Sustainable Watershed Management: Illusion or Reality?
A case of Kerala State in India

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Sustainable Watershed Management: Illusion or Reality?
A case of Kerala State in India

Proefschrift

ter verkrijging van de graad van doctor
aan de Technische Universiteit Delft,
op gezag van de Rector Magnificus, prof. dr. ir. J. T. Fokkema
voorzitter van het College voor Promoties,
in het openbaar te verdedigen

op dinsdag, 19 December 2006 om 17.30 uur

door

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Master of Housing, Kerala University (India)

Geboren te Cochin, Kerala, India

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Sustainable Watershed Management: Illusion or Reality?
A case of Kerala State in India

Thesis

presented for the degree of doctor
at Delft University of Technology
under the authority of the Vice-Chancellor, Prof. dr. ir. J. T. Fokkema,
Chairman of the Board for Doctorates
to be defended in public in the presence of a committee

on tuesday, 19 December 2006 at 17.30 hours

by

Subha VISHNUDAS
Master of Housing, Kerala University (India)

born in Cochin, Kerala, India

This thesis is approved by the promotors:
Prof. dr. ir. H. H. G. Savenije
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To my beloved mother
who lives in heaven

CONTENTS

Acknowledgements

When I started my life as a PhD student in June 2003, I never thought that this would be a personal journey within myself trying hard to attain this goal. I should first thank God the almighty who is always with me in disguise in all my hard times during this journey. Without his blessing I would never have succeeded. I sincerely wish to express my gratitude to all exceptional persons I met during this journey.

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Delft, 10-07-2006

Samenvatting

Lucht, water, aarde, vuur en ruimte zijn de vijf basiselementen van het leven, zoals beschreven in de antieke geschriften van de Veda. Tegenwoordig staan de hulpbronnen van zowel aarde als water bloot aan intensief gebruik en zelfs misbruik. Aarde en water zijn vitale hulpbronnen om het leven in stand te houden en deze hulpbronnen worden steeds schaarser en daardoor belangijker. Water is vluchtig. Het stroomt onder invloed van de zwaartekracht. Het doel van bodembescherming is niet slechts het behouden van de bodem maar ook het vergroten van de capaciteit om regenval op te vangen, de oppervlakkige afstroming te vertragen en de infiltratie te vergroten. De "Upanishad" zegt: "als water rent, laat het dan lopen; als het loopt, laat het dan stilstaan; als het stilstaat, laat het dan gaan zitten; als het zit, breng het dan in slaap. Het doel van bodembehoud is niet slechts de bodem te beschermen maar ook om zijn productiviteit te verhogen.

Bodemerosie is dikwijls rampzalig en het beïnvloedt de chemische fysische en biologische eigenschappen van de grond. Bodemerosie en waterkwaliteitsverslechtering is een wereldwijd probleem. Over de volgende decennia wordt er verwacht dat de wereld 17% meer water nodig heeft om het voedsel voor de groeiende bevolking in de ontwikkelingslanden te verbouwen en dat het totale watergebruik zal toenemen met 40%. Het totale landoppervlak dat beïnvloed wordt door bodemdegradatie wordt geschat op 20 miljoen $(km)^2$ Het behoud van bodem en water is dus essentieel voor ons levensbehoud. Dit kan bewerkstelligd worden door integraal stroomgebiedsbeheer.

Deze thesis beoogt de omstandigheden te bestuderen waaronder duurzaam stroomgebiedsbeheer mogelijk is in de Indiase staat Kerala. Het onderzoek is in drie stappen gedaan. Allereerst is een conceptueel kader geformuleerd (Hoofdstuk 3) op basis van relevante literatuur over stroomgebiedsbeheer (Hoofdstuk 2). Vervolgens is dit conceptueel kader toegepast op twee bestaande casus (Hoofdstuk 4). Tenslotte is de methodologie toegepast op een aangepaste technologie innovatie met geotextiles (Hoofdstuk 5), binnen twee veldexperimenten (Hoofdstuk 6).

Voor succesvol en duurzaam stroomgebiedsbeheer moeten de natuurlijke hulpbronnen niet alleen voor degradatie behoed worden, maar ook onderhouden worden voor een goede productie. Het gebruik van natuurlijke hulpbronnen vereist technologie. Deze dient goed aan de lokale omstandigheden te zijn aangepast, waarvoor een adequate institutionele omgeving vereist is. De mensen moeten dit zelf in stand kunnen houden en de technologie moet kostenefficiënt zijn. De regels voor toegang tot de natuurlijke hulpbronnen moeten helder zijn. En de instituties die het gebruik beheren moeten in de gemeenschap van het stroomgebied verankerd zijn. De relevante actoren en belanghebbenden, voornamelijk binnen de gemeenschap, moeten in het proces betrokken worden vanaf het begin tot het eind, van probleemindentificatie tot implementatie. En tenslotte dient de technologie betaalbaar te zijn. Naast het behoud van de natuurlijke

hulpbronnen, moet het ook het inkomen van de mensen verhogen. Als een project geen tastbare voordelen oplevert voor de bevolking, wordt het nooit duurzaam. Dit kan beschreven worden door de duurzaamheidsketting. Om duurzaam te zijn moeten alle schakels in deze ketting voldoende sterk zijn: de natuurlijke hulpbronnen, de technologie, de instituties en de economie. Voor een project om duurzaam te zijn, moeten alle schakels een voldoende hoog niveau van duurzaamheid hebben. Gebrek aan duurzaamheid in een van deze schakels is genoeg om een project te laten falen.

In de analyse van de twee casus werd gekeken of het succes van duurzaam stroomgebiedsbeheer inderdaad afhangt van de mate van betrokkenheid van de bevolking in het proces. Dit bleek inderdaad zo te zijn. Daarom is in het veldwerk geprobeerd om middels participatief onderzoek de introductie van kokosmatten voor bodembescherming te onderzoeken. Het resultaat toont aan dat deze participatieve benadering de gemeenschap in staat stelt om het effect van de nieuwe technologie waar te nemen en op waarde te schatten. Dientengevolge nemen de boeren de technologie graag over zodra zij de positieve effecten ervan aan den lijve ondervinden. Dit reduceert de overdrachttijd en kan al direct leiden tot een stijging van de opbrengsten, of een afname van de arbeidskosten. Het draagt zo bij aan de productiviteit, duurzaamheid en het welzijn van de bevolking. De effectiviteit van de kokosmatten voor het behoud van bodem en water, en het produceren van meer biomassa, is aangetoond. Het feit dat de kokosmat goedkoop is en vervaardigd en gelegd wordt met plaatselijke arbeid, maakt het een zeer aantrekkelijk alternatief voor duurzaam beheer van kleine stroomgebieden.

Summary

Air, water, earth, fire and space are considered the five basic elements of life in the Veda, the ancient Indian scripture. At present, the soil and water resources of the planet are under intensive use and misuse. Soil and water are vital for sustaining life and these resources are becoming more limited and crucial. Water is fugitive. It flows under gravity. The purpose of soil conservation is not only to preserve the soil but also to capture the rainfall, slow down the water flow and to enhance infiltration. These are not new insights. The Upanishad states: if water is running, make it walk; if water is walking, make it stand; if water is standing, make it sit; if water is sitting, make it sleep.

Soil erosion is more detrimental and affects the chemical, physical and biological properties of the soil. Degradation of soil and water resources is a worldwide problem. Over the next two decades, it is expected that the world will need 17% more water to grow food for the increasing population in developing countries and that total water use will increase by 40%. The total land area subjected to human-induced soil degradation is estimated as 20×10^6 $(km)^2$ Hence conservation of soil and water is essential for the subsistence of life. This can be made possible through sustainable watershed management.

This thesis aims at investigating the condition under which sustainable watershed management is possible in Kerala, in South India. The research has been carried out in three stages. In the first stage a conceptual framework is formulated (Chapter 3) based on the relevant literature (Chapter 2) in the field of watershed management. In the second stage this framework is applied to two existing case studies in Kerala State (Chapter 4). In the third stage, the methodology is used to test out geotextile innovation (Chapter 5) in two field experiments (Chapter 6).

Regarding the first stage, for successful and sustainable watershed management, natural resources should be protected from degradation and maintained for good production. To utilize natural resources, technologies are required. These should be well adapted to local circumstances, and supported by an appropriate institutional setting. People should be able to maintain these themselves and the technologies should be cost effective. The rules defining access and exclusion to natural resources and the services they provide should be transparent. The institutions governing the use of natural resources should be based in the watershed community. It should involve the relevant stakeholders, particularly the community, from problem identification to all levels of planning. And finally technologies should be affordable. It should be conducive to increase income as well as to enhance land conservation. If a project does not yield tangible benefits to the people it is not going to become sustainable. This has been represented by a sustainability chain. For a watershed project to be sustainable, four groups of criteria should be considered related to natural resources, technology, institution and economics respectively. Poor performance in each of these groups can jeopardize sustainability. The process is as strong as the weakest shackle in the chain. For a watershed project to be sustainable, all these groups should perform above a minimum standard. If one element fails, sustainability cannot be achieved.

In the second stage, using this framework, two watershed projects are evaluated that were implemented under people's participation. The notion that people's participation is essential for the success of watershed management has been tested and found to be true in the context of sustainability of watershed projects. In the third stage of this research a participatory research has been carried out on the introduction and use of coir geotextiles for soil and water conservation. The results demonstrate that a participatory approach enables the community to visualize and evaluate the impact of innovative technologies. As a result, farmers readily adapt a technology when they have experienced the positive research outcome. This reduces the adoption time, and can bring significant increase in yield, or decrease in labour costs, helping to enhance productivity, sustainability and improvement of livelihood. The efficiency of coir geotextile has been proved in reducing soil erosion, reducing runoff and enhancing soil moisture as well as vegetation growth. The relative cheapness of the material and the potential for producing and laying the matting with local labour makes the use of coir geotextiles a very attractive option for sustainable development scenarios in watershed management.

Preface

More than 70 percent of the rural people in Kerala have agriculture as their main source of income. The productivity has been affected negatively due to lack of water for irrigation during the summer season and soil erosion and flooding during the monsoon. This demands for a sustainable solution to conserve soil and preserve water for the future. At the same time, about half a million people are working in the coir industry in Kerala to make ends meet, of which about 80 percent are women. The average income of such an individual is less than one Euro a day. The majority of these people live under minimal living conditions. This thesis brings these two issues together and puts forward a novel approach to resolving the predicaments in soil and water preservation while stimulating the coir industry, with a radically new idea of coir geotextiles.

In trying to develop this idea, the first thing that comes to mind is that it is an interdisciplinary problem. Sustainable watershed management is a vaguely defined term because of its complicated branching in many different disciplines. At the same time the methodology developed should be practical and readily implementable, at the village scale. As a result it is inevitable to give more stress to the practical sides of the problem than to strictly apply existing participation theories.

Due to the interdisciplinary aspect of this work, further scopes for future research, have been identified in disciplinary areas such as: (1) cost-benefit analyses to find out how economically feasible the new technology is compared to conventional methods; (2) environmental aspects in terms of impact assessments; (3) sociological aspects of how the socio-economic conditions of the coir workers and the watershed community will be affected on adoption of this technology; (4) hydrological aspects of soil moisture variation with respect to the change in climatic and topographic condition of the watersheds; and (5) geological aspects affecting the infiltration rate, the ground water recharge etc. In addition, it has equally important civil engineering aspects of standardizing the material with respect to the application of geotextile under different field conditions; agricultural aspects of how the crop intensity and soil fertility are affected; irrigation engineering aspects of finding out the difference in irrigation potential in the treated and untreated plots while using coir geotextiles, policy analysis aspects to incorporate all the above factors to formulate new policy, such as how rules and regulations should be modified and new guidelines be issued for the new institutional set up, and finally, ecological concerns on how the ecosystem will be affected.

This thesis does not deal with the disciplinary aspects in detail. Rather it presents a holistic approach based on a technological background where sufficient attention is given to disciplinary fields for sustainable watershed management in Kerala.

Chapter 1 Introduction

1.1 Introduction

In the Brundtland report our Common Future (WCED, 1987) the UN World Commission on Environment and Development linked the issues of environmental protection to global environmental economic growth and development. This report reveals that the entire world is threatened by serious environmental problems and scientific evidence illustrates the rapid destruction of air, water and land and the over-exploitation of natural resources. Scarcity of water and degradation of land are among the most prominent issues of discussion worldwide, concerned with sustainable development. The availability of water greatly influences the prosperity of people and their development potential and health. Although water is a renewable resource, it is also finite. The availability of this vital resource is by no means assured for large sections of the world's population. The requirement of water for irrigation is bound to increase due to population growth and increased demand for food. Over the next two decades, it is expected that the world will need 17% more water to grow food for the increasing population in developing countries and that total water use will increase by 40%. In addition there will be a tremendous pressure to meet water requirements for other purposes, such as for drinking, industrial use, environmental and ecological management. It is estimated that by the year 2025, as much as two-third of the world population will be living in areas facing water stress conditions (WMO, 1997; UNEP, 1999). By the year 2050, the population projected to be living in water-scarce countries will rise to between 1.06 billion and 2.43 billion, representing roughly 13% to 20% of the projected global population. While Africa and parts of western Asia appear particularly vulnerable to increasing water scarcity, the list of potentially affected regions include north-western China, western and southern India, large parts of Pakistan and Mexico, and the western coasts of United States and South America. Water as a scarce and commonly shared resource may become a cause of conflict. To provide water of the right quality to the users, in the right quantities, at the right places and at the right time, by applying environmentally sound techniques and procedures is the challenge in this decade. Hence there is ample need for the effective management of this vital resource.

The degradation of land is a multi-faceted phenomenon, which can be manifested in a variety of forms. It is generally accepted to imply the deterioration of the land surface, by the accelerated removal of soil, the progressive alteration of soil properties, or the loss of vegetative cover from soil. Some of the causes of land degradation are natural, being the consequence of disaster events such as floods, bushfires or drought, whereas others are the consequence of human activities, such as overgrazing, deforestation or poor agricultural practices. Land degradation can itself aggravate the damage caused by natural disasters, by increasing flood run-off or increasing the potential for serious soil erosion. Land degradation is therefore the consequence of a multitude of causes and effects which all contribute to the reduction of the value of the land for human and ecological purposes (UN, 1997). The total land area subjected to human-induced soil degradation is estimated as about 20 x 10^6 $(km)^2$ Of which 30 % is agricultural land, 35% is permanent pastures, and 35 % is forest and wood land. The land affected due to soil erosion is estimated as 11 x 10^6 $(km)^2$ by water erosion and 5.5 x 10^6 $(km)^2$ by wind erosion (Oldeman et al., 1991, cited in: Lal, 2001). Therefore land degradation is a serious issue of the modern era and will remain so during the 21^{st} century (Lal, 2001). It is estimated that 630 million rural poor live in marginal agricultural, forested and arid lands that are particularly prone to degradation without careful management of land and water resources. Land degradation is estimated at about 35% of agricultural land in Asia, 45% in South America, 65% in Africa and 74% in Central America (CGIAR, 2003). These facts call for the need for its conservation, which is possible only through proper watershed management to conserve the basic natural resources, (land and water) and thus uplift the socio-economic condition of the people by providing health, a hygienic atmosphere, improved water quality, flood and drought control.

The terms watershed, catchment, drainage area and river basin are all used to describe a land surface from which water flows downhill to a specified point on a watercourse. The difference between them is essentially a question of scale, whereby the watershed relates to the smallest size of catchments, generally located on the steepest slopes of a river basin. The watershed contains an array of inter-linked and inter-dependent resources and activities, irrespective of political boundaries. It forms a dynamic and integrated bio-physical, economic, social, environmental and political system containing people, agriculture, forestry, industry, services etc. Managing watersheds is a complex phenomenon. Therefore its management requires a variety of physical, social and economic policies and techniques, all aimed at minimizing the adverse consequences of natural disaster events, to improve and enhance the quality of life of the catchment community. Most, if not all, centrally planned watershed programmes fail due to lack of involvement of people in the projects. People's participation appears to be crucial in planning watershed programmes as local people are closest to the real problems.

This study aims at investigating the conditions under which sustainable watershed management is possible in Kerala, South India and more particularly to explore the potential of coir geotextiles as a locally available and affordable solution for sustainable land and water management. The objectives, research questions and hypothesis of the study are as follows.

Objectives

- To develop a conceptual framework to analyze watershed projects in Kerala to find out problems and prospects in the management of watersheds and to evaluate watershed projects in Kerala implemented through people's participation.
- To study the effect of using coir geotextiles in watershed management for reducing soil erosion and runoff and increasing biomass and thus providing a cheap and effective low cost technology that contributes to sustainable watershed management in Kerala.

Research questions

1. What are the aspects that influence the sustainability of watershed management, based on experiences in India and elsewhere?
2. What are the elements of sustainable watershed management and how can these be incorporated into a conceptual framework?
3. How can sustainable watershed management be implemented including the role of people's participation in Kerala?
4. How can coir geotextiles be used in watershed management in Kerala?

Hypothesis

It is hypothesized that sustainable watershed management is possible in Kerala:

a) through people's participation starting from problem identification all the way to implementation of projects
b) by using locally available materials like coir geotextiles and local techniques

1.2 Structure of the thesis

The first research question is answered in Chapter 2, the second is answered in Chapter 3 and the third research question is answered in Chapter 7 building on the results from Chapters 4 and 6. The fourth question is answered in Chapter 5 and 6. Figure 1.1 represents a schematic representation of how each chapter is interlinked.

The first chapter explains the scope of this study in the context of sustainable watershed management, while the second chapter analyses why and how people's participation is important in the management of watersheds. This chapter also illustrates how participatory research helps in adapting innovative technologies and the importance of environmental services in the context of watershed management. The third chapter defines the term 'sustainable watershed management' and derives a conceptual framework for the analysis of watersheds for sustainability. The fourth chapter illustrates the results of the sustainability analysis carried out in two watershed projects in Kerala. The fifth chapter gives a narrative account of the innovative technology for land and water management using coir geotextiles with case studies from different countries. The sixth chapter presents the results of the experimental study conducted using coir geotextiles in the watersheds of Kerala and the seventh chapter provides conclusion on how sustainable watershed management is possible in Kerala.

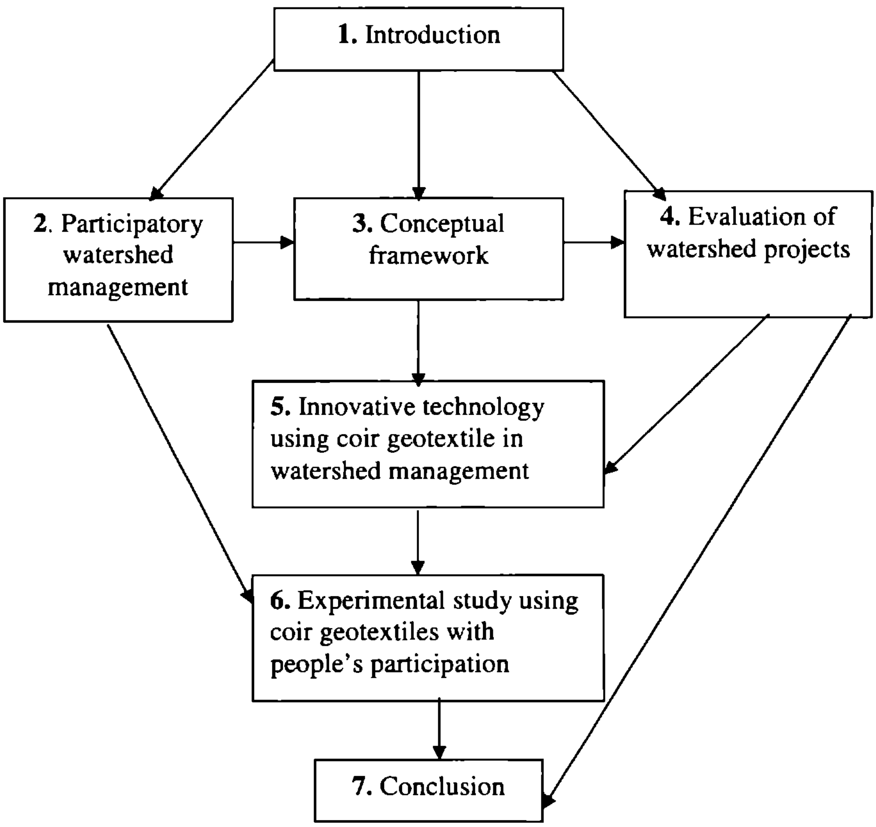

Figure 1.1. Schematic representation of summary of chapters

Chapter 2 Watershed management and people's participation[1]

The first research question is answered in this chapter. It gives an account of the different aspects that influence the sustainability of watershed management and people's participation, in India and elsewhere. The case histories help us to understand how complex the management of the watersheds around the world is. In order to attain sustainability of watersheds, first we should know what the watershed is and its function and then the role of people in this complex phenomenon.

2.1 Introduction

A watershed is an area from which runoff from precipitation flows to a common point to join a lake, river or ocean. With respect to size, a watershed is the smallest in the range of names used for drainage areas: river basins, catchments, sub catchments and watersheds. It varies from a few hectares to hundreds of square kilometers. Each watershed can be treated as an independent hydrological unit, and it facilitates a system approach to land and water use in interconnected upstream and downstream areas. The management practices, intensity of rainfall, land use and topography of the area determine the quality and quantity of water produced in the watershed. In some areas the main concern is to increase soil moisture, increase infiltration into aquifers and reduce runoff, whereas in some other areas priority may be to reduce peak runoff rates to minimize floods. In catchments with hydroelectric dams, the main concern is to minimize soil erosion that deposit into reservoirs and to maintain the base flow. In areas like North America and Europe, major concern is with non-point source pollution that moves through rivers, streams and drains (Kerr and Chung, 2001a). The watershed may often be densely populated and typically contains a variety of land uses, including forests, pastures, rain fed agriculture on sloping lands and both irrigated and rain-fed agriculture in the low lands. Therefore different measures should be considered to achieve the objectives of sustainable management of different watersheds.

Watershed management implies the wise use of natural resources like land, water and biomass in a watershed to obtain optimum production with minimum disturbance to the environment. In the past, the concept of watershed management focused mainly on the management of these resources in medium or large river valleys, aimed at scaling down rapid runoff and excessive soil erosion and to decelerate the rate of siltation of reservoirs and limit the incidence of potentially damaging flash flooding in river courses (Paul, 1997). At present, the overall objectives of watershed development and management programmes take the watershed as the hydrological unit, and aim to adopt

[1] Based on Vishnudas et al. (2006a)

suitable measures for soil and water conservation, provide adequate water for agriculture, domestic use and improve the livelihoods of the inhabitants.

Managing watersheds for sustainable rural development in developing countries is a relatively new concept. In many ways it is much more complex than the old 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 world's semi-arid tropical regions in South Asia and Sub–Saharan Africa, which are characterized by low agricultural productivity, severe natural resource degradation, and high level of poverty (Kerr, 2002). In India, the national policy on watershed management has recently been characterized by a concern that decisions on rehabilitation and subsequent rights and responsibilities should be taken in ways which support the livelihood of poorer groups, especially women, and are institutionally sustainable. All rural development programmes have been reorganized around a watershed approach with an annual budget exceeding US $500 million (Farrington et al., 1999).

Watershed management practices are often complex because multiple users use upper and lower catchments for multiple purposes with conflicts of interests. Hence any intervention adopted may impact on other uses, and moreover different uses are mutually exclusive in nature. The upper watershed may have denuded forests, being common land used for grazing and collecting fire woods by the local community. Watershed projects aiming to protect against soil erosion require reforestation, which in turn provides restriction to grazing and entry into the forest. This will affect rural livelihoods. Usually the wealthiest farmers who own irrigation lands live downstream. The success of watershed projects is determined by the 'environmental services' offered by the poor people to the rich farmers who live downstream (Kerr, 2002). The term 'environmental services' is defined as "the conditions and processes through which ecosystems sustain and fulfill human life, including the provision of food and other goods" (Rosegrant, 2002). In most cases the services provided by ecosystem have not been recognized, not valued economically, not traded in markets and not considered in land management decisions. Recently it has been recognized that if implementing systems of payments for environmental services involves transfer payments from rich urban to poor rural households, they may also contribute to rural development objectives. This has clearly contributed to the popularity of the concept among development organizations (Johnson and Baltodano, 2004).

2.2 Watershed management and people's participation

The needs, constraints and practices of local people have not always been considered in watershed development programmes around the world. This often accounts for the poor performance of such projects. The term 'people's participation' is used discordantly by different people. According to Mirghani and Savenije (1995), people's participation in a project should refer to the stakeholders, inside as well as outside the project area. Stakeholders consist of all categories that will be affected by, have interest in, and can influence the project intervention. The stakeholders are not limited to the target group, but they are extended to cover all the other stakeholders beside the project's intended beneficiaries. Also participation should be part of the early stages of project formulation, as well as decision-making and the final project evaluation. According to Johnson et al. (2001), participation implies that stakeholders work together to set criteria for sustainable management, identify priorities, constraints, evaluate possible solutions, recommend technologies and policies and monitor and evaluate impacts. The new orthodoxy – for example, among multinational donors such as the World Bank and FAO, as well as bilateral donors – is that environmental deterioration can best be reversed through involving local people either directly or through the involvement of Non-Government Organizations (NGOs) in partnerships with the state, transforming the common experience of conflict into co-operation (Jeffery and Vira, 2001, cited in: Dube and Swatuk, 2002). Governments and NGOs have realized that protection of watersheds cannot be achieved without the willing participation of local people (Pretty and Ward, 2001). Therefore for successful and sustainable watershed management, people's participation is essential. This is one of the lessons learned from the failures of centrally planned watershed development projects through which local people have been either coerced or paid to undertake terracing, bunding, destocking and other technical measures that external experts believed would cure watershed degradation (IDB, 1995; Kerr et al., 1996; Rhoades, 1998).

Participation by farmers is essential for the planning of sustainable management of land and water resources. Farmers are closer to the real problems, and therefore they are aware of factors that experts may overlook, and their objectives are more realistic for economic development (Stocking, 1996). Furthermore, farmer's participation in conservation work is also considered important in improving the adoption of the recommended technology (Ashby et al., 1996). The role of science in the new agenda of farmer participation is to describe, understand and seek explanations for practices and views of land users (Stocking, 1996). Many of the existing resource–conserving technologies were discovered by farmers or developed in partnership between agriculture research and local people (Pretty, 1995). Some of them have shown to be more economically viable than recommended technologies by the external experts (Kiome and Stocking, 1995).

At its narrowest, participation in a group is defined in terms of nominal membership (Molinas, 1998) and at its broadest it is a dynamic interactive process in which the disadvantaged have a voice and influence in decision-making (Narayan, 1995;

White, 1996). In terms of objectives, at its narrowest, participation is judged almost entirely by its potential efficiency effects, and at its broadest by its ability to enhance equity, efficiency, empowerment and environmental sustainability (Uphoff, 1991).

2.2.1 Why participation

In most of the centrally planned projects, especially in South Asia and Eastern Africa, soil and water conservation programmes are promoted with standard technical solutions such as terracing, contour bunding etc. on the assumption that soil conservation measures are universally applicable and local farmers are unaware of soil erosion and ignorant of its causes and consequences (Pretty and Shah, 1999, cited in: Johnson et al., 2001). However, these measures, which were often enforced on the people, may cause more erosion than their own indigenous practices, either because the new conservation works are not maintained or are technically inferior to existing practices (Kerr et al., 1996). In India, the large majority of watershed development projects are based on conventional approaches considering only physical planning without attention to socio-economic or ecological conditions (Farrington and Lobo, 1997).

Managing a watershed involves not only individual plots, but also common property resources like forests, springs, gullies, roads and footpaths, and vegetation along streams and rivers (Swallow et al., 2001). The needs and priorities for different users are different in each watershed. By seeking information from farmers about their constraints and priorities, their potential for new technologies, appropriate policies and technology can be designed for each watershed. Therefore participatory watershed management involves all actors to jointly discuss their interests, prioritize their needs, evaluate potential alternatives and implement, monitor and evaluate the project outcomes.

For the sustainability of watersheds, apart from technology and policies for resource use, better organizational mechanisms and processes (through which actors can come together to make decisions) are essential. Case studies of successful projects in Asia and Africa show that these watersheds have community forums for collective action in managing resources and rely on face-to-face contacts to build and maintain mutual trust and understanding. According to Johnson et al. (2001), three issues of particular relevance to watershed management are (1) scales and boundaries, (2) the roles and costs of facilitation, and (3) development of indicators and monitoring systems, so that the impacts of changes in land use can be visualized by the community. The geo-hydrological boundaries and administrative boundaries are generally different in watersheds and hence, for sustaining effective participation, management strategies should be flexible to allow the users to identify boundaries at which they prefer to organize themselves. In the Australian Landcare project and the Indo-German project on watershed management, the establishment and operation of the village watershed committees required a lot of time and effort (Farrington and Lobo, 1997; Johnson et al., 2003). Although transaction costs were relatively high, these could be considered as investments that will later increase the effectiveness of the interventions.

2.2.2 Typology of participation

User participation is recognized as being crucial for the success of watershed development projects. A participatory approach implies a major role for the community and involves partnerships with other interested groups, from bottom to top, and with policy makers. But the key concern is to identify approaches that can attain an efficient, effective and accountable interface between the community, the local bodies, the state and the central bodies (Carney and Farrington, 1998). The substance of participation is often ill-defined and clarification is required regarding who is participating, how and in what. Despite Woodhills's expression (Johnson et al., 2001), "making invisible visible", participatory watershed management is not a neutral concept, but it is a complex system, which involves political issues concerning who has decision-making power and who has access to resources.

Lilja and Ashby (1999) adopted a typology of five modes of participation. This typology was designed to analyze participatory research projects based on who makes decision at what stage of the research process. The typology defines two groups of decision makers: 'Scientists' which include outside agencies, extension systems or formal research agencies, and 'farmers' which includes intended users or other beneficiaries. The five modes of participation are:

1. Conventional (no farmer participation). Scientists make the decision alone without organized communication with farmers.
2. Consultative (farmers' participation). Scientists make the decisions alone, but with organized communication with farmers. Scientists know about farmer's opinions, preferences, and priorities through organized one-way communication with them. Decisions are not made with farmers nor delegated to them.
3. Collaborative (empowering participation). Decision-making is shared between farmers and scientists, and involves organized communication among them. Scientists and farmers know one another's opinion, preferences, and priorities through organized two-way communications. The decision is made jointly. No party has the right to revoke the shared decision.
4. Collegial (empowering participation). Farmers make the decisions collectively in a group process or through individual farmers who are involved in organized communication with scientists. Farmers know about scientist's opinion, preferences, proposals and priorities through organized one-way communication. Farmers may or may not let this information affect their decision.

5. Farmer experimentation (no researcher participation). Farmers make decisions individually or in a group without organized communication with scientists.

'Who makes decisions' clearly effects both the specific decisions that are made within a project as well as the knowledge and skills gained by participants. Hence the innovation process is divided into three stages – *design, testing and diffusion.*

Design Stage: problems or opportunities for research are identified and prioritized and potential solutions to priority problems are determined. Outcome of the decisions at this stage is an array of potential solutions.

Testing Stage: potential solutions are evaluated in the testing stage. Decisions are taken about which solution to test, who does the testing, where and how it is done and how the results are interpreted. Outcomes at this stage feed back to the design stage or result in the identification of technologies for mass distribution at the diffusion stage.

Diffusion Stage: it involves building awareness of recommended solutions among future users. It includes decisions about when, to whom, and in what way to distribute technologies, supply new inputs and teach new skills to potential users.

Pimpert and Pretty (1997) provided a typology of participation in watershed programmes with seven modes of participation (Table 2.1). Empowering participation is found to be essential for strengthening human capital. Training and interaction with researchers will strengthen experimentation and innovative skills among participants and adoption of new technologies.

There are three ways in which participation is associated with watershed management (Johnson and Westermann, 2000),

- *Participatory watershed management*: stakeholders participate in development processes and decisions. Relevant stakeholders jointly discuss and decide about watershed planning and set priorities for taking up development tasks, such as trying out a technology or methodology in a new location.

  Participatory research on watershed management: researchers and other stakeholders work together in the process of developing new technologies or institutions for watershed management. Although research is the focus, all stakeholders participate in the process and decisions are made jointly.

  Research on participatory watershed management: Researchers collect materials from various projects applying participatory watershed methods and carry out analyses in order to understand issues, such as collective action and how stakeholders negotiate and implement natural resources management. This research may or may not be participatory and therefore may or may not involve other stakeholders.

In farmer experimentation, researchers are not involved in any systematic way. Projects may use different types of participation at different stages of the research process. There is no right type of participation. Different types are expected to have different advantages and disadvantages depending on the objectives of the specific project (Johnson and Westermann, 2000).

Table 2.1 Typology of Participation (Pimpert and Pretty, 1997, adapted from Farrington et al., 1999)

Typology	Components of each type
Passive participation	People participate by being told what is going to happen or has already happened
Participation in information giving	People participate by giving answers to questions posed by extractive researchers and project managers
Participation by consultation	People participate by being consulted and external agencies listen to their views. External agencies define both problems and solutions
Participation for material resources	People participate by providing resources–labour in return for cash and food
Functional participation	People participate by forming groups to meet predetermined objectives relating to the project, which can involve the development or promotion of an externally initiated social organization
Interactive participation	People participate in joint analysis, which leads to joint action plans and formation of new groups or strengthen of old ones
Self-mobilization	People participate by taking initiatives independent of external change systems

2.3 Role of stakeholders in watershed management

The past decades have witnessed the planned development and top-down conservation practices of the state, which coerced their citizens to adopt often unsuitable conservation practices that led to the failure of projects. Faulty design, inefficient implementation and corrupt organizations are the major causes for the poor outcomes of the state-centred policies (Agarwal and Gibson, 1999). Kerr (2002), Agarwal (2001), Agarwal and Gibson (1999) and Leach et al. (1999), show that policy makers and researchers have to reconsider the role of the community in bringing about decentralization, resource conservation and management. According to Agarwal and Gibson (1999), the community must be examined in the context of conservation by focusing on the multiple interests and actors within communities, on how these actors influence decision-making and on the internal and external institutions that shape the decision-making process. Community participation, empowerment, governance and sustainability are four main aspects that gained unprecedented visibility and respectability among the large multilateral and bilateral aid agencies. The World Bank, the United Nations and most bilateral programs have made participatory approaches an integral part of policy papers and project design criteria (Botchway, 2001).

A community is considered as a small spatial unit with a set of shared norms. In small units, each household can interact with their neighbours, with whom they share common resources (Agarwal and Gibson, 1999). In some societies, a community has common characteristics such as religion, caste, language or ethnicity. This will enhance the likelihood of cooperative solutions, reduce hierarchal and interactive conflicts, and lead to successful management of resources. For sustainable watershed management, watershed programmes would involve affected and interested people from the process of planning, secure their commitment to execute, monitor and evaluate and maintain the project. There may be conflicting interests, but by negotiation conflicts can be resolved and can bring about joint decision making to attain the common goal. Once the community takes a decision, it becomes binding on all members. This is the essence of a success of a participatory approach to development (Hashim, 1999).

Institutions have formal and informal rules and norms, which constrains some activities and facilitate others; without them social interactions would be impossible (North, 1990). When actors do not share goals and are unequally powerful, institutions can define some powers regarding interaction among actors and to structure the interactions that take place around resources. Chapter 3 provides a more detailed analysis of institutions in watershed management.

Institutional analysis requires identifying a possible set of rules which the group or individuals have to obey and also the processes by which rules are changed in a given situation. For the effective management of a resource, a consistent set of guidelines and rules both at national and local (grass-root) level is required. In order to foster concerted action at both the highest and lowest levels in society, it is often necessary to strengthen the institutional capacity at the intermediate or 'meso' level. At this crucial level, central policies, laws and strategies should be sectorally coordinated and translated into practical plans and actions. For example in Zimbabwe, the appropriate location of this intermediate level may be the district for administration or the river basin for water resources management (Van der Zaag, 2004).

Leach et al. (1999), through case studies from India, South Africa and Ghana, provide a dynamic perspective on the role of institutions in people-environment relations. Diverse institutions, both formal and informal or acting together, shape the ways in which different actor's access, use and derive well-being from environmental resources and services which will in turn have ecological impacts. Formal institutions may have sets of rules that require exogenous enforcement by a third party organization, whereas informal institutions may enforce rules through internal arrangements.

2.4 Property rights, gender and watershed management

In some developing countries much of the land within watersheds is not privately owned. Some are under the forest department or under the state and some are under village-based ownership. Forests and village commons have been important sources of supplementary livelihoods and basic necessities for rural households. In most of the developing countries watershed projects are linked with rural development and poverty alleviation. Managing watersheds may require restricted entry to common land and hence customary access rights of the poor may be denied. Therefore management of common property resources is important in the context of watershed management. Community participation in watershed management usually refers to the participation of only the men, and not really the community, as consisting of men and women. Most rural households meet their subsistence needs from their immediate environment. It is the women in these households who are responsible for accessing these natural resources like fuel and fodder. Therefore degradation to these resources will increase the work burden of women. They have to spend more time and travel more distance to collect resources to meet the needs of the household. Hence women resource users have a greater interest in conserving natural resources. But their participation is not always given importance in the planning and decision-making related to the watershed management. Besides women hardly have control over land resources and landowners mostly control watershed activities, especially since most of the activities start on private lands. Influential members or well-off farmers usually dominate the committees and women rarely get an opportunity to raise issues or voice opinions (Farrington et al., 1999).

2.4.1 Common property resource management

'Common property resource' (CPR) refers to a natural or human-made resource system, whose size or characteristics of which makes it costly, but not impossible, to exclude potential beneficiaries from obtaining benefits from its use. Common property resource management refers to arrangements for managing such resources (Farrington et al., 1999). Garret Hardin in his theory states that resources that are held as common property such as forests, lakes and grazing land will inevitably be overexploited and lead to problems like deforestation, soil erosion and overgrazing and overfishing. Many anthropologists and political scientists have critically argued against his theory and showed that local people around the world have developed institutions and practices that have entitled people to use common property resources in a sustainable manner. The 'tragedy of the commons' is not inherent to CPR-regimes but it may be triggered by general socio-political, economical and environmental issues. Wade (1987), North (1990) and Ostrom (1990) have theoretically proved that CPRs being opened to local institutions, insuring grass-root community participation as well as security such as property rights, are the most effective ways of achieving sustainable use.

According to Hardin's theory, in 'the tragedy of the commons', he concludes: Therein is the tragedy. Each man is locked into a system that compels him to increase his herd without limit, in a world that is limited. Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons (Ostrom, 1990).

Common Property Resources continue to be an important part of community's natural resource endowment in developing countries. Despite their valuable contributions to people's sustenance, environmental stability and the strengthening of private resource based farming systems, CPRs are neglected by researchers, policy makers and development planners alike. Disregard of CPRs and their productive potential is a major missing dimension of rural development strategies in developing countries and reflects much of the administrative indifference to environmental protection. World Bank (1995) illustrated the status and changes in CPRs in the dry tropical regions of India, where, not only CPRs are poorly integrated into rural development strategies but they are left prone to rapid degradation largely induced by other development and welfare policies.

2.4.2 Property rights

Common property resources may be owned by national, regional, or local governments or by communal groups. Sometimes landlords, who formally own the land, make it available for a community as a common property resource. A CPR can also be used as an open access resource by whoever can gain access. A property right can be defined as an administrative authority to undertake particular actions in a specific domain.

Schlager and Ostrom (1992) identified five levels of property rights that are important to CPR. They are access, withdrawal, management, exclusion and alienation. Access: the right to enter a defined physical area; withdrawal: the right to obtain resource units or products of a resource system like catch fish, divert water; management: the right to regulate internal use pattern and transform the resources by making improvements; exclusion: the right to determine who will have access rights and withdrawal rights and how rights may be transferred; alienation: the right to sell or lease management and exclusion rights.

Private property right is defined as equivalent to alienation in economic literature. A system, that does not include the right to alienation, is considered to be ill-defined. Individuals or a community may hold property rights that may or may not include all the rights. Government, a community, an individual or a private corporation may possess full ownership rights.

Schlager and Ostrom (1992) defined five classes of property right holders. They are authorized entrants, authorized users, claimant, proprietor and owner. Authorized entrants can enjoy the beauty of the resources, but do not have the right to harvest from it. Authorized users have the right both to entry and withdrawal of the resources. Claimants possess the operational right of access, withdrawal and also the collective-choice right of managing resources regarding maintenance, decision-making and the authority to devise withdrawal rights. Proprietors have the same rights as claimants but also have the right to determine who may access and harvest resources. Owners possess all the rights including the right to alienate as long as it does not cause any harm to the rights of other holders. Thus all the five rights may be held by single individuals or by collectives. Some attributes of common pool resources are conducive to a communal proprietor or ownership and others are conducive to individual rights to withdrawal, management, exclusion and alienation (Ostrom, 2000).

Van der Zaag (2004) explains the complexity of the property regime of a water resource system with three important physical attributes of water: (1) water is *vital* to sustain life and has no substitute, which means that water has a value to its users, (2) Although water is a renewable resource, it is a *finite* element and therefore use by one actor prevents the use of another, (3) Water is a *fugitive* resource and therefore it is difficult to assess the variation in stock and flow of the resource and to define the boundaries of the resources. Access to and exclusion from natural resources are often difficult to accomplish, since it is often difficult to define clear and unambiguous boundaries of natural resources.

Managing this resource involves relatively complex physical, technical and institutional measures such as:

access to and withdrawal from the resource system
the state of the resource is monitored
its upkeep and maintenance is ensured
rules are enforced
rules are perceived to be legitimate, effective and fair by the vast majority of users
rules are adapted to changing conditions of the resource and its use
leadership is effective and accountable to the users

2.4.3 Gender, property rights and power in watershed management

Gender analysis in property rights and resource management clearly reveals that by paying attention to gender in resource management significant improvements can be achieved in terms of efficiency, environmental sustainability, equity and empowerment of resource users. Differentials in property rights occur not only along gender lines but also along class, caste and age. Property rights to resources such as land, water and biomass play a fundamental role in governing the patterns of natural resource management, as well as in the welfare of individuals, households and communities who depend on those resources. The success of any policy, whether designed to prevent further depletion or degradation of the natural resource, to enhance the resource base, to ensure sustainable resource utilization, or to improve household welfare, would depend on an ability to successfully anticipate the responses of individuals (Meinzen-Dick et al., 1997).

Secure tenure encourages investment in a resource, which leads to higher productivity and efficiency in its use (Besley, 1995; Place and Hazel, 1993). If women are blocked from some activities, leading to the loss of their access to land, their insecurity of tenure can be a barrier to productivity. Improving the equity of resource distribution is a strong theme in property rights. It is different from equality, but it is rather linked to the concept of fairness. This concept corresponds to Engle's (1993) 'need rule': more resources are given to the more disadvantaged member of the household to bring him or her up to the level of the less disadvantaged member. The equality rule corresponds to an equal split, where each person receives an equal share of the resources. The fairness concept depends upon the type of resource, the resource constraints of the household and the values of the resource allocation. The definition of equity has been universally proved differently in different places in different types by different people. According to Meinzen-Dick et al. (1997), acquisition of resource rights through labour contributions (sweat equity) appears to be a more equitable route than cash purchase or inheritance for resource poor households and individuals.

According to Agarwal (1994), empowerment is a process, which enhances the ability of disadvantaged individuals or groups to challenge and change existing power relationships that place them in subordinate economic, social and political positions. Ownership of a resource contributes to empowerment. In societies where women can inherit, their positions will be stronger within the family. In the complexity of land and tree issues, women groups are stronger to fight for their ownership rights to resources. Men and women have different use rights to resources. It varies from grazing and cropping on land; irrigating, washing, watering animals, using water; timber, fruits, leaves, firewood and other products from trees. Rights to land can be acquired through market purchase, inheritance, labour or squatter rights, or through membership in a community. The right to water may be based on access to an irrigated plot and rights to trees may be acquired by planting trees for afforestation or clearing trees in forest areas.

Agarwal (2001) demonstrates how participatory institutions can exclude significant sections of society such as women. Participation is determined especially by rules, norms and perceptions, in addition to the endowments and attributes of those affected. These factors can disadvantage women both separately and collectively. Case studies of community forestry in South Asia show that the exclusion of women not only occurs in joint forest management but also in other collectivities like water user associations, village councils, and even in the new governance structure with decentralized institutions. Social and cultural norms have a considerable effect on women's water rights that are allocated through community membership (Meinzen-Dick et al., 1997). Not only in South Asia, but also in Western countries, social norms define domestic work and childcare as women's work, and social perceptions discount women's abilities and opinions. Hence women's ability to change rules and norms, perceptions and endowments in a gender–progressive direction would depend on their bargaining power with the state, the community and the family.

Property rights are strongly linked to issues in collective action. Communities have their own formal or informal rules to deal with their resources. In societies where women cannot have individual ownership, they may be able to obtain access rights to a common land by forming an organization or group. Community participation does not automatically mean that there is equity for men and women in project design. Generally male-headed families do not involve their women to take part in collective decision. Even in matrilineal communities, decision-making is in the hands of male members. Opposition to include women in decision-making forums is stronger where men's claims were already confirmed. Hence in public decision-making gatherings, traditionally women's exclusion is near universal across South Asia (Agarwal, 2001). Legal systems need to be developed and adapted to assist women to obtain or protect their rights to resources. Where differences in class and caste exist then groups of men are also disadvantaged. Generally rights and positions are in the hands of the male members of the upper caste and class.

Property right problems, inherent to the management of a watershed, are that farmers in an upland region fail to invest in soil conservation measures. They do not consider downstream impacts of their investments and land use pattern. Controversies exist regarding the causes of soil erosion and water scarcity in watersheds. According to Swallow et al. (2001) soil erosion is due to footpaths and roads rather than due to agricultural practice upstream. This may be true in gently sloping areas but in hilly areas changes in the agricultural cropping pattern may cause excessive soil erosion of the topsoil leading to reduction in fertility of soil and exposing the rock surface. Deforestation may not cause seasonal water shortage as trees use more water than other types of vegetation. But, deforestation may result in decrease of groundwater recharge, which reduces base flow and may cause the drying up of rivers. Hence, regions depending on groundwater, may suffer severe scarcity of water in the dry season.

The watershed forms the smallest unit for the collective action of the community. But incongruence between the hydrological and administrative boundary forms a restriction in the interaction of people in a watershed, which in turn hinders the development activities. For effective management of development it would be better if administrative areas coincided with watershed boundaries. The practical challenge for this approach is to attain local social and political support across these political boundaries.

If the farmers do not have secure rights on their land, they will not have the incentive to care for that land and make long-term investments in its improvement (Tiffin and Gichuki, 2000). The landlords do not want the tenants to have strong land rights. In the Philippines, tenant farmers groups who had improved their local natural capital through sustainable agriculture found that this had simply encouraged landlords to take back the formerly degraded farm land without paying compensation for the improvements (Pretty and Ward, 2001). Millions of farmers who live in state forestland are at risk of eviction and hence they do not invest in the land. Conflicts between smallholder farmers and the state may lead to destructive land use practices such as using fire as a weapon.

There are several methods for the collective action of public agencies, resource users and those living upstream and downstream to work together and solve the problems of watershed management. One approach is to create property rights to the watershed services and a market for the exchange of units of those services (Swallow et al., 2001). Collective action for catchment management may be successful when it appeals to the self-motivation of farmers to improve their fields and the welfare of their families (Shaxson, 2000). Case studies from the Philippines and Kenya show that, the three primary motivations for individual farmers to adopt soil and water conservation practices are: reduced risk, increased possibility for cash crop production and avoidance of punishment (Tiffin and Gichuki, 2000). In the Philippines and Kenya, small groups of less than 40 members joined together for the management of catchments. They know each other as neighbours. The groups formed in upstream and downstream areas may negotiate with each other and be linked through an economic network, whereby negative impacts downstream can be compensated. If the watershed is very large and the community is not strong enough to organize itself, then an external agency may be required to organize smaller groups (Swallow et al., 2001). The involvement of Non-Government Organizations (NGOs) in watershed projects has shown successful impacts in watershed management (Kerr and Chung, 2001a; Shah and Raju, 2001). But Rhoades (1998) pointed out that the NGOs have their own agenda, which may not be consistent with farmers' needs. Most innovative NGOs are heavily dependent on the qualities and charisma of their founders (Sen, 1996). They assume themselves as gatekeeper to the community and this may shield the community from external organizations and entities and block the contact with the outside world.

2.5 Watershed management practices in India and other countries

In the 1980s and 1990s, watershed projects in India were very few in number. These aimed to develop semi-arid areas that the Green Revolution had bypassed (GoI, 1990; World Bank, 1990). By late 1990, however watershed development was considered the focal point for rural development and poverty alleviation. In the tenth Five-year plan all development activities envisaged to be based on watershed development (Gol, 2001). At present a wide variety of donor and development agencies are promoting watershed development, which includes central government, state government, non-government agencies, the World Bank, and several bilateral assistance programs.

Early watershed projects performed poorly due to the highly technocratic, top-down approach that did not involve local people and ignored local technical and managerial knowledge (Farrington et al., 1999, Hanumantha Rao, 2000). Watershed management was merely considered as a practice of soil and water conservation. Very few village level projects started in 1970s such as Ralegaon Siddhi, Sukhomajri and Pani Panchayat, focusing on the link between soil conservation and water harvesting turning barren land into green, productive oases (Kerr et al., 2002, GoK, 2002a). In Pani panchayat and Sukhomajri, the landless people shared the rights to additional surface water resources generated by the project in exchange for their cooperation in conserving soil in the upper watershed, where grazing and cutting trees were banned (Seckler, 1986). The success stories of these projects were marked as the basis of major watershed initiatives in India in the 1980s. But only technological approaches were adopted from those three success projects and the lessons related to institutional arrangements were neglected (Gol, 1990). They neither involved nor took effort to organize people to solve the problem collectively. Where village level participation was attempted they typically involved one or two key persons like village leaders. These projects failed due to their centralized structure, rigid technology and lack of attention to institutional arrangements. In the 1980s, NGOs became involved in watershed development, combining technical and institutional interventions, and organizing politically and economically weaker sections to initiate self-help activities (Kerr, 2002). In the 1990's several European bilateral agencies established major watershed initiatives. These projects aimed to promote collaboration between government and NGO projects to draw on the strengths of each and to make government agencies more sensitive to institutional issues (Farrington and Lobo, 1997; Ninan, 1998). But despite a common focus on poverty alleviation in projects sponsored by the European Union, and the German Development Bank (KFW), benefits tended to favor landowners, whereas the landless benefited only marginally (Ninan, 1998). In 1994, under the ministry of rural development, new guidelines were introduced after the Hanumantha Rao Commission on watershed projects, giving unprecedented autonomy to village-level organizations to choose their own watershed technology and obtain assistance from NGOs rather than government line departments (GoI, 1994a, b). These guidelines have given much importance to the need to establish local institutions for collective action; providing funds to the local government for activities connected with watershed management. But they did not define the procedures, which would ensure that the poorest people would not be harmed by this development. In many States, benefits were skewed towards wealthier households. An Indo-German project succeeded at least in one village to convince wealthier people to grant landless people the exclusive fishing rights in a runoff pond established (WOTR, 1999). Kerr et al. (2002) conducted a case study in 70 villages of Maharashtra covering all major watershed schemes. In all these watershed projects, the poorest and most vulnerable people were asked to provide a valuable environmental service to wealthier landowners. As per the calculations of the World Bank (1998), cited in: Beck and Nesmith (2001), in India, the total contribution of income from common property to the rural economy averages $5 billion/year at the rate of $210/year per household.

Section 2.5.1 to 2.5.5 illustrate lessons learned from other countries based on the relevant topics dealing with property rights, collective action, conservation measures, stakeholder participation and participatory research.

2.5.1 Lessons from common property resources

Beck and Nesmith (2001) clearly documented the importance of common property resources (CPR) to rural West Africans. The commons in West Africa includes bush lands, uncultivable lands, fallow lands, waterways, forests, seasonal ponds, low-lying wetlands etc., which are owned by the state, private, communal or open access lands. These areas were widely used by farmers, pastoralists and other rural dwellers. CPRs provide food sources in time of drought and cash from the sale of non-timber forest products and items made out of these. Leaves, fruits, fodder and firewood are the main income sources. Fodder and water for livestock is mainly taken from CPRs. The poorest households depend on bush products for 20% of their food requirements during the off-season compared to 2% and 8% of wealthy and middle-income households. Ayirebi women and children exploited a wide variety of wild products like roots, fibres, fruits, seeds, sap and syrup. Indigenous institutions were functioning at the local level to manage these resources. The 'Tongo' system and other regional institutions provide open and closed seasons for particular resources to ensure that they reach maturity before harvesting, especially in areas of Gambia, Guinea and Sierra Leone. Tongo restrictions evolve and dissolve, with respect to the value of a particular resource to the community at a particular time. Rural institutions such as the council of elders, highly respected individuals, or religious societies or an elderly woman determine the timing of Tongo. The monitoring and enforcement is done by the village youth, which ensures the transfer of community knowledge to the new generation. Tongo serves the purpose of reducing conflict between community members that could arise over theft. In terms of equity, once the ban is withdrawn, all community members could devour in its harvest irrespective of location. Rivers, creeks, lakes and fishing pools provide a livelihood source for people in coastal areas of Nigeria. Most ownership rights are communal, the rights of use accorded to each indigene member of the community. Here also community leaders are the conflict resolvers. Access rules equalize access for locals but exclude non-indigenes. The age and gender hierarchies of rural West Africa clearly place older men in powerful positions in common resource management with women and youth in peripheral roles, despite the primary role that women play in collection of products from common properties. Regarding land tenure, in Nigeria, there are four types of communal land tenure each with different rules of access, different land use decision-makers (family head or elders of family group) and different relationships through which rights of access are asserted. The four types are: extended family land, group family land, clan land and village land (Osemeobo, 1993). Powerful indigenous management systems have been in operation and are still operating in West Africa. State regulations with regard to forest are in conflict with customary land and tree tenure arrangements, which resulted in conflict among user groups and regulators (Beck and Nesmith, 2001).

From the literature on common property resources, irrespective of any country, it is evident that common property resources are vital resources for the poor. They are the only source of livelihood especially during the lean seasons. Women play an important role in collection of resource products and were usually excluded from management. At present due to privatization and modernization, poor people are progressively excluded from these resources and hence conflicts among users are quite distinct.

2.5.2 Lessons from property rights and collective action

In most of the Southeast Asian countries, watershed protection has prime importance in government policies dealing with management of upland areas. The International Center for Research in Agro Forestry (ICRAF, 1998) has conducted studies in three catchments of Southeast Asia: the Mae Chaem Catchment in northern Thailand, Sumber Jaya Catchment in Sumatra, Indonesia, and Manupali catchment in Mindanao, the Philippines. Mae Chaem is the upper-most tributary of the Chao Phraya River, the source of irrigation water for Thailand's main rice growing areas. There are many controversies involving ethnicity, road access and property rights. The Sumber Jaya Catchment is located in the center of the province of Lampung, on the island of Sumatra in Indonesia. It is an upland area surrounding the Bukit Rigis Mountain that forms the headwaters of the Tuland

Bawang River. Migrant farmers from abroad have occupied this area to grow coffee. The Manupali catchment in Bukidnon, Philippines is also an upland area surrounding Kitanglad Range National Park in the southern island of Mindanao. The people here are indigenous Talaandig people and Filippino settlers from other parts of Mindanao and the Visayan islands. Tenant farmers and landowners grow a variety of crops on the steep hill slopes.

Property rights are contested in all the three cases. 70% of the land area in Indonesia is classified as State Forest, and millions of people living here are considered as illegal settlers. Social conflict for land is high and people use fire as the weapon against logging concessions and plantation owners use fire for the eviction of local people. Though the state has declared this catchment as forestland in 1970s, there is continuous conflict between the state forest department and local people. In the Philippines, property rights are also insecure and uncertain. There are often conflicts between the forest departments, indigenous communities and the migrant settlers, and overlapping land claims in the upper watershed area. In the lower watershed area, absentee landlords have given out land, for farming in long-term tenant ship. But the landlords do not want the tenants to have strong land rights hence investments in land are very small. Similar is the case in Mae Chaem catchment also. The mountain ethnic group does not have any property rights. There is social conflict between the forest department and this ethnic group.

In all the three cases, there are strong links between property rights and collective action. Since the fall of the Suharto regime in 1998 in Indonesia, local people raised their voice against the existing property right regime and coercion of the forestry ministry. After the recent trend towards decentralization, the ministry has taken these concerns seriously and has shown some willingness to grant management rights to people, in exchange for local residents abiding by the agreed management plans. This has strengthened the cooperative solution to land use conflicts. In the Philippines, landcare groups were formed at the sub-village level to address local agricultural and environmental problems. Initially, groups are formed to share knowledge of conservation farming practices; these groups are now involved in agricultural sustainability issues and land degradation measures.

In East Africa, there is considerable variation of property rights. The Kenyan portion of Lake Victoria Basin includes protected state forests, large commercial tea estates, and smallholder farming areas (Swallow et al., 2001). Property rights to agricultural land are transparent and almost all agricultural land is under private ownership with registered title deeds. ICRAF has identified three main problems in this catchment area related to property rights. They are (1) over exploitation, poor management and under investment in the river bank areas, that are state property and open access, (2) hillside area, that are used for collective grazing and wood collection, but are held under individual title, (3) degraded hillsides and converted wetlands, that are leased to outsiders on short term contracts. In the Tanzanian portion of lake Victoria, the three main types of land use are extensive agriculture, livestock production and multiple use of wet lands. Customary property rights prevailed in most of the area, with individual rights in intensive farming lands. Pastoral property systems support mobility across large areas. Most conflicts over property rights occur in the wetland areas, where competing land use practices overlap. In Uganda, the majority of the agriculture land is held under customary tenure with patrilineal rules of inheritance, and only a small portion is under the mailo system (Place and Otsuka, 2000). Much of this land is rented for money to tenants and hence at present most of the mailo land is under long-term tenants.

There are different disputes and opportunities for collective action in Uganda, Tanzania and Kenya. The governments of Uganda and Tanzania have decentralized powers to local self-communities who can actively engage with local problems and bring together local policy makers, farmers and technical agencies to implement land management programs. In Kenya, since 1988, the Ministry of agriculture and rural development has applied a focal area approach to soil and water conservation with support from Sida. Each year, conservation officers identify one or two focal areas of small catchments having a population of 200-300 households and form focal area committees. With the help of these groups, conservation officers conduct participatory rural appraisal, identify land management problems and prioritize solutions of land and water conservation. A land management plan is prepared for each farm. Focal area committees and frontline extension staff closely work with the farmers. In 2001, the focal area approach was considered as the main extension approach by the Ministry of Agriculture and named as the National Agriculture and livestock and Extension programme (NALEP). Case studies in Kenya and Philippines show that the "small is beautiful" (Schumacher, 1973) hypothesis holds true in watershed management. Through small groups, upstream and downstream conflicts can be minimized and amicably negotiated.

2.5.3 Lessons from stakeholder participation

Dube and Swatuk (2002) through their case study in Zimbabwe show that equitable stakeholder participation remains more a theoretical dream than a practical reality. The Zimbabwe Water Act was introduced in 1998 with the idea of decentralization of institutions in the management of water resources. This act aims at achieving efficiency, accountability and sustainability through stakeholder participation. But, the case study in the Mazowe pilot project shows the highly political nature of the process. The case study reveals many differences between white and black commercial farmers and gender differences. Kujinga (2002), analyzing the stakeholder participation in the Odzi sub-catchment area, Save Catchment, Zimbabwe, reveals that, there is great need for improved awareness so that rural people understand what stakeholders are and what stakeholder participation is. Some stakeholders do not understand the need to participate in water management issues and do not feel the need to interact with other stakeholders. Also, there is great need for catchment councils to explore different means and strategies of generating income for themselves as donor money can be stopped anytime. Effective stakeholder participation is being hampered by lack of proper representation of stakeholders on catchment and sub-catchment councils, lack of stakeholder involvement in catchment planning, inadequate financial resource for catchment councils for use in water management and the government's unwillingness to stop land invasions by ruling party supporters.

2.5.4 Lessons from participatory research

Johnson et al. (2003) show that community participation in research projects will strengthen the capacity of participants to initiate a continuous process of innovation. Case studies in East and Central Java in Indonesia, Malawi and Zimbabwe in Southern Africa and Honduras in Central America show that user participation at all stages of research provided useful feedback to researchers and helped in improving potential impact of the project to its appropriateness and relevance. In Indonesia, project objective changed from pest management to crop management, in Southern Africa, farmers themselves developed new technology for testing. In Central America, the technological option for the contour bunds as well as the protocol for testing changed.

Ravnborg and Westermann (2002), through case studies in the Colombian Andes under an International Center for Tropical Agriculture (CIAT) project, reviewed the stakeholder identification processes, which facilitated joint learning using a combination of individual interviews, group meetings and joint problem analysis. Resource users were stimulated to recognize the biophysical and social interdependencies related to natural resource management problems and to analyze the problems and to negotiates for how to manage these interdependencies and thus to solve the associated problems. Failing to identify and ensure the participation of all stakeholders in the negotiation process might undermine efforts to improve watershed management. If one particular group such as an indigenous community or landless people would be excluded, it would try to restrain these activities leading to social conflict. An external agency or State government cannot determine farmer's resource management. Rather resource management has to be shaped by the interplay between such factors and relationships, individual farmer's own experience and perceptions. These aspects are to be considered while negotiating for the co-ordination and collective management of natural resources.

This was the result of the case study in Rio Cabuyal watershed in southwest Colombia where the watershed user association failed to incorporate all stakeholders. An indigenous group, the Paeces, was not represented in the watershed user group to protect some important watercourses. Therefore they used fire as weapon to destroy the buffer zone created by the user group. This incident became an important practical reason for developing stakeholder identification and negotiation (Ravnborg and Westermann, 2002). Researchers first organized public meetings and then interviewed individual farmers in order to identify different perceptions and interests that would help structure the subsequent public negotiation of problems and options to improve natural resource management. The process was carried out in six steps: (1) defining the area and its users; (2) introducing the notion of interdependencies; (3) identifying stakeholders; (4) bringing conflicts and interdependencies into the open; (5) negotiating options for improved NRM; and finally (6) implementing and adjusting action plans. This is illustrated with the case study in Guadualito micro watershed. Paeces, Mestizos and Calenos are the three groups living in this watershed. The Paeces, moved to lower reaches of mountain in 1975 where they work as day laborers or caretakers on large farms, Mestizos were born in this area and Calenos have come from other parts of Colombia during the 1980s and 1990s. Small-scale farming combined with day labouring on neighbouring farms are the dominant economic activities. In the first meeting where the notions of interdependencies between resources and among resource users were introduced, participants were positive towards initiating a process to facilitate coordinated NRM. During the individual interviews undertaken for the stakeholder identification, water supply and contamination emerged as one of the key transboundary NRM issues. All the Mestizos and Calenos have piped drinking water and more than half of the Paez families get drinking water from springs and streams. Paez claimed that this water is scarce and contaminated by sewage water and use of insecticides and fungicides in the upstream for which Calenos were to be blamed. On further interviewing Calenos living in the upper part, said that they do not know from where people living in downstream get drinking water and where springs are located. They accepted the existence of the problem but not that they were to blame. Researchers, rather than reinforcing the ethnic dimension of the water problem, presented their interpretation of the water problem as a geographical problem in the group meeting, how upstream land use affects downstream. To deepen the understanding of the water problem and to provide the basis for the development of an action plan, the entire community was divided into two mixed groups comprising people from upstream and downstream, so that each group would visit one half of the watershed, locate each spring, make observations of which activities are carried out that could influence the quantity and quality of the water, and to mark these on a map. On the basis of this inventory, concrete action plans were developed with three important elements: (1) to negotiate with people whose actions affect the quality and quantity of water; (2) to reforest and protect the areas immediately around the springs; and (3) to identify and implement a technical solution to divert run-off water, primarily from the road. These plans are under implementation.

In late 1998, participation of CIAT researchers in the activities became impossible due to the complex situation of the presence of guerrilla and paramilitary groups. Though their involvement came to a halt they have started up capacity building process to disseminate methods developed to improve decision-making in planning, design and implementation of natural resource management initiatives.

2.5.5 Lessons from conservation practices

Fagerström et al. (2003b) state that the integration of farmer's knowledge and perception with researcher's knowledge is important for planning resource–conserving technologies. This study aimed at developing a methodology to optimize land use and conservation measures within socioeconomic and technical abilities of the land users in the Loess plateau. The Loess plateau is a highland area in north central China. The loess soil is highly subject to erosion owing to sparse vegetation and improper land use, particularly using sloping land for the cultivation of food crops, to meet the need of the increasing population (Fagerström et al., 2003a). Farmer's criteria on land suitability, cropping system on slopes to meet food requirement of the villagers and soil workability were evaluated with people's participation. Farmers approved several biological and physical conservation measures, on the basis of which land use scenarios could be formulated. The factors influencing farmers in choosing different land uses were analyzed by comparing the current household economy in relation to production from the land, and predictions of changes in the household income due to differences in land use.

The Loess plateau is exposed to severe soil erosion at the rate of 3720 Mg km-2 year −1. In spite of this excessive soil erosion, the soil here is highly resilient and remains highly productive and hence sustainable land management is possible. But it has a negative impact downstream, which prompted the Chinese government to take measures. The government has made policies for the re-greening of the Loess plateau. But the main problem is that even though local people are acutely aware of alternative conservation land uses suitable for different land facets in the catchment, these are difficult to implement due to the poor living standards and lack of off-farm employment. Support from government in terms of food and seedlings are required as well as employment opportunities for the villagers. The main land use types in the village were cropland, orchard land, woodland, grass land, vegetables and fallow land.

A participatory approach was carried out in three steps. In the first step, researchers studied the existing conditions of the local people, their perspectives on local conditions, farming systems and livelihood strategies and land use, using semi- structured interview with randomly chosen villagers and key informants like township and village leaders, school teachers, village doctors and successful farmers. In the second step, local people analyzed their own problems and alternatives with researchers, with specific roles: local people as planners, village leaders as organizers and researchers as facilitators. In the third step, two-way feedback between farmer–researcher focused on land use scenarios and the possible effects on erosion control and household economy. The output of the whole participatory conservation planning, were finally presented to the local farmers in order to get their feedback at village meetings. At the village meetings, posters with simple visualization were used to facilitate researcher-to-village feedback.

Farmers revealed their preferences for different soil and water conservation measures in the following order: building dams, terraces, planting trees, making field flat and planting grass. In 1950s and 1960s, terraces were constructed, but at present they a poorly maintained. Though terraces provide more resistance to soil erosion, its construction is expensive and hence government support is required. Grass/fallow strips and cropping strips arranged alternately along the contour on sloping land provided preventive measures as – strips acts as a barrier against surface runoff and protect crops and soil from erosion. They can also filter sediment that comes from the slopes above. Grasses can provide green manure for cropland and also fodder to live stock. Crop residues will be left on soil surface, which helps in improving soil properties, and crop yields.

Tenberg et al. (1998) conducted case studies in Kenya with respect to the dynamic aspects of indigenous soil and water conservation (ISWC). Methods used for the studies include participatory survey and evaluations, on-farm monitoring, soil and rainfall analyses and questionnaire surveys. Sources of variability affecting cropping system and land management practices included rainfall, soil fertility, and farmer resource level and farm productivity. Resource poor farmers tended to choose cheaper and less labour demanding techniques, and constructed smaller ISWC structures than better-endowed farmers. The largest diversity of ISWC practices was found on newly opened land with mixed soils. Also on-farm productivity levels indicated that costly investments in soil and water conservation are unfeasible, as this would further increase the risk for negative returns to farming. The implications of the study analysis is that soil and water conservation interventions in marginal areas should build on the existing agro diversity and should take into account the complex interactions between environmental and socio-economic factors that give rise to differences in farming system and land management practices.

2.6 Conclusion

In order to gain a thorough knowledge on the various aspects of watershed management, literature dealing with watershed management from India and other countries has been reviewed. The root cause for the poor performance of centrally planned projects is that they do not consider the need, priority and constraints of the local community. Due to the shape, size, hydrology, socio-cultural and class-gender differences among the community, each watershed has its own unique set of characteristics. The rules, norms and measures formulated for soil and water conservation by external agencies in centrally planned programmes may be suitable for a particular watershed but it may lead to unsustainability in other watersheds.

Lessons from different countries show that people's participation is essential for successful and sustainable watershed management. Therefore watershed development practices should be participatory. This is the lesson learned from the available literature and case studies conducted by various researchers, scholars and anthropologists, economists and research institutions. Also formal and informal rules; gender, property rights and collective action along with appropriate technology and institutional factors are of importance in the context of sustainable watershed management. As a watershed is used by multiple users in the upper and lower catchments, environmental services are to be given due importance from the planning stage.

Chapter 3 Conceptual framework for sustainable watershed management[1]

The second research question is answered in this chapter. A conceptual framework is developed based on the lessons learned from Chapter 2 that helps to understand the different aspects and elements of sustainable watershed management and their interactions.

3.1 Introduction

Sustainable development was defined in the Brundtland report 'Our Common Future' WCED, (1987) as "development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs" Subsequently many authors have used the term sustainable development for specific development activities like sustainable agriculture, sustainable forestry, sustainable energy development, etc. A single development may be considered successful if it is weighed against its specific performance criteria. But, to achieve sustainability, all different aspects of development should be considered simultaneously. For this an integrated approach is essential. Through this framework an attempt is made to integrate different aspects of sustainability in the context of watershed management.

The United Nations Environment Programme (UNEP) observed that "the intensified and unsustainable demand for land, water, marine and coastal resources resulting from the expansion of agriculture and uncontrolled urbanization leads to increased degradation of natural ecosystems and erodes the life supporting systems that uphold human civilization. Caring for natural resources and promoting their sustainable use is an essential response of the world community to ensure its own survival and well-being" (UNEP, 1996). Euston and Gibson (1995), "interpret sustainability broadly to mean a condition in which natural systems and social systems survive and thrive together indefinitely. Sustainability represents a distinctly contemporary imperative, stemming from persistent, unfulfilled claims of solidarity and justice, a deepening understanding of the interrelatedness of life, and the stark realities of the destruction of nature. Today it becomes a basic human responsibility to ensure that both natural and human systems are sustained in a condition of health-for the sake of earth and people"

Many research organizations and individuals have defined sustainability with regard to development in agriculture, forestry, land management etc. The Consultative Group on International Agricultural Research (TAC/CGIAR, 1988, cited in: Prinz, 1998) states that sustainable agriculture is the successful management of resources of agriculture to satisfy changing human needs while maintaining or enhancing the quality

[1] Based on Vishnudas et al. (2005a, 2006b)

of the environment, conserving natural resources. According to Bruenig (1996), "sustainable management of forests should aim at forest structures which keep the rainforest ecosystems as robust, elastic, versatile, adaptable, resistant, resilient and tolerant as possible; canopy openings should be kept within the limits of natural gap formation; stand and soil damage must be minimized; felling cycles must be sufficiently long and tree marking so designed that a selection forest canopy structure and a self regulating stand table are maintained without, or with very little, silvicultural manipulation; production of timber should aim for high quality and versatility. The basic principle is to mimic nature as closely as possible to make profitable use of the natural ecosystem dynamics and adaptability, and reduce costs and risks" Hurni et al. (1996), cited in: Hurni (2000) defines sustainable land management as a system of technologies and or planning that aims to integrate ecological with socio-economic and political principles in the management of land for agricultural and other purposes to achieve intra and intergenerational equity.

For a watershed to be used sustainably, the sustainability of land, agriculture and forest should be considered together. Therefore we define sustainable watershed management as the management of a watershed system with sustainable technological options, which may ensure the sustainability of land, agriculture and forestry or its combinations to conserve natural resources, with adequate institutional and economic options.

3.2 Chain of sustainability

For a watershed to be used sustainably, four main elements need to be considered: natural resources, technology, institutions and economics. A suitable metaphor for these four elements is a chain of shackles, the chain being as strong as the weakest shackle (See Figure 3.1). The functions of each element in the chain are defined as follows:

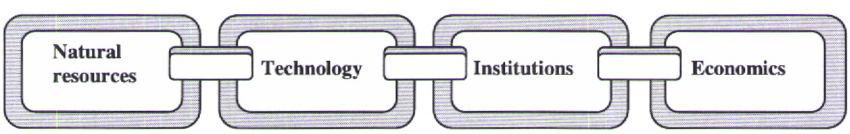

Figure 3.1. Chain of sustainability in watershed management

For successful and sustainable watershed management, natural resources should be protected from degradation and maintained for good production. To utilize natural resources, technologies are required. These should be well adapted to local circumstances, and supported by an appropriate institutional setting. People should be able to maintain these themselves and the technologies should be cost effective. The rules defining access and exclusion to natural resources and the services they provide should be transparent. The institutions governing the use of natural resources should be based in the watershed community. It should involve the relevant stakeholders, particularly the community, from problem identification to all levels of planning. And finally technologies should be affordable. It should be conducive to increase income as well as to enhance land conservation. If a project does not yield tangible benefits to the people it is not going to become sustainable.

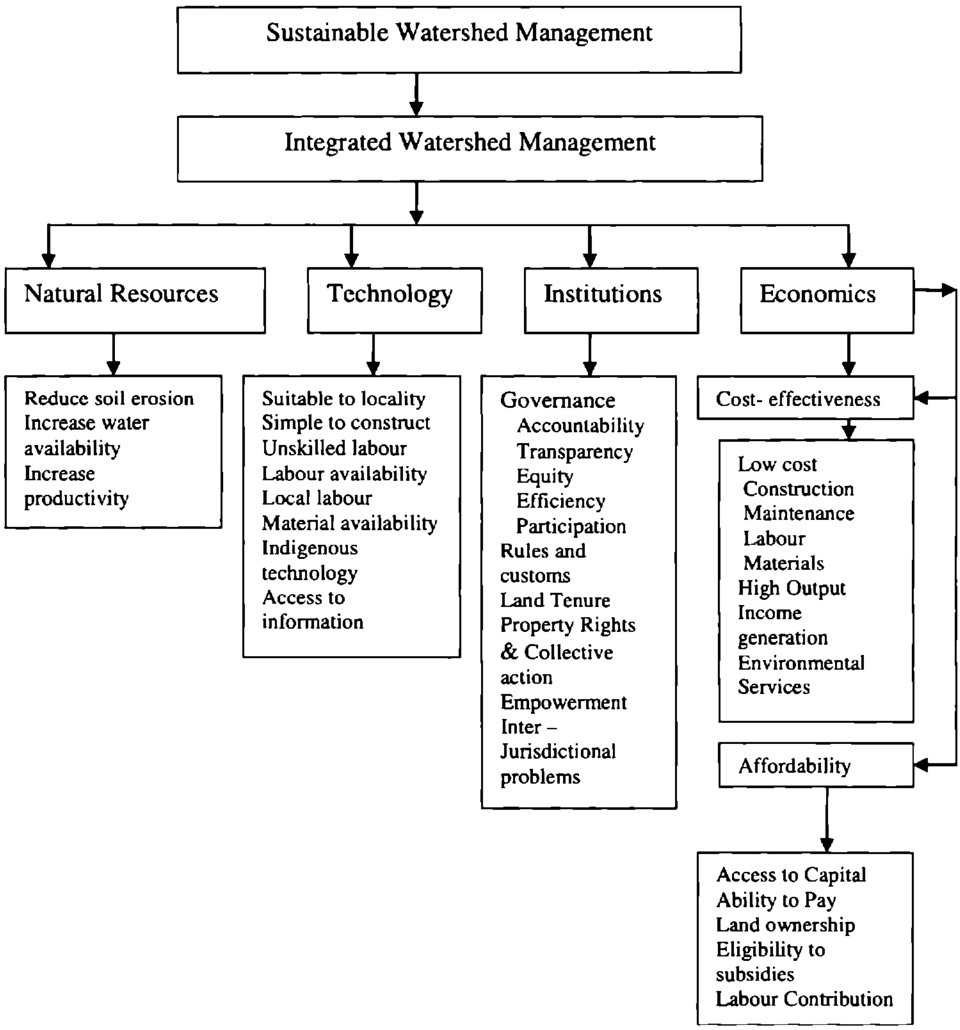

Figure 3.2. Conceptual framework for sustainable watershed management

These four elements of the chain are studied in detail and the factors indicating the sustainability of each element are determined. The conceptual framework outlined here can be applied to watershed evaluation not only in Kerala but also elsewhere in the world with similar situations and will be explored and explained in the next sections (see Figure 3.2).

3.3 Sustainability of natural resources

Degradation of land threatens agricultural productivity and water availability in many developing countries. About 16% of agricultural land in developing countries and a higher proportion of crop and dry lands have degraded moderately or severely mainly through soil erosion, nutrient depletion and salinisation (Scherr, 2000). This degradation can be reversed through appropriate land and water management, which enhances infiltration, stabilizes slopes and increases soil moisture. Fuel, crops and fodder depend upon the availability of soil moisture. Drinking water availability depends upon how much water infiltrates to join groundwater storage, to raise the water table and increase base flow. All these constraints directly depend upon the precipitation, runoff and the conservation measures adopted to prevent soil erosion in the catchment.

Conventional soil and water conservation projects have often failed due to their over emphasis on building structures. The farmers often do not understand the purpose of the terraces and bunds; they may even expect incentives to maintain these structures. Beyond the project these structures may be left unattended and deteriorate. In order to attain sustainability, there should be change in the attitude towards watershed management from a purely technical approach of conservation to a participatory approach by involving people in all phases of project planning and implementation. By considering the traditional practices and experiences of the farmers, experts and scientists could co-develop appropriate technology jointly with the people. Instead of providing engineering structures, semi-permeable vegetative barriers using local materials and local labour can be used. These barriers will filter out sediments, reduce the velocity of runoff and also retain runoff water. This will be less costly compared with constructing engineering structures. Locally available organic manure to substitute expensive chemical fertilizers will reduce water contamination. Soil conservation measures that produce the most rapid return on investment are the most favoured. These include bunds that require relatively small initial investment, provide fodder or fuel, and conserve soil moisture (Kerr and Sanghi, 1992).

Again the farmer's level of access to resources plays a critical role in the acceptability or appropriateness of the various technologies (Johns, 2002). If land is a limiting factor to production then practices that reduce the land area are unlikely to be embraced. If labour is limited, then the gender division of labour and the timing of the various activities become critical to the adoption of technologies; and if capital is limiting then any conservation measure requiring specialized equipment is unlikely to be acceptable (Stocking, 1993, cited in: Johns, 2002).

Another important criterion is that different people use the upstream and downstream catchment for multiple purposes. Protection against soil erosion requires revegetation in the upstream and restricted entry for grazing and firewood collection in hilly areas. This will affect the livelihood of the upstream community especially the poor, the landless and women who relies on commons for survival. Croplands on sloping upper watershed areas may also be treated with soil conservation measures. But, the benefits may disproportionately reach the wealthiest landlords in the downstream catchment who own most of the irrigable land.

Factors indicating sustainability of natural resources

The main factors indicating sustainability of natural resources are explained below (refer to Figure 3.2).

Soil erosion: Soil erosion happens when particles of soil come loose and are carried away by water or wind. The erosion problem is very severe on certain types of soils, on steep slopes, where there is intense rainfall and where the vegetation is removed. Soil conservation means reducing soil erosion and maintaining soil fertility. It relies on increasing the amount of water seeping into the soil, reducing the velocity and amount of runoff, and keeping enough vegetation to protect the soil surface to bind the soil together (IIRR, 2000).

Water availability: Soil conservation is closely related to water conservation. Water conservation relies on trapping runoff water, allowing it to infiltrate into the soil in order to raise the water table and increase the soil moisture level. This can be achieved through conservation efforts like providing pits or dams, ensuring protective cover of vegetation on the soil surface or by providing contour ditches or bunds (IIRR, 2000).

Biomass productivity: Management practices should be such that it should increase production: annual and perennial crops, pastures, trees etc. and in doing so will enhance biomass production while conserving soil and water. In the past little emphasis was given to this approach as a means to achieve conservation. In reality, improvements in a farmer's crop, livestock and land husbandry practices will be more effective in conserving soil and water than the implementation of physical conservation works alone (Shaxson, 1988, cited in: Douglas, 1998).

3.4 Technological sustainability

To achieve sustainable development, sustainable technologies need to be developed, transferred and adopted (Guerin, 2001). Land degradation is a central challenge to sustainable development. At the global scale, key problems threatening natural resources and the sustainability of life support systems are: soil degradation, the availability of water and the loss of biodiversity (WBGU, 1996, cited in: Hurni, 2000). Natural resources can potentially be used in a sustainable way through appropriate technology. Following the sustainability paradigm, 'appropriate' would require that a technology should be ecologically protective, socially acceptable, economically productive, economically viable and reduce risk (Hurni, 1997). Management of watersheds can be made possible by using a variety of technologies such as vegetation conservation like grass contours, alternative tillage techniques and physical structures like terraces, stone bunds etc. The World Bank has given more importance to vegetative measures in watershed management. This supports the global trend that favours choosing technologies that are low cost and more farmer friendly. Successful adaptation of this technology in the World Bank projects was achieved by involving farmers in the choice of technologies, a strategy that helps to implement technologies that are more compatible with existing land uses and surrounding environments and that meet farmers needs (World Bank, 2001).

Watershed management mainly involves management of soil and water, agriculture and forestry. But technical remedies for the management of these resources will only succeed if they can function within and address local socio-economic constraints (FAO, 1999). Farmers rarely adopt recommended technologies by the experts. Technologies intended to improve the productivity and sustainability of small scale farming systems should ideally be simple, low cost, productive, maintainable, low risk to climatic variations, flexible, conservation effective such as reducing runoff while improving soil moisture (FAO, 1999). Also, technologies, which are simpler, more accessible and are relatively more labour intensive rather than capital intensive, generate more employment and trigger more intense local involvement (Paranjape and Joy, 1998). Literature shows that farmers and the village community have developed their own technologies based on local knowledge and materials, which are cost effective, simple and easy to construct and maintain. Scientists have investigated the scientific basis of local technical innovations. This has led researchers to either validate the farmer's practices or improve upon their technical content without losing their comparative advantage of cost effectiveness. Numerous projects in the tropics and subtropics have failed because the technology used turned out to be unsuitable for the specific conditions of the site where they were applied. This unsuitability can be in regard to the natural conditions, to a too high level of technology, or to a too high input and management level and may be incompatible with the local life-style (Prinz, 1998).

Factors for technological sustainability

In order to assess the sustainability of a technology, the following factors are considered to be important (refer to Figure 3.2).

Suitable to locality: Each watershed has its own unique physical characteristics. The choice of technology should be based on local parameters such as soil type, topography, climate, etc. (FAO, 1999).
Simple to construct: The technology should not be too complicated. As the maintenance of the structure has to be done by the local community themselves and as the technology has to be adopted by the farmers after the departure of a project team, its design and construction should be simple to understand and maintain by the farmers (FAO, 1999).
Unskilled labour: Technologies should be easy to construct in terms of time and money. If skilled labour is required, the cost of construction will be high and if the design is complicated then skilled labour will have to be involved (Paranjape and Joy, 1998)
Local labour: Empowering local labour by providing training for the new technology will decrease migration. The more demand for local labour, the more job opportunities and this will improve the livelihood in the watershed (Paranjape and Joy, 1998).
Labour availability: Investments in natural resources for construction of contour bunds or terraces or embankment protections can be particularly labour demanding and may be too expensive to undertake in communities with limited access to labour. For any technology to be adopted, it should be such that it can be carried out during the off-season. Then it does not compete directly with labour for agriculture, and hence the opportunity cost for labour may be lower (McCulloch et al., 1998).
Material availability: Soil conservation is least expensive if the resources required are available in abundance. Conservation programmes should take advantage of local materials for construction (Kerr and Sanghi, 1992). Government programmes in India show that some projects insisted on earthen bund construction even though soil was scarce, simply because they proved optimal under research station conditions. If the material is to be brought from outside, then the transportation cost will be high, which the poor may not be able to afford. Therefore choice of material should take into consideration the proximity at which the material is available while designing the technology.
Indigenous technology: Technological options should take into consideration farmer's indigenous practices. It will be the local farmers who understand the nature of the land, and the real problems they are facing. Earlier top-down, highly technocratic approaches to watershed management paid little attention to local technical and managerial knowledge, which is the root cause of failure of such projects (Kerr, 2002). Reij et al. (1996) cited in: Boyd et al. (2000), reports that local approaches to natural resource management are well suited to complex and dynamic environments.
Access to information: Farmers must know about the availability of new technologies and this knowledge must extend to knowledge about the returns from adoption, which in a risky world requires judgments about alternative possible outcomes of yields and profits. Full information about profitability and risk is rarely available for new technologies,

simply because they are new (McCulloch et al., 1998). Therefore programmes should be planned and implemented in full participation with farmers in order to identify in advance what the farmers will accept and what they will not. Arrangements should be made with farmers to carry out the work on their own land to ensure that they are satisfied with it and to save money (Kerr and Sanghi, 1992).

3.5 Institutional sustainability

The watershed has been recognized as a unit for integrated resource management, where management is not merely limited to land, water and biomass, but also concerned with integration for self-reliance and holistic development of the rural poor. In an operational context, this would mean integrating: different uses and management of resources, different departments with sectoral interest through an inter-disciplinary approach, and towards alleviation of poverty (Mollinga, 2000). All collective efforts are mediated through institutions, and without institutional change we will not move purposefully towards sustainability (Dovers, 2001).

An 'institution' is an underlying, durable pattern of rules and behaviour and 'organizations' is a more changeable manifestation of that (Dovers, 2001). North (1990) defines institutions as 'the rule of the game in society' and organizations may be thought of as 'the players or groups of individuals bound together by some common purpose to achieve objectives' Dovers (2001), drawing partly on Henningham, defines institution as 'a persistent, reasonably predictable arrangement, law, process, custom or organization structuring aspects of the political, social, cultural or economic transactions and relationships in a society. Institutions allow organized and collective efforts towards common concerns and the achievement of social goals. Although by definition persistent, institutions constantly evolve' Thus the failure of any development to attain sustainability may also be due to the inappropriate institutional arrangements. Hence in order to analyze institutional failure or success in a project it is necessary to understand the existing pattern of institutions adopted by that project.

The role of strong institutions at grass root level is crucial for successful watershed management. In the context of watershed management, two kinds of institutions need to link and interact frequently with each other: one involving the internal stakeholders and the other involving the external stakeholders (Farrington et al., 1999). The first is at the community level in the form of self-help groups, user groups or watershed community. These groups are to be empowered and need to be federated at the watershed level for providing a forum for collective action. The second set of institutions encompasses the external agencies such as government, non-government organizations, local administration and researchers. These institutions need to work together for synergy and give top priority to capacity building and financial sustainability of grass root level institutions.

Actors

Each institution involved in the watershed management is closely examined independently to resolve their role in watershed management. The main actors and the important factors are analyzed and discussed below.

For the management to be effective, ***government*** has to take decisions in terms of setting up the foundation in which various local organizations and stakeholders can negotiate solutions to local development and resource management issues. Government is the supreme authority to issue guidelines on the use, management and conservation of natural resources; implementation of the rules formulated and resolution of disputes that arise during the interpretation and application of rules. Government can facilitate development activities through capacity building, and provision of technical and financial support. People may be aware of the alternative conservation measures, but due to poor living standards and lack of off-farm employment, efforts to improve sustainable practices seem to be difficult without support from government (Fagerström et al., 2003b). Though there is a shift from the centralized and state driven management regimes towards decentralized and community based management strategies in the watershed management, the process presents a number of challenges to the institutions. These challenges include proper representation of stakeholders, lack of adequate financial resources, lack of planning and political interferences. Decentralizing water management may shift problem areas from central to local level without providing the necessary financial and material resources (Kujinga, 2002).

Government encompasses various departments both at central and state level. Integrated watershed management presupposes integration of relevant departments such as agriculture, forestry, fisheries and animal husbandry. Hence government should be capable to provide adequate guidelines, financial and institutional support to affected people to undertake responsibilities of complex, conflict-ridden problems in resource conservation practices.

Institutional sustainability may not be achieved without the involvement of ***politicians.*** The practices of local government and also of the government officers in the local bodies are influenced by politics. Considering the political context of most but not all the developing countries, elected representatives govern the local government; they often win elections through threat and money. Political representation may be characterized by class, gender and caste. Generally the richer members from the upper caste of a community dominate local politics and local organizations, which results in benefits going to certain sectors of the community. Hence the poor and weaker sections may often be left unattended. Their marginal representation may or may not be considered in watershed projects. Also administrative boundaries and hydrological watershed boundaries often do not coincide. A watershed may consist of two or more administrative boundaries, and planning for watershed management has to be carried out based on the hydrological boundaries. The practical challenges of mobilizing local social and political support across political boundaries pose a major limitation for watershed planning. Decision-making and allocation of funds for the various project activities depends on the political influence of the ruling party and their influence in the local bodies. Therefore political leaders are to be involved in these projects so that they should support (or do not hinder) new alliances and linkages. Also boundaries are central to the watershed management as they specify the area over which jurisdictions shall apply as well as the roles of stakeholders. Hence Schumacher's (1973) hypothesis can be applied to place jurisdiction at local or community level. As the community is small, the activities will be more transparent to their constituencies and thus it becomes politically more acceptable. Also as the focal areas are small, they fall within a single local government area where members know each other as neighbours (Tiffin and Gichuki, 2000, cited in: Lal, 2000).

According to the World Bank, FAO and many governments, environmental deterioration can be reversed with people's participation either directly or through the involvement of people in participation with the state governments, transforming the common experience of conflict into co-operation. In the former top-down approach of planning, the ***community*** was considered as a hindrance to development programmes rather than a key player. Recent thinking has revived the role of the community in bringing about decentralization, conservation and participation. Participation implies that stakeholders work together to set criteria for sustainable management, identify priority constraints, evaluate possible alternative technologies, formulate policies and monitor and evaluate impacts. All stakeholders must get an opportunity to participate, otherwise more powerful stakeholders are likely to control watershed resources and undertake use practices without regards for their impact on less powerful individuals. Thus the community has to play a dominant role in order to attain sustainability. We have seen from the literature in Chapter 2 that the local communities are closer to the real problems and therefore are aware of factors that experts often do not consider and their objectives are more realistic for economic development. Hence people's participation is essential for the planning of sustainable watershed management.

The literature on the role of ***non-governmental organizations*** (NGOs) in watershed management provides conflicting ideas upon their involvement. Though NGOs have demonstrated the ability to strengthen people's requirement and to provide a supportive role for creating local level organizations, many of them tend to work more as independent implementers than as catalysts for bridging the gap between local people and the state. The challenge of reaching a large number of poor people in resource poor regions has forced governments to involve NGOs, who are better suited for the task of mobilizing people's participation (Farrington et al., 1999). The involvement of NGOs in watershed projects depends on the capacity of the people to organize themselves for collective action.

Researchers are important actors, who can impart knowledge and information, provide assistance in decision-making, may help to prioritize fund allocations in project management and developing innovative technologies for appropriate land and water management. Also integration of user's knowledge and perception with researcher's knowledge is important for identifying resource–conserving technologies. In many places in the world, user participation has been shown successful in the planning of sustainable land management. User participation at all stages of the research provides useful feedback to researchers. It may improve the relevance and appropriateness of the technologies and contributes to actual and potential impact of research (Johnson et al., 2003). Empowering participation (decisions made jointly between researchers and users) should strengthen human capital of participants. Providing training to the people and interaction between people and researchers will strengthen experimentation, problem solving skills and ability to initiate and sustain innovation. Involving people in research often increases project costs in the short run, but it is likely to be cost effective in the long run as the introduced technologies and policies are more appropriate.

Factors for institutional sustainability

In order to build up strong institutions for watershed management, it requires effective involvement of all people. The following indicators represent the important factors for institutional sustainability in the grass root organizations (refer to Figure 3. 2).

Accountability: Accountability is the central component of good governance. Accountability is a highly abstract concept, sometimes interpreted in formalistic and legalistic terms, and sometimes used in a more concrete way to refer to the social, economic and political mechanisms through which some agents become responsive to other agents (Moore, 1995, cited in: Bauman, 1998). Therefore all organizations involved in watershed developments should be accountable to the people and also accountable to the government, who can stop funds and disband committees if procedures are not followed as specified. Accountability and authority should be linked and who is accountable to whom should be well defined.

Transparency: All financial transactions should be transparent. This will ensure that funds are utilized effectively and loans and subsidies reach the intended beneficiaries. Also it will help in eliminating corruption especially among politicians, government officials, NGOs and other external and internal agents involved in the project. It also means that all the decisions are taken as per rules and all information are freely available and accessible to the people who are affected by these decisions. Hence information should be understandable to the community (UNESCAP, 2002).

Equity: Equity is linked to fairness. In watershed management, the entire watershed is considered as a hydrological unit. Each individual in the watershed irrespective of rich and poor, class and gender is expected to know how the system works, since environmental service as well as the mutual linkages and dependencies that exist from people living in upstream to downstream. Therefore 'equity' should be considered as a well-defined working rule (Seckler, 1986). Development interventions should confront inequalities between different social and ethnic groups to reduce the chance of inter-group conflict. Failure to take into consideration different gender perspectives can lead to further marginalization of women and does not contribute to sustainable rural development (FAO, 1999).

Efficiency: Efficiency in governance is directly linked to the effectiveness of resource management. The process and institutions will have to consider the needs and interests of society, which help in producing good results with the best use of resources (UNESCAP, 2002).

Participation: Participation of all who are involved in watershed development is the key element of good governance. This can be achieved through the involvement of external or internal stakeholders either directly or officially or through representatives. The stakeholders include all those who affect or are affected by the policies, decisions and actions of the system. They can be individuals, communities, social groups or institutions of any size, aggregation or level in society. The term thus includes policy makers, planners, and administrators in the government and other organizations, as well as commercial and subsistence user groups (Grimble et al., 1995). Participation of people should be ensured in all level of planning from the problem identification to the implementation level. It should be well organized and informed. If the people are socially and economically vulnerable, their needs and priorities should be emphasized and their involvement in decision-making is not a must (UNESCAP, 2002).

Rules and customs: Social relevance and effectiveness of a project depends on how the rules are enforced. Rules are to be enforced impartially. And this shall be achieved through independent judiciary and uncorrupted officials. Informal rules may be endogenously enforced within the community; they are upheld by mutual agreement among the social actors involved or by relations of power and authority between them (Leach et al., 1999). Informal rules are important particularly in the case of common property resource management.

Land tenure, property rights and collective action: Security of tenure is widely recognized as an important prerequisite to sustainable land management (Jones, 2002). Secure tenure in land will encourage people to invest in land, which leads to increase productivity, and increase in efficiency. This may be facilitated through negotiation of tenancy or rent contracts with emphasis on land management to provide enough long-term security to encourage soil and water conservation. Property rights in watershed management play an important role in governing resource management and may impact on the welfare of the people who depends on these resources. Since people living upstream fail to invest in land and do not consider the downstream impacts, for sustainable solutions to emerge, people should be sufficiently motivated to use resource-conserving practices in their own farms. This in turn needs investments in participatory processes that bring people together to deliberate on common problems, and form new groups or associations capable of developing practices of common benefits (Pretty and Ward, 2001).

Empowerment: Empowerment of women's group may increase the efficiency in resource management. Working collectively, women are often better able to gain rights where they can benefit most. When an additional income is gained through women, they are likely to spend income on household food and inputs into child health and nutrition (Meinzen-Dick et al., 1997).

Boundary of watershed: In the context of watershed management, the administrative boundary and the hydrological boundary of the watershed often do not coincide. Watershed projects when decentralized are attributed to the lower administrative jurisdiction without considering geographical or hydrological parameters of the watershed. This is not conducive to integrated watershed management. In addition, people living beyond the watershed boundary in the same administrative jurisdiction when exempted from project benefits may raise socio-political problems (Dovers, 2001).

3.6 Economical sustainability

Any new technique or any new measure proposed for soil and water conservation has to be economically viable; otherwise people will not accept it. Even if a new measure fulfils the requirements of all other facets of sustainability, but is not economically viable, it is doomed to fail (Prinz, 1998). If people do not have the confidence that they will benefit from investments in technologies, they are less likely to adopt the technologies (McCulloch et al., 1998). Any land management initiative should aim at enabling watershed settlers to adopt practices conducive to increase income as well as to enhance land conservation. Even though people adopt traditional conservation methods, they do accept innovative technologies that improve productivity (Paudel and Thapa, 2004). Even if the technology is economically viable, the economic return from the conservation measures should cover all the farmers input to be sufficiently attractive to be maintained by the farmer. Therefore it is desirable to measure economic viability not only in terms of crop yield but also in terms of function, such as resource conservation and risk minimization (Prinz, 1998).

While designing different structures for soil and water conservation, we need to know the conditions under which households choose to invest in building or maintaining soil and water conservation practices. This can be analyzed through the livelihood strategies adopted by the poor, together with policies and structure, which influence these strategies (Boyd et al., 2000). Literature shows that there is a relationship between household's access to assets and soil and water conservation. According to Anderson and Thampapillai (1990), the level of income, labour availability, access to low cost credit, and secure land tenure are some of the factors influencing the household's attitude towards conservation. The adoption of soil and water conservation represents a decision by households to intensify their agricultural production – to improve output per unit area through capital investment or an increase in labour inputs. It is essential to recognize that soil and water conservation measures impose opportunity costs through their demands on labour, often at times of peak demand (Hailu and Runge - Metzger, 1993, cited in: Boyd et al., 2000). It is often assumed that investing in soil and water conservation is automatically beneficial without looking in detail at the costs and benefits, and particularly the on-farm versus off-farm costs of soil degradation. Investments in soil and water conservation tend to generate returns in the long term, but do not necessarily result in higher yields or income in the short term (Boyd et al., 2000).

Generally poor people do not have enough income to support and sustain their daily needs. People usually perform soil and water conservation work themselves rather than hire labourers. They will hire labour only if the returns are higher than the wages and if they have cash available to pay the wages. People with off-farm income and those who have jobs outside the watershed may not take sufficient care of their land and may not find it profitable to hire others to do the work for them (Kerr and Sanghi, 1992). This will adversely affect the overall development programme towards attaining sustainability. Provision for subsidies should be available for undertaking soil and water conservation works. Subsidies that are offered should be based on a detailed assessment of the local cost of labour and remittances as a result of work undertaken. They are justified by the public benefit of well-maintained watersheds and reduced erosion. If subsidies are used they should be paid directly to the households on completion and verification of agreed work (Smith, 1998).

Development organizations should view income generation and farmer participation as powerful tools for the management of watersheds. Most farmers need cash income for their households. They often purchase staple foods to complement their own production, work as day labourers or migrate to meet their cash needs. Many farmers meet the goal of food security only through additional income generation. Therefore organizations managing watersheds should select practices that are low-cost, productivity-enhancing, value-adding to the farm income, risk-reducing in the short term and which require little labour or management investments in order to ensure their widespread adoption among neighbouring farmers. The local component of the capital costs, like cost of local materials and local labour, are in effect incomes to the local people, since money goes back to the people as wages and as price for the local materials bought from them. Hence economic sustainability determines the efficiency of the management system and it relates to the cost effectiveness and affordability of the various activities in the project (refer to Figure 3.2).

Factors for economical sustainability

The following factors determine the economic sustainability of watershed projects.

Cost Effectiveness: Farmers are incapable of adopting soil conservation technologies that require large capital investments. Construction costs and maintenance, materials and labour should be optimum for the adoption of an innovative technology. The technological choice is highly depended on the overall cost of construction. Mostly soil conservation measures require large initial investments and maintenance works. Small farmers hesitate to adopt new technologies partly due to their suspicion about the benefits of technologies and partly due to other socio-economic constraints (Paudel and Thapa, 2004). Therefore the technology options should be such that net return should be higher than the investment in conservation measures. Using local labour and local materials, job opportunities are created in the watershed. Also increased output from crops and fodder are likely to increase their livelihood. Cost effectiveness may be achieved if the conservation measures are based on understanding of farmer's perception about soil erosion and the condition under which they adopt and maintain conservation measures (Kerr and Sanghi, 1992).

Early efforts to improve land and water management in upland areas provided inadequate incentives and resulted in low adoption and poor maintenance so that improved practices disappeared when the project ended. Land tenure problems, inappropriate technology and inadequate participation explain some of these problems, but the real problem is that there are insufficient incentives for the upstream people to permanently change their land use pattern. As mentioned in Chapter 2, the success of a project is highly depending on the valuable environmental services from people living upstream or downstream. Hence environmental service should be considered as an important tool for the sustainability of the watershed. Since there is no market for environmental services, land users do not receive compensation for such services or consider them when making a land–use decision (World Bank, 2001). The upstream people should be paid by downstream people for the protection of the watershed either through negotiation or through economic linkages (Swallow et al., 2001).

Affordability: Affordability is defined by access to capital and ability to pay. Ability to pay depends, among others, upon ownership of land and eligibility to subsidies. Watershed development is considered a focal point for rural development in many developing countries with the aim of increasing agricultural production and reducing poverty on hill slopes in rural areas (Perez and Tschinkel, 2003). A wide variety of donors and development agencies promote watershed development, including the central government, several state governments and the World Bank and several bilateral assistance programs. Subsidies are given for conservation measures to adopt conservation technologies with respect to the land holding size, ownership of land and repayment capacity of the users. But a large percentage of users in the upstream area are landless and depend on the uncultivated lands to support themselves. Net benefits are skewed towards the wealthiest landowners downstream, while the poorest people have to bear the cost of conservation. Although bilateral agencies establish major watershed initiatives through government and non-governmental organizations, these organizations may prioritize watersheds with fewer landless people, the subsidies may get diverted from the intended beneficiaries. If a watershed approach is adopted in a project where the administrative boundaries do not coincide with the watershed boundary, those living upstream are likely to get greatest amount of subsidies. Then people living within the administrative boundary but outside the watershed boundary may raise opposition. If fixed land improvement grants were provided irrespective of land holding size to each household or individuals, poorer farmers would benefit more than the better off. The management of common property may be implemented through landless labourers by providing them with some rights over these resources. The disadvantage of offering subsidies to households is that people may produce forged documents claiming more than one household in each family to claim more subsidies (Smith, 1998). Another disadvantage is that if the entire cost is borne by the government or other external agency, the sense of ownership on the part of the community will be weak. It is therefore important to insist on the community sharing, in cash or in kind, a substantial part of the costs of the development (Vaidyanathan, 2001). No perfectly equitable system of subsidies is possible though a fixed grant per household may be the most equitable option. Project norms should be flexible to experiment with different subsidy options. Any subsidy that is offered should be based on the detailed assessment of the conservation works executed.

Agricultural input and output prices, taxes, wages, and interest rates influence the income of farm households and their investment strategies for land and water conservation. The poor anticipate and compare returns with respect to the returns from other livelihood options (Scherr, 2000). Reardon and Vosti's (1995) concept of 'conservation investment poverty' highlights poor people's limited capacity to mobilize cash, labour, machinery or other resources even for highly profitable and effective investments. In small farms, the poor may be able to invest incrementally without access to financial credit or hired labour by raising cash through off-farm employment. Through collective action and local credit groups, or through sharecropping and community labour, they could undertake resource-improving investments (Scherr, 2000).

Even though impacts are perceptible, it is difficult to assess the economic value of the numerous potential benefits that do not enter the market. These include ecorestoration, management of groundwater, lower risk of soil erosion and flood protection and maintaining or enhancing biodiversity. Hence the challenge is to introduce an innovative technology which fits into a farming system, which is cost effective and affordable to people.

3.7 Conclusion

Sustainability means maintaining environmental assets or at least not depleting them. The rapid depletion of these essential resources coupled with the degradation of land and atmospheric quality indicate that man has not only exceeded its current social carrying capacity, but is actually reducing future potential and biophysical carrying capacities by extinguishing essential natural capital stock (Rwelamira, 1999). To attain sustainable natural resource use, an integrated approach is essential. Sustainable watershed management may combine sustainable resource use with rural development and poverty alleviation. To achieve sustainable management of watershed and the conservation of natural resources as well as poverty alleviation, there is a need to identify appropriate technologies for watershed management that are affordable and cost effective. Sustainable watershed management needs to be supported by adequate institutional arrangements and must be economically viable. The success or failure of sustainable watershed management depends on what can be symbolized as a chain consisting of four shackles: conservation of natural resources, affordable and effective technology, appropriate institutions and economic feasibility. The chain is as strong as the weakest shackle. If one of them is inadequate, the project fails. The framework developed in this chapter can be used to evaluate watershed projects and may pinpoint at the factors that constrain their sustainability.

Chapter 4 Evaluation of watershed projects in Kerala[1]

The third research question is answered in this chapter. It describes the processes, mechanisms, approaches and impact of two watershed projects implemented through people's participation in Kerala, South India. This chapter also presents the results of the sustainability analysis carried out in these two watershed projects based on the conceptual framework developed in Chapter 3.

4.1 Introduction

During the early 20th century in India, the natural resources were abundant and hence all anthropogenic activities were focused on economic development of the country. However more resources were consumed than required and the technology concentrated on production rather than conservation of raw materials. This led to the situation where resources became scarce and the technocrats were facing a daunting task of finding strategies for conserving the natural resources for future generations.

Land, a non-renewable resource, is central to all primary production systems. It is the most important natural resource upon which all activity is based. Man's progress towards development has, however considerably damaged our land resource base. As a result, land suffers from deforestation, soil erosion and degradation. To harness the full potential of the available land resources and prevent its further degradation, sustainable development programmes are of great importance. The problem of degraded land and its management is complex and multi-dimensional and its development requires a scientific, holistic and innovative approach. Unprecedented population pressures and demands of society on scarce land, water and biological resources and the increasing degradation of these resources is affecting the stability and resilience of our ecosystem and the environment as a whole. The expansion of human settlements and infrastructure, intensification of agriculture, and expansion of agriculture into marginal areas and fragile ecosystems emphasizes the need for integrated planning and management of natural resources.

The increasing pressure on natural resources is also exacerbating conflicts over access and rights to land, water and biological resources, and increasing competition between agriculture and other sectors for declining per capita resources. They affect food security, environmental balance and the well being of the present and future generations. The challenge is to develop and promote sustainable and productive natural resource systems and to protect critical resources and ecosystems through balancing land, water and other resource uses, providing a basis for negotiation, participatory decision-making

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[1] Based on: Vishnudas et al., (2005b, 2005c, 2006b, 2006c)

and conflict resolution among stakeholders, as well as providing an enabling political, social, and economic environment.

This situation is particularly acute in India, which has only 2.4% of the world's geographical area but supports over 16% of the world's population. It has 0.5% of the world's grazing area but it has to support about 18% of the world's cattle population. The population of India as per Census 2001 is 1.03 billion. As per agriculture statistics report (GoI, 2003), 64% of the country's population is dependent upon agriculture as its source of livelihood. The major natural resource-related issues in India are land degradation, forest loss, loss of bio-diversity and decline of fresh water resources. According to the land classification, out of 33 million $(km)^2$ of land in India, approximately 17.5 million $(km)^2$ are classified as degraded land (Farrington et al., 1999). Of this, 50% fall under the cultivated land and the rest is forest and common property land. Long term research by different organizations in the 1970s and 1980s confirmed that the introduction of appropriate physical barriers to soil erosion together with re-vegetation could generate considerable increases in resource productivity. These, in turn, stimulated the formulation of government projects and programmes in support of micro-watershed development.

4.2 Watershed development programmes in India

Watershed development programmes have been implemented in the country by different departments at the Central level and in the States. This includes the National Watershed Development Programme for Rain-fed Areas (NWDPRA), Drought Prone Areas Programme (DPAP), Desert Development Programme (DDP), the Integrated Watershed Development Programme (IWDP) and the Employment Assurance Scheme (EAS). In addition, several externally aided projects have been implemented. The Ministry of Environment and Forest is implementing an Integrated Afforestation and Eco-Development Scheme to promote the development of degraded forests. The Planning Commission of the country follows a similar approach for special area development programmes like the Western Ghat Development Programme (WGDP) and Hill Area Development Programme (HADP). The NWDPRA is under the Ministry of Agriculture and the other programmes are under the Ministry of Rural Areas and Employment.

Although all these programmes have been implemented on watershed basis, each of the schemes, projects and programmes listed above followed separate guidelines, norms, funding pattern etc. The NWDPRA focuses mainly on the rehabilitation of agricultural land, the IWDP focuses on wastelands, the EAS focuses on employment creation opportunities and the DPAP and DDP is focused on agro-climatic conditions.

Most projects have failed to achieve sustainability because of the failure of government agencies to involve people. Costs and benefits of watershed interventions are location-specific and unevenly distributed among the people affected. According to the study conducted by ICAR in Maharashtra and Andhra Pradesh covering several watershed programmes, the increase in agricultural production lasted no more than two years. Structures were abandoned because of lack of maintenance and there was no mechanism for looking after common lands. Farmers were not convinced about the technology introduced on their plots. Farmers were unwilling to contribute towards the costs of works due to lack of faith in the effectiveness of the programme (Farrington et al., 1999).

4.2.1 Common guidelines for watershed development in India

Most development programmes were implemented with a vision on poverty alleviation and drought mitigation in the country. After 20 years of efforts, in 1993, the government of India appointed a technical committee headed by Hanumantha Rao for the evaluation of DPAP and DDP and to suggest measures for improving these programmes. The committee observed that the programmes had made very little impact on the ground though projects had been in operation for over two decades. The committee recommended a holistic approach through micro-watershed planning by taking into consideration the land capability, site condition and local needs of the people. Also it was suggested to prepare development plans with the involvement of the people of the area and the plans should include programmes for soil and water conservation, water harvesting structures, afforestration, pasture development and upgradation of common property resources. Based on these recommendations, a new set of guidelines were formulated by the Ministry of Rural Areas and Employment. These came into effect in April 1995 which was then generally known as 'Common Guidelines' with the concept of 'bottom-up planning' and community participation as a central principle. Following the 73rd and 74th Amendments to the Constitution of India, Panchayati Raj Institutions (PRIs) have been mandated with a greater role in the implementation of developmental programmes at the grass-root level. Through these Amendments, financial and administrative powers were devolved to PRIs from the state government for self governance particularly in planning, implementation and management of economic development activities. To further simplify the procedure and to involve the Panchayati Raj Institutions (PRI)[1] for more meaningful planning, implementation and management of economic development activities in rural areas, guidelines were revised in September 2001. The salient features of the guidelines for watershed development (GoI, 2001) are:

focus on village common lands
equity in sharing the benefits

[1] PRI means local government or local self-government. It is also named a 3-tier panchayat. These are the District Panchayat, Block Panachayat and Grama Panachayat. The administrative State of Kerala is divided into 14 districts and each district is sub-divided into different blocks and each block consists of several Grama (villages).

institutionalized community participation at the village level for implementation and post project maintenance

emphasis on sustainable rural livelihood support systems through self-help groups and user groups

capacity building as a vital component

committee systems at the State and District level for monitoring and implementation

decentralized planning and decision making by the local people of the watershed area

Based on these guidelines each state has formulated their own detailed operational guidelines for each project with people's participation and involvement of PRIs. Projects under different programmes were implemented in each state, in the areas identified under the respective programmes. The projects were implemented mainly through the District Rural Development Agencies (DRDA) of the State. However, the guidelines mentions that wherever it is expedient in the interest of the programmes, the project can be implemented through any department of the state government or an autonomous agency of the Central Government or State Government with the approval of the Department of Land resources.

This chapter illustrates the evaluation of two model watershed programmes in Kerala that adopted the participatory approach. The programmes are evaluated based on the conceptual framework for sustainable watershed management developed in Chapter 3.

4.3 Watershed projects in Kerala

Kerala is located in the southern part of India, having a land area of 38,863 $(km)^2$ It has a tropical climate with a unique topographical setting. It is divided into three physiographic zones parallel to the coastal line: high lands, midlands and lowlands. The highland slopes of the western ghats are characterized by steep slopes. They rise to an average height of 900m with some peaks reaching over 1800m. The rainfall on the area drains towards the lowlands with little resistance. Tropical forests occupy this area and there has been considerable reduction in forest area during the past few decades. The midland is characterized by low hills and valleys, forming the unique watersheds of Kerala with streams flowing through the valleys. The lowlands consist of coastal belts, which receive all the water from the upper reach and are subject to flooding during the monsoon, followed by drought in summer. The bulk of the rainfall in Kerala is received in the two monsoon seasons from June to November. The following six months are relatively dry with little summer rain. This skewed distribution over the year leads to water scarcity during the summer months. The average rainfall on the state is 3000 mm/year, of which

60% is obtained during the southwest monsoon and 25% during the northeast monsoon. The remainder results from summer showers (Sooryamoorthy and Antony, 2003).

In Kerala, land and water management is the most neglected part of water resource development. The entire state is seriously prone to water shortage especially for agriculture during the summer season. As per Census 2001, 74% of the population lives in rural areas of which more than 70% depends on agriculture for their livelihood. Hence scarcity of water is mostly affecting the rural poor. The NWDPRA, IWDP, WGDP projects were implemented in the state through various departments. Most of the watershed projects failed due to lack of involvement of people at all stages of project implementation. Also a standard design was followed in the entire state which did not take into consideration the topography, climate or socio-economic conditions of the watershed. Therefore once the project team withdrew, the structures were left unattended and finally deteriorated.

The idea of watershed management is a relatively recent phenomenon in Kerala. As an experiment, the government of Kerala (GoK) introduced two model watershed projects with people's participation. The Amachal model watershed project in Trivandrum district was directly implemented by the government of Kerala under the WGDP with the concept of 'Participatory Watershed based Integrated Development for Resource Management' (PAWIDREM). The second project was the Attappady watershed project, in Palakkad district, implemented by the government of Kerala through an autonomous institution: the Attappady Hill Area Development Society (AHADS), with a vision of 'ecological restoration of wasteland in Attappady and development of replicable models of participative eco-restoration, so as to prevent further degradation and promote sustainable methods of livelihood for the local people (with special emphasis on tribal population) in harmony with the resource base' In both watersheds, project activities were carried out through user associations. As the sustainability of a watershed depends on the participation of people in the project activities, these two projects were identified for evaluation. Section 4.4 and 4.5 describes the institutional structure, project activities and project impact in detail of these two watershed projects. Section 4.6 analyzes these two projects based on the conceptual framework in the context of sustainable watershed management.

4.4 Participatory watershed management in the midland region – a case study in Trivandrum district

4.4.1 Introduction

The western ghat region of Kerala state covers 450 km out of the total length of 1600 km of the mountain range. This region encompasses 72% of the total geographical area of the state and around 50 % of the state's population. The population of this region increased from seven million in 1971 to sixteen million in 2001. The density of population in this region is 565 persons/(km)^2 whereas the state average is 819 persons/(km)^2 The western ghat region is the second most important hill area of India next to the Himalayas. The region lies in the states of Maharashtra, Karnataka, Kerala, Tamil Nadu and Goa. Important rivers of India have their origin in western ghats and it acts as a barrier to the southwest monsoon causing substantial rainfall over hills (GoK, 2002a). Major problems of the western ghat region are the increasing pressure on land and vegetation, and undesirable agricultural practices. The region is susceptible to accelerated soil erosion, landslides, loss of productivity, seasonal floods and droughts. In order to protect this region, the government of India launched the Western Ghat Development Programme (WGDP) in 1974-'75 (during the fifth five-year plan) as a part of the Hill Area Development Programme of the country. Western Ghat Secretariat of Planning Commission is in charge of coordinating the Western Ghat Development Programme (WGDP) at the national level (GoK, 2002b).

The cardinal approach adopted during the seventh five-year plan (1985-'90) was to execute development programmes for the western ghat region on the basis of watersheds. The eighth five-year plan (1992-'97) followed the same strategy. Its general approach was that of taking up integrated development programmes in compact watersheds keeping in view the over riding priorities of eco-development and eco-restoration as well as the basic needs of the people upstream. During the ninth five-year plan (1997-2002), WGDP operated mainly on the following principles: (a) participatory approach for empowerment of community and implementing watershed projects through watershed communities, (b) facilitation, co-ordination and supervision by a programme implementation agency (PIA, agency deputed by the government for project implementation in the watershed which may be either from Government, NGO or from Panchayati Raj Institutions), (c) project proposals to be demand driven reflecting the felt needs of the community, (d) development of common property resources (CPRs) and sharing of usufruct rights, (e) linkage of watershed communities with Panchayati Raj Institutions (Grama Panchayat, Block Panchayat, District Panchayat), (f) promoting equity for resource poor persons and women, (g) integrated development of natural resources, (h) flexibility in choice of technology, and (i) extension support through line departments. Based on these approaches and experiences, the government of Kerala introduced new guidelines of its own for the implementation of WGDP in the state (GoK, 2002b). The following were the relevance of new guidelines for WGDP implementation in the state.

(1) to integrate implementation of WGDP with the decentralized planning process being institutionalized in Kerala;
(2) to follow the principle of 'people's participation' for the design of locally relevant programmes for integrated and sustainable development of the western ghat

region on a watershed basis through the active involvement of watershed community, Panchayati Raj Institutions, voluntary agencies and government departments/organizations;

(3) to strengthen people's institutions like 'self-help groups', 'neighbourhood groups', 'user groups', 'kudumbasree' (empowerment programme for women under government of Kerala) for organization and execution of location specific development activities in the watershed;

(4) to link watershed based programmes implemented in the region.

This Section describes how these features were implemented and its impact in the 'model watershed project with people's participation in Kerala'

4.4.2 Model watershed in Kerala

In January 2002, the government of Kerala approved the proposal to develop a model participatory watershed management project under the Western Ghat Development Programme. The main theme of the Amachal model watershed is integrated development of the watershed with people's participation, active involvement of Panchayati Raj Institutions and through integration of watershed based development activities of government and non-government organizations (GoK, 2002a). The major thrust of the project is the promotion of people's initiatives for managing the resource trinity-land, water and biomass through needs-based interventions using low cost technology options. This watershed was selected by the Western Ghat Cell (WGC) of Kerala based on the following criteria: possibility of land and water management interventions, relatively small area, predominance of agriculture, no major and minor irrigation projects, unutilized ponds, presence of water scarcity, severe soil erosion, shortage of fire wood and fodder, exploitation of farmers by middle men and traders, unemployment and under-employment of women. This watershed has an area of 105×10^4 m^2 The project duration is three years from 2002-2005.

4.4.3 Amachal watershed

Amachal watershed lies in Trivandrum District, the administrative capital of Kerala (between 8° 28'57" and 8° 29'44"north, 77° 6'26" and 77° 7'16" east). The area has a humid tropical climate with an average rainfall of 1500mm/year and average mean temperature of 26.5°C. There are two distinct monsoons: the southwest monsoon from June to September and the northeast monsoon from October to December. The watershed is characterized by moderately sloping to steep hills intervened by very gently sloping to gently sloping valleys. This watershed experiences severe water scarcity during the dry period from January to May.

There are 510 households in 471 houses in this watershed. The watershed boundary passes through four administrative wards of the Kattakada Panchayat. The total population is 1984 (964 males and 1020 females). It is a Hindu (65%) dominated watershed with 26% Christians and 9% Muslims. 56 % of the population is in the age group 19-55 and 13 % are old aged. The watershed has a high literacy rate of 89%. 34% of the total population is unemployed. Agriculture is the main source of income. 23% of the population is in middle-income group and only 7% belongs to higher income group. The rest belongs to the lower income group. 44% families were found to be in debt mainly on account of agriculture.

4.4.4 Participatory watershed programme: how the project started

The watershed committee was formed on 25-07-2002 in the Amachal watershed for the implementation of the participatory watershed project. The committee consists of 53 members with the president of the Kattakada Grama Panchayat as its chairman and the Panchayat member representing Amachal ward (administrative ward with the largest area in the watershed) as its convener. Of the 53 members, 38 members are from the 19 household groups (HG1 to HG19) of this watershed. These groups are formed from 510 houses with 20-25 houses in each group. One male member and one female member represent each household group. Panchayat members of the other three administrative wards, District Panchayat member, Block Panchayat member, members of the people's institutions in the watershed, Government representatives are the other members of the watershed committee.

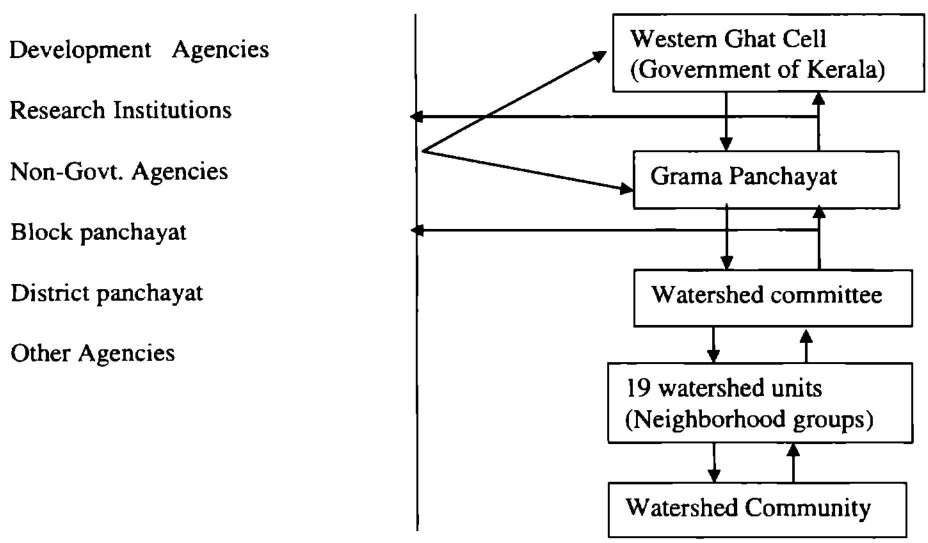

Figure 4.1. Organisational Set-up of Amachal Watershed (adapted from Government of Kerala, 2002c)

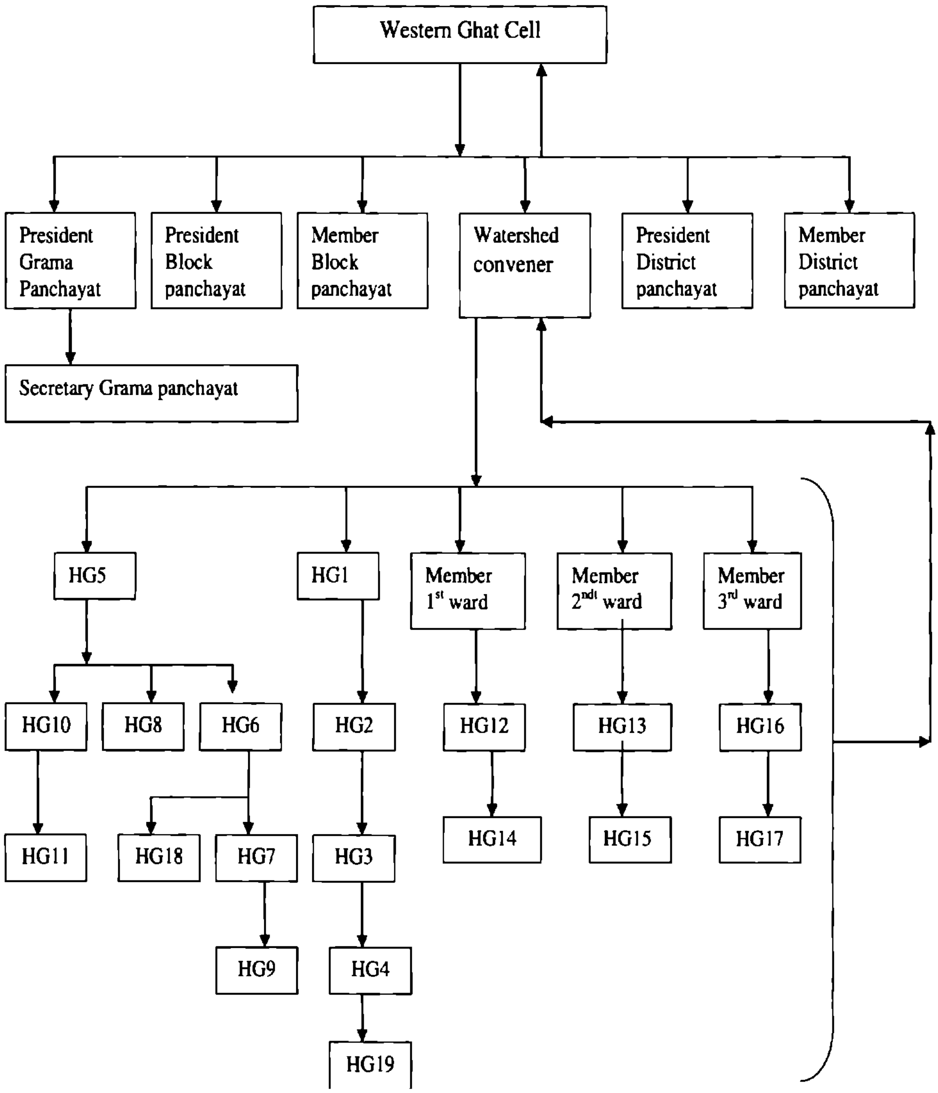

Figure 4.2 Network communication (GoK, 2000c thereafter)

The watershed committee is empowered to take decisions on all aspects of organization and implementation of project activities in the watershed. Figure 4.1 shows the organizational set up of the watershed. The watershed community[1] has established their own communication network so that within an hour the entire community will be receiving all the information and decisions taken from the Western Ghat Cell. The

[1] The watershed community consists of all adult members living in the watershed

chairman of the committee will receive the information from the Western Ghat Cell and will pass the information to the watershed convener. He will communicate to the other ward members and to the household groups as shown in the communication network diagram in Figure 4.2. In the normal government procedure, government will issue an order regarding the decisions taken, which will reach the respective projects only after a couple of months.

Awareness generation, community mobilization, participatory institution building, surveys, training and documentation were the major activities done for strengthening the community to participate in the watershed management programme. The Western Ghat Cell conducted a series of discussions and meetings for ensuring participation of related Panchayati Raj Institutions in the project and also for ensuring integration of development programmes of line departments and other institutions in the watershed. A needs assessment was conducted with focus area as land and water management, income generation activities, and the creation of infrastructural facilities. Each household group presented their needs and prioritization of the needs in the respective household group. In the beginning of the project, people emphasized income generation and infrastructure development.

But after the awareness campaign, the community changed their priorities as listed in the following order: (1) awareness generation and training, (2) literacy and community learning, (3) soil and water conservation, (4) agriculture and allied activities, (5) income generation activities, (6) infrastructure development. Participatory rural appraisal and resource-mapping exercises were conducted in the watershed with the assistance of field experts from NGOs. The effort of the Western Ghat Cell, for motivating and enabling the watershed community to formulate an action plan of their own for integrated development of this micro watershed has been successful. The watershed committee acquired strength and confidence, and was able to prepare a development report and an action plan within eleven months. The Grama Panchayat approved this action plan with necessary modifications on 23-11-2002 (GoK, 2002b). As per the report of the watershed committee of December 2002, twenty one meetings were held within this period to discuss various aspects of this project with government representatives and other relevant officers and agencies.

4.4.5 Project activities

The Amachal watershed project was inaugurated by the then Chief Minister of Kerala during Grama Sabha[1] meeting on 11-12-2002. Thereafter on 26-01-2003, the Grama Panchayat president inaugurated the soil conservation work but due to the delay in releasing the first installment of project funds, implementation of the project started only

[1] Grama sabha means village gathering

on 03-07-2003. The project funds were deposited in the cooperative bank in a special joint account of the watershed committee chairman and the agriculture officer, who was appointed by the government as the implementing officer. Signatures of both these persons are required for the release of the funds. The development works were executed directly by the watershed committee under the leadership of the watershed convener. Sub-committees were formed among the representatives of the household groups for soil conservation, irrigation, agriculture, and monitoring and evaluation. Government officer from the relevant departments are members in the respective sub-committees and provides technical guidance for project implementation. The monitoring and evaluation committee supervises the execution of the work. The secretary of the sub-committee displays day-to-day accounts on the notice board. Household level meetings were held every week and sub-committee meetings were held monthly. Watershed committee meeting was held four times in a year and Grama sabha meets once in a year.

As per the reports of work done by the watershed committee of 01-03-2004, revival of the village pond, construction of contour bunds using loose boulders, construction of an irrigation canal, and digging percolation pits, are the major activities done under irrigation and soil conservation. The second installment of the fund was not released due to unforeseen reasons. The watershed convener complained to the higher official of the Planning Board and based on this complaint, the officer-in-charge of Western Ghats Cell issued a government order to the Grama Panchayat president and implementing officer to release the funds. Even then, they were not ready to release the project funds. A watershed committee meeting was held on 23-12-2003 to discuss this matter presided by the higher officials of the Western Ghat Cell. Government representatives from various departments were also present in the meeting. An official from the irrigation department revealed that he would not certify the estimate of the work done, unless the sub-committee submits the measurement book. Although the sub-committee displays daily accounts, they have not written the daily measurement book, which is treated as the reference document for releasing funds under government projects. Also the official complained that, the activities was executed not based on the government specifications but on an indigenous technology. But the sub-committee convener reported that he was unaware of the daily measurement book, and the higher officials of the irrigation department asked him to take the total measurement at the end of the project. The activities were executed based on the experiences of the elder farmers and hence they could execute more work than that was specified by the government. The implementing officer was of the opinion that he was merely treated as an official to release project funds and complained that he was not consulted for any activities. He reported that this project was not sanctioned through the normal procedure adopted by the government, but based on the action plan submitted by the watershed committee. Hence he could not take the risk of signing the bills submitted by the watershed committee. Also people were not willing to purchase fertilizers from his department. People's argument was that fertilizers were supplied in one single installment instead of three installments as recommended by government. They do not have money to purchase in a single installment.

Although the Grama panchayat president is the chairman of the watershed committee, he was not interested in this project as his administrative ward is not included in this project. He commented that he had to take care of all the wards in his panchayat and he could not give special attention to this watershed. He was of the opinion that it is the responsibility of the watershed convener to accomplish the project.

4.4.6 Project impact

As per the financial statements of the work done by the watershed committee of 01-03-'04, the committee could provide employment for 8200 local labourers. Men and women were given equal wages for unskilled labour. Increased job opportunities have enhanced the livelihood of the watershed community. At present the project is stopped due to lack of support from the government and local politicians. Though the village pond is revived, the rehabilitation of the canal was not completed. Therefore farmers couldn't irrigate their land during the dry spell in January-May'04. They lost paddy crops of about 50,000m^2 There is no coordination between the line departments and the watershed committee. Though the watershed community is highly aware of the concept of watershed, local politicians and the government officials are unaware of the resource management. The watershed committee members revealed that a village pond in this watershed was revived using local labour and indigenous techniques in consultation with experienced farmers with 40% of the cost that was estimated by the government officers. This disappointed the government officials, as they were likely to implement the project in collaboration with contractors, non-government organizations and politicians. The committee members complained that the government had given conventional specifications, which the local people denied to implement, and hence government made technical objection to release fund for the development activities stating that the local techniques were not included in the public work manual of the government. People were highly suspicious about the functioning of the government. Irrespective of political parties all the members of the watershed community were working together. Surprisingly however, local politicians, non-government organizations, private contractors, government officials were not happy.

Local politicians and the other members of the Grama panchayat do not support this project since their administrative wards are not included in the project area. The watershed boundary does not coincide with the administrative boundary of the wards. People living beyond the watershed boundary in the same wards were excluded from project benefits. Local politicians do not want a participatory project to succeed. If people are strengthening themselves to implement development projects, then what will be the role of politicians? The watershed committee is of the opinion that government officers, local politicians, and NGOs want to implement the project as per their own interests. But, the committee got support from the watershed community to have the work implemented directly by the watershed committee. The watershed community suspected corruption in the government departments and they believe that through empowerment and collective action, they can bring about changes in the society. At present, in their watershed people are not divided on the basis of caste, class and gender. They find time to attend meetings and take part in collective action. As neighbours, they know each other and work together. Women are actively involved in Kudumbasree projects, including many income generation activities. Some units under this project are growing fodder grass and vegetables and the profit is divided among the members of the group. Thus dependence on moneylenders and private bankers has considerably reduced. The following are the success and failure factors of the project from the case study analysis.

Success factors

- community involvement from problem identification to decision-making and implementation, in all the activities.
- attitude change of people for collective action.
- increase in employment opportunities, agriculture productivity and overall quality of life.
- action plan for the watershed developments were formulated by the community.
- community listed last priority for individual benefits and infrastructure development.
- indigenous technology and local labour used for the execution of work to increase livelihood in the watershed.
- women empowerment through labour, income generation activities and neighborhood groups.
- watershed community is highly aware of the concept of watershed and requirement for the protection and conservation of natural resources, land, water and biomass for sustainability.
- all the activities in the project are transparent. Social auditing is being carried out and day-to-day account is being displayed on notice board. Therefore chances for corruption are eliminated. Every activity is documented and recorded by the watershed committee.

Failure Factors

- instead of being a facilitator, government did not support the project. Hence this project stopped before the specified project duration.
- government officials who were working actively for the success of this project were transferred to other departments, and people lost faith in government.

lack of awareness among local politicians and government officials regarding the delineation of watershed against administrative boundary. This resulted in a lack of co-operation from other administrative ward members from the local government.

decentralization is not effective among the administrators. Hence the 'bottom up' approach is yet to be practiced.

lack of coordination between government officials, local politicians and watershed committee.

4.5 Participatory watershed management in the highland region- a case study in Attappady hills

4.5.1 Introduction

Attappady is located in the northeastern part of Palakkad District, in the western ghat region of Kerala (between 10° 55' and 11° 15' North and 76°21' and 76° 48' East). It has an area of 745 $(km)^2$ spread over three panachayats namely Agali, Pudur and Sholayur; which is included in the manipulation zone of the Nilgiri biosphere reserve by the Department of Environment, government of India (CWRDM, 1994). According to the National Wasteland Development Board, Palakkad is one of the districts in Kerala with the highest proportion of wastelands relative to its geographical area, most of which extends over Attappady. Over-exploitation and improper management of natural resources coupled with faulty land use practices turned Attappady into a degraded zone of the western ghat region.

The Attappady valley differs from the rest of the humid tropical area in Kerala mainly because of the rainfall characteristics and its peculiar geographical location and physiography. Factors such as degraded wasteland and general backwardness of the area with a large tribal population make Attappady hydrologically and socially unique. There has been drastic change in the Attappady ecosystem during the recent past, due to deforestation and migration. The hills of Attappady were once the forest land of Kerala. At present it is on the verge of extreme degradation. According to the land classification of government of Kerala, of the total land area of 745 $(km)^2$, 60% is under forest land, 17% under agriculture, 21 % under wastelands and 2% in other uses. Presently, about 50% of the total area is considered as degraded. The forest lands constitute about 46 % of the total degraded area while the wastelands account for about 42%. The main inhabitants of this area are tribal people, forming the socially and economically weaker section of society. These tribal people earn their livelihood from agriculture and non-timber forest products.

This section describes a narrative account of the processes, mechanisms, approaches and impacts on a watershed project implemented in this region through people's participation.

4.5.2 Background study

Originally, the major part of the forest land was under private ownership of the Zamorins of Calicut. In 1963, the Land Ceiling Act came into effect, which resulted in large scale alienation of tribal lands in Attappady. By enforcement of the Land Reforms Legislation Act, 1970 and the Vesting and Assignment Act, 1971, cited in: AHADS (2003), 'the property ownership of private forests' was transferred to the provincial government forest department. As a result during the few years preceding and following the implementation of this act, almost all private forests in the area were subjected to severe deforestation. During this period a large number of people migrated from Tamil Nadu and other parts of Kerala, and slowly asserted their superiority over the tribal people. According to the 2001 Census, the total population of Attappady was 66,000. Out of the total population, nearly 65% were settlers, who migrated from other parts of Kerala and Tamil Nadu. The tribal people constituted a majority of the population in 1951 (95%), but had become a minority by 1991 (40%). The high incidence of land alienation, coupled with almost total degradation of the natural resource base, made them dependent on the settlers, which further weakened their status in society. Tribal people revealed that, in the 1960s and 1970s, they leased their land to the settlers for a period of 2-5 years. However, after the lease period they didn't get back their land as there was no clear evidence to prove their ownership. The settlers subsequently proved the land as their own through forged documents. Over a period of time, the tribal people were expelled to the most unproductive land on the hill tops and steep slopes and the settlers occupied the valley region.

In the past, tribal people depended on the forest for medicinal plants, honey, resin, fodder, fuel and grazing. They sold these goods at low prices downstream. Women spent time in the forest for grazing and collecting forest products and men worked on farms as labours for low wages. They did not have the habit of saving. 80% of the men were addicted to alcohol. Death from starvation was quite common in the tribal hamlets in the off season. Due to deforestation, tribal communities lost their primary source of livelihood and have steadily descended into starvation and poverty. A study conducted by IRTC (1998) showed that under various government projects, 0.86 million euros (INR 43.77 crores) were spent since 1987 on different development activities. However, the report says that a major percentage of this investment exists merely on paper.

Massive encroachment over forest and cultivated lands, introduction of unsustainable cropping systems, and excessive grazing inflicted heavy damage on the ecosystem and the livelihood support systems of the people. Due to deforestation of the catchments, perennial rivers dried up, springs disappeared and water quality worsened considerably, leading to series of diseases and ill health of the tribal people along with starvation. Extensive felling of trees and the tillage along the slopes with bullock carts led to increased soil erosion, runoff and depletion of groundwater. Along with this even more unsustainable practices such as brick making using the thin topsoil became a regular practice in Eastern Attappady (Karat, 2003).

4.5.3 Ecorestoration in Attappady hills: how the project started

The Attappady Hill Area Development Society (AHADS) was formed in 1995 for the implementation of the Attappady Wasteland Comprehensive Environmental Conservation Project for the ecorestoration of Attappady hills. It is an autonomous organization working under the Department of Rural Development, Government of Kerala. The duration of the project was 8 years from 1996-2004, which was extended for another five years. There are 160 hamlets in this watershed with 20-30 houses in each hamlet. The density of population in this watershed is only 88 per $(km)^2$ against state's average 819 per $(km)^2$ The entire population in this region lives below the poverty line. The watershed is divided into 15 sub-watersheds and a multi-disciplinary team was formed under five team leaders for the implementation of the project. Detailed studies were carried out in 5 sub-watersheds. The project was financed by the Japanese Bank for International Co-operation (JBIC), with a total budget of 4.4 million euros (INR 219 crores); consisting of a loan component of 3.5 million euros (INR 176 crores) from JBIC and 0.8 million euros (INR 42 crores) from the state government.

Unit of planning and implementation: The eco-restoration activities were planned and implemented using a participatory approach on a watershed basis. The area has two major river basins, namely Bhavani and Bharatapuzha. The Bhavani River has four sub-basins and Bharatapuzha River has one. These five sub- basins of the two rivers were treated as the main watersheds and it was again sub-divided into 15 watersheds and 146 micro watersheds without considering the state administrative boundaries (IRMA, 2004). The region has two distinct climatic patterns. The eastern portion of Attappady is a rain shadow region with an average rainfall of less than 600 mm/year and the western side of Attappady is a rain-fed area with an average rainfall of 2500 mm/year. Physiographically, the area is characterized by an undulating steep to very steep topography with elevation ranging from 450-2300m. The type of soil varies from loamy sand to sandy loam in upper reaches and clayey loam to clay in the valley region. Erratic rainfall along with poor soil moisture retention has rendered these lands erosive leading to desertification. The mean maximum and minimum temperatures of the Attappady Block are 33°C and 23°C. Relative humidity ranges from 56-91% in the western Attappady and 62-92% in the eastern Attappady. Mean wind velocity ranges from 5–10 km/hr (AHADS, 2004).

***Organizational set up*:** A 31 member State-level High Power Committee (HPC) was constituted with the Chief Minister as the chairman; the Minister of Rural Development as the vice- chairman and the Principal Secretary of the government of Kerala, Rural Development Department as the member secretary. The HPC is given the responsibility of approving the annual action plan, annual budget, financial, auditing, approval of staffing and service conditions of staff of the AHADS.

A 32 member governing body was constituted to control, administrate and manage the affairs of the AHADS. The Principal Secretary of the government of Kerala's Rural Development Department is the Chairman of the governing body and the Project Director of AHADS is the member secretary of this body. Apart from these officials, there are: three individual area experts from the Tribal Affairs Department, the Dry Land Agriculture Department and the Women Welfare Department; five representatives from User Associations; six representatives from the three- tier Panchayats of Attappady; the Member of Parliament; the Member of State Legislative Assembly; and fourteen government officials from various departments and institutions.

Unlike the traditional system of top-down planning undertaken at the upper echelons of the organization, in the functional set up of AHADS, five distinct interlinked levels of project planning and management were adopted for the implementation of the project. The organizational set up is presented in Figure 4.3. They are:

1. perspective planning at the project level through AHADS
2. watershed level through the Development Units (DU)
3. micro-watershed level through User Associations (UA), *Local Action Group(LAG) an operational unit works under UA in the sub micro watershed level*
4. tribal hamlet level through Ooru Vikasana Samithi (OVS)
5. forest conservation and afforestration through Joint Forest Management Committee (JFMC)

AHADS, the implementing agency, consists of a Project Director (PD), who is the chief executive of AHADS. He is assisted by a Joint Project Director (JPD) in all the activities. Since the major sector of the total land comes under the forest land, both these officers are appointed from the Indian Forestry Service. Five Deputy Project Directors (DPD) and twelve Assistant Directors (AD) work under JPD. Figure 4.4 shows the functional organizational chart of AHADS. Assistant Director is the team leader, who organizes all the activities in the development units. Multidisciplinary team under each team leader were formed from different areas like forestry, soil conservation, water resource development, agronomy and training and awareness creation for the implementation of the project activities in an integrated manner. These teams identify, initiate and manage the various items of work involved in their respective Development Units.

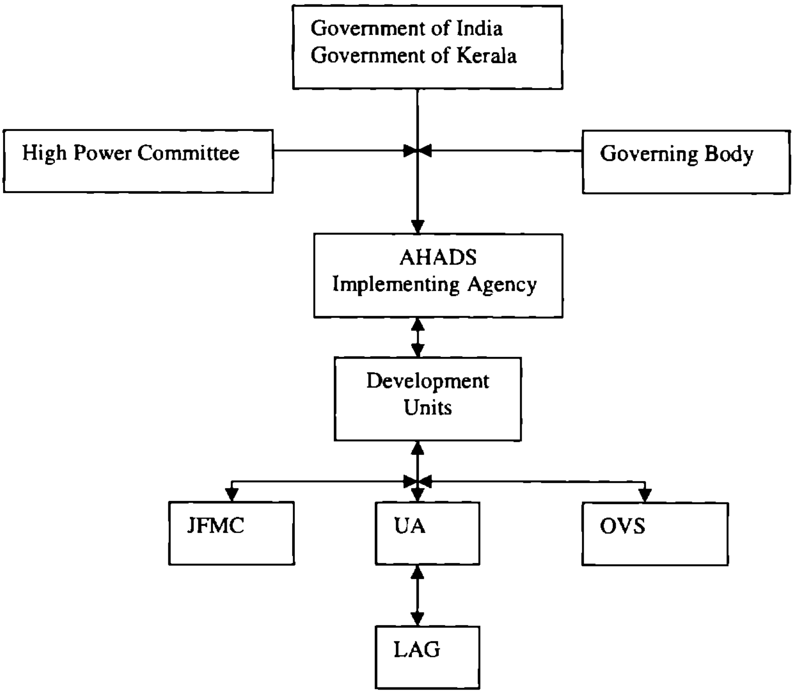

Figure 4.3. Organizational set up of AHADS (adapted from AHADS, 2004)

User Association (UA) is a registered organization representing the total population of the respective micro watershed. It includes both the tribal and non tribal people. The main responsibility of a UA is to implement the activities with respect to micro plans prepared by AHADS with people's participation. A contract was signed between AHADS and UA for implementation of different activities. Out of 146 micro watersheds, only 93 have human inhabitants. UA were formed in all these 93 micro watersheds. The executive Committee of a UA has nine elected members and election has been held in every two years. In order to ensure the participation of tribal people and women in the committee, the following norms were followed (AHADS, 2004): (a) out of the two positions- the president and secretary, one post should be held by a tribal person, (b) out of the four positions- the president, the vice-president, the secretary, the treasurer, at least one position should be held by a woman, (c) out of the nine members, at least five members should be women and four members from the tribal group.

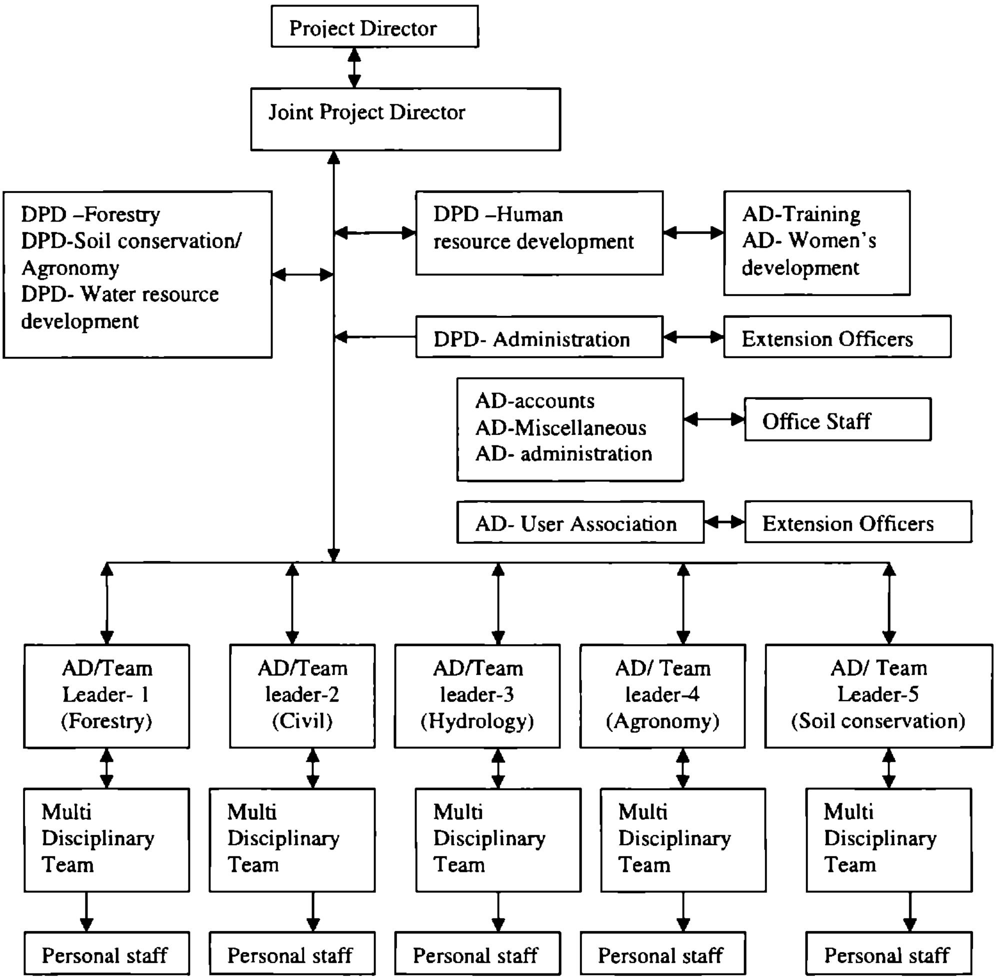

Figure 4.4 Functional organizational chart of AHADS (AHADS, 2004 thereafter)

UAs were found to be too big to attend to the details of the needs of the area of which it was composed. Therefore ***Local Action Groups*** (LAG) were organized for the project implementation at local level as a representative body of all the beneficiaries within an area of 0.5-1.0$(km)^2$ in a micro watershed. This group is responsible for the coordination of various activities to be undertaken on these lands including the employment of labour. A LAG consists of a leader, an assistant leader and members. Leader and assistant leader were selected in a meeting convened by the respective UG. Leader and assistant leader earn income through supervisory work (IRMA 2004; AHADS, 2004).

***Ooru Vikasana Samiti** (OVS)* is an un-registered organization at each tribal hamlet to address the common issues of these marginalized communities. In 160 of the 188 tribal hamlets OVS have been formed. To ensure women participation, among the nine elected members of each hamlet, five of them should be women.

***Joint Forest Management Committee** (JFMC)* is an unregistered organization formed for the reforestation of degraded forest land located near human inhabitations. All adults in the neighborhood were eligible to become members in JFMC. At present 29 JFMCs were formed. Each committee has a president, vice president, treasurer and five executive members based on elections. The post of secretary is held by staff (forestry) of AHADS. In order to ensure the participation of women and tribal people, executive committees were formed such that, out of the eight executive members, five were to be women and five were to be from the tribal community irrespective of their gender (Karun et al., 2005).

All the members of the grass root organizations are scheduled to meet every week and general body meetings were held four times in a year. The Team leader of the corresponding DU presides over the meetings.

4.5.4 Project activities

The project was inaugurated by the then Chief Minister of Kerala on 11-02-'96, with a duration of eight years from 1996-97 to 2003-04. The original project document had only broad details and hence the Centre for Water Resources Development and Management (CWRDM) was assigned to make a detailed design of the project in August 1996. In October 1998, CWRDM submitted ecorestoration plans for 13 development units but these plans were not detailed enough for the physical implementation. It was then decided to take micro-watersheds as the lowest unit for field level action plans. In April 1999 the project activities were started with people's participation, on the basis of the micro plans formulated for each development unit by the multi disciplinary team of AHADS. Sixty User Associations were registered in 1999 in the different development units. Physical implementation of the project was started on 22-04-2000. In the initial stage, the implementation started along the functional lines in phases in different development units, but it slowed down the progress of implementation. It was later in 2002 that this approach was replaced by multi-disciplinary teams that started implementation in an integrated manner simultaneously in all the development units, combining the local knowledge and adaptable scientific agriculture and engineering practices. Each team was assisted by volunteers from the User Association at the field level. All the activities of the project were implemented through the people's organizations. This included soil conservation, agronomy, water resource development, forestry, and income generation activities.

As the majority of the people are illiterate and also as a result of virtual failure of previous government projects and resultant socio-economic conditions of people, apathy and callousness towards developmental projects had developed among the people. Hence, AHADS spent about 2-3 years in the initial stage on organizing beneficiary associations at grass root level and capacity building to administer the project implementation and accounting and documenting project impacts. Various participatory measures were undertaken towards facilitating integration of technological packages of practices under different field conditions. These includes, participatory rural appraisal techniques, group meetings, environmental literacy campaign, training programmes to elected members from UG, LAG, OVS, JFMC in group dynamics, maintenance of accounts, conflict resolution for the smooth handling of execution of works and to help them maintain transparency.

Water is the most crucial resource in this region. Soil and water conservation development works have played a major role in the implementation of the project. The various works implemented through UAs include percolation ponds, contour trenches, check dams, gully plugs, sub-surface dikes, diversion weirs, contour bunds and terracing. Through the sustainable agroforestry system, prime importance was given to the promotion of multipurpose tree species to fit the diverse agro-climatic zones of the area. The tree species includes horticultural crops, mainly cashew, mango and other fruit species and silvicultural species such as neem, silver oak, casuarinas etc. (Karun et al. 2005). Planting was done through JFMCs in different development units. PRA was conducted to prioritize the need of the forest dependant community. Treated areas were fenced with barbed wire and adequate fire protection measures were provided by making fire lines to prevent grazing and forest fire. Watchmen were provided to ensure the protection in the initial period of treatment.

Along with the eco-restoration programme, medicinal plants were promoted in the degraded lands in the area through OVS. Considering the mal-nutrition and sickle cell disease among the tribal people due to the change in food habits, agricultural activities were promoting nutrient gardens in the tribal hamlets. Both nutrient gardens and medicinal plants would strengthen the livelihood of the tribal people. In order to make the project sustainable, income generation activities such like broom making, coir pith compost, vermin compost, local nurseries to cater for the huge requirement of the planting material, were also started. Under human resource development, training and awareness programme were continued to members of UA, LAG, JFMC, and OVS in order to ensure full participation of all the members belonging to the grass root level institutions. Training sessions on various participatory programmes, need for conservation of nature etc. were conducted with resource persons from relevant disciplines. Along with these activities, the construction of roads and houses was taken up in the development units.

4.5.5 Project impact

As per the report on October 2004, AHADS provided 1.4 million man days of employment. Total expenditure was 0.94 million euros which is around 30% of the total budget. The percentage of actual expenditure varies from 1% for income generation activities to 51% for land and water conservation in degraded forest land and private land. The physical progress of work seems to be slightly higher to this percentage as there is a difference between actual expenditure and the budget estimate. The budget estimate is based on the rate specified in the government public manual. But the wages are distributed based on the prevailing local rates. The funds were released to the UA/OVS/JFMC for the implementation of the various activities which comes under the project. The signatories of the bank account are the president and secretary of each association. Social auditing is conducted by the external members of each organization along with AHADS representative.

Increase in availability of water, which is a visual impact for the illiterate society had a very positive impact on the project after 4 years of physical implementation. Many streams and springs were regenerated; those farmers who were reluctant to give their land for physical implementation of the structures started giving land for conservation activities. Abandon of land by the settlers from agriculture have been considerably reduced. People started cultivation their own land. Figures 4.5 and 4.6 show Attappady in 1994 and 2005. Land value has increased from 10-30% in the project area within the project time. No death from starvation was reported during the project period.

Many tribal people and settlers, who were once working with AHADS as labourers during the initial stage of implementation, started cultivating their own land. They understood the need for conservation measures and they realized the ill effect of the consequences from their own experiences. All these together contributed to increase their confidence in AHADS and to work with AHADS. Members in the JFMC started to construct cattle sheds in hamlets to reduce grazing. This shows that they realized the need and necessity to conserve the common property resources that they depend on for their livelihood. Income generation activities based on locally produced agricultural products gained substantial momentum. But the slower progress in this field is due to the lack of experience in agriculture, since agriculture was never a part of the traditional life of the tribal people.

Figure 4.5. Attappady in 1994

Figure 4.6. Attappady in 2005

Along with these positive impacts a few negative impacts were also documented which adversely affected project implementation. Though the project was inaugurated in 1996, physical implementation was started only after four years. This was mainly because of the administrative hierarchy of the organization. The High Power Committee delayed the approval for appointing the technical consultants and also in appointing sufficient staff members proposed by AHADS. Also HPC released only half the advance amount requested for the physical implementation of the project. This reduced the scale of implementation during the specified period (IRMA, 2004). Though the team leaders are from specialized fields they lack in providing technical guidance to their team members due to the pressure of administrative work assigned to them. This has adversely affected the effectiveness and pace of implementation.

Some settler farmers are unhappy with the development activities of AHADS as the wages given by AHADS are higher than local rates. They also complained that the increase in wage rate and non-availability of labourers to work in their field threatens the sustenance of agricultural activities in Attappady. Shortage of labour was faced in AHADS also during October to December as some activities coincided with agriculture activities.

Most of the income generation activities failed. The broom making unit was stopped due to the labour union and vested interest of the traders. Tribal people were selling brooms through middlemen, and once AHADS had taken up this activity, the influence of middlemen was reduced. All the government projects were implemented by the local line departments with the influence of local politicians, contractors and officers of the line department. Contractors were totally eliminated, since the project was taken up through grass root organizations. Local politicians, local NGOs, various officers of different line departments of the government feel that their roles have been reduced after the intervention of AHADS. The representations from all the relevant departments of the government were in the governing body, but there is no coordination between AHADS and these line departments. This may be mainly because of the reluctance of the officers to bottom-up planning. Members of few User Associations reported that there were some allegations in their group due to the intervention from local politicians. They say that AHADS discriminates against settlers and favours tribal people by giving more emphasis to hamlet developments such as housing and infrastructure for the tribal community.

4.6 Sustainability analysis of watershed projects

This section presents the results of the sustainability analysis carried out for the evaluation of the two participatory watershed projects described in sections 4.4 and 4.5. As we have seen in Chapter 3, for a watershed project to be sustainable, four groups of criteria should be considered, mainly natural resources, technology, institution and economics respectively. Poor performance in each of these groups can jeopardize sustainability. The process is as strong as the weakest shackle in the chain. For a watershed project to be sustainable, all these groups should perform above a minimum standard. If one element fails, sustainability cannot be achieved.

4.6.1 Outline of the approach adopted

Both qualitative and quantitative approaches have been used for the evaluation of the two watershed projects. In this study the main objective was not to obtain a numerical estimate of project performance, but to develop an in-depth understanding of the impact of a project. Since both projects were implemented through a participatory approach, more emphasis was given to the qualitative analysis based on the perception of the people, who actually experienced the project and its positive and negative impacts.

Moreover qualitative analysis can provide information about important impacts that are not known a priori, and also about the process that link cause and effect, and about how beneficiaries see the impacts (Kerr and Chung, 2001b).

An indicator or a component or an element devoid of context has no value. Only in the context of a pre-specified value does it acquire meaning (Moxey, 1998, cited in: Rigby et al., 2000). Such pre-defined values are often referred to as thresholds, targets and benchmark or reference levels (Gallopin, 1997). Thresholds are boundary levels of a variable, which are based on the expertise to represent the point at which significant changes occur. Thresholds are particularly important in an agri-environmental context given the propensity of ecological systems to flip from one state to another (Moxey, 1998, cited in: Rigby et al., 2000). When an indicator passes this level then the system is considered to be unsustainable or on the road to unsustainability (Rigby et al., 2000).

4.6.2 The analysis

The analysis has been done based on the primary and secondary information collected about the watersheds. Primary information has been collected through a questionnaire survey. In addition, open-ended interviews were conducted with village men and women, individually and in groups; and individual interviews with key informants especially with office bearers of the state, local bodies, village leaders, local politicians, watershed committee and experienced farmers. Also secondary data has been collected from published reports on case studies in India and in Kerala.

Simple Multi-Attribute Rating Techniques is used for evaluation. Although this method may not capture all of the complexities inherent in the watershed, it is transparent to decision makers so that it is likely to lead to insights and a greater understanding of the nature of the problem. Also this method is quite robust with respect to the interval scale values used (Goodwin and Wright, 1997). This modeling technique allows the assessment of all component of each element of sustainable watershed management in one overview, in such a way that a useful comparison of elements becomes possible.

A group of 100 people has been selected randomly from each watershed for the survey. This includes local farmers, people from user associations, watershed committee and women's groups. People were asked to score components of each element in the framework according to their performance in the field in the range 10-50, with a maximum of 50 and minimum of 10. A score of '50' indicates 'good', '40' indicates 'more than satisfactory', '30' indicates 'satisfactory' '20' indicate 'less than satisfactory', '10' indicates 'bad'. As there will always be some impact of any technology in the watershed for soil and water conservation, the score '0' was not assigned. The evaluation was done based on a threshold band, which defines that those components which lie within the 'threshold band' need attention to become sustainable. The components that lie below the threshold band are considered unsustainable while those lying above the threshold contribute to sustainability. As each of the four elements of the sustainability chain is of equal importance, each element has been given an equal weight of 0.25. Within each element, equal weights have been assigned to the components of the element. In the chain, there is no compensation between high and low scores for individual elements. But within an element, components can compensate each other's performance. Table 4.1 shows the aggregate score of each element and components of the Sustainable Watershed Management (SWM).

The threshold band was fixed with a minimum value of 5 and maximum value of 7.5 of the aggregate score of an element, which means that those components having a score between 'less than satisfactory' and 'satisfactory' (i.e. 20-30) will be in the threshold band, which needs consideration to achieve sustainability. Figure 4.7 shows the comparison of the watershed projects with the different elements of the SWM. Values in the figure indicate that the Attappady watershed lies above the threshold band for natural resources (8.9), technology (7.7) and institutions (10.9), whereas the Amachal watershed lies inside the threshold band with natural resources (6.2), technology (5.0) and institutions (7.2). However, economic sustainability of both the watersheds lies below the threshold value: Amachal (3.7), Attappady (2.7), which shows that both projects are on the road to unsustainability due to low economic performance.

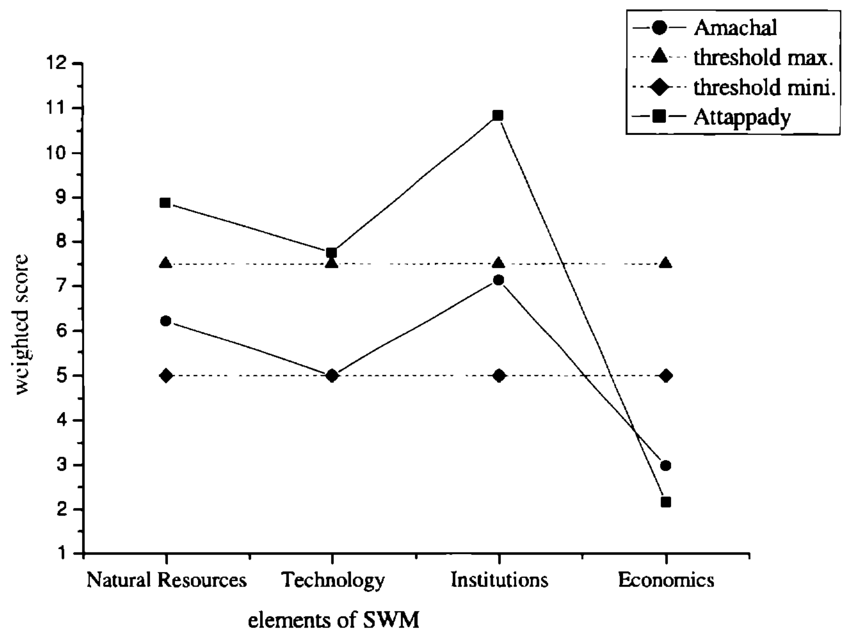

Figure 4.7. Comparison of watersheds with elements of sustainability

Table 4.1 Aggregate score of the elements of SWM

	Element	Weight	Factors	Weight	Amachal Watershed		Attappady Watershed	
					Mean Score	Weighted Score	Mean Score	Weighted Score
SWM	Natural Resources	0.25	Reduction in Soil erosion	0.083	23.71	1.98	40.77	3.4
			Increase in water Availability		28.49	2.37	46.64	3.89
			Increase in biomass/Crops		22.43	1.87	19.17	1.6
			Aggregate Score			6.22		8.88
	Technology	0.25	Suitable to locality	0.05	26.84	1.34	34.32	1.72
			Simple to construct		13.48	0.67	12.15	0.61
			Unskilled labour /labour availability/ Local labour		25.78	1.29	25.72	1.29
			Material availability		10.54	0.53	42.45	2.12
			Indigenous technology/ access to information		23.3	1.17	40.33	2.02
			Aggregate Score			5		7.75
	Institutions	0.25	Governance	0.05	33.44	1.67	46.58	2.33
			Rules &Custom/ Property Rights/ Collective Action		29.4	1.47	46.99	2.35
			Empowerment		31.7	1.59	29.5	1.48
			People's Participation		37.96	1.9	45.18	2.26
			Involvement of Project Implementing Agency (PIA)		10.14	0.51	48.38	2.42
			Aggregate Score			7.13		10.83
	Economics	0.25	*Cost effectiveness*	0.05				
			Low Cost		15.37	0.77	11.7	0.59
			High Output/ income gen.		19.28	0.96	12.72	0.64
			Affordable					
			Access to Capital		14.05	0.7	10.51	0.53
			Ability to Pay/ labour Contr.		12.94	0.65	10	0.5
			Eligibility to Subsidies		13.41	0.67	10	0.5
			Aggregate score			3.7		2.7

min. wt. score- 2.5, max. wt. score- 12.5, threshold mini. value-5, threshold max. value - 7.5

4.6.3 Evaluation of results

While considering the total score of each element in the sustainability chain, effect of one component may compensate the effect of another to get an optimum score. But shackles in the chain will be weakened with the individual effect of each component. In order to have an in-depth analysis of the projects, each element was closely examined with respect to the components in the framework.

Sustainability of natural resources: the sustainability of natural resources depends on the reduction in soil erosion (NR1), increase in water availability (NR2) and increase in biomass and crop production (NR3). Figure 4.8 shows the 'score rose' for sustainability of natural resources for the two watersheds. A 'score rose' is a diagram which represents the average score of each component in an element.

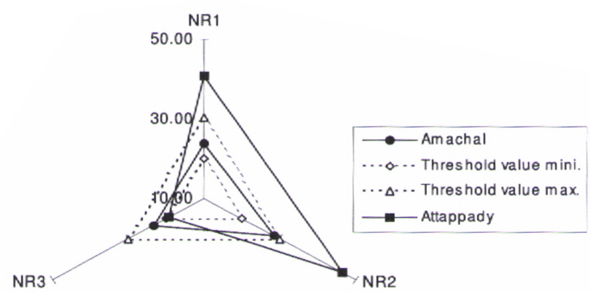

Figure 4.8. Score rose for sustainability of natural resources

In Amachal, people revealed that there is reduction in soil erosion and increase of water in their wells due to the conservation measures implemented in the watershed, but the project was not executed in a consistent manner. In some areas conservation measures were implemented whereas in some other areas no work was executed at all. Even then people achieved increased crop yields and also biomass. The area under bananas and tapioca was increased from 400-2000m^2 The average water level in the wells increased with 1-2 m. Therefore the overall impact shows that the average score of the element lies in the threshold band and contributes to sustainability. In Attappady, an impressive improvement of the state of the natural resources was observed. People revealed that water for their primary needs was extremely scarce before the implementation of the project. During the study period, the water level in the wells increased with 1.5-2.75 m. Soil erosion and gully formation were considerably reduced. Streams and springs regenerated. However, though there was an increase in biomass, crop production does not increase. Only a few people started cultivating their land. This is mainly because tribal people depend on forest products for their livelihood and they are not familiar with agricultural practices. Hence the average score for NR1 and NR2 lies well above the threshold band and that of NR3 lies below the threshold band. They compensate each other in this element. The individual scores of each component in this element show that natural resources need attention in Amachal and Attappady is in pace with sustainability.

Technological sustainability: technological sustainability depends on various components. The technology should be suitable to the geographic situation (T1), simple to construct (T2), make use of unskilled labour (T3), which should be timely available (T4), preferably locally (T5), make use of locally available material (T6), and indigenous technology (T7), and there should be access to information (T8). Components T3-T5 are combined in Table 1. Figure 4.9 presents the score rose for technological sustainability. Average scores for (T1) in both watersheds show that technology is suitable for conserving natural resources. Though Figure 4.7 shows that the aggregate score for the technology element is adequate to sustain the natural resources in the Amachal watershed, in Figure 4.9 components - T2, T3 and T6 lies below the threshold band.

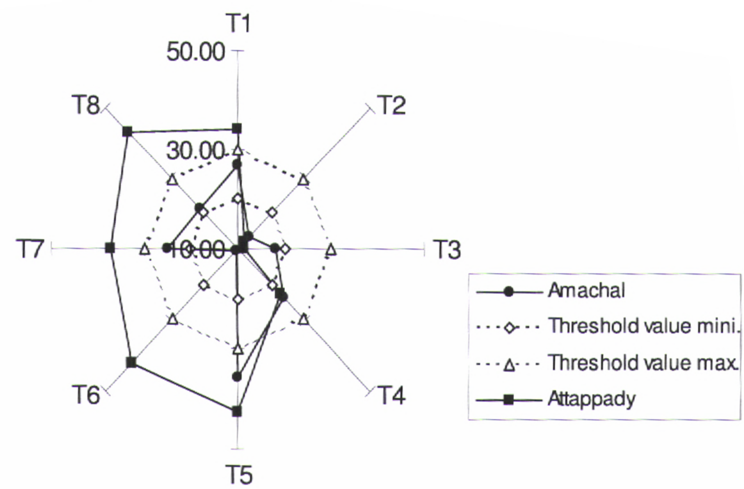

Figure 4.9. Score rose for technological sustainability

This is because construction of contour bunds were done using loose boulders transported from the neighbouring state therefore overall cost of construction is higher than the traditional earthen bunds adopted by the farmers. In the case of Attappady watershed, bench terraces and gully plugging were done for the soil and water conservation, which is highly labour intensive and requires skilled labour. Hence T2 and T3 lie below the threshold value. T6 has a higher score as stones were quarried from the watershed. But it may become a threat to the ecosystem. Although, indigenous technology (T7) was considered while planning the project in both cases, access to information (T8) from the technical experts seems to be very low in Amachal watershed. In both watersheds, local labour (T5) was involved effectively and job opportunities increased. Hence migration outside the watershed in search of employment was reduced during the project period. But T3 and T6 has direct links with the economic sustainability. Individual scores of each component in both watersheds show that the technological element needs special attention to attain sustainability.

Institutional sustainability: as with the other elements, institutional sustainability can determine whether the project becomes a success or a failure. The components of this element are four governance elements: accountability (IN1), transparency (IN2), equity (IN3), efficiency of the governance structure (IN4). Subsequently it includes people's participation (IN5), participation of the Project Implementing Agency (IN6), correspondence with rules and customs, property rights and collective action and land tenure (IN7), empowerment (IN8), inter-jurisdiction (IN9) and environmental services (IN10). In Table 4.1 governance elements IN1-IN4 are combined together. Figure 4.10 presents the score rose for institutional sustainability.

Both watershed projects were implemented with people's participation. User associations were formulated among the people for the implementation of the project in both watersheds. The high scores show that the people's institutions work under good governance (IN1-4). The setup is transparent in all the activities and it is evident that if people's institutions are strengthened, a project can become successful. User associations are efficient in managing watersheds and they work with the community. Equity is ensured for both men and women in allocation of labour and among all class and caste. The higher score in both watersheds shows their willingness to participate in the project both individually and collectively (IN5). But the score of the participation (IN6) of the project-implementing agency (PIA) of the Amachal watershed indicates that their involvement in the project is not adequate at all. Even though project was directly implemented by the government, this project stopped even before the specified duration of project. People lost faith in the government. Also contractors and local politicians along with government officers were not interested to implement the project through the people. There was no integration of line departments in this project. People complained that they were not getting technical assistance and guidance from the officers. Government officers were reluctant towards the bottom–up approach in project implementation. Even then the project succeeded partially.

In both watersheds people secured land tenure and property rights to their own land (IN7). In the Attappady watershed, though tribal people were expelled from the downstream valley to upstream hilltops, they own the land upstream. Some land was given for lease in both watersheds for cultivation. People of the Amachal watershed revealed that they work collectively by contributing towards maintaining and functioning of the temple and church in the watersheds with their own association. Even before the project started they made contributions to the poorest people in the watershed during the off-season. But the lengthy procedure in sanctioning different activities from the line department delayed overall implementation. Hence government should revise the existing rules in response to the needs of the project.

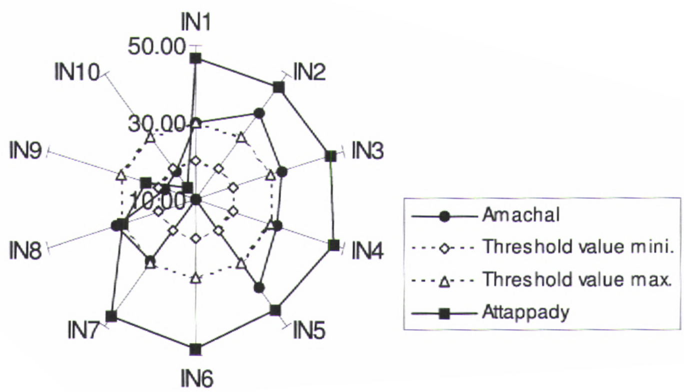

Figure 4.10. Score rose for institutional sustainability

Women were given priority in both watersheds and women empowerment programmes (IN8) were included in the project. They were given opportunities to speak at meetings and also in decision-making in neighbourhood meetings. For the same type of work, both men and women were given equal wages in the Amachal watershed. The higher score in these components shows that people were empowered through this project. The administrative boundary (IN9) does not coincide with the watershed boundary; there were political issues between the Watershed Committee and the local government in the Amachal Watershed. The watershed lies in different administrative boundaries; and hence ward members were not supporting this project, because people beyond the boundary of their administrative wards were not getting any benefits from the project. This may affect their political image. In the case of Attappady, micro-watersheds were distinguished based on the hydrological boundary and user associations were formed in each micro unit. PIA being an autonomous body, their involvement in the project is very high. The high score shows that they are working closely with the people providing technical guidance and awareness creation among the people to work collectively through user associations. People expressed their confidence in the working of the PIA. Environmental services (IN10) were not considered as an important criterion in both watersheds. People didn't give a positive response on sharing their resources. People revealed that they could provide on farm employment to the poor people, but they are not willing to share the resources.

Economical sustainability: this element in the sustainability chain determines the adoption of any technology introduced by the project. The components of this element are construction and maintenance costs (E1), labour cost (E2), price of materials (E3), the value of the output (E4), income generation (E5), access to capital (E6), ability to pay (E7), eligibility to subsidies (E8) and the cost of labour contribution (E9). Figure 4.11 presents the score rose for economic sustainability.

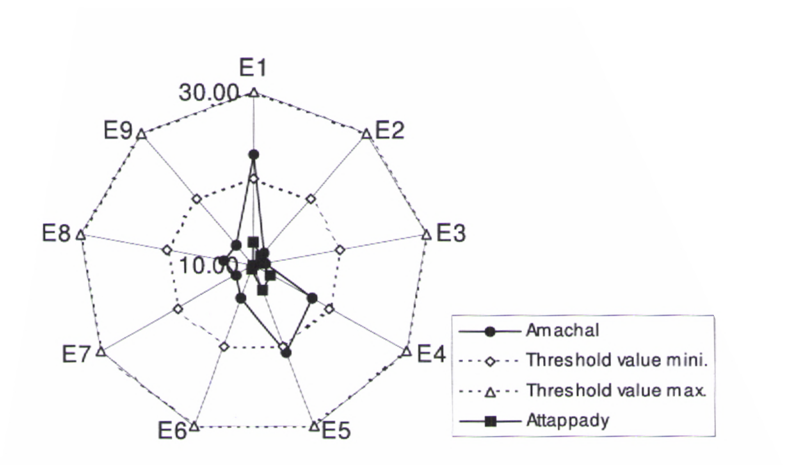

Figure 4.11. Score rose for economic sustainability

Once the project team withdraws, if the introduced technology is affordable, people may adopt that technology, otherwise the structure will be left unattended and deteriorates in the long run. In both watersheds, all components being below the threshold band indicate that this element is unsustainable. The technology used in both watersheds indicates high cost of construction (E1-3), which people cannot afford themselves. The cost of construction comes around 2-2.5 euro/m^2 People revealed that they cannot adapt this technology without financial support from the government. Though there is increase in production of crops, people in the Amachal watershed revealed that the net income was less than the overall cost of construction (E4). In Attappady, few people started cultivating cereals and banana, but it was used for their own livelihood. Scores show that income generation activities (E5) were given lowest priority in the watershed programme. As the majority of the population depends on agriculture, here the dependence on natural resources is large. In Amachal, people complained that the criteria for subsidies were not consistent with natural resource management. It is based on ownership of land and the income level. The majority of the people revealed that those who own more land, but are unable to pay the contributory amount, are not eligible to get the subsidy (E8) and their access to capital for soil and water conservation were denied (E6). In this watershed, 80% of the investment was from subsidy and 10% was received from the local government. 10% was fixed as the beneficiary contribution either in terms of labour or material. But, the rate of subsidy was changed after one year of implementation and was reduced to overall 50%. Hence people of the watershed were unable to afford 50% of the cost of construction and thus the conservation measures were also stopped along with the project (E7), even though people were highly aware of the need to conserve the watershed. Also people said that the present strategy provides an opportunity for officers towards corruption. People suspected that the benefits may divert from the intended beneficiaries. In the case of Attappady, tribal people who belong to the socially and economically weaker section of society cannot afford any cost of construction and the entire project was run with 100% subsidy. They were totally depending on the wages from the project. They do not know agricultural practices or any other income generation activities. The majority of the people living in both watersheds depend on the wages they receive from the project, and hence they cannot contribute free labour to the project (E9). Hence the high cost of construction together with low output and less subsidy leads to an unsustainable economic development. As this element lies below the threshold value, the entire chain is broken. Hence this element is of great importance in both watersheds in order to achieve sustainability.

4.7 Conclusion

The study was conducted during the period December 2003 to June 2005. Evaluation of an ongoing project helps to improve or change the strategy for better performance rather than lead to unsustainability. Considering the case study in Amachal watershed it is evident that, although decentralization is said to be effective in Kerala, it still remains on a paper in the context of watershed management. Sustainability of watersheds depends on political factors, on the support watershed institutions receive, and the involvement of local people. To act collectively, people require an enabling environment where they can interact with each other and find their own solutions. In the operational guidelines of the Western Ghat Development Programme, emphasis is given to choice of technology, but government departments are reluctant to adopt technologies that are not specified in the Kerala Government Manual for Public Works. The government manual should include vegetative measures for the conservation of soil and water. Again awareness among politicians and government officials about the 'watershed concept' is essential, so that they support or do not hinder development activities. The departments are not actively involved in the watershed projects since the leadership is not assigned and hierarchy is not defined. Therefore 'who is accountable to whom' should be well defined.

The case study of the Attappady watershed presents the following results. The entire community unanimously stated that project components were planned and implemented by the people themselves through the grass root level democratic institutions with guidance received from AHADS. They expressed their confidence in the corruption-free functioning of AHADS for the development activities. Impact of soil and water conservation works, reforestation programme, agriculture, infrastructure and income generation activities through grass root organizations shows that Attappady is in pace with sustainable development. The overall impact shows progressive change in the environment and also in the livelihood of the local people through the improvement of biophysical resource base. Co-ordination between multi- disciplinary teams may help in replicating the physical implementation of different structures for soil and water conservation, in different development units.

Construction of bench terraces involving cutting and filling of earth is cumbersome and expensive. Cultivation is practiced on these terraces. But this is all very difficult, since farmers are resource poor in manpower and materials for this tedious work.

The project has created significant employment opportunities and thereby increased the livelihood through implementation of different activities, but sustainability in the long term is still a question as very low priority has been given to income generation activities (0.34% of the total budget). People were incapable to strengthen themselves and it requires at least the younger generation to break with the present scenario through education and awareness creation for the conservation of the natural resources.

The delay in decision making by the High Power Committee considerably affected the progress of implementation. For the timely implementation of the project, decision making regarding administration and financial matters should be assigned to the governing body. HPC could monitor the overall progress of the project.

Although there was political interference from external agencies such as contractors, and politicians against the development activities of AHADS, members in the grass root organizations from opponent political parties and the leaders from these parties were working together and adjusted themselves with the new concepts. They fully participated with these organizations irrespective of party differences. Due to the non-coordination of government line departments with AHADS in few development units there is overlap of project activities such as housing and road construction.

The case study clearly reveals that the problem of environmental degradation could not be solved without addressing the socio-economic problems of the area. This situation can be overcome, only through payment of 'environmental service' by the wealthy people living downstream to the poor who live upstream for preserving and conserving the watershed. This can be implemented through economic linkages in terms of employment, education and basic facilities and amenities of the tribal people living upstream.

The sustainability analysis of the two watershed projects clearly shows that the success of a watershed project depends on the sustainability of all the elements in the sustainability chain. Institutional sustainability can be ensured only with the willing participation of the people in watershed projects. The participation of an autonomous institution in Attappady shows that it is possible to manage the projects on the basis of hydrological boundaries, and watershed institutions can be formulated by involving the relevant line departments. Integration of relevant line departments may promote timely technical assistance and guidance. Technical experts should associate with people on-farm rather than issuing government orders on paper. Government officials should be willing to follow a bottom-up approach for the efficient management of watershed projects with people's participation. Cultural activities in the Amachal watershed prove that people can work collectively. A similar strategy can be adopted for maintaining the watersheds through user groups.

In both projects, people depend mainly on natural resources for their survival. People should be empowered so that they can rely on alternative income generation activities apart from the complete dependence on natural resources. Appropriate technologies, people's participation, effective conservation and economic feasibility are the key elements essential for the sustainable management of natural resources. Appropriate technology addresses both the production and conservation objectives of the resource-poor in the context of conservation and socio-economic environments. Simple and low-cost technologies are more acceptable for farmers rather than expensive and labour intensive conservation techniques. Farmers need technologies which they can easily understand and implement on their farms without the need for public subsidies. Therefore an alternate technological option is essential in Kerala using locally available materials incorporating indigenous technology and local labour and which provides a means for income generation activities for a cost effective sustainable management of the watershed. In both projects studied, the weakest shackle in the sustainability chain appears to be the economic sustainability of the projects. If a project does not generate enough benefits to off-set costs of construction and maintenance, it will clearly not become sustainable.

Chapter 5 Technology option using coir geotextiles for sustainable land and water management[1]

The fourth research question is partially answered in this chapter. From the analysis of the watershed projects in Chapter 4, it is evident that simple and low-cost technologies are more acceptable for farmers rather than expensive and labour intensive conservation techniques. This chapter gives an account of experiences with using natural fibres in land and water management, with special emphasis to coir geotextiles.

5.1 Introduction

Soil erosion is increasingly recognized as a problem which needs an effective and economic solution. Several slope protection methods are currently used to stabilize slopes. Among these methods biotechnical methods, making use of natural vegetation, are becoming more popular mainly for environmental and economic reasons. Natural vegetation on slopes is able to self-maintain, brake and dilute the kinetic energy of the rain and also provide surface roughness which slows the runoff velocity. The root system reinforces the soil and also aids infiltration of water by improving the porosity of soils (Ranganathan, 1994; Ahn et al., 2002). However there are certain limitations which can hamper the establishment of vegetation: it is susceptible to drought, it is difficult to get established on slopes, it is unable to resist severe scour or high runoff and it is slow to establish (Abramson et al., 1995). The effect of vegetation is only fully realized once it has reached maturity. During the critical stage of plant establishment the beneficial engineering properties of the vegetation may not be apparent and a site is still highly susceptible to soil erosion. Without immediate, appropriate and adequate protection, slopes can suffer from severe soil erosion and instability, which in turn makes vegetation establishment extremely difficult. Erosion of seeds and seedlings from unprotected sites by surface runoff and winds is costly since all previous attempts to establish vegetation on the slope have to be repeated (Rickson, 1995). Hence a protective covering on soil is required which resists soil erosion, retains runoff and facilitates establishment of vegetation on the surface. By protecting the surface, these covering materials dissipate the energy of raindrop impact, increase infiltration by reducing surface sealing and reduce the velocity of overland flow. In addition they help to reduce intense solar radiation, suppress extreme fluctuations of soil temperature, reduce water loss through evaporation and increase soil moisture, which can assist in creating ideal conditions for plant growth (Sutherland et al., 1998; Ziegler et al., 1997).

Over the past decade, geosynthetics have played a significant role in geo-environmental engineering applications. Woven and nonwoven geosynthetics have been

[1] Based on Vishnudas et al. (2006d)

used in various applications such as soil stabilization, turf reinforcement, erosion control, separation, filtration and drainage. Depending on the application, they are available under various trade names such as rolled erosion control systems (RECSs), geosynthetic matting, geotextiles, erosion control blankets (ECBs), erosion control re-vegetation mats (ECRMs) and turf reinforcement mats. Despite the technological advances made in this relatively new discipline, the majority of research has focused on geotextiles made from synthetic materials. The use of naturally occurring fibre products for similar applications has not received significant consideration despite their potential (Ogbobe et al., 1998). In addition, strength properties of natural fibres are often superior to synthetic fibres (Mandal, 1987). Recently, pilot projects have been launched as field trials using natural geotextiles in various applications, but not much scientific literature is available with regard to the use of bio-degradable geotextiles as a practical solution in geo-environmental engineering especially in the field of watershed management.

5.2 Historical perspective

Sutherland (1998a) in a review dealing with erosion control systems reveals that there were only nineteen publications during the early years upto 1990 which included only six journal articles that dealt with RECSs applied to slopes and their influence on erosion, runoff or vegetation. Of these most were qualitative demonstration studies or laboratory tests with rainfall simulation. During that period no scientific attempts were made to examine fibre properties both natural and synthetic and their ability to reduce soil erosion or runoff or to facilitate the establishment of vegetation. Since 1990, there were twenty seven publications in this field, but only 22% in scientific journals against 32% in the preceding decade (Sutherland, 1998b). Jute netting was the first geotextile used to protect slopes from erosion (Duley, 1939, cited in: Sutherland, 1998a). It was demonstrated that there is increased infiltration of water into the soil if covered by burlap (composed of jute fibres) compared to straw or bare soil. Dudeck et al. (1970) studied the performance of RECSs (excelsior and jute) focusing on grass establishment and micro-climate modifications on 50% slopes. It was observed that moisture in the upper layer of the soil just beneath the RECSs was significantly greater (20-24%) than in the bare control plot (13%). Also the temperature at a depth of 1.3 cm was significantly lower (12-15°C) compared to the control plot (22°C). The moderate micro climate beneath the RECs favoured greater soil moisture storage and a less hostile temperature regime producing significantly greater vegetation biomass compared to bare soil. Ingold and Thomson (1990) through a laboratory model study illustrated that synthetic materials are less effective in controlling sediment or soil loss as compared to natural fibres. Cammack (1988) reported that field trials conducted with coir geotextiles in Australia and in Germany have proven their efficiency in river bank protection and embankment stabilization. Also the performance of coir geotextiles with a density of 0.50 kg/m^2 is reported to reduce runoff and soil loss by 77% and 98% respectively. In the field study conducted in India using jute geotextiles on 30-40% and 60-70% slopes, it was demonstrated that jute geotextiles helped in retaining moisture and reduced erosion considerably (Ranganathan, 1994). The field study by Mapa (1996) in SriLanka, showed that coir geotextiles are an effective agronomic method for soil and water conservation. Results indicated that soil temperature was reduced by 4°C in the treatment plot compared to the control plot, and that soil erosion was reduced from 1.8 kg/m^2 in the control plot to 0.07 kg/m^2 in the treatment plot. The increase in soil moisture storage for coir-treated plots is due to reduced evaporation from the surface (Wagner-Riddle et al., 1996, cited in: Sutherland, 1998b). Sutherland et al. (1998) conducted a controlled greenhouse experiment over thirty nine days in Honolulu, Hawaii, to study the influence of RECSs on soil moisture content, biomass production and nutrient assimilation. Results reveal that all the RECSs conserved more moisture in the soil profile than the bare treatment. Also, comparing the efficiency of coir and jute, soil covered by coir geotextile retained significantly more moisture than jute geotextiles. Among the paired comparison of coir geotextiles with different mesh type, those providing more surface cover (93%) retained more moisture than the others (77%), due to less evaporation of soil water.

Through this study an attempt is made to exploit the potential of coir geotextile in watershed management in Kerala, South India, where coir is abundantly available. If the efficacy of coir is proven, it can be used to strengthen watershed structures, thereby offering an attractive alternative for conventional methods.

5.3 Coir as an agriculture product

'Coir' is the agricultural fibre obtained from the husk of the coconut fruit which surrounds the base shell. It provides the raw material for the coir industry. India is the largest producer of coir fibre (66% of the world production) of which Kerala account for two-thirds. Out of the total annual global production of coconuts, only 10% of the coconut husk is used for fibre extraction which is estimated to be around 0.5 x 10^6 t/year of coir (FAO, 2002). Out of this, only about 30% enters the world trade. The exports in the form of fibre and yarn from producing countries are used for value addition in the importing countries. Sri Lanka is the largest exporter of coir fibre followed by Thailand and India.

Coir fibre making in Kerala dates back to the 11th and 12th centuries as it is mentioned in the chronicles of Arab writers and European traders (Ayyar et al., 2002). It was used for making ropes, carpets and matting. The first factory to manufacture coir products was started at Alleppey district in Kerala by a European entrepreneur in 1859. At present the industry consists of about ten thousand tiny and small units. Public sector undertakings and co-operatives play a dominant role in the state's coir industry. The production and processing methods in the coir industry continue to be traditional.

Coconut farmers or the end product manufactures are not involved in the primary and extensive sector of husk collection, retting, fibre extraction and spinning of yarn. The extraction of coir fibre and production of coir yarn is mainly a household industry in the coastal areas of Kerala. The coir industry has the potential to provide employment at low investment cost and a large number of people depend on this industry for their livelihood. It provides employment to about 0.5 million people of Kerala alone of which 80 % are women.

5.4 Coir properties

Coir fibres are of different types and are classified according to varying degrees of color, length and thickness. The length of coir fibre varies from 50 mm to 150 mm and diameters vary from 0.2 mm to 0.6 mm. The fibre is of two types, depending on the process of extraction: white fibre and brown fibre. White fibre is extracted after retting mature coconut husks for 9-12 months, followed by beating of the retted husks with a mallet manually to thrash out the coir pith. Brown fibre is extracted by mechanical means after soaking the husks for a short period in water. The brown fibre is relatively inferior in terms of quality. Brown coir is mainly used for ropes, rubberized coir and in upholstery. The extracted fibres are then spun into yarn of different counts and grammage. The yarn is classified in terms of type of fibre, colour (natural), twisting and spinning. The yarn is then converted into mats in handlooms, semi automatic looms or power looms. The scorage of yarn differs among different types of geotextiles. The scorage of the yarn is the number of strands that can be laid close to each other without overlapping in a length of 0.9 m (1 yard). Figures 5.1 to 5.4 show the various processes involved from dehusking to yarn making.

Figure 5.1 Dehusking from coconut shell

Figure 5.2 Retting of coconut husk

Figure 5.3 Fibre extraction by beating husks after retting

Figure 5.4 Twining coir fibres for yarn making

Table 5. 1 comparative properties of natural fibres (adapted from Ayyar et al., 2002)

Fibre	Coir	Sisal	Jute
Texture	Smooth, tough , cylindrical and twisted fibre	Long, rough and twisted fibre	Soft and resilient fibre
Density (g/cm^3)	1.40	1.45	1.3
Spiral angle (degree)	30-45	10-22	8.1
Cellulose/lignin content (%)	43/45	67/12	61/12
Elongation at break (%)	15-40	3-7	1-1.2
Elastic modulus (GN/m^2)	4-6	9-16	
Tenacity(MN/m^2)	131-175	568-640	440-533

Table 5.1 shows the comparative properties of different natural fibres. Coir is a lignocelluloses polymeric fibre with 45% lignin and 43% cellulose. Coir fibres are less sensitive to UV radiation due to leaching out of photo-sensitive materials from its surface during the retting process. It has a low tenacity value (a unit used to measure the strength of a fibre or yarn, which is usually calculated by dividing the breaking force by the linear density (*linear density in rope specification is weight / unit length*)) but the elongation is much higher compared to other natural fibres (Ayyar et al., 2002). It is a natural biodegradable material with a highly crystalline structure with the spiral angle of the micro fibres ranging between 30-45^{o} This leads to a greater extensibility than in most other natural fibres. Its high lignin content contributes to higher durability and slow biodegradation compared to other natural fibres (Balan and Rao, 1996). In order to standardize the tensile behavior and biodegradability characteristics of coir, studies were initiated at the Indian Institute of Technology, Delhi. The work included an evaluation of the physical and engineering characteristics and the biodegradability behavior of coir/jute geotextiles in different soil environments, a detailed explanation of which is given in section 5.5 (Balan, 1995; Rao and Dutta, 2005).

Table 5. 2 Manufacturing details of different types of coir geotextiles (adapted from Ayyar et al., 2002)

Designation	Type of warp yarn	Approx. scorage of warp yarn(No.)	Ends per dm	Type of weft yarn	Picks per dm	Mass (kg/m^2)
MMA1	Anjengo	14	9	Vycome	8	0.650
MMA2	Anjengo	12	19	Aratory	11	1.400
MMA3	Anjengo	12	11	Aratory	7	0.700
MMA4	Anjengo	11	13	Aratory	7	0.900
MMA5	Anjengo	11	18	Anjengo	9	1.300
MMR1	Aratory	15	14	Aratory	14	0.875
MMV1	Vycome	13	9	Vycome	8	0.740
MMV2	Vycome	12	4	Vycome	4	0.400

There are two types of coir mats (geotextiles) available: non-woven mats and woven mats. Non–woven mats are made from loose fibres, which are interlocked by needle punching or rubberizing. Woven mats are available in different mesh openings ranging from 3 to 25 mm. A higher density means a tighter mesh and less open area. Over the years many varieties have been developed in India and are now commercially available in different mesh matting with international trade names such as: MMA1, MMV1, MMR1 etc., where MM stands for mesh matting and A, V or R stands for the name of yarns based on the place of origin. Manufacturing details of different types of coir geotextiles are given in Table 5.2.

5.5 Engineering properties of coir geotextiles

Balan (1995), and Rao and Dutta (2005) studied the tensile strength behaviour of woven and non-woven coir geotextiles with different samples under different deformation rates and different aspect ratios. The influence of aspect ratio (from 1 to 8) was studied with 200 mm wide specimens, by varying the length from 25 mm to 200 mm. The influence of width was studied by varying the specimen width from 25 mm to 200 mm, keeping the length constant at 100 mm. Rao and Dutt (2005) used four different varities of woven geotextiles with density varying from 0.34 kg/m^2 to 1.34 kg/m^2 and non-woven geotextiles with density varying from 0.39 kg/m^2 to 0.65 kg/m^2 Balan (1995) used woven geotextiles with a density of 1.75 kg/m^2 and non- woven geotextiles with a density of 0.90 kg/m^2 In both studies, results clearly reveal that woven products exhibit higher strength compared to non-woven products and tensile elongation at failure is higher for the non-woven geotextiles. The ratio of width to length (aspect ratio) does not have any influence on the tensile strength within the range tested. The results also indicate that there is a fair level of uniformity in the specimens, despite the variation that could be expected in a natural material (Balan, 1995; Rao and Dutt, 2005). With regards to the durability study, jute and coir can have a life of more than one and two-three years respectively (Rao and Dutt, 2005). Coir has the highest tensile strength of any natural fiber and retains much of its tensile strength when wet. It is also very long lasting, with infield service life of 4 to 10 years (English, 1997). The reason for the greater strength of coir is its high lignin content (Rao and Balan, 2000). Because of its high tensile and wet strength, coir matting can be used in very high flow velocity conditions (English, 1997). Tests conducted by Schurholz (1991) on jute, sisal, coir and cotton over a prolonged period of time in highly fertile soil maintained at high humidity (90%) and moderate temperature revealed that coir retained 20% of its strength after one year whereas cotton degraded in six weeks and jute degraded in eight weeks. According Schurholz, coir can better withstand traction effect due to flooding than any other natural fabric. Alternate drying and wetting of coir yarns did not accelerate the degradation of coir samples as it was observed that coir retained 30% of its original strength after one year (Balan and

Rao, 1996). Its water absorption varies from 12% to 25% under 65 % and 95 % humidity. When coir geotextiles were fully soaked in water, it absorbs 40 % of moisture (Balan, 1995). This hydroscopic property helps to retain soil moisture in field application. When the coir gets degraded in the soil over time, it adds fertility to the soil.

5.6 Coir geotextiles in India and abroad

The growing awareness and concern over the impact on the environment of the use and disposal of synthetic material has recently led to renewed interest in the possible advantage of natural fibres (Ranganathan, 1994). The high cost of synthetics has limited the application and widespread use of geotextiles and related products in India (Datye and Gore, 1994; Kaniraj and Rao, 1994). From 1989, against an estimated worldwide consumption of more than one billion square metres of geotextiles per annum, the Indian consumption was an insignificant 0.5 million m^2/a (Natarajan and Rao, 1989, cited in: Kaniraj and Rao, 1994). Several universities and research institutes in India have pursued research on geotextiles and their applications. But most of them are laboratory works on the use of geotextiles. Field studies have been inadequate (Mandal, 1987; Rickson, 1995). The use of coir geotextiles in various field applications in India and abroad has been reviewed and detailed in this section.

Soil erosion is one of the most serious problems facing mankind today. On impact with an unprotected soil surface, raindrops loosen the soil particles, causing an incremental movement of the suspended particles down slope. Soils are susceptible to erosion by flowing water even at very low flow rates. If the energy of falling rain can be absorbed or dissipated by vegetation or some other soil cover or surface obstruction, the energy transfer to the soil particles will be reduced and hence soil erosion. In India, about 27% of the land is subjected to severe soil erosion and the annual loss is estimated at 1.6 kg/m^2 (Lekha, 2004). Theisen (1992) stated that soil loss is a continually occurring process in natural ecosystems and successfully reclaimed sites. The goal of any revegetation or erosion control project should be to stabilize soils and manage erosion in an economical manner (Theisen, 1988, cited in: Theisen, 1992). When geotextiles are used, they absorb part of the impact and kinetic energy of raindrops and reduce surface runoff. Also seeds and vegetations are protected from being washed away (Anil, 2004). Rao and Balan (2000), in their erosion control study, showed that coir geotextile (MMA3 and MMV2) is capable to prevent surface erosion of particles along the surface of a slope and facilitates the sedimentation of soil on previously exposed rock surfaces. Even after seven months, the matting retained 56% of its original strength against the reported value of 56% reduction in strength in six months by Oostbuizer and Kruger (1994) cited in: Rao and Balan (2000). Figures 5.5 and 5.6 show the vegetation growth on a rock surface on application of coir geotextile.

Figure 5.5 Laying of coir geotextiles on rock surface

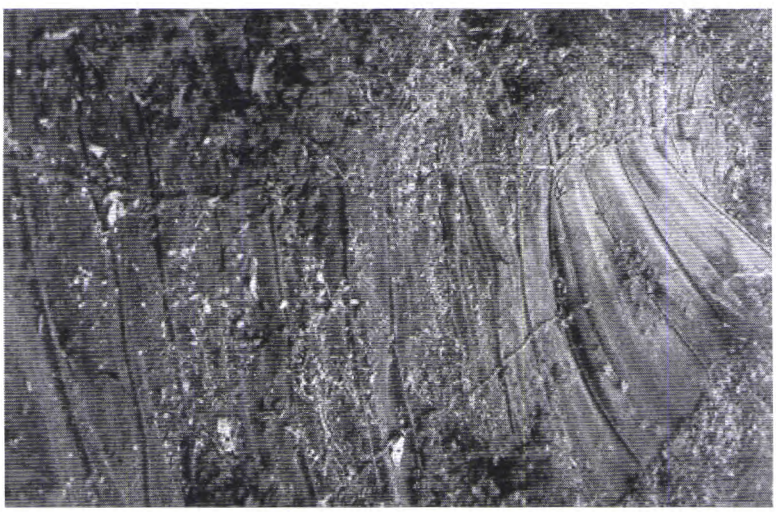

Figure 5.6 Establishing vegetation on rock surfaces treated with coir geotextiles

Anil and Sebastian (2003) in their study using coir geotextile (MMV1) on different slopes show that there is considerable reduction in soil erosion in the treatment plots. In the treatment plots with a slope of 20%, soil conservation was 77 times higher compared to control plots; on a slope of 30-40% it was 17 times higher. Also there is considerable reduction in the time that it takes for the different treatments to achieve slope stabilization. Plots with geotextiles stabilized earlier than the control plots. Reduction in soil loss is mainly due to the coir matting, which reduces the raindrop impact as it intercepts the direct contact with soil. Lekha (2004), in her field trial using coir geotextile (MMA3) for slope stabilization, observed that after seven months of laying, coir retained 22% of the strength of a fresh sample. Also the reduction in soil erosion and increase in vegetation is significant in plots treated with geotextile. Thomson and Ingold (1986) through their study revealed that geotextiles can be used in combination with vegetation to provide a composite solution of soil erosion control.

Balan (2003) presented a field trial carried out in Kerala using coir geotextiles. A study was carried out in a watershed in Idukki district. Gullies of 3-4 m wide at the top and 0.5-0.8 m wide at the bottom with an average depth of 1.5m were plugged using coir geotextiles (MMR1) at an interval of 10m. After one monsoon season, gullies on the upstream side had a siltation of 45cm and on the downstream side a siltation of 10cm. Figure 5.7 shows the gully plugging with coir geotextiles.

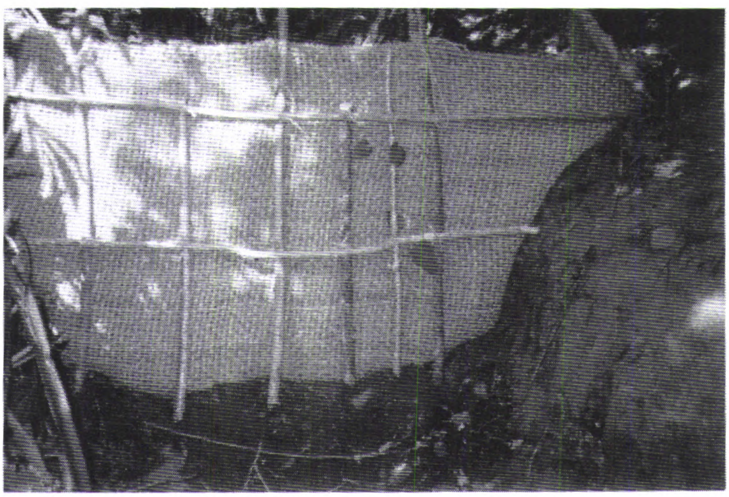

Figure 5.7 Gully plugging using coir geotextiles

Lekha (2004) observed that coir netting spread over seeded slopes shields the soil and seeds until the field is permanently stabilized with vegetation by providing a physical barrier between the soil particles and rainwater. She also observed a 32% increase in the organic carbon content on the protected slope compared to a non-protected slope during the monsoon period, which is the most critical season as regards loss of nutrients. The high accumulation of organic matter in the protected plot is because nutrients are preserved from leaching away due to the binding effect of the plants and the arresting of overland flow by the geotextile. In addition, the bio-degradation of the coir fabric adds to the organic content of the soil.

A field study conducted by Sudhakaran (1994) showed that coir geotextiles are effective in riverbank protection and also that it is economical in its use with 50% reduction in cost compared to the conventional gravel lining. Other successful case studies in the application of coir geotextiles for river bank stabilization around the world are given below.

- Cammack (1988) reported the use of coir geotextiles in the Noora basin in Australia, for causeway protection to prevent wave-lap erosion in saline water condition. He also reported the successful case study of Gooburrum main canal bank protection using coir geotextiles.

  Lee (2001) through his case studies revealed that coir geotextiles and coco logs were widely used for river training works in Korea.

  Schurholz (1992) illustrated various field trials using coir geotextiles in Germany. It includes stabilization of a creek bed and its bank using woven geotextiles, river bank stabilization and revegetation of shore lines by sedimentation.

  Sotir and Simms (1991) illustrated case studies of river bank stabilization using coir geotextiles in USA. In Longfellow Creek Bypass channel, coir geotexiles with selected plants were used to stabilize trapezoidal channel slopes. Results show that the use of coir geotextiles in and along streams and river bank protection, and for the establishment of healthy riparian zones for aquatic enhancement appears to be a viable alternative.

  White (1991) reported various control techniques adopted by the Illinois Department of Conservation for the control of stream bank erosion of the Crow Creek. Coir geotextiles were found to be the most effective and environmentally sound biotechnical application to effectively enhance our environment.

5.7 Conclusion

There is always a strong link between land and water management. Many measures are implemented primarily to one or the other, but both serve the same purpose. Reduction of surface runoff by structures or by changes in land management will also help in reducing soil erosion. Conservation measures taken for the reduction in soil erosion will reduce the velocity of overland flow, prevent splash erosion or formation of surface crusts or break down of structures, all of which will increase infiltration and thus enhance water conservation.

From the limited literature available, it is evident that coir geotextile is capable to reduce soil erosion. Coir geotextile has an open area of 40 to 70 percent. Hence it allows the growth of grass and provides a large number of miniature porous check dams per square metre of soil. It slows down and catches runoff so that sediment settles and water either passes through the matting or percolates into the underlying soil. As geotextiles degrade, they provide mulch and conserve moisture for plant growth. These properties of coir can be used for an efficient management of land and water in the context of sustainable watershed management. Coir is biodegradable, environmentally friendly and at the same time cost effective. In this decade, it is necessary to identify farmer-friendly technology options which are affordable and acceptable to the farmers to adapt a technology with locally available material for the management of land and water conservation. Results of the field experiment conducted using coir geotextiles in Kerala are presented in the following chapter.

Chapter 6 Experimental study using coir geotextiles in watershed management[1]

The fourth research question is answered in this chapter, which presents the results of the field experiments conducted in Kerala, South India, to test the effectiveness of coir geotextiles in watershed management. It also illustrates how participatory research was carried out on the introduction and use of coir geotextiles for soil and water conservation.

6.1 Participatory research using coir geotextiles for embankment protection - a case study in a midland region of Kerala

6.1.1 Importance of participatory research

From the case studies explained in Chapter 4 and the knowledge gained from Chapter 2 and the conceptual framework, it is clearly evident that the involvement of people is essential for the success of watershed management. Through joint experimentation with the people, participation can be enhanced substantially contributing to a project's success. By participatory research beneficiaries receive training and experience in the design, implementation and evaluation of experiments. In this way their capacity for innovation can be substantially increased (Johnson et al., 2003). Bunch and Lopez (1999), through their study revealed that, for farmers to accept soil conservation technologies, the technology should enhance yields. It is the increase in yield that convinces the farmers of the value of soil conservation. If the yields have increased or costs have decreased, artificial incentives are not required. On the other hand if yields have not increased, no artificial incentive will make the adoption of the technology sustainable. Hence it was decided to conduct the experimental study with people's participation and the results show that through experimentation with people, people can visualize directly the impact of the introduced technology. In addition it helps to develop innovation capacity both for individuals and communities.

6.1.2 The subject of research

Detention ponds are traditional water conservation structures used for drinking, domestic and irrigation purposes in Kerala, and they are the major water source for the village community. These ponds also act as an infiltration basin or recharge basin, which enhance groundwater recharge. In almost all micro-watersheds there is one village pond which is under the control of the local government called a Panchayat. During monsoon, the side banks of these ponds erode and the ponds get silted up. The same silt from the pond is subsequently used to restore the side banks but it is often eroded before

[1] Based on: Vishnudas et al. (2005d, 2006e, 2006f)

vegetation can establish. Hence continuous maintenance is required for deepening and desilting of ponds to maintain their water holding capacity. Neither the local government nor the community may have enough funds for these labour intensive works. Ultimately the ponds get filled up and deteriorate and the area becomes subject to water shortage during the summer season and even during dry spells.

Most watershed projects meant to support communities propose conventional stone bunds for soil and water conservation. However, the majority of the people cannot afford these structures without support from the government. Hence it is interesting to look for an alternative material which is effective in reducing soil erosion, enhancing soil moisture and vegetation growth, and which at the same time is economically attractive and can be manufactured locally. The aim of this experiment was to study the effectiveness of coir geotextiles for embankment protection and to provide an alternative, cost effective option to reduce soil erosion, increase vegetation growth and increase soil moisture availability.

6.1.3 Study area

The Amachal watershed in the Trivandrum District, in the western ghat region of Kerala, has been selected for the experimental study to test the effectiveness of using coir geotextiles for embankment protection. Details of this watershed have been explained in Chapter 4. During the field study, peak rainfall in the experimental period is observed in the month of October (429 mm/month) followed by June (243 mm/month). Rainfall events are generally of high intensity and short duration especially in the southwest monsoon. This rainfall typically is in the form of an evening shower with a clear sky during the day. The mean annual temperature is 26.5°C. The area experiences a humid tropical climate with the relative humidity varying from 62-100% (GoK, 2002d).

6.1.4 Methodology adopted for implementation

A meeting was held on 23-12-2003 with watershed committee members to identify a suitable area for experimentation. Watershed committee members included all stakeholders, government officers, administrative ward members, members of the local government and the members of the User Association. The site chosen for the study was the main village pond (explained in Section 6.1.5). A watershed community meeting was held on 05-04-2004 and a technical session was held on the same day on the application of coir geotextile for erosion control. Experimentation started on the 17-05-2004. The banks of the pond were evened and debris was removed. Training for installation of coir geotextiles was given to selected labourers of the community, who were registered in the Watershed Committee. Installation of geotextiles started on 19-05-2004. Being a new technology, the committee was not fully confident in its feasibility. On the first day, the committee only provided eight labourers and as a result only a small portion of the work could be completed. Fortunately, there was a heavy downpour on the second day. The entire community saw the effect of the reduction in soil erosion in the treatment plot. On the third day, the watershed committee provided forty labours to complete the work. Work was started at 6.30 hrs and the work was completed at 19.00 hrs, covering the entire area treated with coir geotextile of 1100m^2 Figures 6.1 and 6.2 show the photograph of the immediate impact on the treated plot and the control plot on the third day of installation.

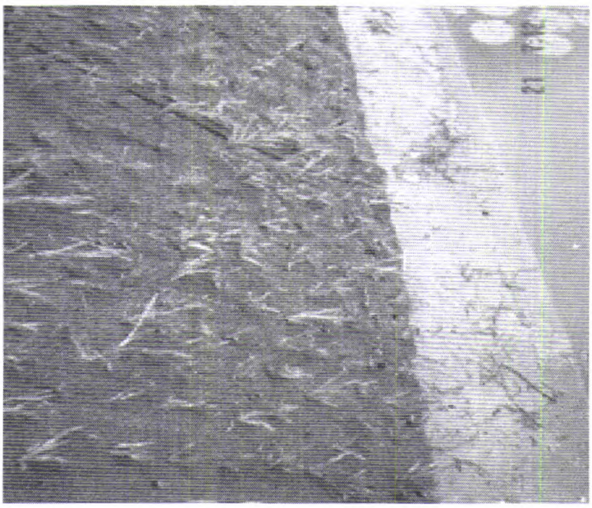

Figure 6.1. CGG, third day of installation

Figure 6.2. CP, third day of installation

6.1.5 Experimental setup

(i) Materials

Coir is used in this experiment as a temporary erosion control measure to facilitate the establishment of vegetation and to stabilize steep slopes such as embankments of ponds. Coir matting selected for the study is MMV1 with the smallest mesh opening of 6 x 6 mm^2 and a density of 0.74 kg/m^2 The tensile strength of fresh geotextile is 13.8 kN/m. The selection of material was based on the steepness of the slopes. Literature shows that for higher slopes, geotextiles with small mesh openings are better to reduce soil erosion and absorb the impact of raindrops.

(ii) Field layout and installation techniques

A village pond in the watershed has been selected for the field experiment. The side banks of this pond become eroded even during summer showers. The type of soil is silty sand. The capacity of the pond is 48m x 123m x 2.1m.

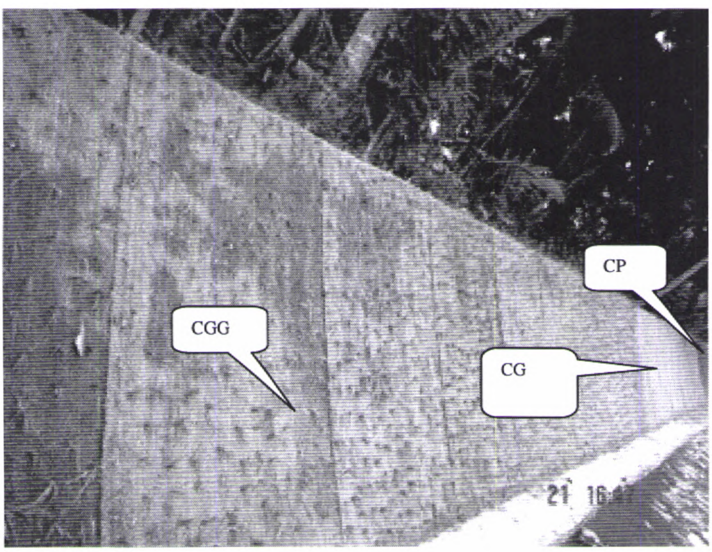

Figure 6.3. Side of pond with different treatments

The pond has a natural depression on one side. The water level in the pond fluctuates from season to season. The slope of the embankment is 70^0 The height of the exposed slope of the embankment is about 3 m. The length of the embankment varies from 3.1m to 3.5m. Erosion is caused by both rainfall and runoff. The limitation for providing a gentle slope to the embankment is that three sides of the pond are surrounded by existing village roads and the other side is a pedestrian road. Beyond the road on two sides, there are existing irrigation canal. Conventional method using rubble for the protection of the embankment is very expensive and hence the community opts for the vegetative measures. The experiment consists of three treatments (a) coir geotextiles with planted grass (CGG), (b) coir geotextile alone (CG) and (c) control plot (CP); replicated four times along the sides of the pond. Each side of the pond was divided in three equal parts for the three treatments. For all treatments a distinction was made between the upper and lower portion of the slope, because the people indicated that generally there is more erosion from the top of the slope if the slope is unprotected Figure 6.3 shows the side of the pond with different treatments.

Figure 6.4. Laying of geotextiles on the side bank of the pond

The coir was laid during 17-22 May 2004, just before the onset of the monsoon. The installation procedure followed was generally similar to that used for surface erosion control. All the vegetation was removed and the soil on the surface of the slope was well graded to remove unevenness, since any irregularity may allow water to flow under the matting and thus cause undercutting (Rao and Balan, 2000). Trenches of 30cm x 30cm were dug at the top of the slope to anchor the geotextile. Rolls of the matting were first anchored in the top trench and then unrolled along the slope. Anchoring was done using bamboo pins cut to a length of 25-30 cm, instead of iron hooks used conventionally. Pins were driven at right angles to the slope to anchor the matting. Each roll was given minimum overlap of 15 cm and anchored firmly with bamboo pins spaced in a grid of 1m spacing. Bamboo pins were also driven at the joints with a spacing of 1m (See Figure 6.4). At the bottom, matting was rolled in two layers and anchored with bamboo pins to hold the soil eroded if any and also to reduce the intensity of runoff. According to conventional practice, trenches were also dug at the bottom of the slope. After installation, matting was pressed to closely follow the soil surface. Trenches were backfilled and compacted.

(iii) Planting of grass

The common grass species *Axonopus compressus* was selected for the study. This species is used as fodder in this watershed. It was planted in the treatment plots at a spacing of 10cm.

6.1.6 Monitoring

Rainfall was measured using a self-recording rain gauge installed in the field. Soil moisture, vegetation, nutrient loss and bio-degradation of coir were measured from all the three treatments directly. A group of 60 people has been selected randomly from the user community living within the vicinity of the pond for monitoring and evaluation. The user community themselves developed indicators for the qualitative evaluation. They included length of grass, colour of grass, uniformity of grass, density of grass and soil erosion.

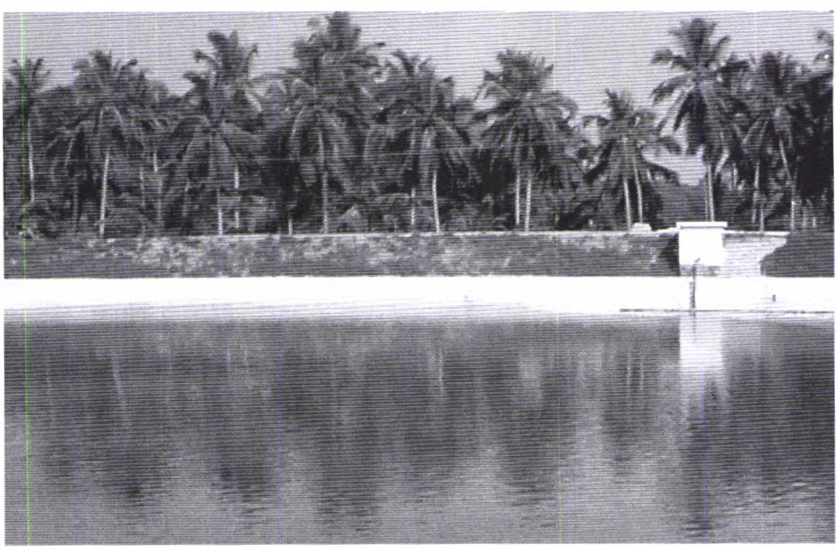

Figure 6.5. Pond before treatment

Data sheets were provided for scoring. In parallel, a quantitative study has been conducted with respect to rainfall, soil moisture and nutrient contents of the soil, vegetation growth and bio-degradation of the coir. Figure 6.5 and Figure 6.6 show the pond before and after the treatment.

Figure 6.6. Pond after treatment

6.1.7 Results and discussions

(i) *Soil Moisture*

Soil moisture was determined by gravimetric method from different treatment plots. Soil samples from 10 cm depth (*over the course of a growing season, plants extract about 40% of their water from the upper part of the root zone*) were collected monthly and its initial weight was recorded (w_1). Subsequently samples were dried in sunlight until a constant weight was obtained, which was considered as the oven-dry weight (w_2). Variation in soil moisture in different treatments with respect to rainfall is presented in Figure 6.7. Soil moisture was found to be declining subsequently during the observation period even with an increase in rainfall events (40-120 mm/day) in the month of October, due to the peculiarity of the southwest monsoon. Soil moisture in CGG is 21 % higher than in the control plot during the dry period. In CG, soil moisture is less than in CGG. This is because in CGG, *Axonopus compressus* is well established as a canopy reducing solar radiation. Whereas in CG, the area was invaded with the same natural vegetation as in the control plot and most of this vegetation consists of shrubs and broad-leaved plants. These plants dried up from December onwards, and less moisture was retained than in CGG. In CP, the density and uniformity of vegetation was much less along with the occurrence of soil erosion and runoff. Hence moisture retention was least in these plots. Soil moisture retained during the dry period in CGG, CG and CP experiments are in the ratio 1: 0.75: 0.21.

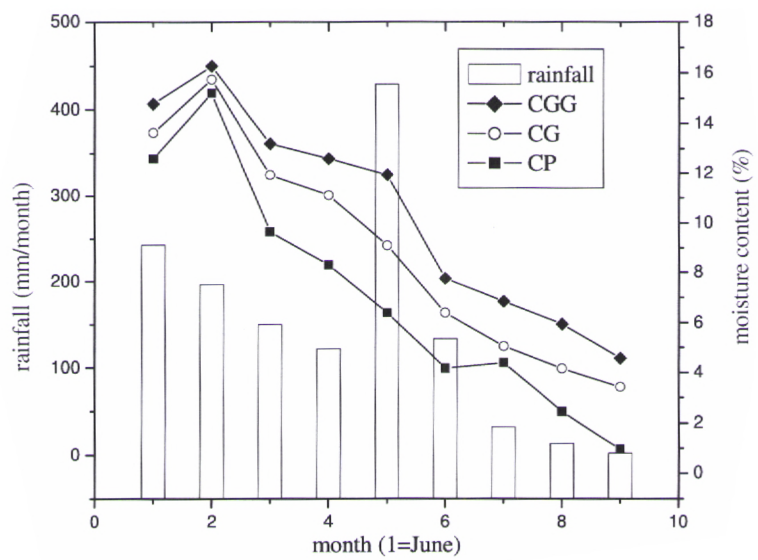

Figure 6.7. Variation in soil moisture with respect to rainfall

(ii) *Vegetation*

Coir matting installed to cover the soil surface provides ample opportunity for the growth of vegetation. Even degraded geotextile contributes to the organic composition of the soil and promotes vegetation. Length of grass, weed intensity, uniformity and density of grass has been considered as measures for vegetation growth. Within nine months, vegetation was well established and the slope was stabilized in the area covered with geotextiles. Average length of the grass of the same species as that in CGG is being measured from all the plots to compare the length of grass. The vegetation was protected from harvesting during the study period.

Figure 6.8 shows the variation in height of the vegetation at all plots. Growth of vegetation in CGG shows greater values than in CG. The control plot shows the lowest value. In CGG, vegetation established well before it started at CG and CP. In CG and CP, vegetation established with different varieties of weeds, whereas in CGG only *Axonopus compressus* was grown. This vegetation started drying up in December and even at that time the control plots were not stabilized. Intensity of plants per m^2 was identified from June'04 to Feb'05. Among the grasses *Axonopus compressus* and *Heteropogon contortus* alone survived after December. Maximum intensity was found to be of Axonopus compressus. Perception analysis of the response of participants on length of grass is explained in part (vi) of this section.

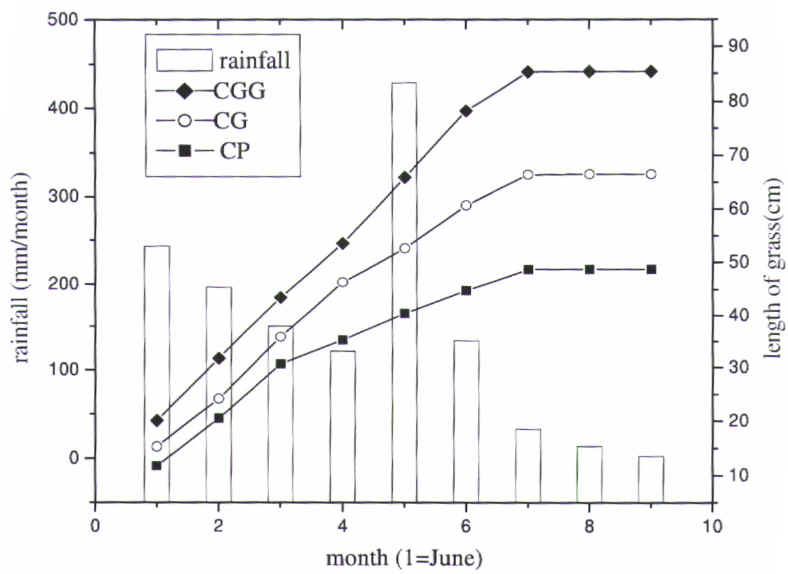

Figure 6.8. Length of grass (measured)

(iii) Biodegradation of coir

Biodegradation of coir was studied based on ultimate tensile strength of the matting collected from the field during the period. The tensile strength test is carried out using the wide-width strip tensile test for geotextiles, a uniaxial tensile test in which the entire width of a 200 mm wide specimen is gripped in the clamps and the gage length is 100 mm (ASTM standard D 4595-86). Figure 6.9 shows the degradation curve of the geotextile with respect to time. The coir retained 19 % of the strength of a fresh sample after nine months. After seven months, it was observed that tensile strength of geotextiles was reduced by about 70 %. By that time a sustainable erosion control measure by the establishment of vegetation was observed in the CGG and CG plots whereas erosion persisted in the control plots. Hence the increase in the rate of degradation during the period did not affect the effectiveness of coir geotextiles as an erosion control measure.

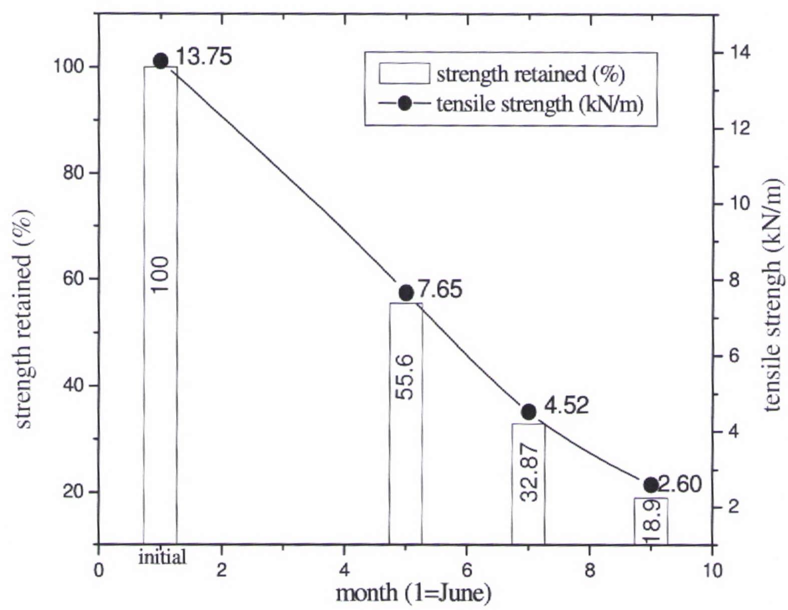

Figure 6.9. Bio-degradation of coir with time

(iv) Nutrient losses

High intensity rainfalls in the tropics result in top soil erosion. Soil samples from the surface (top soil) were periodically collected from the field and tested in the laboratory for Nitrogen, Phosphorous, Potassium and organic carbon. In all the plots, it was seen that loss in NPK and organic carbon was higher in CP than in the plots treated with coir geotextiles. The bio-degradation of coir fibre and reduction in surface runoff contribute to the improvement in the organic content in protected plot.

The net loss of nutrients during the study period in CGG, CG and CP are in the ratio 1: 1.3: 6.2 for Nitrogen, 1: 1.4: 3.5 for Phosphorous and 1: 1.4: 4.9 for Potassium. The loss in organic carbon in the three plots is in the ratio 1: 1.4: 2.8. Difference in values in CGG and CG may be due to leaching of nutrients in CG during the initial stage. Figure 6.10 and Figure 6.11 show variation in loss of NPK and organic carbon during the study period in the three treatments.

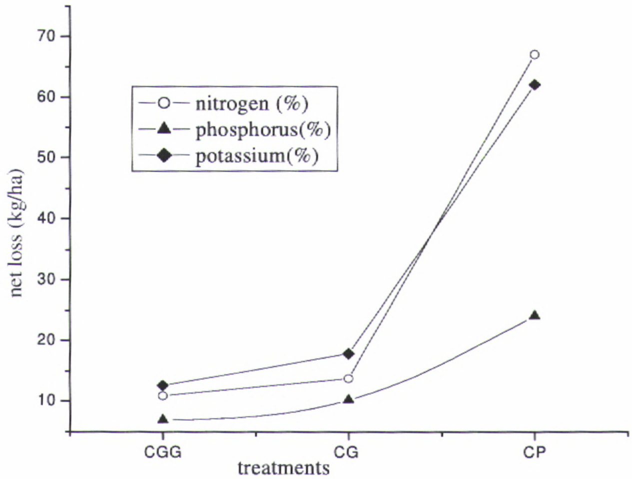

Figure 6.10. Net loss of NPK in different treatments, between May' 04 and February' 05

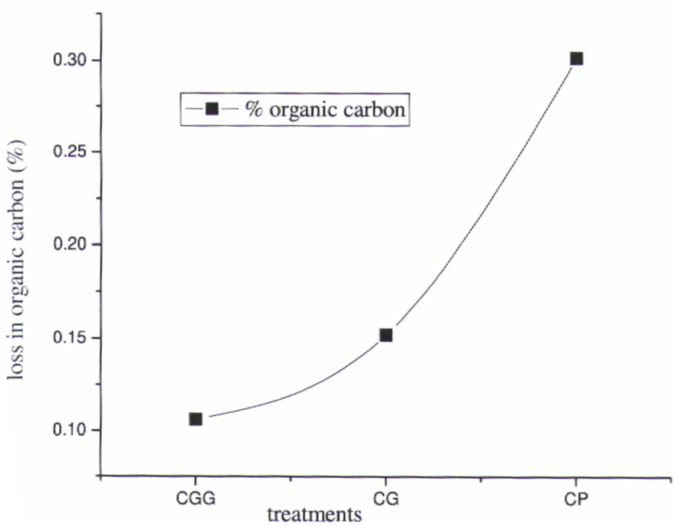

Figure 6.11. Percentage loss in organic carbon in different treatments between May '04 and February '05

(v) Cost analysis

Goshal and Som (1993) cited in: Kaniraj and Rao (1994) have presented an economical evaluation of the use of geotextiles from the Indian perspective. They compared the costs with synthetic geotextiles and conventional methods for typical geotechnical problems in four metropolitan cities of India. Even with synthetic geotextiles, it was found to be economical than the conventional practices. Hence, in developing countries like India, if the efficiency of natural fibers can be effectively utilized, where it is abundantly available, this will prove to be a sustainable and affordable solution in many applications.

In this study, the cost of construction includes materials, transportation and labour charges. By the conventional method of slope protection using stone pitching is 2.50 euro/m^2 However, by using coir geotextiles, the construction cost are less than 1 euro/m^2 which includes the cost of geotextile and cost for clearing the site, laying geotextiles and planting grass on the surface. Moreover, unlike conventional structures, this structure provides a means for cultivation of fodder or other crops for the rural poor.

vi. Perception Analysis of the response of the participants

As mentioned in (ii) of Section 6.1.5, people were asked to score indicator performance in the field in the range 10-50, with a maximum of 50 and minimum of 10. A score of '50' indicates 'good', '40' indicates 'more than satisfactory', '30' indicates 'satisfactory', '20' indicate 'less than satisfactory', and '10' indicates 'bad' As there will always be some impact of any technology in the watershed for soil and water conservation, the score '0' was not assigned. The perception of the people has been statistically analysed by ANOVA[1]. The monitoring was carried out for 9 months, with 3 treatments on 4 areas.

The key criteria in ANOVA for performance analysis are:

1. comparing the treatments A1 (CGG), A2 (CG) and A3 (CP), the degree of freedom (df)[2] = 2. For 5% significance the F[3] value is 3 and for 1% significance F = 4.6. The critical difference[4] (CD) for soil erosion is 0.9 and for growth of vegetation is 1.1.
2. comparing the effect of treatment over 9 months (B1= June), the degree of freedom (df) = 16 (2 x 8). For 5% significance, the F value is 1.7 and for 1% significance, the F value is 2.0.

a. Perception on soil erosion

In this study the F value obtained for soil erosion in the upper portion is 1763 and the F value obtained for soil erosion in the lower portion is 1684. With a F value of 4.6 at 1%

[1] ANOVA is a procedure to test for the difference in variability among treatments and between treatments
[2] Number of observations (n) in a sample that can vary freely, df= n-1
[3] F value is the ratio of the variance between groups to the variance within groups.
[4] Critical Difference (CD) is the minimum difference between a pair of means to be significantly different from each other.

significance, this shows that there is a highly significant difference between the three treatments. Figure 6.12 shows the mean response of the participants with respect to soil erosion in treated and untreated plots.

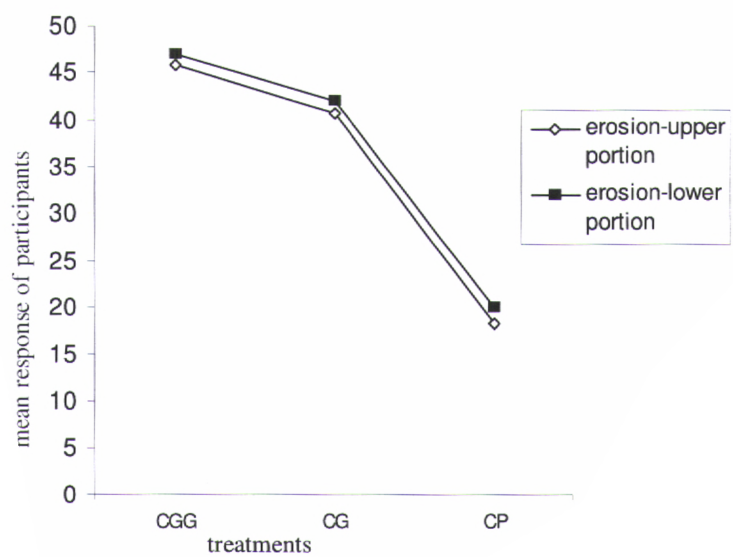

Figure 6.12. Analysis by ANOVA; response of participants on soil erosion from upper and lower portion of the sides of the pond

In the upper portion of the slope, the difference in the mean score between CGG (46) and CG (41) is 5, and the difference between CG (41) and CP (18) is 23. The mean difference between CGG (46) and CP (18) is 28. The critical difference (CD) = 0.9. This shows that treated plots are significantly different from the untreated plots and also that treatment CG is similar to CGG in reducing soil erosion from the upper portion. In the lower portion, the results are similar. The difference in the mean between CGG (47) and CG (42) is 5, and between CG (42) and CP (20) is 22. The mean difference between CGG (47) and CP (20) is 27. Figure 6.13 shows the mean response of participants in monitoring the effect of geotextiles in reducing soil erosion in the upper and lower portion as a function of time. Considering treatment (A) and time (B1-B9), degree of freedom df = 16; the F value for 5% significance is 1.7 and for 1% significance F = 2. In this study, the F value obtained for soil erosion in the upper portion is 50 and for the lower portion is 26. The figure clearly illustrates that there is considerable difference in reducing soil erosion from the upper and the lower portion in treated and untreated plots even at the initial stage. From this, it is evident that erosion persists in the control plots during the later stages, whereas the slopes of the plots treated with geotextiles stabilized with the establishment of vegetation.

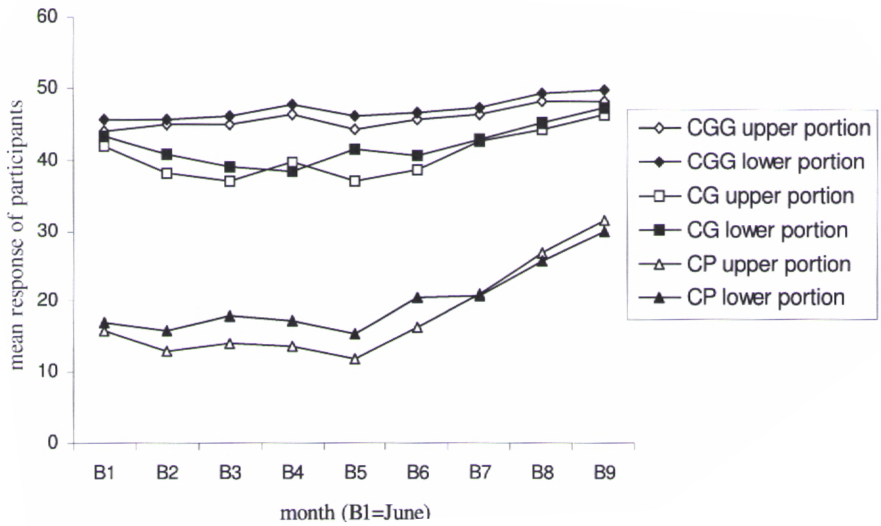

Figure 6.13. Analysis by ANOVA; response of participants on soil erosion as a function of time

b. Perception on growth of vegetation

The indicators developed for the evaluation of growth of vegetation were: the height of the vegetation (length of the grass), colour of the grass, uniformity and density of the grass. The height of the vegetation indicates the establishment of vegetative matter. Uniformity and density of vegetation indicates the ability of the surface to hold seedling from washing away. The colour of the vegetation is an indicator related to the nutrient content of the soil. In the control plots, top soil erosion was high and hence less colour of grass was observed. Whereas in treated plots, coir geotextiles acted as a surface cover which protected the slope from top soil erosion from the initial stage and retained more soil moisture than in the control plots. The biodegradation of coir also contributed to the nutrient content of the soil. Figure 6.14 represents the ANOVA analysis of the indicators that represent vegetation growth in treated and untreated plots. For the degree of freedom df = 2, the F value is 4.6 at 1% significance and at 5% significance F = 3. In this study, the F value obtained for the length of grass is 1321, and for the colour of grass is 1096. Uniformity and density of grass have an F value of 655 and 774 respectively. The mean response of participants shows that there is significant variation between the treated and untreated plots.

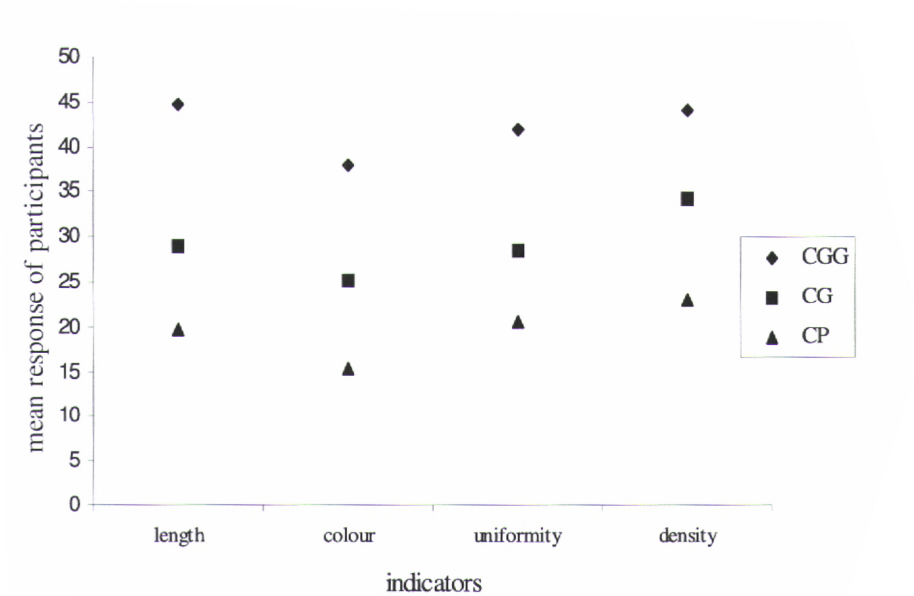

Figure 6.14. Analysis by ANOVA; response of participants on growth of vegetation

The average length of the sampled leaves, at any period, is assumed to be indicative of the vegetation growth at that period. The ANOVA table for the perceived length of the grass is shown in Table 6.1 (qualitative data).

In the CGG experiment, the length of the grass generally increased over the first four-five months. Minimum response on length of grass was noted in the initial months, and gradually it increased until the month of November. In this study the F value = 10.8, which shows that there is highly significant difference between treatments. Among the three different treatments significant increase in length of grass was observed in geotextile with grass plots compared to control plots.

Table 6.1 ANNOVA table; response of participants on length of grass, whole treatment

	B1	B2	B3	B4	B5	B6	B7	B8	B9
C1A1	32	35	42	45	47	46	44	42	36
C1A2	21	25	30	30	33	35	36	29	31
C1A3	13	20	22	20	23	19	17	18	28
C2A1	44	45	44	47	48	48	45	43	42
C2A2	39	41	32	34	35	30	21	25	28
C2A3	19	28	23	19	19	15	15	14	19
C3A1	46	47	49	49	48	49	48	46	43
C3A2	42	32	34	34	31	27	24	21	28
C3A3	30	30	21	18	19	18	15	16	19
C4A1	45	46	46	44	50	47	47	46	44
C4A2	31	29	26	21	24	19	18	23	24
C4A3	23	22	21	20	20	18	18	16	19

F= 10.8

A- Treatment, A1= CGG, A2 = CG, A3 = CP respectively, C- Sides of the pond, C1= North, B- Month, (1= June)

Since the F value for length of grass is 1321, the treatments are very effective and differences between treatments are highly significant. The mean value for treatment CGG is 44, for CG is 28 and CP is 19. The mean difference between CGG and CG is 15 and between CG and CP is 9, whereas mean difference between CGG and CP is 24, while the critical difference CD = 0.9. This shows that treatment CGG is significantly different from CP, and CGG and CG are significantly different from CP. This shows that variations in the height of vegetation in the three treatments were similar in both qualitative and quantitative analysis. The critical difference for length, colour, uniformity and density of grass is 1.1. In Figure 6.22, difference in mean observation between CGG, CG and CP is much higher than the critical difference. This is mainly because, by the time vegetation established in the treated plots planted with grass, natural vegetation was established in plots treated with geotextile alone. In the control plots, due to lack of protective covering, the slope was not stabilized due to erosion. Figure 6.15 to 6.17 show the photographs of the plots under different treatments.

Figure 6.15. CGG, thick vegetation after 7 months

Figure 6.16. CG, natural vegetation after 7 months

Figure 6.17. CP, less density, non uniform vegetation with soil erosion, after 7 months

6.1.8 Survey analysis

A survey was conducted in the watershed in April 2005 to evaluate the impact of the participatory research. The community revealed that the experiment improved their willingness to adopt a new technology and that it visualized the immediate impact of the technology. They also revealed that if coir geotextiles were used to strengthen the traditional earthen bunds, then they would not require skilled labour. Along with reduction in soil erosion and thereby increase in availability of water, they could plant fodder grass on these structures to feed their livestock.

Of the sixty respondents, 5% belonged to a higher income group, 35% to a middle income group and the rest to the economically weaker section. The higher income group did not have any specific preference for the conventional or innovative material for soil and water conservation. The middle income group preferred the coir geotextiles, because it requires less labour for construction and at the same time will provide fodder. The lower income group emphasized the adoption of this technology. If this would become the main-stream technology for soil conservation, user association could organize a society for spinning, yarning and manufacturing of geotextiles, as an income generation activity along with fodder grass cultivation. This would increase job opportunities in the watershed and hence provide a means for poverty alleviation. Again this technology requires only unskilled labour, implying that job opportunities would be available for both men and women. Higher income groups were of the opinion that this technology shall be included in the public works manual of the government, so that vegetated structures are also included in the manual. At present only structural measures are included in the government manual. Also they were of the opinion that if this technology can be successively promoted, coir geotextiles can be manufactured in User Groups and then it can be available at lower costs, so that cost per unit area can be reduced.

6.2 Coir geotextile for slope stabilization and cultivation – a case study in a highland region of Kerala

6.2.1 Subject of research

Soil erosion is a serious problem affecting crop productivity and the income of farmers in the highland region. High intensity monsoon rains, combined with the runoff energy that is generated on steep slopes contribute to high erosion rates. A sloping field is not only vulnerable to soil erosion it may also suffer from moisture deficiency. Slopeland farmers everywhere face similar problems. Conservation technologies may reduce soil and nutrient losses, and thus preserve water holding capacity and soil fertility, and make possible sustainable crop production on steep slopes, but the construction of physical structure like bench terraces are often labour intensive and expensive since both construction and maintenance requires high investments.

The effectiveness of terraces decreases mainly due to erosion. Hence there is a need for a technology that stabilizes bench terraces, which is simple, effective and economically viable. In this study efficiency of coir geotextile is tested as an alternative for expensive bench terraces.

6.2.2 Back ground study

Anil (2006) in an experimental study conducted under research condition using multi slot devices illustrated that at 40 % slope, the soil loss of a control plot is 12 % greater than the soil loss of a plot treated with coir geotextiles (MMA3). Of the total volume of 4.89 m^3 of water received as rainfall per square meter, 0.02 m^3 was absorbed by coir geotextile, 0.15 m^3 was lost as runoff and the remaining 4.72 m^3 was assumed to infiltrate into the soil. The plot size was 25m long along the slope and 5m wide. Balan (1995) in his study on the durability of coir geotextiles illustrated that when coir was embedded in soil, coir retained 43% of its strength in alkaline media at pH value =11 and 60% at pH value =3. Degradation was found to be faster between pH values of 6 and 8, the strength retained was 34% and 26% respectively. But the moisture absorption capacity of the geotextile increased as degradation advanced. After one year the moisture absorption of the degraded geotextile was 2.5 times that of the fresh sample. This property is of particular advantage in enhancing soil moisture and vegetation growth. These two studies formed the basis of this study under field conditions.

Figure 6.18. Conventional bench terraces with dry rubble packed bunds and earthen bunds

In Kerala, terraces are made initially with contour bunds constructed with dry rubble packing of 75 cm to 1.2 m high on slopes. These are constructed in such a way that the lower bund is level with the mid-slope between two bunds, so that a natural terrace forms after a few years of cultivation. By this time risers become deteriorated due to erosion and top soil is washed away. The maintenance of these structures was normally done by constructing earthen embankments on top of risers. (See Figure 6.18).

But these structures breech during heavy rainfall. Hence the conventional method does not help to enhance vegetation growth or productivity from the slope. A small initial movement in this unstable slope can trigger further soil water movement resulting in soil erosion and land slides. Thus cultivation in slopeland became difficult for poor farmers. Since slopes of more than 20% require physical measures for slope stabilization, in this study risers of the terraces are eliminated and slopes have been treated with coir geotextiles.

6.2.3 Study area

Initially a site was selected in the Attappady watershed for the field experiment. But due to delays in getting administrative go-ahead from AHADS, the experimental study was conducted in the Kumbazha watershed in the highland region of Kerala, in Pathanmthitta District (9° 51' 20''N, 76° 13' 54''E). It is in the western ghat region where 50 % of the total geographical area is covered by forests. This district is pre-dominantly an agricultural district with 75% of the people directly engaged in agriculture. The density of the population is $574/(km)^2$ It has an undulating topography, and hills have steep gradients. The main crops raised in this region are paddy, rubber, coconut and tapioca. In some regions, cashew, pineapple and vegetables are cultivated. Tapioca has been the staple food of this region over the last two decades for the small scale and poor farmers living upstream. Due to soil erosion, presently this tuber crop is not recommended in the highland region. Now they use rice as their main food which is supplied by the government with subsidy.

The climate is humid tropical with two monsoons. The temperature varies from 23°C 39°C. The relative humidity varies from 62-100% (GOK, 2003). The highest rainfall recorded in the year 2000 occurred in August (490mm/month) and in 2001 and 2003 it occurred in June (567mm/month) and July (601mm/month). Peak rainfall in the experimental period was observed in the month of August (419 mm/month) followed by June (265 mm/month).

6.2.4 Experimental set up

(i) Materials

Coir matting selected for the study was MMA3 with a mesh opening of 6mm x 10.5mm and a density of 0.70 kg/m^2

(ii) Field Layout and installation techniques

In order to ensure acceptance and practice of soil conservation by the farmers, a site has been selected in a farmer's field. Three plots were selected for conducting the experiment. The well demarcated plots were first leveled and debris was removed. Slopes of the risers were shaped to 40% slope and terraces were leveled with a gradient of 3%. The size of the plot is 5m along slope and 25m wide. The terrace width was kept at 5m. See Figure 6.19. The type of soil is forest loam.

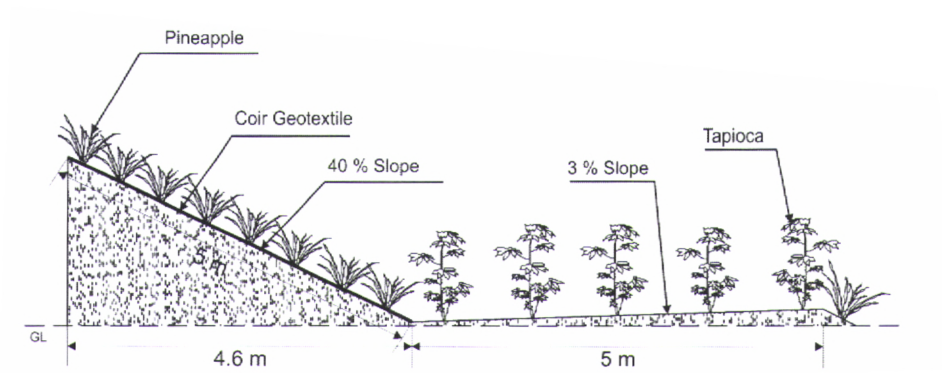

Figure 6.19. Cross section – slopeland cultivation; alternate conservation technique using coir geotextile

A narrow trench was made at the top and the bottom of the slope to anchor the geotextile. A roll of matting was slowly guided down the slope. The geotextile was stapled at regular interval using J-clips. 15cm overlap was provided at the joints. The three treatments were coir geotextile planted with crop (CGC), coir geotextile alone (CG), the control plot (CP).

(iii) Planting of crop

a) Selection of crop

The crop selection was made based on the farmer's interest. Tapioca being their staple food, it was selected as a food crop for the terrace. The crop for the riser was selected based on the following factors:

1. it should not cause any damage to the slope
2. the slope should not require maintenance for a minimum of four years
3. it should provide an income to the farmers
4. it should withstand drought and be adequate for the highland region

Considering the above factors, pineapple (Ananas Comosus) was selected as the crop for slope land cultivation. It is a tropical fruit with a worldwide market. Kerala is one of the major pineapple producing states in India, and India is one of the important pineapple growing countries in the world. This crop can withstand drought because of its ability to retain water in the leaves which is used during these periods. This plant has very low transpiration rates as it closes its stomata during the day and opens them during the night.

One main crop followed by two ratoons (basal suckers) is the usual crop cycle followed by farmers in Kerala. The economic life of a pineapple plantation is expected to be around 4 years and after the fourth year the plot needs to be uprooted and replanted. Farmers say that in the past they have maintained 3 to 4 crops over a period of 5 years.

b) Spacing

Tapioca was planted at a spacing of 1m x 1m. For the planting of pineapple the mesh of the geotextile was widened and planting pits were made with a stake. Suckers were planted at 10-15cm depth at a spacing of 45cm x 60cm and after two rows the spacing is 90 cm (see Figure 6.20). Care was taken while planting suckers not to disturb the weft and wrap of the geotextile as it may cause erosion.

Figure 6.20. Slope treated with coir geotextile planted with pineapple and tapioca on the terraces

Figure 6.21. Soil moisture determination using profile probe

6.2.5 Monitoring

Rainfall has been measured using a self-recording rain gauge installed in the field. The moisture absorption of the geotextile was measured as 5.6% of its weight. The efficiency of coir geotextile for reducing soil erosion was observed by the farmers in the adjacent watershed where the scientific study was conducted under research conditions by Anil (2006). The impact of the geotextiles on reduced erosion was not measured, it is assumed that it is of similar magnitude in this study. The soil moisture contents at 10cm, 20cm, 30cm and 40cm depth were measured in the treatment plot and control plot using a profile probe (see Figure 6.21) and results were analyzed with respect to the rainfall received during the observation period.

6.2.6 Results and discussions

Figures 6.22-25 show the variation of the soil moisture in the three treatments with respect to rainfall at varying depth. At 10cm depth during the dry season, the moisture content in CGC was found to be 32% more than that of CP. In the initial stages soil moisture in CGC was higher than CG. But in later stages, after 6 months, the moisture content in CGC is approaching that of CG. This is due to the absorption of moisture by the crop which grows better in CGC over the course of the growing season. The moisture content at 20cm, 30cm and 40cm are at higher rates in CGC and CG than in control plot. The variation in soil moisture is largely depending on the rate of transpiration and the establishment of the root zone. This effect is uniform in all the treatments till the permanent wilting point occurs. But this condition did not happen here and hence even in the summer season, crops can be sustained without irrigation.

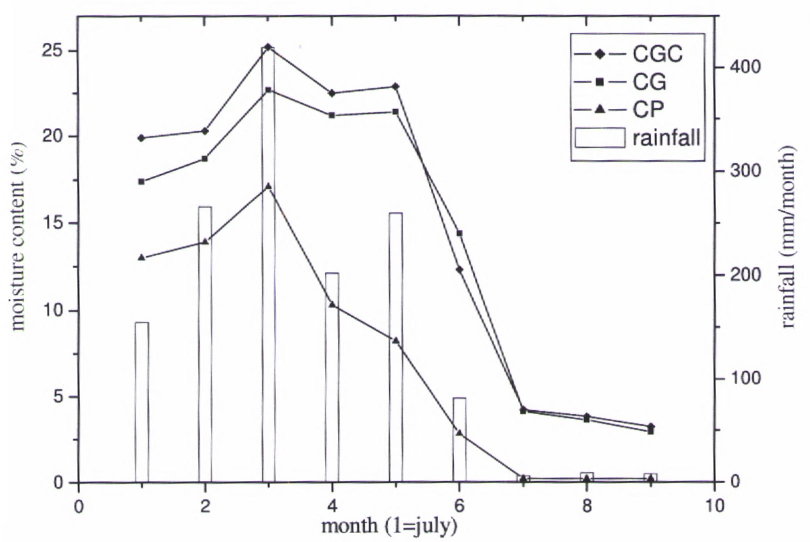

Figure 6.22. Variation in soil moisture at 10cm depth

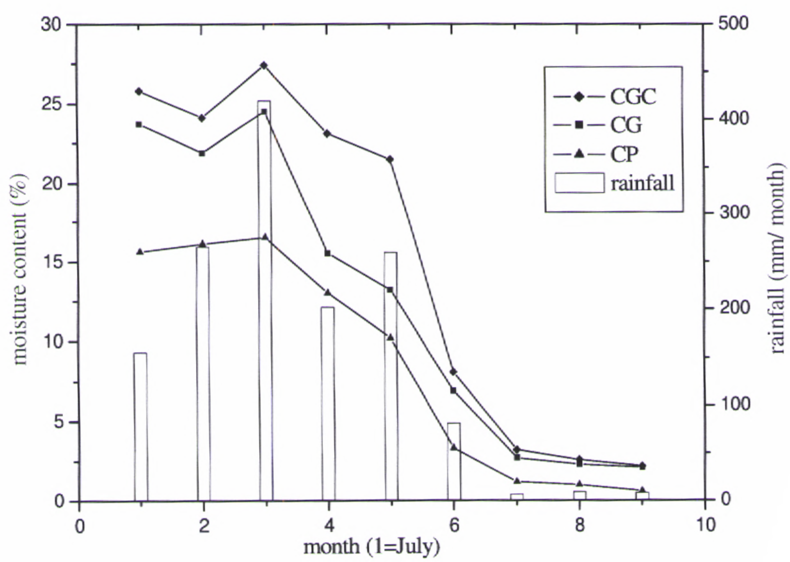

Figure 6.23. Variation in soil moisture at 20cm depth

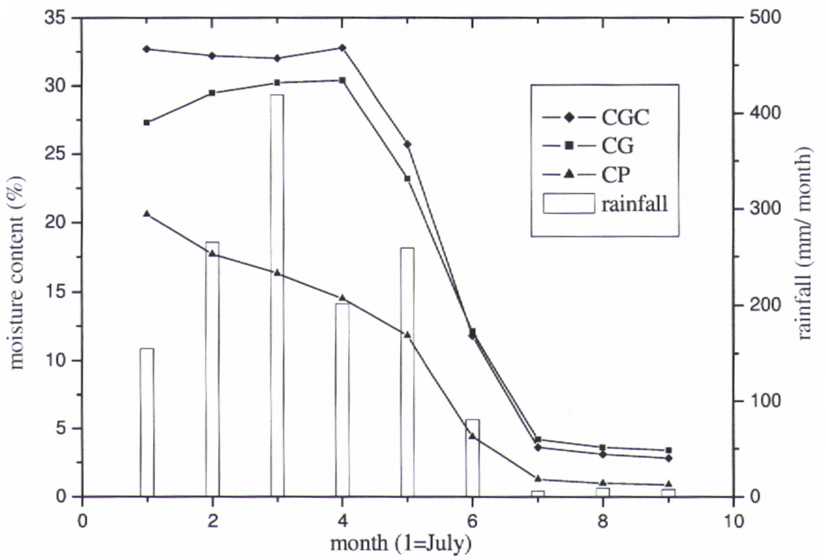

Figure 6.24. Variation in soil moisture at 30cm depth

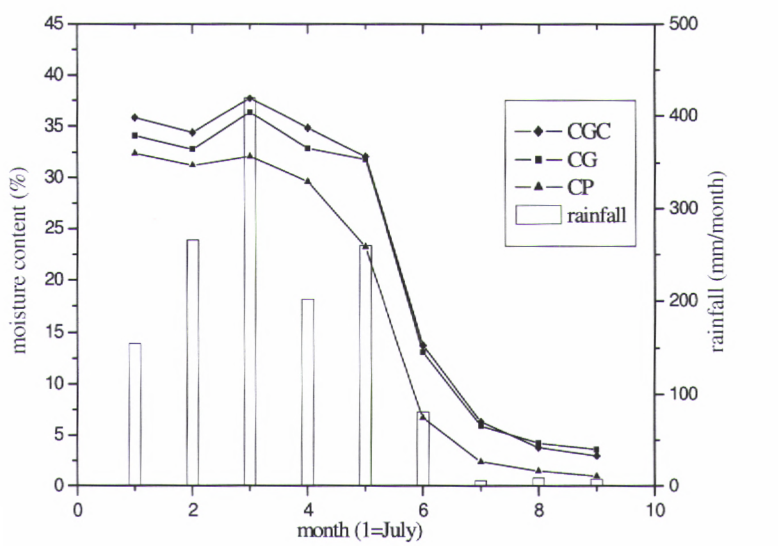

Figure 6.25. Variation in soil moisture at 40cm depth

The higher percentage in moisture content in the treated plot is due to the mesh opening in the geotextile. It provides a large number of miniature porous check dams per square metre of soil. It slows down and catches runoff so that sediment settles and water passes through the matting and infiltrates into the underlying soil. As the geotextiles degraded, they acted as mulch and conserved moisture for plant growth. The hygroscopic property of the geotextile also contributed to the increase in soil moisture. Hence from the experiment it was observed that coir geotextiles can retain moisture in the root zone and promote cultivation on the slopeland.

6.3 Conclusion

Field experiments, involving a local community in Kerala, have clearly demonstrated the effectiveness of coir geotextiles to stabilize banks of hydraulic structures and particularly the steeply sloping banks of a pond. The community was very enthusiastic about the effectiveness of the coir, particularly in combination with a local grass variety. The coir with grass appeared to be the most effective to prevent erosion, to retain moisture and nutrients and to facilitate grass growth. Moreover the slope with grass was productive in providing fodder. The degradation of the natural fibres over time did not result in any loss of effectiveness. On the contrary: the fibre contributed to the natural fertility of the soil after the vegetation cover was well established and the geotextile was no longer needed for bank stability.

The qualitative analysis shows that the perception of people on various indicators is significantly different between plots treated with coir geotextiles and control plots. The analysis proves that the perception of the user community is similar to that obtained from the quantitative analysis. This demonstrates that through participatory research, farmers can work in close association with researchers and gain knowledge through their involvement in the experiments. As a result, they study the direct impact of the new technology themselves and more readily adopt successful technologies.

The experiment in the highland region aimed at providing an alternative for bench terraces to stabilize the slopes for cultivation. From the results it is evident that the slopes treated with geotextile and crops have the highest moisture retention capacity followed by geotextiles alone and then the control plot. The application of geotextile on slopeland increases moisture availability in the soil and enhances infiltration. Since the slopes were stabilized with the application of geotextiles, sediment deposits on the terraces due to erosion were minimized and hence cultivation is possible both on the slopes and terraces. As the poor and marginal farmers occupy the highland region, this method provides an economically viable option for income generation and food security along with slope stabilization. This method can also be applied to wasteland cultivation in the highland region.

Persistent poverty and environmental degradation demand a constant effort to improve the effectiveness and impact of agricultural and natural resource management research. Poor farmers are often trapped in situations where they are degrading their natural resources and lack access to more productive and sustainable technologies. The main reason for this is that available technology is often unsuitable for them given their objectives and constraints. Farmers readily adopt a technology when they have experienced the positive research outcome. This reduces the adoption time, and can bring significant increase in yield, or decrease in labour costs, helping to enhance productivity, sustainability and improvement of livelihood. The relative cheapness of the material and the potential for producing and laying the matting with local labour makes the use of coir geotextile a very attractive option for sustainable development scenarios in watershed management.

Chapter 7 Conclusion

Have the research questions been answered?

This research aimed at studying the conditions under which sustainable watershed management is possible in Kerala, South India and more particularly to exploit the potential of coir geotextile as a locally available and affordable solution for sustainable land and water management. The study was conducted based on the hypothesis that a sustainable watershed management is possible in Kerala with people's participation and by using locally available materials and local techniques. The hypothesis was tested and found to be true in the context of sustainable watershed management in Kerala.

From the lessons learned from India and the rest of the world in the field of watershed management (Chapter 2), a conceptual framework was developed and tested as the analytical tool for the sustainability analysis of two watershed projects in Kerala (Chapter 3).

The analysis shows that the weakest shackle in the chain appears to be the economic sustainability of the projects. In both case studies (Chapter 4), due to high cost of construction, soil and water conservation can be done only with external financial support (from the government).

Experiences with using natural fibres (Chapter 5) show that coir can be used for an effective management of land and water in the context of sustainable watershed management. The experimental study using coir geotextiles (Chapter 6) clearly demonstrated its effectiveness in strengthening small watershed structures. Along with providing surface cover to the slopes, it helps in establishing vegetation, and it increases the fertility of the soil. Once the vegetation is established, the geotextile is no longer required for the stability of the structure. It has an immediate effect on reducing soil erosion, absorbs kinetic energy of raindrop impact and hence reduces runoff, and enhances infiltration. The study has also shown that coir geotextiles can replace expensive bench terraces in the highland region.

The results of the participatory research carried out in the Amachal watershed (Section 6.1) show that incorporating farmers in an innovation process helps them to address their own problems as well as seek appropriate information when necessary. Also the participatory approach enables the community to visualize and evaluate the impact of innovative technologies.

Is coir an attractive material for soil conservation in community managed watersheds in Kerala?

Coir is an agriculture fibre which is abundantly available in Kerala. The efficiency of coir geotextiles to increase moisture availability in soil enhances cultivation in the slopeland.

It is an affordable material and also easy to install. Fibre extraction to yarn making of coir is being done in cottage industries. The coir industry is labour intensive and provides employment to more than five hundred thousand persons in Kerala alone of which women constitute 80 per cent. Coir geotextile manufacturing units can be started in self-help groups which can be registered suppliers to Watershed Development Agencies in the State. Thus an economical linkage can be made between self-help groups of coir workers and watershed committees. Unlike other conventional soil and water conservation structures, this structure itself provides land for cultivation. Thus land used for conservation measures can also be effectively utilized. Therefore coir geotextile provides a livelihood and an important source of food security for many farmers in Kerala.

Is people's participation essential for successful and sustainable watershed management?

The thesis has shown that the role of the community in watershed projects is crucial. Since people are closest to the real problems, while planning watershed projects, they should be involved all the way from problem identification to decision making. From the case studies it is evident that in the context of watershed management, projects can use different type of participation at different stages. As watersheds are unique in all aspects, the right type of participation can be decided based on the characteristics of the watershed.

Conventionally, researchers and scientists conduct experiments in the laboratory or research institutions after which it is directly implemented or recommended to the people through development projects. But such a technology may not be adopted by the people beyond the project duration, often because the technology was not appropriate or was imposed on farmers. The result of the participatory research carried out in the Amachal watershed proves that science and technology are socially constructed. It has been shown that actively involving people in experiments enhances their ability in selecting new technologies. In many instances farmers have adapted existing technologies to their situations, and developed interesting improvements. Watershed management projects could benefit from such local innovations and access their suitability for wider implementations rather than recommending conventional technologies.

Again to become sustainable, watershed management should be considered as a process of property creation, because ownership and responsibility of land and water conservation nearly always coincide. When new conservation measures are implemented in a watershed, new relationships among people related to these objects of property emerge (Coward, 1986a, b). If the external agencies implement projects with people's participation, people feel that they own them and they are responsible for the operation and maintenance. Thus institutions that deal with the management of watersheds should adopt an 'entitlement' perspective.

Sustainable Watershed Management - an illusion or reality?

The word 'sustainable' in the context of watershed management can become a 'reality' as long as the chain of sustainable watershed management remains intact. For a watershed to be used sustainably, four main elements need to be considered: natural resources, technology, institution and economics. A suitable metaphor for these four elements is a chain of shackles, the chain being as strong as the weakest shackle. If one of the shackles is weak and breaks, the entire system will collapse. The factors in each element of the chain can compensate each other to attain sustainability of that element. But there cannot be any compensation between each element in the chain. Hence care should be taken by the implementing agencies to evaluate ongoing projects in order to identify those elements that need attention. From the case studies it was inferred that Sustainable Watershed Management becomes a reality by implementing economically viable technology options and by letting the affected/interested people participate in all levels of planning.

Recommendations

a. Watershed projects are generally evaluated after completion to assess whether the project was a success or a failure. In addition watershed guidelines are formulated taking into account the experiences of successful case studies. However in formulating guidelines for watershed projects, important knowledge can be gained from failures. In so doing projects can be made successful. The conceptual framework developed in Chapter 3 can be applied for the sustainability analysis of watershed projects (completed/ ongoing) implemented under different schemes. Subsequently, based on these findings, guidelines for new watershed projects can be made less rigid and more responsive to the specific contexts in which they operate. As an example may serve a finding of Chapter 4, which recommends that the manual of the Public Works Departments should not only include guidelines for structural approaches (check dams, etc.) but also should include vegetative measures.
b. Coir geotextiles have been used successfully for erosion control purposes in India and abroad. But not many scientific studies are available for the proper selection of the material. In-field suitability of coir application may vary with respect to the type of soil, moisture retention capacity, infiltration rate and nutrient content of the soil, and the physiographic and climatic conditions of the region. Our experimental study using coir geotextile was conducted at a plot scale for only a short duration. Long term studies into field conditions are to be conducted to measure the impact under various soil and climatic conditions.

c. Moreover, participatory research is required for assessing the acceptability of coir geotextiles when implemented at a wider scale under geophysical and climatic conditions that differ from the field sites investigated in this thesis.

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