meyer and Turner-II, 1992). Land cover change stemming from human land uses represents a major source and a major element of global environment change (Thomas, 1956; Turner-II et al., 1994). Changes in land cover can be related to natural dynamics (vegetation, succession, intra or inter-annual variability) or to human activities (Bonetemps et al., 2008), for instance due to fire, deforestation and agriculture or urban expansion.The most powerful contemporary forces that drive LULC change are increasing human activities and climatic change (Xu, 2008). However, the same kind of land cover change can have different sources in different areas (Meyer and Turner-II, 1992). Land cover changes have a significant impact on ecosystem conditions (hydrology, climate change and biogeochemical cycles) and create environmental issues (Bonetemps et al., 2008, Skole et al., 1997). Information about land cover change is very essential in natural resource management (Boles et al., 2004).

LULC change has become a central component in current strategies for managing natural resources and monitoring environmental changes. Land cover change and the subsequent potential loss of natural resources due to conversion to anthropogenic use is regarded as one of the more pervasive environmental threats (Wickham, 2000). The change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (Singh, 1989). It is an important process in monitoring and mapping natural resources because it provides quantitative analysis of the spatial distribution of the population of interest.

Macleod and Congalton (1998) listed four aspects of change detection which are important when monitoring natural resources:

i. Detecting the changes that have occurred.

ii. Identifying the nature of the change.

iii. Measuring the areal extent of the change.

iv. Assessing the spatial pattern of the change.

The Lidder catchment which constitutes a segment of the western Himalaya has also exhibited the undesirable changes in its LULC change and its spatial pattern during the last five decades from 1961 to 2010. The ever increasing demographic pressure coupled with the growing energy demands for domestic and tourism sector have brought about significant changes in the LULC of Lidder catchment during the last half century. This change in the LULC has influenced the ecology of the area.

7.5.1. Catchment Level Land Use Land Cover Change

The post classification LULC change comparisons are presented at catchment level for four time periods (table 7.5). The analysis has revealed that there has been a considerable change in various LULC categories (fig. 7.9). The area under built-up, waste lands and horticulture has continuously increased while the area under dense forests, glaciers and agriculture has continuously shown a decreasing trend from 1961 to 2010. The other land cover categories of water bodies, sparse forests, meadows and scrub lands have shown a variable character as they have registered a fluctuating trend by registering decrease for some decade and then increased or vice versa.

The analysis of table 7.5 has revealed that the built-up area has increased from 0.5 km^2 in 1961 to 2.22 km^2 in 2010 thus registering a growth of 347.05 percent with the average annual growth of 7.08 percent. This is the highest overall growth recorded by any LULC category from 1961 to 2010. The area under waste lands has increased from 154.69 km^2 in 1961 to 307.2 km^2 in 2010 registering a growth of 98.59 percent with the average annual growth of 2.01 percent. This increase of 152.51 km^2 in waste land area is the highest land transformation in Lidder catchment which means that more than 3 km^2 of land is transformed into waste lands each year. The area under horticulture has registered an increase of 49.96 km^2 from 1992 to 2010 with the average annual increase of 2.78 km^2 which amounts to the average percentage growth of 7.58 percent.

The area under dense forests has continuously decreased by 191.53 km^2 from 344.5 km^2 in 1961 to 152.97 km^2 in 2010 with the average annual decrease of 3.91 km^2 per year (fig. 7.10). The dense forests have decreased by 32.17 percent (110.82 km^2) from 1961-1992 while they have decrease by 21.01 percent (40.68 km^2) from 2001-2010. The degradation of dense forests is evident from plate 7.9. The area under glaciers has also decreased from 42.49 km^2 in 1961 to 20.59 percent in 2010 registering a negative growth of 51.54 percent with an average annual loss of 0.45 km^2 each year. The glaciers have decreased by 24.22 percent in thirty years from 1961 to 1992 while they have decreased by 20.5 percent in the last nine years which indicates that the glaciers are receding at faster rates. The area under water bodies has decreased from 1961 to 2001 but has increased from 2001 to 2010 registering the overall negative growth of 9.74 percent from 1961 to 2010 which amounts to the average annual loss of 0.2 percent. This is the lowest change in any LULC category in the catchment.

The area under agriculture has decreased from 187.9 km^2 (in 1961) to 113.27 km^2 (in 2010) on account of the land use change from agriculture to horticulture (plate 7.10 and plate 7.11) and partly due to the conversion of agriculture area into residential areas.

Table 7.5: Land use land cover change in Lidder catchment, (1961-2010)

LULC category	Area (km^2)				Net Change				Annual rate of change (1961-2010)
	1961	1992	2001	2010	1961-92	1992-01	2001-10	1961-10	
Built-up	5.76 (0.50)	11.99 (1.03)	16.73 (1.44)	25.75 (2.22)	6.23 (108.16)	4.74 (39.53)	9.02 (53.92)	19.99 (347.05)	0.41 (7.08)
Water bodies	17.76 (1.53)	16.33 (1.41)	15.77 (1.36)	16.03 (1.38)	-1.43 (-8.05)	-0.56 (-3.43)	0.26 (1.65)	-1.73 (-9.74)	-0.04 (-0.20)
Dense forests	344.5 (29.71)	233.68 (20.16)	193.65 (16.70)	152.97 (13.19)	-110.82 (-32.17)	-40.03 (-17.13)	-40.68 (-21.01)	-191.53 (-55.60)	-3.91 (-1.13)
Sparse forests	268.2 (23.13)	304.72 (26.28)	302.68 (26.11)	273.04 (23.55)	36.52 (13.62)	-2.04 (-0.67)	-29.64 (-9.79)	4.84 (1.80)	0.10 (0.04)
Agriculture	187.9 (16.21)	161.72 (13.95)	131.45 (11.34)	113.27 (9.77)	-26.18 (-13.93)	-30.27 (-18.72)	-18.18 (-13.83)	-74.63 (-39.72)	-1.52 (-0.81)
Horticulture	- -	36.60 (3.16)	68.79 (5.93)	86.56 (7.47)	- -	32.19 (87.95)	17.77 (25.83)	49.96* (136.5)	2.78* (7.58)
Waste lands	154.69 (13.34)	236.52 (20.40)	269.08 (23.21)	307.2 (26.50)	81.83 (52.90)	32.56 (13.77)	38.12 (14.17)	152.51 (98.59)	3.11 (2.01)
Meadows	36.05 (3.11)	29.82 (2.57)	31.38 (2.71)	48.72 (4.20)	-6.23 (-17.28)	1.56 (5.23)	17.34 (55.26)	12.67 (35.15)	0.26 (0.72)
Glacier	42.49 (3.66)	32.20 (2.78)	25.9 (2.23)	20.59 (1.78)	-10.29 (-24.22)	-6.3 (-19.57)	-5.31 (-20.50)	-21.9 (-51.54)	-0.45 (-1.05)
Scrub	102.03 (8.80)	95.80 (8.26)	103.95 (8.97)	115.25 (9.94)	-6.23 (-6.11)	8.15 (8.51)	11.3 (10.87)	13.22 (12.96)	0.27 (0.26)

Source: Source: Compiled from SOI toposheets, 1961 and Land Sat ETM, September 1992, 2001 and IRS P6 LISS III, September 2010
Note: Figures in parenthesis indicate percentage area to total area
*The change in horticulture is calculated between 1992 and 2010.

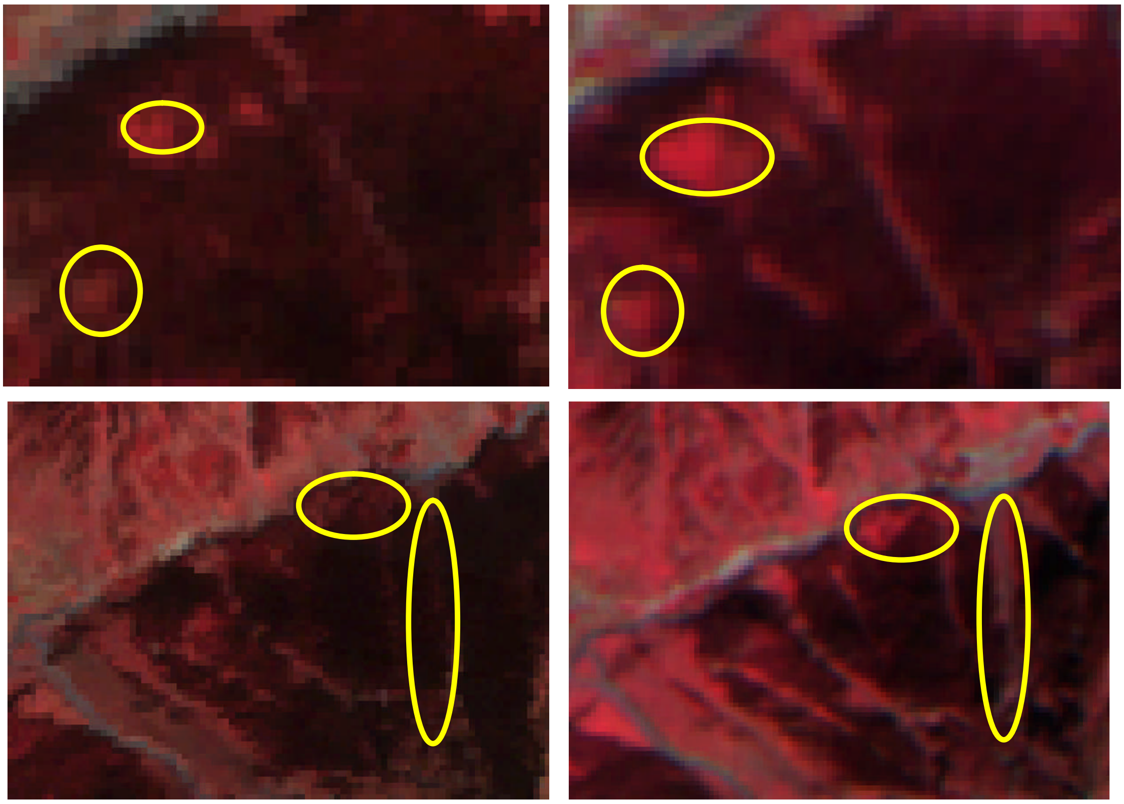


Plate 7.9: Degradation dense forests from the year 1992 (left) to 2010 (right)

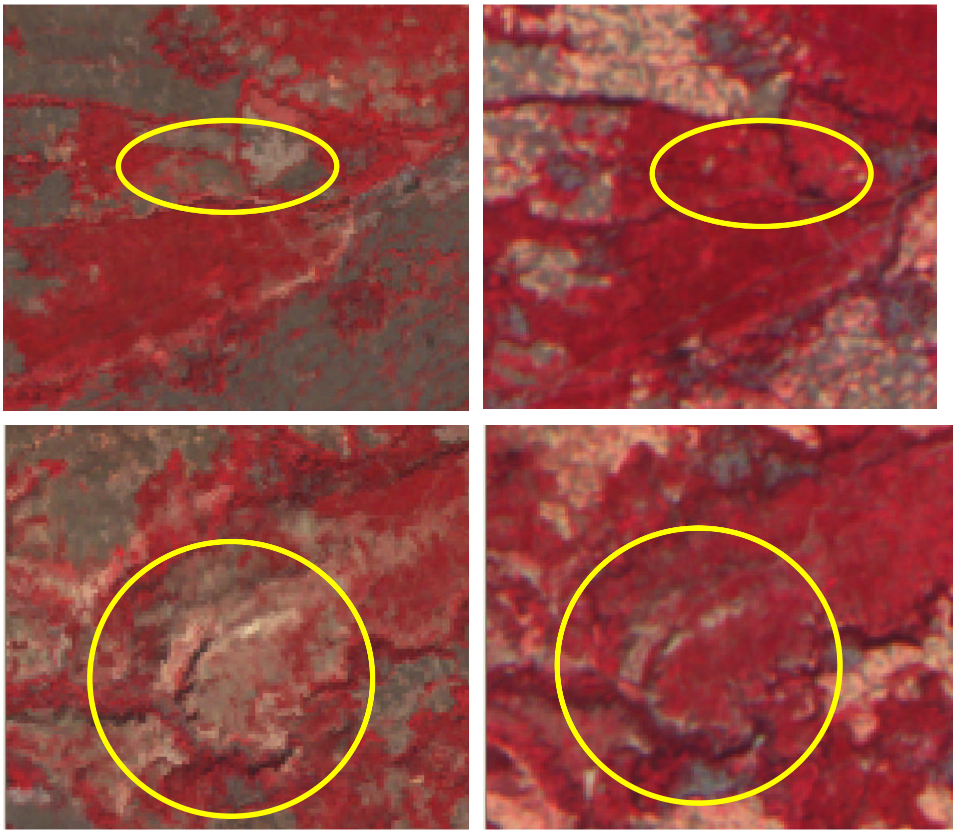
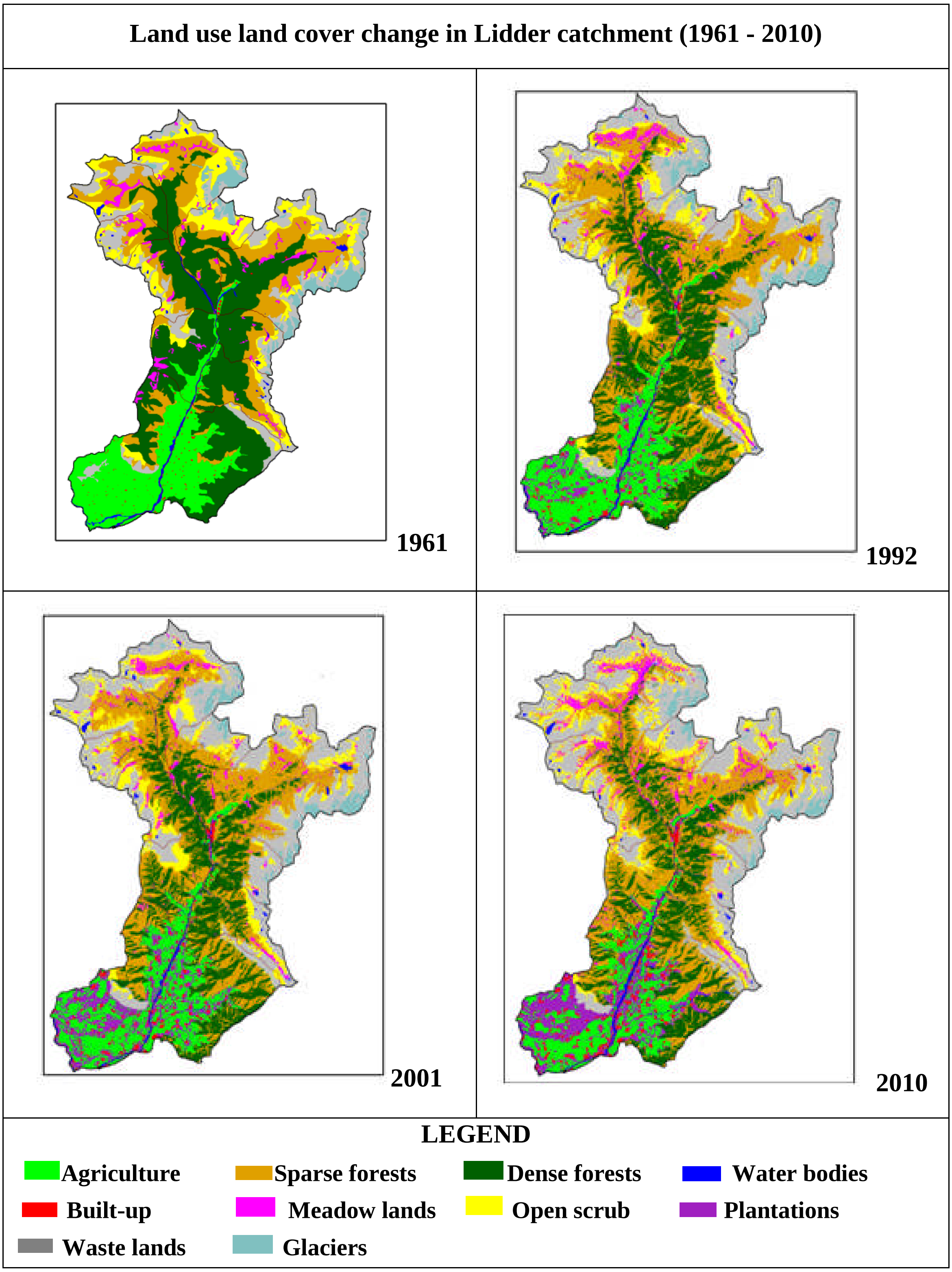


Plate 7.10: Agricultural area in 1992 (left) changed into horticulture (right) in 2010



Source: SOI toposheets 1961; Satellite data 1992, 2001 and 2010

Fig. 7.9

Plate 7.11: Agricultural area converted into horticulture in the year (a) 2001 (b) 2005

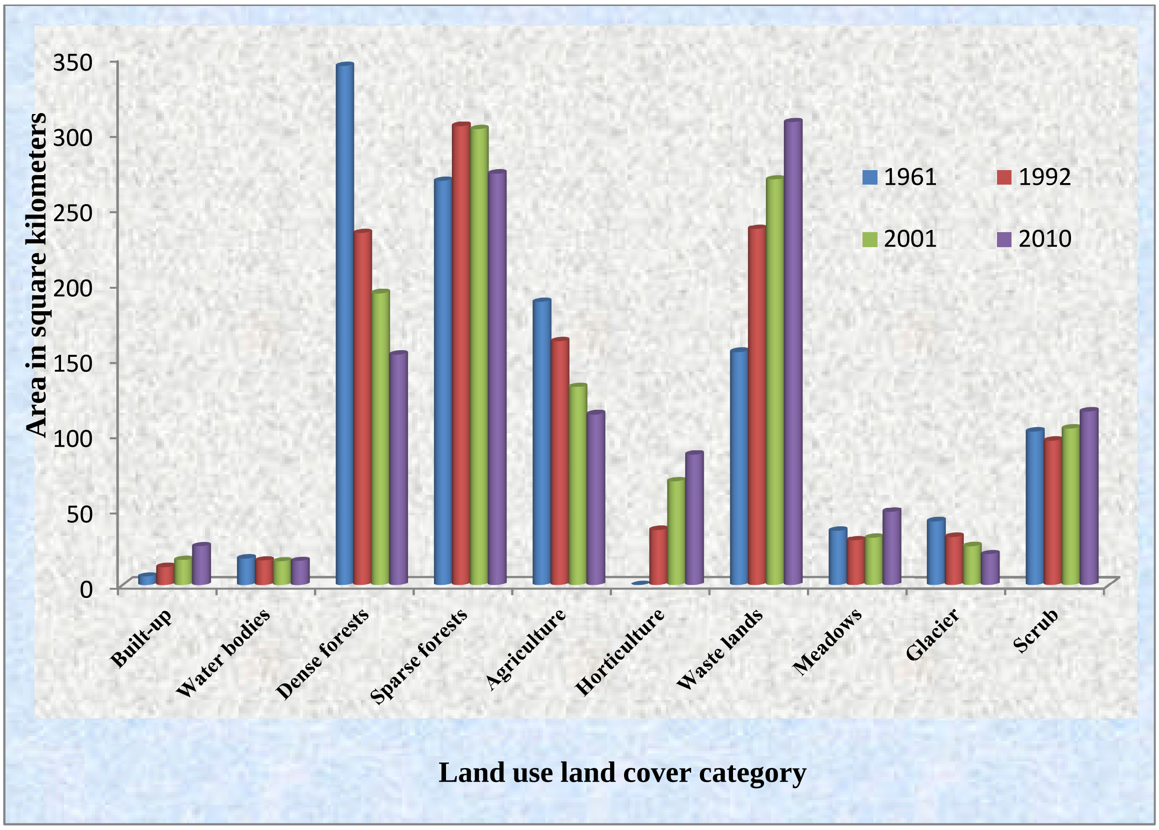


Fig. 7.10: Change in area under different LULC categories in Lidder catchment, (1961-2010)

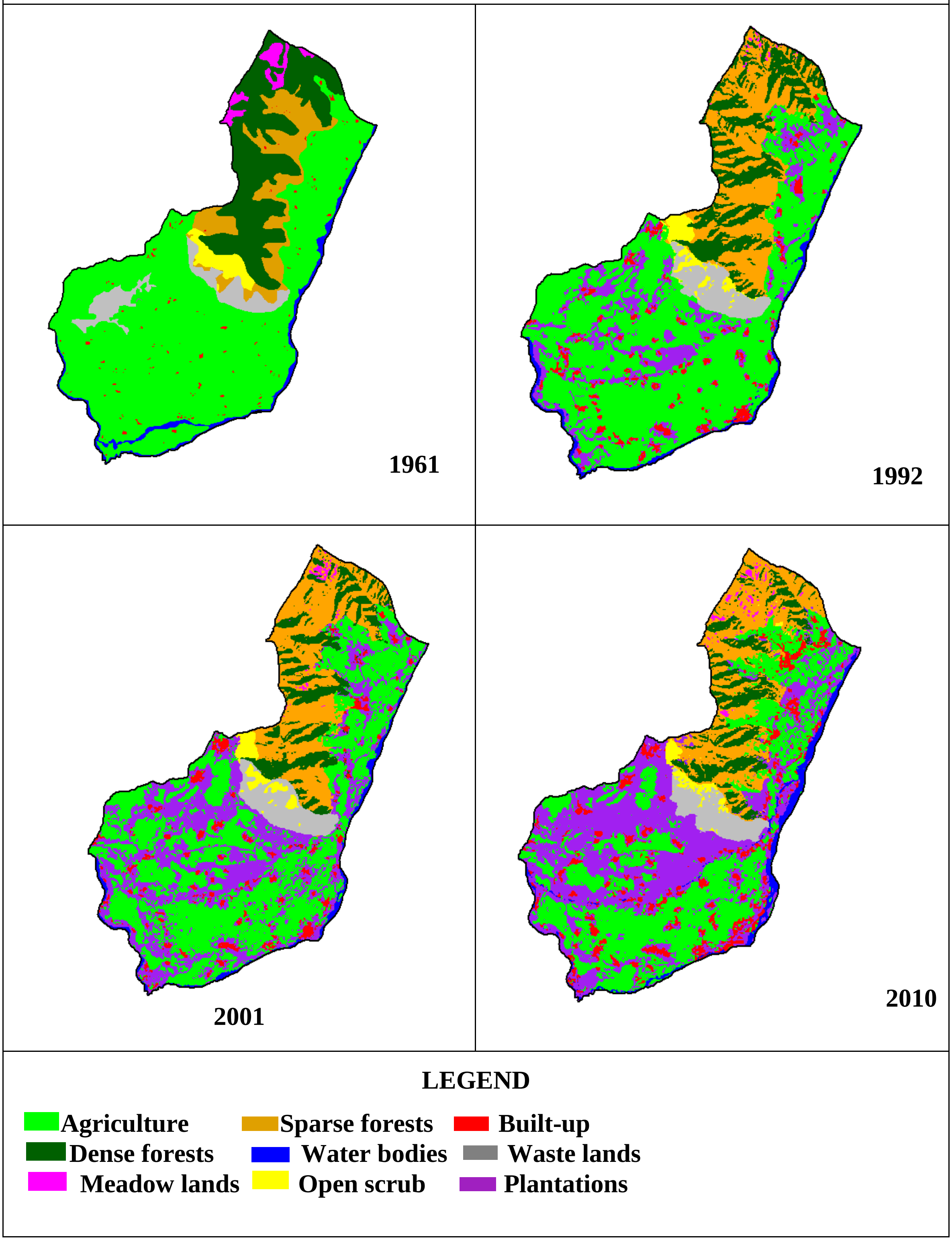
The sparse forests have initially increased from 1961 to 1992 on account of large scale deforestation which changed dense forests to sparse forests. From 1992 to 2010 sparse forests have decreased because of further degradation and conversion of sparse forests to scrubs and meadows and waste lands. The temporal analysis has further revealed that the sparse forests have increased by only 4.84 km^2 during the last fifty years but it is important to mention here that there have been large scale spatial changes in sparse forests where they have replaced the dense forests but are being replaced by scrubs, meadows and waste lands. The area under scrubs has also shown an increase of 13.22 km^2 during last fifty years with the average annual increase of 0.27 km^2. These have decreased from 1962 to 1992 but increased from 1992 to 2010. The meadows have initially decreased from 1961 to 1992 but then increased from 1992 to 2010 with the overall increase of 12.67 km^2 which amounts to the average annual increase of 0.26 km^2 (0.72 percent).

7.5.2. Watershed Wise Land Use Land Cover Change

The watershed wise LULC change has been carried out from 1961 to 2010 for four time periods (table 7.6). The LULC categories of water bodies, dense forests, sparse forests, scrubs and waste lands are found in all the eleven watersheds. Glaciers are nonexistent in the five out of seven watersheds of West Lidder sub-catchment and the two watersheds of East Lidder sub-catchment. Meadows are found in all the watersheds except 1E7A4. Only six watersheds are inhabited and hence the Built-up is found in those six watersheds while agriculture and horticulture are found in seven watersheds. It is because of the fact that the people living in adjoining watersheds practice agriculture in watershed 1E7B2. The percentage change in LULC categories is given in table 7.7 with the average annual growth in table 7.8 while the watershed wise change in different LULC categories has been presented in figure 7.11 to figure 7.32.

The analysis of LULC change (table 7.6) has revealed that the area under built-up category has increased in all the inhabited watersheds from 1961 to 2010 with the highest increase (9.13 km^2) registered in watershed 1E7A1 (fig. 7.11 and fig. 7.12) followed by watershed 1E7A4 (7.4 km^2) which amounts to the growth of 409.42 percent and 477.42 percent respectively (table 7.7). These are the two watersheds which constitute more than 89 percent of the total population of Lidder catchment and where the population growth, density and household growth is very high.

Land use land cover change in watershed 1E7A1 (1961 - 2010)



Source: SOI toposheets 1961; Satellite data 1992, 2001 and 2010

Fig.7.11

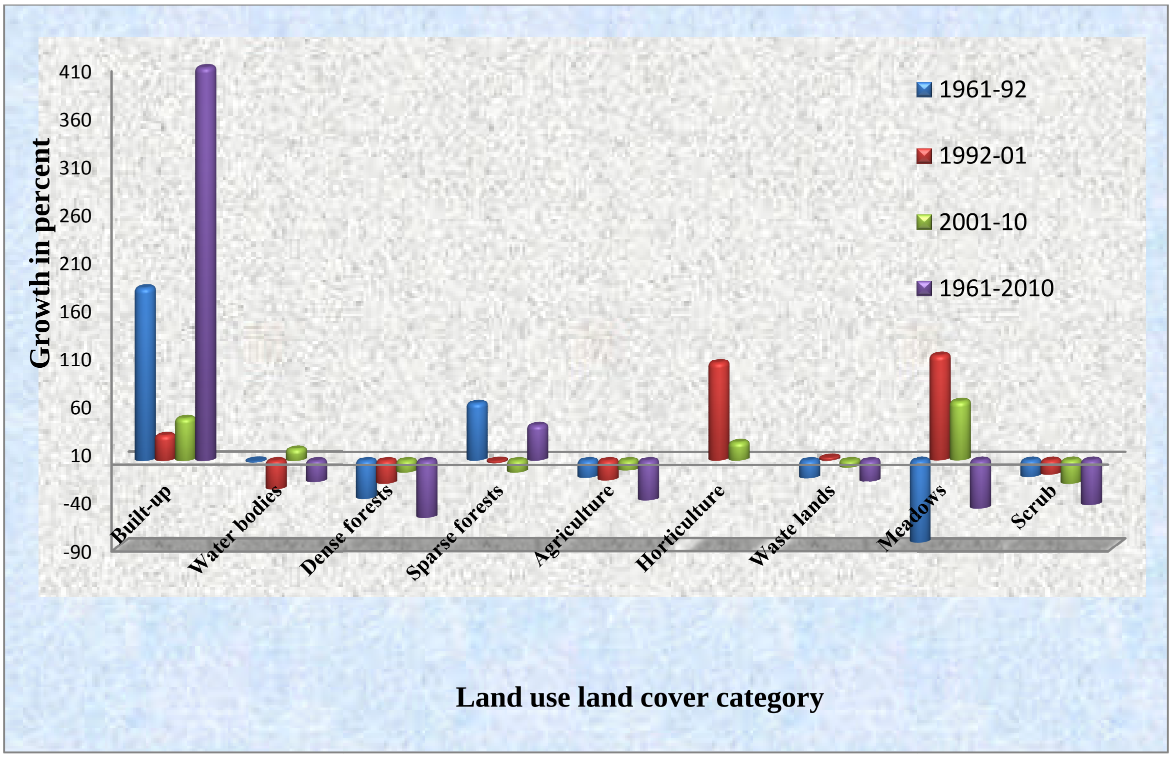


Fig. 7.12: Percentage growth in LULC categories in watershed 1E7A1

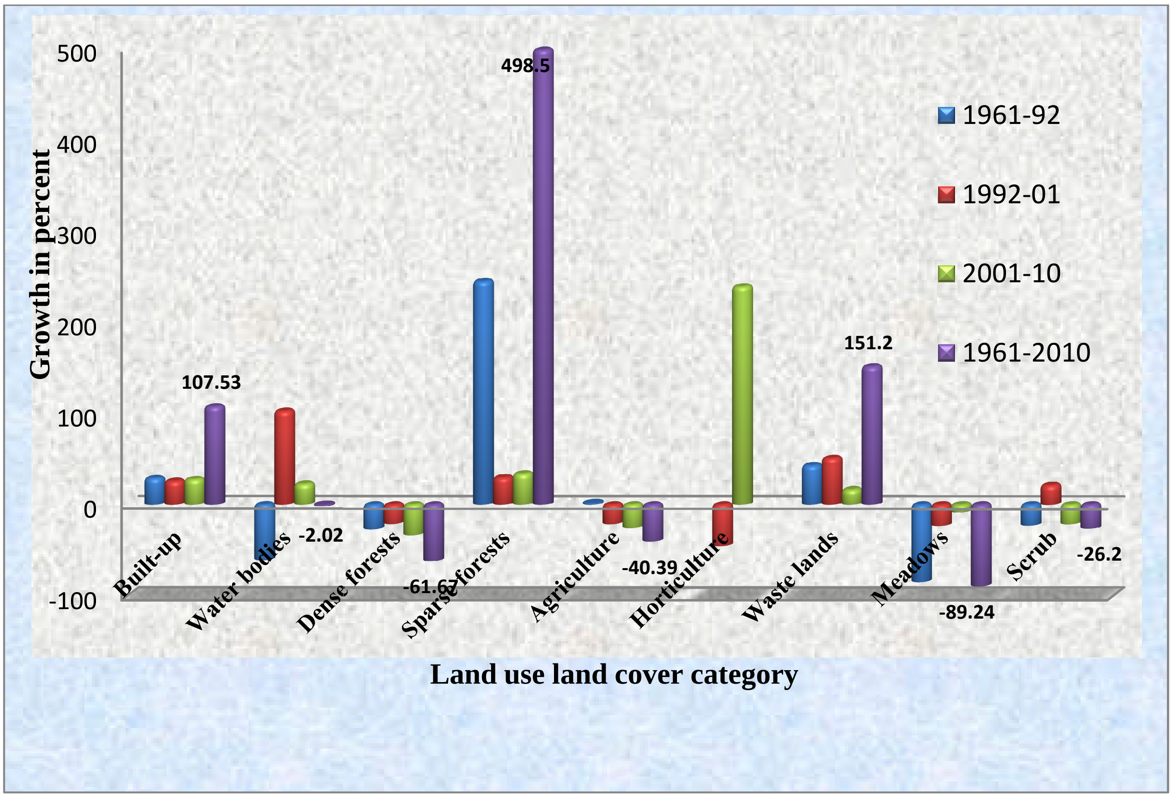
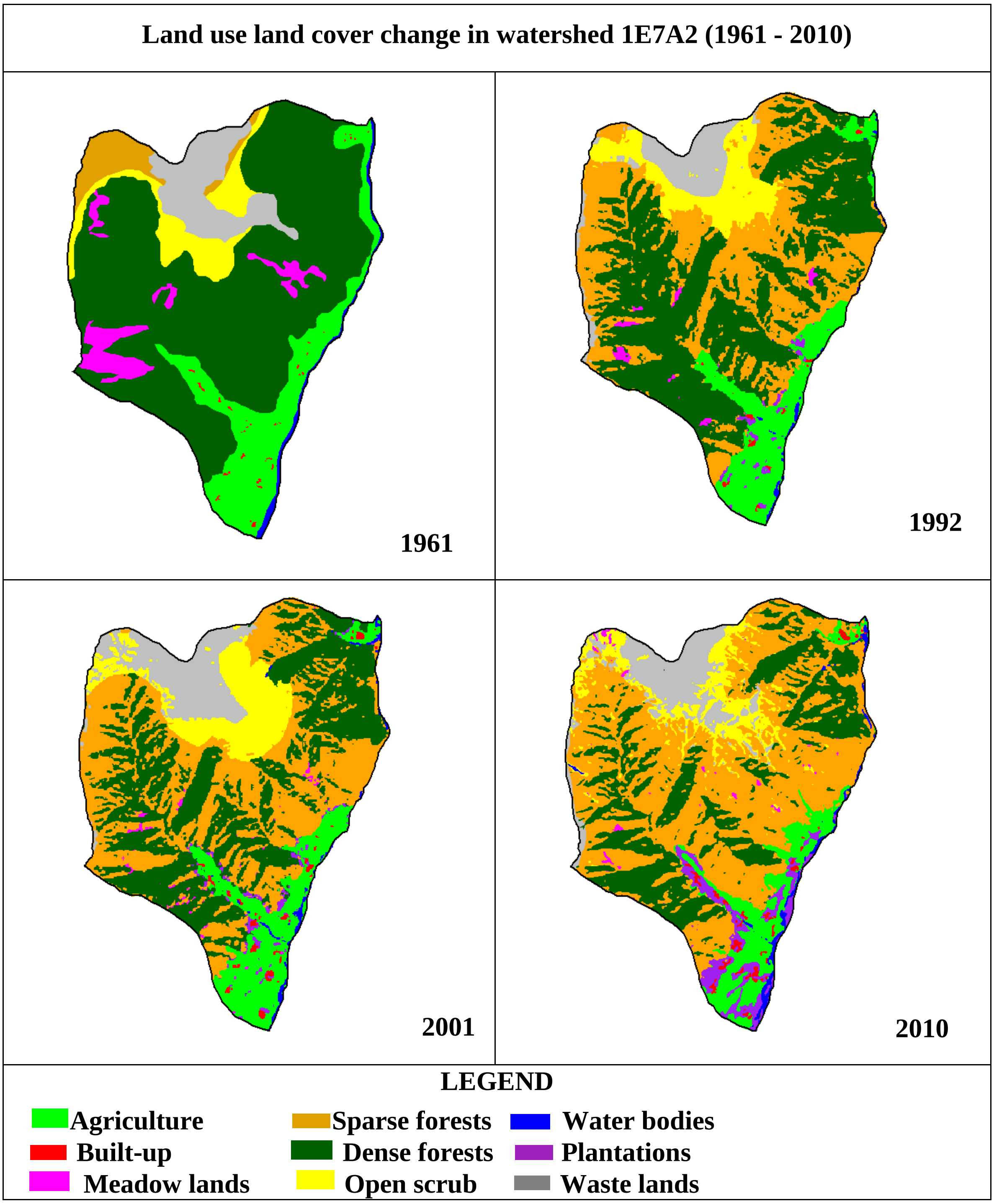


Fig. 7.13: Percentage growth in LULC categories in watershed 1E7A2



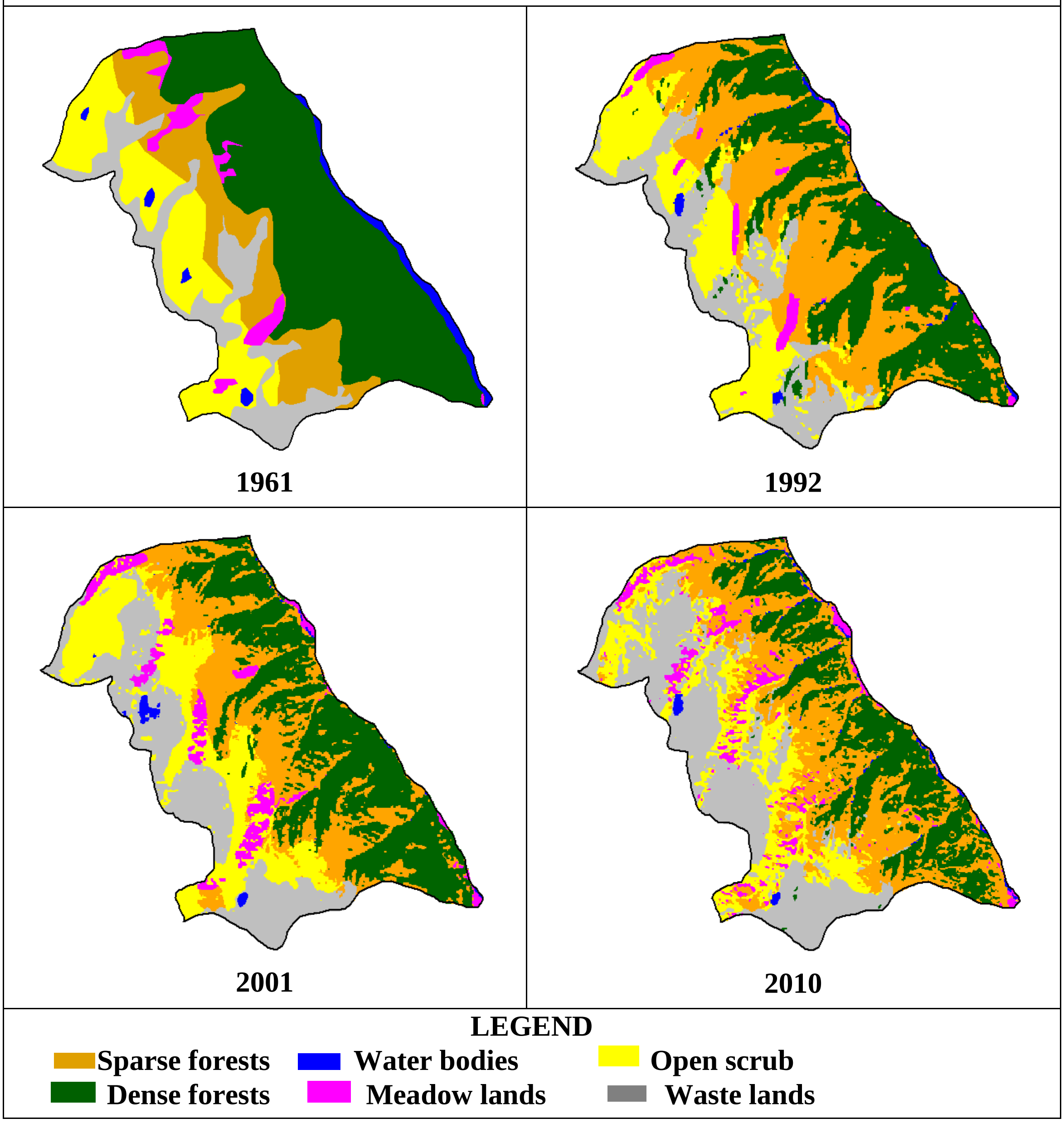
Source: SOI toposheets 1961; Satellite data 1992, 2001 and 2010

Fig.7.14

Water bodies are found in all the eleven watersheds and they have shown increase as well as decrease for different time periods. They have registered an overall increase in five watersheds and decrease in the remaining six watersheds. However the highest percentage change (76.92 percent) was recorded for watershed 1E7A4 (fig. 7.17 and fig. 7.18) while the highest change in terms of area was recorded for watershed 1E7B1 (table

7.6) where it has decreased by 0.73 km^2 from 1961 to 2010. The glaciers have been considerably reduced in all the four watersheds where glaciers are found. The highest decrease in terms of area is recorded for watershed 1E7B1 where they have reduced by 11 km^2 which amounts to the negative growth of 50.93 percent from 1961 to 2010 (fig. 7.25 and fig.7.26). The highest negative growth in glacier area (71.89 km^2) was recorded for watershed 1E7B2 (fig. 7.27 and fig.7.28).

Land use land cover change in watershed 1E7A3 (1961 - 2010)



Source: SOI toposheets 1961; Satellite data 1992, 2001 and 2010

Fig.7.15

Table 7.6: Watershed wise LULC change (Area in km^2) in Lidder catchment (1961-2010)

Watershed	Land use land cover category										
	Period	**Built-up**	**Water bodies**	**Dense forests**	**Sparse forests**	**Agriculture**	**Horticulture**	**Waste lands**	**Meadows**	**Glacier**	**Scrub**
1E7A1	**1961-92**	4.01	-0.08	-12.09	8.75	-18.97		-1.48	-1.78		-0.64
	1992-01	1.65	-1.58	-4.47	-0.54	-17.89	22.73	0.22	0.34		-0.46
	2001-10	3.47	0.45	-1.75	-2.84	-7.21	8.60	-0.49	0.40		-0.63
	1961-2010	9.13	-1.21	-18.31	5.37	-44.07		-1.75	-1.04		-1.73
1E7A2	**1961-92**	0.27	-0.60	-11.35	13.06	0.18		1.25	-2.68		-1.69
	1992-01	0.31	0.40	-6.49	5.48	-2.21	-0.71	2.12	-0.11		1.21
	2001-10	0.42	0.18	-8.14	8.08	-2.09	2.03	1.03	-0.03		-1.48
	1961-2010	1.00	-0.02	-25.98	26.62	-4.12		4.40	-2.82		-1.96
1E7A3	**1961-92**		-1.03	-7.96	7.39			1.34	-0.55		0.81
	1992-01		-0.22	-0.69	-4.40			2.59	1.75		0.97
	2001-10		0.16	-5.35	3.78			4.26	0.02		-2.87
	1961-2010		-1.09	-14.00	6.77			8.19	1.22		-1.09
1E7A4	**1961-92**		0.19	-1.03	0.08			3.89	-2.50		-0.63
	1992-01		0.12	-1.40	-1.86			1.31	0.74		1.09
	2001-10		-0.11	-0.13	-4.71			1.70	1.83		1.42
	1961-2010		0.20	-2.56	-6.49			6.90	0.07		1.88
1E7A5	**1961-92**		0.53	-7.59	-0.52			7.86	-2.40		2.12
	1992-01		0.05	-2.03	-3.84			4.64	0.57		0.61
	2001-10		-0.25	-0.35	-14.39			4.86	4.33		5.80
	1961-2010		0.33	-9.97	-18.75			17.36	2.50		8.53
1E7A6	**1961-92**		0.31	-6.20	-9.65			25.71	6.40	-3.01	-13.56
	1992-01		0.20	-4.99	4.71			3.13	-3.86	-1.31	2.12
	2001-10		-0.23	-0.99	-14.79			10.35	4.59	-1.66	2.73
	1961-2010		0.28	-12.18	-19.73			39.19	7.13	-5.98	-8.71
1E7A7	**1961-92**	0.11	0.36	-4.22	-3.13	0.23		9.42	0.14	-2.29	-0.74
	1992-01	0.14	-0.40	-1.82	2.73	0.24	0.03	2.52	0.51	-0.68	-3.27
	2001-10	0.28	-0.15	-7.32	0.25	0.39	0.27	-0.50	1.77	-0.15	5.16
	1961-2010	0.53	-0.19	-13.36	-0.15	0.86		11.44	2.42	-3.12	1.15
1E7B1	**1961-92**	0.11	-1.76	-24.06	4.40	1.34		20.56	-3.45	-3.55	5.85
	1992-01	0.51	0.94	-8.79	-9.30	0.10	-0.08	10.86	1.97	-4.12	7.91
	2001-10	0.81	0.09	-2.39	-14.55	0.15	0.50	12.54	4.27	-3.34	1.92
	1961-2010	1.43	-0.73	-35.24	-19.45	1.59		43.96	2.79	-11.01	15.68
1E7B2	**1961-92**		-0.15	-4.03	-3.30	-0.46		10.91	-0.19	-1.44	-1.41
	1992-01		0.42	-3.54	3.05	0.28	0.01	0.58	-0.11	-0.19	-0.59
	2001-10		-0.25	-3.64	2.15	0.09	0.34	0.03	0.05	-0.16	1.35
	1961-2010		0.02	-11.21	1.90	-0.09		11.52	-0.25	-1.79	-0.65
1E7B3	**1961-92**	0.02	0.50	-4.98	-4.51	-0.67		3.95	0.78		4.51
	1992-01	0.14	-0.27	-3.23	0.71	0.22	0.42	3.91	-0.29		-1.61
	2001-10	0.21	-0.24	-6.05	4.34	0.63	0.36	2.83	0.16		-2.24
	1961-2010	0.37	-0.01	-14.26	0.54	0.18		10.69	0.65		0.66
1E7B4	**1961-92**	1.71	0.30	-27.31	23.95	-7.83		-1.58			-0.85
	1992-01	1.90	-0.22	-2.58	1.22	-11.01	9.79	0.68			0.17
	2001-10	3.79	0.61	-4.57	3.04	-10.14	5.67	1.51			0.14
	1961-2010	7.40	0.69	-34.46	28.21	-28.98		0.61			-0.54

Source: Compiled from SOI toposheets, 1961 and Land Sat ETM, September 1992, 2001 and IRS P6 LISS III, September 2010

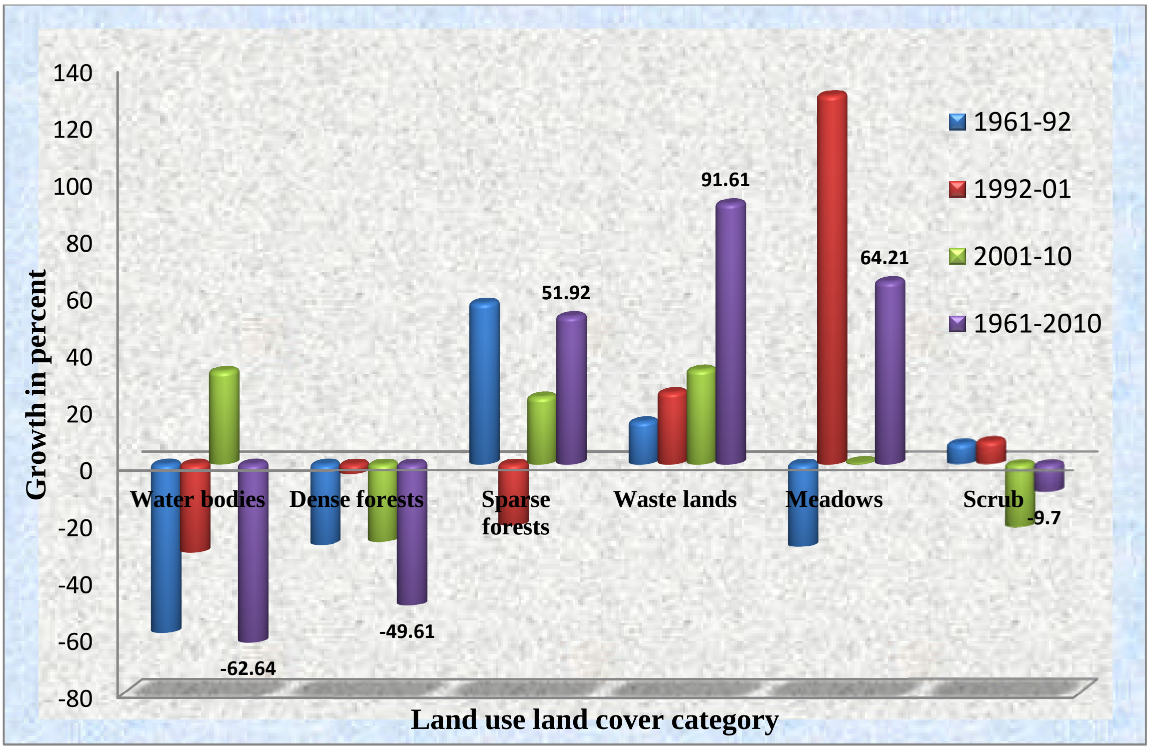


Fig. 7.16: Percentage growth in LULC categories in watershed 1E7A3.

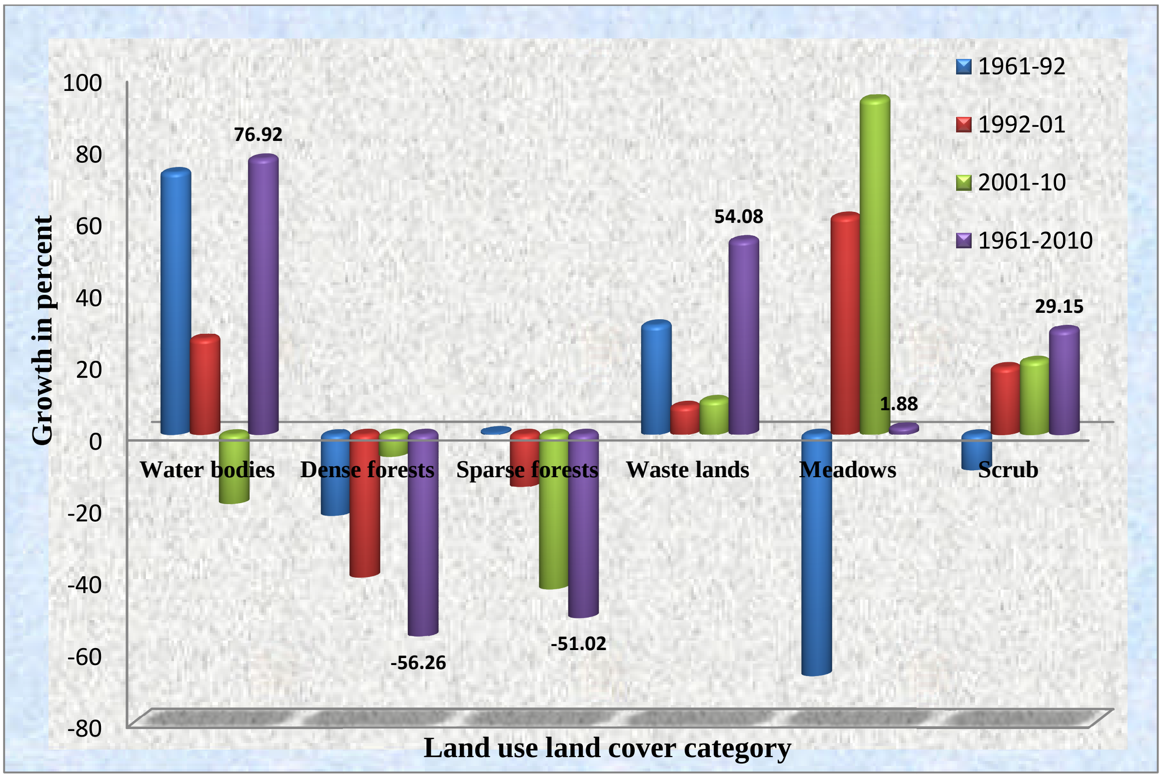
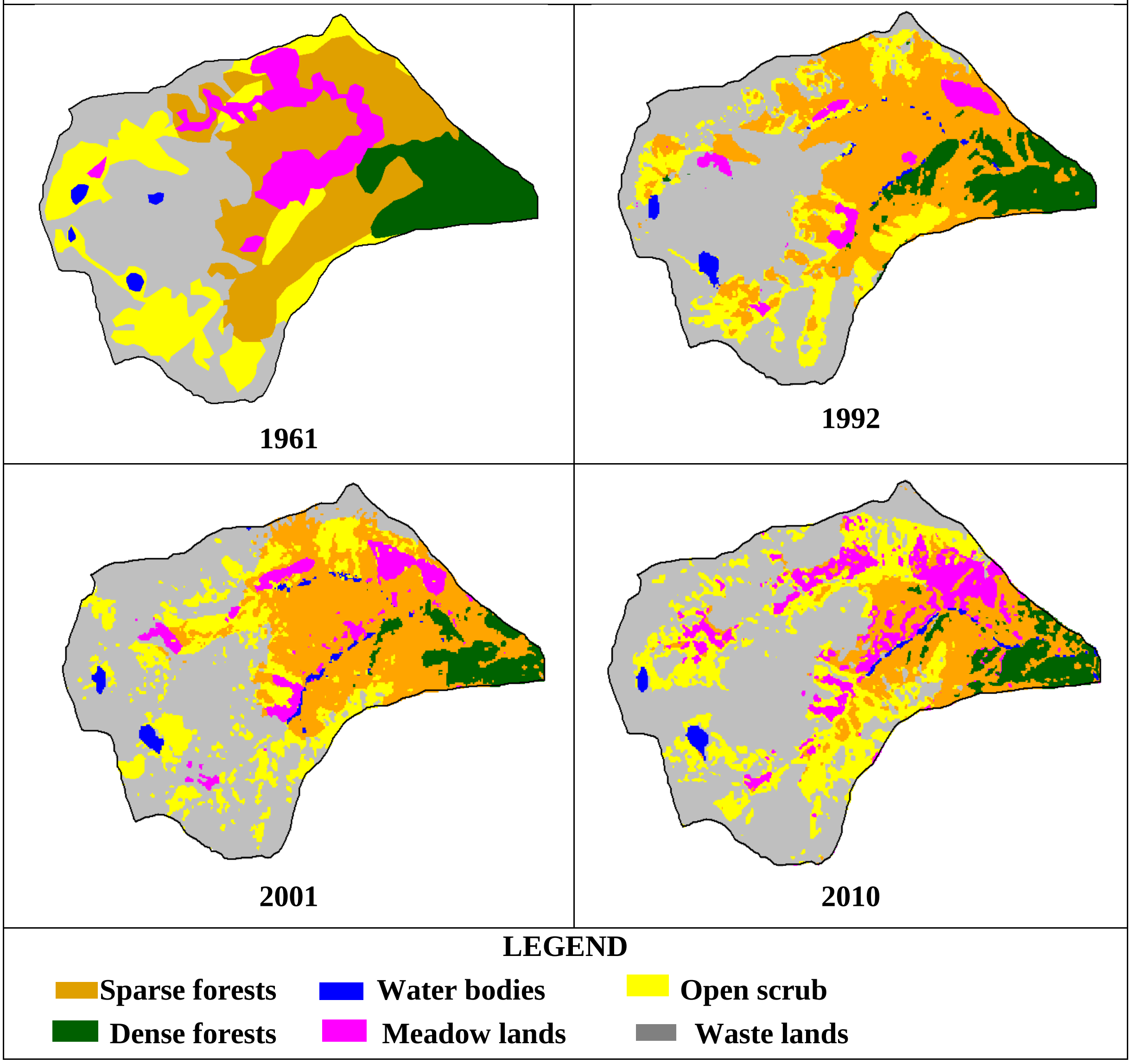


Fig. 7.17: Percentage growth in LULC categories in watershed 1E7A4

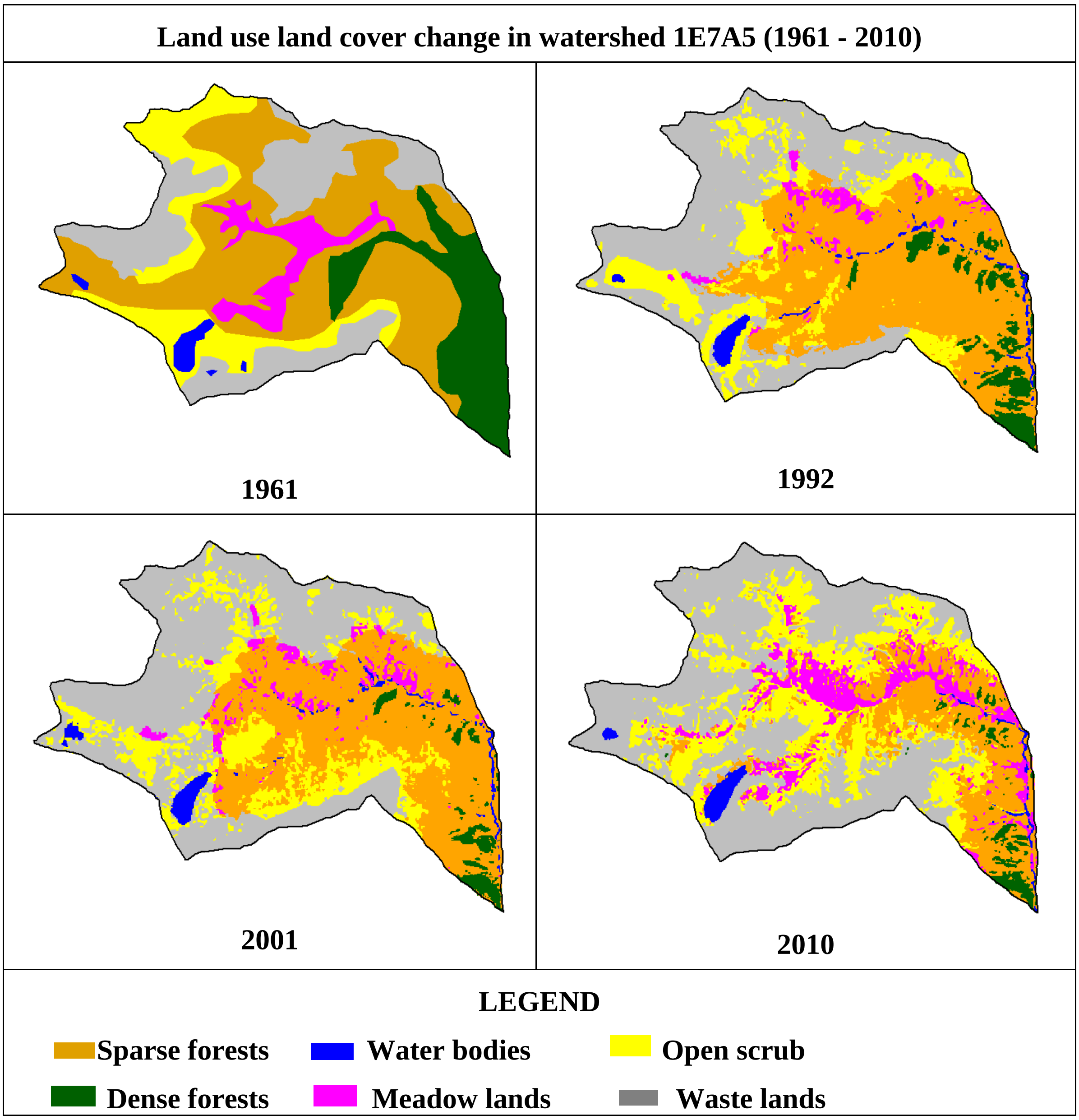
Land use land cover change in watershed 1E7A4 (1961 - 2010)



Source: SOI toposheets 1961; Satellite data 1992, 2001 and 2010

Fig.7.18

The forest area is found in all the watersheds in varying proportions. It has been degraded considerably both in terms of modification (conversion of dense forests in to sparse forests) as well as conversion (from forest to non-forest uses). This is a two step process in which dense forests are first changed into sparse forests and then sparse forests are put to non-forest uses. This is substantiated by the fact that the dense forests have decreased in all the watersheds with the highest decrease recorded for watershed 1E7B1 and 1E7B4 where it has decreased by 35.24 km^2 and 34.46 km^2 respectively (table 7.6). However the highest degradation was recorded for watersheds 1E7A5, 1E7A6 and 1E7B1 where it has registered the negative growth of 86.25 percent, 71.94 percent and 71.01 percent respectively (table 7.7). The sparse forests have increased in six watersheds and decreased in five watersheds with the highest growth of 498.5 percent in watershed 1E7A2 (fig. 7.13 and fig. 7.14) which is the highest percentage growth of all the LULC classes in the catchment. The sparse forests have increased in lower elevations where they have replaced dense forests and decreased in relatively higher elevations where sparse forests are replaced by scrubs and waste lands. The highest increase in sparse forest area (28.21 km^2) was recorded for watershed 1E7B4 (fig. 7.31 and fig.7.32) from 1961 to 2010 while the highest decrease of 19.73 km^2 was recorded for watershed 1E7A6 from 1961 to 2010 (table 7.6).



Source: SOI toposheets 1961; Satellite data 1992, 2001 and 2010

Fig.7.19

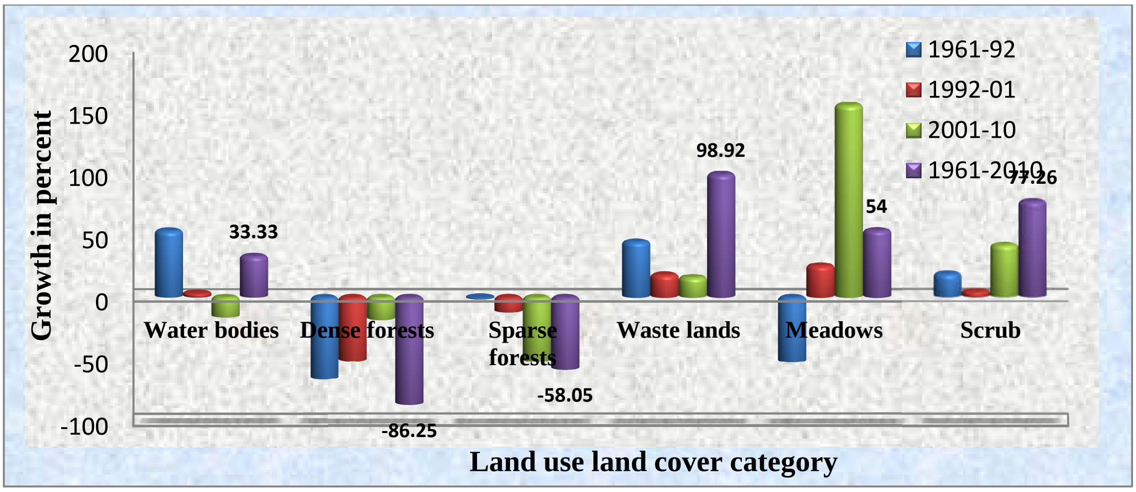


Fig. 7.20: Percentage growth in LULC categories in watershed 1E7A5

The area under agriculture has increased in two watersheds of 1E7A7 (fig. 7.23 and fig. 7.24) and 1E7B1 while it has decreased in the remaining seven watersheds where agriculture is being practiced. The highest decrease in agricultural area is recorded for watershed 1E7A1 (44.07 km^2) with the highest negative growth of 44.37 percent in watershed 1E7B4 (table 7.7). The prime reason for decreasing area under agriculture is the large scale conversion of agriculture into horticulture especially in the last two decades. The highest growth in agriculture (330.77 percent) was recorded for watershed 1E7A7 because of direct conversion of forest into agriculture. The area under horticulture has increased in all the seven watersheds from 2001 to 2010 where horticulture is found while it has decreased in two watersheds from 1992 to 2001. The highest growth is recorded for watershed 1E7B2 where it has registered the growth of 425 percent. However the highest increase in terms of area is recorded for watershed 1E7A1 where it has increased by 22.73 km^2 from 1992 to 2010. It is important to mention here that large agricultural area have been transformed into horticulture area particularly apple orchards during the last two decades.

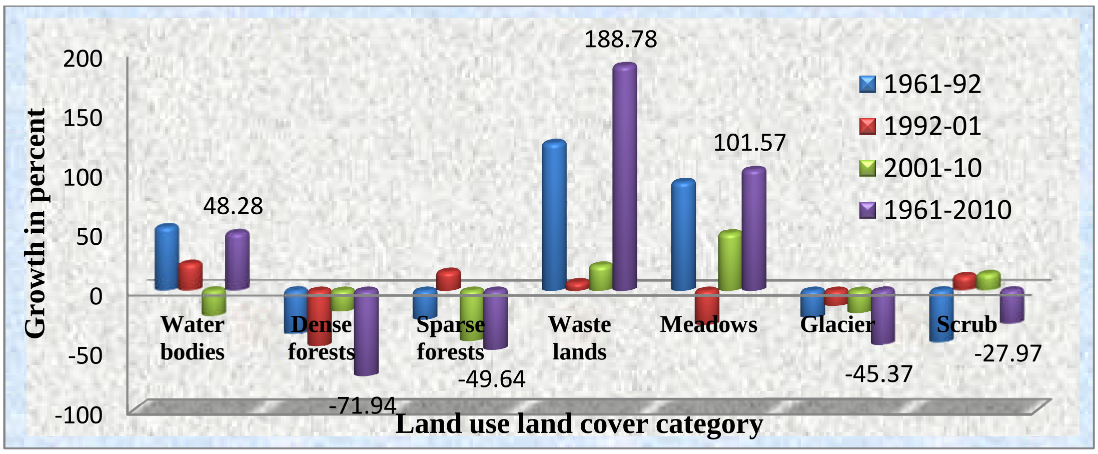
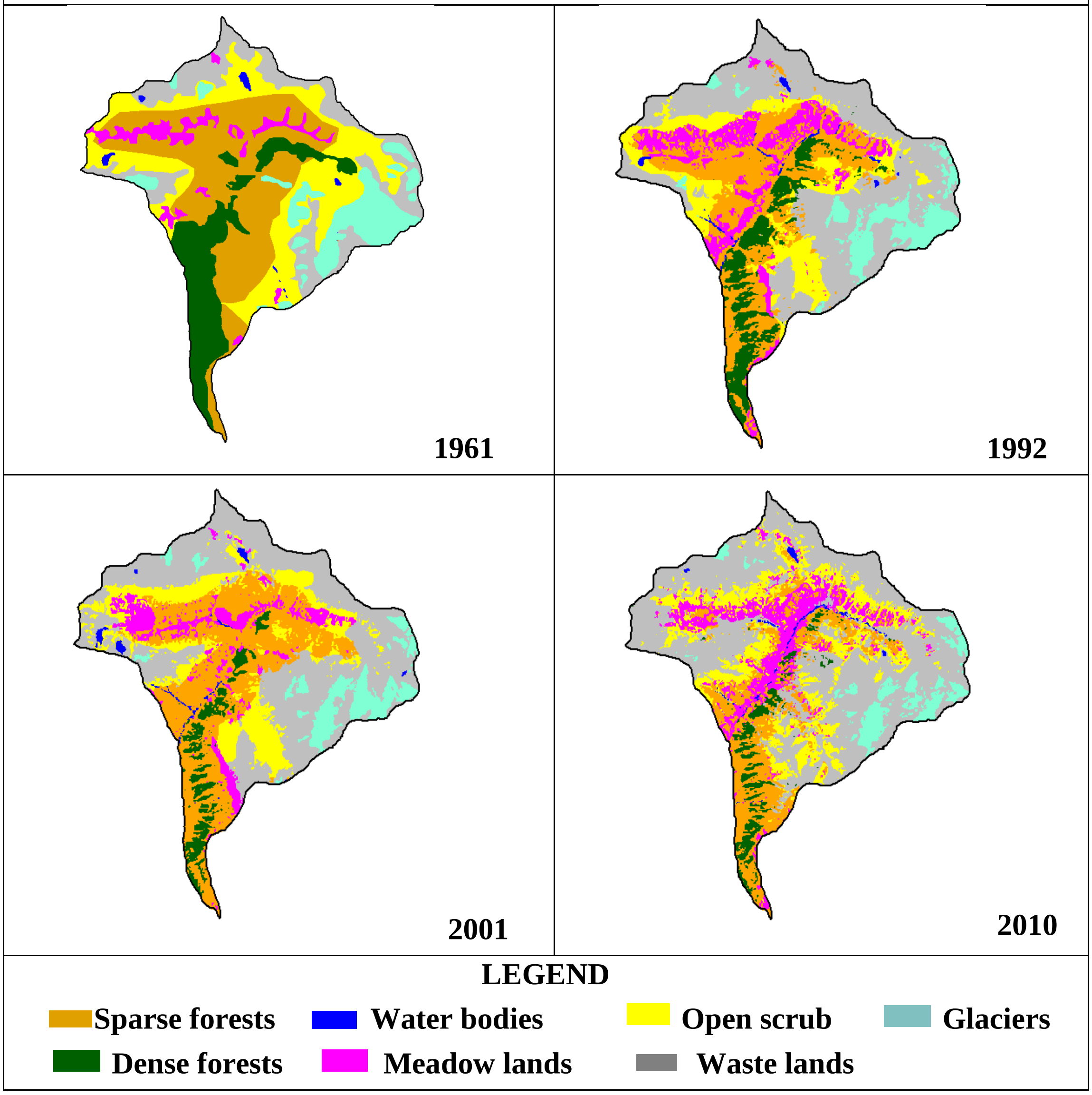


Fig. 7.21: Percentage growth in LULC categories in watershed 1E7A6

Land use land cover change in watershed 1E7A6 (1961 - 2010)



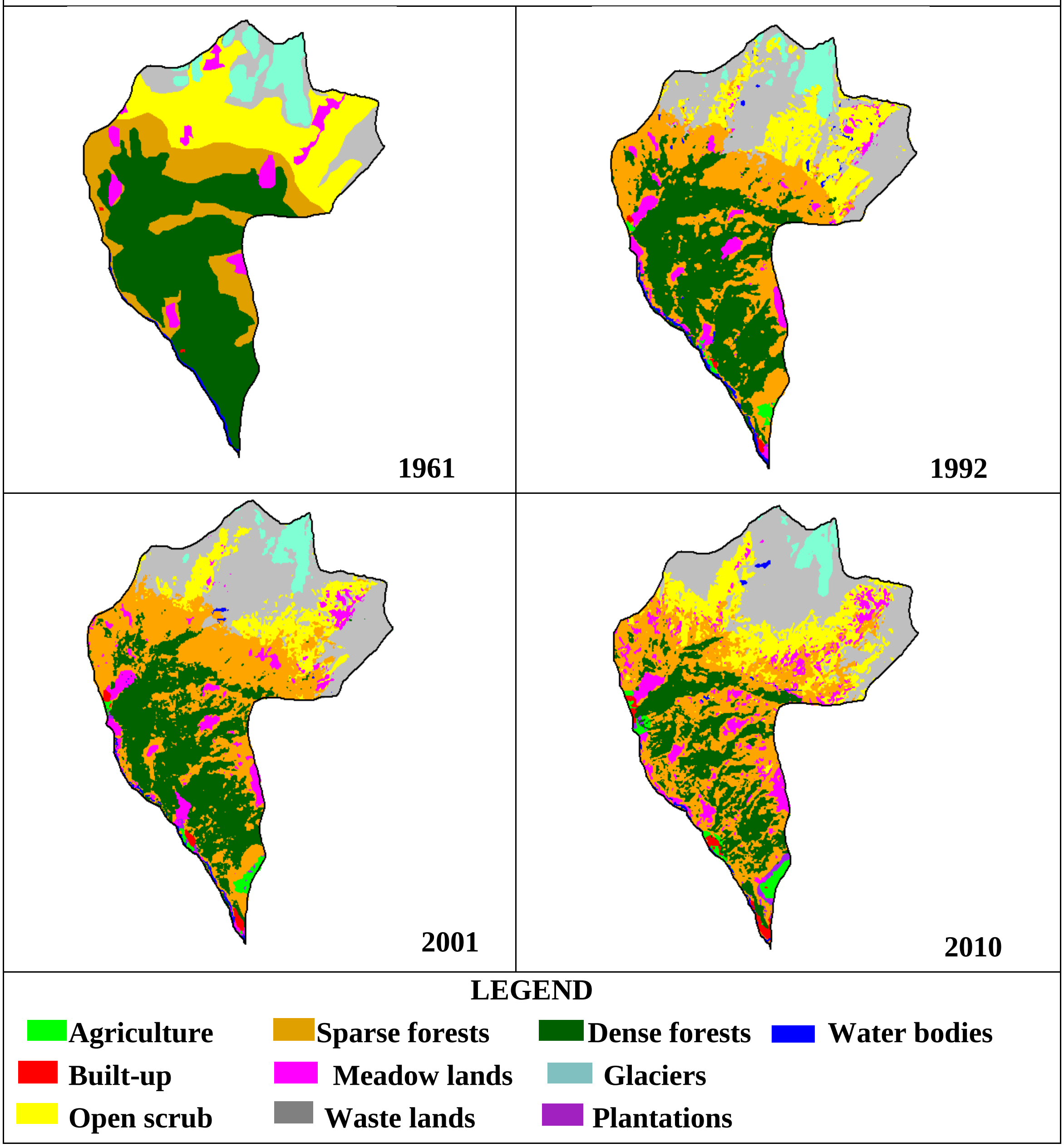
Source: SOI toposheets 1961; Satellite data 1992, 2001 and 2010

Fig.7.22

The area under waste lands has increased in ten watersheds while it has decreased in the watershed 1E7A1 by 21.63 percent (table 7.7). The highest growth in waste lands (188.78 percent) was recorded for watershed 1E7A6 (fig. 7.21 and fig. 7.22) while the highest waste land area has increased in watershed 1E7B1 by 43.96 km^2 (table 7.6). The increase in waste land area is mainly at the cost of scrub lands, meadows and sparse forests. The waste land area in watershed 1E7A1 was used for agriculture purposes and hence this watershed has registered decrease in waste land area. Meadows are found in ten watersheds and have increased in seven watersheds and decreased in three watersheds with the highest growth (154.64 percent) recorded for watershed 1E7A5 (fig. 7.19 and fig.

7.20) from 2001 to 2010. The highest negative growth (89.24 percent) is recorded for watershed 1E7A2. Scrub lands found in all the eleven watersheds have decreased in seven watersheds and increased in four watersheds. The highest increase was recorded for watershed 1E7B1 where it has increased by 15.68 km^2 with the highest growth of 222.41 percent (table 7.7) from 1961 to 2010 where as the highest decrease was registered for watershed 1E7A6 where it has decreased by 13.56 km^2 from 1961 to 1992.

Land use land cover change in watershed 1E7A7 (1961 - 2010)



Source: SOI toposheets 1961; Satellite data 1992, 2001 and 2010

Fig.7.23

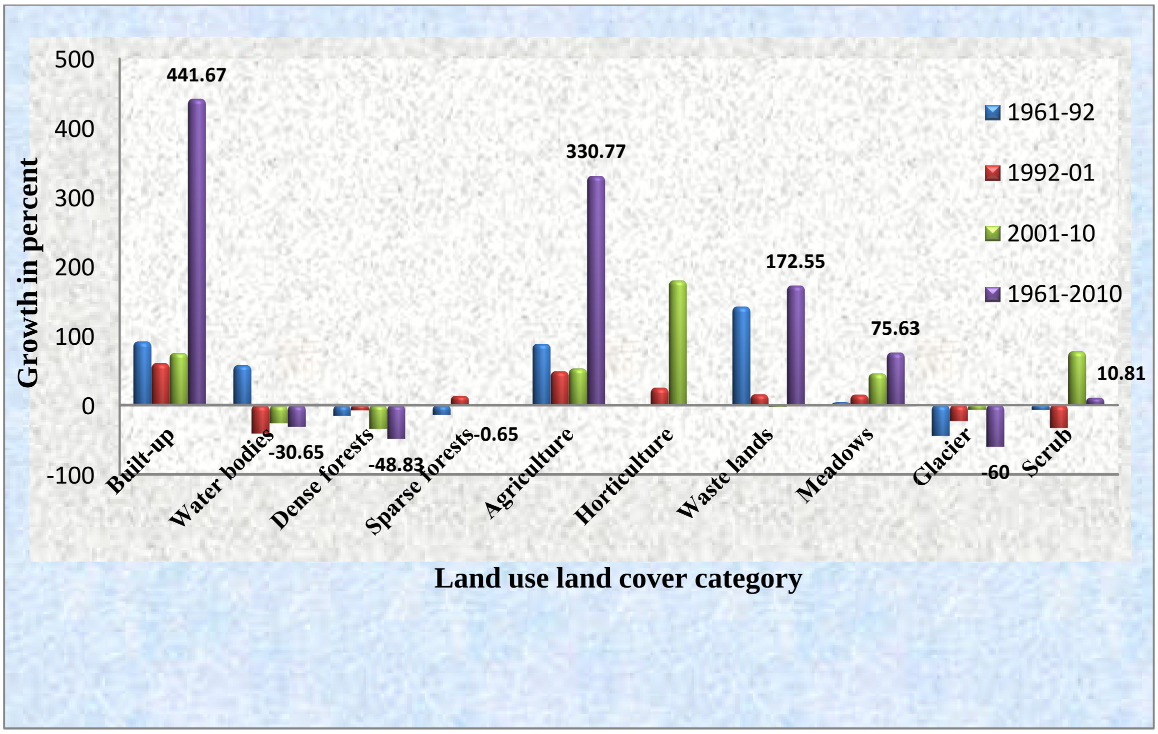


Fig. 7.24: Percentage growth in LULC categories in watershed 1E7A7

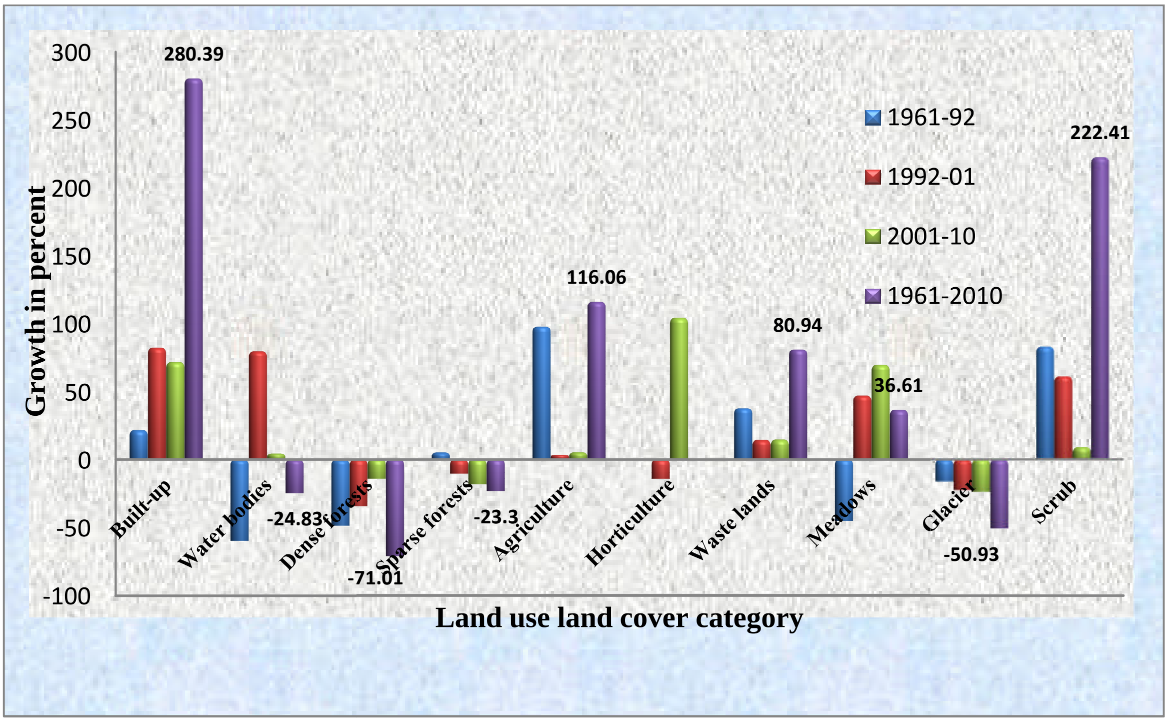


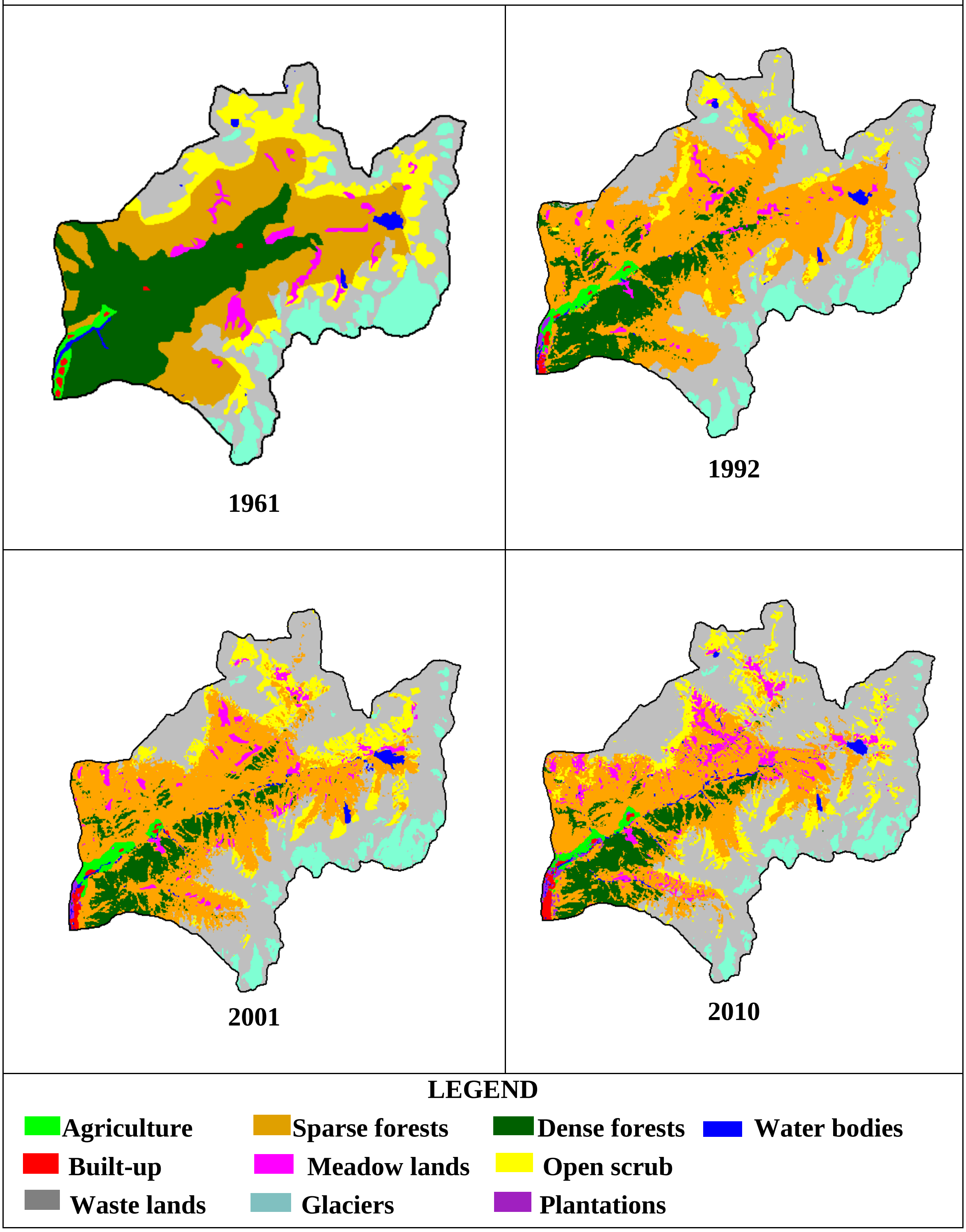
Fig. 7.25: Percentage growth in LULC categories in watershed 1E7B1

Table 7.7: Watershed wise percentage growth in LULC, Lidder catchment (1961-2010)

Watershed	Period	LULC category									
		Built-up	Water bodies	Dense forests	Sparse forests	Agriculture	Horticulture	Waste lands	Meadows	Glacier	Scrub
1E7A1	1961-92	179.82	-1.48	-39.48	59.73	-17.83		-18.29	-85.17		-17.07
	1992-01	26.44	-29.64	-24.12	-2.31	-20.46	102.02	3.33	109.68		-14.79
	2001-10	43.98	12.00	-12.45	-12.42	-10.37	19.11	-7.17	61.54		-23.77
	1961-2010	409.42	-22.37	-59.80	36.66	-41.42		-21.63	-49.76		-46.13
1E7A2	1961-92	29.03	-60.61	-26.94	244.57	1.76		42.96	-84.81		-22.59
	1992-01	25.83	102.56	-21.09	29.78	-21.29	-45.51	50.96	-22.92		20.90
	2001-10	27.81	22.78	-33.51	33.84	-25.58	238.82	16.40	-8.11		-21.14
	1961-2010	107.53	-2.02	-61.67	498.50	-40.39		151.20	-89.24		-26.20
1E7A3	1961-92		-59.20	-28.21	56.67			14.99	-28.95		7.21
	1992-01		-30.99	-3.41	-21.54			25.19	129.63		8.05
	2001-10		32.65	-27.34	23.58			33.10	0.65		-22.04
	1961-2010		-62.64	-49.61	51.92			91.61	64.21		-9.70
1E7A4	1961-92		73.08	-22.64	0.63			30.49	-67.20		-9.77
	1992-01		26.67	-39.77	-14.53			7.87	60.66		18.73
	2001-10		-19.30	-6.13	-43.05			9.47	93.37		20.55
	1961-2010		76.92	-56.26	-51.02			54.08	1.88		29.15
1E7A5	1961-92		53.54	-65.66	-1.61			44.79	-51.84		19.20
	1992-01		3.29	-51.13	-12.08			18.26	25.56		4.64
	2001-10		-15.92	-18.04	-51.50			16.17	154.64		42.12
	1961-2010		33.33	-86.25	-58.05			98.92	54.00		77.26
1E7A6	1961-92		53.45	-36.62	-24.28			123.84	91.17	-22.84	-43.55
	1992-01		22.47	-46.51	15.65			6.74	-28.76	-12.88	12.06
	2001-10		-21.10	-17.25	-42.49			20.87	48.01	-18.74	13.86
	1961-2010		48.28	-71.94	-49.64			188.78	101.57	-45.37	-27.97
1E7A7	1961-92	91.67	58.06	-15.42	-13.51	88.46		142.08	4.37	-44.04	-6.95
	1992-01	60.87	-40.82	-7.87	13.63	48.98	25.00	15.70	15.27	-23.37	-33.03
	2001-10	75.68	-25.86	-34.33	1.10	53.42	180.00	-2.69	45.97	-6.73	77.83
	1961-2010	441.67	-30.65	-48.83	-0.65	330.77		172.55	75.63	-60.00	10.81
1E7B1	1961-92	21.57	-59.86	-48.48	5.27	97.81		37.86	-45.28	-16.42	82.98
	1992-01	82.26	79.66	-34.38	-10.58	3.69	-14.29	14.51	47.24	-22.80	61.32
	2001-10	71.68	4.25	-14.24	-18.52	5.34	104.17	14.63	69.54	-23.94	9.23
	1961-2010	280.39	-24.83	-71.01	-23.30	116.06		80.94	36.61	-50.93	222.41
1E7B2	1961-92		-23.81	-16.02	-26.87	-58.23		161.15	-15.08	-57.83	-34.22
	1992-01		87.50	-16.76	33.96	84.85	14.29	3.28	-10.28	-18.10	-21.77
	2001-10		-27.78	-20.71	17.87	14.75	425.00	0.16	5.21	-18.60	63.68
	1961-2010		3.17	-44.57	15.47	-11.39		170.16	-19.84	-71.89	-15.78
1E7B3	1961-92	4.76	48.54	-14.44	-20.57	-18.77		46.75	53.79		64.15
	1992-01	31.82	-17.65	-10.95	4.08	7.59	105.00	31.53	-13.00		-13.95
	2001-10	36.21	-19.05	-23.03	23.94	20.19	43.90	17.35	8.25		-22.56
	1961-2010	88.10	-0.97	-41.36	2.46	5.04		126.51	44.83		9.39
1E7B4	1961-92	110.32	11.67	-36.97	250.52	-11.99		-21.01			-40.67
	1992-01	58.28	-7.67	-5.54	3.64	-19.15	84.32	11.45			13.71
	2001-10	73.45	23.02	-10.39	8.75	-21.82	26.50	22.81			9.93
	1961-2010	477.42	26.85	-46.65	295.08	-44.37		8.11			-25.84

Source: Source: Compiled from SOI toposheets, 1961 and Land Sat ETM, September 1992, 2001 and IRS P6 LISS III, September 2010

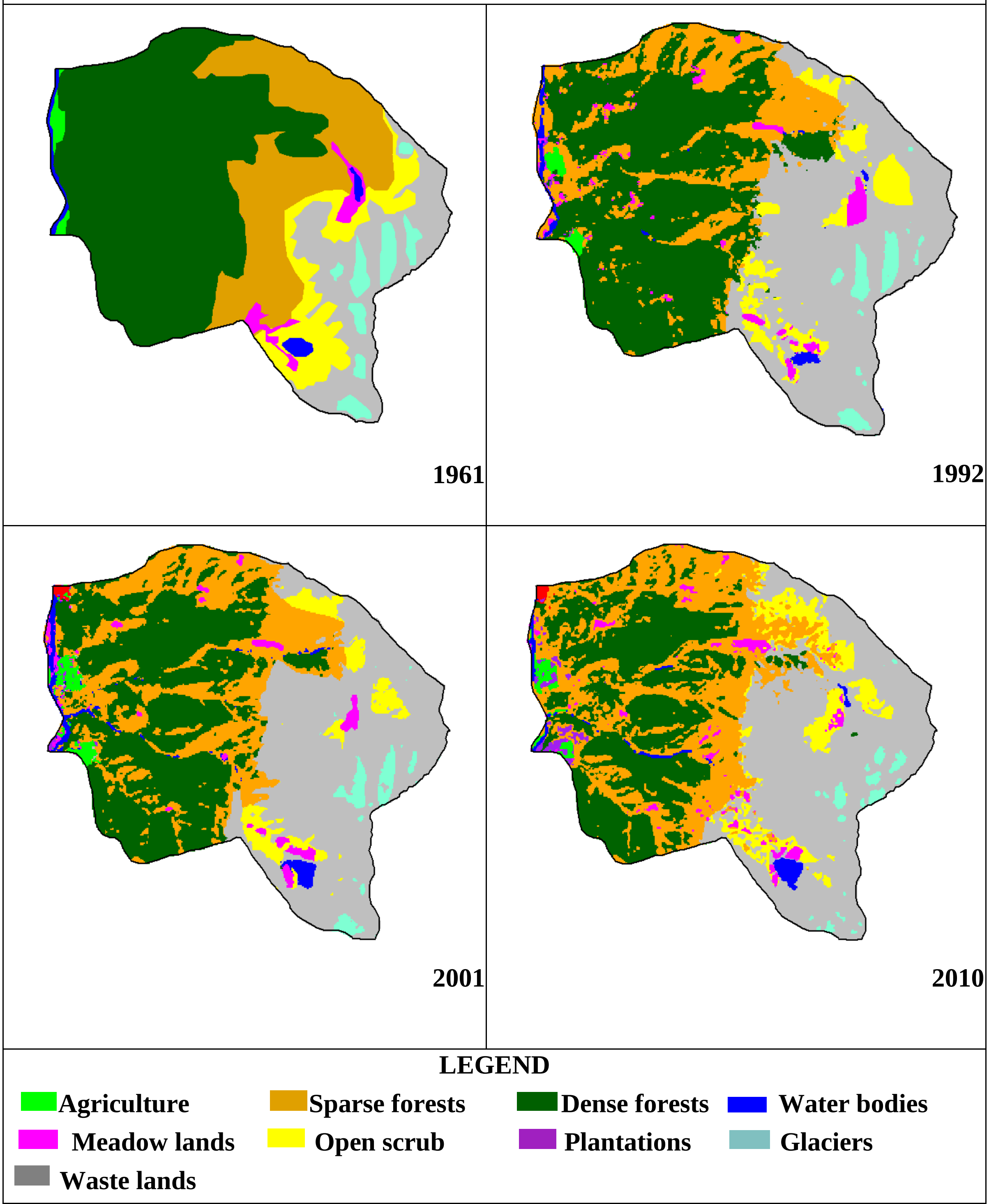
Land use land cover change in watershed 1E7B1 (1961 - 2010)



Source: SOI toposheets 1961; Satellite data 1992, 2001 and 2010

Fig.7.26

Land use land cover change in watershed 1E7B2 (1961 - 2010)



Source: SOI toposheets 1961; Satellite data 1992, 2001 and 2010

Fig.7.27

Table 7.8: Watershed wise average annual growth in LULC, Lidder catchment (1961-2010)

Watershed	Period	LULC category									
		Built-up	Water bodies	Dense forests	Sparse forests	Agriculture	Horticulture	Waste lands	Meadows	Glacier	Scrub
1E7A1	1961-92	5.8	0.03	-1.3	1.9	-0.6		-0.6	-2.7		-0.6
	1992-01	2.9	-3.3	-2.7	-0.3	-2.3	11.3	0.4	12.2		-1.6
	2001-10	4.9	1.3	-1.4	-1.4	-1.2	2.1	-0.8	6.8		-2.6
	1961-2010	8.4	-0.5	-1.2	0.7	-0.8		-0.4	-1.0		-0.9
1E7A2	1961-92	0.9	-2.0	-0.9	7.9	0.1		1.4	-2.7		-0.7
	1992-01	2.9	11.4	-2.3	3.3	-2.4	-5.1	5.7	-2.5		2.3
	2001-10	3.1	2.5	-3.7	3.8	-2.8	26.5	1.8	-0.9		-2.3
	1961-2010	2.2	0.04	-1.3	10.2	-0.8		3.1	-1.8		-0.5
1E7A3	1961-92		-1.9	-0.9	1.8			0.5	-0.9		0.2
	1992-01		-3.4	-0.4	-2.4			2.8	14.4		0.9
	2001-10		3.6	-3.0	2.6			3.7	0.1		-2.4
	1961-2010		-1.3	-1.0	1.1			1.9	1.3		-0.2
1E7A4	1961-92		2.4	-0.7	0.0			1.0	-2.2		-0.3
	1992-01		3.0	-4.4	-1.6			0.9	6.7		2.1
	2001-10		-2.1	-0.7	-4.8			1.1	10.4		2.3
	1961-2010		1.6	-1.1	-1.0			1.1	**0.0**		0.6
1E7A5	1961-92		1.7	-2.1	-0.1			1.4	-1.7		0.6
	1992-01		0.4	-5.7	-1.3			2.0	2.8		0.5
	2001-10		-1.8	-2.0	-5.7			1.8	17.2		4.7
	1961-2010		0.7	-1.8	-1.2			2.0	1.1		1.6
1E7A6	1961-92		1.7	-1.2	-0.8			4.0	2.9	-0.7	-1.4
	1992-01		2.5	-5.2	1.7			0.7	-3.2	-1.4	1.3
	2001-10		-2.3	-1.9	-4.7			2.3	5.3	-2.1	1.5
	1961-2010		1.0	-1.5	-1.0			3.9	2.1	-0.9	-0.6
1E7A7	1961-92	3.0	1.9	-0.5	-0.4	2.9		4.6	0.1	-1.4	-0.2
	1992-01	6.8	-4.5	-0.9	1.5	5.4	2.8	1.7	1.7	-2.6	-3.7
	2001-10	8.4	-2.9	-3.8	0.1	5.9	20.0	-0.3	5.1	-0.7	8.6
	1961-2010	9.0	-0.6	-1.0	0.0	6.8		3.5	1.5	-1.2	0.2
1E7B1	1961-92	0.7	-1.9	-1.6	0.2	3.2		1.2	-1.5	-0.5	2.7
	1992-01	9.1	8.9	-3.8	-1.2	0.4	-1.6	1.6	5.2	-2.5	6.8
	2001-10	8.0	0.5	-1.6	-2.1	0.6	11.6	1.6	7.7	-2.7	1.0
	1961-2010	5.7	-0.5	-1.4	-0.5	2.4		1.7	0.7	-1.0	4.5
1E7B2	1961-92		-0.8	-0.5	-0.9	-1.9		5.2	-0.5	-1.9	-1.1
	1992-01		9.7	-1.9	3.8	9.4	1.6	0.4	-1.1	-2.0	-2.4
	2001-10		-3.1	-2.3	2.0	1.6	47.2	0.0	0.6	-2.1	7.1
	1961-2010		0.1	-0.9	0.3	-0.2		3.5	-0.4	-1.5	-0.3
1E7B3	1961-92	0.2	1.6	-0.5	-0.7	-0.6		1.5	1.7		2.1
	1992-01	3.5	-2.0	-1.2	0.5	0.8	11.7	3.5	-1.4		-1.6
	2001-10	4.0	-2.1	-2.6	2.7	2.2	4.9	1.9	0.9		-2.5
	1961-2010	1.8	0.0	-0.8	0.1	0.1		2.6	0.9		0.2
1E7B4	1961-92	3.6	0.4	-1.2	8.1	-0.4		-0.7			-1.3
	1992-01	6.5	-0.9	-0.6	0.4	-2.1	9.4	1.3			1.5
	2001-10	8.2	2.6	-1.2	1.0	-2.4	2.9	2.5			1.1
	1961-2010	9.7	0.5	-1.0	6.0	-0.9		0.2			-0.5

Source: Compiled from SOI toposheets, 1961 and Land Sat ETM, September 1992, 2001 and IRS P6 LISS III, September 2010

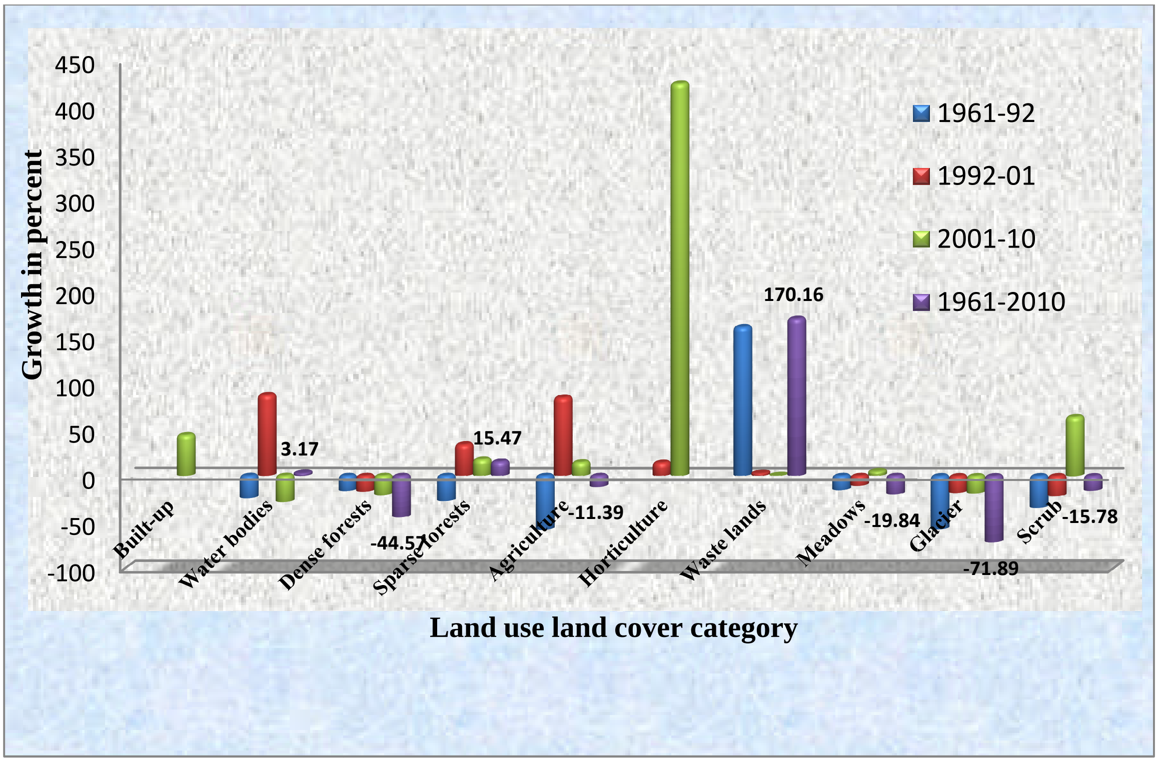


Fig. 7.28: Percentage growth in LULC categories in watershed 1E7B2

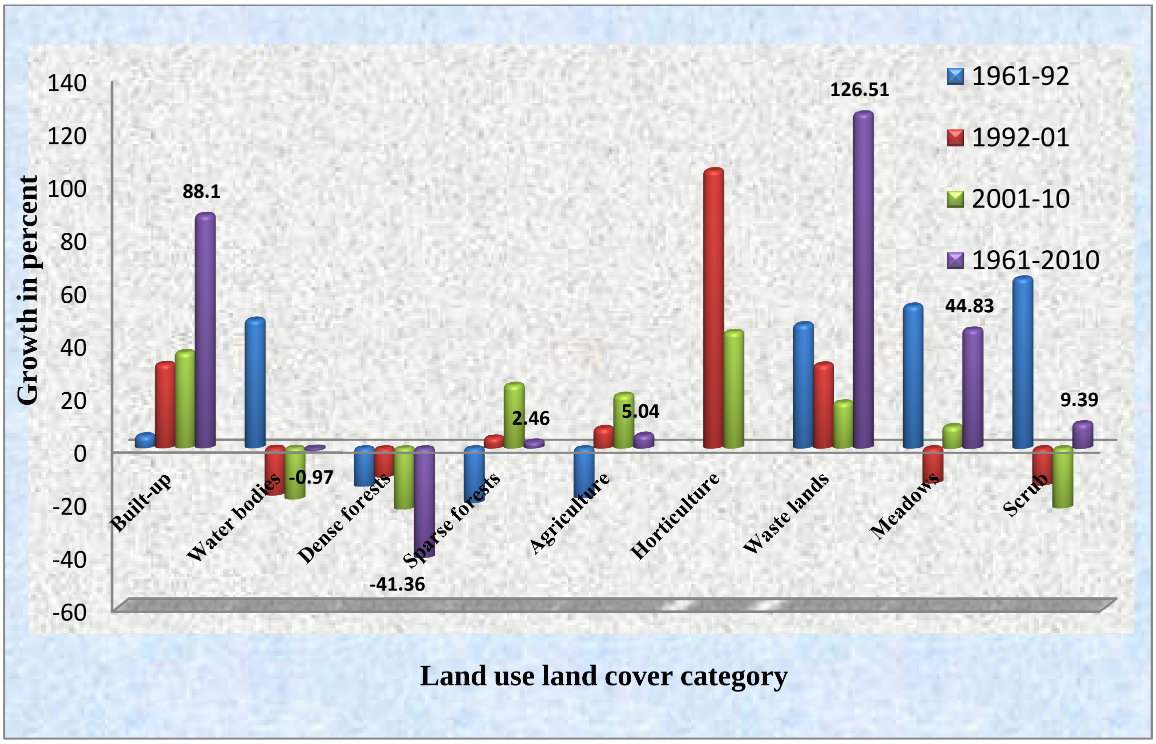
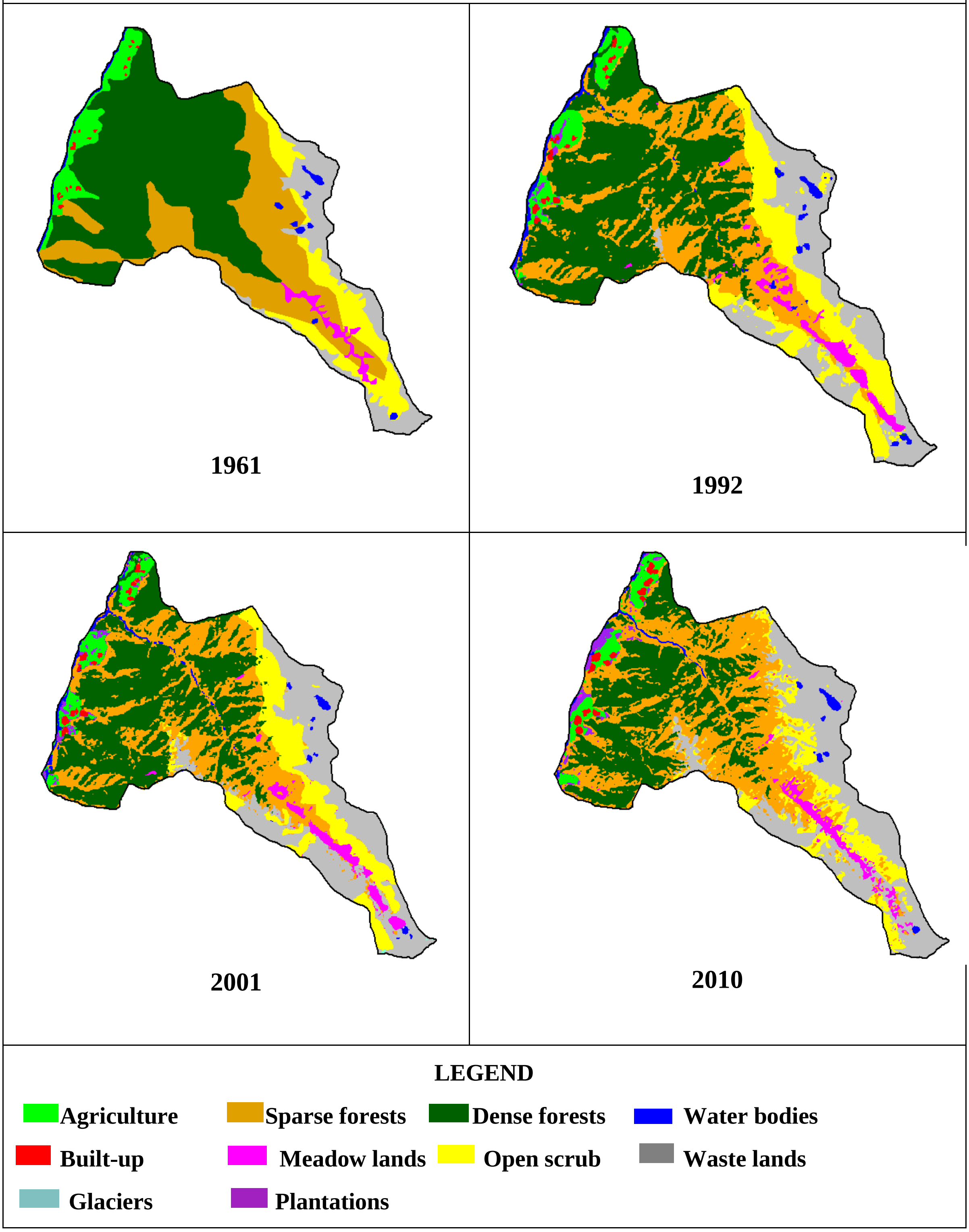


Fig. 7.29: Percentage growth in LULC categories in watershed 1E7B3

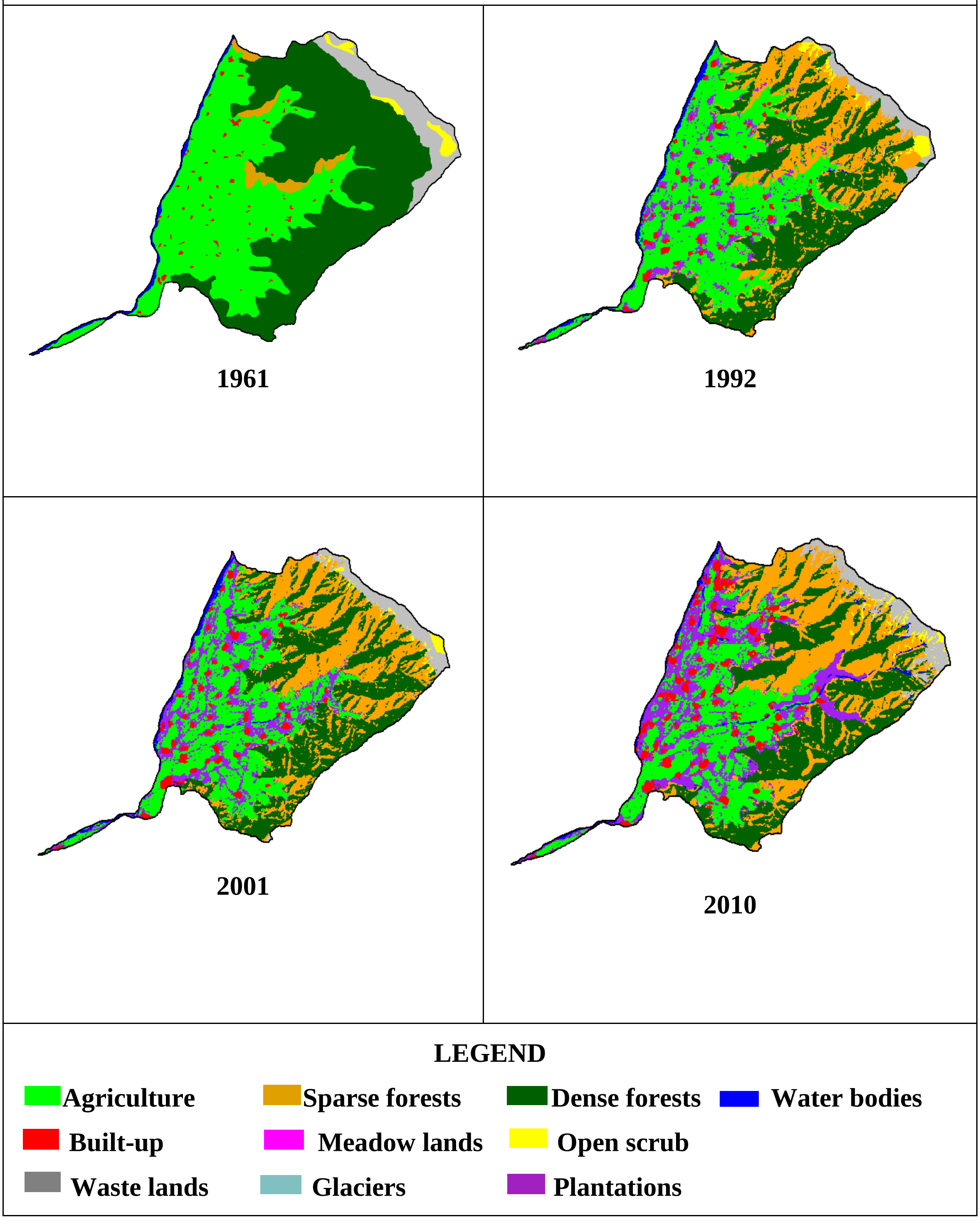
Land use land cover change in watershed 1E7B3 (1961 - 2010)



Source: SOI toposheets 1961; Satellite data 1992, 2001 and 2010

Fig.7.30

Land use land cover change in watershed 1E7B4 (1961 - 2010)



Source: SOI toposheets 1961; Satellite data 1992, 2001 and 2010

Fig. 7.31

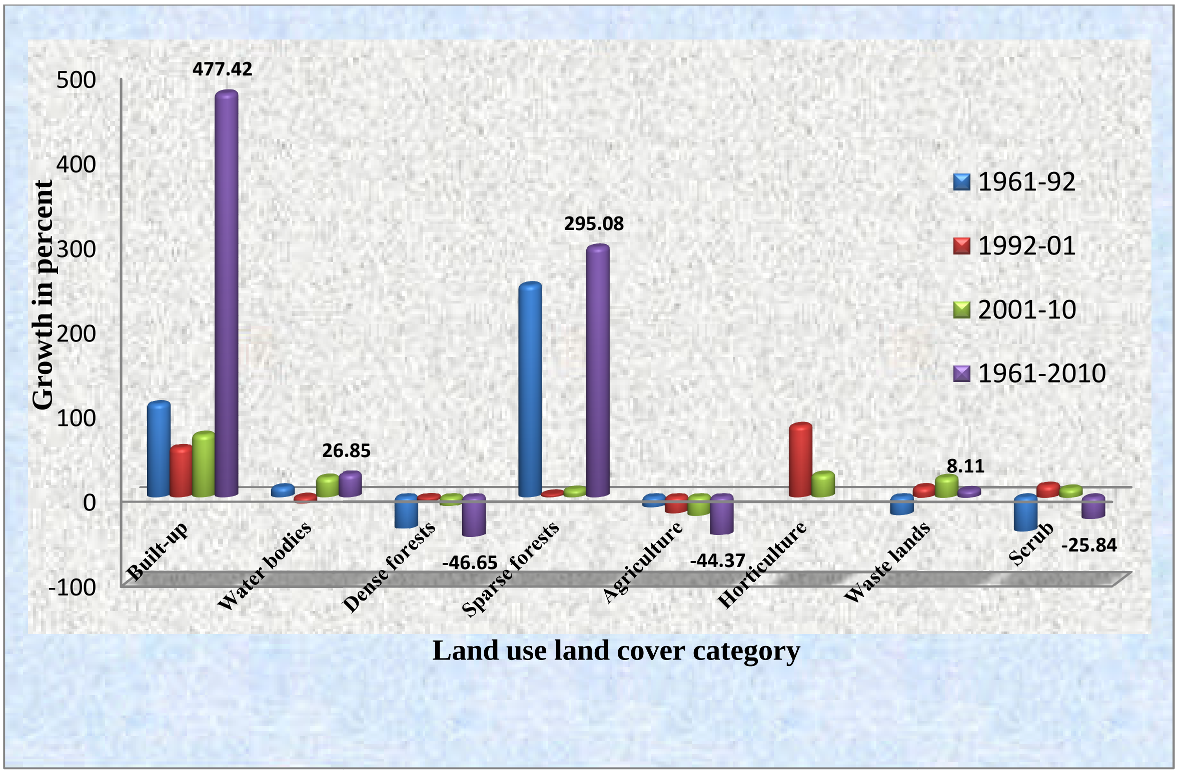


Fig. 7.32: Percentage growth in LULC categories in watershed 1E7B4

The Process of land transformation as observed in the present study has been presented in figure 7.33. On the basis of the preceding analysis, the watersheds of lidder catchment could be divided into three groups so far as the LULC change and its drivers are concerned. The first group consists of two watersheds of 1E7A1 and 1E7B1 which are located in the lidder flood plain. These two watersheds are densely populated and cover more than 89 percent of the total population of the catchment. The important driving forces of land use change in these two watersheds are population growth and maximisation of economic returns from arable land. The tremendous population growth has resulted into the expansion of built-up area at the cost of agricultural land and forests. The maximisation of economic returns has resulted into the conversion of agricultural land into horticulture because apple orchards earn much more income per hectare than paddy cultivation. It is important to mention here that from the last fifteen years there has been large scale conversion of agriculture to horticulture in these watersheds.

The second group consists of four watersheds of 1E7A2, 1E7A7, 1E7B1 and 1E7B3. The LULC change in these watersheds is from dense to sparse forests mainly on account of tourism and population growth. The watersheds of 1E7A7 and 1E7B1 are under tremendous tourist pressure as these watersheds not only cover the Pahalgam town and Aru village but also the important route to Amarnath cave. The tourist related infrastructure is expanding very fast in this region which is responsible for LULC change. However the main cause of LULC change in the other two watersheds is mainly on account of the native population growth. The glaciers found in three out of the four watersheds have reduced and changed to waste lands on account of the rise in average temperature by 1^0C from the last thirty years.

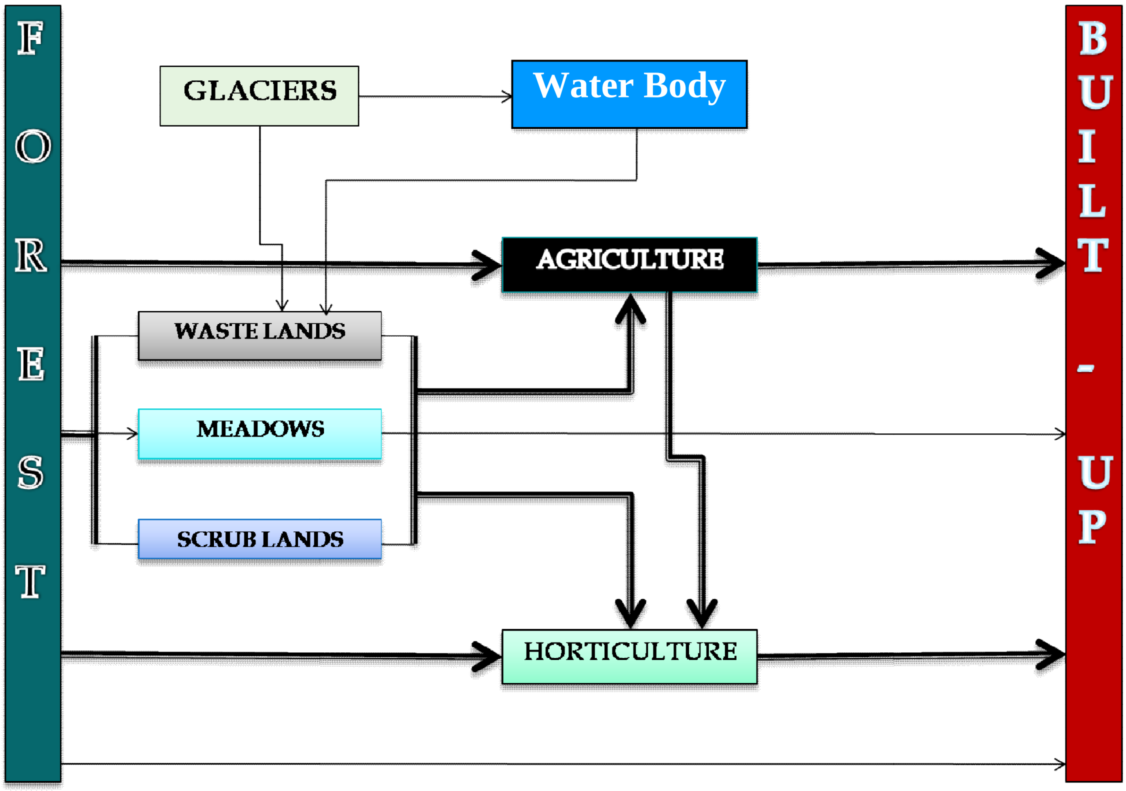


Fig. 7.33: Model of land transformation in Lidder catchment

The third group consists of five uninhabited watersheds located in the higher reaches of the catchment mainly towards northwest. The land transformation in these watersheds is from scrubs to waste lands and from dense forests to sparse forests and from sparse forests to meadows or waste lands. The overall vegetation density in these watersheds has reduced considerably over the last fifty years. Though the LULC change in these watersheds is mainly due to tourism, but the impact of tourism is less intense as compared to the northeast of the catchment. The tourism is confined to the site seeing and trekking to Kolahoi glacier, Tarsar and Marsar lakes and Lidderwat. It is also important to mention here that the deforestation in these uninhabited watersheds is because of the fact that the illegal felling of trees in the catchment is now-a-days carried on in the remote areas which are usually not monitored regularly by the concerned authorities.

CHAPTER - 8

WATERSHED PRIORITIZATION

Interactions between people and the environment are complex and dynamic. Many natural resource management challenges stem from complex and changing social processes, public demands and human values. Increased application and integration of social science in natural resource management decisions can lead to increased efficacy in management actions and improved public acceptability. Management strategy in terms of watershed prioritization has been presented for sustainable management of natural resources in Lidder catchment. The prioritization not only helps in the identification of watersheds which have been severely degraded and need immediate attention but also explains its causes and is thus helpful in reducing degradation of watersheds.

It is often difficult and economically unfeasible to consider a big catchment at once for management. The large financial and manpower commitments involved in treating watersheds require a selective approach to identifying smaller hydrological units for more efficient and better targeted resource management programs. Division of a catchment into watersheds and their evaluation on critical condition based on factors indicating degradation is the best way to prioritize watersheds for efficient management. The concept of watershed prioritization recognizes that we will not be able to restore all degraded areas at once even with the most adamant proposed management. Therefore, we must focus watershed restoration efforts on selected watersheds where we can hope to make a meaningful difference. The purpose of the prioritization process is to identify the watersheds best suited for priority action in which to conduct management.

The magnitude and intensity of the human impact is not same throughout Lidder catchment. The analysis has revealed that some of the watersheds are experiencing growing anthropogenic pressure beyond their carrying capacity which has resulted in unhealthy changes in their ecological framework. Therefore any conservation and management strategy of the catchment needs to be formulated on the basis of the watershed prioritization. The resource development programmes are applied generally on watershed basis and thus prioritization is essential for proper planning and management of natural resources for sustainable development (Vittala et al., 2008). Drainage basins, catchments and the sub-catchments are the fundamental units of the management of the land and water, identified as planning units for administrative purposes to conserve natural resources (Moore et al., 1977; Honore, 1999). The watershed management concept recognizes the interrelationship among the linkages between upland and lowlands, land use, geomorphology, slope and soil (Tideman, 1996). Thus the integrated approach plays an important role for sustainable development and management of natural resources (Khan et al., 2001; Gosain and Rao, 2004). The integrated impact of various socio-economic and bio-physical indicators of environmental change was used for prioritization of watersheds.

8.1. PRIORITIZATION INDICATORS

Since environmental degradation is the result of both socio-economic characteristics and the geo-physical attributes of a particular watershed, an integrated approach incorporating both the socio-economic behavior and geo-physical attributes needs to be evaluated on watershed basis. In developing countries watershed management is becoming increasingly important and attention is shifting to overall socio-economic welfare along with better water and soil conservation. This is specifically true for India where the population is continuing to grow at a rapid pace. Unprecedented economic activity is affecting LULC patterns and hence environmental quality. More lands are being brought under cultivation as there is an increased requirement to grow more food. The integrated effect of various socio-economic, geo-physical and LULC indicators is evaluated to recommend the priority rating of the watersheds and are discussed as follows:

8.1.1. Socio-economic Indicators

i) Population: The absolute number of people in any region is an important indicator of human impact (Wickham, 2000). Population is often assumed to be primary driver of environmental change in general and change in LULC in particular (Mather and Needle, 2000). More the population of an area, greater the impact on the environment. The total population of Lidder catchment is 233664 persons (Census of India, 2011) with 89.14 per cent residing in only two watersheds 1E7A1 (127158 persons) and 1E7B4 (81145 persons) while five watersheds are uninhabited. The population of the remaining four inhabited watersheds is less than 11 percent of the total population of the catchment. The watershed with highest population is assigned rank one while the watershed with lowest population is assigned sixth rank. The uninhabited watersheds are assigned the common rank of nine. Thus the watershed with lowest rank value is of highest priority and vice versa.

ii) Population growth: The greater the economic opportunities at a particular place, the more the population growth. High population growth usually causes high rates of environmental deterioration. Population growth is a significant driver of deforestation, as it is of various other forms of environmental change or degradation. There is an inverse relationship between national forest trends and population (Mather and Needle, 2000). In other words there is a positive correlation between population growth and deforestation (Brown and Pearce, 1994). Thus, environment degradation is a consequence of economic changes and population increase (Karan and Lijima, 1985). The rapid growth in human numbers in developing world imposes unsustainable burdens on the environment resource base to meet the demands of ever greater numbers of people (Myers, 1992). There exists a strong correlation between population growth and annual change in land cover especially forest clearance (Allen and Barnes, 1985). The average annual population growth from 1961 to 2011 is calculated in the present study. Lidder catchment has registered an annual population growth rate of 4.74 per cent since 1961. The highest growth rate is recorded in watershed 1E7B1 (7.74 per cent/year) followed by watershed 1E7A7 (6.06 per cent/year). The population growth rate in other watersheds ranges between 4.33 per cent/year to 4.78 per cent/year. The watershed with highest population growth is given rank one and the watershed with the lowest population growth is given the sixth rank while the uninhabited watersheds share a common rank of nine.

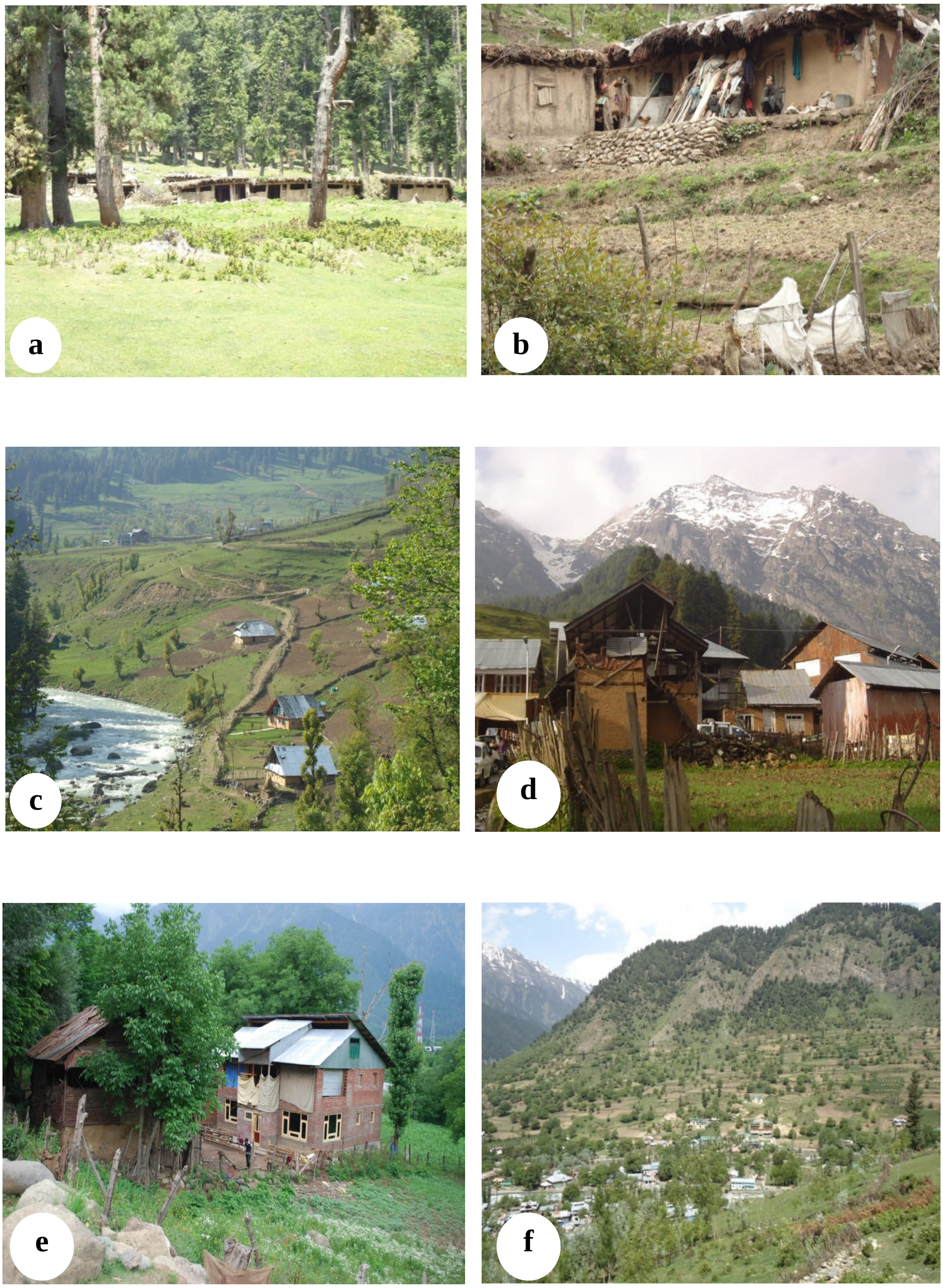


Plate 8.1: Rural settlements expansion on different LULC categories (a) Forest land (b) Agriculture land at high altitudes (C) Terraced agriculture Land (d) Meadow Land (e) fresh plantation land (f) Horticulture and forest land

The degradation of environment in Lidder catchment is caused to a great extent by the demographic growth and resultant settlement expansion as it alters the utilization pattern of resources structure available in a region. The changes in the various land use categories have been as a direct response to the requirements of growing population. The expansion of rural settlements in different watersheds has been mostly on forests, agriculture and horticulture lands as shown in plate 8.1.

iii) Density of population: It represents the man-land ratio and serves as an important indicator of intensity of human impact on earth. The higher the population density, the greater the impact on the environment. Population density can be chosen as an integrated indicator of anthropogenic load on regional landscapes (Isachenko, 2001). The population density in Lidder catchment is much higher (201.5 persons/km^2) than the state average (124 persons/km^2). The highest density is found in watershed 1E7A1 (734 persons per km^2) followed by watershed 1E7B4 (499 persons/km^2) while the lowest population density is found in watershed 1E7A7 (12 persons/km^2). The watershed with highest population density is assigned rank one while the watershed with the lowest population density is assigned rank six. The uninhabited watersheds share a common rank of nine. Thus the lowest rank value means highest priority and vice versa.

iv) Physiological density: It is expressed as a ratio of population to net shown area and indicates the agricultural impact. Greater the physiological density, greater is the impact on the environment. The physiological density in Lidder catchment is 1597 persons/km^2 of net sown area**.** It is highest in watershed 1E7B1 (3474 persons/km^2 of net sown area) followed by watershed 1E7B3 (2392 persons/km^2 of net sown area) while it is lowest in watershed 1E7A7 (1225 persons/km^2 of net sown area). The watershed with highest physiological density is given rank one and the watershed with lowest physiological density is given rank six while the uninhabited watersheds share a common rank of nine. Hence the watershed with lowest rank value is of high priority and vice versa.

v) Literacy: Literacy rate is an important indicator of overall socioeconomic development of an area. The mountainous areas are usually characterized by low levels of literacy. The overall literacy rate in Lidder catchment is 53.3 percent. The highest literacy is found in watershed 1E7B4 (55.2 percent) while the lowest literacy was found in watershed 1E7A7 (43.3 percent). The watershed with lowest literacy is given rank one while the watershed with highest literacy is given the sixth rank. Thus the lowest rank value means highest priority and vice versa.

vi) Average monthly household income: Income is very important indicator of economic development of an area. Rural poverty is an important issue in watersheds which is directly impacting on the environment. It is found that the poor people are mostly relying on forest fuel wood as their main source of energy as compared to the rich and hence they contribute significantly to deforestation. The watershed with lowest income was given the rank one and the watershed with highest income is given rank six. Thus the lowest rank value means highest priority and vice versa. The uninhabited watersheds share a common rank of nine.

vii) Dependency ratio: Expressed as the ratio of unproductive population to productive population, it serves as an important indicator of economic development of a region. The watershed with highest dependency ratio was given the rank one while the watershed with lowest dependency ratio was given the rank six. The highest rank value means low priority and the lowest rank value means high priority.

viii) Magnitude of firewood consumption: This is an important indicator which is used to assess the demand and pressure on the available forest stock. The magnitude and pattern of energy consumption of households reflect a high degree of dependence and use of fuel wood as a source of energy for different purposes especially for cooking and heating purposes. Easy access to firewood, lower levels of household income, commercialization of fuel wood and limited availability and lack of accessibility to procure LPG are among the leading causes responsible for heavy dependence on fuel wood. The commercialization of fuel wood has contributed towards the augmentation of house hold income for a number of rural households. It is mostly the women folk and the unemployed youth who are involved in the collection of fuel wood which is then being supplied to the hotels and guest houses mostly comprising of low and medium category hotels. A considerable part of fuel wood is also converted into charcoal which is in high demand throughout the Kashmir valley used as a heating fuel during the winter season. This high rate of fuel wood utilization on long term basis both in commercial and domestic sectors could pose a potential threat to the forest stock of the area which may lead to large scale deforestation and degradation of forests.

The average fire wood consumption in Lidder catchment is 10 kg/day/household. It is highest in watersheds 1E7A7 (13 kg/day) and 1E7B1 (12 kg/day) which are located in forest area where forest wood is easily available and winters are relatively severe. The firewood consumption is lowest in watershed 1E7A1 (6 kg/day). The watershed with highest fuel wood consumption is given rank one and the watershed with lowest fuel wood consumption is given rank six while the uninhabited watersheds were given a common rank of nine. The high magnitude of fire wood consumption by the households has put a severe stress on the forest stock of the catchment which has lead to steady deforestation in the lower reaches of the different catchments. The stocks of fire wood piled up by the households is displayed in plates 8.2.

Plate 8.2: (a) Extraction of fire wood (b) Fire wood stocks for domestic use

ix) Livestock population: This is an important indicator which is used to assess the impact of grazing on the environment. The more the livestock, the greater they consume and hence the impact on the environment particularly grazing lands is more. The watershed with highest livestock population is given rank one while the watershed with the lowest livestock population is given rank six. Thus the highest rank value means lowest priority and the lowest rank value means highest priority.

As a result of growing population pressure in terms of timber extraction and excessive grazing, the watersheds like 1E7A7, 1E7B1 and 1E7B3 have experienced a fragmentation of the terrestrial ecosystem (indicated in plate 8.3) which generated a mosaic of habitats that communicate among them through natural corridors, since there are no important barriers to stop the population interaction and exchanges.

Plate 8.3: Unregulated grazing in forest and meadow lands

x) Tourist pressure: Tourism is one of the important factors of environmental change in the study area (Bhat et al. 2007). The impact of tourism is most pronounced in the watersheds of 1E7A7 and 1E7B1 which constitute the beautiful meadow of Aru and Pahalgam town respectively where tourist infrastructure is developing very fast and more than 50 percent of the working population is engaged with tourism. The watersheds were given the rank from one to eleven depending on the intensity of tourism impact (table 8.1). In case of tie, the respective ranks were added up and divided by the number of watersheds which have got the same value. The lowest rank value means highest priority and vice versa. The impact of tourism has been assessed on the basis of recreational area available, development of tourist infrastructure and use of natural resources for tourism development as is evident from the following points.

A. Unplanned development of hotels: There has been continuous expansion of tourist accommodation especially the construction of new hotels mostly in the ecologically sensitive land uses like forests and meadows, river fronts and unstable hill slopes in the watersheds of 1E7A7 and 1E7B1 as highlighted in plate 8.4.

Plate 8.4: Construction of hotels on ecologically sensitive LULC categories (a) Clearing forest land for hotel construction (b) Hotel in the heart of forest land (c) Tourist huts on meadow land (d) Hotel constructed on captured river front (e) Hotel construction on dry agriculture land (f) Damaged coniferous trees

B. Location of Yatra base camps in ecologically sensitive areas: In order to provide accommodation to the yatries temporary base camps are developed with tented accommodation. But all the base camps are located on the banks of different tributaries of river lidder and along the ecologically sensitive areas as indicated in plate 8.5. These camping sites may lead to the various degrees of environmental and land degradation.

Plate 8.5: Tented accommodation for pilgrimage tourists (Yatris) at ecologically sensitive LULC categories (a) & (b) Meadow lands (c) Water body (d) Scrub lands (e) & (f) Forests

C. Development of unmarked road tracks: Though development of road transport infrastructure is underdeveloped in Lidder catchment with limited internal accessibility between the different settlements especially located in upper parts of the catchment at higher altitudes. The tourist town of Pahalgam experiences huge traffic flow during the summer tourist season. The road transport facility has been extended to various ecologically sensitive areas which have resulted in the fragmentation of different eco-habitats especially forests, meadows and grazing lands. Moreover the use of ponies as mode of transport to various tourist sites has resulted in multiple braided pattern of unmarked pathways which have lead to the degradation of soil and forests, trampling of meadowlands and have also enhanced the vulnerability of unstable slopes. The plate 8.6 displays the braided pattern of unmarked pathways through ecologically sensitive areas used by ponies to carry the tourists to various tourist destinations.

Plate 8.6: Unmarked multiple tracks through ecologically sensitive LULC categories (a) Unmarked pony track through meadow land (b) Braiding pattern of multiple tracks lead to degradation of forest soil (c) Pony tracks through unstable slopes and snow covered area (d) Forest fragmentation as a result of road construction

D. Generation of solid and liquid waste: The generation of solid waste is one of the major thrusts not only to the environment of Lidder catchment but also to the tourism itself. Huge quantities of liquid and solid waste is being generated by tourism which ultimately finds its way into lidder river as there is no waste treatment plant or any other waste management policy to avoid environmental degradation. Moreover the Yatra base camps of Nunwan, Zagipal, Chandanwari and Sheshnag are not adequately equipped to deal sufficiently with the collection of solid waste during Yatra period. Considerable quantities of unmanaged solid waste from these camps and also huge quantities of solid waste have been found in the form of trail garbage all along the route to Amarnath cave which finally find their disposal in the main water body of Lidder river. The adverse impacts of solid wastes disposal along ecologically sensitive sites and its long term impact on the environment can be gauged from plates 8.7.

Plate 8.7: Disposal of solid waste along ecologically sensitive sites (a) Residential site (b) Lidder stream (c) Residential and hotel drainage line (d) Meadow land (e) & (f) Forest land (g) Forest degradation as a result of unscientific disposal of solid waste (h) Open dumping site along a streamlet of river lidder

Table: 8.1: Values of prioritization indicators for different watersheds of Lidder catchment

Watershed	Socio-economic									Tourism	Geophysical				Land use land cover							
															Existing (percent)				Average annual growth			
	Population (thousands)	population growth (Percent)	Population density (persons/km^2)	Physiological density (persons/km^2 of net sown area)	Literacy (percent)	Average monthly income (INR)	Dependency ratio	Firewood consumption (kg/day)	Livestock population	Tourism impact	Dominant Slope category (degree)	Dominant Altitude zone (masl)	Drainage density	Stream frequency	Built-up	Agriculture	Waste lands	Forests	Built-up	Agriculture	Wastelands	Dense forests
1E7A1	127	4.76	734	1463	50	8000	0.44	6	157288	very low	< 5	< 2000	1.52	1.84	6.56	66.92	3.66	18.66	8.4	8.97	-0.4	-1.20
1E7A2	8	4.78	110	1388	48.3	7200	0.68	9	12842	very low	30-40	2000-2500	3.4	5.1	2.64	12.25	9.99	65.78	2.2	-12.16	3.1	-1.23
1E7A3										low	20-30	3500-4000	2.84	3.58			26.32	52.29			1.9	-0.99
1E7A4										very low	20-30	3500-4000	2.86	3.39			48.59	20.32			1.1	-1.13
1E7A5										very low	20-30	3500-4000	2.7	3.24			44.72	19.39			2	-1.72
1E7A6										very low	20-30	3500-4000	1.96	2.36			46.34	19.15			3.9	-1.44
1E7A7	0.9	6.06	12	1225	43.3	6500	0.57	13	1427	high	20-30	3000-3500	2.04	2.28	0.84	2	23.41	47.95	9	492.31	3.5	-0.98
1E7B1	10.3	7.47	45	3474	54.9	7300	0.52	12	12099	very high	20-30	4000-4500	3.05	4.19	0.85	1.72	43	34.31	5.7	187.59	1.7	-1.42
1E7B2										medium	30-40	3500-4000	3.35	4.39	0.24	2.09	34.19	52.57	0	41.77	3.5	-0.89
1E7B3	6	4.33	77	2392	44.5	7000	0.79	10	7714	low	20-30	3500-4000	3.52	5.26	1.01	6.29	24.43	54.48	1.8	38.1	2.6	-0.83
1E7B4	81	4.63	499	1713	55.2	7500	0.47	7	114269	very low	< 5	< 2000	2.23	2.83	5.51	39.02	5	47.5	9.7	-2.92	0.2	-0.93

Source: Computed from SOI toposheets, 1961, Census of India, 1961 - 2011, LANDSAT ETM, September, 2001, 1992, IRS P6 LISS III, September 2010 and field survey, 2011

Table: 8.2: Ranks of prioritization indicators for different watersheds of Lidder catchment

Watershed	Socio-economic										Geophysical				Land use land cover								Composite value	Priority Rating
															Existing (percent)				Average annual growth					
	Population (thousands)	population growth (Percent)	Population density (persons/km²)	Physiological density (persons/km² of net sown area)	Literacy (percent)	Average monthly income (INR)	Dependency ratio	Firewood consumption (kg/day)	Livestock population	Tourism impact	Dominant Slope category (degree)	Dominant Altitude zone (masl)	Drainage density	Stream frequency	Built-up	Agriculture	Waste lands	Forests	Built-up	Agriculture	Wastelands	Dense forests		
1E7A1	1	4	1	4	4	6	6	6	1	8.5	11	11	11	11	1	1	11	1	3	5	11	5	**123.5**	**Medium**
1E7A2	4	3	3	5	3	3	2	4	3	8.5	1	9	2	2	3	3	9	11	6	6	4	4	**98.5**	**High**
1E7A3	9	9	9	9	9	9	9	9	9	4.5	5	4	6	5	9	9.5	6	8	9	9.5	7	7	**170.5**	**Low**
1E7A4	9	9	9	9	9	9	9	9	9	8.5	3	2	5	6	9	9.5	1	4	9	9.5	9	6	**162.5**	**Low**
1E7A5	9	9	9	9	9	9	9	9	9	8.5	4	3	7	7	9	9.5	3	3	9	9.5	6	1	**160.5**	**Low**
1E7A6	9	9	9	9	9	9	9	9	9	8.5	7	5	10	9	9	9.5	2	2	9	9.5	1	2	**164.5**	**Low**
1E7A7	6	2	6	6	1	1	3	1	6	2	9	8	9	10	6	6	8	7	2	1	1.5	8	**109.5**	**High**
1E7B1	3	1	5	1	5	4	4	2	4	1	8	1	4	4	5	7	4	5	4	2	8	3	**85**	**High**
1E7B2	9	9	9	9	9	9	9	9	9	3	2	7	3	3	9	5	5	9	9	3	1.5	10	**150.5**	**Low**
1E7B3	5	6	4	2	2	2	1	3	5	4.5	6	6	1	1	4	4	7	10	5	4	5	11	**98.5**	**High**
1E7B4	2	5	2	3	6	5	5	5	2	8.5	10	10	8	8	2	2	10	6	1	7	10	9	**126.5**	**Medium**

Source: Computed from SOI toposheets, 1961, Census of India, 1961 - 2011, LANDSAT ETM, September, 2001, 1992, IRS P6 LISS III, September 2010 and field survey, 2011

8.1.2. Geo-physical Indicators

i. Slope: It is the ratio of vertical rise to horizontal run expressed as percentage or degrees of angle. Greater the slope of an area, higher the soil erosion and vice versa. The watersheds are prioritized on the basis of the dominant slope category (table 8.1). However many watersheds have same dominant slope category. In this case the percentage area under the particular slope category is used to assign priority. The watershed with its maximum area under relatively higher slope category is assigned rank one and the watershed with its maximum area under gentle slope is assigned the rank eleven. Therefore the low rank value means high priority and vice versa.

ii. Altitude: The high altitude watersheds are more susceptible to erosion as compared to low altitude watersheds. The watershed with its maximum area falling in high altitude zone was given rank one while the watershed with its maximum area in low altitude was given rank eleven. Hence, the low rank value means high priority and vice versa. In case of more than one watershed having the same dominant altitude zone, the percentage area under that altitude zone was used to assign priority.

iii. Drainage density: Drainage density has a direct impact on the soil erosion and landscape dissection. The watershed with highest drainage density was assigned rank one which means high priority and vice versa.

iv. Stream frequency: It is the number of stream segments per unit area. The higher number of stream units means higher rates of erosion. The watershed with highest stream frequency was given rank one as high priority while the watershed with lowest stream frequency was given rank eleven with lowest priority (table 8.2).

8.1.3. Land Use Land Cover Indicators

Changes in LULC are most important (Lambin et al., 2001). LULC change is gaining recognition as a key driver of environmental change (Riebsame et al., 1999). The Lidder catchment has exhibited the undesirable changes in its LULC pattern since 1961. The total area under a particular LULC category as well as its average annual growth is considered for watershed prioritization.

i) Area under forests: The dominance of forests is an indication of ecosystem stability and strength. The watershed with lowest percentage of forest cover was assigned rank one as high priority while the watershed with highest percentage of forest cover was assigned rank eleven as lowest priority. The statistics was used for the year 2010 which was generated from satellite data.

ii) Deforestation: Deforestation is not only an important indicator of environmental degradation but also of the anthropogenic impact on the watersheds. The average annual loss of dense forests from 1961 to 2010 is used for priority analysis. The watershed with highest average annual loss of dense forests was assigned rank one as high priority while that with the lowest loss was assigned rank eleven as lowest priority.

iii) Area under agriculture: More the area under agriculture greater the impact on the environment. The watershed with highest area under agriculture was assigned rank one as high priority while the area under lowest percentage area under agriculture was given lowest priority. The watersheds without any agricultural area were given a common rank.

iv) Expansion of agriculture: Increase in the area under agriculture means more pressure on the land especially in mountainous areas like Lidder catchment. The primary reason for forest destruction has always been the expansion of agriculture in order to grow food (Williams, 1997). The average annual percentage growth in the area under agricultural land is used for priority analysis. Since the increase in agricultural land in the catchment has been mostly at the expense of forest land, the watershed with highest average annual growth is given rank one as high priority and vice versa.

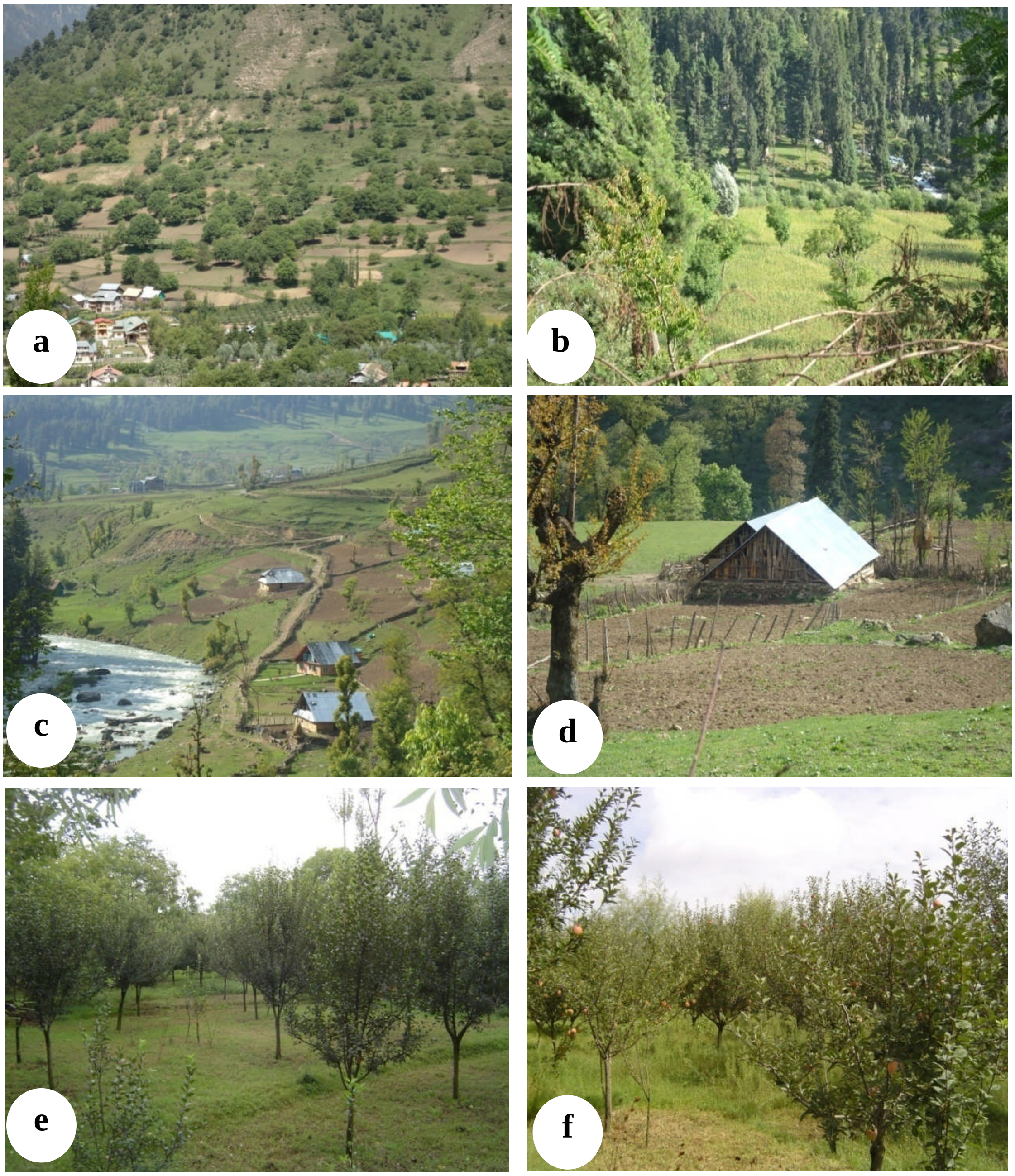


Plate 8.8: Agriculture expansion on various LULC categories (a) & (b) sparse forests (c) sloppy meadow land (d) flat topped meadow land (e) previously paddy land (f) previously dry agriculture land

It has been observed that due to the increased population pressure on the less fertile scarce agriculture land resource base of the catchment, there has been marked expansion of agriculture and horticulture land in some watersheds like 1E7A1,1E7A7, 1E7B1 and 1E7B4 on account of conversion of different land uses especially sparse forests, grazing and meadow land. The conversion of various land uses into agriculture land is exhibited in plate 8.8.

v) Area under waste lands: Aforestation can be done on the waste lands which would help to reduce soil erosion and excessive impact on the forests by providing fuel wood. The watershed with highest percentage of wasteland area was assigned high priority while the watershed with lowest wasteland area was given low priority.

vi) Waste land expansion: It is an important indicator of land degradation caused by human beings. The average annual growth of waste land is used for priority analysis. The watershed with the highest average annual growth in waste lands is assigned rank one as high priority and the watershed with lowest average annual growth in wasteland area was given rank eleven as low priority.

vii) Built-up area: The conversion of agriculture to built-up area not only reduces the area under agriculture but it also affects the hydrology of the watersheds by reducing percolation of rain water. More the area under built-up category, greater the impact on the environment. The watershed with maximum percentage of watershed area under built-up category was given rank one as high priority and vice versa. The uninhabited watersheds share a common rank.

viii) Built-up expansion: Built-up increases at the cost of agriculture which further pushes into higher slopes in mountainous areas which means further deterioration of the environment. The Lidder valley being one of the leading tourist nodes of Kashmir valley is experiencing a substantial increase in the built-up area mainly because of the development of tourist infrastructure related activities and the growth of native population. The watershed with highest average annual growth of built-up area was assigned rank one as high priority and vice versa.

The expansion of urban settlements in the form of built up and commercial area has encroached on a number of land use categories like forests, meadows and grazing lands, unstable slopes, river fronts and already scarce agriculture and horticulture lands especially in watersheds like 1E7B1 as has been shown in plates 8.9.

Plate 8.9: Urban settlement expansion on various LULC categories (a) Meadow land (b) Forest land (c) Water bodies (d) Horticulture land

8.2. PRIORITY REGIONS

The prioritization indicators as listed in table 8.1 have been used to work out the composite scores (table 8.2) for ranking the watersheds in order to prioritize them. The watershed 1E7B1 has attained the lowest composite value (85) which means that it demands highest priority while the watershed 1E7A3 has attained the highest composite value (170.5) which means that it needs lowest priority. The different watersheds of Lidder catchment have been classified in three prioritization zones (high priority, medium priority and low priority) on the basis of the rank composite scores (fig. 8.1).

1. **High priority zone:** This zone consists of four watersheds of 1E7B1, 1E7B3, 1E7A2 and 1E7A7. This zone is under tremendous human impact as the watershed 1E7B1 is extensively used as a tourist destination as the tourist town of Pahalgam is

situated in this watershed. The watershed consists of the most of the tourist infrastructure in terms of various accommodation units and remains very crowded in tourist season. The Base camps of Chandanwari, Zajipal and Sheshnag are also located in this watershed which are extensively used in yatra season and are a major source of water pollution. Apart from the highest tourism impact the watershed has experienced the highest population growth with the highest physiological density and the highest percentage area under altitude zone of 4000-4500 meters above sea level. The watersheds of 1E7A2 and 1E7B3 have got the same composite value (98.5) which comprise the mid altitude zone of Lidder catchment. The watershed 1E7A2 has highest percentage area under steep slope category and ranks second so far as drainage density and stream frequency are concerned. Moreover the watershed ranks third in other seven variables. However the watershed has the highest percentage of forests. The watershed 1E7B3 has highest dependency ratio and the highest drainage density and stream frequency. The watershed ranks second in physiological density and has low literacy and low average monthly household income. The watershed 1E7A7 is under substantial tourist pressure (2nd rank) and has lowest literacy and lowest average monthly household income. The watershed has also the highest fuel wood consumption and the highest growth in area under agriculture.

2. **Medium priority zone:** This zone consists of the two watersheds of 1E7A1 and 1E7B4. These watersheds are the most populous and together constitute more than 89 percent of the total population of the catchment. The watershed 1E7A1 has the highest population with highest population density, highest livestock population and highest area under built-up and agriculture and the lowest area under forests. This shows that most of the anthropogenic factors are dominating in this watershed. However the gentle slope, relatively low altitude, lowest drainage density and stream frequency and lowest area under wastelands and decrease in the wasteland area are the physical indicators which indicate that the watershed needs low priority. Same is the case with the watershed 1E7B3 where the physical setting is not a problem and waste lands constitute lowest percentage. This watershed has attained the highest average annual growth in built-up area.
3. **Low priority zone:** This zone consists of five uninhabited watersheds of 1E7A3,1E7A4, 1E7A5, 1E7A6 and 1E7B2 and hence is under lowest priority. However the highest average annual loss of dense forests is recorded in watershed 1E7A5 and highest average annual increase of wastelands is found watershed 1E7A6.

LIDDER CATCHMENT
WATERSHED PRIORITIZATION MAP

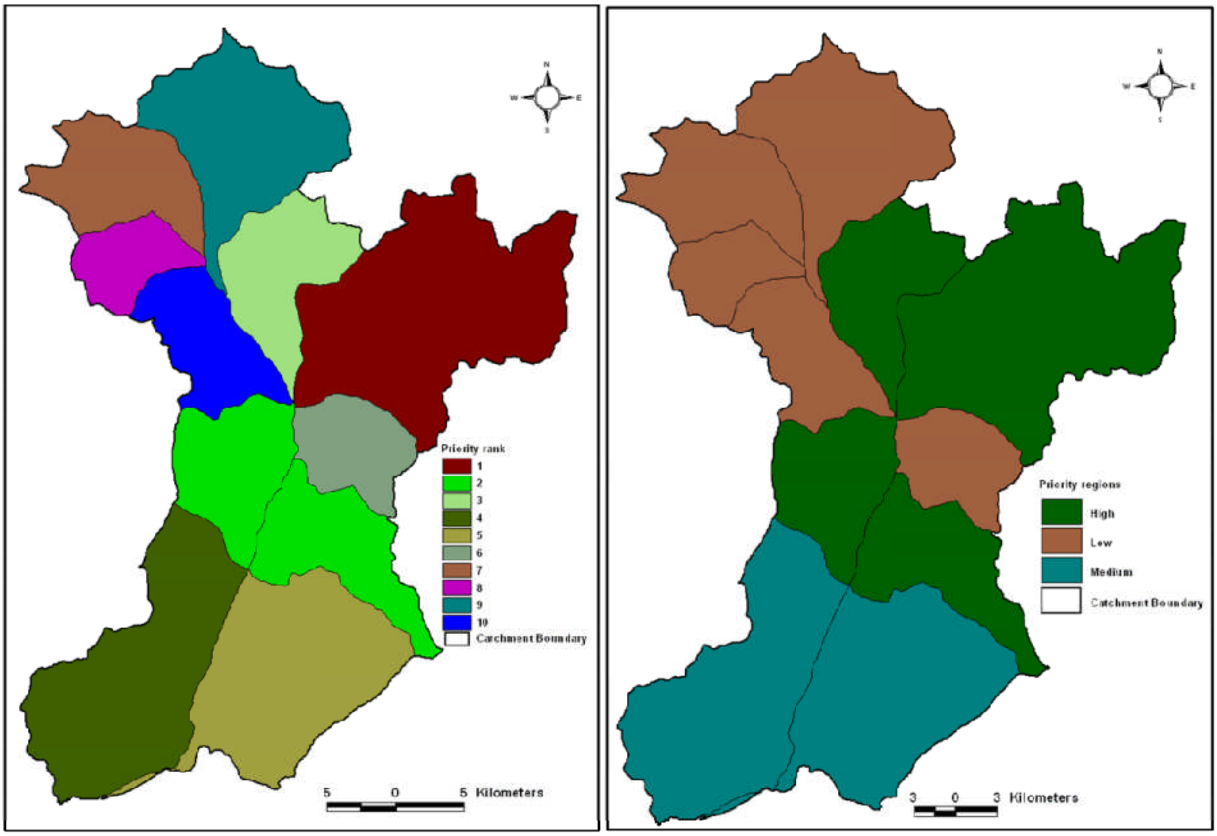


Fig. 8.1

CHAPTER - 9

CONCLUSIONS AND RECOMMENDATIONS

9.1. CONCLUSIONS

The Himalayas form an unstable zone. Being tectonically active, economically underdeveloped and the most densely populated mountain ecosystem, they are highly vulnerable to human intervention and impact. Here the natural factors cause more harm to environment but the human interface aggravates the situation. There has been serious imbalance in the Himalayan ecosystem brought about by over-exploitation of the natural resources. When the environment starts to deteriorate on steep mountain slopes, it deteriorates quickly far more so than on gentle slopes and on plains and the damage is far more likely to be irreversible. The major causes of environmental change in the Himalaya are various anthropogenic activities particularly land use not only those of present but also the impression of past activities. Land management objectives have changed with time with changing socio-economic conditions, technological innovations and policy interventions, leading to change in traditional land use practices.

The Lidder catchment is experiencing high growth rate of population, large scale deforestation, tremendous increase in degraded waste lands and pilgrimage as well as recreational tourism which is adversely affecting the carrying capacity of the region. If the current rate of population growth, the influx of tourism and deforestation continues, the Lidder catchment will become very fragile and might face an ecological disaster. Socio-economic transformation and LULC change has impacted heavily on the regional environment, mainly manifested by the extension of cultivation into marginal lands and forested areas, degradation of cultivated lands, deterioration of grazing lands, soil erosion, landslides, increase in the mean monthly minimum and maximum temperatures and the development of tourism. The preceding analysis has revealed that the Lidder valley is undergoing an undesirable LULC change that poses a serious threat to its fragile ecological environment. Being the leading tourist node receiving more than 70 percent tourist arrivals of Kashmir valley accompanied with domestic anthropogenic pressure, the existing carrying capacity of the Lidder valley has been exceeded thus adversely affecting its sustainable tourism base. Thus the need of the hour is to explore and devise the sustainable tourism development strategies that would form a unique symbiosis and harmony with natural environment. In fact such strategies must focus on working for a regenerative ecosystem that should promise stability in economic, social and ecological environments.

The study area is experiencing an increasing anthropogenic interference as a result of mass tourist inflow which has changed the demographic and economic scenario of the catchment. This situation has stressed the already weak economic base of the area which is characterized by heavy reliance on agricultural sector and other natural resources especially the forests. The energy and food requirements of the native and floating tourist population are being met through local resource base which have mainly encroached the forest resource of the area. The high rate of fuel wood utilization on long term basis both in commercial and domestic sectors has posed a potential threat to the forest stock of the area which may lead to large scale deforestation and degradation of forests. Besides this the weak tourist infrastructure base, biased and unplanned economic activities of the local dwellers and non-existence of government tourism policy, have resulted in a continuous and fast change in the LULC of the catchment from forest to non-forest uses and the consequent degradation of the various available resource potentialities of the catchment. The tourist carrying capacity has been assessed in order to attain sustainable tourism development by limiting the number of tourist arrivals as the present tourist flow exceeds the tourist carrying capacity of the region in summer season.

Environmental issues should be dealt together. Isolated measures to cope with one of them can sometimes make others worse. There is the need to develop an integrated interdisciplinary methodology for the investigation of sustainability in its three major dimensions- ecological, social and economic. The watershed is the smallest unit where the evaluation of human-induced impacts upon natural resources becomes possible. The resource development programmes are applied generally on watershed basis and thus prioritization is essential for proper planning and management of natural resources for sustainable development. Remote sensing and GIS are very useful in assessing the spatio-temporal dynamics of various socio-economic and geo-physical characteristics of an area over a given period of time. This study has shown that remote sensing and GIS can be used as appropriate tools for watershed prioritization.

The magnitude and intensity of the human impact is not same throughout Lidder catchment. The analysis has revealed that some of the watersheds are experiencing growing anthropogenic pressure beyond their carrying capacity which has resulted in unhealthy changes in their ecological framework. The prioritization of the watersheds has enabled to assess the varying degree of human impact these regions are prone to, if not utilized rationally with respect to the environmental carrying capacity. The resource potentialities of the catchment need to be evaluated objectively to identify the potential sectors of development and their carrying capacity which would help in the integrated development of the catchment and its stakeholders in an eco-friendly and sustainable manner. Therefore any conservation and management strategy of the Lidder catchment needs to be formulated on the basis of the watershed prioritization.

9.2. FINDINGS

The inferences and findings not only lead to vital insights possible for enhancement of scientific knowledge in the area of research on environmental change, but also to local decision making by identifying new approaches for analysis of natural resource management practices and its associated impacts at watershed level. The main inferences drawn from the present study are summarized as follows:

I. The Lidder catchment with an area of 1159.38 km^2 constituting about 10 per cent of the total catchment area of river Jhelum is predominantly a mountainous one bounded on all sides by lofty mountains except on south. The upper parts of the catchment comprise of exposed rock surfaces and cliffs mostly overlaid with recessional moraines and a number of prominent glaciers and high altitude lakes. The middle part of the catchment has a considerable area under dense forests and large sized meadows. A number of small terraced alluvial fanes and cones have been formed along the main drainage channel. The lower parts of the catchment are covered with flood plain of river

Lidder and a sporadic presence of Karewa lands could be observed in this part of the catchment. The general elevation ranges from 1596 meters (Gur Village) to 5425 meters (Kolahoi peak) with the average altitude of 3510 meters. Out of the total area only 22.4 per cent has moderate slope while more than 60 per cent has steep to very steep slope.

II. Lidder river which is formed due to the confluence of East and West Lidder streams is one of the major right bank tributary of river Jhelum. It is a 6th order stream comprising of 3857 lower order streams. Horton's law of stream lengths and Law of stream numbers holds good in Lidder catchment.

III. The climate of the catchment is governed by altitude, topography and amount of rainfall received. The valley experiences temperatures varying from as low as -9.8°C in the winter to as high as 27°C in summer. The mean minimum as well as the mean maximum temperatures have increased considerably (1.1°C each) during the last three decades. The catchment receives 124 cm of average annual precipitation with its considerable share in the form of winter snowfall. The precipitation has decreased by 12 cm associated with a corresponding decrease in the number of rainy days by nine days during the last three decades.

IV. Lidder river has 914 cusecs with the highest discharge recorded for the months of May and June (1733 cusecs and 1729 cusecs respectively). The discharge has initially increased by 120 cusecs from 890 during the decade 1961-70 to 1010 cusecs in 1971-81. However the discharge has registered a decreasing trend from 1971-81 to 1981-90 where it has decreased by 40 cusecs and has remained constant (834 cusecs) from the last two decades. The discharge has decreased for only those months which experience relatively higher temperature (June to November) with the highest decrease of 772 cusecs recorded for June while it has increased in the months which have relatively low temperatures (December to May) with the highest increase of 368 cusecs recorded for the month of May.

V. The Lidder catchment comprises of eleven watersheds among which six watersheds are inhabited by 120 rural settlements and three urban centers of Pahalgam, Aishmuqam and Seer Kanaligund while five watersheds are uninhabited.

VI. The catchment is inhabited by a population of 2.34 lac persons (Census of India, 2011) distributed among 35.8 thousand households with the average household size of 6.5 persons per household. The number of households has registered a growth of 197.3 per cent from 1961 to 2011 with the average annual household growth of 3.95 percent. Urban population constitutes 9.7 percent which has shown a growth of 1080 percent from 1961 to 2011 mainly because of the addition of two new urban centers in 2011.

VII. The distribution of population is highly uneven as 89 per cent of the total population is residing in only two watersheds while five watersheds are uninhabited. The sex ratio is 947 females/thousand males which is higher than the sex ratio of 883 females/thousand males for the state of Jammu and Kashmir and 914 females/thousand males for the country as a whole (Census of India, 2011). Literacy rate is 53.3 per cent with the male literacy rate of 64.2 per cent and female literacy rate of 41.8 per cent against the literacy rate of 68.74 per cent for the Jammu and Kashmir state with the male literacy rate of 78.26 per cent and female literacy rate of 58.01 per cent (Census of India, 2011).

VIII. Population density is 201 persons/km^2 which is much higher not only than the state average of 124 persons/km^2 (census of India, 2011) but also than that of Indian Himalayan Region as a whole (74 persons per square kilometer). The physiological density is very high in Lidder catchment (1597 persons/ km^2 of net sown area) owing to high growth rate of population on one hand and constant net sown area available on the other hand

IX. Population of catchment has grown more than 3.3 fold from 69.3 thousand persons in 1961 to 2.34 lac persons in 2011. The highest population growth rates in the watersheds 1E7B1 and 1E7A7 are directly related to tourism. The proportion of the population in the age-group of less than 14 years is 25.4 percent where as 6.3 per cent is in the age group of 60 years and more. The economically productive population in the age group of 15 to 59 years age constitutes 68.3 per cent of the total population.

X. The occupational structure is dominated by primary sector (45.7 per cent) followed by service sector (44.7 per cent) while the secondary sector is quite insignificant as only 9.6 per cent of the working population is engaged in small scale household industrial sector. The primary sector is dominating in the lower parts of the catchment where agriculture land is available while tourism dominates in the upper parts of the catchment. About 68.3 percent of the population is in the economically productive age group that could be fully utilized as a human resource. The percentage of actual workers is 41.8 percent with the employment gap of 26.5 per cent while as participation rate of workers is 61.3 per cent with the dependency ratio of 0.46. The average household income has been estimated at Rs. 7250 /month.

XI. The magnitude and pattern of energy consumption for both households and hoteliers reflect a high degree of dependence and use of fuel wood as a source of energy for different purposes especially for cooking and heating purposes. The average consumption of fuel wood has been worked out to be about 430 quintals/day comprising of 280 quintals/day by households and 150 quintals/day by hoteliers and guest houses. The average consumption of fuel wood for the households is about 10 kg/household/day. Easy access to firewood, lower levels of household income, commercialization of fuel wood and limited availability and lack of accessibility to procure LPG are among the leading causes responsible for heavy dependence on fuel wood. The commercialization of fuel wood has contributed towards the augmentation of household income for a number of rural households. It is mostly the women folk and the unemployed youth who are involved in the collection of fuel wood which is being supplied to the hotels and guest houses mostly comprising of low and medium category hotels. A considerable part of fuel wood is also converted into charcoal which is in high demand throughout the Kashmir valley used as a heating fuel during the winter season.

XII. Live stock constitutes one of the significant ancillary primary economic sectors of the entire catchment. It has a livestock population of 3.05 lac units with the highest number found in watershed 1E7A1 (1.6 lac) because it covers more than 48 per cent of the total villages of the catchment. This huge livestock population is mostly fed on the meadow and grazing lands of the catchment which may lead to their degradation in the absence of proper regulation and management strategy.

XIII. The per capita land availability is 5.5 kanals/household. The expansion of commercial farming of apple orchards and steady growth in the tourism industry have initiated a series of developmental impulses to facilitate the improvements in the regional economy which is largely subsistence based. This has brought drastic change in land and resource use. The household economy strongly depends on access to common or state owned forest or grazing land as private agricultural holdings are small and many are land less in Lidder catchment.

XIV. Lidder valley receives more than 70 per cent of the tourists visiting Kashmir valley which has boosted the process of urbanization in the area. The three months of May, June and July constitute about 83 percent of the total tourist flow to Pahalgam. These three months bare more than seven lac tourists (including yatries) which is certainly beyond the carrying capacity of the region which has been estimated at 4300 tourists/day for summer season. The tourist flow to Pahalgam is well below the carrying capacity for most part of the year. The growth of tourist flow has been associated with a corresponding growth in tourist accommodation infrastructure. There are presently 231 accommodation units comprising of 84 hotels and 147 guest houses having about 2907 rooms with a capacity of 5763 beds which exceeds the exiting threshold number of daily average carrying capacity of 4300 tourists/day. The comparative analysis of bed capacity, room strength and tourist flow to Pahalgam and primary survey of tourists has revealed that there is shortage of accommodation during the months of July and August as daily tourist flow during these months is higher than that of the available accommodation because of Yatris. However the availability of accommodation at Nunwan base camp which provides accommodation for yatries has considerably reduced the pressure on the hotels and guest houses. While as during the remaining part of the year room occupancy levels are significantly low in all categories of accommodation sector which suggests that the existing tourist accommodation capacity is not only adequate but also in excess to the existing average tourist carrying capacity.

XV. The tourist accommodation sector generates about 2682 metric tons of solid waste annually comprising 975 metric tons from hotels and 1707 metric tons from Yatri (Pilgrims) base campuses. The three months of June, July and August constitute about 83 per cent (2231 metric tons) of total annual generation with an average generation of about 24.77 metric tons/day. The per capita generation of solid waste is about 2.40 kg/day.

XVI. Three tourist potential regions were identified in Lidder catchment on the basis of tourist attraction, infrastructure and tourist activity.

XVII. The varied topography of Lidder catchment greatly determines the degree of variation in LULC pattern within the region. The LULC pattern has been changing since 1960’s as a result of the mounting pressure on the natural resources. The increasing anthropogenic pressure mostly on account of growth in tourism sector and agriculture developments has lead to undesirable LULC change in the catchment.

XVIII. The area under dense forests has decreased by 191.53 km^2 from the year 1961 to 2010 with the average annual loss of 3.91 km^2 per year. The sparse forests have registered a variable trend throughout the study period. They have initially registered an increase of 13.62 percent from 1961 to 1992, but in the decade of 1992 to 2001, they showed a slight decrease of 0.67 percent. However from 2001 to 2010, they have decreased by 9.79 percent. This could be attributed to the fact that the dense forests were initially changed into sparse forests and in the later stage these sparse patches were utilized for agriculture and residential purposes.

XIX. The area under glaciers has also decreased from 42.49 km^2 in 1961 to 20.59 km^2 in 2010 registering the negative growth of 51.54 percent with the average annual loss of 0.45 km^2. The area under horticulture has registered an increase of 49.96 km^2 from 1992 to 2010 with the average annual increase of 2.78 km^2 which amounts to the average percentage growth of 7.58 percent. Waste lands have increased from 154.69 km^2 in 1961 to 307.2 km^2 in 2010 registering a growth of 98.59 percent with the average annual growth of 2.01 percent. While as the area under water bodies has decreased from 1961 to 2001 but has increased from 2001 to 2010 registering the overall negative growth of 9.74 percent from 1961 to 2010 which amounts to the average annual loss of 0.2 percent. Area under meadows have initially decreased from 1961 to 1992 but then increased from 1992 to 2010 with the overall increase of 12.67 km^2 which amounts to the average annual increase of 0.26 km^2 (0.72 percent). The area under scrubs has also shown an increase of 13.22 km^2 from the last fifty years with the average annual increase of 0.27 km^2. They have decreased from 1962 to 1992 but increased from 1992 to 2010.

XX. Built-up area has increased from 0.5 km^2 in 1961 to 2.22 km^2 in 2010 thus registering a growth of 347.05 percent with the average annual growth of 7.08 percent. The area under agriculture is decreasing from 187.9 km^2 (in 1961) to 113.27 km^2 (in 2010) on account of the land use change from agriculture to horticulture and partly due to the conversion of agriculture area into residential areas. The area under waste lands, horticulture, meadows and built-up has increased at the cost of the area under forests, water bodies, agriculture and glaciers. In case of the uninhabited watersheds the trend of LULC change is that of decrease of dense forests, water bodies and glaciers and increase in waste lands.

XXI. The Lidder catchment has been divided into three priority regions. The high priority region is under tremendous tourist pressure while as in the medium priority region demographic drivers have a major role in environmental destruction. The low priority region constitutes the uninhabited watersheds of the catchment.

9.3. SUGGESTIONS

The Lidder catchment being mountainous area is characterized by diverse physiographic disposition comprising of immature landforms and fragile ecological set up which are highly susceptible to various natural and anthropogenic influences. The catchment is undergoing through unprecedented and undesirable LULC changes mostly driven by the processes resulting in the rapid expansion of agriculture related activities, unplanned urbanization and development of mass tourism related infrastructure which have also lead to adverse impacts on the Lidder watershed system leading to the degradation of its vital natural resources. The symptoms of deterioration are quite noticeable in the form of deforestation, deteriorating aquatic system and changes in hydro-meteorological regime, degradation of meadow and pasture resources and highly undesirable changes in the various LULC categories. The following set of recommendations framed on the basis of the inferences drawn from the present study have mainly focused to address the key concerns of watershed degradation driven by a wide range of anthropogenic influences. These recommendations are expected to serve as vital inputs for formulating the sustainable natural resource management strategy to ensure the sustainable development of the available resource potentialities of Lidder catchment.

I. The Lidder catchment being a mountainous one is very fragile and every development programme must be viewed in terms of its environmental impact before implementation. A comprehensive land use plan must be formulated for Lidder catchment in order to avoid the negative effects of haphazard and unplanned development. It is important to mention here that the undesirable LULC change has not only resulted into increase in mean minimum and mean maximum temperature but has also caused reduction in annual precipitation and glaciers in the catchment. The cultivation on the higher slopes must be stopped or at most the cultivation of only permanent tree crops must be encouraged there. The agricultural land is under tremendous impact as physiological density is very high in Lidder catchment. Employment opportunities must be provided in other sectors in order to reduce burden on agricultural lands and to raise standard of living of the inhabited population.

II. Though the regional economy is largely a subsistence agrarian economy with its roots in agriculture and livestock pastoral activities, it has also a heavy reliance on tourism sector. Tourism industry constitutes the main source of substantial portion of household income and also provides a wide range of employment opportunities to the bulk of its work force. Though given the huge potential of tourism in employment and revenue generation, the developmental benefits of this sector have not trickled down to the gross root level. The economic benefits especially with regard to reasonable levels of income generation are yet to be shared by the larger sections of the rural common population of the area as these have remained largely confined to a section of the affluent urban class from Anantnag and Srinagar city. This inequitable share of economic benefits may lead to social unrest in the local population which needs to be addressed as they constitute an important component in capacity of local stake holders whose involvement and participation is quite significant in the process of promotion and growth of sustainable tourism industry in the region. The seasonal character of tourism sector, low level of social development of local population and the lack of integration of local economy with tourism sector constitute the plausible causes for lower levels of economic benefits of tourism sector for the larger sections of the local population. It is pertinent to propose here that the tourism policy in the region should be adopted as a useful and relevant strategy for alleviation of poverty of the masses. All the possible forward and backward linkages of the local economy need to be explored and strengthened in order to integrate it with the tourism sector necessary for the generation of higher levels of employment and income for local masses. It is also proposed that the local population may be encouraged and also facilitated by way of offering short term social and technical training programmes to equip them with necessary professional skills needed in carrying out various activities in the tourism industry.

III. The high rate of fuel wood utilization both in commercial and domestic sectors needs to be curbed by taking appropriate measures as it could pose a serious threat to the available forest stock of the area. There should be easy availability of LPG in the villages in order to encourage its domestic use by the households. And at the same time mandatory restrictions shall be imposed on the use of forest firewood consumption by hotels and guest houses.

IV. It is imperative that the daily tourist flow needs to be regulated during the peak months as per the carrying capacity limit as a part of sustainable eco-tourism strategy. It is therefore proposed that the existing tourist accommodation infrastructure of hotels and guest houses need not to be expanded, instead a moratorium on the construction of new hotels, guest houses and tourist huts should be put in place for a reasonable period of time. Efforts should be focused to improve the quality of the available accommodation infrastructure by way of ensuring the suitable management of sewage and solid waste a much desired activity not only for maintaining a safe public health and hygiene but also to preserve aquatic ecological system of this picturesque tourist node. Pahalgam has got a huge winter tourism potential which needs to be promoted. A well developed comprehensive infrastructure like accessibility, uninterrupted power supply, winter sports infrastructural facilities needs to be provided for promotion of winter tourism.

V. A number of ecologically sensitive areas such as dense forest areas, meadows and pasture lands and river fronts have been marked for construction of hotels and huts for tourists. This process of encroachment on forest and other ecologically sensitive areas is proposed to be curbed effectively. The construction of hotels is also taking place along the sloppy foothills which could activate the process of destabilization of these vulnerable foot hill slopes. Any type of constructional activity on slopes more than 30 degrees may not be allowed. Instead both agronomic and engineering measures need to be initiated for the stabilization of these steep slopes for the stability of landforms.

VI. The existing practice of both solid waste collection and disposal is not only unscientific but inadequate as well. The collected solid waste of the town is dumped openly at Sarbal, a site located on the right bank of a stream flowing into Lidder river which poses a potential threat to pollute the river waters especially during the torrential rainfall. An alternative site needs to be selected away from the water body for its safe disposal preferably in the vicinity of downstream area outside the limits of PDA. Subsequently an Integrated Solid Waste Management may be put in place for efficient waste management for the area focusing on waste prevention, recycling and composting and combustion and disposal in properly designed, constructed and managed landfills.

VII. The Yatra base camps of Nunwan, Zagipal, Chandanwari and Sheshnag are not also adequately equipped to deal sufficiently with the collection of solid waste during Yatra period. Considerable quantities of unmanaged solid waste from these camps and also huge quantities of solid waste have been found in the form of trail garbage all along the route to Amarnath cave which finally get their disposal in the main water body of Lidder river. All these problem need to be attended on priority basis in order to avoid its hazardous effects on the land resources and aquatic system of the area.

VIII. The per capita land availability in Lidder catchment is very low (5.5 kanals/household). The region being the mountainous one is not that suitable for agricultural purposes. Adequate measures must be taken to reduce soil erosion as it was found that agricultural is practiced on higher slopes. More over irrigation facilities are lacking especially in the upper watersheds which depend on rainfall only. Irrigation facilities need to be provided so that people may enjoy higher returns from agriculture. Assistance must be given to the farmers to grow such vegetables that are extensively used by hotels and guest houses.

IX. The livestock population outnumbers human population in the Lidder catchment. Overgrazing of the meadows must be stopped and the recent range management techniques must be adopted.

X. Where population pressures do not permit a return of mountain slopes to forest, which might be the ecological ideal, the introduction of permanent tree crops like apples, apricots, nuts or timber plantation may be a good compromise. Horticulture is important in Lidder catchment as it provides not only the higher income per unit area of land but also more employment and can be practiced on marginal lands which are otherwise unsuitable for the production of field crops.

XI. An agro-forestry programme is urgently needed to support watershed management and to meet the growing demand for fuel and fodder which is otherwise met by deforestation. The problem of waste lands has not been perceived properly in the hills especially in view of their large scale expansion, community participation for rehabilitating waste lands should receive top priority.

XII. Lidder catchment is an educationally backward area. Special care must be taken to make this area educationally sound so that people can respond positively to the changing social, economic and physical environment. The position of woman in the society should be improved by providing them education as woman literacy is very low as compared to male literacy in Lidder catchment.

XIII. Demographic attributes figure among the prominent drivers of watershed degradation in the catchment. People should be sensitized about the various consequences of over population as the population growth is very high in Lidder catchment.

XIV. Participatory approach involving local stakeholders should be adopted in the management and development of natural resources. This would not only help in easy implementation of various development programmes but would also generate public acceptability. For every watershed a people's committee should be formed comprising representatives from every village of the watershed.

XV. The watershed prioritization carried out in the present study must be adopted as it would act as a means of sustainable development by identifying the various causes of environmental degradation in Lidder catchment.

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APPENDICES

Annexure-1

Assessment of Anthropogenic Impact on Land Use Dynamics in Lidder Catchment of Kashmir Valley

(*ICSSR funded research project)*

Department of Geography and Regional Development, University of Kashmir

HOUSEHOLD QUESTIONNAIRE / SCHEDULE

1. **Name of the village……………………………………………………………………………**
   Census code ………………………Watershed code…………………………………….
2. **Name of the household head………………………………………………………….....**
3. **Family size: Persons…………………. Male…………………Female……………………..**
4. **House type Kachha Pacca**
   Number of stories……………..….. Number of rooms……………………………….
5. **Demographic profile:**

S.No	Relationship with household head	Sex M/F	Age	Marital status	Education	Occupation	Income rupees/month
1.							
2.							
3.							
4.							
5.							
6.							
7.							
8.							
9.							
10.							

6. **Use of forest land in terms of extraction of following products:**

Name of product	Weight/Vol. per week	Self consumed/Marketing purpose
Firewood		
Fodder		
Timber		
Wild vegetables		
Medicinal plants		
Others(specify)		

Annexure-1

7. Source and magnitude of energy consumption:

Type of energy	Source	Quantity/day	Rate/unit
Firewood			
Cow dung			
LPG			
Kerosene			
Others (specify)			

8. Ownership of livestock:

Kind of livestock	Number	Kind of livestock	Number
Horses/Ponies		Goats	
Cows		Chickens	
Bullocks		Ducks	
Sheep		Others(specify)	

9. Cropping pattern

Total land (kanals)	Crops grown	Land under each crop	Irrigated	Un-irrigated	Productivity/kanal

10. Source of water supply
i) Canals ii) Tube wells iii) Lidder river iv) Tape water.

11. Associated with tourism
If yes, type of association……………………………………………
Income from tourism……………………….rupees/month

12. Do you have
a) Radio b) T.V. c) Refrigerator d) Vehicle e) Mobile phone (no's) f) Landline
13. Sanitation
i) Latrine/bathroom attached with house ii) Separate latrine and bathroom
14. Latrine type
i) Pit latrine ii) Latrine with water tank and modern swill out facilities.

15. Personal remarks:

Annexure-II

Assessment of Anthropogenic Impact on Land Use Dynamics in Lidder Catchment of Kashmir Valley

(*ICSSR funded research project)*

Department of Geography and Regional Development, University of Kashmir

TOURIST QUESTIONNAIRE / SCHEDULE

1. Name of the respondent……………………………………………………………………….
2. Nationality………………………………………
3. Permanent address…………………………………………………………Rural/ Urban
4. Religion……………………………………..
5. Sex: Male/female
6. Age………………………………
7. Are you travelling individually or with family?
   If with family, How many members………………male…….female…………
8. How many times you have visited this place before
   i) First time ii) Twice iii) Thrice iv) Four times
9. Education

   a) Illiterate b) Primary C) Matriculate D) Intermediate E) Graduate F) Post graduate G) Professional

10. Occupation
    a) Business b) Govt. Service c) Professional d) Student e) Retired f) others
11. Average income (Rupees/month)

a) <15000 b) 15000-25000 c) 25000-50000 d) 50000-75000 e) more than 75000

12. Purpose of visit
    a) Pleasure b) Pilgrimage c) Trekking d) Business e) Education f) Others
13. Places visited or supposed to visit
    b) Pahalgam b) Gulmarg c) Srinagar d) Sonamarg e) Verinag f) Others (specify)
14. Expenditure pattern

Category	Rupees/day	Category	Rupees/day
Accommodation		Recreation	
Transport		Eatables	
Shopping		Pony charges	

15. Mode of transport used

    a) Public transport b) Personal vehicle c) Private transport

16. Length of stay at:

    a) Kashmir Valley……………….days b) Pahalgam…………days

17. Type of water used

    a) Bottled water b) Tap water c) Both

18. Type of food used

    a) Processed food b) Hotel food c) Langar d) Self cooked

19. Tourist perception survey

    19a. Accommodation

    a) Poor b) Average c) Good d) Excellent

    19b. Transport

    a) Poor b) Average c) Good d) Excellent

    19c. Administrative arrangement

    a) Poor b) Average c) Good d) Excellent

    19d. Food quality

    a) Poor b) Average c) Good d) Excellent

    19e. Local population

    a) Adverse b) Friendly c) Cooperative d)Indifferent

    19f. Local environment/surroundings

    a) Repulsive b) Fine c) Pleasant d) Outstanding

    19g. Regulation of number of tourists

    a) Should be regulated b) Should not be regulated

    How many tourists should visit Pahalgam per year………………

20. Remarks about the conservation of ecology

Annexure -III

Assessment of Anthropogenic Impact on Land Use Dynamics in Lidder Catchment of Kashmir Valley

(*ICSSR funded research project)*

Department of Geography and Regional Development, University of Kashmir

HOTEL/GUEST HOUSE/DHABA QUESTIONNAIRE / SCHEDULE

1. Name of the hotel..Category...................................
2. Name of the owner................................. ....Residence.............................
3. Name of the respondent.............................Age…...Education.............................
4. Designation..
5. Location coordinates………………........Planning zone...
6. Distance from the River.....................
7. Nature of the material- Concrete, Wooden, Both
8. Land area under the hotel.........................
9. Status of the land –Government, Private leased/ Owned
10. Number of ; buildings......... ....Stories...........rooms...............beds.................
11. Rate per room. Summer............................ Winter..
12. Number of Shops within the hotel..
13. Working season (months) ……………………………................................
14. Do you stay with family: yes/no, if yes, number of members..............................
15. How many tea stalls/dhabas/hotels/restaurants do you have ....
16. How many tourists attend your hotel during:
    i) Yatra......................................./day
    ii) Summer..................................../day
    iii) Winter....................................../day
    iv) On an average............................/day

Annexure -III

17. Total number of persons working in your hotel ……………..................

S. no	Name	Qualification	Designation	Salary (Rupees/month)	Original Residence
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					

18 . Energy consumption for cooking in your hotel:

Kerosene litres/day ……………..

Firewood kgs/day ……………..

LPG lts/month ....

Coal kgs/day...

19. Do you purchase fuel wood from:

Local people, rate per quintal……………..... Rs.

Forest depot, rate per quintal ………………. Rs.

20. How much of waste product you generate daily

A. > 5 b. 5-15 kgs c. 15-30 kgs d.30-45 kgs e. < 45 kgs

21. Method of waste disposal- Dust bins/Open disposal/Disposed into river

22. Average litres of water used for washing the utensils ………….. lts/day

23. Is there any separate drainage channel (outlet) for this waste water Yes/No.

If yes, Disposal-Open/Soakage pits/River/

24. Number of washrooms/bathrooms in your hotel.................................

Disposal- Open/ Soakage pits/River.

25. How many employees you have for solid waste handling purpose in the hotel ____________

26. Do you have solid waste segregation provision in the Hotel , if yes, kindly indicate what kind of material you segregate at source_________________________________

Annexure -III

27. Do you have any facility to compost biodegradable waste like left over- food and garden trimmings

a. Yes ( ) b. No ( )

28. What is being done with the recyclable solid waste like plastic bottles, tin cases and paper

a. Sold to a recyclable unit b. Dumped at any site

29. What best describes your feeling about recycling and composting of hotel solid waste.

a. Glad to do it. b. Willing to do it. C. Don't care about it. d. Don't want to do it.

30. Have you imposed restriction on the use of any material like polythene

Yes ( ) No ( ) or any other material________________________

31. How many waste containers are installed in your hotel __________ and what is their capacity____________________

32. How many waste containers get filled with solid waste/ day .

During peak tourist season 1. 2. 3. 4. None.

During off season 1. 2. 3. 4. None.

33. How far is the dust bin installed by Pahalgam Development Authority from the Hotel .

a. 5-15mts. away. b. 5-25mts. away c. 25-35mts. away d. more than 35mts. away

34. How you would like to describe the overall waste handling provided by Pahalgam Development Authority

a. poor b. Satisfactory C. excellent

35. Do you have idea for better solid waste management?

____

____

____

36. What facilities should be provided by the government to preserve the environment of this place…………………………………….....................

37. Total income from the hotel..rupees/month

38. 15. Personal remarks

____

____

____

Annexure- IV

Assessment of Anthropogenic Impact on Land Use Dynamics in Lidder Catchment of Kashmir Valley

(*ICSSR funded research project)*

Department of Geography and Regional Development, University of Kashmir

Name of Hotel ……………..............Category …. …………… Date………..………

Material Category		**Solid waste generation in kilograms**								
		Day 1	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**	**Weekly Average**	
									Absolute	**Percentage**
Compostable	Fruit waste									
	Leftover food									
	Vegetable Waste									
	Garden clippings									
Recyclable	Metal									
	Glass									
	paper									
	plastics									
Miscellaneous	Non-recyclable plastics									
	Non-recyclable paper									
	Others eg Dirt, Rubber, Cloth									
TOTAL										

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GEOGRAPHY

WATERSHED BASED DRAINAGE MORPHOMETRIC ANALYSIS OF LIDDER CATCHMENT IN KASHMIR VALLEY USING GEOGRAPHICAL INFORMATION SYSTEM

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Abstract

The quantitative analysis of drainage system is an important aspect of characterization of watersheds. Using watershed as a basic unit in morphometric analysis is the most logical choice because all hydrologic and geomorphic processes occur within the watershed. Lidder catchment which constitutes a segment of the western Himalayas with an area of 1159.38 km^2 (10% of the river Jhelum catchment) has been selected as the study area. Various linear and areal aspects of the catchment were computed at watershed level. This was achieved using GIS to provide digital data that can be manipulated for different calculations. The analysis has revealed that the total number as well as total length of stream segments is maximum in first order streams and decreases as the stream order increases. Horton's laws of stream numbers and stream lengths also hold good. The bifurcation ratio between different successive orders is almost constant. The drainage density values of the different watersheds exhibit high degree of positive correlation (0.97) with the stream frequency suggesting that there is an increase in stream population with respect to increasing drainage density and vice versa.

Keywords: Watershed; GIS; Lidder; Morphometry

Introduction

Morphometry is the measurement and mathematical analysis of the configuration of the earth's surface, shape and dimension of its landforms (Agarwal, 1998; Obi Reddy et al., 2002). A major emphasis in geomorphology over the past several decades has been on the development of quantitative physiographic methods to describe the evolution and behavior of surface drainage networks (Horton, 1945; Leopold & Maddock, 1953; Abrahams, 1984). Most previous morphometric analyses were based on arbitrary areas or individual channel segments. Using watershed as a basic unit in morphometric analysis is the most logical choice. A watershed is the surface area drained by a part or the totality of one or several given water courses and can be taken as a basic erosional landscape element where land and water resources interact in a perceptible manner. In fact, they are the fundamental units of the fluvial landscape and a great amount of research has focused on their geometric characteristics, including the topology of the stream networks and quantitative description of drainage texture, pattern and shape (Abrahams, 1984). The morphometric characteristics at the watershed scale may contain important information regarding its formation and development because all hydrologic and geomorphic processes occur within the watershed (Singh, 1992).

The quantitative analysis of morphometric parameters is found to be of immense utility in river basin evaluation, watershed prioritization for soil and water conservation and natural resources management at watershed level. Morphometric analysis of a watershed provides a quantitative description of the drainage system which is an important aspect of the characterization of watersheds (Strahler, 1964). The influence of drainage morphometry is very significant in understanding the landform processes, soil physical properties and erosional characteristics. Drainage characteristics of many river basins and sub basins in different parts of the globe have been studied using conventional methods (Horton, 1945; Strahler, 1957, 1964; Krishnamurthy et al., 1996). Geographical Information System (GIS) techniques are now a days used for assessing various terrain and morphometric parameters of the drainage basins and watersheds, as they provide a flexible environment and a powerful tool for the manipulation and analysis of spatial information. In the present study stream number, order, frequency, density and bifurcation ratio are derived and tabulated on the basis of areal and linear properties of drainage channels using GIS based on drainage lines as represented over the topographical maps (scale 1:50,000).

Study area

The Lidder catchment occupies the south eastern part of the Kashmir valley (Fig. 1.1) and is situated between 33º 45' 01" N - 34º 15' 35" N and 75º 06' 00" E

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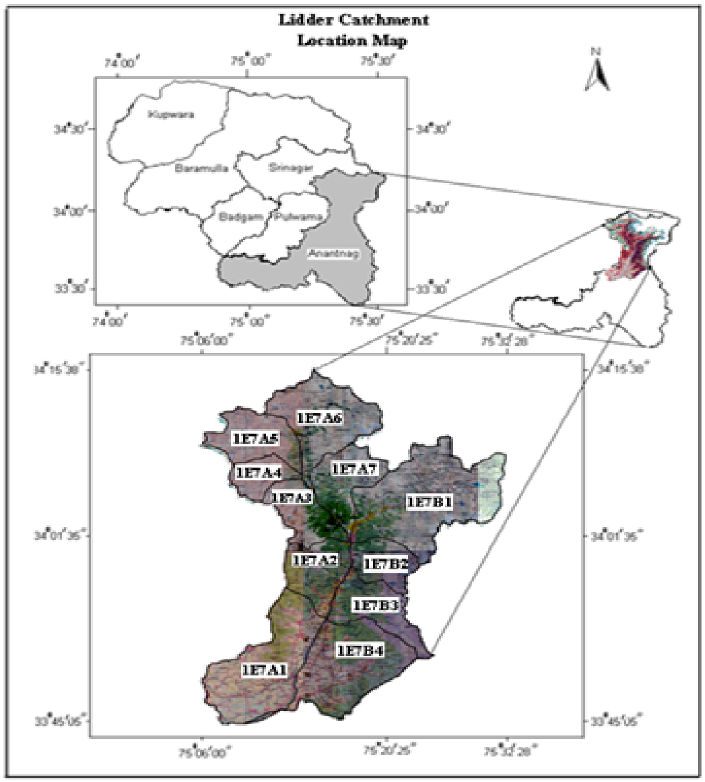
– 75º 32' 29" E. The Lidder valley forms part of the middle Himalayas and lies between the Pir Panjal range in the south and south-east, the north Kashmir range in the north-east and Zanskar range in the south-west.

Fig. 1.1: Location map of Lidder catchment



Source: Generated from SOI toposheets 1961

The Lidder valley has been carved out by river Lidder, a right bank tributary of river Jhelum. It has a catchment area of 1159.38 km^2, which constitute about 10 per cent of the total catchment area of river Jhelum (Bhat et al., 2007). The valley begins from the base of the two snow fields, the Kolahoi and sheshnag where from its two main upper streams; the West and the East Lidder originate and join near the famous tourist town of Pahalgam. It joins the Jhelum (upper stream of Indus river) at Gur village after travelling a course of 70 kms (Raza et al., 1978). The area gradually rises in elevation from south (1600 meters) to north (5425 meters).

The study area reveals a variegated topography due to the combined action of glaciers and rivers. The valley possesses distinctive climatic characteristics because of its high altitude location and its geophysical setting, being enclosed on all sides by high mountain ranges. The valley is characterized by sub-Mediterranean type of climate with nearly 70 per cent of its annual precipitation concentrated in winter and spring months (Meher, 1971).

Methodology

Morphometric analysis of a drainage system requires delineation of all existing streams. The stream delineation was done digitally in GIS (Arcview ver: 3.2a) system. All tributaries of different extents and patterns were digitized from survey of India toposheets 1961 (1:50,000 scale) and the catchment boundary was also determined for Lidder catchment. Similarly, two sub-catchments consisting of 11 watersheds were also delineated and measured for intensive study. Digitization work was carried out for entire analysis of drainage morphometry. The different morphometric parameters have been determined as shown in table1.1.

Table 1.1: Morphometric parameters with formula

S. no	Morphometric parameters	Formula	Reference
1	Stream order	Hierarchical rank	Strahler (1964)
2	Stream length (Lμ)	Length of the stream	Horton (1945)
3	Mean stream length (Lsm)	Lsm = Lμ/Nμ Where, Lμ = total stream length of order 'μ' Nμ = total no. of stream segments of order 'μ'	Strahler (1964)
4	Bifurcation ratio (Rb)	Rb = Nμ / Nμ +1 Where, Rb = Bifurcation ratio, Nμ = No. of stream segments of a given order and Nμ +1= No. of stream segments of next higher order.	Schumn (1956)
5	Mean bifurcation ratio (Rbm)	Rbm = Average of bifurcation ratios of all orders	Strahler (1957)
6	Drainage density (Dd)	Dd = Lμ/A Where, Dd = Drainage density. Lμ = Total stream length of all orders and A = Area of the basin (km^2).	Horton (1932)
7	Drainage frequency (Fs)	Fs = Nμ/A Where, Fs = Drainage frequency. Lμ = Total no. of streams of all orders and A = Area of the basin (km^2).	Horton (1932)

Results and Discussion

The drainage characteristics of Lidder catchment have been examined with particular reference to fallowing:

Stream Ordering

The designation of stream order is the first step in the drainage basin analysis. It is defined as a measure of the position of a stream in the hierarchy of tributaries (Leopord, Wolman and Miller, 1969). There are 3858 streams linked with 6 orders of streams (fig 1.2) sprawled over an area of 1159.38 km^2. A perusal of table 1.2 indicates that the Lidder river which is the trunk stream in Lidder catchment is of the sixth order. Out of the eleven watersheds, one watershed (1E7A3) is of third order, five watersheds (1E7A1, 1E7A2, 1E7A4, 1E7A5 and 1E7B3) are of fourth order, four watersheds (1E7A6, 1E7A7, 1E7B2 and 1E7B4) are of fifth order and one watershed (1E7B1) is of sixth order. The highest number of stream segments is found in watershed 1E7B1 (958 stream segments) followed by watershed 1E7B4 (460 stream segments) while the lowest number of stream segments is found in watershed 1E7A4 (137). It is observed that there is a decrease in stream frequency as the stream order increases. First order streams constitute 80.19 per cent while second order streams constitute 15.70 per cent of the total number of streams. Third and fourth order streams constitute 3.29 per cent and 0.64 per cent of the total number of streams respectively while fifth and sixth order streams together constitute only 0.18 per cent of the total number of streams. Thus the law of lower the order higher the number of streams is implied throughout the catchment.

Fig. 1.2: Map showing different stream orders in Lidder catchment

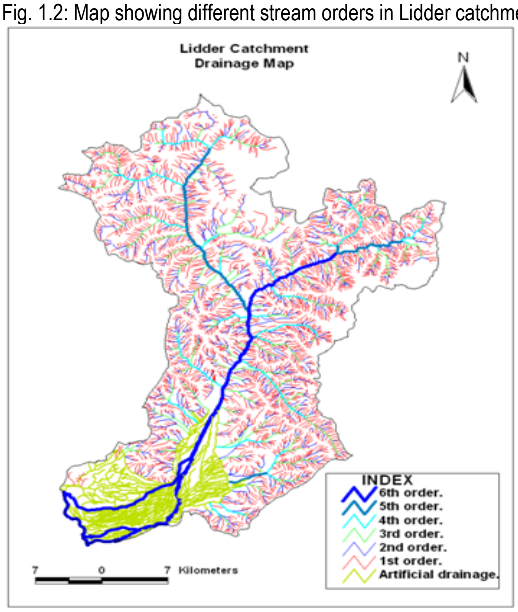


Table 1.2: Order wise Stream Number and Stream Length

Watershed Code	Area km.²	1st order		2nd order		3rd order		4th order		5th order		6th order		Total	
		No.	Length	No.	Length	No.	Length	No.	Length	No.	Length	No.	Length	No.	Length
1E7A1	173.24	247	135.03	59	59.59	10	23.81	1	4.30	-	-	1	50.16	318	262.79
1E7A2	73.14	287	156.30	67	47.29	16	19.62	2	12.50	-	-	1	13.34	373	249.05
1E7A3	65.08	194	129.59	33	31.87	6	23.32	-	-	-	-	-	-	233	184.78
1E7A4	40.46	117	84.55	17	17.39	2	10.48	1	3.32	-	-	-	-	137	115.74
1E7A5	78.07	216	155.87	30	30.47	6	15.72	1	8.49	-	-	-	-	253	210.55
1E7A6	129.36	246	171.9	47	43.50	10	14.42	2	10.20	1	14.19	-	-	306	254.21
1E7A7	77.19	136	86.10	30	37.12	7	20.82	2	4.64	1	9.45	-	-	176	158.13
1E7B1	228.52	769	485.97	152	119.26	27	47.88	7	21.92	2	9.06	1	13.12	958	697.21
1E7B2	53.49	191	122.96	33	32.43	7	11.54	3	11.64	1	0.51	-	-	235	179.08
1E7B3	78.36	335	191.27	62	46.61	14	27.20	1	10.53	-	-	-	-	412	275.61
1E7B4	162.47	356	235.02	76	68.88	22	38.36	5	15.64	1	4.24	-	-	460	362.14
Lidder Catchment	1159.38	3094	1954.56	606	524.31	127	253.17	25	103.18	5	37.45	1	76.62	3858	2949.29

Stream number

The number of stream segments in each order is known as stream number. Horton (1945) gave the law of stream numbers which states that the number of stream segments of successively lower orders in a given basin tend to form a geometric series beginning with the single segment of the highest order and increasing according to constant bifurcation ratio. In other words "the number of streams of different orders in a given drainage basin tend closely to approximate an inverse geometric series in which the first term is unity and the ratio is bifurcation ratio". It is expressed in the form of negative exponential function as:

$N\mu = Rb^{(K-\mu)}$. …………… (i)

Also, the total number of stream segments of the catchment can be calculated as:

$\Sigma\mu = Rb^{K}-1/ Rb-1$…………… (ii)

Where,

Nμ = Number of stream segments of a given order; Rb = Constant Bifurcation ratio.

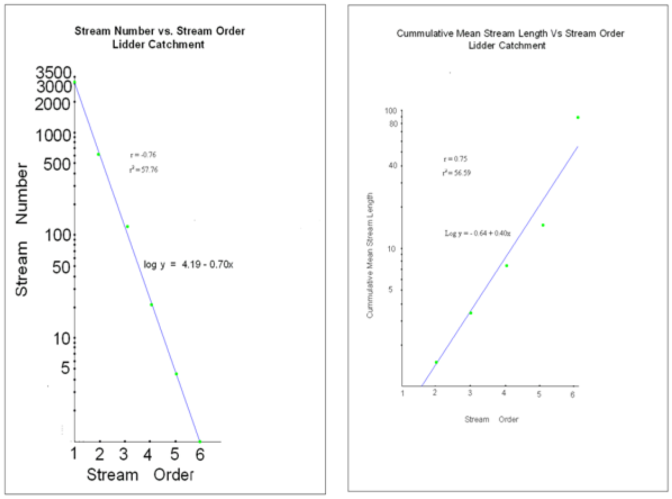
μ = Basin order and K = Highest order of the basin.

Table 1.3: Order wise actual and calculated number of Streams

Stream Order	Number of streams		Mean stream length		Calculated cumulative Mean stream length.
	Actual	Calculated	Actual	cumulative	
1st order	3094	1845.28	0.63	0.63	0.63
2nd order	606	410.06	0.86	1.49	2.24
3rd order	127	91.12	1.99	3.48	7.98
4th order	25	20.25	4.12	7.60	28.42
5th order	5	4.5	7.49	15.09	101.20
6th order	1	1	76.62	91.71	360.24
Total	3858	2372.5			

It is clear from table 1.3 that the computed values of stream numbers does not match with the actual values of stream numbers. However the deviations decrease from lower to higher orders. The regression line plotted on semi log graph (fig. 1.3) almost validates the Horton's law of stream number as the coefficient of correlation is -0.76 and the percentage variance explained is 57.76 per cent.

Fig. 1.3: Relation between stream order, stream number and mean stream length



Stream Length

Stream length is indicative of chronological developments of the stream segments including interlude tectonic disturbances. Mean stream length reveals the characteristic size of components of a drainage network and its contributing surfaces (Strahler, 1964).

Table 1.4. Order wise mean stream length

Watershed code	Mean stream length in kilometers.					
	1st order	2nd order	3rd order	4th order	5th order	6th order
1E7A1	0.55 (51.38)	0.84 (18.83)	2.38 (9.06)	4.30 (1.64)	-	50.16 (19.09)
1E7A2	0.54 (62.76)	0.70 (18.99)	1.23 (7.88)	6.25 (5.02)	-	13.34 (5.35)
1E7A3	0.67 (70.13)	0.96 (17.25)	3.89 (12.62)	-	-	-
1E7A4	0.72 (73.05)	1.02 (15.02)	5.24 (9.05)	3.32 (2.88)	-	-
1E7A5	0.72 (74.03)	1.01 (14.47)	2.62 (7.47)	8.49 (4.03)	-	-
1E7A6	0.70 (67.62)	0.92 (17.11)	1.44 (5.67)	5.10 (4.01)	14.19 (5.59)	-
1E7A7	0.63 (54.45)	1.24 (23.47)	2.97 (13.17)	2.32 (2.93)	9.45 (5.98)	-
1E7B1	0.63 (69.70)	0.78 (17.10)	1.77 (6.87)	3.13 (3.14)	4.53 (1.30)	13.12 (1.89)
1E7B2	0.64 (68.38)	0.98 (18.20)	1.65 (6.54)	3.88 (6.60)	0.51 (0.28)	-
1E7B3	0.57 (69.40)	0.75 (16.91)	1.94 (9.87)	10.53 (3.82)	-	-
1E7B4	0.66 (64.90)	0.90 (19.02)	1.74 (10.59)	3.13 (4.32)	4.24 (1.17)	-
Lidder Catchment	0.63 (66.27)	0.86 (17.78)	1.99 (8.58)	4.12 (3.50)	7.49 (1.27)	76.62 (2.60)
Cumulative mean stream length	0.63	1.49	3.48	7.6	15.09	91.71

Figures in parenthesis show Percentage stream length contributed by different stream orders

From table 1.4 it is evident that the length of first order streams constitute 66.27 per cent of the total stream length with second order (17.78 per cent), third order (8.58 per cent), fourth order (3.50 per cent), fifth order (1.27per cent) and the sixth order (2.60 per cent). The total length of 1st and 2nd order streams constitutes 84.04 per cent of the total stream length. It can be inferred that the total length of stream segments is maximum in first order streams and decreases as the stream order increases. However sixth order is an exception where the total stream length (76.62 kms) is more than that of the fifth order (37.45 kms). This anomaly is also found in watersheds 1E7A1 (between fourth and sixth orders), 1E7A2 (between fourth and sixth orders), 1E7A6 (between fourth and fifth orders), 1E7A7 (between fourth and fifth orders) and 1E7B1 (between fifth and sixth orders) where the total length of the lower order streams is less than that of the total length of their respective higher orders. Generally higher the order, longer the length of streams is noticed in nature. This is also true for Lidder catchment as well as for all the eleven watersheds (table 1.4). But the watershed 1E7B2 is an exception where the mean stream length of fourth order (11.64 kms) is much higher than that of the fifth order (0.51 kms). These variations from general observation may be due to flowing of streams from high altitude, change in rock type and variation in slope and topography (Singh and Singh, 1997; Vittala et al., 2004).

Horton's law of Stream Lengths: Horton (1945) in his law of stream lengths stated that the cumulative mean lengths of stream segments of each of the successive orders in a basin tend closely to approximate a direct geometric series in which the first term is the mean length of streams of the first order. He suggested the fallowing positive exponential function model of stream lengths.

$L\mu = L1\ RL^{(\mu-1)}$………….. (iii)

Where,

$L\mu$ = Cumulative Mean Length of the given order; L1 = Mean Length of the first order

RL = Constant length ratio and μ = Given order.

The regression line plotted on semi log graph (fig. 1.3) tends to validate Horton's Law of stream lengths as the coefficient of correlation is 0.75 and the percentage variance is 56.59. However the values obtained (table 1.3) by using equation (iii) does not match with the actual values. This is because of the fact that in nature constant mean stream length between different orders does not exist.

Bifurcation ratio (Rb)

Bifurcation ratio is related to the branching pattern of a drainage network and is defined as the ratio between the total number of stream segments of one order to that of the next higher order in a drainage basin (Schumn, 1956). It is a dimensionless property and shows the degree of integration prevailing between streams of various orders in a drainage basin. Horton (1945) considered Rb as an index of relief and dissection while Strahler (1957) demonstrated that Rb shows only a small variation for different regions with different environments except where powerful geological control dominates.

Table 1.5. Watershed wise drainage frequency, density and bifurcation ratio between different orders

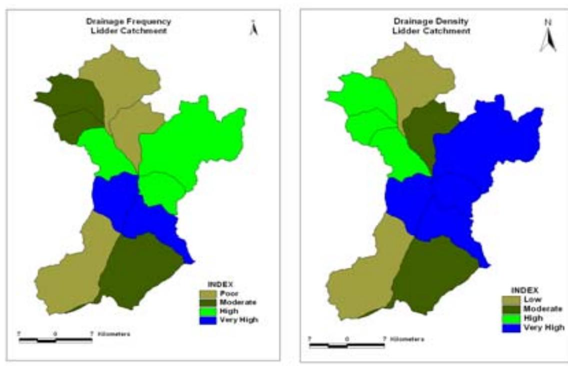
Watershed code	Drainage Frequency	Drainage Density	Bifurcation ratio between different orders					
			1st & 2nd	2nd & 3rd	3rd & 4th	4th & 5th	5th & 6th	Mean Bifurcation ratio
1E7A1	1.84	1.52	4.19	5.90	10.00	-	-	6.70
1E7A2	5.10	3.40	4.28	4.18	8.00	-	-	5.49
1E7A3	3.58	2.84	5.88	5.50	-	-	-	5.69
1E7A4	3.39	2.86	6.88	8.50	2.00	-	-	5.79
1E7A5	3.24	2.70	7.20	5.00	6.00	-	-	6.06
1E7A6	2.36	1.96	5.23	4.70	5.00	2.00	-	4.23
1E7A7	2.28	2.04	4.53	4.29	3.50	2.00	-	3.58
1E7B1	4.19	3.05	5.06	5.63	3.86	3.50	2.00	4.01
1E7B2	4.39	3.35	5.79	4.71	2.33	3.00	-	3.96
1E7B3	5.26	3.52	5.40	4.43	14.00	-	-	7.94
1E7B4	2.83	2.23	4.68	3.45	4.40	5.00	-	4.38
Lidder Catchment	3.33	2.54	5.10	4.77	5.08	5.00	5.00	5.00

A perusal of table 1.5 shows that the Rb between different successive orders is almost constant for Lidder catchment ranging from 4.77 to 5.08 with the mean bifurcation ratio of 5. This is because of the same geological and lithological development of the catchment. The highest Rb (14.00) is found between 3rd and 4th order in watershed 1E7B3 which indicates corresponding highest overland flow and discharge due to hilly metamorphic formation associated with high slope configuration. The lowest Rb is found between 4^{th} and 5^{th} orders in watersheds 1E7A6 and 1E7A7 and between 5^{th} and 6^{th} orders in watershed 1E7B1. The higher values of Rb indicate strong structural control in the drainage pattern whereas the lower values indicate that the watersheds are less affected by structural disturbances (Stahler, 1964; Nag, 1998; Vittala et al., 2004). The mean bifurcation ratio is highest in watershed 1E7B3 (7.94) while it is lowest in watershed 1E7A7 (3.58).

Drainage frequency or Stream frequency (Fs)

It is defined as the total number of stream segments of all orders per unit area (Horton, 1932). It is an index of the various stages of landscape evolution. The occurrence of stream segments depends on the nature and structure of rocks, vegetation cover, nature and amount of rainfall and soil permeability. The Fs in Lidder catchment is 3.33. It varies from 1.84 stream segments in watershed 1E7A1 to 5.26 stream segments in watershed 1E7B3. Thus it has been possible to identify four categories of Fs; Poor (below $2.5/km^2$), Moderate (2.5-$3.5/km^2$), High (3.5-$4.5/km^2$) and Very High (Above $4.5/km^2$) as shown in fig. 1.4. The analysis of the table 1.5 reveals that 32.76 per cent of the total catchment area of Lidder has poor Fs, while 24.23 per cent has moderate, 29.94 per cent has high and only 13.07 per cent has very high Fs.

Fig. 1.4: Distribution of Drainage frequency and Drainage density in Lidder catchment



The poor to moderate Fs in the watersheds of 1E7A1 and 1E7B4 is attributed to agricultural land use (54.23 per cent) with the consequent development of artificial drainage which is not considered here. Poor Fs in the watersheds of 1E7A6 and 1E7A7 could be attributed to rugged topography and steep barren slopes. The highest Fs in watershed 1E7B3 is because of the fact that it falls in the zone of fluvial channels and the presence of ridges on both sides of the valley which results in elongated drainage with highest Fs. The Fs decreases as we move to higher altitudes from south to north of the catchment. The watersheds falling in the zone of fluvial channels (Koal, 1990) have highest Fs as compared to the watersheds in the zone of melt water channels.

Drainage Density (Dd)

The measurement of Dd is a useful numerical measure of landscape dissection and runoff potential (Chorley, 1969). On the one hand, the Dd is a result of interacting factors controlling the surface runoff; on the other hand, it is itself influencing the output of water and sediment from the drainage basin (Ozdemir and Bird, 2009). Dd is known to vary with climate and vegetation (Moglen et al., 1998), soil and rock properties (Kelson and Wells, 1989), relief (Oguchi, 1997) and landscape evolution processes. The Dd of the Lidder catchment is $2.54\ kms/km^2$. It varies from $1.52\ kms/km^2$ in watershed 1E7A1 to $3.52\ kms/km^2$ in watershed 1E7B3.

The watersheds can be grouped into four categories on the basis of Dd as Low (below $2.0 kms/km^2$), Moderate (2.0-$2.5 kms/km^2$), High (2.5-$3.0 kms/km^2$) and Very High (Above $3.0 kms/km^2$) as shown in fig. 1.4. The analysis of the table 1.5 reveals that in Lidder catchment 26.10 per cent of the area has low Dd, 20.67 per cent has moderate Dd, 15.83 per cent has high while 37.39 has very high Dd. It is found that the watersheds of East Lidder sub-catchment have higher Dd as compared to the watersheds of West Lidder sub-catchment. The analysis has further shown that the Dd values of the different watersheds exhibit high degree of positive correlation (0.97) with the Fs suggesting that there is an increase in stream population with respect to increasing Dd and vice versa.

Conclusion

The drainage basin is being frequently selected as an ideal geomorphological unit. Watershed as a basic unit of morphometric analysis has gained importance because of its topographic and hydrological unity. GIS techniques characterized by very high accuracy of mapping and measurement prove to be a competent tool in morphometric analysis. Drainage density and stream frequency are the most useful criterion for the morphometric classification of drainage basins which certainly control the runoff pattern, sediment yield and other hydrological parameters of the drainage basin. The Drainage density appears significantly higher in 1E7B3 and 1E7B2 watershed implying the existence of impermeable rocks and high relief. It is observed that there is a decrease in stream frequency as the stream order increases. The law of lower the order higher the number of streams is implied throughout the catchment. The total length of stream segments is maximum in first order streams and decreases as the stream order increases. The study has shown that the catchment is in conformity with the Hoton's law of stream numbers and law of stream lengths. The same geological and lithological development of the catchment has resulted into more or less constant bifurcation ratio between different successive orders in Lidder catchment.

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