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Geospatial technology for sustainable development: A strategic framework for Sarbari Khad Watershed of Himachal Pradesh

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Abstract--The recent events in the Himalayas have depicted more than ever, that we require development strategy for the Himalayas that assesses the susceptibility of the region and requirement for the safety of environment. There is no distrust that the economic growth is the need of the region, but this cannot come on the cost of the environmental degradation. The resource base of Himalayan watersheds sustains traditional mountain societies. However, driven by population explosion, the Himalayan environment has experienced the effects of extension and intensification of agriculture, deforestation; land use and land cover changes and land degradation. The fragile watersheds of Himalayan region are facing multiple and complex environmental crisis and challenges. Therefore, the objectives of the present paper are following – (i) to identify the key drivers for maintaining environment services of the Himalayan watersheds; (ii) to assess the resource base and processes operating within the watershed as an ecosystem; (iii) to establish links between ecological and social ecosystem services and finally (iv) to analyze the LULC (Land use/Land cover) changes and patterns to evolve a sustainable strategy based on geospatial technology. The overall aim is point out strategies based on geospatial technology which lead to achieve economic growth with distributive justice and ecological balance.

Keywords---sustainable development, livelihood, watershed, remote sensing, natural resources.

Introduction

There are numerous definitions and perspectives on sustainable development. Basically all these perspectives indicate that sustainable development is the clue that human societies must live and meet their needs without endangering the ability of future generations to fulfill their own needs. Sustainable development is an organizing principle to fulfill human development goals while concurrently sustaining the ability of natural systems to offer the natural properties and ecosystem facilities on which the economy and society depends. It aims for a state of society where living conditions and resources are employed to continue to meet human needs without deteriorating the integrity and stability of the natural systems.

This explains that a large number of different interpretations that have arisen should be more concise if once we develop an “index”. Given a development index, sustainable development can only mean one thing: the index should not decline over time (Pearce and Atkinson, 1993). As an interdisciplinary field, sustainable development takes advantage from the contributions and perspectives of several areas that emphasise the relationship between society and resources. These include common property research which investigates how jointly held resources can be used sustainably (Berkes, 1989). From ecological economies’ point of view, it is concerned with the use of natural capital pool without depletion (Daly, 1991; Janson et.al., 1994) and similarly, more broadly, if one looks at the field of development which includes the study of participatory institutions and adaptations of local populations for livelihood security (Gadgil et.al. 1993; Saxena et. Al., 1994; Verma et.al. 2021)

Identification of problems and priority of issues differs from region to region and time to time. Moreover, all problems cannot be solved to the satisfaction of all people. Yet, the process of integration enables one to take up a realistic approach of what best is or could be possible and feasible. For the wellbeing of human kind two main issues are noticed in the area i.e. environmental and socio-economical. These issues could be resolved by designing and integrating appropriate planning by incorporating indigenous and modern technology in collaboration with local institutions.

Only few decades’ back farmers of Sarbari Khad were cultivating a number of traditional varieties of food crops like, wheat, amaranths, finger millets, barley and different kind of beans under subsistence farming but, recently intensity and frequency these traditional crops have decreased tremendously (Singh, 1995). The farmers are cultivating high yielding varieties of wheat, paddy and a variety of fruit bearing trees such as apple, almond, cherry, pear as cash crops. These days, traditional crops are no longer cultivated in the region except at the higher elevations, where also few farmers are starting fruit bearing tree crops. Whole of Sarbari Khad is under change from traditional to cultivation of cash crops. To assess the resource base of the watershed and to analyse the LULC changes

geospatial techniques have been applied in this study. The present study details a micro level analysis of role of local institutions for the management of common property natural resources, identifies the reasons for changing land use patterns including crops diversity and its imperatives and possible package of sustainable development for Sarbari Khad watershed in north western Himalaya.

The Study Area

The Sarbari Khad Watershed of the Beas River Basin has been selected as the study area (Fig. 1). It mainly extends between 31°54' 30" N latitudes to 32° 6' 30" N latitudes and 76° 56' E to 77° 7' 40" E longitudes. It occupies an area of 930.30 Km². The SarbariKhad Watershed covers western part of the Kullu district. It consists of 13 villages in Kullu and Nagar revenue blocks. They are Pichhbhar, Bath, Bastori, Bhalyani, Dughilag, DunkhriGahar, Gahar, Gramang, Majhat, Mashna, Peej, Phallan and Pichhli. The watershed also includes some parts of Kullu town. Total population of the watershed is 15247 people. Agriculture is considered to be the main economic activity of the people of the area. Tourism is also an important economic activity in the region.

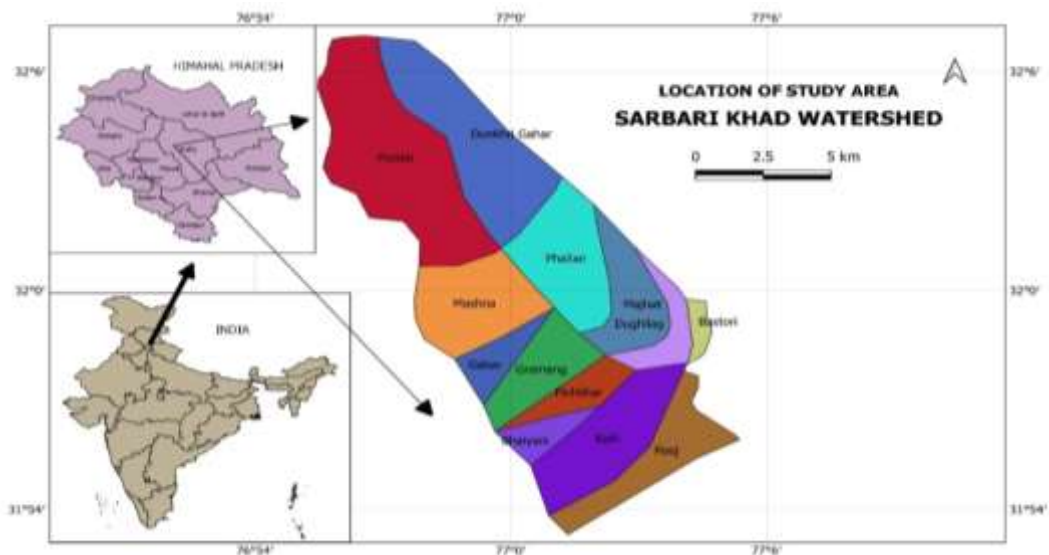


Figure 1

The area is a natural region delineated topographically and hydrologically as it is bounded by Pir-Panjal Range and Beas River. The altitude varies from 1500 to 4000 meter above mean sea level that increases from south to north. The area can be broadly classified into snow cover, barren land, pastures, forested valley. The climate ranges from sub-tropical to alpine. The mean annual temperature in the region ranges from mild in summers and cold in winters. The area receives sufficient rainfall. Rainfall is distributed throughout the year with two peaks of summer monsoon and winter. The summer season rainfall is from monsoon and the winter rainfall and snowfall is associated and attributed to western disturbances and storms.

Management of Common Resources

The legal classification which includes the categories of reserve forest (RF), areas of minimal use rights for the local population; demarcated reserve forest (DPF), with more local use rights in the less commercially valuable parts of the forest and undemarcated protected forest (UPF) in the Sarbari Khad Watershed region. In general, use rights in DPF lands are more specific, whereas UPF are not very clear, and there is disagreement regarding the status even among the government departments. Villagers' rights include grazing, timber for house construction, fodder and animal bedding leaf litter material, wood for fuel and tool making and minor forest produce collection such as medicinal herbs.

Some of the government owned land has been traditionally allocated by village institutions for collection of fodder, leaf litter and fuel wood. In mountain ecosystems also many of the natural resources have historically been used as common property resources. Most Himalayan forests are protected and are under the control of Forest Department but they are regularly used by local people and viewed as "their" forest (Moench, 1989). There is enough literature in India dealing with commons and the dependence of poor people on the commons for their livelihood (Jodha, 1986, Messerschmidt, 1993). Common property theory emphasizes the importance of understanding property rights and institutions. A number of village committees are found functioning in Sarbari Khad Watershed which looks after the management of traditionally allocated government land as common resource. Committee members are elected democratically from the local population.

There are two more committees in the Sarbari Khad Watershed formed by the initiation of government agencies. One is Mahila Mandal (a Women's organization) and other is Jungle Committee. The role of these committees is integrated and mainly focusses on cooperative work required for village level resource management. Mahila Mandal has also taken the task of promotion of social equity, prevention of liquor drinking, and upgrading education. Jungle committee has 17 members from the local villages and three from the forest department. This committee takes active part in prevention of illegal felling of trees and plantation of trees.

Change in Land Use Pattern

In the Himalayan a region (Moench, 1989; Ramakrishnan, 1992) agricultural practice integrated with animal husbandry and forest products were predominantly subsistence level and same was the situation of land use in Sarbari Khad Watershed. At present three possible land use systems are noted in the region. One is valley systems, second is low land terraces and third is high land terraced systems. Two periods were taken as example to contend changes in the watershed. During the middle of 1800s the region was deeply involved in the production of opium and tobacco for national and foreign markets (Harcourt, 1870). After independence, paddy was the main crop in the region mainly in irrigated fields and in non-irrigated fields, maize was the main crop. Generally, only one crop in a year was harvested in the valley field. At middle and higher slopes maize, local variety of wheat, millet, barley and beans were the major

crops. But after 1993-94 these traditional crops have been replaced by new varieties of wheat and fruit trees except at minor scale cultivation of mixed crop like maize, pulses being still practiced at higher terraced sloppy land. Major changes in irrigated field of the valley area, there is rotation of paddy and wheat high yielding variety but earlier rotation was paddy to paddy. Most of irrigated and unirrigated fields have been planted with fruit trees like apple, plum, cherry and almond and none of the crops are grown under 20 year old farms. Middle slopes and terraces have also been brought under this tree crops. Crops like wheat, barley, millets are not grown in large scale partly due to crops and partly due to high market oriented and demanded new varieties of crops; traditionally lesser-known crops have no market value due to its poor taste. Recently at higher altitude terraces, where traditional crops were climatically suitable to grow are now being replaced by apple trees. Therefore, the whole watershed is under process of transformation from a mixed crop agricultural landscape to a fruit belt. (Figure: 2).

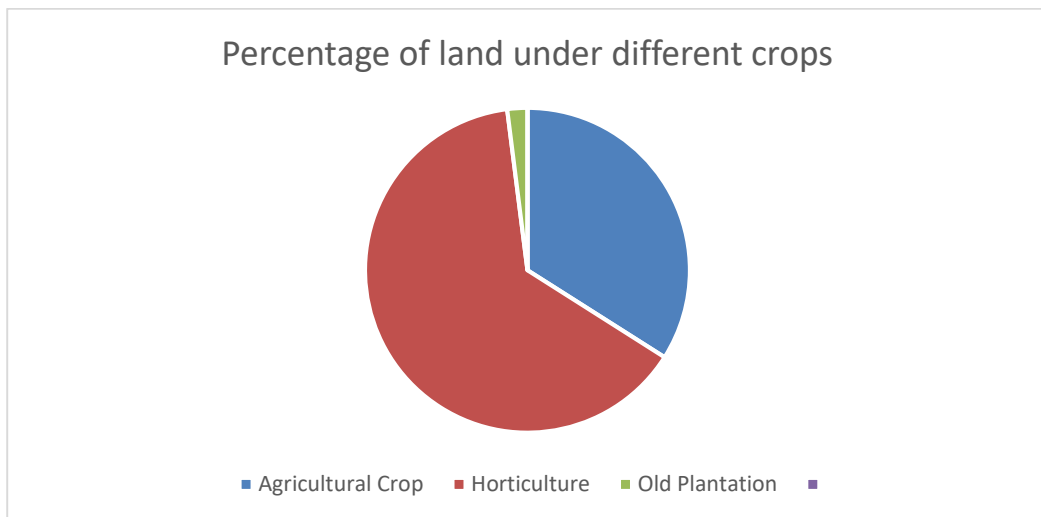
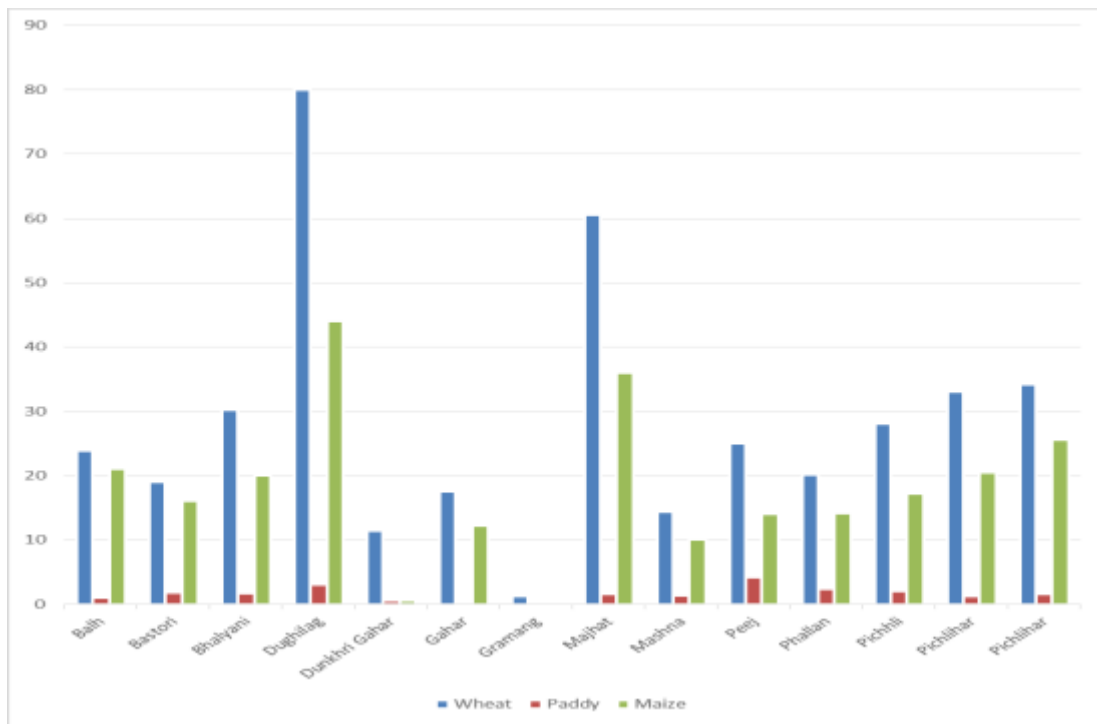


Figure: 2

Out of total arable land in the watershed around 34 percent of the land is under agricultural crops, whereas 64 percent of land under horticulture crops system where food crops are growing along with the fruit crops and only two percent of land is under traditional fruit plantation which is more than 25 year old. Due to invasion of apple and other fruit trees, three crop species are already extinct from the study area (Singh et.al., 1996). Therefore, such changes in the land use system might accelerate the further loss of crop bio-diversity in the area. Change in land use pattern also compelled the farmers to use heavy amount of inorganic fertilizers and pesticides.

Due to climate change and other requirement of land there is low production in the lower elevations (1000-1300 m). Therefore, a shift of plantation has commenced from lower to higher elevation (1500-2000 m). The valley areas have been replaced with a number of vegetable crops which are mainly cash driven (Figure 4).

Figure 4: Area under High Yielding Crops (in Hectare)



Source: District Census Handbook, Kullu, 2011

A heavy demand has resulted in tremendous tree cover fringe of settlement and also has accelerated uncontrolled feedback effect over landscape characterizing unrepairable landslide, drying of spring water channel and loss of fodder and fuel wood (Figure 3).

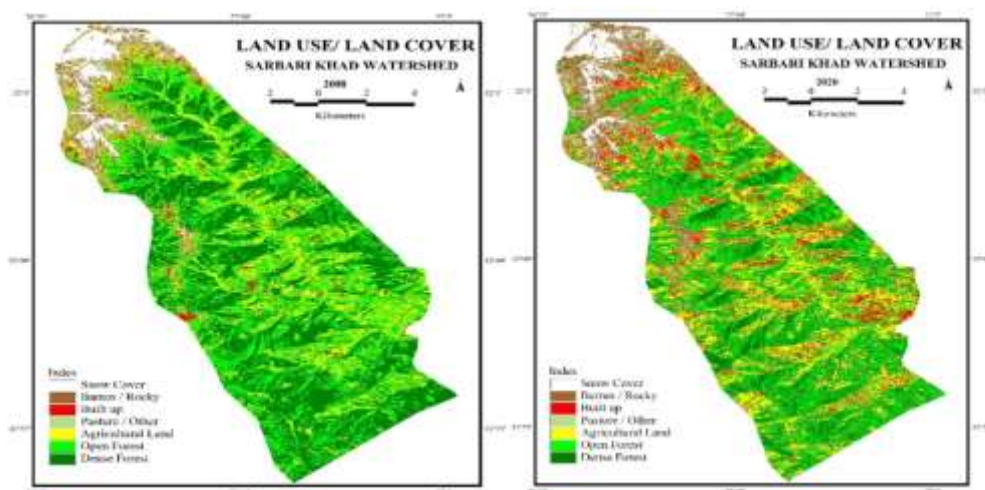


Figure:5 Change in Land use / Land Cover, 2008-2020

Table 1: Landuse/ Land cover change (2008 to 2020)

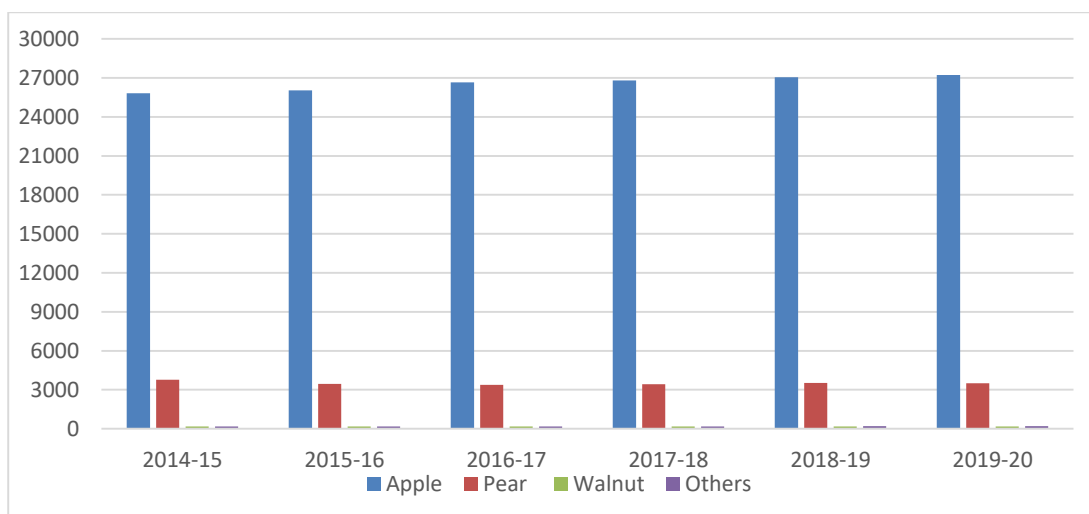
Class	Area (hectare) 2008	Area (hectare) 2020	Change in Area	Percentage of Change
Agriculture	3109.93	5687.96	1578.03	82.89
Builtupand Settlements	371.75	989.58	617.83	166.19
Barren and Rocky	482.15	718.24	236.09	48.96
Dense Forest	6946.42	5057.33	-1889.09	-27.19
Open Forest	6043.08	4726.03	-1317.05	-21.79
Pastures/Others	298.63	164.3	865.67	-44.98
Snow Cover	829.08	736.75	-92.33	-11.13

The satellite image analysis depicts that in the 2008 (Fig. 5a) about 4.59 per cent and 2.67 per cent of the area is under snow cover and barren/ rocky surfaces. The snow cover has reduced by 11.13 per cent in twelve years whereas the rocky/barren land increased by almost 48.96 per cent in 2020 (Table 1). This change was also noted during the field work while doing interviews and visits in the area. The area under dense forest, open forest and pastures shows a considerable negative change during this time period. Dense forest has reduced by 27.19 per cent, open forest by 21.79 per cent and pastures reduced by 44.98 per cent from 2008 to 2020. This conversion mainly comes in agriculture land. There is substantial increase in agricultural land (82.89 per cent) and settlements by 166.19 per cent during the study time span. The change is due to the development of horticulture and expansion of orchards in this area. Change in settlement area is immense due to the development of tourism industry, local infrastructure and hydro power project. Therefore, the built-up area intensified and expanded in the whole study area.

Changes in Socio-Economic Profile

Changes in land use systems and the local economy replicate a more essential change in the way a society relates to its natural environment. There are two major factors responsible for changes in the socio-economic conditions of the Sarbari Khad Watershed region. One is the introduction and expansion of high yielding variety of crops and fruit producing trees and other is tourism industry. Apple orchards existed in the Sarbari Khad Watershed since many years, though it was on a minor scale, but the explosive increase in orchards is a phenomenon of only the last 15-25 years. Heavy government subsidy is also one of the causes of changing the crops diversity and promoting more and more plantation of horticulture trees (Figure 6). Apple economy has induced the people of the area to follow to tourism industry.

Figure 6: Area under Different Fruits Crops (in hectare)



Source: Deputy Director, Horticulture, Kullu

Both horticulture and tourism intricately led to an evolution of changes in land use patterns. This socio-economic profile has induced changes in the social setup of the people. The demand for timber has increased as tourism developed in the area. The time taken and distance covered to bring fodder and fuel wood has changed. It has increased from 2-3 hours to 6-7 hours. Agriculture practices were more women-based responsibility out; now men are more responsible for horticulture crops in terms of search of market potential.

There are multiple dimensions of sustainable development. Based on study, local farmers' perceptions and knowledge and climatic suitability of the region, the major priorities for economic advancement were assessed, possibilities for improvement in technological efficiency of pre-existing traditional knowledge-based land production systems, scientific innovations in industry-based market oriented production system and social implications in the changing spatio-temporal scale were assessed. The major suggestions are following:

- A. In valley and river belt area, which has irrigated land should be brought under cultivation of paddy and wheat for food security and non-irrigated land with gentle slope should be promoted for the cultivation of fruits trees like apple, plum, pear, cherry and almond. This can be used up to an elevation range of 1000 m to 1500 m throughout the watershed.
- B. Slopes adjacent to valley land and lower middle terraces in the elevation range of 1200-2000 m should be cultivated with horticulture crops like apple, almond, cherry and plum intermingled with food crops. Leguminous crops should be grown which could improve the soil nutrient status required for the growing apple.
- C. A good fertile patch with gentle sloppy land area at higher terraces (1700-2200 m) land, which is lying here and there, should be under traditional crops for food security. This is high risk zone area and is suitable for traditional mixed crop cultivation.

- D. A number of medicinal plants of economic value should be grown at an elevational range of 2500-4000 m.
- E. Government owned forest land particularly undermarked forest land should be brought under plantation of fodder and fuel wood tree species with the involvement of local committees which would decrease human and livestock pressure over protected forest.

Sustainable Watershed Development

Sustainable development is defined as "Addressing the necessities of current generation without compromising the capacity of future generation to meet their needs".

1. The main purpose behind Sustainable watershed management is to
 - To ensure the land and water assets.
 - To preserve eco-friendly habitat for Water resources for future generations.
 - Optimum utilization of water resources for future development while securing present.
2. By adding the concept of integration & sustainability to watershed management we can redefine it as reconciliation and manageability of land, water, economic and social assets to overhaul human welfare in a quality living.
3. Framework for sustainable watershed development includes basically following three phases or stages:
 - Three phases: Technical, Planning and Watershed community outreach.
 - Technical stage: Identifies the effects of rapid development on a watershed's resources. In this stage the role of remote sensing techniques becomes very important specially for inaccessible mountain watershed ecosystems. Spatial and temporal changes in LULC are efficiently analysed with the help of these geospatial techniques.
 - Planning stage: Develop management strategies that procedures balance between regional economic advancement and ecological stability. The multi-layer and integrated analyses through Geographical Information System provide the capacity for modelling and planning.
 - Watershed community outreach: Innovative approach to ensure and protect regional resources through community involvement programs.

To make the sustainable strategy practically possible following issues are to be addresses on priority and permanent basis:

- Conflicting government strategy;
- Poor institutional arrangement and co-ordination;
- Lack of local's associations and backing;
- Lack of funding; and inappropriate Technology

Conclusion

The success of an approach and strategy for sustainable development of Himalayan watersheds depends on local participation and local institutions. Integrated and local level management of resources is the key to goal of sustainable development. The goal is to address the issues of distributive justice and ecological balance along with economic growth. Focus is to be kept on intra generation and inter-generation equity. The strategy is to shift from 'touch me not' to 'use me wisely'. A system is to be evolved which provides ways for successful eco-friendly living of communities. Such development approaches formulation requires looking and designing incorporating present and past deep understanding of the existing systems by giving priority to the socio-cultural profile, economic and environmental advancement which could be achieved not in isolation but designed in an integrated manner for sustainable development of the watershed.

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