PARTICIPATORY GEOMATICS IN PROCESS BASED WATERSHED DEVELOPMENT

Thesis
Submitted in partial fulfillment of the requirement for the degree of
DOCTOR OF PHILOSOPHY

By

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DECLARATION

By the Ph.D Research Scholar

I here by ***declare*** that the Research Thesis entitled **Participatory Geomatics in Process based watershed development** which is being submitted to the **National Institute of Technology Karnataka, Surathkal** in partial fulfillment of the requirements for the award of the degree of **Doctor of Philosophy** in **Applied Mechanics & Hydraulics** is a ***bonafide report of the research work carried out by me***. The material contained in this research thesis has not been submitted to any University or Institution for the award of any degree.

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CERTIFICATE

This is to certify that the Research Thesis entitled **Participatory Geomatics in Process based watershed development** submitted by **Diwakar P G** (Register Number: AM06P03) as the record of the research work carried out by her is *accepted as the Research Thesis submission* in partial fulfillment of the requirements for the award of degree of **Doctor of Philosophy**

Research Guide

Dr. S G Mayya

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Abstract

Watershed, being a hydrological unit, has its importance as a physical, biological and socio-economic entity for planning and management of natural resources. Optimal use of land and water resources in a sustainable manner results in long-term benefits to the society. Developmental activities in rural areas for resource conservation are recognized as one of the major challenges and also a complex problem to deal with. Watershed development has been in vogue for a long time and several developmental programmes have been implemented over time, but there is a need to review the conventional methods. Remote Sensing and Geographic Information System technologies are well established in these areas. Further, it is noted that community participation in the developmental process, along with monitoring and evaluation, plays a key role. Considering that about 70% of Indians live in rural areas and large proportion of these areas depend on rain fed agriculture, spread over different agro-climatic zones, it is found pertinent to explore participatory methods for natural resources management. Not much work is done on process based participatory watershed development with geomatics technology interventions.

The present research focus is on developing such a model with appropriate integration of modern tools and technologies. The conventional model is analysed and an improved process based model is suggested. The proposed model is suitably improved with community role at every stage of development with an optimal blend of conventional and contemporary techniques. Participatory geomatics and information technology solutions, through innovative means, are considered for watershed development including monitoring and evalution. The proposed techniques are successfully tested through Karnataka Watershed Development programme, Karnataka State, India and the results are discussed. The outcome indicates many positive developments, that is, effective use of modern technology in planning and implementation which has resulted in improved agriculture productvity, reduced runoof, increased infiltration, self employment, improved livestock and milk yield, better socio-economic conditions and livelihood options. It is concluded that innovative means of implementing participatory watershed development have given rich dividends for natural resources development.

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ACRONYMS

Acronyms	Description
AIS&LUS	All India Soils and Land Use Survey
ACZ	Agro Climatic Zones
ANN	Artificial Neural Networks
AWiFS	Advanced Wide Field Sensor
BPN	Back Propagation Network
CBO	Community Based Organisation
CPR	Common Property Resources
CDZ	Central Dry Zone
DEM	Digital Elevation Model
DWT	Discrete Wavelet Transforms
EPA	Entry Point Activities
EDZ	Eastern Dry Zone
FCC	False Color Composite
FFS	Farmer Field School
GIS	Geographic Information System
GP	Grama Panchayat
GUI	Graphic User Interface
ICRISAT	International Crop Research Institute for Semi Arid Tropics
IRS	Indian Remote Sensing Satelllite
IT	Information Technology
LISS	Linear Imaging Self Scanning system
LMS	Least Mean Square
LU LC	Land Use and Land cover
MIS	Management Information System
M&E	Monitoring & Evaluation
MLP	Multi Layer Perceptron
MSE	Mean Square Error
MSL	Mean Sea Level
MWS	Micro Watershed Society

MXL	Maximum Likelihood Classification
NCC	Natural Color Composite
NGO	NonGovernmental Organisation
NNRMS	National Natural Resources Management System
NTZ	Northern Transition zone
PAN	Panchromatic
PRA	Participatory Rural Appraisal
RDBMS	Relational Database Management System
RRA	Rapid Rural Appraisal
SCS-CN	Soil Conservation Services-Curve Number
SHG	Self Help Group
SQL	Structured Query Language
SWS	Sub Watershed
TCC	True Color Composite
UG	User Group
VBT	Village Based Training
WC	Watershed Committee
ZP	Zilla Panchayat

CHAPTER 1

INTRODUCTION

1.0 BACKGROUND

Watershed, being a hydrological unit, has its importance as a physical, biological and socio-economic entity for planning and management of natural resources. Optimal use of land and water resources in a sustainable manner results in long-term benefits to the society. Development and conservation activities often lead towards building of various alternative approaches and scenarios for planning. While development requires actual implementation of activities based on scientific planning, the conservation decisions are taken based on multiple scenarios and their possible long term impacts on environment. It often amounts to a choice from limited alternatives amongst many uncertainties with an expectation of best results. It could lead to adverse results, if unscientific planning and other local influencing factors play a major role in decision-making. While planning, there are possibilities to develop multiple alternatives and analyse their possible impacts, based on a set of ground realities, environmental and local issues. Participation of local community is an important factor that needs to be accounted for while planning, as their knowledge and practical experience provides much needed inputs for planning. In an ideal situation the scientific inputs, active community participation and systematic analysis of the entire system leads to better decision making and development (Peterson et al, 2003). There is a growing concern on land resource management and the relative degradation in land quality that is leading to more research in the discipline of land and water management using improved and better practices. Development using watershed approach under a coordinated framework helps in better management of resources with respect to peoples' aspirations within a hydrological unit. Hence, Integrated watershed development has assumed unique importance considering the sustainability perspectives and is certainly the need of the hour (Sayer J and Campbell B M 2004).

Adoption of an optimal combination of scientific tools and peoples' participation, in the context of integrated resource management for holistic development in rural areas is the need of the hour. The emphasize is also on the need for integrated natural resource management, redefining the roles of government agencies, development of a programmes with science inputs for more sustainable future of rural landscapes and so on. Conventional approach in the area of agricultural science has given rise to technologies that can improve the performance of natural resource systems. For instance, if one is to provide for sustainable livelihood for the millions of people in rural tropical landscapes and if one has to ensure the maintenance of the global environmental benefits that they provide, then there is a need to influence these development trajectories. Hence, the study focus is to mobilize existing knowledge, incorporate new knowledge, treat management issues through scientific means and deal with real-life problems for optimal development. Active participation by local community is also an important element for successful implementation (Yang P et. al. 2007).

Rain fed agriculture plays an important role in global food production. About 80% of agriculture is from rain fed areas and contributes about 58% to the global food demand. They are often associated with poverty, malnutrition, water scarcity, severe land degradation, and poor physical and financial infrastructure (Suhas 2009). In India, a major share of developmental activities is concentrated in the rural areas as a large proportion of population depends on agricultural activities and rural livelihood. India is rich in its natural resources endowment and this needs to be optimally put to use for best gains for the country. Rain fed agriculture covers about 60% of the net sown area. Out of this about 18% of the rain fed crop area lies in the arid region which receives less than 500 mm annual rainfall. Out of the 127 Agro-climatic zones in India, 73 are predominantly rain fed. Majority of rural poor and marginal farmers in these zones depend predominantly on the rain fed agriculture, which is risky and distress prone (DAC, Annual Report, 2011). In such areas, agricultural activities are extremely difficult proposition and demands different methods of circumventing the dependencies on unpredictable rains. These areas have poor irrigation facilities and even protective or life saving irrigation is just not possible. These areas generally receive rainfall, which is highly uncertain and erratic. The agricultural activities that solely depend upon such rainfall conditions are prone for lot of hardships, particularly for the villagers living in such areas are highly poverty stricken, live under poor health conditions, poor infrastructure and plagued by unemployment problems, making the entire area unproductive and unsustainable for development.

Growth in population will have direct impact on food and water requirements and hence additional demand for basic resources, which in turn requires improved crop production, import-export policies, diversification in cropping strategies, cropping intensity and so on (Report on the National policy for farmers 2007). With the increase in demand for food production, better methods of managing natural resources on a sustainable basis becomes important, keeping in view the overall economic conditions and impact on import-export of food grains. The green-blue water analysis of water constraints and opportunities for global food production on current croplands and comprehensive assessment of water management in agriculture has recommended that future food production should be concentrated on existing agricultural land in order to avoid further loss of ecosystem functions from terrestrial lands (Falkenmark et. al. 2009). Green water for food production is almost three times more than blue water (5000 km^3 versus 1800 km^3) globally and hence Innovative mechanism to share the knowledge with the farmers and other stakeholders are very much needed as the traditional extension mechanisms worldwide, particularly in developing countries in Asia and Africa, are not effective (Suhas 2009). Considering such a situation, it is required to give special emphasis on the developmental strategies of dry land areas or rain fed areas with innovative strategies to enhance food production from such areas. While there are large tracts of irrigated areas in the country providing ample productivity, the management practices for sustainability is much different and equally important as compared to the dry land areas. The strategies for irrigated areas is more on management practices with respect to water, fertility and the type of crops adapted in different seasons. With the dynamics of population looming large in front of the nation, these irrigated tracts alone will not be able to sustain the increased demand of food production and hence there is an urgent need to bring dry land areas under productive cultivation to meet the increasing demand on crop production (From Hariyali to Neeranchal, 2006). Perhaps, strategies for such a situation should be more focused on development of areas based on terrain dependent processes which are more adaptable to the local conditions and hence watershed development would be an automatic choice.

1.1 WATERSHED

A Watershed could be defined as an area of land that drains water, sediment and dissolved materials to a common outlet point. The term is not restricted to surface water runoff, but includes interactions with subsurface water also (Aisha Al-Qurashi and Neil McIntyre, 2008). Watersheds vary from large river basins to just a few hectares or less in size. A watershed is a hydrological unit that are described and used as physical, biological and also, on many occasions, as a socio-economic-political unit for planning and management of natural resources. All India Soils and Land Use Survey (AIS&LUS) has brought out a classification scheme which is popularly used for various developmental projects in India. The coding standards that have been devised works hierarchically across Region, Basin, Catchment, Sub-catchment, Watershed, Sub-watershed, Mini-watershed and Micro-watershed for the entire country (watershed atlas of India, 1990). National database standards, which addresses the GIS database creation standards for various themes, uses this nomenclature and coding standards for delineation and use of such data (NNRMS Standards, 2005). This brings out the importance of how watersheds are subsets of a major terrain characterization process and hence any developmental activity can use such information and guidelines for better results. While these are natural boundaries, delineated based on terrain features, and are useful for optimal land and water management. The administrative boundaries like state, district, taluk and villages are used for administering the developmental programme and for proper linkages with the stakeholders for effective implementation. Under GIS, the overlay of watershed with that of village boundaries produces an output that can be effectively used for proper implementation of watershed programmes. Implementation of watershed programmes is administratively based on the coverage of a cluster of villages with respect to the selected watershed boundary and hence there is a need for proper relationship between the two for planning and implementation.

1.2 BASIC CONSIDERATIONS

Watershed development is generally implemented through a set of field interventions with an objective of conserving soil and water resources with due considerations to terrain and topography, while improving the socio-economic status of the farming community for sustainable development. It encompasses a complex set of natural resource parameters, which have interdependencies that need to be carefully analysed for optimal planning. With successful planning and implementation of such plans, the health of soil and water is improved resulting in benefits to the local populace. Important considerations on the parameters that need to be integrated while implementing watershed development programmes are given due weightage. These indicators share a complex relationship that need to be analysed by experts while taking due cognizance of local knowledge while planning and decision making.

Some of the basic indicators that are considered under this study are:

a. Topography, terrain slopes and gradients,
b. Nature of soil
c. Agro-climatic conditions
d. Natural resources characteristics
e. Current land use practices in the terrain with emphasis on private land and common land
f. Socio-economic conditions of the populace with special reference to the farming community
g. Benefit to people living in villages, both land-owners and land-less
h. Livestock situation and dependency of the population on livestock

Creating strong baseline information on the terrain characteristics and natural resource parameters is of great importance before planning for developmental strategies. The parameters like soil, water, status of land use /land cover, socio-economic status, livestock coverage etc., plays a major role in planning. In addition, the human factor and their desire for development are important parameters for development.

It is also essential to consider the human factor and livestock related aspects for arriving at a holistic and inclusive approach for development. Agricultural activities depend on the human labour and draught animal power in many of the watersheds. Livestock form an integral part of both the farming and landless. Participation of local communities, both farming and landless, leads to an inclusive approach for holistic development. While the landless can be effectively utilized in a watersheds for labour, income generation activities and common land development (major share of the produce can be enjoyed by the farming community who are engaged in actual developmental), training & capacity building, optimal farm management practices, adoption of new technologies on a sustainable development.

An ideal watershed development plan may be hard to adapt and implement without proper planning, community participation and acceptance by the locals. In such cases one should ensure that proper plans are made, which would not only improve field conditions and environment in the long run while providing economic benefits to the people living in the watershed. This necessitates analyzing the dynamics of a rural scenario, which includes land-based and land-less community who need to be engaged in the overall development of watersheds and villages. Hence, to achieve best results, it is required to define a set of processes that engage all types of communities in the watershed. This could be done by building strong and committed community based organisations (CBOs), like, Self Help Groups (SHGs) who are normally encouraged to adopt micro-credit schemes, they could be strong labour force to indulge in developmental activities, particularly in development of common land or Government land meant for community utilisation etc. Some of these strategies for the non-farm sector, when implemented in parallel with the farm development leads to better returns and sustainable development of watersheds.

1.3 LOCAL ADAPTATION

Development strategy needs to address involvement of local community on all aspects of watershed interventions. The development plans should always be locale specific and adaptable for that specific watershed. While extending the same to another area under similar conditions, it is necessary to make appropriate adjustments before adopting the same for successful implementation. Each watershed development program is unique in many aspects and hence needs to be addressed in the local context for better results. It is important to properly define the various processes involved and at every stage it is required to involve the participation of the local community to make it result oriented and sustainable. It provides ample scope to learn and improvise on a continuous basis. Managing a watershed for satisfying the demands of the local people is a difficult task if one has to maintain a reasonable balance between usually conflicting environmental factors and the demand. The solution to these complex issues requires the use of mathematical techniques to take into account conflicting objectives (Sadeghi et al, 2009).

In India, there is a significant focus on watershed development in dry-land / rain fed agriculture areas with a clear focus on rural development. It is necessary to understand these dry land or rain fed agricultural systems and characterize them for developmental strategy. Indicators that help in better understanding of such terrains need to be identified to evolve specific treatments that are locally adoptable.

1.4 RAIN FED AGRICULTURE SYSTEM

Rain fed agricultural system, in India, is in a highly vulnerable situation. This is due to a number of complex factors associated with natural resources and the socio-economic system that prevails in these areas. Uncertainty associated with the seasonal rainfall, unpredictable climatic conditions, unevenly distributed rainfall both spatial and temporal and absence of other reliable sources of water makes the agricultural activities and the livelihood of communities in these regions more difficult. On the other hand, the problems associated with land resources, such as, soil erosion, depletion of micro-nutrients in soil, poor soil fertility, sparse vegetal cover, high degree of degradation, low productivity, poor infrastructure and poor investment capabilities of the farmers are the other limitations.

The most important challenge in such areas is the optimal utilization of rain water so that the health of land and village community is better maintained. There also exists a direct relationship of such a system with productivity, poverty, socio-economy, health etc. that makes it even more complex. Rain fed agriculture system is characterized by its inherent limitations with respect to development, particularly the land and water resources. Investments on watershed development in rain fed agriculture system have large payoffs in terms of yield improvements, poverty alleviation and environmental sustainability through huge social, economic and environmental paybacks (Rockstrom et. al. 2007). A comprehensive assessment of investments made in rain fed agriculture system with respect to watershed development programs in India, has been carried out by a consortium of experts lead by International Crop Research Institute for Semi Arid Tropics - ICRISAT (Suhas et. al. 2008). The recommendations from the comprehensive assessment of watershed management in agriculture observe that "the investments in watershed management are the entry point to unlock the potential in rain fed agriculture". This is because improvement in rain fed agriculture requires investments in soil, crop and farm management. There is a need for better management methods, as conservation measures adopted with respect to rainwater alone cannot reduce the risk of frequent dry spells in rain fed agriculture. It also requires investment and support for adoption of comprehensive approach along with management of runoff. The potential for improving productivity is particularly high in smallholdings. Commission on National Policy for farmers in India (2007) has stressed on the importance of rain fed agriculture and emphasized on the need for adoption of integrated watershed management approach through community participation, convergence of activities in the watersheds, adoption of innovative participatory consortium for technical backstopping, soil health and most importantly enhancing investments in rain fed areas. The report also highlights the need to enhance the soil capital and insulating farmers from the risks, bridging the yield gaps by adopting existing technologies and connecting research and development initiatives in the country. Amongst many other recommendations, the commission also recommends the watershed approach as the most appropriate one for lifting the economy of rain fed areas in a manner that is efficient, affordable and sustainable. The commission has further emphasized the need to adopt integrated water resources management approach for enhancing water use efficiency for reducing the poverty. The report of the Working Group on Natural Resource Management (2007), rightly points out that the stipulated overall GDP growth of 9 per cent, for the plan period of 2007 – 2012, could not be achieved because of the ongoing degraded and shrinking natural resources of the country. The report further quotes "The business as usual will not do and the Natural Resources Management, particularly through watershed approach needs major adjustments and shifts in the strategies and approaches" (The Report of the Working Group on Natural Resource Management in India, 2007).

1.5 NEED FOR DEVELOPMENTAL STRATEGIES

Present day governance gives much importance for management of land and water resources with integrated approach, equity and sustainability. Multi-pronged strategy for sustainable development with special emphasis on the development of poorer sections of the society, including the natural resource base, needs to be addressed in a more focused manner. Watershed development has evolved into a programme with objectives of simultaneous pursuit of biophysical and rural development that promotes rural livelihoods. However, the watershed development programme is more complex and hence there is a need for integrated planning and implementation of newer strategies for more effective development and results (Qi and Altinakar, 2010).

It is essential to take up developmental activities in rain fed agricultural areas for improving production potential of the degraded areas. Such development should address soil and water conservation, drainage line treatment, improvement in biomass and livelihood opportunities for local people to ensure sustainable development in the long run. Conventional and traditional methods have been in use for long with similar objectives, but there are not only gaps in the strategies adopted in planning and implementation but also lukewarm approach in transformation of conventional approach by adoption of scientific and technological developments. For example, traditional ground surveys, poor methods of creating resources database, lack of usable base data, lack of integrated approach, poor participation from stakeholders and improper monitoring systems makes it unsustainable and less effective. Hence, a strong need is felt to improve methods that are more practical and adaptable at field level for sustainable development involving earth observation from space, use of multi-thematic maps under geospatial environment as decision support, scientific inputs for planning, participatory and transparent approach in decision making and strong monitoring and evaluation system.

1.6 AGRO-CLIMATIC & AGRO-ECOLOGICAL ZONES

Agro-climatic and Agro-ecological conditions play an important role in characterizing a particular area with respect to the natural resources and the climatic factors prevalent in that area. Any plan for the development of resources, in particular the water resource, should take into consideration the agro-climatic and ecological conditions for evolving scientifically sound plan. In India, such zones have been well defined and documented for necessary reference and adaptation (Gajbhiye KS and Mandal C 2000). India is a unique country that has rich diversity of resources both with respect to landforms and the climatic behaviour. Typically, lofty mountains, deltas, high altitude forests, peninsular plateaus, variety of geological formations, varying from arctic cold to equatorial hot and rainfall from extreme aridity with a few centimeters to the world's maximum rainfall of several hundred centimeters play an important role in arriving at effective development plan for watersheds. Further, with such varying environmental situations in the country, India also has varieties of soils, undulating terrain, climate and other dynamic factors, making it more challenging to arrive at a proper decision for optimal land and water management. Therefore, a systematic appraisal of agro-climatic and agro-ecological regions is required to be used to enable scientific grouping of relatively homogenous regions in terms of soil, climate and physiography with requisite moisture conditions in planning appropriate land use (Ramachandra et al. 2004). Depending upon the soil, bioclimatic type and physiographic situations, the country has been grouped into 20 agro-eco regions and 60 agro-eco sub-regions**,** which is geospatially an important factor to be considered for any developmental purposes. Watershed development programme, which depends on natural resources, weather, climate and environmental factors for evolving developmental strategies will have to consider agro-climatic conditions also as a part of planning process.

1.7 NEED FOR INNOVATIVE APPROACH

Development in Science and Technology has enabled numerous possibilities and alternative means of finding optimal solutions for watershed development. Depending on the type of terrain, the agro-climatic conditions, soil type, land use / land cover, current practices, status of water resources and prevailing socio-economic condition, it is possible to analyse and evolve locale specific action plan for development. Strategies for watershed development depend on the local knowledge on land, water, weather and climatic conditions, historical experiences, participation of village community and specific implementation options. While it is well understood that the entire procedure is time bound, complex and ground intensive, choice of appropriate technologies helps in providing suitable alternatives for better planning and development. Various options available in the form of geospatial technologies, Global Positioning System based ground data collection, remote sensing inputs for natural resources inventory, digital elevation models for terrain characterisation, geospatial database with linkages to socio-economic parameters for planning, near real-time data collection and effective monitoring mechanism enables to arrive at a more meaningful, efficient and effective watershed development alternatives.

The challenge lies in how these technologies and alternatives could successfully be positioned in a system to make it realizable. It leads to a situation that there is a strong need to evolve suitable methodologies and systems which are well aligned with developmental processes that enables evolving strategies for result oriented framework for better management of natural resources. These processes could be a set of activities, which involves both social and natural resources aspects that are inter-dependent and needs special consideration while drawing developmental plans. Processes and technological choices contribute significantly in adopting acceptable methods for development. Due to the synoptic nature of satellite remote sensing technology and also various possibilities of using geospatial data, there are unique promises of looking at the problem in a new perspective. With availability of high spatial resolution imaging from space, at regular time intervals, newer and better solutions are forthcoming. With a well-defined set of processes in place, it is required to adopt an integrated approach for the choice of technological interventions to achieve the goals of watershed development with a strong mechanism for monitoring and evaluation. Such an attempt is made in the present study through a systematic analysis of the existing system and to arrive at improved alternative methods with appropriate scientific and technological inputs.

A detailed literature survey is done, with a primary focus on exploring the various approaches followed elsewhere in evolving a process oriented, holistic and integrated watershed development strategies. The literature survey addresses the following aspects, (1) prevailing techniques and technologies for data analysis and use of geospatial technologies, (2) processes involved in watershed development and involvement of village community in planning (3) practical use of space imaging and geospatial data in the process of development and (4) methodologies for monitoring and evaluation. All these aspects are explored for possible improvements and adaptation. It is also planned to identify gap areas, if any, while proposing alternative and improved methods for planning, development, monitoring and evaluation.

CHAPTER 2

LITERATURE SURVEY

2.0 INTRODUCTION

Watershed development is a complex process, which involves a number of factors associated with land and water resources, socio-economic conditions of the community, and the related environmental issues. Watershed development programmes have traditionally been done using government funds and the implementation is done as part of the government's plans. In most of the programmes, the local people do not get an opportunity to participate and such initiatives make little impact on the field and with the local community. Hence, there is a need to explore alternative methods that allow stakeholders' participation and other technologies.

Different methods are followed depending on local factors and terrain conditions. Technology inputs do provide several alternative methods for watershed development. At the same time the conventional methods are also being followed in many programmes. Hence, there is a need for literature survey to take stock on various methods and approaches used for watershed development.

There are many references on watershed development methods and procedures, which are primarily focused on soil and water conservation measures, different types of land treatment, use of remote sensing and GIS techniques for planning and impact assessments and case studies on watersheds, including participatory approaches. Similarly, there are many references, which address advanced data processing techniques and geospatial solutions. In view of this a detailed literature survey is conducted, keep in mind, the importance of using participatory approaches and technology elements. Following are the details on the literature survey, presented with a special focus on some of the aspects mentioned above and also on the participatory approaches.

2.1 AGRO-CLIMATIC ZONES

Gajbhiye KS and Mandal C, (2000), have provided a detailed account of Agro-Ecological zones, their soil resources and cropping systems. Such information is an important reference information for implementing varieties of natural resources development programmes. The paper gives a detailed account of climatic factors, soil, land use and various environmental aspects.

Ramachandra T V et al., (2004), have worked on Bioresources status in Karnataka, with a detailed account of the status. Using the data of bioresource availability and demand, bioresource status is computed for all the agroclimatic zones. They also bring out details on the agro-climatic zones of Karnataka.

2.2 WATERSHED MANAGEMENT

Chakarvorty *et al.* (2001), did a study of Ballowal-Sounkhri village in Hoshiarpur district of Punjab and have reported an approach to water resources management through water harvesting structures. The study has inferred that if the excess rain water stored in the catchment were to be conveyed through small channels to the field as per the agriculture requirement in different seasons of the year, it would not only help in attaining self sufficiency in agriculture production, but would also reduce soil loss, achieve recharging of aquifers as well as increase agriculture production in the area.

Davenport T E, (2003), has written a book on watershed project management guide. This publication provides a detailed account of various aspects of watershed development and management.

Peterson G D et al, (2003), have described on scenario planning tool for conservation in an uncertain world. The paper brings out details on conservation and planning. The paper addresses construction of conservation and planning scenarios by a diverse group of people for a single, stated purpose, by incorporating a variety of quantitative and qualitative information in the decision-making process.

Sayer J, Campbell B M, (2004), have written a book on the "The Science of sustainable development: local livelihoods and global environment", published by Cambridge press. They elaborate on the need for practical research for natural resources conservation and development with involvement of local community.

Catacutan D C et. al. (2006), have presented their work on economic growth and watershed management: drivers of R & D innovations. The paper focuses the research innovations in the form of agroforestry and conservation farming technologies carried out through communities in Manupali watershed. This proved to be apparently successful with large number of households and local communities adopting conservative farming technologies.

Mula R P, et. al. (2007), have brought out details on mid-term evaluation of watersheds: Experiences in Kerala. They bring out many features with respect to peoples' participation in developmental process, including the local panchayat. However, there is no mention of any scientific and technological tools being used in such a developmental programme.

Al-Qurashi A and McIntyre N, (2008) have worked on the performance of different rainfall – runoff models as applied to arid catchment in Oman. When selecting a rainfall–runoff model for application to an arid region, the stresses the need to consider the spatial features of rainfall and the variability and non-linearity of losses, and to match model complexity to the availability and quality of data.

Veum K S et al, (2009) have reported on an interesting study on the role of biogeochemistery of terrestrial and aquatic ecosystems including the mobilization and transport of nutrients and pollutants across watersheds. Using a paired-watershed approach, the objectives of this study were to determine the effect of grass and agroforestry buffers on runoff and dissolved organic carbon (DOC) loss, compare runoff and DOC losses between the growing and fallow seasons, and investigate crop effects on runoff and DOC losses. These aspects in tune with the basic objective of biogeochemistry of terrestrial and aquatic ecosystems is brought.

Zhou Y et al (2009), have examined the impacts on Chaobai watershed due to agricultural water transfers from upstream of Miyun Reservoir to downstream municipal uses in Beijing, China. The study examines the impacts of water reallocation on crop production and farmers' income and discusses issues relating to current compensation mechanisms.

Jack K B, (2009), examines the environmental interventions services in the upstream and downstream users in Nyaza Province, Kenya. Upstream and downstream individuals are paired in a standard investment game, in which the upstream investment represents land use decisions and the downstream users respond with a choice of compensation payment. This kind of a participatory intervention brings in specific enforcement treatment and at the same time transparency, which is a typical social problem in a watershed.

Qi H and Altinakar M S, (2010) have highlighted in their paper on the conceptual framework of agricultural land use planning with BMP for integrated watershed management. They considered many aspects of watershed management, but with specific reference and importance to landuse. The authors are of the opinion that although its importance in achieving sustainable development has long been recognized, a land use planning methodology based on a systems approach involving realistic computational modeling and meta-heuristic optimization is still lacking in the current practice of integrated watershed management.

Durbude D G et al, (2011), have worked on soil and water conservation. They observedthat Soil Conservation Service Curve Number (SCS-CN) method is widely used in determination of direct surface run-off in long-term (continuous) hydrologic simulation models. They have analysed on a modified model to avoid the unrealistic sudden jump in V_0 by incorporating conceptual Soil Moisture Accounting (SMA) procedure and variation of daily CN based on antecedent moisture amount instead of antecedent moisture condition.

2.2.1 Participatory watershed development

Schiff L R, et. Al., (1997), have elucidated on understanding complex information environments, particularly with respect to social analysis of watershed planning which is brought out under ACM Digital Library as conference proceedings. They specially examine the question that if digital libraries are viewed as both social and technological artifacts, then effective design requires that one must understand the social world in which each functions. Specific topics related to information practices and maps, the use and interpretation of geographic information system (GIS) and other related aspects like geographically-based representations are discussed at length. Initial findings regarding watershed planning, as part of U C Berkeley Digital Library project is also reported.

Turton C, (1998) has brought out a special publication on “Enhancing livelihoods through participatory watershed development in India”, published by Overseas Development Institute, UK. It is concluded that the success of the traditional methods used in implementation are patchy, particularly with respect to common property resources. It is also concluded that there is limitation on scalability of the approach.

Johnson N et al, (2002), have reported on the importance of having stakeholders’ participation in watershed management. They attribute the poor performance of the programme to the failure in recognizing the needs, constraints and practices of the local community. They stress the need for stakeholders’ participation at all levels of watershed development programme and also highlight the complexities associated with such a system.

Finenec, C. (2003) has presented his work on explorations of participatory GIS in three andean watersheds, which involves community in mapping and various other participatory activities. The author explains the difficulty in creation of GIS maps, thematic maps and other geospatial data to impart knowledge about local natural resources. The study brings out the details on the importance of GIS, GPS, aerial photos and involvement of NGOs in social research.

Behl K G, (2003), in his study on cadastral map specification, methodology and infrastructure for adoption by the states has brought out the importance of these maps. He also concludes that cadastral maps are found to be very useful in planning and execution of various activities by Panchayats Raj System.

McCall M K and Minang P A, (2005), have published their work on assessing participatory GIS for community-based natural resource management with regard to the community forests in Cameroon. The paper critically reviews and analyses participatory GIS (PGIS) and participatory mapping applications for natural resources management in developing countries.

Farooq U, et. Al., (2005), have discussed on the participatory design for Sustainable watershed management considering community computing application. It is in the area of sustainable, long-term participatory design for community. They have adopted a perspective that emphasis\zes participatory design as a learning process and introduces hierarchical and lateral (collaboratively constructed zones of proximal development) aspects of learning. This involves more in providing field-based training and skill development for the community to learn and use the skill sets at local level.

Rambaldi G, et al., (2006), have analysed the participatory spatial information management and communication in developing countries, and has defined PGIS concept as merging of participatory development methods with geo-spatial technologies. They also emphasize this as an emergent development practice in its own right. The paper concludes by highlighting the legitimacy for local knowledge, which generates a great sense of confidence and pride and prepares the participant communities in dealing with outsiders. They have focused more on the technologies ,which could be brought to use as a part of participatory GIS but no reference has been made on practical applications.

Subha V, (2006), has studied on the importance of community participation at all stages of development, capacity building and skill development aspects, But, specific aspects related to natural resources planning, use of technology as input and participatory development has not been addressed..

Carroll J M and Rosson M B, (2007), have addressed the issue of the direct involvement of end-users and other stakeholders in developing information systems, applications, infrastructures, and associated work practices. It is concluded is a challenging domain for further developing participatory design.

Swamikannu N, 2009, has discussed a dynamic and non-linear bio-economic model, incorporating both economic and biophysical aspects of development for a micro-watershed. He has attempted to assess the impact of key watershed management technological interventions on social well being of rural poor and condition of natural resource base. The study has highlighted the effect of conflicting technologies while developing specific solutions for watershed development. The stress is on those technologies that have multiple impacts in terms of meeting both welfare of the farmers and sustaining natural resources objectives must be prioritized.

Bartlett A G, (2010), has analysed community participation in restoring Australian forest landscapes, to protect and restoration of public and private land. Specific reference is made to the national, regional and local work of communities engaged in restoring forest landscapes.

2.3 TECHNOLOGY IN WATERSHED DEVELOPMENT

Varieties of research work have been carried out in the use of technology in watershed development. Predominantly, the publications are in integration of thematic information for watershed development, soils and land capability, stream flow, runoff modeling and sedimentation estimation, GIS database for watershed development etc.

Following publications are grouped based on the area of work:

Yildirim H, et. al. (2001), Remote Sensing and GIS for Natural resources database and watershed development.

Srivastava R *et al.* (2001): Satellite remote sensing other observations for soil related studies, land capability and suitability for development.

Harindranath C S *et al.* (2001): Satellite remote sensing for soil types, land capability, irrigability and suitability related research.

Bhagavan S V B K and Raghu V, (2001) High resolution thematic information and action plan preparation for objective of conservation, up-gradation and optimal utilization of natural resources to attain sustainable agriculture production.

Ghouse M *et al.,* (2001), created GIS databases for geospatial analysis and watershed development,

Patel N R *et al.* (2001), GIS based thematic information for watershed development.

Sathish A and Badrinath M S, (2001), Remote sensing based thematic maps for locale-specific action plans for water and agricultural resources development.

Gupta R D *et al.* (2001), GIS based spatial model for action plan preparation and facilities development.

Maji A K, *et al.* (2001), Soil survey and resources mapping with other natural resources themes for integrated planning using GIS.

Ramalingam M et al., (2002), Management of natural resources using remote sensing and GIS as a part of geospatial solution.

Rao S S et al, (2003), Remote sensing and GIS based performance index for watershed development.

Durbude D G and Venkatesh B, (2004): Site suitability analysis for soil and water conservation structures in a watershed using remote sensing and GIS techniques.

Gosain A K and Rao S, (2004), GIS-based technologies for watershed management with a specific focus on hydrological model.

Pandey V K et. al., (2006), Multi-theme analysis for watershed model, hydrological model, runoff and sediment yield.

Lokesha N et al. (2007), Integrated study of multiple-layers for action plan preparation in a watershed.

McVicar T R et al, (2007): Use of coarse spatial resolution satellite data for designing a decision support system with a focus on re-vegetation in prioritized areas.

Martin D and Saha S K, (2007): Remote sensing and GIS in soil inventory, prioritization of sub-watersheds using USLE model and land evaluation studies using land productivity index.

Zhang Y and Barten P K, (2009) GIS based spatial technology is used to present a sustainable good water in a watershed area, including watershed forest management information system.

Ames D P et al, (2009): Estimation of stream channel geometry with multiple regression analysis using GIS-derived watershed characteristics including multi-thematic layers. The method can significantly improve estimates of stream width and depth for use in flow-routing software models.

2.3.1 Image classification and Change analysis

Benediktsson J A et al, (1990), have attempted to compare neural network learning procedures with statistical methods in classification of multisource remote sensing and geographic data. Statistical multisource classification by means of Bayesian classification theory is also investigated and modified. Experimental results have shown that the two different approaches have unique advantages and disadvantages.

DeKok, R.et. al., (1999) have studied on Object based image analysis of high resolution data in the alpine forest area. They have discussed data processing related to a typical multi-resolution satellite sensor, multispectral and panchromatic bands, with high spatial resolution. They have concluded that the whole construction of pixel-objects and the object based image analysis allows an image interpretation, which surpasses traditional spectral analysis.

Jeon, B. and Landgrebe, D. (1999), have discussed on partially supervised classification using weighted unsupervised clustering. The paper addresses a classification problem in which class definition through training samples or otherwise is provided a priori only for a particular class of interest. They have highlighted time and effort required to label samples necessary for defining all the classes existent in a given data set by collecting ground truth or by other means. They have verified the effectiveness of the proposed method by both simulated and real data.

Tadjudin S and Landgrebe, D A, (2000), have worked on image classification with specific reference to parameter estimation for mixture models. Their proposed method assigns full weight to training samples, but automatically gives reduced weight to unlabeled samples. Their experimental results show that the robust method prevents performance deterioration due to statistical outliers in the data as compared to estimates obtained from the direct Expectation Maximization (EM) approach.

Shi J and Malik J, (2000) have discussed specifically on image segmentation with a novel global criterion, the normalized cut, for segmenting the graph. The criterion measures both the total dissimilarity between the different groups as well as the total similarlity within the groups. They have also shown that an efficient computational technique based on a generalized eigenvalue problem can be used to optimize this criterion.

Zhang G P, (2000) has taken up a survey on the neural networks used for classification. He has examined the issues of posterior probability estimation, the link between neural and conventional classifiers, learning and generalization tradeoff in classification, the feature variable selection, as well as the effect of misclassification costs

Dundar M M and Landgrebe D, (2003) have reported on the image classification and have examined varieties of techniques in the process. They have used hyperspectral data and tried to characterize them as family of responses for classification. They propose a semi-supervised binary classifier, which seeks to incorporate unlabeled data into the training in order to improve the quantitative definitions of classes and hence improve the classifier performance at no extra cost.

Alzir F B et al, (2003), have worked on object oriented analysis and semantic network techniques to classify high resolution satellite data. The objects are derived from multiresolution segmentation (from multispectral image, Ikonos) including hierarchical principles for sub-objects. This hierarchy is the bedding for the semantic network. The knowledge is in the semantic basis. The classification is based on fuzzy rules by means of descriptors such as form, texture and relations between objects and sub-objects.

Vijaykumar, et al. (2004) have carried out a study of Land Use Mapping of Kandi Belt of Jammu Region using IRS LISS III satellite data. The study also helped in suggesting various alternate land use practices for better sustainability.

Mundia C.N and Aniya M (2005) has done a study on land use / land cover changes and urban expansion of Nairobi city using Landsat MSS data, TM and ETM images and GIS techniques. Multi-temporal comparisons are made to highlight how urban growth has resulted in change in the landscape through a time series image analysis.

Joshi P.K *et al.* (2005) have reported on mapping of different land use / land cover classes in the cold deserts in the Nubra valley in Ladakh, India using Remote Sensing and GIS. The mapping helped in identifying the important areas for biodiversity conservation; pasture development, plantation and predicting the distribution of valuable and rare medicinal herbs, which may have great potential for bio-prospecting.

Kressler F P et al, (2005) have reported on enhanced semi-automatic image classification of high resolution data and have suggested for an object oriented classifier. That is, initial usage of segmentation based classifiers, followed by hierarchical classification based on fuzzy functions for easy adaptation to newer data sets. The result is then integrated with vector data to identify different land user categories.

Omkar S N et al, (2007) have made an attempt to compare many classification techniques for high resolution satellite data to find out the efficiency of classifier. The work involves, use of many advanced classifiers and test their performance with very high spatial resolution satellite data. They are of the opinion that no single classifier can prove to satisfactorily classify all the basic land cover classes of an urban region and they have stressed the need for examining multiple classifiers. They have used Bayesian classifier, artificial neural network, evolutionary algorithms and swarm intelligence techniques. The high resolution Quickbird data has been used for the experiments.

Yu Q et. al., (2007), have attempted to study on factors affecting the spatial variation of classification uncertainty in an object-based vegetation mapping. They have studied six categories of factors in an object-based classification, which amongst others includes topography, sample object density, and spatial composition. The classification uncertainty is modeled as a function of various factors using a mixed linear model. The result of this study has helped in understanding classification errors and suggested further improvement of the classifications from aerial imaging platform

Chant T D and Kelly M, (2009) have brought out their research on the use of high resolution satellite images to quantify changes in horizontal canopy structure to the oak woodlands in China Camp State Park, California, USA. An object-based change detection technique is developed to track changes of individual objects using 4-band 1 m spatial resolution with help of GIS. The method has allowed closer monitoring of gaps, thus revealing ecologically meaningful results in a landscape-scale analysis.

Castilla G et. al., (2009) introduce an automated change detection and delineation tool for remote sensing images. The Land-cover Change Mapper (LCM) generates polygon vector layer of regions deemed to have undergone significant change in land-cover. This is demonstrated using 1000 sq km area of western Canada using SPOT imagery, compares with a commercial tool and reports on its thematic and spatial accuracies.

Linke J et. al., (2009), have worked on a framework for generating temporally and categorically dynamic land-cover maps that provide a reliable and adaptable foundation for change detection, considering a spatio-temporal disturbance-inventory database. This is found to be useful to backdate and update both continuous and categorical reference maps.

Yuan H et al, (2009), have studied on an automated ANN classification system consisting of two modules: an unsupervised Kohonen's Self-Organizing Mapping (SOM) neural network module, and a supervised Multilayer Perceptron (MLP) neural network module using the Back propagation (BP) training algorithm. It is concluded that the automated ANN classification system can be utilized for LU/LC applications and will be particularly useful when traditional statistical classification methods are not suitable due to a statistically abnormal distribution of the input data.

2.3.2 Image Fusion

Lisowska A (2005), has focused his study on the various methods of using wavelet transforms for digital image coding and processing. The results have been particularly useful towards adaptation towards high spatial resolution image fusion.

Svab A and Ostir K, (2006), have explored on high- image fusion methods that work on the principle of component substitution; intensity-hue-saturation method, Brovey transform and multiplicative method using different satellites and sensor images. It concluded that for preserving spectral characteristics, one needs a high level of similarity between the panchromatic image and the respective multispectral intensity. It has also been brought out that spatial resolution is best preserved in the event of an unchanged input panchromatic image.

Shi W et. al., (2007), have brought out details on the use of wavelet transformation-based method for fusing high-resolution satellite images, specially the fusion of one-band panchromatic and four-band multispectral IKONOS images. Results are evaluated based on both visual evaluation and a quantitative analysis. The quantitative analysis has demonstrated that four-band wavelet transformation method provides improved fused images.

Lewis J J et. Al, (2007), have reported on pixel and region based image fusion with complex wavelets. They have reviewed a number of pixel-based image fusion algorithms, to perform fusion and compared with region-based image fusion method, which facilitates increased flexibility with the definition of a variety of fusion rules. Characteristics of each region are calculated and a region-based approach is used to fuse the images, region-by-region, in the wavelet domain. This method gives results comparable to the pixel-based fusion methods.

Cakir H I and Khorram S, (2008), have worked on a pixel level data fusion approach based on correspondence analysis (CA), which is applied to fuse panchromatic data with multispectral data in order to improve the quality of final fused image. In the CA-based fusion approach, fusion takes place in the last component as opposed to the first component of the PCA-based approach. This approach has given very good spectral accuracy on synthesis of multispectral and high spatial resolution panchromatic imagery.

Gangkofner U G et al, (2008), have analysed on pixel-level image fusion combining complementary image data, that is low-spectral high spatial resolution data with high-spectral low spatial resolution data. It is attempted to refine and improve High-Pass Filter Additive (HPFA) fusion methods. The results are evaluated visually and by spectral and spatial metrics in comparison with wavelet-based image fusion results as a benchmark.

2.3.3 DEM, GIS & Web technology

Toutin T, (2004) attempted to extract of digital elevation model (DEM) from IKONOS in-track stereo images using a 3D physical model developed. Stereo photogrammetric bundle adjustment, area based multiscale image matching methods and 3D semiautomatic editing tools are used to generate DEM for further comparison with Lidar based elevation data. A 3D visual classification of stereo images for landuse and landcover are also done, including accuracy evaluation. The evaluation shows that the DEM error is linearly correlated with slope.

Huang B and Claramunt C, (2004), in their publication, have highlighted their research on environmental simulation within a virtual environment, wherein they try to build visualization as an integral part of environmental simulation to facilitate comprehension of a complex system, such as environmental processes.

Patra S K et al, (2006) have carried out a detailed analysis on natural color composite generation techniques from satellite data. The use of multispectral images, that is near infrared, red, green and blue channel data in generating different types of color composites have been studied. Specific focus of the work is when blue band is absent, like some of the recent satellites of IRS series, wherein alternative methods are explored to still generate good natural color composites.

Yang P et. al., (2007), have reported on their work on web based architecture and spatial web services to integrate geospatial metadata, data, analysis and presentation through distributed portals. NASA's earth science gateway is designed and developed as an example to test the proposed architecture in sharing earth observations, simulations and other geospatial resources.

Wagtendonk A J and De Jeu R A M, (2007) have tried to explore the potential of mobile GIS and other mobile computing methods to support better and more efficient scientific data collection and analysis. They have presented an ex-post evaluation framework in estimating the added value of mobile computing method.

Rinaudo F, et al., (2007), have worked on GIS and Web-GIS, commercial and open source platforms. The focus of the work is on cultural heritage documentation using GIS technology in order to document it before restoration, conservation and management. It is concluded that open Source approach offers more interesting advantages than commercial approach such as the growing of local expertise and the possibility of sharing the developed solutions without any costs.

Shah P B and Thakkar N J, (2008), have carried out work on the database standards and GIS tools for geospatial data processing under Geospatial metadata services – ISRO's initiative. Specific mention of national natural resources management system (NNRMS) as entity, which supports national requirements of natural resources management and development through systematic inventory of natural resources have been made.

Bhuvan Web portal design and development, 2009 – The Indian Earth Observation Visualisation portal showcasing IRS images in 2D and 3D. National Open Earth observation Data Archival (NOEDA) is an open source available under Bhuvan for free data download including DEM tiles with 30 m (1 arc sec) postings.

2.3.4 Optimisation Techniques

Yuan X et al., (2008), have brought out multi-objective optimization models of watershed management with complexity of nature and humans interactions.

Sadeghi S H R et. al., (2009) have discussed optimisation techchniques for watershed related studies. An optimization problem has been formulated for Brimvand watershed, Iran to find out the most suitable land allocation to different types of land use activities by considering the various natural resources constraints like, soil, vegetation, water etc. The result of the study has revealed that the amount of soil erosion and benefit could be significant. The sensitivity analyses has shown that the objective functions are strongly susceptible to the constraint of maximum summation of irrigated farming and orchard areas.

2.4 TECHNICAL REPORTS

Integrated Mission for Sustainable Development (IMSD), (1994), was a mapping missions that gave guidelines to consider methods for improvement of land resources in those areas where land resources were reported to be poor or belonged to wastelands. The report discusses integrated study of land and water resources for development and management, on a sustainable basis, using natural resources maps derived from remote sensing and other collateral data.

National (Natural) Resources Information System (NRIS) Standards, (1999), has been a national mission taken up by ISRO, Department of Space, in a view to provide GIS oriented digital database on natural resources for district level development in the country. It standardized information for decision makers on natural resources related to land, water, forests, minerals, soils, oceans, etc. and socio-economic information such as demographic data, financial allocations, development targets, etc.

Kerr J M et. al., (2002) have discussed Watershed Development Projects In India by carrying out an analysis of about 86 villages in Maharashtra and Andhra Pradesh. The review brings out the various facts related to watershed development being done using conventional techniques, the procedures adopted in some of the Government sponsored schemes and their limitations. The use of technology and its advantages has not been reported. It brings out the fact that participatory approach performs better than the typical technocratic, top-down counterparts. However, there is a mention of the poor monitoring and evaluation methods used in the implementations, which are important points for consideration for future.

Technical report on Watershed Characterisation, prioritization, development planning and monitoring – A remote sensing approach, (2002). The report has specific focus on various techniques for sedimentation, runoff and erosion computations, drainage morphometric analysis using GIS solution, characterization of a watershed based on various land and water related parameters, watershed response modeling, watershed management and impact assessment related aspects.

National Natural Resources Management System (NNRMS) Standards, (2005), has been a follow-up exercise of NRIS Standards to evolve GIS database standards at National level (India) for carrying out various developmental activities at various levels and scales.

Enabling rural poor for better livelihoods through improved natural resource management in SAT India, (2005), is a DFID-NRSP (UK) project with an aim to incorporate public participation in developmental activities. Identification and promotion strategies for sustainable management of natural resources to improve the livelihoods of landless, small, marginal farmers and herders (including women) have been highlighted. Conventional methods are extensively used in implementation and it is found to be time consuming and complex. But, the sustainability aspects are not assessed and also there is no significant use of monitoring and evaluation.

Meta Analysis to assess impact of watershed program and people's participation, comprehensive assessment research report No.8, 2005. An exhaustive review of 311 watersheds was done through an analysis taken up by ICRISAT to study the impact of watershed programmes implemented through Ministries of Agriculture and Rural Development (India) during previous 5 year plan periods. The analysis is based on the data made available from Ministry and State departments. But, there are no systematic methodologies followed in such data collection and archival.

From Hariyali to Neeranchal, 2006, is a report of the Technical Committee on Watershed Programmes in India. The report gives an account of the various methods adopted in implementation of watershed development in the India by going through varieties of committee reports, technical documents and also revisiting the existing watersheds and implemented programs in various parts of the country to arrive at newer methods and approaches. The report provides specific recommendations and action points for adoption for future watershed developments in India.

Report of the working group on Natural Resources Management for the 11th Five year plan, Volume 1, 2007, brought out by Planning commission, Government of India, highlights comprehensive integrated development of multiple natural resources on watershed basis, situation specific and need-based development of individual resources (outside the watersheds) and Integrated crop-livestock-fish-biomass farming system based management of natural resources, especially in rainfed areas (inside and outside the watershed programmes).

Report on the National policy for farmers, 2007, brought out by the Department of Agriculture & Cooperation, Ministry of Agriculture, Government of India ihas suggested to rejuvenate of the farm sector and bring lasting improvement in the economic condition of the farmers. This has evolved subsequent to the report of the National Commission of Farmers, which was revised in 2006. The policy aims to improve the economic viability of farming by substantially improving the net income of farmers in addition to productivity, profitability, land, water and support services to provide appropriate price policy, risk management measures.

Common Guidelines for Watershed Development Projects, 2008, is a technical report brought out by the Ministry of Rural Development (MoRD), Government of India. This is one of the recent technical reports brought out by the government with the participation of large number of stakeholders in the country from all parts of the country, which includes, Government departments, NGOs, Scientific organizations, progressive farmers etc. The report provides detailed guidelines for implementation of watershed development in the country at State level. A popular programme launched by MoRD under the name 'Integrated Watershed Management Programme (IWMP)' has already started using these guidelines for implementation.

Community watersheds as growth engines for development of dryland areas, 2008, is a report on comprehensive assessment of watershed programs in India. It dwells upon all aspects of watershed development so far carried out in India by the Ministries of Rural Development and Agriculture under various Government schemes. The authors are drawn from different organizations and institutions with specific domain knowledge in diversified areas to analyse all aspects of developments and their impacts. The report gives a detailed account of such programmes and also provides specific recommendations for the future aspects of watershed development in the country.

2.5 SUMMARY

An attempt is made here to analyse the study done so far in a structured manner by categorizing published work under different categories. The reported study highlights the need for \integrated watershed development and to incorporate different agro-climatic regions in such study. The importance of space based remote sensing through improved classification methods, fusion techniques and geomatics solutions are highlighted. Participatory methods in implementing different types of developmental programmes, use of GIS, Remote sensing, information technology and other technologies have been used sited, but they are specific to a particular field and isolated rather than their usage in an integrated manner through processes of development.

It is also noted that there is no literature, which address process-based watershed development and hence is identified as gap area. Customized solutions for watershed development with process-based participatory methods are also not forth coming. Watershed development and impact assessments are considered as independent topics rather than in a comprehensive and holistic manner for development.

2.6 MOTIVATION FOR RESEARCH

Considering the importance of local community and embedding science and technology tools in watershed development, it is attempted to analyse these factors in the study. Science inputs and technology implementation need to be integrated in a simple way to enable the village community to participate, learn and implement natural resources development in their own fields. The research work attempts to address many facets of watershed development like social, natural resources, environment, capacitation and empowerment aspects with the use of technology in a simplified manner.

The focus is on technology usage in a process driven watershed development model. It is attempted to blend technology and conventional methods to find optimal solution for the problems of dry land areas, which are plagued with issues of land and water management problems. The study is to highlight two important aspects, one being the importance of processes in a development paradigm and the other being the participatory methods involving simplified technology inputs as an aid for development.

There are large tracts of dry lands in India, which have potential to be productive but not utilized well due to lack of scientific approach and poor management practices. Watershed development is possibly the only best way to improve the situation in dry land areas with improved methods, formulation and management. With world focus on food and water security, rapidly changing climate scenario, ever-increasing population and several other issues, the demand on land and its produce need to be optimized and sustained. Hence, the global problem of sustainability of natural resources is an important issue that needs practical research and suitable solution.

Hence, the issue of process driven watershed development with technology inputs and participatory methods is considered for research problem, particularly for rain fed rural areas. Considering the Indian situation, 70% of the Indian population lives in villages and rural areas while a large portion of this population depend on the dry land areas for their livelihood. Most of the people living in these regions have multitude of problems to face on a daily basis, in spite of various developmental efforts. This is one of main motivating factor to consider the research problem of participatory watershed development with geomatics tools for solution.

The intention is to explore on the possibilities of developing simplified solutions for watershed development by systematic analysis of existing conventional procedures, suggest improved processes, adopt participatory methods, integrate geomatics technology and propose an improved process based model that could benefit rural areas. It is also proposed to develop new strategies for monitoring and evaluation, using the combination of space-based imaging, information technology and other methods.

CHAPTER 3

OBJECTIVES & PROBLEM FORMULATION

3.0 INTRODUCTION

Watershed development is one of the most practiced and considered ecologically friendly approach for management of rainwater and natural resources. These methods are expected to provide rich dividends in the rain-fed areas and are capable of addressing many natural, social and environmental problems in the society, if planned and implemented in a scientific and systematic manner. Proper management of natural resources at catchment or watershed scale would produce multiple benefits in terms of increased food production, improved livelihoods, environmental protection, maintenance of biodiversity and the social-well being of the society at large.

The natural resources available are finite and need to be developed for the benefit of present legitimate stakeholders and preserved for the future generation, by adopting optimal developmental strategies. Over exploitation of land and water resources without due consideration to sustainability aspects can gradually result in unexpected adverse impacts, such as, productivity, increased land degradation and in turn significant impact on livelihoods. Integrated approach in the development of watersheds can result in better management, in terms of land, water and society. Consideration on processes can help in attaining better sustainability due to ensured capacity building and hence strong participation by the community.

The scope of current study is to explore watershed development processes, introduce new tools and technological solutions while evolving new strategies for monitoring and evaluation. Specific objectives are:

- Systematic Analysis of various processes that are stipulated under conventional watershed development methods
- Propose an improved process-based watershed development model that supports stakeholder involvement, including monitoring and evaluation, with suitable integration of tools and technologies

- Design, develop and deploy these tools and technologies with a focus on community involvement
- Field-test the proposed process-based model for watershed development by integrating developed tools and technologies.
- Discuss specific outcomes of the process-based watershed development approach

3.1 PROBLEM FORMULATION

While, watershed development involves optimal management of land and water resources for making it result-oriented, it is essential that special emphasis be given to social factors and the village community. Due to poor planning, adaptation, poor participation of the stakeholders and complexities in integrating multiple influencing parameters of development, the developments often end up with poor impacts. The challenge in this study is to integrate technology elements across the various process elements, adopt innovative approaches towards participation by stakeholders and explore methods to improve the overall performance of development at grass-root level.

Some of the important highlights from the literature survey are also the community participation in watershed development for better results at field level (Bartlett A G, 2010). However, the literature does not bring out specific references on the processes adopted and their linkages to the participatory planning which is an important aspect of development. While most of the publications present the watershed development as a problem involving natural resources management, very few works bring out sociological, participatory processes, community-based planning and environmental issues with respect to land and water management. Hence, the study attempts to incorporate these elements in addition to new techniques, adopt concept of systems approach and consider various parameters of watershed development through a process driven mechanism. The study elucidates the processes involved in watershed development and at the same time attempts to integrate some of the technology elements for planning, implementation, monitoring and evaluation. However, the following are some of the important considerations for pre-process activities.

i. Watershed prioritization and delineation, based on Agro-climatic conditions, terrain factors, environmental parameters, socio-economic and livestock status

ii. Preparation of natural resources information, village parcel boundaries data and compilation of socio-economic data under GIS environment for selected watersheds

Even though watershed development primarily emphasizes on soil and water conservation measures, there are not many publications on attempts made to define processes underlying such developments. Reports siting importance of participatory processes and use of technology for planning and development are not forthcoming. In the present study, an attempt is made to define the participatory processes involved in watershed development. Further, improved technology initiatives are taken by adopting appropriate geomatic tools and information technologies at various stages of planning, implementation, monitoring and evaluation.

3.2 PROCESS OF DEVELOPMENT

Definition of processes is a significant step towards building necessary procedures for watershed development. Logical sequences of steps, with necessary backward and forward linkages, define the various developmental activities as processes. Considering the intricacies involved in watershed development, which is multi-thematic and multi-disciplinary with multiple interactions between humans and the environment for arriving at best practices. Broad processes identified for development are, process-Initiation, local community mobilization and formation of affinity groups, capacity building, planning and implementation based on stakeholder participation etc. Monitoring and evaluation is separately embedded into the model for making the entire development more effective and result-oriented.

3.2.1 Process-Initiation: The process of development is initiated through the entry of a facilitator to the watershed, creation of baseline and mobilization of the community to take up developmental activities in the identified watersheds.

i. Entry of facilitator to the watershed – Facilitator could be Non Government Organisations (NGOs) or Government agency with local knowledge of the watershed and rural development. They play a major role of interfacing between the village communities and the implementing agency during the entire process of development.

ii. **Village-Community mobilization –** The success of participatory approach depends on the willingness of the community to be part of developmental processes and hence community mobilization is an essential initial step. Community mobilization processes include awareness and rapport building, focus-group discussions, specific sensitization programs on conservation etc.

iii. **Establishing Baseline –** Collection of baseline information on natural resources and social parameters of the watershed. This not only helps in further planning of various other processes, but also in assessment of impact at the end.

iv. **Entry point Activities –** This is an important pre-cursor for participatory processes. Identification of specific problems in villages through preples' participation, transform the problem in a set of activities and implement the activity through the community. This helps in building confidence amongst village community on participatory decision-making processes. Stakeholders need to evolve widely acceptable activities for the village and participate in their implementation to achieve the expected results. Hence, Entry Point Activities (EPA) helps in preparing the community in collective decision-making which is much needed when actual watershed development is taken up by them.

v. **Formation of Social Groups –** The village community can be broadly categorized into two categories, namely, land-based farmers and the landless. It is important that these categories of stakeholders are brought into the process of decision-making at micro-watershed level. With a strategy to include all types of stakeholders into decision making process, following social groups are formed. This is an important process which leads them to work in groups while also participating in decision making.

   a. <u>Self Help Groups (SHGs)</u> – These are small groups of local community, mostly dominated by women. They are formed based on co-operative concept and meant to organize micro-credits based activities to benefit individuals and their families, as needed, and also to support watershed development activities. Normally, about 20 women members make a group of SHG.

b. User Groups (UGs) – These groups mainly consist of farmers who are the direct beneficiaries of development. They are involved in farm-based activities and decide upon the activities to be taken up in their respective micro-catchments under the selected micro-watershed. Normally, about 40 such farmers make a user group.

c. Watershed Committees (WCs) – This is the major decision making group and it represents all facets of stakeholders at micro-watershed level. SHGs, UGs, artisans, progressive farmers and Government representatives put together form a WC with at least 50% women representation (considering the equity and inclusiveness criteria). This is the group that is responsible for all developments in the micro-watershed. SHGs, UGs and WCs put together are also known as Community Based Organisation (CBO), which together are responsible for various activities under watershed.

3.2.2 Training & capacity building – This process enables all stakeholders to learn about watershed development and brings them on to a common platform of understanding the various nuances of developmental planning and implementation. Through this process the village community is empowered with the basic knowledge of development and management at watershed level.

3.2.3 Participatory Rural Appraisal (PRA) – This is one of the important processes that enable the community to prepare their own plan of development. The stakeholders are encouraged to participate in planning and decision-making through field-level interactive sessions. They get an opportunity to share their field-level problems and bring out issues that need to be solved as part of development process.

3.2.4 Action plan preparation – Successful PRA leads to comprehensive action plan preparation. All the stakeholders are involved in action plan preparation by taking major decisions on individual farmland (private land) as well as in common land (Government land in villages) for a comprehensive watershed development through group activities.

3.2.5 Approval of action plan – This is a process through which the Government body participates in providing approval for action plans prepared by the stakeholders, based on a set of criteria. The plans are approved, based on evaluation of the criteria adopted for land and water conservation, including socio-economic development. Action plans are normally prepared for implementation in 3-year timeframe.

3.2.6 Implementation, Monitoring and Evaluation – This is an important parallel activity which is carried out independent of developmental activities to ensure developments as per plan. The approved plan, for both short-term and long-term implementation, provides a logical framework for the proposed activities in a watershed. Hence, monitoring and evaluation, within itself, is a set of processes that need to be followed in parallel with developmental processes that plays a major role in the ultimate result.

3.2.7 Process completion & withdrawal – With completion of all planned activities and physical interventions, there is a need for systematic withdrawal of the facilitator to set a stage for the stakeholders to manage resources themselves. As a part of this process, the assets developed are handed over to the local community (Gram-Panchayat) for further operations, maintenance and management for sustainable future.

3.2.8 Impact assessment – Impact assessment is nothing but evaluation of the processes followed and actual development achieved. This process attempts to evaluate, both qualitatively and quantitatively, the outcome of the various activities undertaken in terms of natural resources as well as social developments that have occurred in the micro-watershed.

The sequence of events, that are traditionally documented for implementation as a set of processes in a watershed development programme is presented as a flow diagram in Fig 3.1.

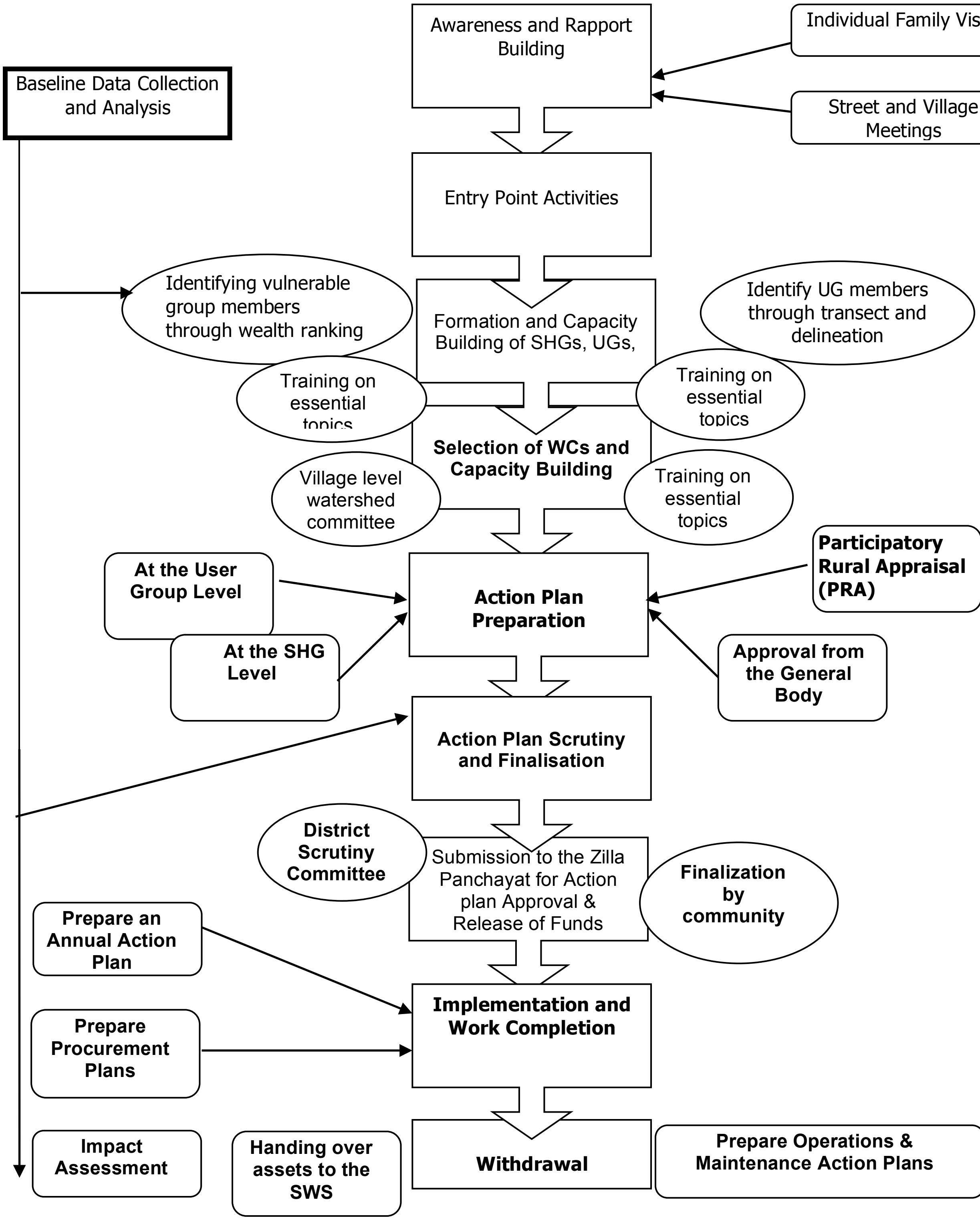


Fig. 3.1 Processes as followed for watershed development

3.3 Proposed Process based Model

The Study is aimed at evolving a practical approach to implement process-based participatory methods of watershed development with integration of appropriate technologies for optimal solution. Concepts of systems approach for the analysis of existing methods and adaptation of improved methods at field level for better results is attempted.

The conventional method involving broad processes is presented in the form of a road map in Fig 3.2, describing all major process elements, highlighting the sequence of events for watershed development.

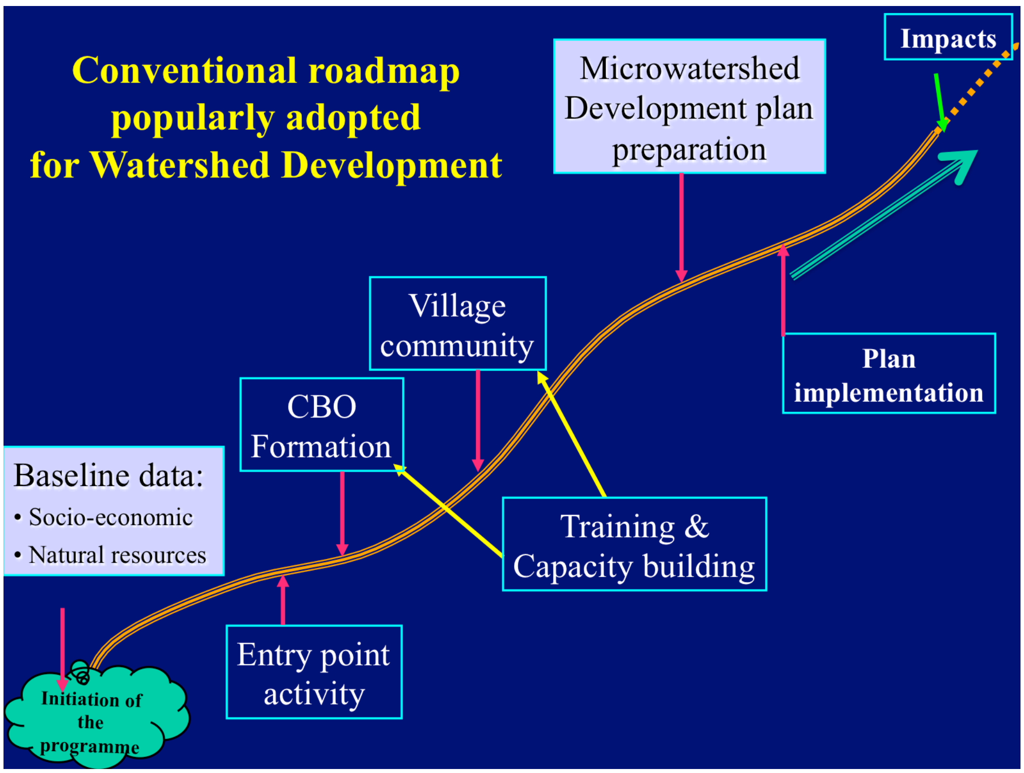


Fig. 3.2 Conventional method for watershed development

The procedures used in the conventional system are the basis for exploring new strategies for watershed development. In the present study, a set of interventions with integration of new methods is proposed for implementation, analysis and performance evaluation. The important social aspects, which also need to be studied are incorporated in the model for better planning of the proposed activities. The proposed process-based approach as compared to the conventional system is given in Table 3.1 that highlights the importance of each stage of development and proposed improvements.

Table 3.1 Proposed Technical interventions for Process based model

SL NO.	STIPULATED PROCESSES IN CONVENTIONAL METHODS	PROCESSES PROPOSED WITH TECHNOLOGY INTERVENTION
1.	**Entry of the facilitator to the watershed**	
	• Basic knowledge through published report followed by Rapid Rural Appraisal (RRA) at field level. • Basic sensitization to community, group interactions, • Census data, other secondary sources and field data collection.	• A-priori acquisition and processing of satellite images and GIS-based thematic Maps • Advance preparation on potential field level problems due to geospatial data • Census data and other secondary source data. • Focused field level sensitization and winning confidence of the local people. • Group interactions, & field data collection are further used
2.	**Village Community mobilization**	
	• Methods like, grama-panchayat (village level decision making body) meetings, focused group discussions, sensitization to local bodies etc. are planned to mobilise peoples' participation.	• Apriori analysis of geospatial data helps in better planning and strategy building. • Building of better strategies and field preparations • Grama-panchayat meetings, focused group discussions, sensitization to local bodies etc. are further held to mobilise people to participate.
3.	• **Entry point Activity:** Objective here is to do a pilot activity with peoples' participation to gain confidence of the locals.	
	• Village level discussions, decision making by panchayat, activity selection, plan approval and implementation are routinely done.	• Use of large scale Geospatial data helps in appropriate decision-making by community. • Active community participation due to geospatial data and better problem identification.

SL NO.	STIPULATED PROCESSES IN CONVENTIONAL METHODS	PROCESSES PROPOSED WITH TECHNOLOGY INTERVENTION
		• Village-level discussions, decision making, activity selection, plan approval and implementation. • Monitoring of implementation
4.	**Baseline data collection**	
	• Field surveys and house-hold surveys are planned for data collection on Natural resources and socio economic parameters • Routine data collection	• Remote sensing data is used for mapping of natural resources and creation of baseline GIS database. • Sampling Design for systematic field survey and household surveys. Integration of census and other socio- economic parameters
5.	**Formation of Social Groups**	
	• Use of baseline data on socio-economic parameters and information on Below Poverty Line (BPL) information, manually prepared maps of micro-watershed, if available • Formation of Community Based Organisations (CBOs) at micro-watershed level covering land-less, BPL and marginal farmers (Often randomly done)	• Use of baseline data on socio-economic parameters, particularly the information on BPL and geospatial data at village and cadastral level with respect to micro-watershed • Formation of Community Based Organisations (CBOs) at micro-watershed level covering land-less, BPL and marginal farmers
6.	**Training & Capacity building**	
	• Training of CBOs and other stakeholders on various subjects related to Watershed development – these are not systematically done • Training programmes are planned for group dynamics, book keeping, specific activities of Self Help Groups, User Groups and Watershed Committees and on natural resources development.	• High Resolution Satellite Images and GIS Maps on resources are used as an aid in Systematic training of the CBOs on watershed Development • Training programmes are planned for group dynamics, book keeping, specific activities of Self Help Groups, User Groups and Watershed Committees and on natural resources development.

SL NO.	STIPULATED PROCESSES IN CONVENTIONAL METHODS	PROCESSES PROPOSED WITH TECHNOLOGY INTERVENTION
7.	**Participatory Rural Appraisal (PRA)**	
	• Conduct of PRA is done by arranging group discussions at watershed level, stakeholders level discussions etc. (This is an important process but is poorly done due to lack of data and information)	• PRAs are planned with the help of High Resolution Satellite Images, natural resources data layers from GIS, Participatory MIS and GIS tools • Improvised MIS and GIS tools with Local language interface could make PRA more effective. • PRAs are supported by active participation of stakeholders, focus on local issues, private and common land issues development • Interactive sessions with the stakeholders through map interface, selective field surveys, stakeholder level discussion etc could further enhance the process response.
8.	**Action plan preparation**	
	• Often, action plans are not prepared through a consultative process and with peoples' participation • Limited or no participation of locals, low scientific inputs are used and decisions are subjective in nature • Lack of systematic documentation of the process	• Successful PRA leads to sound action plan preparation • Scientific planning processes are adopted using inputs from satellite images and GIS-based thematic maps through a participatory planning process • Customized IT solutions allows systematic action plan preparation at field level • Customized GIS software provides real-time action plan map preparation in the field • Documentation of action plan is done on the field and with stakeholders and this ensures transparency in planning process

SL NO.	STIPULATED PROCESSES IN CONVENTIONAL METHODS	PROCESSES PROPOSED WITH TECHNOLOGY INTERVENTION
9.	**Assistance for approval of action plan by competent authority**	
	• Hand-written/ manual-methods are used in presenting action plans • Choice of interventions for action plan preparation is subjective • Due to Manual methods, validation of action plans is subjective and hence not uniform.	• Participatory and scientific criteria based action plan preparation process ensures reliable inputs • Participatory MIS and GIS solutions for preparation of action plan ensure automatic report preparation and action plan map generation at the field. • Automated validation of action plans through IT-based solutions allows use of well defined scientific criteria for decision making • Ease in approval process due to systematic documentation, criteria based decision making, Improved efficiency in follow-up
10.	**Implementation, Monitoring & Evaluation**	
	• Poor implementation due to poor planning and lack of scientific inputs and participation • Non-systematic and crude methods of reporting makes the monitoring and evaluation ineffective • Improper baseline data poses problems in evaluation, impact evaluations are often not possible • Manual methods of field visits and surveys adopted for monitoring and evaluation are less effective, more time consuming and hence not result oriented.	• MIS and GIS based reports and maps for systematic implementation • Better peoples' participation is ensured • Online monitoring system for all processes – better quality of works and transparency • Remote sensing for mid-course corrections • Systematic Baseline data geospatial platform and field samples enables effective impact assessment (both qualitative and quantitative).

SL NO.	STIPULATED PROCESSES IN CONVENTIONAL METHODS	PROCESSES PROPOSED WITH TECHNOLOGY INTERVENTION
11.	**Completion of all physical interventions and withdrawal**	
	• Absence of well-defined procedures or documentation. • Hence, withdrawal plans are not adoptable.	• MIS and GIS databases serve as the backbone. Actual achievements are updated on the system. • Remote sensing and GIS data helps as permanent information for long term sustainability. • Hence, smooth transfer of all assets to the local bodies is simplified. • Structured withdrawal possible - All geospatial and scientific data are provided to local bodies for future reference and post-implementation management.
12.	**Impacts assessment**	
	• Due to poor (or no) baseline data impact assessments are subjective • Absence systematic records on the processes followed, action plans and mid-course implementation status, makes it difficult for impact assessment. • Impact assessment often turns out to be subjective due to above reasons.	• Systematic baseline data both from space and ground makes it possible to conduct accurate impact assessments • Since all indicators are well defined in the beginning, all datasets are standardized and hence final impact assessments are well organized. • The design leads to data-rich procedures and hence assessments are precise • Impact assessments are done based on a combination of remote sensing, GIS and sample field data with reference to the baseline database.

The above table highlights the proposed process-based model for watershed development by appropriately choosing the new technological tools as against the conventional procedures. The proposed methodology requires satellite remote sensing data, geospatial databases on thematic layers, Participatory GIS tools, information technology for Participatory MIS, new methods for concurrent monitoring and change detection techniques. A new road map for watershed development based on improved process elements as defined above can be represented as shown in Fig 3.3.

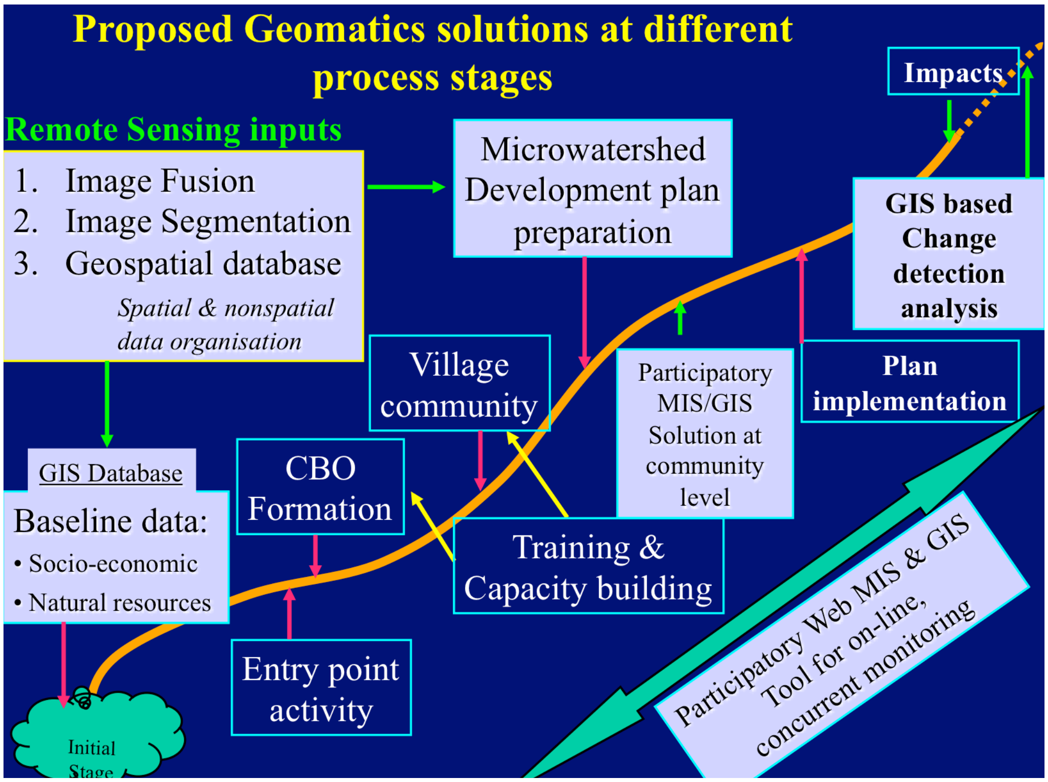


Fig. 3.3 Proposed Geomatics solutions at different process stages of implementation

A comparison of Fig 3.2 and Fig 3.3 indicates that the proposed process-based model with technological interventions could provide several new possibilities. This calls for new software tools development as proposed under different processes to achieve the set objectives.

3.4 MONITORING AND EVALUATION

The problem formulation provides yet another dimension to the proposed model, that is, use of information technology for online monitoring of different process stages and impact evaluation using multi-time satellite remote sensing data with ground sampling.

Concurrent monitoring helps in making required mid-course corrections and steering the programme with respect to proposed objectives. The design of the M & E is a combination of discrete and concurrent monitoring methods, which are (a) input-output monitoring and (b) impact assessments respectively. The input-output monitoring is done in tandem with the implementation of various processes of development, which also uses field sample survey data for validation. Advance information on major investments on the field could drive process analysts to track and analyse such processes with respect to quality of implementation. It is necessary to develop a technology based M&E system that uses discrete remote sensing inputs, Information technology solutions for concurrent monitoring of implementation and geospatial database for change analysis.

3.5 SUMMARY

In summary, a participatory and process-based model for watershed development, including M&E methods are proposed. Specific Geomatics tools and Information technology solutions are also proposed to be developed as part of improved approach. An improved road map for process based development is proposed in comparison with conventional approach as a part of present study. A comprehensive monitoring and evaluation method, to evaluate the efficiency of the proposed process-based watershed development, through online M&E and space-based observations are also proposed.

CHAPTER 4

BROAD METHODOLOGY FRAMEWORK AND DESIGN

4.0 INTRODUCTION

Process based Watershed development with suitable integration of participatory methods and geomatics tools are proposed in the study. The proposed methodology has a consideration on different processes of development with the integration of community aspirations, experts' knowledge and use of innovative technologies for better management of natural resources. New techniques for online monitoring, participatory GIS techniques and satellite-based earth observation data for decision making at stakeholders level are developed for better implementation, monitoring and assessment of the outcomes.

4.1 DESIGN OF PROCESS BASED MODEL

On the basis of the problem definition and scope of research work, the design for process based model for watershed development is discussed. The process based model is primarily a social problem which needs to be addressed through scientific and technological tools. It is important to note that community participation is very important for successful watershed development and hence the processes are defined with community involvement in different stages of development. Hence the methodology includes optimum combination of science, technology and social aspects for development and implementation.

4.1.1 Watershed Delineation

Basic requirement for watershed development is the delineation of precise watershed boundaries. Traditionally, topographic maps are used for manual delineation of watershed boundaries by marking the ridgelines with reference to contours, natural streams and other indicators (Watershed Atlas of India 1990). Considering the Indian example, 1:50,000 scale maps are available for the entire country which provides contour lines at 20m intervals and are good reference data for this purpose. In addition to this, village boundaries are also required to meet the requirements of planning and proper administration of development. Data on village clusters are generally considered for coverage of contiguous micro-watersheds for planning and development. Analysing such data sets under a GIS domain helps in efficient planning.

This necessitates preparation of base layers for GIS database organisation, followed by accurate registration of contour lines or Digital Elevation Model (DEM) as a reference to delineate watershed boundaries. Other GIS layers like, slope, river streams, drainage network and surface water bodies are also used as reference while delineating watershed boundaries. The advantage of the technology is that multiple GIS layers could be simultaneously used for better control and accurate watershed delineation. Considering the size and area of coverage, national standards for watersheds are also defined which follows a systematic hierarchy, ie., Basin, Sub-Basin, catchment, sub-catchment, watershed, sub-watershed, micro-watershed and micro-mini catchments (Watershed Atlas of India 1990). Such guidelines are used for systematic preparation of geospatial database up to micro-watershed level for planning purposes. For example, micro-watershed boundaries (thick lines) are overlaid on village boundaries (thin lines), as in Fig 4.1, to identify those villages that come under development unit for better administrative control.

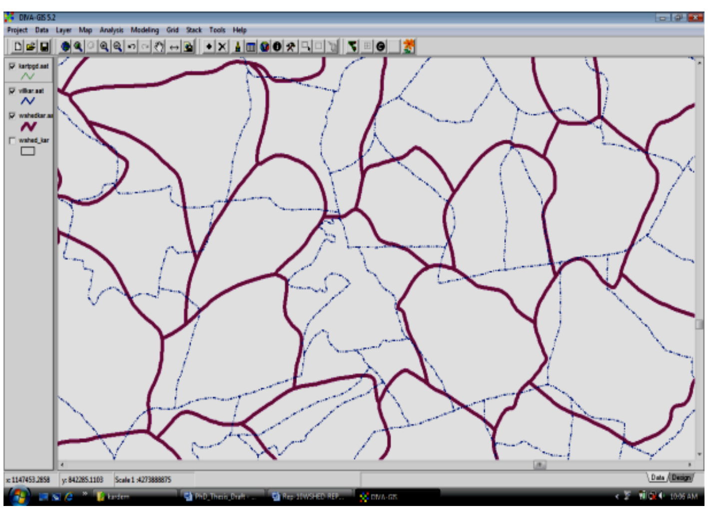


Fig. 4.1 Micro-watershed boundaries overlaid on village boundaries for Uttanur sub-watershed, Kolar District

This kind of visualization helps in identifying villages from selected watersheds and further in better planning of other activities. GIS technology enables linkage of attribute tables (tabular data of description) with vector data, which in turn helps in deriving desired information about villages or micro-watersheds. Geospatial queries enable visualization of required spatial and non-spatial data as desired while planning.

Digital Elevation Models (DEM), derived from satellite stereo, serves as important input (Fig 4.2a). DEMs are used for validation of watershed boundaries. While contours provide information on heights through discrete contour intervals, DEMs generated from satellite stereo coverage, provide continuous height information at specific grid spacing depending on the DEM postings. The elevation data used in this present study is taken from DEM derived from CARTOSAT-1 Stereo with 30 meter postings as available on open source inputs of Bhuvan web-portal (Bhuvan Web portal 2009). The watershed boundaries are initially delineated in the digital domain using topographic reference as backdrop (Pandey et. al. 2006). These are further validated and refined using DEMs and relief shaded maps. For example, Fig 4.2a and 4.2b highlights DEM and relief shaded map respectively for parts of Kolar District. Vector overlays and digital map creation facilities under GIS environment are effectively used in the present study for validation of sub-watersheds and also for creation of digital geospatial database elements. This kind of cross-referencing ensures that the terrain related factors well accounted for while watershed delineation and finalization of boundaries for development.

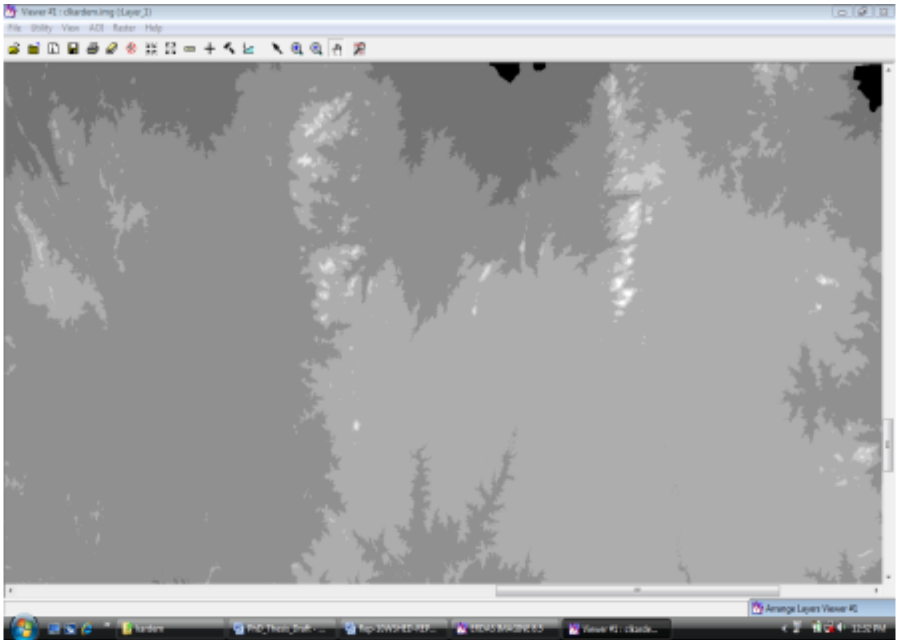


Fig. 4.2a: Digital Elevation Model (DEM) in raster form

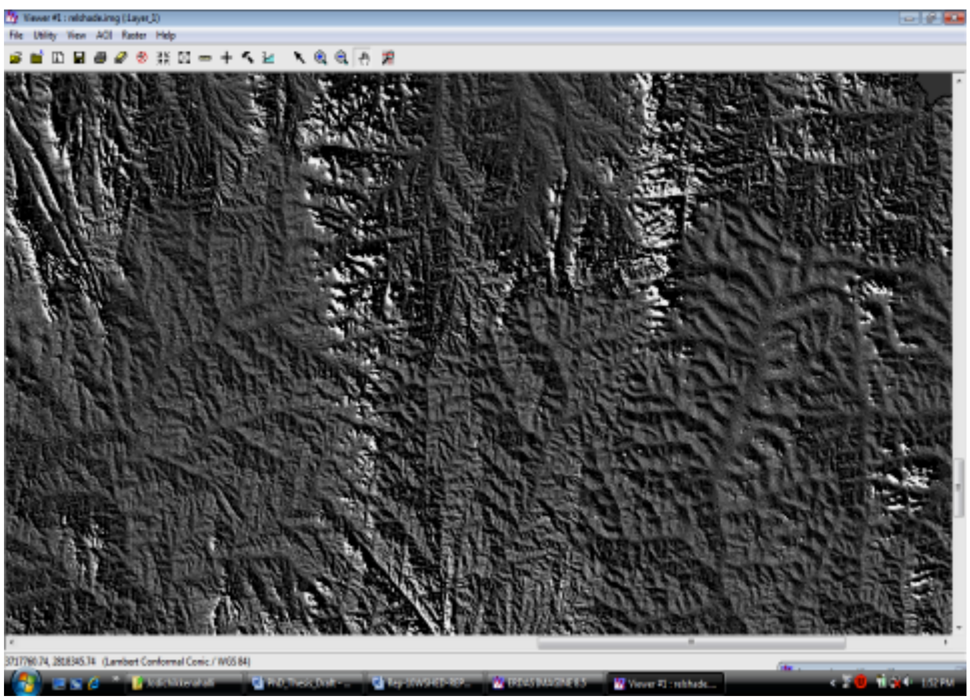


Fig. 4.2b   Relief shaded image generated from DEM highlighting the terrain details

A Sample sub-watershed from Kolar District that represents one major development unit, with 6 contiguous micro-watersheds as its subset, are presented in Fig 4.2c. Also, selected GIS layers like, major drainage network, surface water bodies and slope layer (for one micro-watershed as sample depiction) are also presented in the example. The watershed development depends on such inputs in spatial form and is critical for all other developmental activities that follow. Each micro-watershed is one development unit and respective village groups and watershed committees will be responsible for their respective micro-watersheds. The derivation of such information and making it available to stakeholders who are actually involved in development is particularly important. Hence, from the example presented in Fig 4.2c, it may be inferred that there would be 6 independent Community Based Organisations (CBOs), which will work for their respective micro-watersheds for development. This, in turn, would enable the development of the entire sub-watershed on a parallel basis by the respective groups.

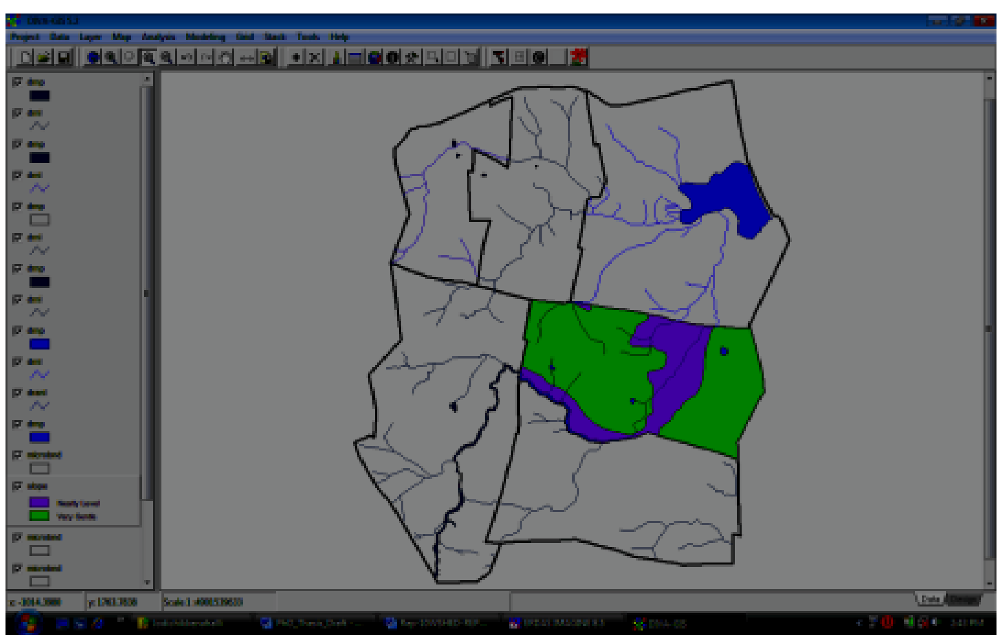


Fig 4.2c Sub-watershed and 6 micro-watersheds of kolar district

Once the sub-watershed, micro-watersheds and corresponding village boundaries are well established, it is also required to overlay cadastral database of those specific villages for the purpose of identification of beneficiaries or stakeholders on the basis of land holding, with respect to their field survey numbers, as available from the revenue records. This facilitates creation of required boundaries database for fuse at the initial stage.

4.1.2 Baseline data creation

Baseline data collection and systematic organization of the collected data are essential fundamental step in the process. This helps in effective planning, implementation, monitoring and assessment of performance of programmes. Appropriate indicators for natural resources utilization and for establishing the socio-economic conditions of the stakeholders are the primary elements for tracking and monitoring during the implementation phases. Baseline data provides the necessary benchmark or serves as a foundation to monitor the performance at various stages of implementation. In addition to the identification of indicators for data collection, it is equally important to arrive at appropriate strategies for data collection and its analysis. The basic data needed in the present study are broadly classified into (i) natural resources (land and water), (ii) Socio economic data.

4.1.3 Natural Resources (Land and Water)

Indian Remote Sensing (IRS) Satellites provide high resolution capabilities through a series of satellites, namely, IRS 1C, IRS 1D and IRS P6, which are effectively used as input data. IRS 1C and 1D are satellites with similar imaging capabilities which include high resolution Panchromatic and medium resolution LISS 3. IRS P6 provides multiple options for imaging which include Advanced Wide field sensor (AWifs) with high revisit capability, medium resolution imaging with LISS 3 and high resolution multispectral imaging with LISS 4. While, LISS 4 imaging with 5.8 m spatial resolution is directly amenable for digital mapping using classification techniques, the panchromatic band (5.8 m spatial resolution) and LISS 3 multispectral bands (23 m spatial resolution) are used as inputs for merging before preparation of large scale maps. Image fusion techniques, to generate high resolution synthetic multispectral images at 5.8 m spatial resolution, are considered using panchromatic and multispectral data. An attempt is also made to generate images using different image fusion techniques, namely,

(a) Principal Component Analysis (PCA)

(b) Broovey's technique

(c) multiplicative linear transform and

(d) Discrete Wavelet Transforms (DWT)

The fusion images generated using these techniques are compared so as to arrive at the optimal technique that represents features effectively for image interpretation and mapping. Literature survey shows publications on image fusion and their comparison (Svab and Ostir, 2006, Gangkofner et. al. 2008). A similar mechanism is adopted in the present study, but the objective here is to adopt and use the fusion methods, which provides the best feature discriminability under different agro-climatic conditions.

Image classification using maximum likelihood method, artificial neural network (with improved software design for ground truth and training methods) and interactive interpretation methods are used to prepare land use and land cover maps. These are supervised methods that help in producing maps which are amenable for use by the community for decision making. These maps are directly coded and imported into GIS platform as a geodatabase.

Land use and Land cover maps are developed using high resolution satellite data. Further, information on soil, geology, geomorphology, ground water prospects, slopes, drainage network, water bodies etc., are also created and used as geodatabase elements under GIS platform. These GIS layers not only help in spatial representation of the natural resources database in a watershed, but also help in providing much needed inputs for the scientific planning and decision making to decide upon interventions for development. Similarly, water resources related data layers are developed representing surface and ground water components as a part of comprehensive database creation. The baseline data is thus generated at large scale (1:10,000) using high resolution satellite data, sample ground validation, other ancillary inputs including the cadastral reference from land records.

4.1.4 Sample Design for Socio-Economic data

Village level Database creation on some of the socio-economic aspects gives information on the village communities. To create a representative database on such aspects, a sampling strategy is designed and developed in such a way that proper assessment is available across watersheds at different stages of implementation, such as, initial, middle and end of implementation. Following basic steps are considered as part of the sampling design when implemented at State level.

(a) Coverage of micro-watersheds that are discretely distributed across different Agro-climatic regions with respect to districts and blocks in a State.

(b) Based on the terrain characteristics, such as ridges, Middle portion and Valleys, the micro-watersheds are selected from identified sub-watersheds

(c) The farming community living under each of such segregated regions is further broadly categorized into Marginal, Small, Big, and land-less on the basis of land holdings and economic status.

Sample size for socio-economic data collection is chosen as per the above classification, to generate and organize the data that better represents the conditions at the field level.

A sampling design with multi-stage criteria for data collection is adopted.

Stage-1: Selection of Agro-climatic zones across different districts and simple random sampling of sub-watersheds within each such zones

Stage-2: Within each sub-watershed, selection of micro-watersheds using area-based sampling approach based on terrain type, namely, Ridge, Middle and Valley

Stage-3: Within each terrain type household sampling is done. Stratification of the households is done based on farming size, that is, Marginal, Small, Big and Landless, for data collection.

Sampling approach adopted in the present study is highlighted through an illustration in Fig 4.3. The illustration, taken from the study area, shows an example of sub-watershed (SWS), corresponding micro-watersheds (MWSs) with the selection of 3 MWSs situated in the ridge, middle and valley portions respectively. Example of a cadastral map taken from one of the MWSs, random samples of parcels (distributed across the entire MWS) and housing cluster for sampling are also depicted. The household sampling criteria gives equal weights for the choice of different income groups to enable representative samples from different categories of farmers. The sampling design discussed above attempts to highlight the hierarchical method adopted in reaching out to the households for socio-economic data collection and also the use of remote sensing and GIS database for natural resources information. The methodology also ensures that an unbiased sampling is done which truly represents all sections of the society at MWS level, thereby providing a true picture of the socio-economic status of the village community involved in developmental works.

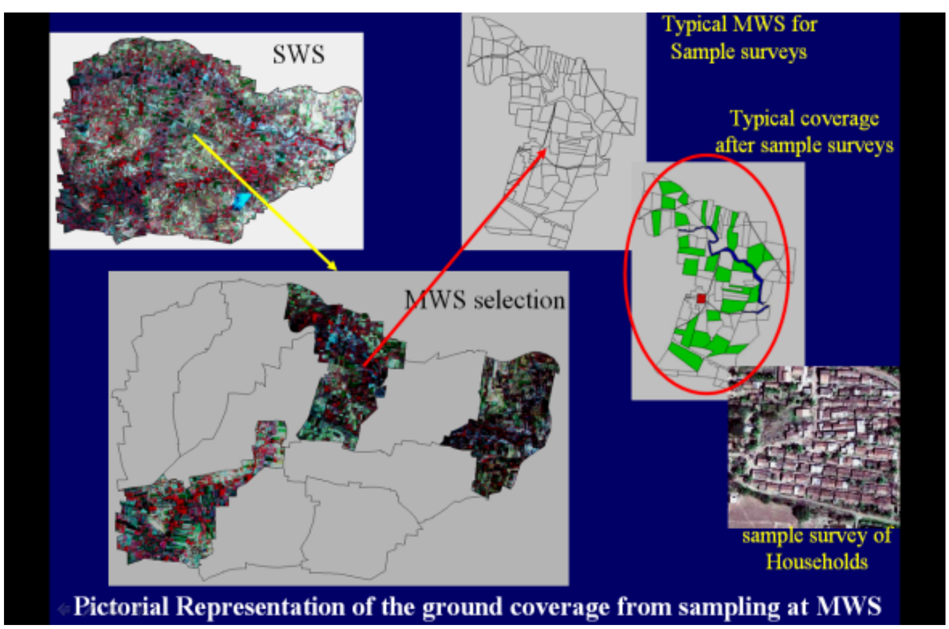


Fig 4.3 Area based sampling for micro-watershed selection

4.1.5 Control Areas

Establishing control villages as part of sample design is another important aspect that is considered while establishing the baseline data. These villages are located outside the selected watershed areas and within the corresponding agro-climatic zone. Data from the control villages serve as an important observation point to help in calibrating changes in the treated micro-watersheds. This helps in analysing the actual impacts due to treatment as compared to un-treated areas. This is also useful to overcome any bias that may be committed during impact analysis. The procedure ensures that same conditions prevail within and outside the treated areas and hence the actual impacts will be observed as part of impact analysis. Hence, the sample design with control area identification serves as an effective indicator that brings out actual impacts from development.

4.2 PEOPLE-CENTRIC PROCESSES

The community participation is one of the fundamental elements of the process based watershed development programme. The processes considered for involvement of the stakeholders are important for the success of the developmental strategies. Village level facilitators address the social sector in the watershed developmental activities and prepare the communities through a series of training and capacity building. Facilitator plays a pivotal role and a good interface between the implementing agency and the villagers. They also ensure that local community will actively involve and participate in all developmental activities. Their role is critical for watershed development.

Village community participates in various processes of watershed development, which involves varieties of activities, starting from simple sensitization on watershed development to implementation and post-implementation processes. Each of these processes needs to be carefully executed and monitored. To facilitate and monitor various processes of development, there is need of identification and design of new tools and technologies. These are specially identified and developed as part of research objectives. Some of the important processes considered are:

1) Village community mobilization – Sensitization of village people on watershed development.
2) Entry point activity – A village-level activity, with peoples' participation, to initiate participation in a developmental activity
3) Formation of Community Based Organisation – Formation of affinity groups for men, women and youth to involve as village groups in various activities of watershed development.
4) Training and capacity building for the community – Educating and skill development amongst villagers for active involvement in watershed development.
5) Participatory action plan preparation – Enable local groups and village community to participate in plan preparation and decision-making processes.
6) Action plan approval and implementation – Evaluation of action plan and sanctioning of approval for action plans prepared by the community. Village communities also organize themselves to implement approved action plans and hence enable labour for the landless farmers.
7) Post implementation processes and sustainability – Above processes prepare villagers to develop and manage their own resources. Hence, for sustainable development the assets are handed over to village community.

These are some of the major people-centric processes that help in building a strong foundation for the community to develop and sustain watershed development. The potential advantages of using GIS and other technologies are explored for planning and decision-making.

GIS and Information Technology (IT) tools are designed, developed and applied as a part of processes. On examining several stipulations of conventional methods used in development, major processes are highlighted in Table 3.1. These processes are also shown in the form of a road map for development in Fig 3.3. Table 3.1 also presents the proposed improvisation planned as part of the study using technology alternatives. This also highlights a blend of technology and conventional interventions for development. Use of remote sensing inputs, image processing techniques, geospatial data, GIS for decision making, participatory GIS, participatory MIS, unified MIS and GIS solutions for action plan management, web-based solution (webMIS and GIS) for concurrent monitoring and evaluation, sampling design for household and field surveys and data analysis are some of the important highlights of the methodologies developed under the study.

4.2.1 Participatory Rural Appraisal (PRA)

PRA is of the important social process, normally administered by the local facilitators, involving villagers, in planning and decision making with respect to developmental activities. The process is meant to capture information on the present status of land use and problems problems faced by individuals through a participatory appraisal. The information gathered, not only serves as an important input for baseline database, but also helps in planning site-specific interventions for developmental planning. Traditionally, facilitators conduct PRA exercises with stakeholders' participation to provide inputs on various aspects related to farming practices, village development and other issues. This is normally done in a central place within watershed area, enabling all stakeholders to participate.

In the present stsudy an attempt is made on introducing geospatial data and maps of required area for PRA exercise to facilitate better planning process. Geospatial database, prepared at micro-watershed level, come handy and can play an important role in making PRA exercise more meaningful and effective. The local community can be facilitated to use these maps of the micro-watershed along with cadastral overlays and thematic maps with local language interface for better understanding and interactions in PRA exercise. A simple GIS solution in a PRA process with specific information on land and water for the micro-watershed helps the village people with scientific inputs for informed decision-making.

4.3 ACTION PLAN PREPARATION

This is one of the most important steps of watershed development process. The action plans are prepared by primarily considering the baseline data, generated on various activities involved in the development processes. Public participation, along with large scale geospatial data helps in the preparation of such plans. Specific software designs are conceived and developed to make the process of action plan preparation more scientific and efficient. Following software developments are undertaken to enable the local level watershed interventions.

(i) High resolution Geospatial Solution: It involves preparation of high resolution satellite data and geospatial database on basic natural resources and action plans for land and water resources development. This serves as a critical input in assisting the local communities in planning and decision making.

(ii) Participatory MIS solution: This includes customized software solution to capture action plan components and peoples' aspirations at field level with respect to private and common lands at micro-watershed level with facilities for automatic technical scrutiny and easy evaluation of action plans.

(iii) Participatory GIS solutions: Development of customised GIS solution to depict scientifically acceptable action plans at cadastral level for implementation and monitoring. A GIS viewer is also developed that enables multiple GIS layer visualization, overlays and geospatial query as some of the major facilities.

(iv) Local language interface and report generation: Activities documented as part of PRA and consolidated Action plans are generated as reports in the local language for submission to Zilla Panchayat (ZP – District level decision making body) for approval, which is the local body for approval of action plans for implementation.

The interventions finalised at micro-watershed level, not only ensures peoples' participation but also supports smooth implementation, providing useful geospatial solution for local level planning.

4.4 ACTION PLAN IMPLEMENTATION

Subsequent to technical scrutiny of the action plan, the implementation process is taken up that involves varieties of on-field activities. That is, developmental activities in watersheds with respect to both private and common lands. This is a process that also needs close monitoring of implementation across the ridge, middle and valley portions of any selected micro-watersheds. Action plan implementation takes place for about 3 years at field level, which poses the unique challenge of concurrent data collection for monitoring. It is important that planned activities are implemented within this period. During this period it is required to collect online data on various developmental activities and to facilitate sample field validations on a regular basis for effective monitoring.

A Web based MIS and GIS solution is developed to monitor and track various events that are implemented as part of action plans. Also, remote sensing techniques are used to highlight mid-term and final impacts due to implementation.

4.5 DESIGN OF MONITORING AND EVALUATION (M&E)

The study is intended to focus on M&E in addition to process level interventions. While methodology developed for various process interventions address specific improvements in the implementation stage itself, the M&E is more focused on concurrent and discrete monitoring methods to track various aspects of implementation. However, not much study on concurrent monitoring methods adopted for M & E has been reported. Hence considering the various stages of watershed development, the M&E methodologies are developed and tested for its efficacy in the present study.

The success of M&E rests on reliable data collection from the field, data analysis and near real-time reflection of field situation for decision making and mid-course correction. This involves design and development of information systems that is able to provide on-line information for effective monitoring and management. Considering these aspects, following M&E methodologies have been developed with specific objectives of making it practically adaptable and usable. M&E methodology suggested in the current study is of 2 types (i) Concurrent monitoring and (ii) Discrete monitoring.

4.5.1 Concurrent Monitoring

Concurrent monitoring enables tracking of specific indicators, which are dynamic and are amenable for continuous monitoring at micro-watershed level. Discrete monitoring is done using space based imaging and sample field validations at specific time intervals to highlight short-term and long term impacts due to field implementations. Process monitoring is a field intensive method and uses extensive field data, to draw conclusions on quality of implementation. However, in the present study the processes are observed using sampling techniques for collection of field and households data. The inputs are used with concurrent data from MIS systems for effective monitoring of on-going processes. The proposed M&E model also proposes self-evaluation from the community to bring about transparency in the system. The M&E Model with highlights on various activities in different types of monitoring methods is presented in Fig 4.4.

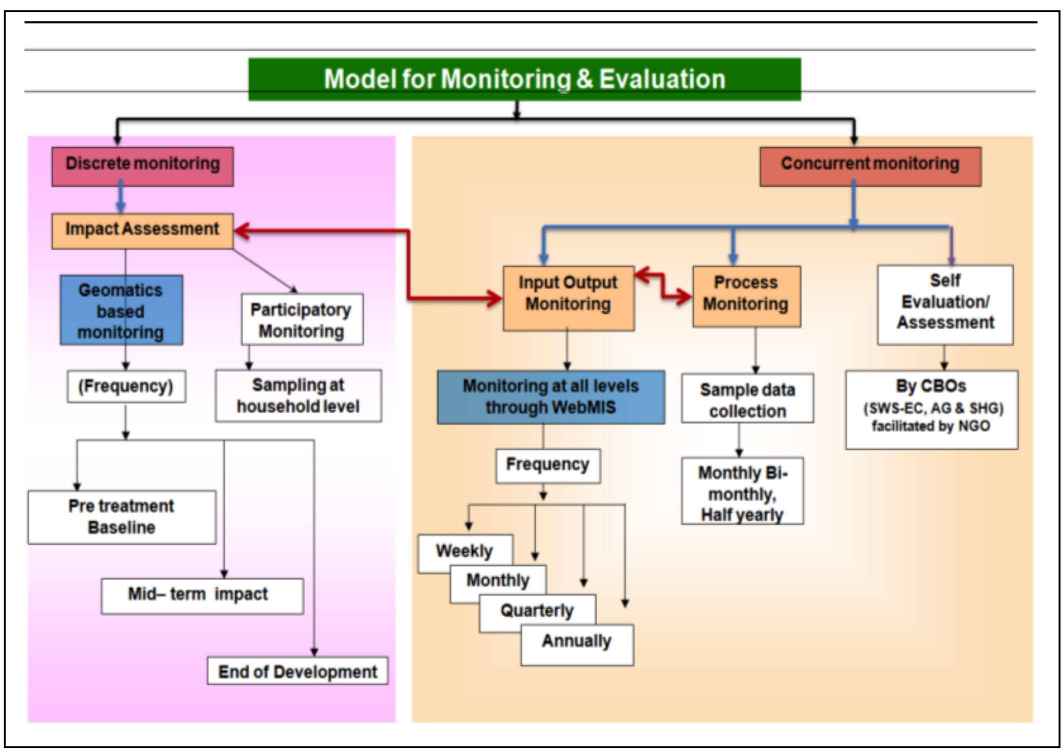


Fig 4.4 Monitoring & Evaluation Strategy for Decision Support

This is an approach that captures continuous information on the various field based activities as it happens. Monitoring methods like input-output monitoring and process monitoring work in coherence with each other as a strategy to ensure high quality of implementation. While input-output monitoring tracks various aspects of watershed development through MIS and GIS solution, the process monitoring is done by conducting sample field surveys at micro-watershed level. The field survey based process monitoring uses MIS reports as a cross-validation tool for monitoring various activities with respect to quality of implementation. Hence, a close link between these two monitoring methods facilitates effective tracking and monitoring of all developmental activities. The importance of the information system lies in developing necessary key indicators that can optimally track processes. The other basic necessity for the design of information system is to make it on-line and easily accessible for near real-time decision making.

4.5.2 Discrete Monitoring

This approach involves the use of remote sensing and GIS for measuring mid-course impacts due to interventions in micro-watersheds and sample field verification on specific indicators for the purpose. Baseline images, which are representative of the pre-intervention status, are considered for comparison and generation of impact assessments at discrete time intervals. Ideally, depending on the timeframe for implementation, the remote sensing and GIS based assessments are done at different time intervals, such as, mid-term and end-of-implementation to measure impacts. The methodology makes use of multi-temporal satellite data for processing, analysis and comparison using multi-temporal image comparisons and change detection techniques.

4.6 SUMMARY

An attempt is made in this chapter to address broad methodologies for development and the various design elements for realization. The focus is also on development and use of technology for process-based watershed development model. This includes both social and natural resources related parameters for design and development of methods. They are in the area of, image processing, geospatial technologies, sampling design for household and field data collection, participatory MIS and GIS solutions and methods for M&E. An attempt is made to broadly highlight the different processes involved in watershed development. The focus is also on specific areas of the programme where better technology can be adopted as part of intervention to improve upon conventional methods. In addition, the proposed M&E methods with an optimal blend of conventional methods and technology are also presented. Keeping this as the basis, the proposed methodologies and their flow with respect processes of watershed development are addressed.

CHAPTER 5
STUDY AREA & DATA USED

5.0 INTRODUCTION

The methodology developed, in the present study, needs to be applied and tested on watersheds. Considering the broad methodology framework, it is required to collect varieties of data from different sources, such as, baseline data, sample field data, near real-time data on implementation and also space-based images at different stages of implementation. Monitoring and evaluation of the performance of the proposed model is another important aspect of the study. Hence, collection of relevant data at the beginning, during implementation and at the end of implementation is essential.

The study area falls in the Karnataka State, India and is located in the dry land farming areas of the State. Thus the watershed programme spread across 5 districts, namely, Kolar, Tumkur, Chitradurga, Haveri and Dharwar is considered for the study area. The data from watershed development programme, taken up as a part of Karnataka Watershed Development Project by the Government of Karnataka with an objective to develop 77 sub-watersheds comprising of 742 micro-watersheds are considered for the study. The satellite images and other data collected by Indian Space Research Organisation (ISRO), as a part of the programme, is utilized in the present study.

The following are the criteria adopted for implementation of the proposed methodology. (a) watershed development in dry land area/ rain-fed agricultural land (b) involvement of village community in development process, (c) use of remote sensing and GIS solution, (d) study area spread across different agro-climatic zones so that there is opportunity to test the performance under different conditions, (e) Governmental support for implementation of the project.

5.1 GENERAL PHYSIOGRAPHIC INFORMATION

The state is divided into 3 major physiographic regions, namely, the Deccan plateau, the hill ranges known as Western Ghats or Malnad region and Coastal plains on the west coast of India. The coastal plains is referred to the region on the west coast of India, adjacent to the Arabian Sea. It is separated by the rest of the interior land by a hill range known as western ghats consisting of evergreen, semi-evergreen forests with highly undulating terrain. The eastern part of the state falls under Deccan Plateau, that are predominantly dominated by dry lands, also known as maidan region.

The five districts of Karnataka state considered for implementation of watershed development programme extends from south to north. The northern part of the region comprising of Dharwar district has relatively high undulations due to its vicinity to the malnad region while the southern part has the rolling surface with granitic hills and gentle slopes. Particularly, elevations of the plateau region, like Tumkur and Kolar districts, range from 600 to 900 meter above Mean Sea Level (MSL).

5.1.1 Terrain Characteristics and Typical problems

Eleven groups of soil order are recognized, based on differences in soil formation processes, as reflected in the nature and sequence of soil horizons. The taxonomic classification of soils in Karnataka are grouped into 7 orders, 12 suborders, 27 great groups, 47 subgroups and 96 soil families (Ramachandra TV et al, 2004). The state receives 80% of the annual rainfall during southwest monsoon period, followed by the remaining portion of the rainfall which is spread across other seasons. The windward side of the ghats receives an average rainfall of 3350 mm while about 600-700 mm of rainfall is received on the leeward side. The temperature is generally the lowest at the beginning of January which increases thereafter towards the month of March. In the southern maidan region, the highest temperature occurs in April, whereas in the northern maidan and the coastal areas it is in May. In January the mean daily temperature is slightly above 30^0 C in the northern maidan areas, and it goes beyond 40^0 C around May.

Low and erratic rainfall, high temperatures, deficient soil fertility and low water holding capacity characterizes the agricultural zones of the area. Soil erodibility is moderate to high in Dharwad, Haveri and Chitradurga districts and soil moisture is also low.

A majority of rivers are small and seasonal. Irrigation tanks, constructed long ago, are in poor condition due to heavy siltation and poor maintenance. Most of the dug wells have dried up and are replaced by bore wells. The erratic rainfall and groundwater structures have contributed to decline in ground water levels and silting of tanks. In certain areas, even shallow bore wells have become dry. Irrigation facility is very limited.

These districts have a very poor forest cover, about 5% of the area only. The forests are mostly open and consist of mixed species. These are over exploited for a very long time. The predominant vegetation consists of thorny shrubs, bushes and rough grasses. They have very few species of wild animals due to poor forest cover.

Agriculture and allied activities continue to be the mainstay of the populace, despite low productivity and high costs of production. Agriculture is plagued with a number of problems, such as, lack of irrigation, lack of finance, lack of marketing facilities, low productivity, low returns. Land holdings are mostly small and scattered. The extent of barren land is high and cultivable wasteland is significant.

A significant proportion of population depends on labour for living. There is a preponderance of small and marginal farmers, whose farming is not at all remunerative. They work as labourers on other's fields to supplement incomes. Most of the people are forced to take up labour in distant places. Migration is a regular feature, with all its social and economic ramifications.

Livestock density is high and a large proportion is unsustainable. There is problem of fodder and it has become severe due to reduction in common property resources that were actively used, till recently, for grazing. Common Property Resources (CPRs) are not present in many villages and in those few villages where CPRs exist, management is poor. Low quality of livestock has proved to be uneconomical.

Significant proportions of households live in congested and unhygienic conditions. Low possession of assets clearly points to the backwardness of the households.

There exist villages lacking basic facilities. Several villages face the problem of drinking water shortages. Marketing, power, finance, road and transport continue to be daunting problems. Thus there exists a state of backwardness. Specific details on some of the important characteristics of the study are highlighted below.

5.2 AGRO-CLIMATIC ZONES

Karnataka is divided into 10 agro-climatic zones taking into consideration the amount of rainfall, as well as the spatial and temporal distribution, soil type, texture, depth and physiochemical properties, terrain height, topography, major crops and type of vegetation. Agro-climatic zones of Karnataka are geospatially depicted in Fig 5.1. Following are the agro-climatic zones in which the study area is situated. Each micro-watershed belongs to one of the following agro-climatic region and their characteristics are as follows:

5.2.1 Central dry zone

This zone covers an area of 1.94 M ha. The annual rainfall varies from 453.5 and 717.7 mm, of which more than 55% is received in Kharif season. The elevation ranges between 450m and 900m MSL The soils are predominantly red sandy loams and shallow to deep black cotton soil in the remaining areas. The principal crops grown in the region are ragi, jowar, pulses and oil seeds. Entire Chitradurga and parts of Tumkur districts are covered under this zone.

5.2.2 Eastern dry zone

This zone consists of an area of 1.81 M ha. The annual rainfall varies from 679.1 mm to 888.9 mm. More than 50% of it is received during the Kharif season. The elevation varies from 800 to 900 m MSL. Major portion of the area consists of red loamy soils and the rest are dominated by laterites. The main crops in the region are ragi, rice, pulses, maize and oil seeds. Parts of Tumkur district and entire Kolar district come under this region.

5.2.3 Southern dry zone

This zone extends over an area of 1.74 Mha. The annual rainfall varies from 670.6 mm to 888.6 mm, of which more than 50% rain is received in Kharif season. The elevation varies between 450 and 900 m MSL. The soils are mainly red sandy loam and red loamy in some areas. The principal crops grown are rice, ragi, pulses, jowar, tobacco and millets. Parts of Tumkur district come under this zone.

5.2.4 Northern transitional zone

This zone comprises of an area of 1.19 M ha. The annual rainfall ranges from 619.4 mm to 1303.2 mm. About 61% of rainfall is generally received in Kharif season. The elevation varies from 450 to 900 m MSL. The soil is shallow, medium black clay and red sandy loam in equal proportions. The main crops grown are rice, jowar, groundnut, pulses, and tobacco. Parts of Haveri and Dharwad districts comes in this zone.

5.2.5 Hilly zone

This zone covers an area of 2.56 Mha. The annual rainfall in the region varies from 904.4 mm to 3695.1 mm. About 75% of the rainfall is received in Kharif season. The soil is red sandy loam in majority of the areas. The principal crops are rice and pulses. Parts of Haveri district belongs to this zone.

These 5 Agro-climatic regions are considered and the data collected from these regions are analysed in the present study.

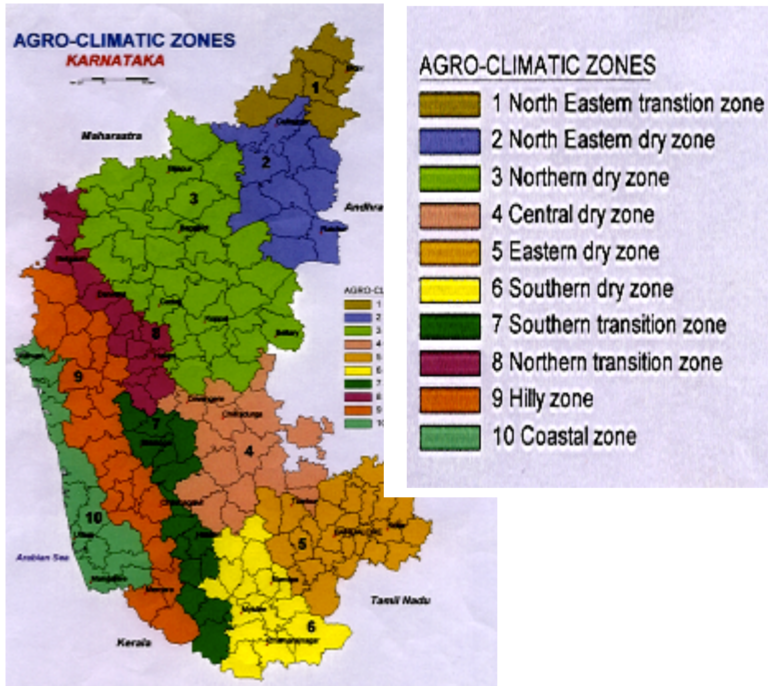


Fig. 5.1: Agro-climatic Zones of Karnataka with District and Taluk boundary overlaid

5.3 CHARACTERISTICS OF WATERSHED DEVELOPMENT PROGRAMME

The extent of Karnataka Watershed Development Programme is defined based on the coverage of dry land areas, cutting across different Agro-climatic regions in the State. The objective of the programme is to develop the identified 77 sub-watersheds, distributed across the selected 5 districts of Karnataka, with an average size of each sub-watershed being 7,500 Ha. Considering the practicality of implementation, these sub-watersheds are further sub divided into a total of 742 micro-watersheds. Each micro-watershed measures to about 600 Ha on an average. Further, the developmental activities are planned and implemented in a phased manner, with 10 watersheds in phase 1, 20 watersheds in phase 2 and the remaining 47 watersheds in phase 3. Each phase is implemented in all 5 districts with maximum number of watersheds covered under Kolar and Tumkur districts. The locations of these watersheds are shown on the Karnataka State map Fig 5.2.

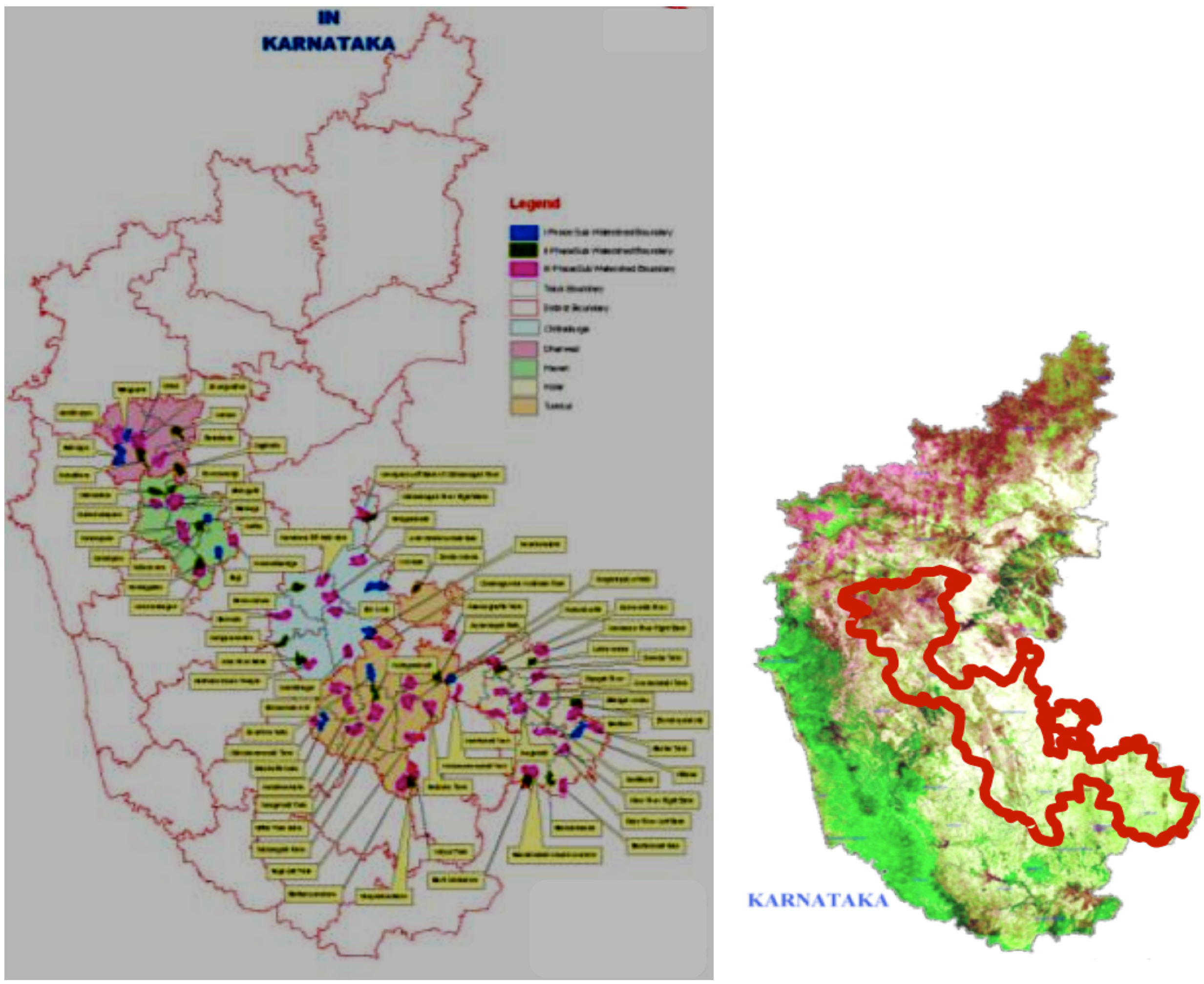


Fig. 5.2: Location and distribution of 77 sub-watersheds in 5 Districts of Karnataka.

The phasing of the development is done primarily to take advantage of the learning process from previous phase and to incorporate the improvements in the successive phases. Hence, a gradual increase in the number of watersheds across different phases is observed.

The five districts of Chitradurga, Dharwad, Haveri, Tumkur and Kolar lie between latitudes 15.5^0N & 12.75^0 N and between longitudes 74.48^0 E & 78.58^0 E and It covers a total area of 36,290 sq. km. There are about 350,000 households, spread over these watersheds which require development, both in terms of natural resources and livelihood, as part of this programme.

5.3.1 Weather and Climate

Kolar, Tumkur and southern Chitradurga districts normally experience high temperature, seasonally dry tropical climate while Haveri, Dharwad and northern Chitradurga experience high temperature but come under semi-arid conditions. The temperature of the region increase northwards and there are areas that experience temperatures as high as 41^{0}C and dry spells. The annual period is usually divided into four seasons as follows:

- Summer from March to May;
- Southwest monsoon from June to September;
- Northeast monsoon between October and November; and;
- Winter or dry season from December to February.

The average rainfall varies from 565 mm in Chitradurga district to 772 mm in Dharwad district, as shown in Table 5.1. The five districts experience considerable fluctuations of rainfall and are mostly drought prone areas.

Table 5.1 Average Rainfall in the Project Districts

District	Average Rainfall (mm)
Chitradurga	565.0
Dharwad	772.0
Haveri	754.0
Kolar	744.0
Tumkur	686.0

Source: *Rainfall & Agricultural Situation in Karnataka,* Drought Monitoring Cell, Bangalore

5.3.2 Drainage and Surface water

A majority of the rivers in the region are small and seasonal. A number of these streams and rivulets have been harnessed for the purposes of irrigation. There are a number of irrigation tanks in the region that were constructed hundreds of years ago, particularly in Kolar, Tumkur, Haveri and Dharwad districts. However, these are in very poor condition, with large number of them are ineffective because of siltation and poor maintenance. Main rivers and important tributaries in the region are given in Table 5.2.

Table 5.2 Drainage basin and Surface Water source

District	Basin	Main Rivers	Important Tributaries
Chitradurga	Krishna	Vedavati & Tungabhadra (perennial)	Janagahalla, Suvarnamukhi, Syagahalla, Garani, Nayakanhatti
Haveri and Dharwad	Krishna	Malaprabha and Tungabhadra (perennial)	Bennihalla, Shalmala (west flowing), Varada, Kumudvati, Dharma
Kolar	Cauvery	Palar, North Pinakini, South Pinakini	Arkavathi, Chitravathi, Nangihole, Kumar, Kushavathi, Markandaya, Papaghni, Vrishabhavathi, Vardamanhole
Tumkur	Cauvery	Shimsha, Jayamangali, Suvarnamukhi	Naga, Nagini, Doddahalla, Chik Tore

5.3.3 Soil characteristics

The soils found in the region are predominantly red and black cotton soil. The soil textures normally vary from sandy to loamy, though gravelly and clayey soils are also found. The depths of the soils vary from shallow to very deep. Red soils on higher elevations are characterized by high infiltration, more runoff and low water holding capacity. Black soils are rich in organic content and are characterized by high water holding capacity and low infiltration. The soils are acidic in nature which may be ameliorated using gypsum in all the five districts. The soil characteristics for 5 districts are given in Table 5.3

Table 5.3 Soil Characteristics of the study area

District	Soils
Chitradurga	The major soil group in the district is red sandy soil followed by mixed red and black soil, deep black soil, red loamy soil and medium black soil. The soils are moderately fertile.
Haveri & Dharwad	The predominant soil that occupies the greatest part of the district is black cotton soil. The other varieties of soils found in the district are brown soil, red soil, sandy soil, and alluvial soil. The moisture retentive capacity of this soil enables the crops to sustain during seasons of drought. This black cotton soil is suitable for raising cotton, wheat, gram, ragi, jowar and oilseeds.
Kolar	The eastern part of the district has patches of red and a good amount of black cotton soils. The red loam soil is suitable for cultivation and responds well to manure and other treatments. The soil is particularly suitable for growing vegetables. Gravelly soil is found in the northern, southern and central parts of the district. Clay loam is found in the north western and central taluks of the district. These soils have good moisture-retention capacity and allow deep furrowing.
Tumkur	The soils of the district are hard and poor in general. The soil is acidic with low to medium soil fertility status during wet conditions. Red, gravelly, sandy, clay, loam, black soil, sandy loam and sandy clay are the main types of soil found in various parts of the district.

Source: *District Gazetteers of Chitradurga, Dharwad, Haveri, Kolar and Tumkur.*

5.3.4 Sociological condition

As per the census figures, the rural population in the study area is higher than the state average of 69.1%. The percentage of rural population of Dharwad district is much below the state average while it is significantly higher in the other districts. The share of population of the vulnerable groups and economically weaker sections in the region is also higher than the state average. For Dharwad, it is considerably lower than the state average, while the other districts have higher percentages of populations. Kolar and Chitradurga districts have the highest percentage of such groups. The sample villages have about 15,680 households with a population of about 89,834. Male population is 45,618 while female population is 44,216. There are about 18,473 persons belonging to vulnerable groups and economically weaker sections in these areas.

5.4 DATA USED

Considering the proposed methodology and the need for data analysis, following data collection strategies are planned. (1) sample field surveys, (2) Data collection from Information Systems (MIS and GIS), (3) Multi-time Remote Sensing data, and (4) Multi-thematic GIS databases of micro-watersheds.

5.4.1 Sampling Design for field surveys

Watershed implementation is done in a phased manner. For the present study, data from phase 1 and 2 are mostly considered for field sampling and analysis, considering the implementation timeframe and data availability. However, data from phase 3 is also used in some cases to illustrate the results of watershed development.

A total of 30 sub-watersheds (10 SWS in phase 1 and 20 SWS in phase 2 respectively) covering five districts in the study are covered in first two phases. Amongst these, 14 sub watersheds (5 from phase I and 9 from phase II) distributed across different Agro-Climatic Zones (ACZ) are selected for sample data collection and analysis. Stratified Random sampling is adopted, based on the criteria of agro climatic conditions for data collection. Each Sub-watershed is divided into about 7 to 8 micro-watersheds with each covering an area of 500 Ha, on the basis of topographic gradients (ridge, middle portion and valley portion). This has an advantage of easy community mobilization, their participation and implementation. For sampling purposes, 3 micro-watersheds representing different topographic gradients (ridge, middle portion and valley), are selected for data collection. From each such micro-watershed, sample villages are randomly identified for field data collection with equitable distribution of different types of farming community.

Also, villages are randomly chosen outside the study area as **control villages**, with the criteria that no Government schemes or interventions are currently implemented in such villages. This ensures that control villages truly act as controls areas for impact assessment, particularly, considering the natural conditions prevailing in the neighbourhood and their influence on the development. The procedure, mentioned here, is followed for field data collection to ensure that all types of terrain, environment and socio-economic sectors are well represented as a part of sampling (Table 5.4).

On an average, each village in the study area comprises of about 350 households. A 10% household sampling criteria is chosen for data collection to achieve the required accuracy. Accordingly, 35 households are sampled for each micro watershed, aggregating to 105 samples from 3 micro-watersheds of each sub-watershed. In addition, 15 households are also sampled from control villages from non-treated areas. The household selection within a micro-watershed is selected based on the criteria of farmer's land holdings (Small, Marginal, Big and land less). Such criteria based household surveys helps in better stratifications of different classes of farmers for further analysis during impact studies.

The sample data is collected in the initial stage as part of baseline and further in the mid-term to study the trends and provide feedback for further improvement as a part of mid-course correction. Towards the end, that is post-implementation stage, one more sampling is done for making the final impact assessment.

Table 5.4 List of Sampled Micro-watersheds and villages of Phase - 1 & 2

Phase	Zone	District	Sub Watershed	Micro Watershed	R/M/V	Village	
						Treated	Control
Phase - I	Central Dry Zone	Chitradurga	Suvarnamukhi	Huvinahole	Valley	Huvinahole	Eswaragere
				Ikkanur	Middle	Ikkanur	Myadanahole
				Kodihalli 1	Ridge	Kodihalli 1	
				Kodihalli 2	Middle	Kodihalli 2	
				Kurubarahalli	Ridge	Kurubarahalli	Sankapura
				Venukalgudda	Valley	Venukalgudda	
	Eastern Dry Zone	Kolar	Kumudavathi	Kurudi	Middle	Hunasavadi	Kurudi
				Kundihalli	Valley	Hampasandra	Kurubarapalya
				Ranganahalli	Valley	Jalihalli	Jodibisalahalli
				Netravathi	Ridge	Arasapurathananda	
				Vishveshwaraiah	Ridge	Ranganahalli	
				Kaveri	Middle	Ramapura	
				Vinayaka	Middle	Kadaranahalli	
				Maruthi	Middle	Hosaupparahalli	
				Nehru	Valley	Kurudi	
				Papaganahalli	Middle	Ramapura	
		Tumkur	Devaratota Halla	Bhootappana Katte	Valley	Iddanahalli	Jogayyanapalya
				Echalahalla	Ridge	Thupadakona	
				Karekallu Bhootappa	Ridge	Manganahalli	
				Sri Maruthi	Middle	Kilaradhalli	Kanchiganahalli
	North Transition Zone	Dharwar	Managundi	Shivaganga	Ridge	Mansoor	
				Marutheshwar	Middle	Nuggikere	Nigadi
				Kadasiddeshwar	Middle	Yarikoppa	Basavanakoppa
				Basaveshwar	Valley	Managundi	
				Gajanana	Valley	Benakanakatti	
				Vivekananda	Valley	Managundi	
		Haveri	Itagi	Maruthi	Ridge	Magoda	Ramadodda
				Haleshwara	Ridge	Itagi	
				Chowdeshwari	Middle	Devaragondana	
				Hucheshwara	Middle	Kak	
				Kumudvathi	Valley	Mastur	

Phase	Zone	District	Sub Watershed	Micro Watershed	R/M/V	Village Treated	Village Control
				Anjaneya	Valley	Manakur	
				Gurudeva	Middle	Kamadodda	
				Ramanjaneya	Valley	Shagadadu	
Phase-II	Central Dry Zone	Chitradurga	Beeravaranala	Beeravara	Valley	Beeravara	Iyana Halli
				Kalkunte	Middle	Kalkunte	Chikkabegere
				Obawanagathi Halli	Ridge	Obawanagathi Halli	Chikkena Halli
			V.C.H. Right Bank	Hosuru	Middle	Hosuru	Kalyam
				Nagasamudra	Valley	Nagasamudra	Guddada Halli
				Roppa – I	Ridge	Ashokasiddapura	Machari
	Eastern Dry Zone	Kolar	Chendur	Byrasagara	Ridge	Byrasagara	Mykahalli
				Chikkakurubara Halli	Middle	Chikkakurubara Halli	Bandralahalli
				Kambalahalli	Valley	Kambalahalli	M.M. Palli
			Markanda Halla	Alambadi	Ridge	Alambadi	Gajaga
				Doddapura	Middle	Doddapura	Guttahalli
				Naganahalli	Valley	Naganahalli	Beemangana Halli
		Tumkur	Kalingana Halla	G. kerehalla	Valley	K. Halli	Bodathimmana Halli
				Malleswara	Middle	M. Dore	Anakasandra
				Narasimha Swamy	Ridge	Unaganala	Hosakere
			Jayamangali Halli	Anjaneya Swamy	Middle	Eagihalli	Sunnavadi
				Jayalakshmi	Valley	Hanumantapura	Badachndana Halli
				Marikamba	Ridge	Ranganahalli	Shettihalli
	North Transition Zone	Dharwar	Yarnal	Amrutheshwar	Ridge	Annigeri	Koliwad
				Bhumithai	Valley	Shisuvinahalli	Belhar
				Ishwarlingeshwar	Middle	Bhadrapur	Ingnahalli
		Haveri	Doddagubbi	Marula Siddeshwara	Ridge	Nesvi - II	Billahalli
				Shivashakti	Valley	Doddagubbi	Horagoppa
				Veerabhadreshwara	Middle	Mavintop	Dandigehalli

Phase	Zone	District	Sub Watershed	Micro Watershed	R/M/V	Village	
						Treated	Control
			Hosaneralgi	Chandrodaya	Ridge	Chillurbadni	Gonal
				Gramadevathe	Valley	Hosaneralgi	Nandihalli
				Kenjedeshwari	Middle	Mathordi	Jakenakatte

Note: *R/M/V represents Ridge, Middle and Valley*

5.4.2 Data collection from Information Systems (MIS & GIS)

As a part of process interventions, varieties of information systems are proposed for development with respect to different process stages. Each of these packages generate large amount of data that are amenable for processing, analysis and monitoring. The data available from online Web-based MIS, Participatory GIS and MIS for action plan preparation serve as important input data for analysis and monitoring. In addition, the remote sensing and GIS data generated as part of Baseline and impacts are also used for analysis and interpretation.

5.4.3 Multi-time Remote Sensing data

Remote Sensing data from different platforms of Indian Remote sensing Satellite (IRS) series are used under the study. For creation of database for baseline on natural resources status, data from IRS 1C and 1D satellites are used, which are multi-tier imaging systems. Both these satellites are identical with Advanced Wide Field Sensor (AWiFS) providing large swath and 56 m spatial resolution, Linear Imaging Self-scaning System (LISS 3) with medium swath and 24 m spatial resolution and Panchromatic (PAN) camera system with smaller swath and 5.8 m spatial resolution. Subsequently, next generation of satelllites, namely, RESOURCESAT-1 and CARTOSAT-1 are used for mid-term and post-implementation phases, with improved and high spatial resolution imaging capabilities. RESOURCESAT-1 provides AWiFS, LISS 3 and LISS 4 (LISS 4 being medium swath multispectral imaging capability at 5.8 m spatial resolution), and CARTOSAT-1 provides stereo and mono imaging capabilities with medium swath and 2.5 m spatial resolution.

Satellite data usage in the study is as follows

- IRS 1C, 1D LISS 3 and PAN data are used together in the multi-spectral domain. These images are used to produce baseline maps at 1:10,000 scale.
- Multi-temporal, multi-spectral and multi-sensor images from (i) RESOURCESAT-1 LISS 4 & CARTOSAT-1 and (ii) IRS LISS 3 and PAN are used for monitoring.
- Multispectral high resolution LISS 4 data is also used for digital image classification and for large scale land use & land cover map preparation
- Digital Elevation Models derived from CARTOSAT-1 stereo coverage are used for value addition to watershed maps and boundary validation
- High spatial resolution images from IRS LISS 3 & PAN, RESOURCESAT-1 and CARTOSAT-1 are also used for change detection studies and impact assessment
- A few satellite data sets area also used for selected micro-watersheds, under different agro-climatic regions, for monitoring of some of the process parameters.

5.4.4 GIS databases

The natural resources maps derived from remote sensing images and other sources are transformed into geospatial database layers. These layers are used as reference database for each of the micro-watersheds of the study area.

These GIS datasets are also used for creating a database repository for ready reference and use by decision makers, PRA exercises at micro-watersheds, action plan preparation, change detection and impact assessment.

5.5 SUMMARY

Considering the complex nature of watershed development, the study area and data sets are carefully chosen and positioned. While the study area, representing predominantly the dry zones in Karnataka, is carefully analysed with respect to agro-climatic conditions for all data collection strategies, care is also taken to see that different sources of data are considered for the study. The data sourcing is planned from field surveys, through sampling design, secondary sources from available databases, data inputs from information systems which includes field-level planning data as well as concurrent data from the field while implementation, space-based data from different satellite platforms as needed for various planning and monitoring activities. In addition, reference is also made to GIS data repository which serves as a common base for the entire study area through information systems for all requirements of geospatial data. A comprehensive plan for data organization for the identified sub-watersheds in the study area are considered to apply the methodologies developed under the study.

CHAPTER 6

GEOMATICS AND INFORMATION SYSTEMS

6.0 INTRODUCTION

The process guidelines for watershed development are followed to develop a practically implementable model with help of geomatics tools and information technology. The aim is to improve upon the conventional methods with contemporary tools and techniques for better planning, implementation, monitoring and impact assessment. The various tools and techniques proposed in chapter 3 and 4 are addressed using Geomatics tools and Information technology. Following are the broad areas of such development.

1. Digital Image Processing and pattern recognition for preparation of natural resources data layers and community-friendly information for field level usage.
2. Geospatial database organisation on natural resources layers.
3. Multi-thematic data analysis and suggestive action plan preparation
4. Participatory GIS and MIS tools with local language interface for community level action plan preparation by the stakeholders.
5. Online WebMIS solution for concurrent monitoring of action plan implementation.
6. Multi-temporal data analysis and impact assessments.

6.1 DIGITAL IMAGE ANALYSIS

Geospatial data at large scales can play an important role in watershed development. This also provides possibilities of site-specific information that encourage peoples' participation. Hence, there is a need for high spatial resolution satellite images and preparation of user-friendly maps for field level usage. Images from Indian Remote Sensing (IRS) satellite system are found suitable for such requirements. The research study attempts to develop improved quality of images for watershed development with community participation. Multi-sensor, multi-platform and multi-temporal data sets are used as input for processing, mapping and analysis. Data processing from such varied sources pose challenges related to image geometry and radiometry while deriving high quality value added products. In order to overcome such challenges and to address field level requirements, following processing methods are considered.

6.1.1 Multisensor Image Fusion Techniques

IRS satellite series has the unique distinction of producing versatile combination of sensors which can be put to use for high quality actionable products. During mid and later part of 90s IRS 1C and 1D satellites were flown with optimal combination of sensors, such as, Wide Field Sensor (WiFS) with 188 m, LISS 3 with 23 m and Panchromatic with 6.8 m spatial resolutions and different imaging swaths respectively. This was followed by IRS P6 satellite during mid 2000 that produced even better combination of sensors, such as, Advanced WiFS (AWiFS) with 55 m, LISS 3 with 23 m and LISS 4 with 5.8 m spatial resolution respectively. Further, CARTOSAT 1 with 2.5 m panchromatic band and stereo viewing capabilities followed by CARTOSAT 2 with better than 1 m spatial imaging capabilities were launched. To make best use of multi-satellite, multi-sensor and multi-resolution imaging capabilities, popular image fusion techniques are considered with different sensor combination. One of the basic requirements for participatory watershed development is to develop high spatial resolution images which are village specific in nature. Such images should be usable by by farming community for planning and development.

An attempt is made to examine different methods of fusion to adopt the best suitable method for various agro-climatic conditions. Image fusion is chosen by based on its performance of scene spectral statistics, geometry and visual analysis of fusion image. Following are the fusion methods used for generating output image products and for comparison.

A. Linear Multiplicative method
B. Brovey's method
C. Principal Component Analysis based method
D. Discrete Wavelet method.

6.1.1.1 Linear Multiplicative method

This method is uses the linear band combination of two raster images with pre-defined weights to produce a fused product. The weights are provided depending on the spatial characteristics, feature of interest and prior experience.

6.1.1.2 Fusion by Brovey's Algorithm

This algorithm uses ratioing technique and band combination with both multi-spectral and panchromtatic channel to produce optimal fusion outputs. This is expected to visually increase contrast in the lower and higher ends of the output image histogram, resulting in a different nature of merged product.

6..1.3 Principal Component Analysis (PCA)

Principal component analysis (PCA) is a well known method of de-correlation to produce best multispectral bands for image interpretation in the multispectral domain. The same analogy is further extended by addition of panchromatic channel as part of fusion technique. It is based on the component substitution technique wherein after transforming low spatial resolution multi-band colour image to principal components, the first principle component (PC1) is substituted by the high-resolution panchromatic data before reverse transformation. That is, inverse PCA is applied to derive the fused image.

6.1.1.4 Discrete Wavelet Transformation (DWT)

Wavelet based pixel-level image fusion scheme increases the information content of fused image by selecting the most significant features from input images and transferring them into the composite image. This process takes place in the multi-resolution pyramid domain. Information fusion is achieved by creating a new, fused pyramid representation that contains all the significant information from the multi-resolution pyramids of the input images.

One of the important features of using DWT for image fusion is the advantage of configuring digital filters that retain much of the original radiometry of the multispectral bands (Shi et al 2007). This not only produces a synthetically high spatial resolution multispectral image but also provides the radiometry, which is closely comparable to the original multispectral image. Hence, the DWT method technically provides better promise as compared to others due its unique properties that helps in developing merged products which are synthetically high spatial resolution multispectral bands, amenable for further analysis. Software tools for DWT based image fusion is developed and used as part of this research work. The outputs generated from the above methods is further discussed in the subsequent chapter under results and discussions.

6.1.2 Image Classification for land use mapping

Derivation of information on status of land utilization and land cover is important for management and monitoring of watershed development activities. Wide range of thematic layers are used as part of planning exercise, but land use and land cover data is more frequently required at different stages of watershed development. Image fusion outputs provide effective means of producing such information, which could be directly integrated into the GIS domain as vector geospatial layer. However, high resolution images like IRS LISS 4 are used as input for multispectral classification to create digitally classified images. Considering such possibilities, both manual and digital classification methods are done based on input image type.

Maximum likelihood classification and hybrid classification techniques are explored for generating digital land use and land cover maps. Maximum likelihood classification, being a probabilistic method of statistical inference, is a well known technique for classification of satellite images of medium spatial resolution, such as, IRS LISS 3 sensor with 23 m resolution. However, classification of high resolution images like IRS LISS 4, poses a new challenge of providing large number of labeled samples (ground truth training samples) to produce accurate maps at field level through iterations of improvements in ground truth samples (Omkar et. al. 2007). Hence, a hybrid classification method is proposed and explored that uses semi-automatic approach for preparation of labeled samples through an object-based segmentation approach. The new design uses image segmentation and vectorisation as an aid in creating ground truth training samples followed by image classification. As part of this procedure, Artificial Neural Network (ANN) classifier with back-propagation is also used for image classification and the resultant outputs are evaluated.

6.1.2.1 Digital Classification Approach

Maximum Likelihood Classifier (MLC) and a hybrid classifier with ANN are considered in the research study. The MLC primarily uses ground truth information as training set parameters and class-signatures, such as, class mean and variance-covariance matrix are computed for all classes. As the basis for MLC is the assumption of Gaussian distribution for probability computation, individual probabilities are calculated for all pixels based on training set signatures. Reject thresholds are set as probability of rejecting a particular class due to poor probability value and accordingly the corresponding pixels are labeled as null/ reject class based on threshold criteria. The reject thresholds are decided with respect to 2sigma or 3 sigma limits of the Gaussian curve. Hence, the probability of a pixel **x** occurring in a class c_i is given by,

$$p(x \mid c_i) = (2p)^{-N/2} \ |S_i|^{-1/2} \ exp\{-(1/2)(x-m_i)^t \ | \ S_i \ |^{-1}(x-m_i)\}$$

where $\mathbf{m_i}$ *and* S_i *are the mean vector and covariance matrix for data in class* c_i.

The above method, which is based on computation of probability for individual pixel, performs well when the training sets are accurate, exhaustive and covers wide varieties of classes present in the scene-in-question. Hence, this procedure depends on the training set definition process and its intensive coverage of all types of features and signatures. However, for high spatial resolution images, large number of labeled ground truth samples are required to achieve good performance of classification and classification accuracies depend directly on this factor, which is expensive and time consuming.

6.1.2.2 Hybrid Classifier

The classification procedure here is designed and developed using principles of object-based semi-automatic approach for preparing ground truth samples (Kressler et. al. 2005). The software tools use hybrid combination of image segmentation, vectorisation, line thinning and vector overlay for creating ground truth samples, followed by artificial neural network (ANN) classifier for image classification. ANN is one of the popular classifiers which does not use the scene statistics for classification and is more non-parametric in nature (Zhang 2000). Following are the details on the semi-automatic approach for image classification. Unlike the MLC method, this method does not use scene parameter in classification and hence it falls into a category of non-parametric classifier.

- Adaptive Image filtering (to remove noise pixels, if required).
- Image Segmentation – adaptive tool for coarser or finer segments.
- Vectorisation of image-segments
- Line Thinning and vector overlay for feature identification
- Simplified procedure for training set definition
- Training of ANN
- Image Classification.

i) Adaptive Image Filtering:

To ensure that noise levels in the image is reduced; it is required to initially process the input data for noise reduction. The statistics of the scene and its sensitivity for further classification is kept intact by choosing adaptable median filter. Median filters have low pass characteristics and they remove additive white noise based on the preset threshold. The median filter tends to produce regions of constant or nearly constant intensity which results in better segmentation results.

ii) Image Segmentation

Pattern recognition and segmentation techniques are particularly useful in Remote Sensing to classify or group pixels of similar characteristics. Usually the *a-priori* labels on the pixels are not available and therefore segmentation techniques are needed to group pixels based on the observed reflectance in various bands of multispectral image. The segmentation procedure is implemented using algorithms such as region merge, watershed, region grow etc. A simple Region Merge algorithm is chosen in the present context due to its simplicity and adaptability without being computationally expensive.

<u>*Segmentation procedure*</u>:

Consider the current pixel location (k, l). All locations (k-1, *) and (k+1, *) of the previous and succeeding rows and the locations (k, j), 0<=j<l, of the current image are assigned to image regions during image read operation in a row wise manner. Therefore, pixel (k, l) has some adjacent region 'R_i ' in its neighborhood unless (k, l) is at starting position pixel (0, 0) or at end of the scene.

First, the pixel (k. l) is merged with one of its adjacent regions R_i based on the mean reflectance 'm_i' and standard deviation 's_i' of the region. Merging is allowed if the pixel intensity f (k, l) is close to the class mean m_i. The performance of this algorithm is based on the choice of the Merging Rule:

P (R_i U (k. l)) of pixel (k. l) to a class R_i.

Hence, the merging rule can be based on the region mean m_i and standard deviation s_i.

$$| f (k, l) - m_i | <= T,$$

where T is a threshold parameter.

If the merge criteria fails, the pixel is assigned to a new region. If no region in the pixel neighborhood satisfies this expression then this pixel is assigned to a new region. If more than one region is found in the pixel neighborhood which satisfies this equation then the pixel is merged to the region R_i having minimal difference | f (k, l) - m_i |. The growth of the region heavily depends upon the parameter T. The threshold T decides the coarseness or denseness of the segments and user can decide on the homogeneity factor with respect to the segments based on value of T.

iii) Training set definition (labeling of samples)

The segmentation output is vectorised based on similar spectral properties. Line thinning applied on these vectors and are further used as overlays on colour composite image for training set definition. Rapid training set definition and Ground Truth (GT) data creation is done to train the system on the known classes and their signatures. Unlike the traditional interactive method of GT definition, the user has to only identify segment of interest and provide corresponding attribute information for that segment. This process is is simple and quick to create training set data for classification.

iv) Artificial Neural Network (ANN)

Artificial Neural Networks (ANNs) are widely used technique in the field of machine learning. ANN is an adaptive non-linear system that learns to perform a function from data. ANNs, are simple data processing elements operating in parallel. Commonly, neural networks are trained, such that, a particular input leads to a specific target output. After the training phase the ANN parameters are fixed and the system is deployed to solve the problem at hand. The nonlinear nature of processing between the neural network elements provides the system with required flexibility to achieve practically any desired response. The number of input neurons represents the independent variables of the system and the output neurons represent the response of the system. The most widely used neural network methods for classification are Multi-Layer Perceptron (MLP) (Marchant and Onyango, 2003).

Simple mathematical function, *sigmoid function* $y_j = (1/[1 + e^{-x_j}])$, where x_j is local field (weighted sum of inputs + bias), is adopted as a node transfer function to enable neural network learning process (Hecht-Nielsen, 1989). This expression also has the convenient property that their derivatives can be re-written in terms of the function itself, which improves efficiency of the network and simplifies the mathematics further. The *sigmoid function* is one of the most widely used node transfer functions and hence it is adopted in the present work.

Multi-layer perceptrons are typically trained using error back-propagation algorithm. This is a supervised error-correction learning algorithm and is a generalization of the Least Mean Square (LMS) algorithm. Learning consists of two passes through the different layers of an MLP network – forward and backward. In the forward pass, the output (response) of the network to an input vector is computed and all the synaptic weights are kept fixed in this phase (Hecht-Nielsen, 1989). During the backward pass, the error signal is propagated backward through the network and the weights are adjusted using an error-correction rule. After the weight adjustment, the output of the network moves statistically closer to the desired response.

The error signal at the output of neuron j at iteration n is defined by (Hecht-Nielsen, 1989),

$$e_j(n) = d_j(n) - y_j(n)$$

The total instantaneous error $\varepsilon(n)$ for all the neurons in the output layer is therefore,

$$J(n) = \frac{1}{2}\sum_{j \in C} e_j^2(n)$$

where the set C contains all the neurons in the output layer.

The objective is to derive a learning algorithm for minimizing error with respect to the free parameters (Haykin, 1994). The network outputs ($y_j(n)$) are then compared with the respective desired responses ($d_j(n)$), yielding the error signals ($e_j(n)$). The error signals are back propagated to adjust the free parameters and the entire process is repeated until it converges to the threshold value of mean square error.

v) Back Propagation network (BPN) Training Algorithm

The principal advantages of back-propagation are the simplicity and reasonable speed of computation, in addition to the adaptability of the network for different datasets. The training algorithm for a BPN consists of the following steps:

a. <u>Selection and Preparation of Training Data</u>

The learning of the neural network depends on how many of those repetitive sample sets of similar features are presented to the network. That is, multiple samples of different features are presented to the network as a part of learning of the ANN.

b. <u>Momentum of neuron connection weights:</u>

This allows handling of all the computations related to the input, hidden and output layers in iterations. This allows for calculation of Mean Squared Error (MSE) between the actual output and the desired output for the given input and for given training samples. Since the interest is in the *shape* of the error curve rather than the precise MSE function, there is no need to divide by the number of outputs and the minimization algorithm will still find the correct minimum.

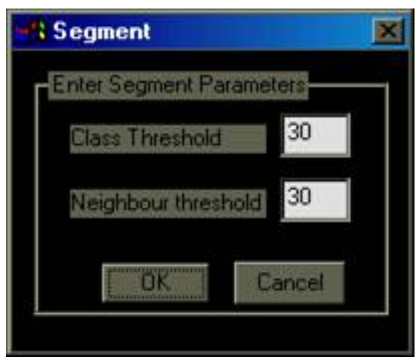
vi) Software Design and development

The proposed algorithms are designed and developed to realize a specific software package. Open visualization software tool like "ImageShop freeware" is used for image display functions as part of the package. The fully customized software package is explained in steps through various options, viz., "**b1 to b12**".

b1 b2 b3 b4 b5 b6 b7 b8 b9 b10 b11 b12

1. Multi-band satellite image loading from the file menu for working Image Directory is created. The directory structure, where all temporary files, output files for processing and the default directory are also kept as options. This directory can be changed as desired using **b1** option.

2.  **b2** option is used to carry out image segmentation by selecting number of classes and neighbour thresholds (default threshold value is also provided). Following option for interaction is provided.



Outcome of this process is a segmented image with spectrally homogenous classes.

3.  **b3** option is used for vectorisation of segmented image to a user defined vector file. Subsequently, the Line thinning algorithm" is applied to extract feature vectors.

4. **b4** option is later used to generate scene parameters which is meant for use after ground truth training set identificqtion process is complete.

5.  **b5** option is used to overlay vectors on the input image, as shown in Fig 6.0A, for selecting feature segments as a part of ground truth definition process.

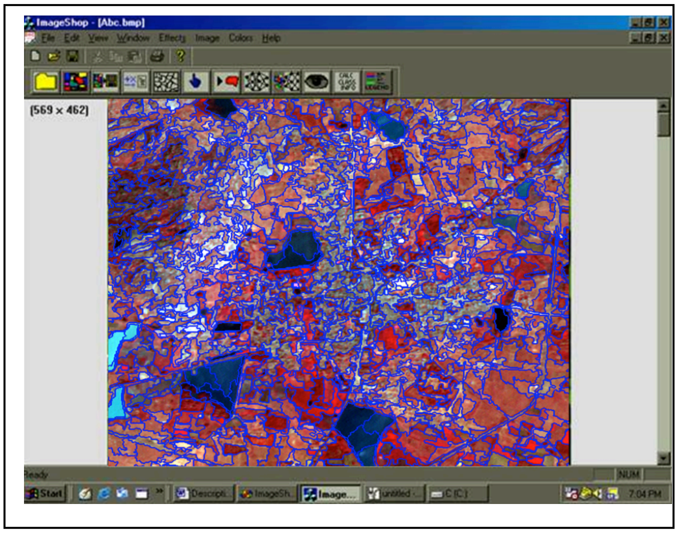


Fig. 6.0A Vector overlay on satellite image

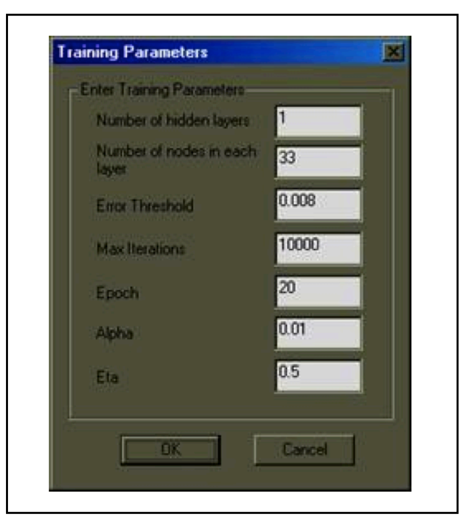
6.  **b6** is an interactive process of choosing ground truth sample segments and assigning them to desired classes. Following user interaction is used for creating segment-wise information on training set. Segment information dialog box enables to define class name and class number as part of attribute data.

After segment information is provided, a color dialog box for choice of color for the selected class is assigned. Color assignment is either user-defined or automatic.

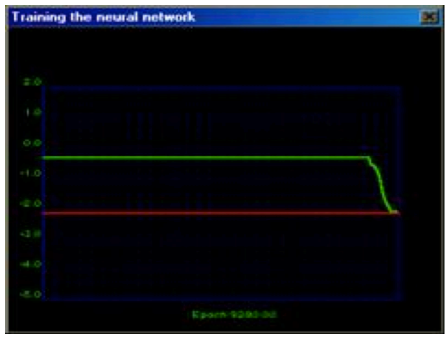
All the selected segments are displayed in white color to highlight the already selected segments. This process is continued until all desired ground truth class definitions are complete. Once the class selections are over for current class, **b7**  option is used to continue the process.

7.  **b6** option is selected again to end choice of segments and assignment of classes. This cycle is repeated for desired number of classes.

8.  **b8** is selected to initiate the training of the Artificial Neural Network process. A training information box is displayed for providing inputs.



On invocation of the ANN training program, the iterative process of network training with back propagation is initiated. The progress of the ANN training process is displayed at every stage. The x-axis shows the number of iteration and y-axis shows the current error rate.



The red line denotes the target. If the training ends and the green curve is far from the red line, this indicates that the network could not be trained satisfactorily. Hence, this calls for re-training of the network by changing the number of hidden layers or number of nodes.

9. However, after successful training,  **b9** option is used to classify the entire image using the trained network.

10.  **b10** option is used to display the final classified image (Fig 6.0B)

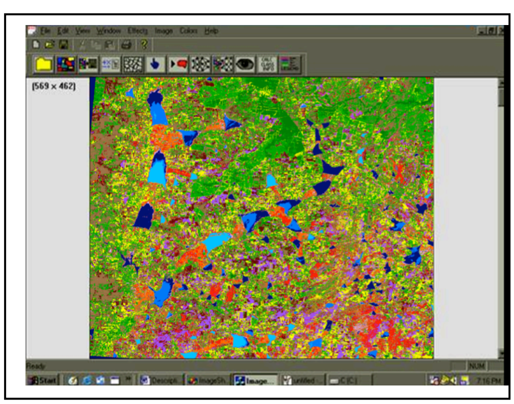


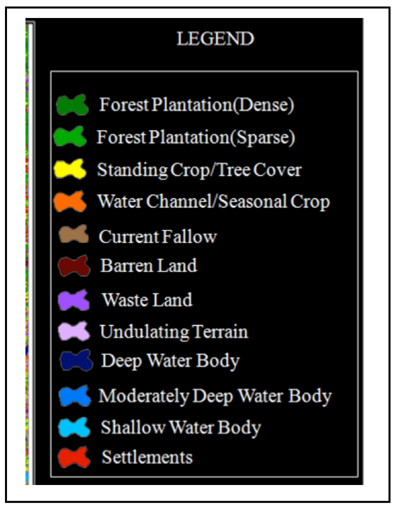
Fig. 6.0B Classified image from ANN

11. 

b11 is used to calculate the area statistics of classified image

12. 

b12 is used to display the legend for the classified image as shown in Fig 6.0B, which is generated from the attribute table that is created while ground truth sample creation process. This legend helps in interpreting the final classified image with respect to the different colors representing a particular feature class in the output thematic map.



The software package described above is specially designed to explore the possibilities of using alternative methods for supervised training, particularly when handling high resolution satellite images for achieving better classification accuracies. The other advantage of this approach is in adopting any classification approach after successful ground truth sample data and signature creation.

6.2 GEOSPATIAL DATABASE ORGANISATION

Digital maps derived from Satellite remote sensing and other means provide a vital platform for planning and decision support. The processed data from space platforms are transformed into feature-rich GIS database for interpretation and analysis. Watershed development is a multi-disciplinary subject and it requires the involvement of experts from different thematic disciplines to create required natural resources database. Thematic maps, created with thematic expertise, are further transformed into digital geospatial maps through a process of GIS database creation and attribution. The GIS database, including base layers, that are required for watershed development is created as follows.

I. **Base layers** – Administrative boundaries (including village boundaries), settlements, road infrastructure, cadastral boundary;

II. **Themes -** Soil type, Slope, drainage network, watershed boundaries, geomorphology, geology, structures, lithology, ground water maps, land use/ land cover, land and water resources action plan maps

Important requirements related to database organisation, their standardization, design and development of user-friendly GIS based software solutions are realised for decision-making at local level. This is particularly important when the geographical spread and number of watersheds are large in number. To facilitate such situations at different levels of decision-making hierarchy, creation of centralised geospatial data repository of relevant GIS layers with simple GIS tools for display, query and analysis is developed.

Geographical hierarchy is important while designing coding standards of GIS database organisation and access at all levels of usage. Administrative hierarchy plays an important role in identification and management of Watershed development. For instance, different States take up development through their respective Districts and it is essential to organize the database by considering respective State grids with necessary map projection parameters. State, being a larger geographic setup, requires organizing database either as a geographic database with no projection or use of map projections like Lambert Conformal Conic Projection with 2 standard parallels and WGS84 datum to create State Grid before creating relevant databases for selected watersheds. The geo-referenced multi-layer geo-database elements are organized by following pre-defined GIS database standards (Shah and Thakkar 2008). A well-documented National GIS database standards at national level is used in the present study for organizing all geospatial data elements according to the stipulated standards (NNRMS Standards, June 2005). The database adheres to the specific elements related to spatial framework, content standards and other specifications. For deriving consistent results from various geospatial database layers, these specifications of the standards are necessary. For example, content standards for land use and land cover database is presented in Table 6.1.

Table 6.1 Database Standards for Land use / Land cover Layer

LEVEL – 1		LEVEL - 2		LEVEL - 3		SYMBOL
1	**Built – up land**	1.1	Towns/Cities			01
		1.2	Villages			02
2	**Agricultural Land**	2.1	Crop land	2.1.1	Kharif	03
				2.1.2	Tank irrigated kharif	3a
				2.1.3	Rabi	04
				2.1.4	Kharif + Rabi (Double cropped)	05
		2.2	Fallow			06
		2.3	Plantation			07
3	**Forest**	3.1	Evergreen/ Semi evergreen	3.1.1	Dense	08
				3.2.2	Open	09
		3.2	Deciduous (Moist & Dry)	3.2.1	Dense	10
				3.2.2	Open	11
		3.3	Scrub Forest			12
		3.4	Forest Blank			13
		3.5	Forest Plantations			14
		3.6	Mangroves			15
4	**Wastelands**	4.1	Salt Affected Land			16
		4.2	Waterlogged Land			17
		4.3	Marshy / Swampy Land			18
		4.4	Gullied / Ravinous Land			19
		4.5	Land with scrub			20
		4.6	Land without scrub			21

LEVEL – 1		LEVEL - 2		LEVEL - 3		SYMBOL
		4.7	Sandy area (Coastal & Desertic)			22
		4.8	Mining/ Industrial Wasteland			23
		4.9	Barren Rocky / Stony Waste/ Sheet Rock Area			24
5	**Water Bodies**	5.1	River / Stream			-
		5.2	Canals			-
		5.3	Lake / Reservoirs / Tanks			25
6	**Others**	6.1	Shifting Cultivation			26
		6.2	Grassland/ Grazing land	6.2.1	Dense	27
				6.2.2	Degraded	28
		6.3	Salt Pans			29
		6.4	Snow covered / Glacial Area			

A multi-layered geospatial database for one of the sub-watersheds is given in Fig 6.1.

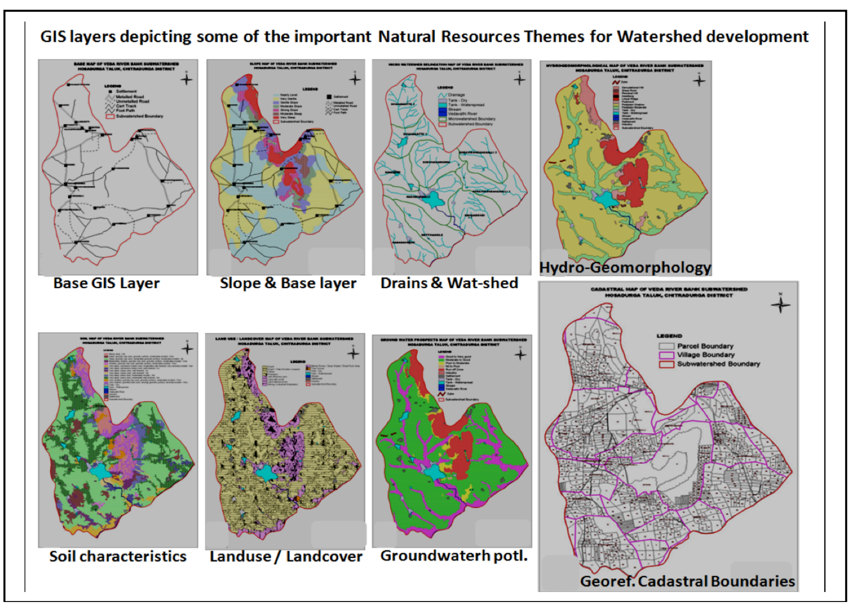


Fig. 6.1 Geospatial thematic Layers as resource information

Fig 6.1 illustrates some of the important geospatial layers, like, base layers, slope, drainage network, hydro-geomorphology, soil, land use and land cover, groundwater potential and cadastral database.

6.3 SUGGESTIVE ACTION PLANS FOR DEVELOPMENT

Multi-theme database integration helps the farming community to prepare suitable action plans for land and water resources development. Spatial analysis tools and overlay techniques using GIS tools provides varieties of scenarios for preparation of developmental plans for land and water. Initially, various combinations of GIS layers are selected for analysis of terrain parameters. For example, GIS layers, such as soil, slope, geomorphology, land use & land cover, surface water and drainage network play an important role in understanding in generating such scenarios. Attribute tables from these layers play an important role in decision making, map reading and suitable projection of the maps for analysis. Based on the analysis and visualization of various combinations of the selected data layers, specific recommendations on suitable watershed interventions are determined by field experts at cadastral level, which are further updated with field trails and additional attributes. These attributes are tabulated as look-up-tables for reference and geospatial decision making process.

Following alternative land use practices, as suggested by experts, are coded into GIS system and are customized for action plan preparation as required. Based on expert's advice and community aspirations, new attributes also created as a part of GIS database update for action plan preparation.

- Agro Forestry
- Agro-Horticulture
- Afforestation
- Commercial Horticulture
    - ◊ Commercial seed production
    - ◊ Commercial agro horticulture
- Dry Land Horticulture
    - ◊ Dry land agricutlure

◊ Fodder and Fuel

◊ Forest plantations

◊ Gap Afforestation

◊ Horti-silvi-pasture

◊ Intensive Agriculture / Double cropping

- Sericulture
- Saline reclamation / Green Manuring / Saline resistant varieties

◊ Silvi-pasture

While slopes, contours and DEM play a major role in identifying specific activities related to water conservation, GIS layers on water bodies, drainage lines, hydro-geomorphology, and others are interpreted in an integrated manner to provide site specific action plans for development as shown in Fig 6.2. These interventions are used as inputs for further verification through field observations and improved with the community participation and field experts at field level before administering them for implementation.

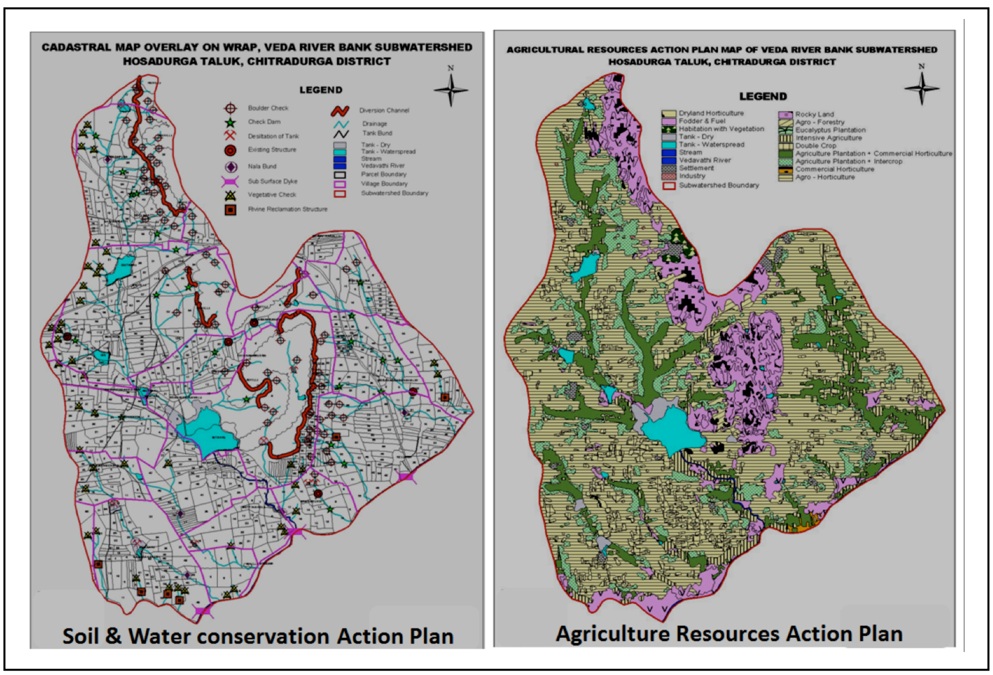


Fig-6.2: Geospatial presentation of Action plans

6.4 PARTICIPATORY ACTION PLAN PREPARATION

Action plan preparation with the involvement of village community is one of the important processes of watershed development. This process necessitates the use of natural resources information for planning and decision making. It is reported that many watershed development programmes around the world have performed poorly because they failed to take into account the needs, constraints, and practices of local people. (Johnson et. al. 2002). Hence, specific attempt is made in the present study to incorporate all aspects of participatory development and software packages are designed and developed to enable participatory planning and development. Here the attempt is to enhance participation of stakeholders for effective planning at grass root level. The software design is realised in such a way that it enables creation of necessary data related to community aspirations and at the same time provides geospatial information on natural resources to facilitate field level planning. The process also provides near-real-time database update at micro-watershed level for preparation of action plans. The design has analysis capabilities, such as, Equity and inclusiveness that ensures participation of all stakeholders. The software design and development aspects are presented here.

6.4.1 Participatory MIS Design and Development

Participatory MIS is designed to support, through simple user interface, the various elements of action plan preparation with special emphasis on stakeholders' aspirations. Important emphasis is on simplification, auto-install and customization, local language interface, easy usage at community level and ability to function on all configurations and flavors of Microsoft windows operating system (as Microsoft Windows operating system is most popularly used in rural areas). The end user of the application software are the locals, through facilitators, and it is necessary that they understand the information available in the database. Hence, the adaptability of the software in the local language is considered as an important criterion for design. It is attempted in the present study to facilitate both input and output through local language interface so that it is better adapted and easily understood for use by local community.

The software package uses commonly available DataBase Management System for storing tabular information. "Baraha 5.0" an application program interfaces (APIs) for local language interface (kannada) is used for Graphic User Interface (GUI) as a part of front-end design. The design of the software package includes the following functions.

I. Systematic organization of beneficiary details in tabular structures
II. Organisation of beneficiary-wise action plans for land treatment with respect to physical, financial and stakeholders' participation
III. Developmental activities on Private and Common Land as input
IV. Generation of varieties of reports, both in local language and English
V. Computation of estimated costs for all stipulated watershed treatments
VI. It also facilitates database creation and reporting with respect to different vulnerable groups, farm-size classes (land holdings of individual farmers) and also on the location of watersheds of the beneficiaries

6.4.1.2 Participatory MIS Database Design

The Package is used at micro-watershed level, which comprises of cluster of villages and hence a large number of CBOs for database creation and analysis. Each micro-watershed is assigned a unique identification code with respect to its location. A unique 12-character coding system is adopted for creation of micro-watershed boundary master, based on the State-District–Taluk– subwatershed–micro-watershed hierarchy and is linked to village database. The GUI for boundary master creation is shown in Fig 6.3.

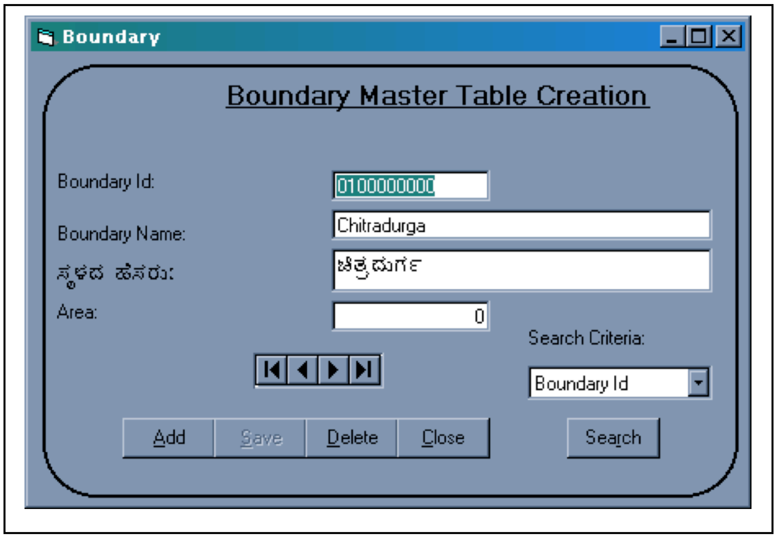


Fig 6.3: Creation of Watershed boundary Master Database

6.4.1.3 Database for Micro-watersheds

Participatory MIS, at community level, will need to create detailed information on individual farmers to allow systematic analysis of all data and facilitate locale-specific action plan. This requires system analysis at community level to arrive at a set of tables and designs that address all aspects of plan preparation. This is done through a series of field-level workshops with stakeholders' participation. Table 6.2 presents database requirement at an overall level for action plan preparation.

Table 6.2 Database Tables for Action plan

Sl No	Table Description
1	Activity List
2	User Group – Farmers
3	Beneficiary_category
4	Beneficiary
5	Boundary
6	Vulnerable group
7	Common land_Activity
8	Common land_Survey_No
9	Demonstrations
10	Land_type

Sl No	Table Description
11	Location
12	Paste Errors
13	Pvt.land_Activity
14	Pvt.land_Survey_No
15	Part_plan_info
16	SHG
17	Action Plan
18	Watershed Group – SWS
19	SWS_info
20	Treat_Untreat

Database structures related to tables mentioned in Table 6.2 are created based on the field requirements. These structures provide the basis for storage of all data elements for participatory planning at micro-watershed level. The process of participatory planning and the PRA process results in creation of these databases that gives developmental perspectives for both private land and common land treatment. The participatory planning is coordinated amongst Community Based Organisations (CBOs), which is nothing but Self Help Groups (SHGs), User Groups (UGs), vulnerable groups and Watershed committee, through their collective wisdom. The details of software design and package functionalities are presented as follows.

6.4.1.4 Salient Functionalities

At Micro-watershed level there are many activities that are planned in mutual consultation and through expert advice on the field and are created as part of the database for plan preparation. The finalized set of activities is approved for implementation as part of private and common land development. Following are some of the important database elements and functionalities that are created as part of planning process.

i. Watershed Society: As a part of watershed society database structure, details on Private Land and Common Land development activities are created. Database is organized based on categories and sub-categories of land and water development activities.

ii. Action Plan: This provides action plan details, date of creation and submission for technical validation and approval.

iii. Private Land treatment: This contains three basic parameters related to (a) details on beneficiaries, (b) their parcel/ cadastral number, and (c) land use details.

iv. Common Land treatment: This contains two parameters related to the parcel/ cadastral number and details of activities.

6.4.1.5 Action plan and report generation

Package supports varieties of outputs and reports that helps in analyzing all aspects of micro-watershed development. Following are some of the important outputs that are provided by the package. These outputs provide important insights on the way the community plans its development through participatory processes.

i. Frozen Queries: These are reports generated from a set of pre-defined functions that serve as quick reference on action plan for easy adaptation at field level.
ii. Action Plan Overview: This generates a comprehensive report on all proposed works that includes area covered, investments, community contributions etc.
iii. Private Land: This report provides details of all private land developments at farmer's level
iv. Common Land: This report provides details of all common land developments
v. Private and Common Land: This report is a compilation of both private and common land details for a give micro watershed. Hence, this gives a scenario of the entire development of the area in a comprehensive manner.

6.4.1.6 Analysis on Inclusiveness

Action plan preparation includes varieties of activities and aspirations of farming community, irrespective of socio-economic status or location of the farm. To ensure transparency in planning process and true reflection of developmental objectives, social factors such as equity and inclusiveness are analysed from the action plan database.

Micro-watershed, depending on the agro-climatic setup, would contain about 300 or 500 farming families and hence it is essential that the benefits of development reach out to all stakeholders. To facilitate the process of transparency, which ensures equity and Inclusiveness, an analysis and reporting module is developed to provide specific inputs on poor and vulnerable groups. Specific parameters are considered for analysis and inference of the development as follows:

i. Social Category: The module provides information on participation of weaker sections and vulnerable groups. Inclusiveness with respect to participation of vulnerable groups are analysed as part of action plan preparation.

ii. Farm Size: This module provides information on community participation with respect to landholdings, size and their distribution. The report also brings out the actual commitment for each activity as planned by community.

iii. Location of watershed: This module provides location-wise (ridge, middle and valley regions) information on the type of activities planned. The criterion is important for validation of the action plan with respect to terrain and gradients.

iv. Beneficiary-wise Details: Beneficiary details with respect to Area Groups are analysed in this report. That is, activities as planned with respect to beneficiaries and total area covered for each activity are analysed.

6.4.1.7 Analysis on Equity

Equity analysis enables an assessment of equitable distribution of various developmental activities with respect to social categories, farm-size, investments in private land by different categories of farmers etc. This helps in validation of action plan with respect to following parameters.

i. Farm size: Information on the area to be treated with respect to farm size
ii. Social category: Information on the area to be treated with respect to the social category of the community
iii. Investment made by community with respect to farm-size
iv. Investment made with respect to different social categories

v. Investment made with respect to location (ridge, middle portion and valley)
vi. Contribution and involvement in development by vulnerable categories
vii. Contribution and involvement by community with respect to different farm sizes

6.4.1.8 Software Design and Development

The design and development of Graphic User interface with bi-lingual interface for action plan preparation is presented in the Fig 6.4 and Fig 6.5. The database generated for specific micro-catchments representing the respective UGs, as a part of micro-watershed, are also organized as part of action plan for decision-making processes.

Fig. 6.4: Participatory MIS with local laungage interface

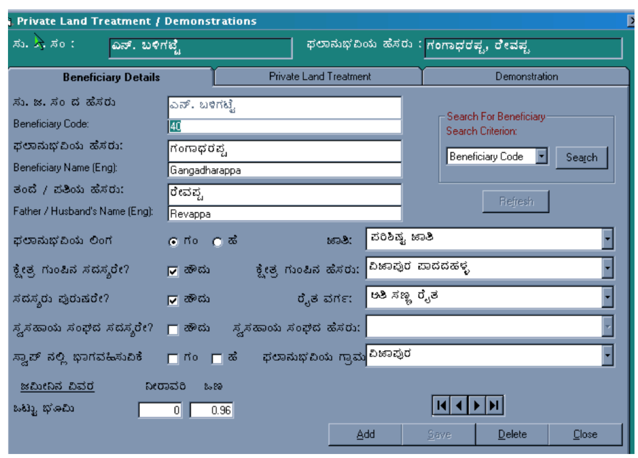


Fig 6.5: User interface - private land treatment

6.4.2 Participatory GIS design and development

Traditionally, watershed development plans are prepared based on general opinion from villagers and limited requirement analysis. Such an approach leads to undesired results and does not facilitate community participation in planning. While participatory MIS provides varieties of information on multi-sectoral planning, the participatory GIS software facilitates geospatial visualization and analysis of developmental activities and their possible impacts. Geospatial database layers of the micro-watershed are suitably integrated to provide locale-specific action plan that is further field verified before implementation. Since, these GIS layers are site-specific and are overlaid with cadastral boundaries, it is possible to use them for decision making at community level and at the same time educate farming community with scientific knowledge of watershed development.

In the present research study, participatory GIS software is designed for practical adaptation and use at field level for action plan preparation with community participation. Two GIS software tools are designed and developed in the present study using open source GIS tools "The Geotools", which is a JAVA based tool.

1) Action plan map creator
2) Geospatial data viewer

"GeoTools" is an open-source JAVA toolkit with a library of GIS functions. It is utilized to build an interactive map-based solution for geospatial applications. Software Codes and callable libraries are available under "Geotools" for development of interactive mapping and applications. It allows execution of JAVA Applets or SWINGS applications on a wide range of platforms without the need for any additional software plug-in.

The system architecture to meet above requirements is summarized in Fig 6.6.

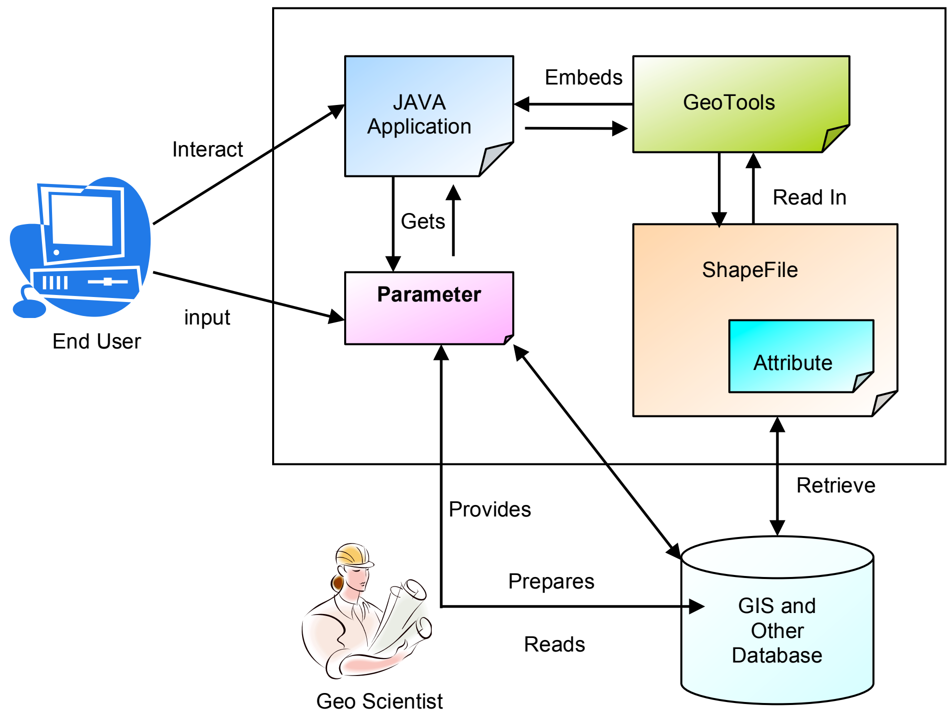


Fig. 6.6 System Architecture for GIS based Action plan map creator/

Based on this architecture, a detailed plan of action for design and development of the software systems is adopted for both the packages. The class diagram for action plan creator is presented in Fig 6.7.

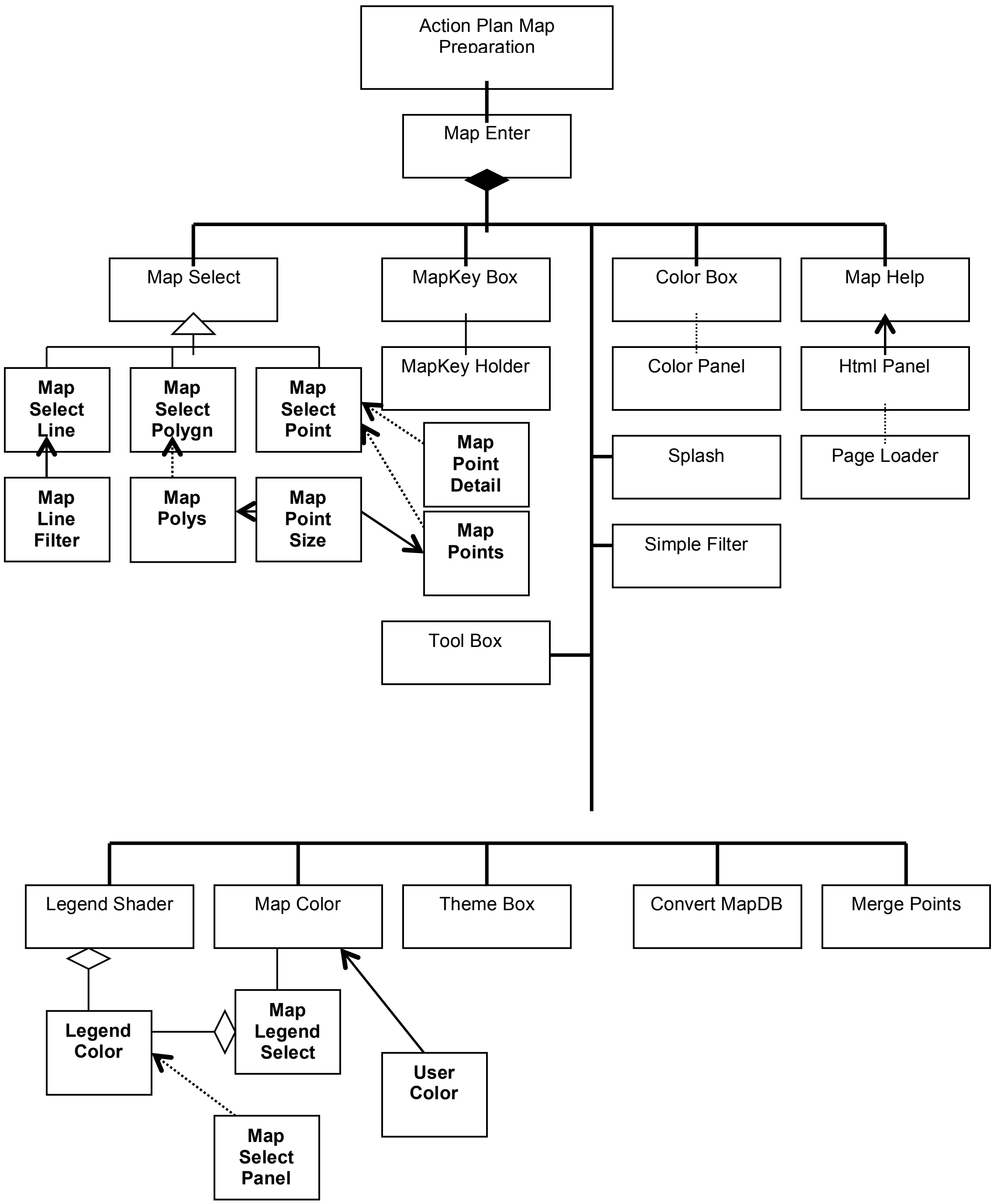


Fig. 6.7 Class Diagram for Action Plan map Creator

JAVA Swings is used for user-friendly interactions and GUI for the packages. Java Swing is a large set of components ranging from the very simple labels to some advanced features like tables, trees and styled text documents. By virtue of JAVA being "platform independent", it is observed that Swing buttons or text areas looks and functions identically on Macintosh, Solaris, Linux, and Windows platforms. The design eliminates the need to test and debug applications on each target platform. Thus Swings is a GUI toolkit that is as good as any other commercial GUI toolkits and even better in several aspects and hence used for developing all user interface elements. The package can easily function on any operating system without major changes in the source. Some of the key functionalities developed and made operationally available for use under the package are:

- Graphics symbols library, representing more than 120 different types of watershed development activities, is created as a master database. Action plan depiction using these symbols is facilitated under the package. Fig 6.8 illustrates a set of symbols
- The watershed activities symbol library is separately maintained in the database for Private land and common land activities.
- Simple GUI is provided to insert or remove a watershed activity symbol as a part of interactive process.
- A tool is provided to monitor the status of any activity through a geospatial query, such as, planned, in process and completed
- A tool is also provided to monitor 3 broad categories of activities in the geospatial domain, namely, Private land, Common land and Demonstration activities.
- Options are provided to display activity names, from attribute table, through a toggle button. Watershed symbol library, tagged with activity name that are separately stored under a database, provides the required visualization.
- While creating action plan maps, user can also display resource layers in the background for reference. The action plan map is superimposed for visualization and analysis, as required. However, by default, the Cadastral layer is loaded and

"switched on" to enable symbols creation and display of different types of action plan elements.

- The "Resource map viewer" has slightly a different set of functionalities as compared to the "Action plan Creator" module. This tool enables display, overlay, geospatial query and other visualization operations using the multi-theme geospatial layers
- The Viewer application also allows display of satellite image (GeoTiff Format), as a backdrop, for necessary cross referencing purposes.
- On the right-hand side of the display, legends for the corresponding map layer is also displayed with unique color codes as assigned to the respective maps.
- Both Packages allow multiple map display for visualization, either from same micro-watersheds or more than one micro-watershed, based on map extent.

Thus, the GIS package developed is useful for varieties of purposes, particularly for watershed development, as it enables visualization, zoom-in, zoom-out, panning of images or maps, multiple map overlays, selection of area of interest, monitoring of activities and interactive geospatial queries of different natural resources layers.

6.4.2.1 GIS package and its operations

Following illustrations show some of the key functionalities of these packages as follows. Fig 6.9 shows a micro-watershed with cadastral boundaries with facilities to prepare action plan, Fig 6.10 shows the GIS viewer with multiple themes and overlays. Fig 6.11 shows the possibilities of satellite image display as a cross-reference to the thematic maps and Fig 6.12 displays the multiple adjacent micro-watershed maps with the overlay of cadastral boundary on drainage lines layer.

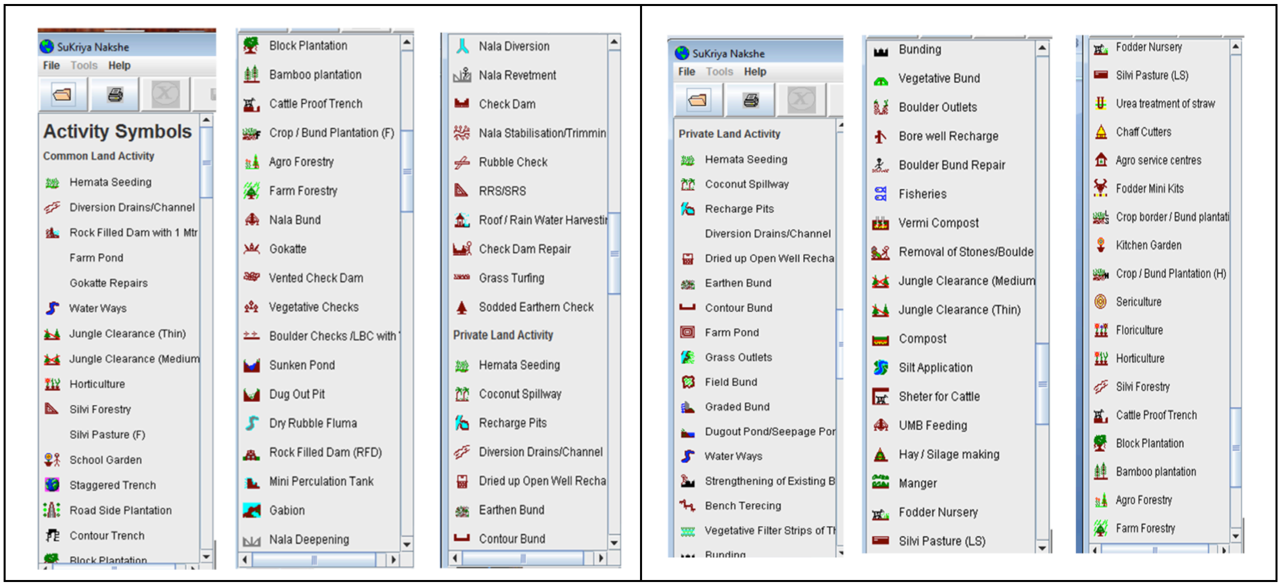


Fig – 6.8 : Symbol library for Private land and Common land development

Fig. 6.9: Action plan preparation

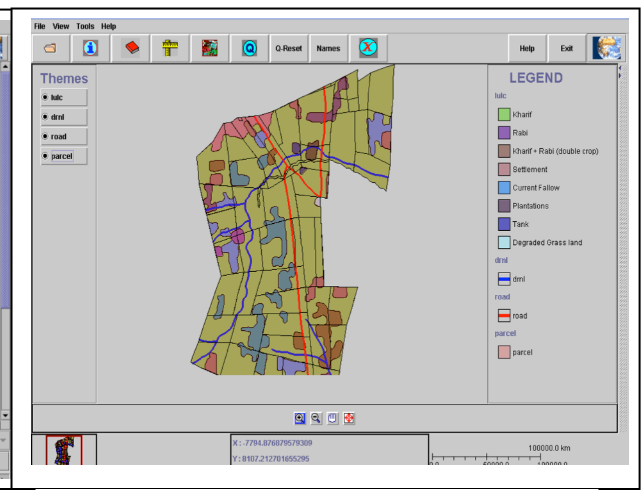


Fig. 6.10: Resource maps overlay

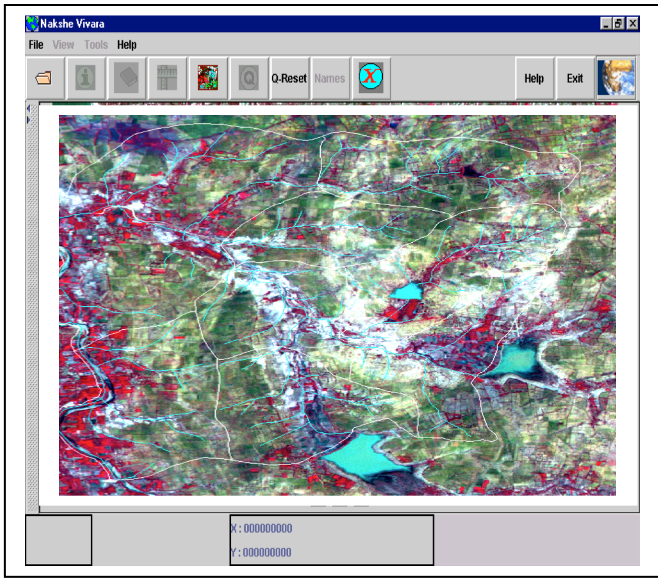


Fig. 6.11: Satellite image Viewer

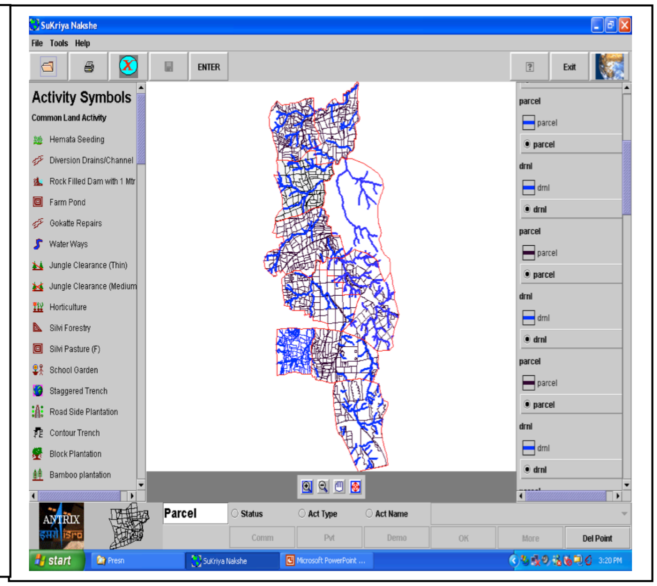


Fig. 6.12: multiple micro-watershed display

6.4.3 Inter-operability of Participatory MIS and GIS solutions

Participatory MIS and GIS have distinct functionalities to facilitate on-field activities of action plan preparation. The two packages are made interoperable so that the stakeholders have the best advantage of using MIS database and GIS maps while planning watershed development activities. "GeoLink" tool is provided that allows beneficiary level database creation with simultaneous preparation of action plan maps. "Geolink" is a GUI that allows GIS facilities as a popup while all other tabular details for private land and common land activities are created on participatory MIS software package. Following illustration in Fig 6.13 demonstrates this aspect of the package.

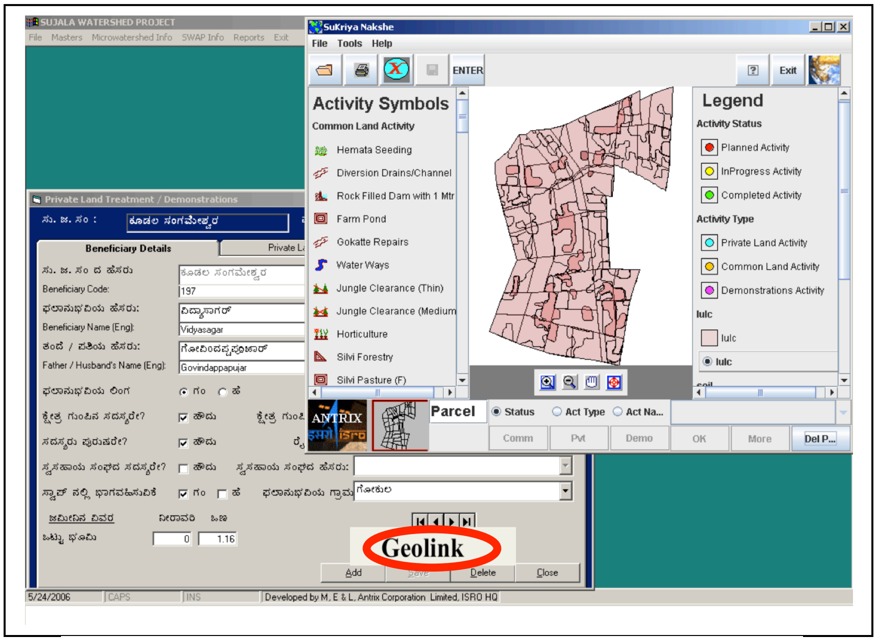


Fig 6.13: Integration of PMIS and PGIS Modules

6.5 WEB BASED ONLINE MANAGEMENT INFORMATION SYSTEM

Watershed development is a continuous process, which involves a sequence of processes to achieve the ultimate goal of sustainable development. Monitoring of various developmental processes is essential to ensure that the investments are appropriately and midcourse corrections, if required, are effectively done. Manual methods of monitoring are cumbersome, subjective, manpower intensive, time consuming and often less effective. Hence, an alternative methods of online data collection is developed to improve the effectiveness of plan implementation. The development is particularly useful for concurrent data collection and analysis with large number of geographically distributed watersheds. The design involves parameterization of specific processes of watershed development that are amenable for monitoring. There are many challenges in this design, particularly the choice of indicators that enables measurement of various social and environmental parameters of development. The design and development of the software package is presented in the following sections.

6.5.1 Analysis of field requirements

Watershed Development, implemented across different agro-climatic regions or a number of watersheds, necessitates periodic smooth dataflow from the field with respect to various implementation processes. Such data elements provide inputs on current status of various tasks and sub-tasks of implementation processes, such as:

1. Field level Facilitators and their activities
2. District level details
3. Entry point activities at village level
4. Formation of social groups and their activities
5. Social activities of Community based organizations (CBO)
6. Training and capacity building
7. Action Plan implementation processes

The package needs to satisfy the following requirements with respect to the data collection, analysis and report generation on various activities:

a. User will be able to smoothly navigate and use package for providing inputs
b. User to be provided with simple means for Input and output of data on a periodic basis
c. Facility to accept multiple user access for concurrent data and information services
d. Facility to support queries, report generation and analysis
e. Facility to support online charts (pie charts, bar graphs, etc,) for graphic analysis
f. Facility for view and print reports
g. Facility for graphical depiction of multi-temporal data

A requirement elicitation process has extracted the above set of broad requirements. This requires the software solution to handle them in the way described below:

A. Map-click or textual selection of area of interest through selection of State, followed by district, taluk, sub watershed, micro watershed and villages.

B. Software design is based on client-server architecture with thin-client and fat-server. The MIS Server is capable of catering to multiple concurrent users at the same time with functionalities of simple GUI for field level data entry. This architecture also facilitates spatial and non-spatial data representation. Each client query is processed at server and responded on the network.

C. To ensure secure access to the application and data, a user authentication system is required. Hence, design of user authentication module is part of the software system. That is, a district level user would view and provide inputs about corresponding district only. A super-user at topmost level in the hierarchy will have provision to access any level.

D. On selection of region of interest, the user can interact with the software and provide inputs and generate reports. The system also supports displays, which are dynamically created in the form of menus that consists of queries, applicable to a particular area. Pre-defined reports that allow the user to view results of queries such as monthly status reports, progress reports, performance evaluation, target vs. achievements, etc., along with a graphical presentation of the output (pie charts, trend graphs, bar graphs etc).

E. For those villages that are not connected on the communication network, a provision for off-line data entry is required as part of the design. The package need to automatically collate data from all the interactive sessions and compile data at local machine for offline uplink.

F. The reports and charts are dynamically produced in HTML format. The package also provides the user with an option to view and save the same in a printable format, like PDF (Portable Document Format) files.

G. Satellite images and maps of all the districts and micro-watersheds are stored as repository on the server and also at the district systems for access, cross-reference and analysis. These vector maps can also be used for online reference.

H. The GUI guides the user through varieties of categories and activities which are based on a combination of social and environmental indicators.

6.5.2 Software Design and architecture

The client-server model of implementation of online MIS has client-end and server-end functionalities. The entire software design gets implemented at server-end, while the client-end works as a internet browser based application. The entire GUI for front-end and software menus are rendered on the client system but are executed at server-end through PHP scripting language. The following illustrations highlights the package requirements from the perspectives of the system administrator and the authentication of users at the various levels of the user-hierarchy, as shown in Fig 6.14 and 6.15 respectively.

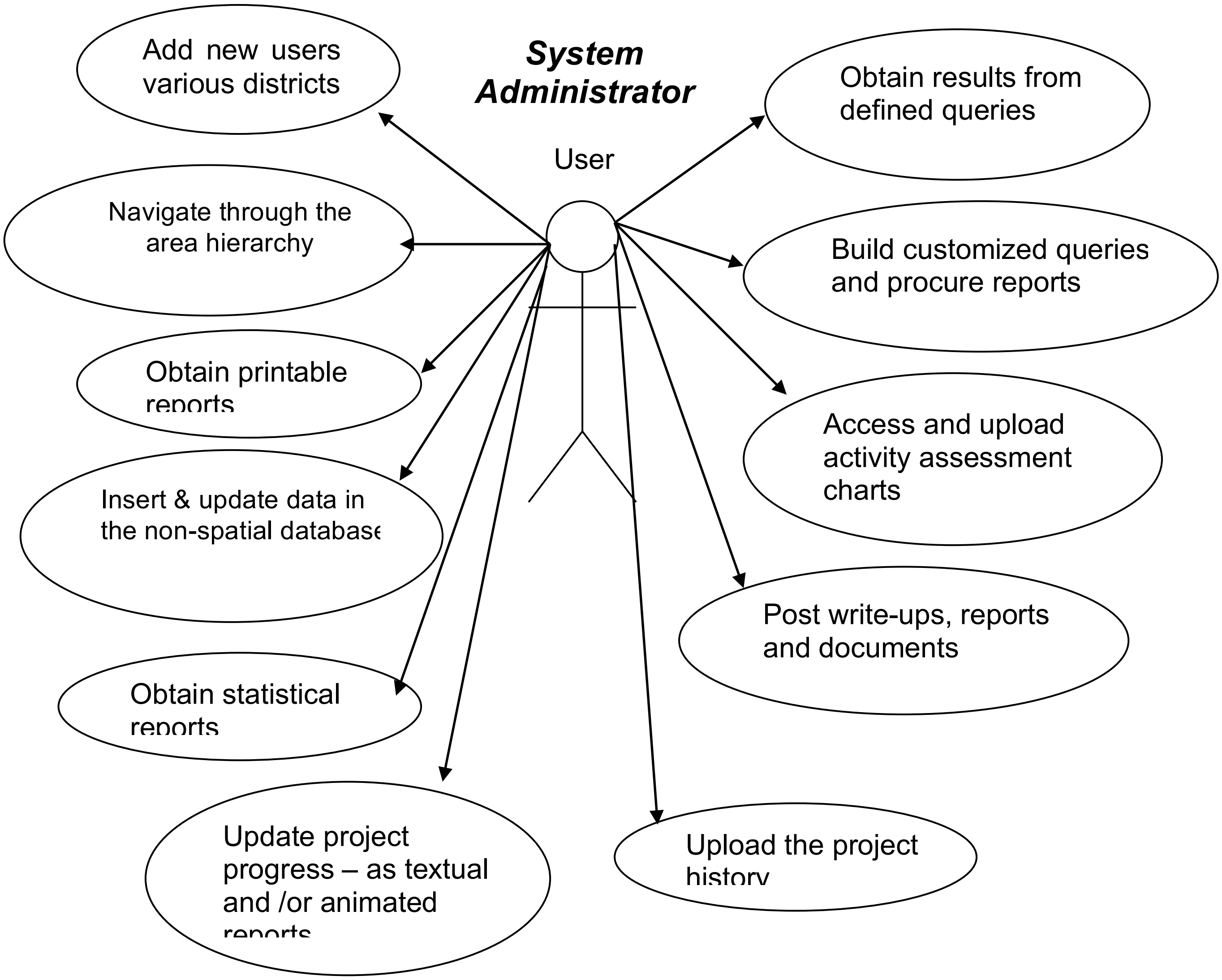


Fig. 6.14: MIS Design and Architecture – System Administrator's perspective

User Authorisation

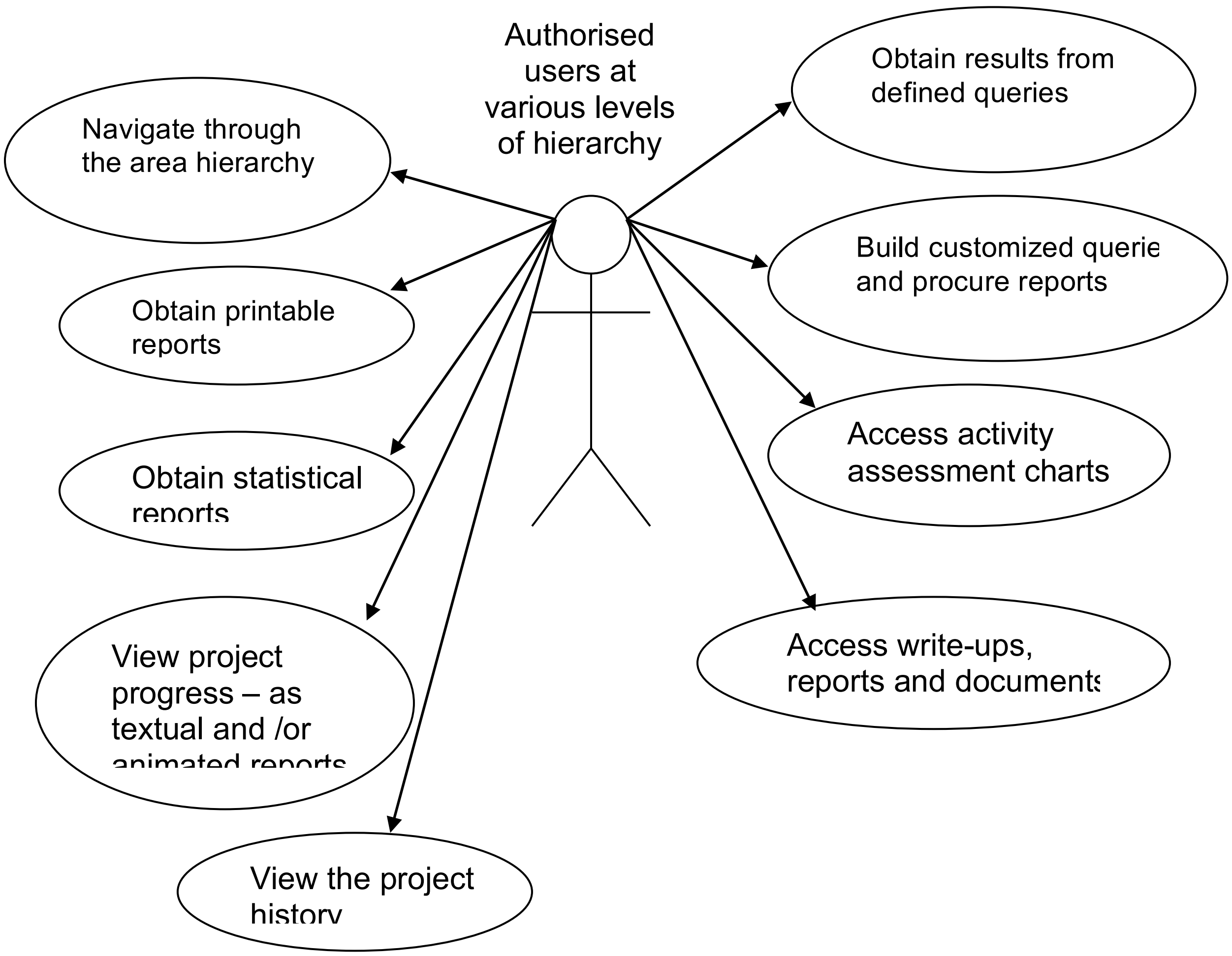


Fig 6.15: MIS Design and Architecture – Users' perspective

6.5.3 Server-End Software requirement

Open source software tools are used in realizing the design to enable a cost-effective solution and enable online data collection on developmental activities. Following server-side software scripts are developed for Web based MIS development. The tools at the server-end can provide necessary inputs and functionalities for effective concurrent monitoring. Some of the important system considerations are:

a) Operating System: Design and development is done in such a way that it supports both Linux and Windows Operating Systems as a server-end solution. However, client-end is a browser based solution which can work on any operating system.

b) Relational Database: Open source RDBMS, PostgreSQL, is used at the server end to provide all necessary support for data storage, online queries, analysis, geodatabase support for GIS data and varieties of graphic analysis support**.** PostgreSQL is available under relaxed licensing policy and is free for use. This allows user-defined data types, supports transactions, views and sub-queries, provides better support for ANSI SQL, provides Data Integrity constraints, such as, Check constraints, Triggers, Rules, Stored Procedures, full constraints for Date column types etc., allows specialised data types, especially geospatial data, with special algorithms to store 3D data and Object-Relational inheritance

c) Web Server: Open source "Apache Tomcat server tool" is as the web server tool at the server end which is easily customisable with add-on modules, which is built on a modular concept, this is secure and widely used, provides support for authentication, supports Virtual hosting facility, that is, address based and name based virtual hosts are configurable.

d) Server Side Scripting: PHP scripting language is adopted for developing server side scripting, Php is a free and open source software, the scripting language is supported on a number of platforms works in conjunction with a number of web servers, it facilitates creation of dynamic web content, XML usage is supported under this scripting language, function related to images, graphs and charts can be dynamically handled, the scripts allow generation of PDF documents on the fly

e) WebGIS applications: The server-end open source application tool enables development and customisation of Mapserver utilities, publishing of GIS maps with varieties of user services, hence supporting a whole lot of geospatial solutions

6.5.4 Client-End requirements

At the client-end, there is no requirement for any application software or a plug-in but for the commonly available internet browser. However, the applications is usable only if the network connectivity is available. A general architecture of the client and server end connectivity and operations is presented in Fig 6.16.

System Architecture and design

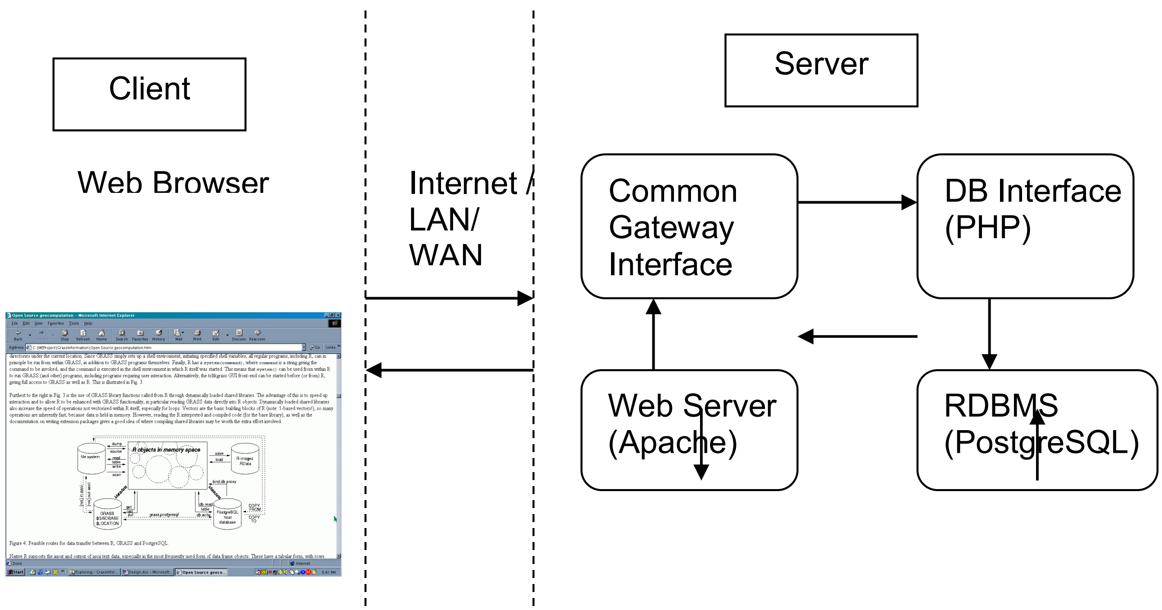


Fig – 6.16: System components and Information flow

One of the most important advantage of such a design is the installation and maintenance of the application at only the server-end and no system overheads or software maintenance at client-end. The package functions on any internet browser, like, Microsoft IE (6.0 or later), Mozilla Firefox, Netscape (7 or later), Google Crome etc. The package could also be used on LAN or WAN or Internet without any modifications to the server-end tools. The Information system allows data entry at individual micro-watershed level. The parameters for data input and information generation capabilities of the package and other features are highlighted in the following sections.

6.5.5 Software Development and functionalities

The software development provides simple map-based user interface for providing stakeholder-friendly front-end. The GUI allows users to navigate through the hierarchy of area selection for input, query or reports. The package comprehensively provides input and analysis functions for all important processes of watershed development, on a concurrent basis. As the package is accessible through a hierarchical framework, users can access and use relevant information at all levels. The district level users can access any watershed of their choice that are geographically located within the District. A State level user, who also has super-user privileges, will have access to all levels of entire hierarchy for input and output related operations. The report generation and analysis also follows similar hierarchy of selection for generating varieties of report.

At the micro-watershed level, following information are available

A. Micro Watershed Map: The micro-watershed map is displayed on this interactive web page. This basically provides the micro-watershed boundary for visualisataion.

B. Study Area details: All the names of all the villages covered within the micro watershed boundary are displayed along with the project area details. Each village is hyperlinked for additional information.

C. Watershed Society: The name of the watershed Society is displayed as a hyperlink leading to specific information.

D. Parameters for periodic Information: Periodic updates are available at micro watershed level on the following items.

   1) Watershed Action Plan: Two levels of information are available through this:

      i. Master plan for 3 years and plan for the current year are provided based on the participatory watershed development plan prepared at stakeholders' level: This is includes Action plan, area coverage, number of SHGs, proposed investments etc.

      ii. Weekly Accomplishments with respect to proposed action plan, on various aspects of implementation, is updated for each micro watershed through regular online interactions.

2) User Groups (UG): This provides a list of all the area groups in the selected micro-watershed. Each UG name is a query-link that leads to AG-specific information. Details like date of formation, member composition, number of acres covered, action plan implementation by UG and capacity Building

3) Micro Watershed Activities: The various activities carried out in private land and common land are regularly updated at the server-end from the field through online database update functions. Against each activity, the physical and financial details are entered from the field. Broad areas of database updates are:

    i. The current details of work done
    ii. Cumulated information till the previous month
    iii. Cumulated accomplishment against the plan from the beginning of implementation

4) Income Generation Activities (IGA): These are specific activities for those farmers who do not posses land resources, but still participate in the overall development through skill development and labour. The Package provides specific features to track skill development activities like, initiation of an enterprise and their updates at individual and group level under each SHG.

5) Formation of Watershed Society: Following information about each micro-watershed are available with respect to watershed society

    i. Name, date of formation
    ii. Category of farmers (Landless, Small, Medium, Big), and the number of acres covered for each category.
    iii. Common Property Resources - area covered under each CPR
    iv. Number of Area Groups and SHGs
    v. Micro-Watershed Registration related details
    vi. Executive Committee details - member composition, EC attendance, and General Body Meeting details

6) Village level details: Awareness Building Activities are very important at village level. Hence, periodic information on specific parameters are obtained from the field for the following activities

   i. Village visits and meetings: Information on informal meetings, street and colony-wise visits, Gram Panchayat (GP) meetings etc., are updated on MIS for monitoring.

   ii. Publicity Campaigns: Information on watershed development is publicized through wall paintings, greenery initiatives (Hasiruhabba), street plays, group meetings, pamphlets on natural resources conservation and so on. These activities are captured and monitored.

   iii. Entry Point Activities (EPA): Information is given with respect to revenue village or hamlet in which EPA is initiated and carried out. For each village or hamlet the activities that are planned and carried out is first captured with respect to sub-parameters and monitored.

   iv. SHG Formation: Information about the total number of vulnerable households, number of SHGs formed, number of vulnerable households covered under SHGs with respect to Landless, Small, Medium, Big and vulnerable groups are captured and updated for monitoring.

   v. SHG-wise details: Information on SHGs, date of formation, bank linkages, account number, and other details for each SHG are captured from the field and updated for monitoring. In addition, specific details regarding each SHG is also provided

   vi. SHG Performance: Information related to the members, weekly participation, village level meetings, banking details, number of members availing loans, interest earned on loans, other sources of funding, savings, and other details are captured and updated as a part of SHG performance.

6.5.6 Data flow and synthesis

Application software at the server-end and its wide connectivity to across large geographical spread enables simultaneous data collection and management. Network connectivity in for the form of wide area and wireless networks enables users from the watershed-end to uplink data on the implementation progress from the field. Following illustrations show the actual data flow and synthesis of such data at different administrative hierarchies. Watershed management at different administrative hierarchies can get significant boost with such an arrangement, wherein the knowledge of field-happenings are available on a click of a button on the web-based online information system. Fig 6.17 illustrates the data flow from different field level functionaries for aggregation at district level before it is further synthesized at State or head quarter level for enabling monitoring and management.

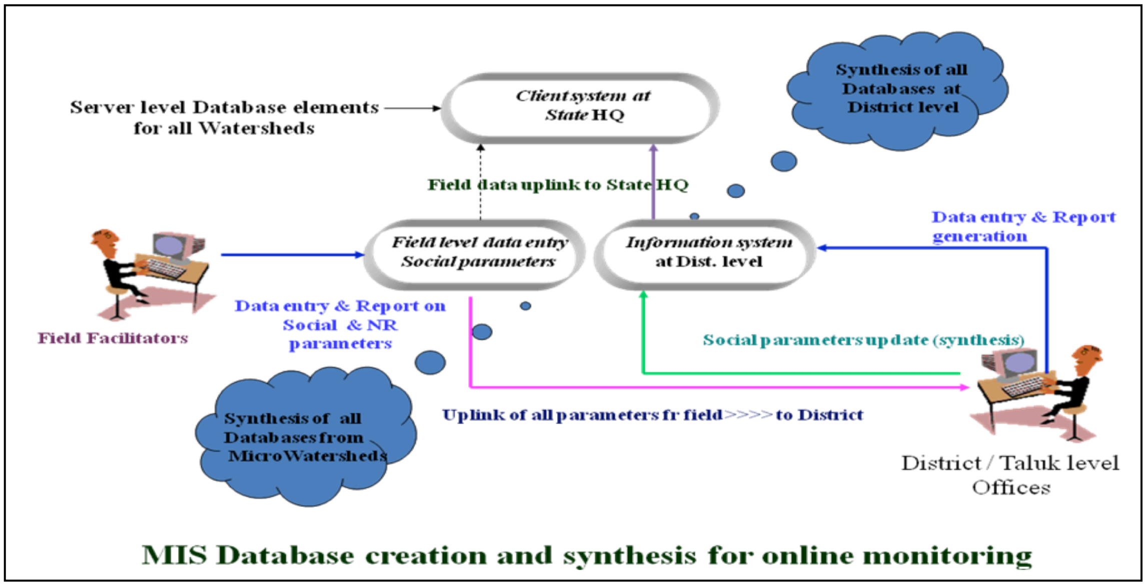


Fig – 6.17 Data Flow, Aggregation and Synthesis for online monitoring

Fig 6.18 illustrates the data flow from clusters of micro-watersheds to districts, followed by further synthesis at state level.

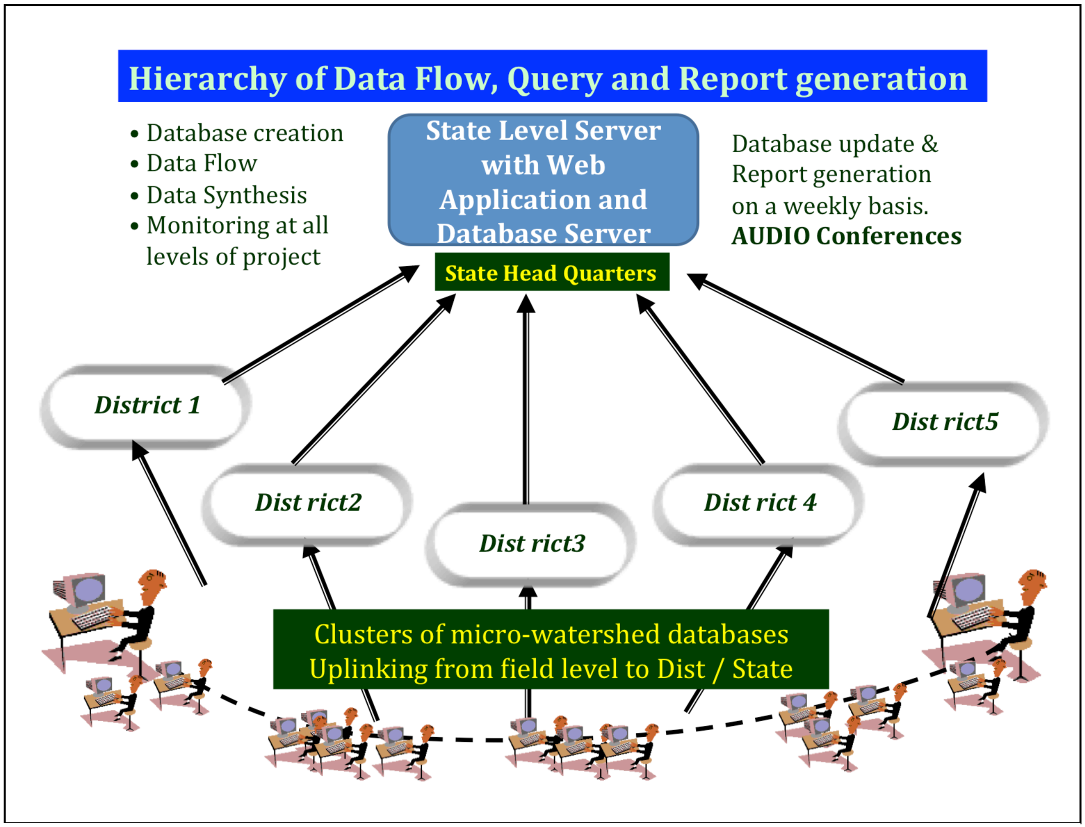


Fig. 6.18: Overall Dataflow at all levels for concurrent monitoring

The Fig 6.18 also shows the scalability of the design for large-scale usage and database creation, parallel data flow and simultaneous synthesis for monitoring at all levels. This also facilitates regular database update on various indicators and parameters that could be used for close monitoring of field level interventions and even for audio conferences from State or head quarters to facilitate monitoring and management.

Fig 6.19 illustrates the overall architecture and design of the web based MIS and GIS software package that is developed for online services and analysis.

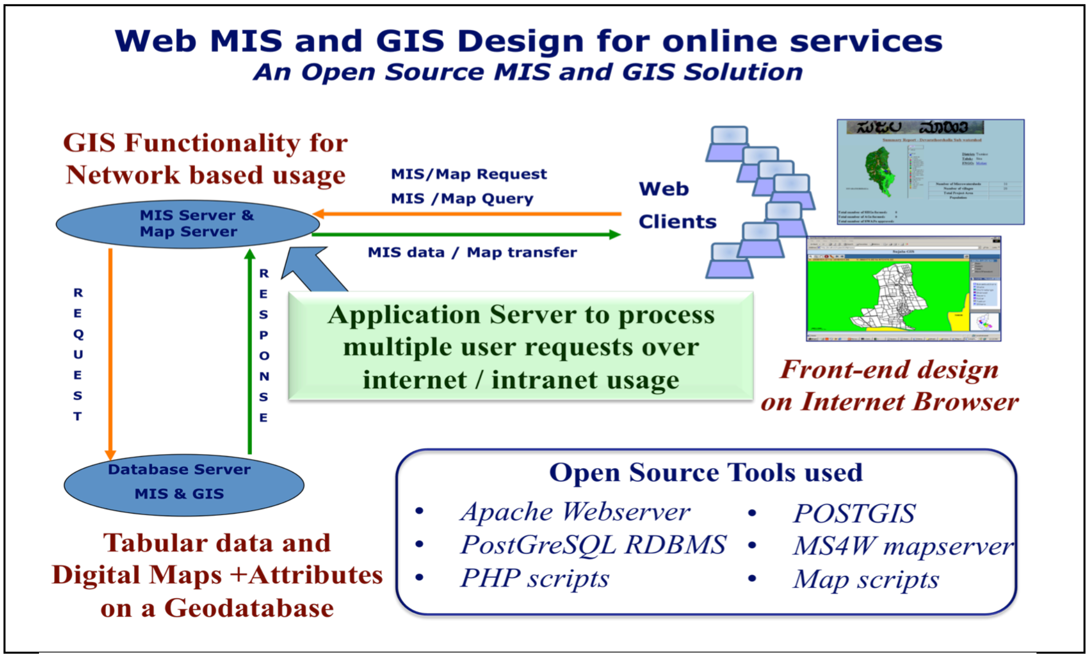


Fig – 6.19: Architecture and Design for WebMIS/GIS configuration

The server components highlight the MIS and GIS applications that support all transactions field level functionaries and the administrators at different levels. The network configuration with request and response are also highlighted at server end with its linkage to the tabular data on RDBMS with necessary geodatabase for reference.

Fig 6.20 shows the front end design of the Web-based MIS package which presents the study area in the opening screen. Entry to the package is based on successful authentication for which valid username and password is a prerequisite. The study area highlights selected districts in which the watershed developments are planned. Further interactions are through a systematic hierarchical "drill-down" menu arrangement for data entry and report generation as desired by the user through online interaction.

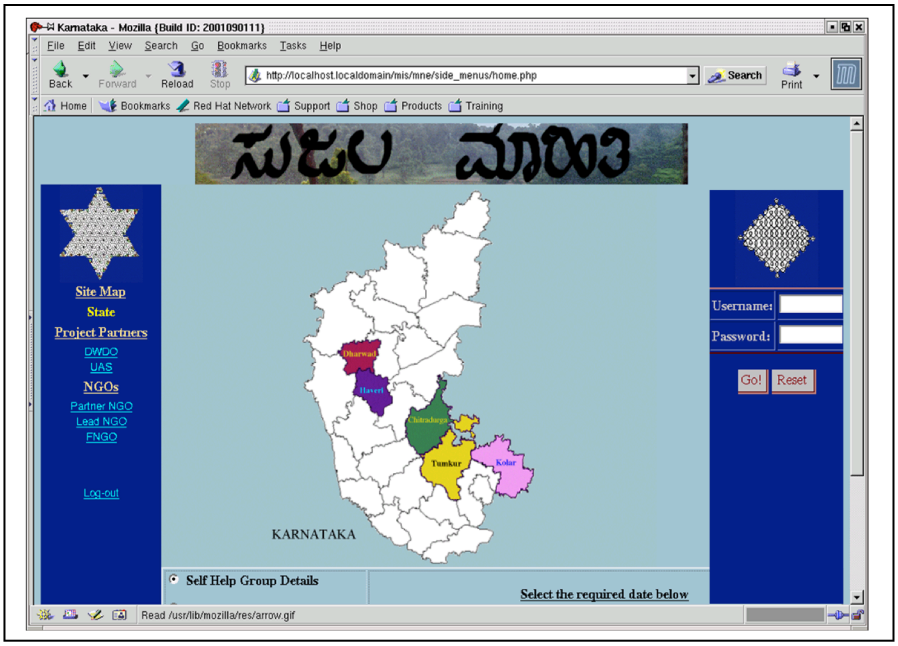


Fig – 6.20: Front-end Design for WebMIS/GIS

Fig 6.21 illustrates details on the various options for online database creation and analysis under the package for, including report generation. The package attempts to capture important parameters of various processes with respect to watershed development. This includes annual plan database that is derived by extraction of information from the local level participatory MIS database, Entry Point Activity that provides necessary initiation of developmental activities for the facilitators and provides details on CBOs, regular assessment of various watershed development activities, until the end of implementation and withdrawal. The package is used on a continuous basis, by field functionaries, for data up-linking and analysis throughout the developmental phase. Each of these main activities have specific sub-activities which are monitored as part of data collection, analysis and management.

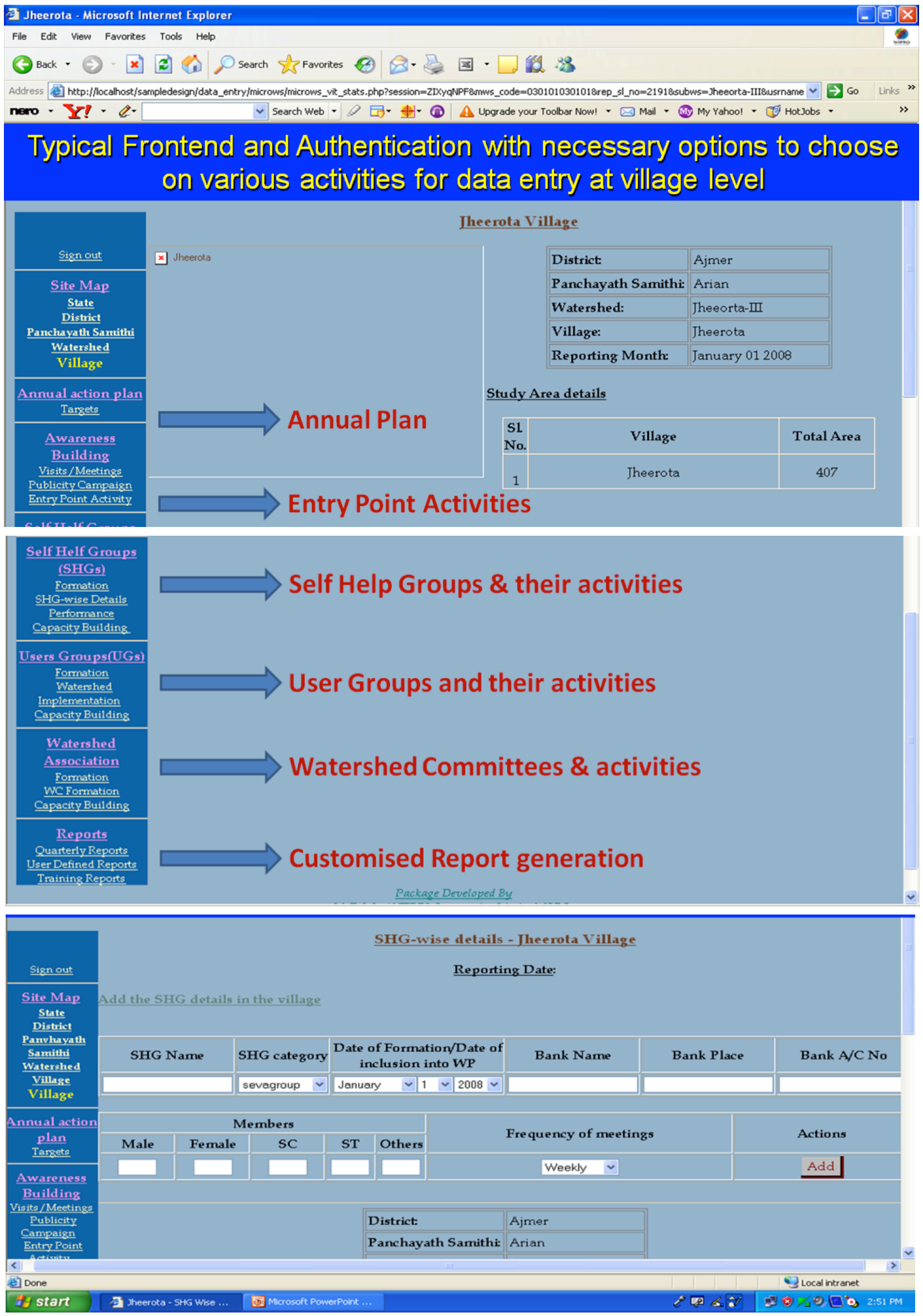


Fig. 6.21 Activities of Development and client-end data entry options

6.5.7 Software for offline data synchronisation

The web-based MIS provides necessary features for near-real-time data collection, analysis and reports for decision making. The tool facilitates dataflow from many sites for effective concurrent data synthesis at higher levels for monitoring. While dataflow is ensured from all connected villages, there could be many other villages that are not connected on the network to provide data online and it is also observed that electricity is also one of the critical problems in many rural areas. Hence, a stand-alone software design is conceived and developed to address off-line data entry which stores the required data on the local machine with a facility to port the same on a media that could be used later for up-linking to the MIS server and data synchronization. Fig 6.22 shows the front-end design of the software tool what works on a local machine with similar user interface as in web-based software tool. At the end of data entry an ".SQL" file is automatically created on the system on a monthly basis that keeps storing all transactions and data entry on the local machine. Anytime the updated ".SQL" file can be e-mailed to the server-end, as an attachment, which in-turn is synchronized with the server database. This procedure is as good as online MIS system, except that the local desktop is not connected to the server for online data entry.

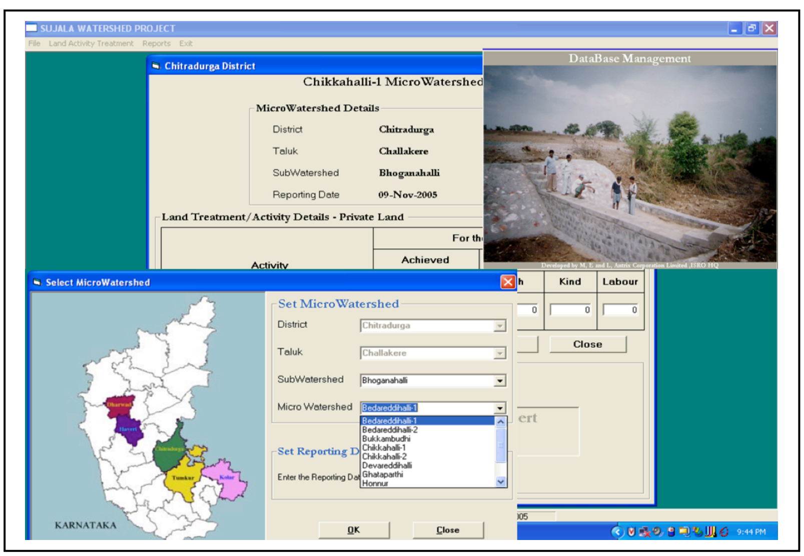


Fig 6.22: Offline MIS as a Desktop version

Hence, the software design is highly adoptable, replicable and scalable for different types of usage.

6.6 SUMMARY

Tools and techniques that could be adopted to improve watershed development processes have been elaborated in the chapter. An optimum combination of high resolution satellite data, geospatial technology and Information technology solutions are developed for integration into the conventional processes of watershed development. While doing so, methods of fusion is evaluated and a universally adaptable DWT based fusion method is adopted, hybrid classification technique with a semi-automatic method of class labeling method is also demonstrated with neural networks, specific software tools are also designed and developed for participatory planning and PRA exercises using MIS and GIS techniques with local language interface, a web-based online monitoring tool is realized which addresses important indicators for effective management and close watch on the various processes, remote sensing and GIS tools are used preparing detailed baseline database that serves as a strong reference for impact assessments. In summary, the chapter brings out the details of all the tools and technologies that are required to be integrated into the process based model for watershed development as proposed in the study.

CHAPTER 7

RESULTS AND DISCUSSIONS

7.0 INTRODUCTION

The basic objective of the study is to design and develop a simple-to-adapt process based model with appropriate technological intervention and participatory approach to effectively implement watershed development programme in a given terrain. Considering the complex nature of the problem with diversified factors, such as, terrain features, agro-climatic conditions, status of land and water, socio-economics, livestock population etc, an attempt is made to integrate them through a set of processes and technology, involving the community, for scientific planning, implementation and improved results. Further, the focus is also to design and develop an approach for monitoring and evaluation of the process based watershed development programme. Geomatics and Information Technology solutions are adopted and tested in the present study. The results and outcome are presented here.

7.1 IMAGE ANALYSIS

The process-based model involves the use of geomatics and other techniques as a part of implementation. The technological interventions, such as, geospatial database for baseline information, remote sensing based natural resources assessment, Participatory GIS and IT solution for planning, web-based MIS and GIS for online monitoring and geomatics for change detection and impact assessment, are some of them which are developed and tested. These techniques enable multi-level monitoring and are shown to be advantageous for the stakeholders and the implementing authorities. The use of technology in monitoring and evaluation amply demonstrate robustness of the system in effective performance.

The model, developed in the study, is tested by implementation in one of the watershed development programmes “The Sujala Programme”, in Karnataka State, India. The results of actual implementation of such tools and techniques, adopted at different stages of development are presented here.

7.1.1 Image Fusion and value addition

The image fusion techniques produce high quality images that are amenable for enhanced visual interpretation and thematic maps at large scale. The image fusion techniques are tested in all 3 Agro-climatic regions namely, (1) Eastern Dry zone, (2) Central Dry zone and (3) Northern transition zone, for comparative analysis, under the study.

Co-registered images, IRS LISS3 and PAN data, 23m and 5.8m resolution are shown in Fig 7.1a & Fig 7.1b respectively, covering parts of Kolar district (Eastern dry zone). These images are used as input for image fusion using 4 different fusion techniques.

Fig. 7.1a IRS LISS 3 False color composite (FCC)

Fig. 7.1b IRS Panchromatic Black & white image

The test data is selected specially because it represents varieties of features, like, crop land, plantations, water bodies, agriculture-fallow, barren land and so on. The performance of fusion outputs are assessed with respect to best discrimination possibilities of such features in the final output image. The fusion images are developed using the 4 different techniques, namely PCA, Linear multiplicative technique, Brovey's method and Discrete Wavelet Transforms (DWT). These are presented in fig 7.1c, 7.1d, 7.1e and 7.1f respectively**.** On fusion, the products are resampled to 5.8 m spatial resolution and are presented as false color composites, which are further used for natural resources maps preparation. The resultant images are analysed for their performance using spectral statistics and visual image interpretation.

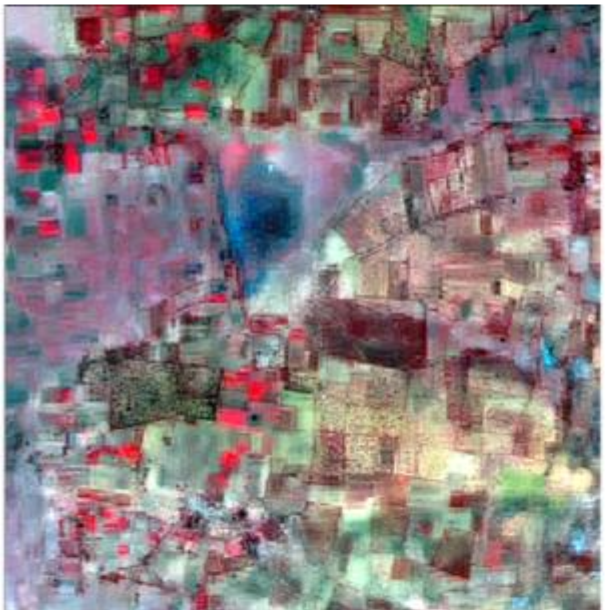


Fig. 7.1c PCA technique

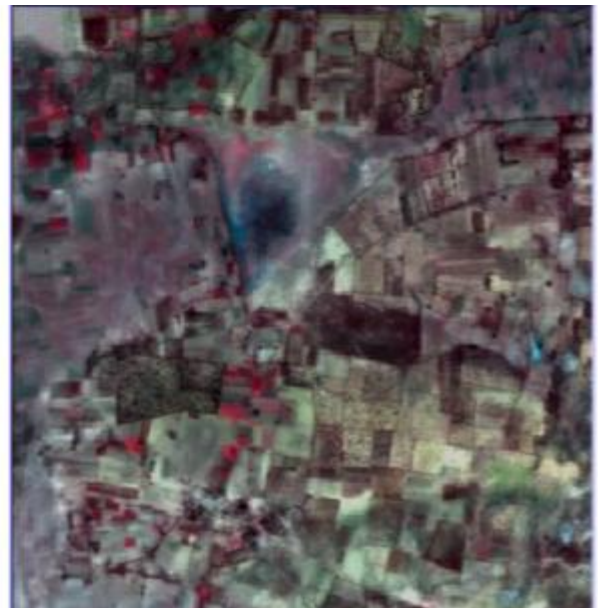


Fig. 7.1d Linear multiplicative technique

Fig. 7.1e Brovey's method

Fig. 7.1f Discrete Wavelet Transforms

The spectral behavior of different features, in each of these images, does show subtle differences. It is observed that output generated by DWT method is much superior with respect to visual appeal and feature depiction. Images produced by other methods are less effective in this respect. The spectral statistics derived from fusion outputs are also presented in Table 7.1, which brings out similar inference.

Table 7.1 Spectral Statistics from input and fused images

Data Source	Statistical parameters	InfraRed Band	Red Band	Green Band
LISS3 Data	**Maximum**	255	235	217
	Mean	111.953	88.006	100.752
	Median	121	95	110
	Std Dev	41.407	35.003	35.966
Principal component Analysis		**I R**	**RED**	**GREEN**
	Maximum	280	222	198
	Mean	79.02	60.392	72.898
	Median	84.063	64.969	78.375
	Std Dev	29.929	25.499	26.433
Brovey's Transform		**I R**	**RED**	**GREEN**
	Maximum	175	191	146
	Mean	104.02	93.50	70.41
	Median	104	93	70
	Std Dev	17.182	13.42	15.53
Linear Multiplicative technique		**I R**	**RED**	**GREEN**
	Maximum	242.162	205.001	174.511
	Mean	39.301	31.112	35.093
	Median	40.672	31.364	36.811
	Std Dev	18.053	15.396	15.029
Discrete Wavelet Transform		**I R**	**RED**	**GREEN**
	Maximum	254	235	217
	Mean	124.269	97.653	111.75
	Median	124	98	112
	Std Dev	39.259	29.24	24.273

It is observed that the mean spectral reflectance and standard deviation produced by DWT approaches is closely comparable to that of LISS3 multi-spectral image statistics. Based on these observations, image fusion using DWT method is also adopted for data sets from other agro-climatic zones also. Images of chennamanagathi halli micro-watershed, Chitradurga District (Central Dry Zone) and Ittagi micro-watershed, Haveri District (Northern transition zone) are used for fusion and the output is presented in Fig 7.2a and 7.2b.

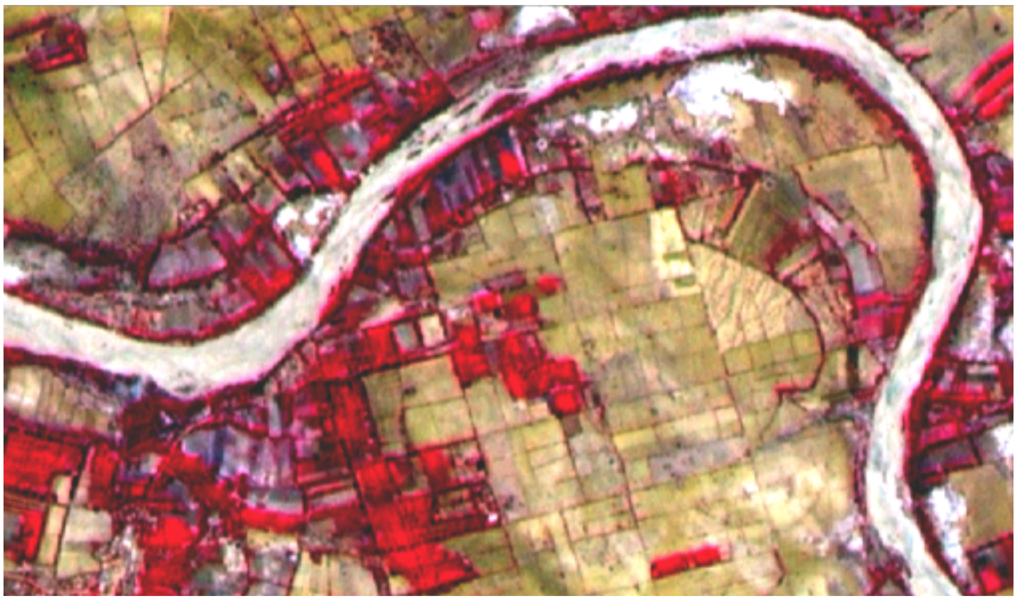


Fig. 7.2a Output of Image Fusion from LISS 3 + PAN for chitradurga

Fig. 7.2b Output of Image Fusion from LISS 3 + PAN for Haveri Dist.

The output of fusion has produced an interesting image, presented in Fig 7.2a. It clearly shows features, such as, standing crops with good vegetation vigour, vegetative bunds, eroded areas, sandy river bed, different types of fallow areas etc. Such discrimination of features greatly assists in accurate mapping of natural resources in the micro-watershed area.

The fused image in Fig 7.2b highlights agricultural fields, which includes standing crops, different types of fallow land, plantations, black cotton soil area, small village cluster and other features. Hence, a 5.8m resolution output image derived from the fusion technique adopted in the present study, helps in mapping at 1:10,000 thematic maps.

RESOURCESAT-1 LISS 3 and CARTOSAT 1 are used to produce fused image at 2.5 m spatial resolution and the result is shown in Fig 7.2c. A small portion of coverage, as highlighted in Fig 7.2d, is used as input at 2.5m spatial resolution.

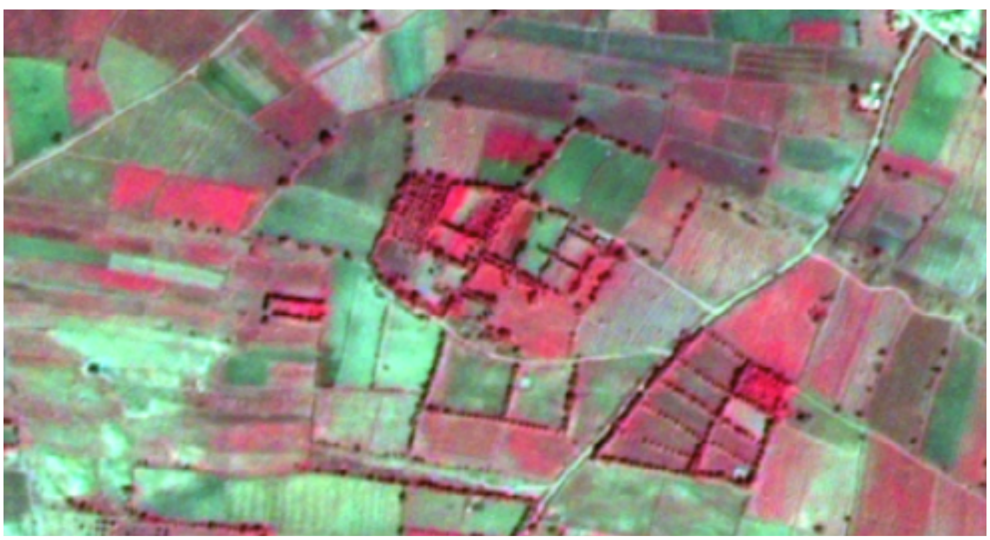


Fig. 7.2c Fused image using IRS LISS 4 + Cartosat-1

Fig 7.2c demonstrates the output resolution that is about 4 times better than that of the one in Fig 7.2b. The resolution is so good that even individual trees and footpaths (unmetalled roads) are interpretable in addition to other field level details of land use and land cover. Such high quality images are used as part of participatory planning and monitoring.

False color composite (FCC) images are normally used by experts for interpretation and mapping. However, for participatory planning, the village community needs images that are much simpler and easy to understand. Hence, Natural Color Composites (NCC) or True Color Composites (TCC) images are specially generated to meet such purposes where village community can directly use these pictures for making their own plans.

7.1.2 Satellite Images for village community – NCC products

While using data from IRS satellites, the multispectral bands data that are used for FCC generation are green, red and infrared respectively. It is observed that blue, instead of green spectrum, produces better NCCs. Hence, a simple method of spectral transformation is used. It establishes a relationship between FCC and NCC in the spectral domain to produce a spectrally transformed blue, red and infrared band to produce true color composite images in natural colors. Fig 7.3 illustrates such a product.

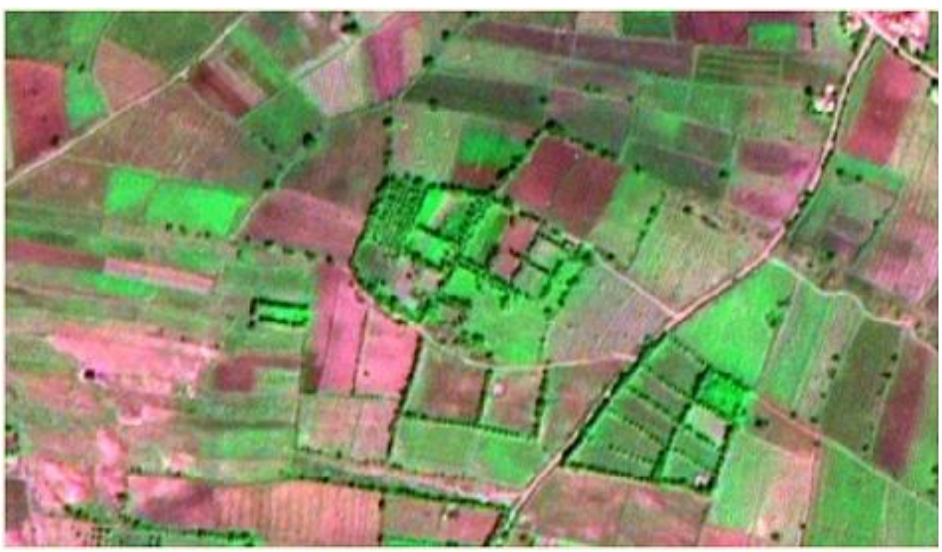


Fig. 7.3 FCC transformed to community-friendly NCC

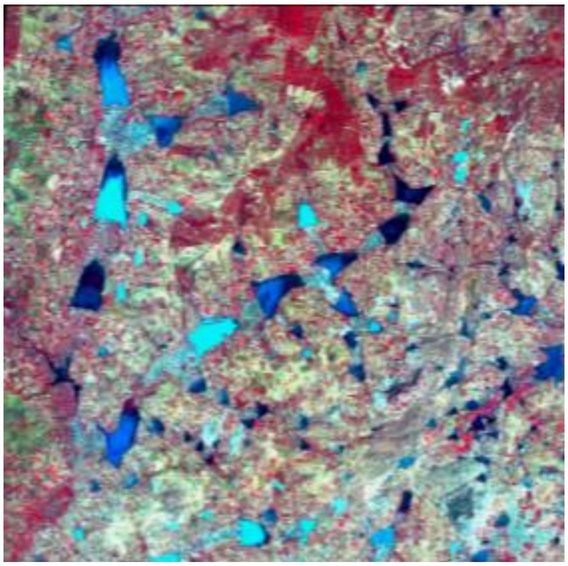
It is seen that NCC has better visual appeal and it is easy for a farmer to interpret features on the images with respect to specific details on the field. The synoptic view of the entire watershed at such resolutions has provided better perspectives of the field level problems. These products are provided to the village community as a part of participatory planning process and it has helped the community to think in larger perspectives with respect to catchments rather than one's own farmland. There groups are able to work together in developing larger portions of the watershed with common goal of sustainable development.

7.2 Digital Image Classification

Resource maps are critical inputs for integrated planning of natural resources development. Of the many GIS layers used, land use and land cover layer attains specific importance as it serves as input for participatory planning, monitoring and impact assessments. Satellite data at 5.8 m spatial resolution is primarily used for preparation of digital thematic maps at 1:10,000 scales. The input could either be a fused image or RESOURCESAT LISS 4 and both of them are at 5.8 m resolution. Fused images are directly interpreted under GIS domain for mapping, while LISS 4 images can be digitally classified for deriving land use and land cover maps. With a view to reduce time in preparing such maps, a new method of hybrid classification, with semi-automated ground truth sample data creation, is developed and compared with the well known maximum likelihood classification and the results are presented. It also clearly indicates that the proposed method is better than maximum likelihood method of classification.

7.2.1 Maximum Likelihood (MXL) technique

Supervised classification methods have been in use for a long and are well established for image classification. MXL method, being a per-pixel classifier, is better suited technique for medium and low spatial resolution satellite data. IRS LISS 4 image, with 5.8 m spatial resolution, is used for digital mapping (Fig 7.4). The result obtained from MXL classifier is shown in Fig 7.5. However, about 100 labeled training samples are used for ground truth and statistical signature generation.



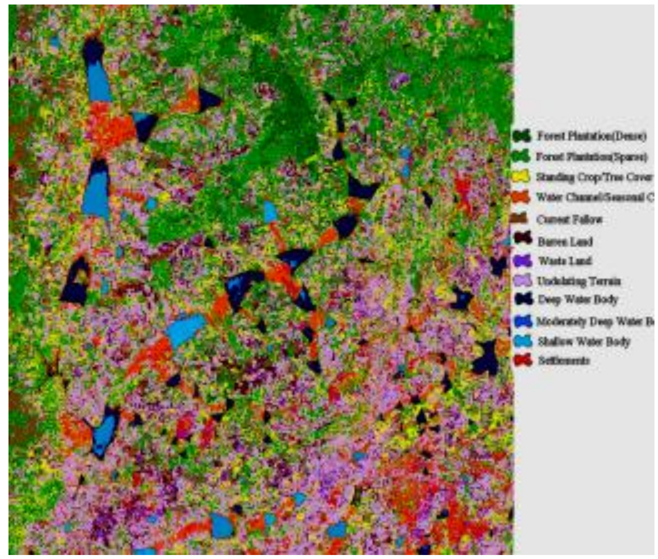


Fig. 7.4 Input image, IRS LISS 4 FCC

Fig. 7.5 Classification output from MXL

7.2.2 Hybrid Classification technique

Some of the challenges faced in digital classification of high spatial resolution images are:

a. Need for large number of ground truth samples to reduce probability of mis-classification and reject classes or outliers
b. Manual identification of training set polygons introduces subjectivity
c. Overlapping or Class Mixtures (heterogeneous pixels) are quite common in manual methods and hence poor classification performance
d. Multiple iterations of ground truth data refinements required to improve training sets.
e. Problem of null or reject classes due to poor training set definitions.

Hence, to overcome such limitations, an attempt is made to develop and use a hybrid classification approach. The result is encouraging and presented in Fig. 7.6.

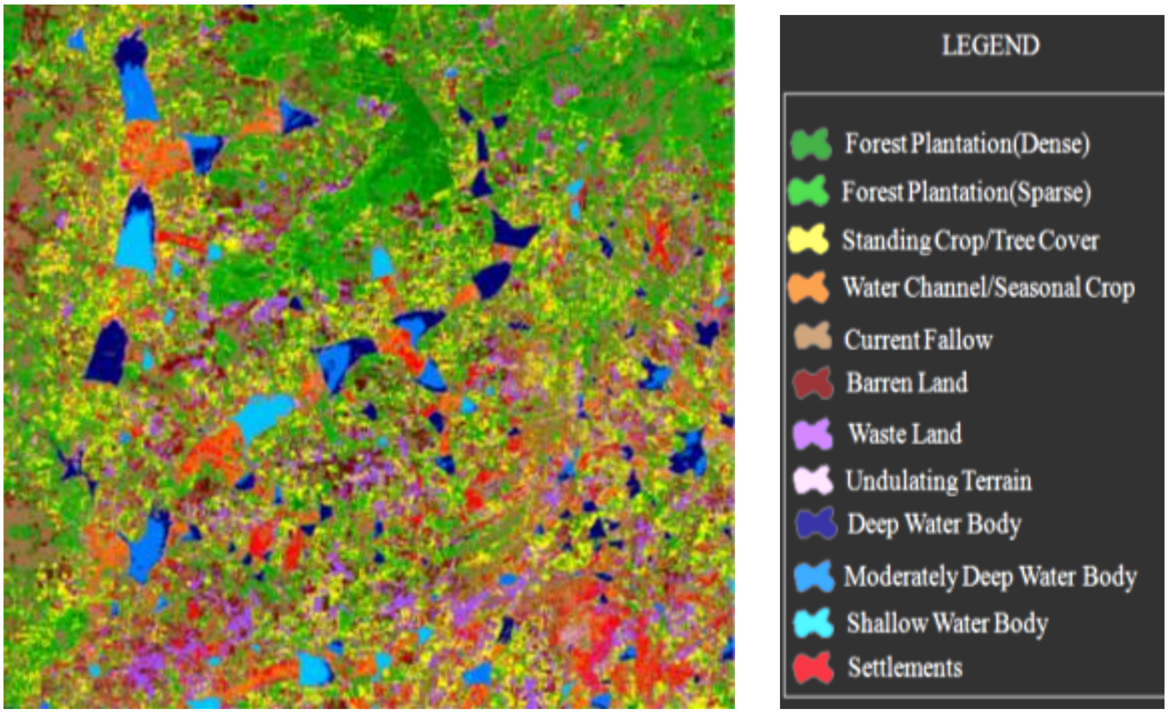


Fig. 7.6: Output from Hybrid classifier

The classification output from both the classification methods are closely comparable. However, the limitation in the hybrid method is the time taken for convergence in training iteration of the ANN. This is due to the network training architecture and iterative process involved, which can be fine- tuned based on prior experience. This limitation could also be overcome by using alternative classification technique at the last stage of the procedure. But, there are many advantages in the hybrid approach like automatic segmentation that generates feature polygons, vectorised polygons for choice, ease of training set identification using semi-automatic approach, choice of classification technique etc,. Hence, the method developed has high adaptability and helps in image classification with greater efficiency.

7.2.3 Accuracy Assessment

Image classification assessment allows evaluation of output image with respect to the reference image and hence performance of classification. The objective here is to evaluate the output of different classification techniques and to determine its adaptability for further use at field level. Common means of expressing classification accuracy is in the preparation of a classification error matrix.

The "Kappa statistic $\acute{K}$ " is a commonly used measure for comparison of mapping accuracies. In the present study, for measuring the accuracy of classification from both the methods, Kappa statistic is used. $\acute{K}$ usually ranges between 0 and 1. As the value of $\acute{K}$ approaches 1, it is considered to be good classification and vice-a-versa.

The overall accuracy includes only the data along the major diagonal and excludes the errors of omission and commission, while $\acute{K}$ incorporates the non-diagonal elements of the error matrix as a product of the row and column. The assessment technique not only provides information on the overall accuracy of classification, but also provides information on the performance of the classifier for individual classes that can be compared and assessed.

The result on the classification accuracy, as obtained from hybrid classifier as well as from MXL classifier are given in Table 7.2 and 7.3 respectively**.** Both these tables refer to producer's and user's accuracies respectively. Producer's accuracy is the percentage of a particular class type on the ground that is correctly classified on the map. It is calculated as the ratio of the number of correctly classified pixels for a class to the total number of ground truth pixels for that class. User's accuracy is the percentage of a class on the map that matches the corresponding class on the ground. Therefore, "producer's accuracy is a measure of the accuracy of a particular classification scheme," whereas "user's accuracy is a measure of the reliability of an output map generated from a classification scheme"

Table 7.2 Accuracy statistics of LISS IV image classified by Hybrid classifier

Class Name	Producer's Accuracy (%)	User's Accuracy (%)	Kappa Statistics
Forest Plantation (Dense)	93.33	87.50	0.86
Forest Plantation (Sparse)	98.34	97.23	0.97
Standing Crop / Tree Cover	82.94	97.00	0.95
Water Channel / Seasonal Crop	83.89	85.93	0.89
Current Fallow	83.75	90.00	0.89
Barren Land	78.57	84.61	0.83
Wasteland	82.14	95.50	0.95
Undulating Uplands	70.45	71.45	0.79
Deep Water Body	100.0	100.0	1.00
Moderately Deep Water Body	100.0	90.91	0.90
Shallow Water Body	100.0	100.0	1.00
Settlements	78.90	81.56	0.89

Overall Accuracy: 89.500% *Overall Kappa Statistic*: 0.89

Table 7.3 Accuracy statistics of the LISS IV image classified by MXL classifier

Class Name	Producer's Accuracy (%)	User's Accuracy (%)	Kappa Statistics
Forest Plantation (Dense)	100.0	100.0	1.00
Forest Plantation (Sparse)	100.0	84.62	0.84
Standing Crop / Tree Cover	90.95	97.44	0.97
Water Channel / Seasonal Crop	56.35	49.86	0.51
Current Fallow	84.90	88.46	0.88
Barren Land	92.49	94.87	0.84
Wasteland	82.14	95.50	0.95
Undulating Uplands	65.21	66.89	0.65
Deep Water Body	100.0	100.0	1.00
Moderately Deep Water Body	92.86	100.0	1.00
Shallow Water Body	100.0	100.0	0.91
Settlements	65.64	67.97	0.69

Over all Accuracy: 79.32% *Overall Kappa Statistic*: 0.78

The performance of MXL classifier is relatively inferior compared to that of hybrid classifier. The ANN based hybrid classifier has performed better with respect to consistency of classification performance for individual classes and also the overall classification accuracy.

7.2.4 Interactive Interpretation and mapping

In the present study, both visual interpretation and digital classification techniques are used to prepare land use and land cover maps for selected micro-watersheds depending on the type of input image and ground truth samples. An interactively interpreted land use and land cover map on a GIS platform using high resolution fused image (5.8m) of Chennammanagathi halli, Chitradurga District is presented in Fig 7.7 & 7.8.

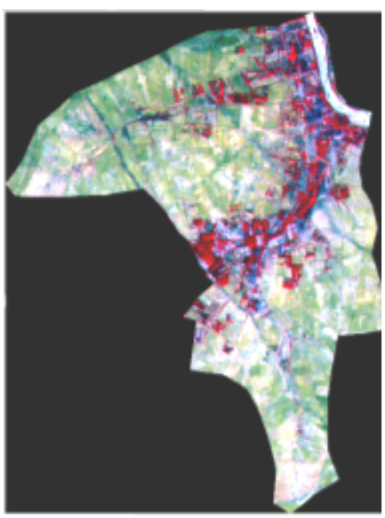


Fig 7.7 FCC of Fused Image

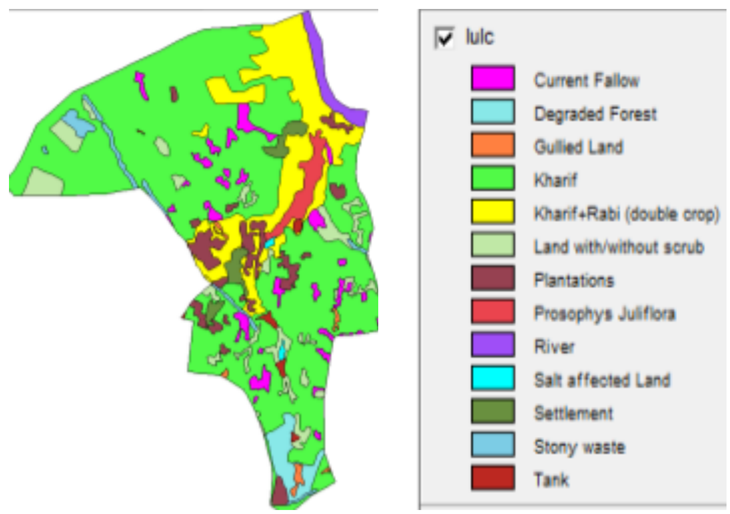


Fig 7.8: Land use/ Land cover map

The images in Fig 7.7 shows the false color composite which is a derived product from image fusion at 5.8 m spatial resolution. The image is visually interpreted in a GIS environment to prepare a land use and land cover map, as shown in Fig 7.8.

7.3 GIS database organisation

Each micro-watershed consists of 15 geospatial layers that include base layers, watershed boundary, village and cadastral boundary, geology, geomorphology, geological structure, groundwater prospects, land use and land cover, soils, slope, land resources action plan and water resources action plan, other than satellite image. These geospatial data layers are prepared using the software tools and interpretation procedures provided as a part of design from the present study. All these database layers are further passed through quality evaluation based on defined database content standards, reorganized and integrated into a common geospatial database repository for access and use. Considering that it is a large scale development of land and water resources with 742 micro-watersheds across 5 Districts, the problem is to not only organize all the geospatial layers with respect to administrative hierarchy but also to develop necessary geospatial tool for database query and analysis.

7.3.1 Geospatial solution

A Customized software solution to visualize, query, overlay and analyse geospatial data on natural resources, for any selected micro-watershed of interest, is developed. The administrative hierarchy is used for the design of drill-down menus to select District, Taluk, Sub-watershed and finally the micro-watershed for geospatial display, query and analysis. The basic objective here is to provide simple user interface for decision makers to utilize the software for analyzing locale-specific databases at different levels for planning, decision making and monitoring.

The customized software solution is designed and developed using simple geospatial tools, which helps in building the required GIS functionalities for usage by planners as well as stakeholders. Following are the features that are enabled in the software, which help the users to choose any specific micro-watershed of interest based on administrative hierarchy (Fig. 7.9a, 7.9b, 7.9c).

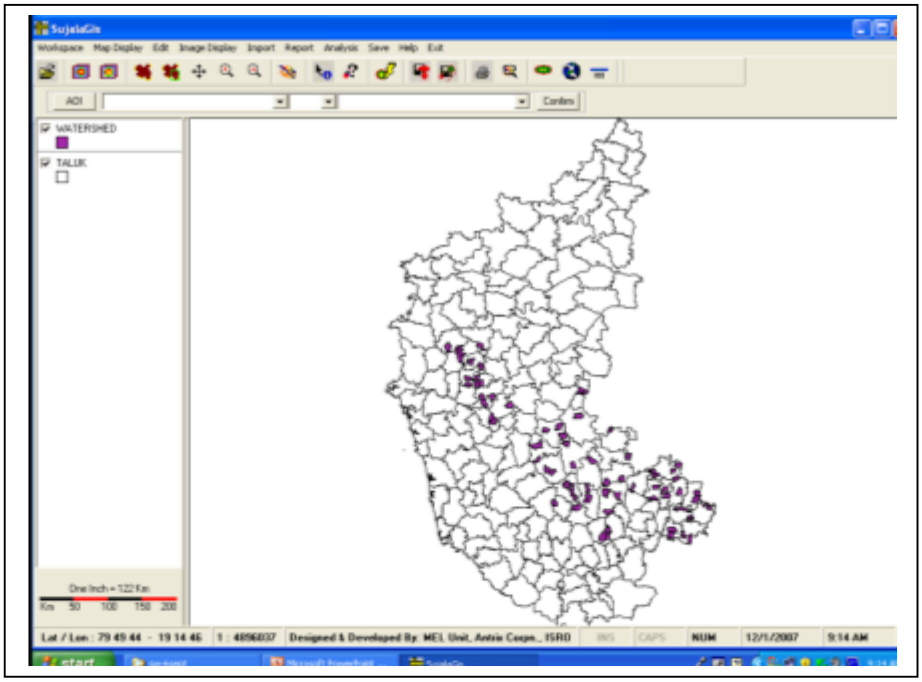


Fig. 7.9a Geospatial data of Taluk with sub-watershed boundaries

Fig 7.9a illustrates an example of the display of the Karnataka state with taluk boundaries and selection of micro-watersheds.

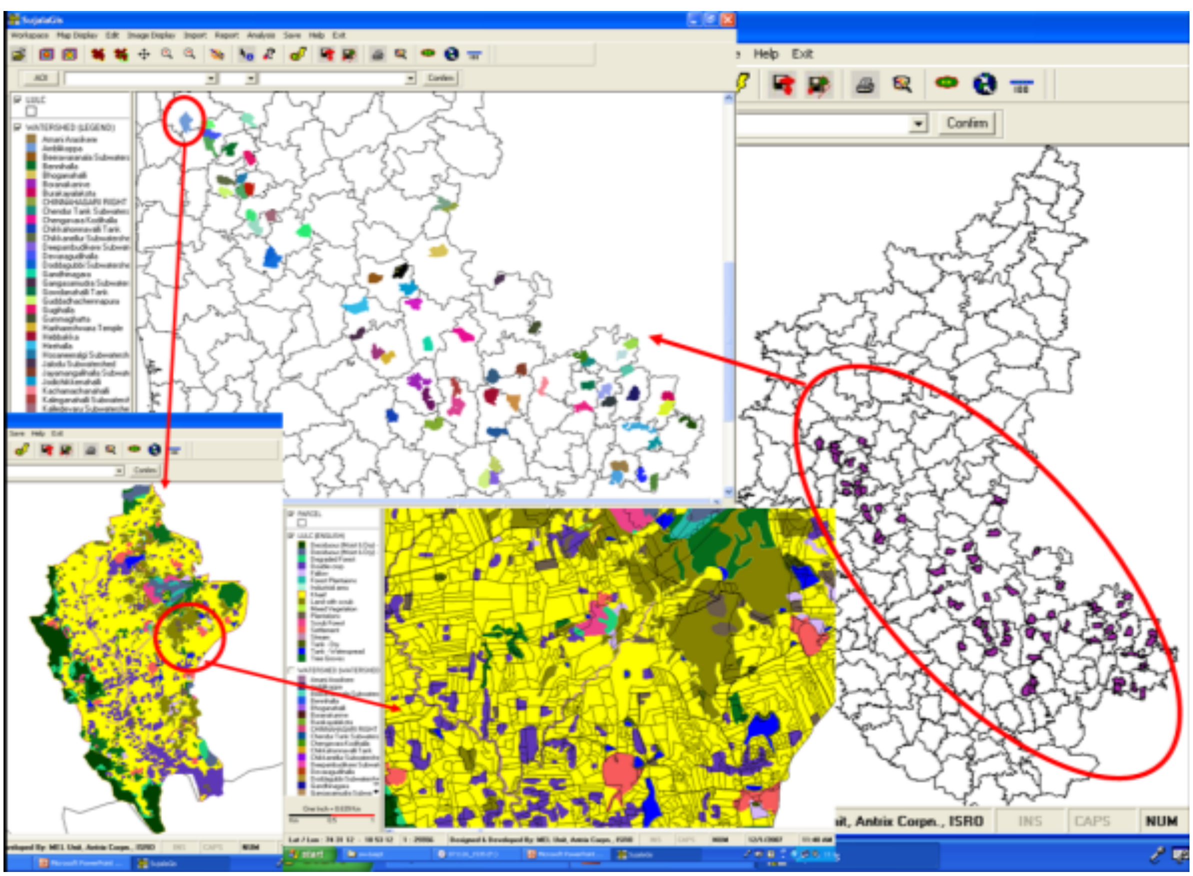


Fig. 7.9b Selection and display of desired geospatial data

Fig 7.9b illustrates the selection and display of a micro-watershed of a district with respect to specific theme, for example land use, with cadastral overlay. The package, in different steps, facilitates extraction of the area of interest and display of geospatial parameters for query and analysis. Various options that are provided under the software package include map and image display, attribute query, map overlay, extract of selected areas, map extent, zoom, pan and other features in the form of simple menus and icons for user-friendly interface (Fig 7.9c).

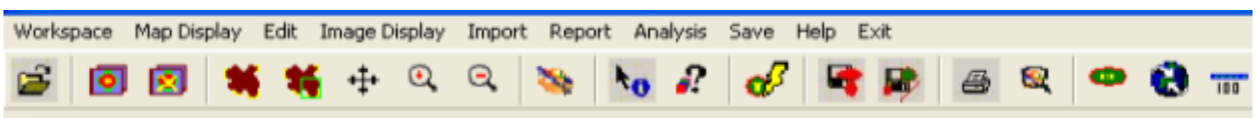


Fig-7.9c Software tool for Geospatial database organisation

For example, Mudianur micro-watershed of Kolar district is extracted for display with a few selected geospatial layers that represent different resource maps, which are referred at field level while generating action plans (Fig 7.10).

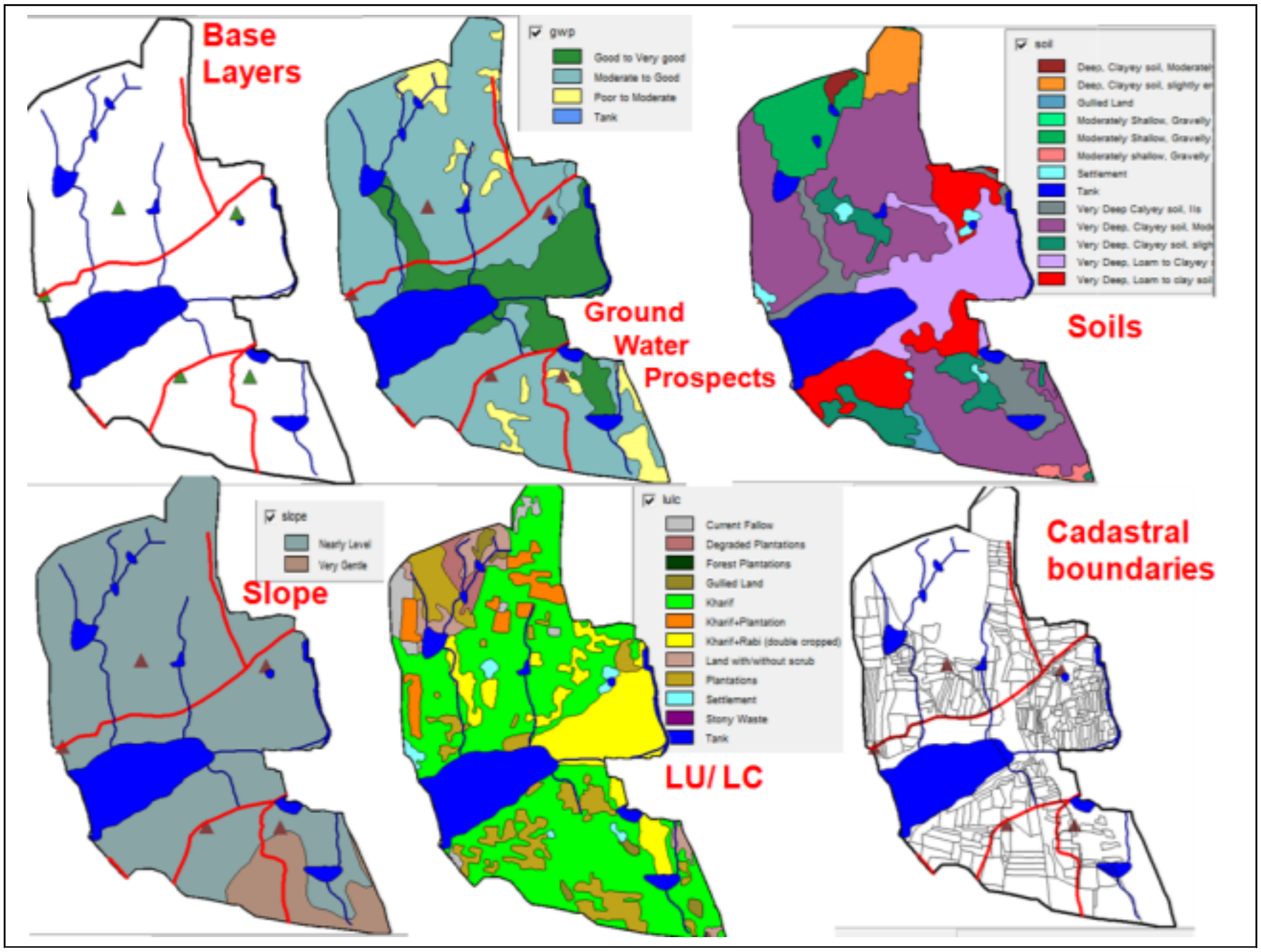


Fig. 7.10 Important GIS layers extracted for Mudianur Micro-watershed, Kolar District as input for deriving land and water resources action plans

The illustration above presents important GIS layers, namely, Base layers, land use and land cover (LU/ LC), soils, slopes, ground water prospects, drainage, surface bodies and cadastral boundaries. The database serves as a good baseline information with respect to natural resources for the community to use for action plan preparation. These layers are accessible not only at local community level but also at decision makers' level (both in the form of hard copy and in softcopy). The GIS software interface is provided to enable display, query and analysis at all levels of planning and decision-making. Analysis of these inputs, with expert's knowledge and peoples' aspirations, helps in preparation of an acceptable land and water resources development plan. The same database is further used for change analysis and impact assessment in the post-implementation phase.

7.4 Geospatial data as input for Participatory Planning

Activities conducted through a participatory planning process are illustrated in Fig 7.11a and 7.11b respectively. Fig 7.11a shows different GIS layers used as input in the planning process and also for participatory field validation.

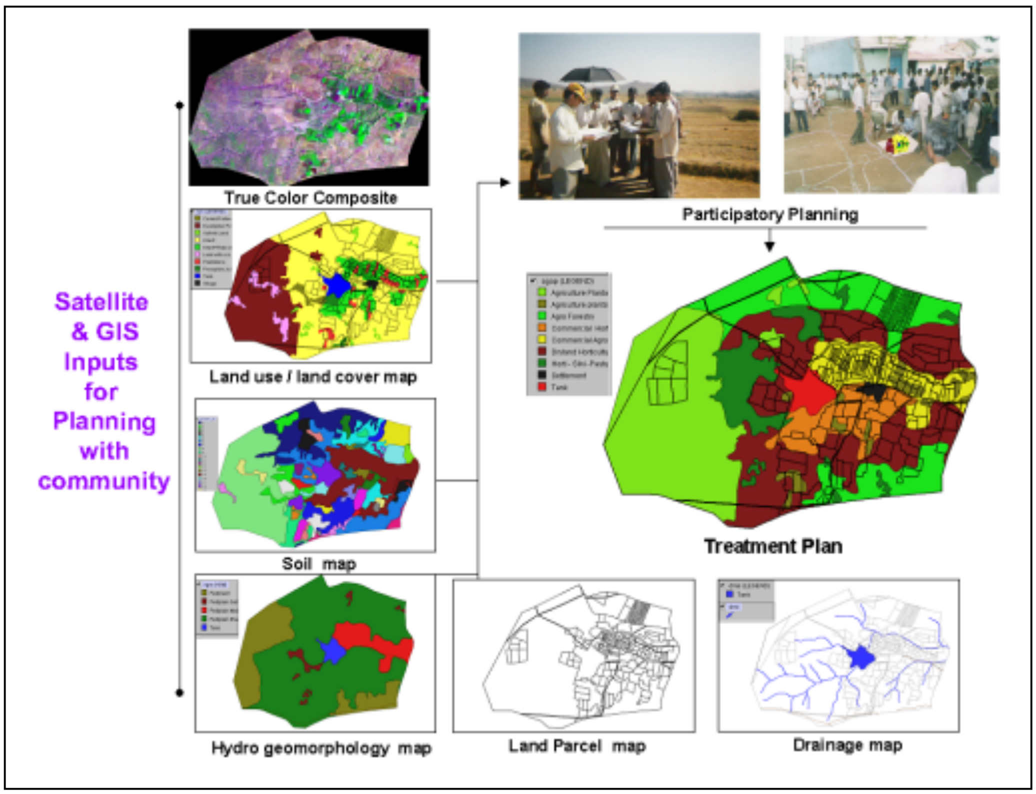


Fig 7.11a Use of Satellite image & GIS for action plan preparation

Fig 7.11b illustrates the actual process of participatory planning, wherein correlation of chalk-powder diagram of the watershed on the ground is compared with high resolution satellite image and geospatial map for planning and decision making.

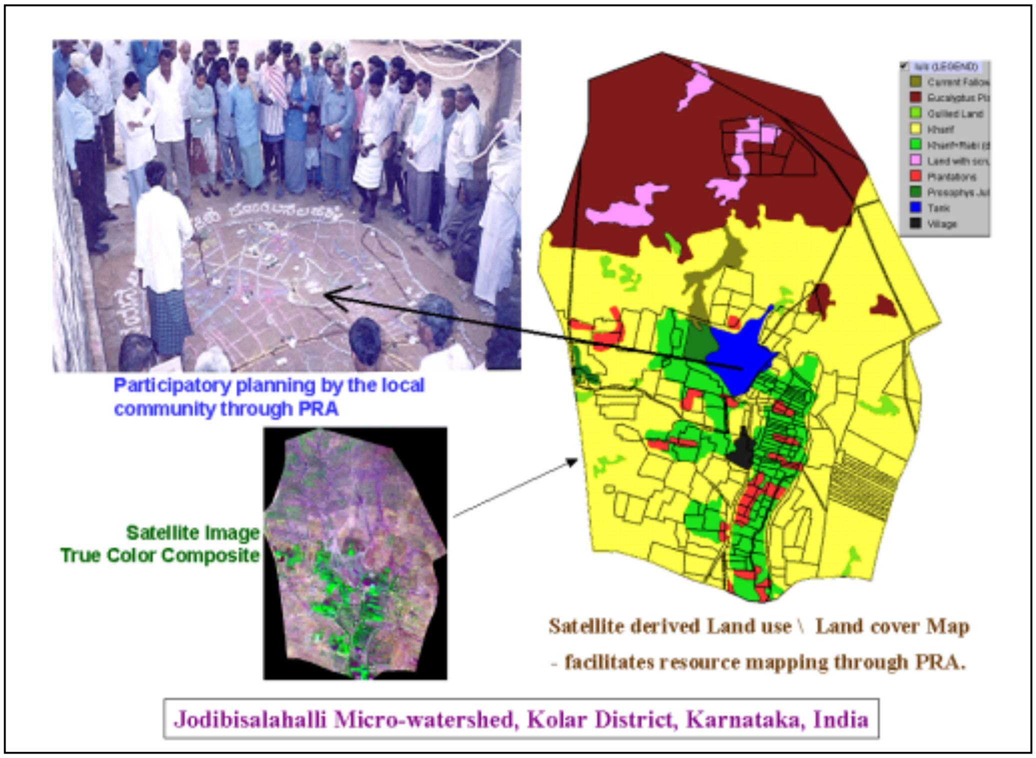


Fig 7.11b: PRA Exercise done using Satellite image & GIS inputs

7.4.1 Participatory Action Plan Preparation

Action plans are prepared at micro-watershed level, which generally covers an area of about 500 Ha. Normal practice is that the action plans are prepared by officials or experts and are implemented with very little focus on processes. Community participation and capacity building at local level rarely happens due to lack of participatory processes. Process of learning and sustainability of such programmes are always in question. Hence, the process-based approach with active participation by the village community in action plan preparation and implementation is explored in the present study for its adoption and impacts.

Participatory rural appraisal (PRA) exercises are conducted at micro-watershed level by the field facilitators, but with technology inputs on various natural resources parameters. Scientific inputs in the form of remote sensing data and thematic maps in terms of GIS layers, particularly the soil, slope, water, land use and land cover, cadastral boundaries etc. are introduced at the local community level which could virtually sensitize them on conservation, watershed development and different modes of treatment for better results.

This new ways of conducting PRA at local level, adopted in the present study has given encouoraging results and its implementation is discussed in three parts.

(a) Introduction of spatial maps to educate local people about their land and its capability. They are trained to select suitable interventions through participation, while incorporating their requirements, Fig 7.11a & 711b.

(b) Community-level participatory GIS tools are used to prepare action plans while incorporating peoples' aspirations. Action plan generated from such a process is presented in Fig. 7.12.

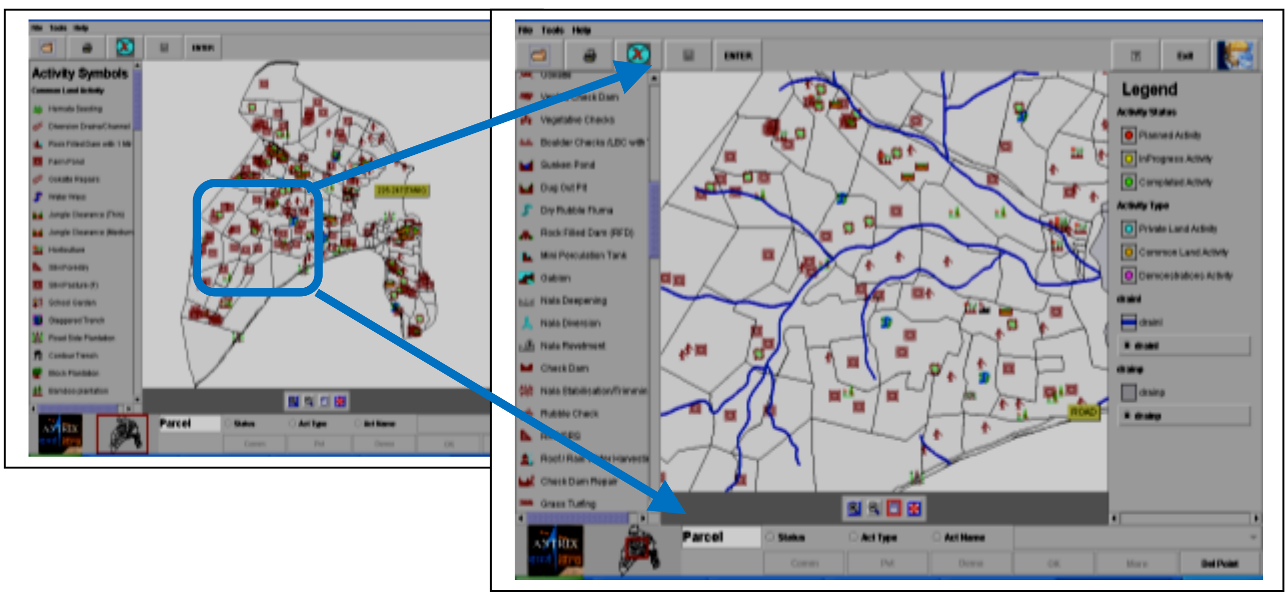


Fig. 7.12 Participatory GIS for Action Plan depiction & monitoring

This Open source GIS package, developed and customized for specific purpose, has enabled virtual visualization of action plans on a geospatial platform by the local community, during plan preparation. This allowed better understanding of land and water related treatments both at local level and at overall level for comprehensive planning. The result is also significant in terms of community working in groups towards achieving the ultimate goal of development as part of implementation of action plans.

(c) Local-level MIS is also used to create detailed information on individual farmers, including the choice of activities as per the aspirations of the stakeholder, thus enabling a "Participatory MIS". The tool is used, covering the entire micro-watershed, for action plan preparation including GIS maps that depicts location-based information for each intervention. The software also enables database creation and provides for varieties of reports for further analysis. The package has a very simple front-end design and operates through local language interface facilitating greater transparency amongst local people in terms of planning and development (Fig 7.13).

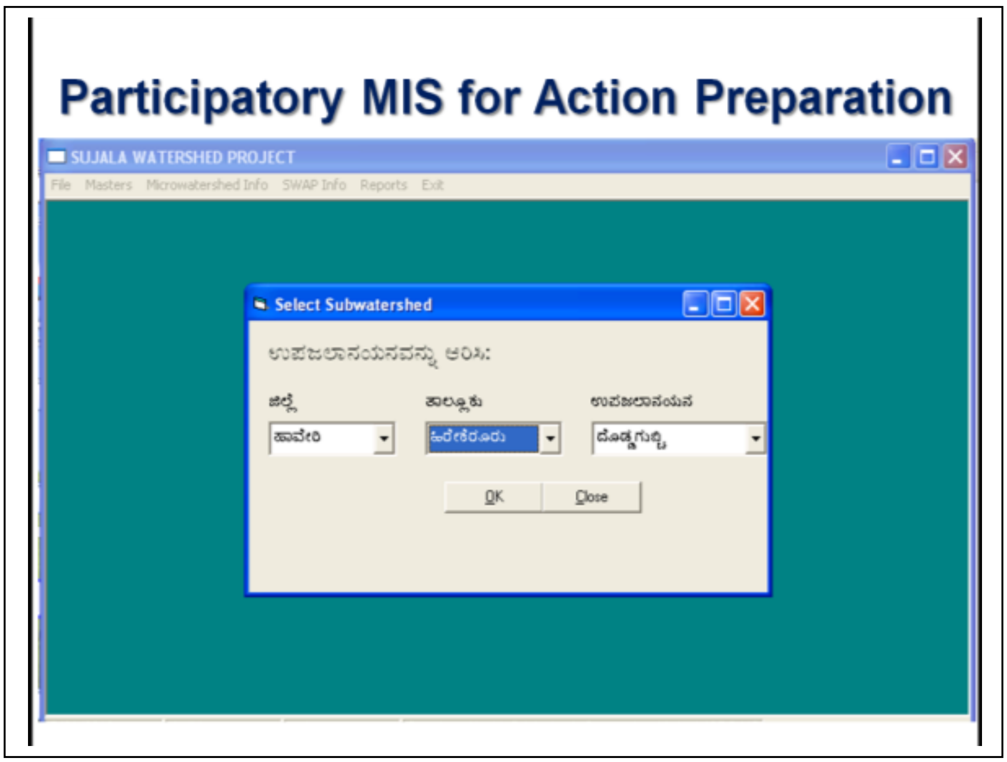


Fig. 7.13 Software Package for Participatory MIS

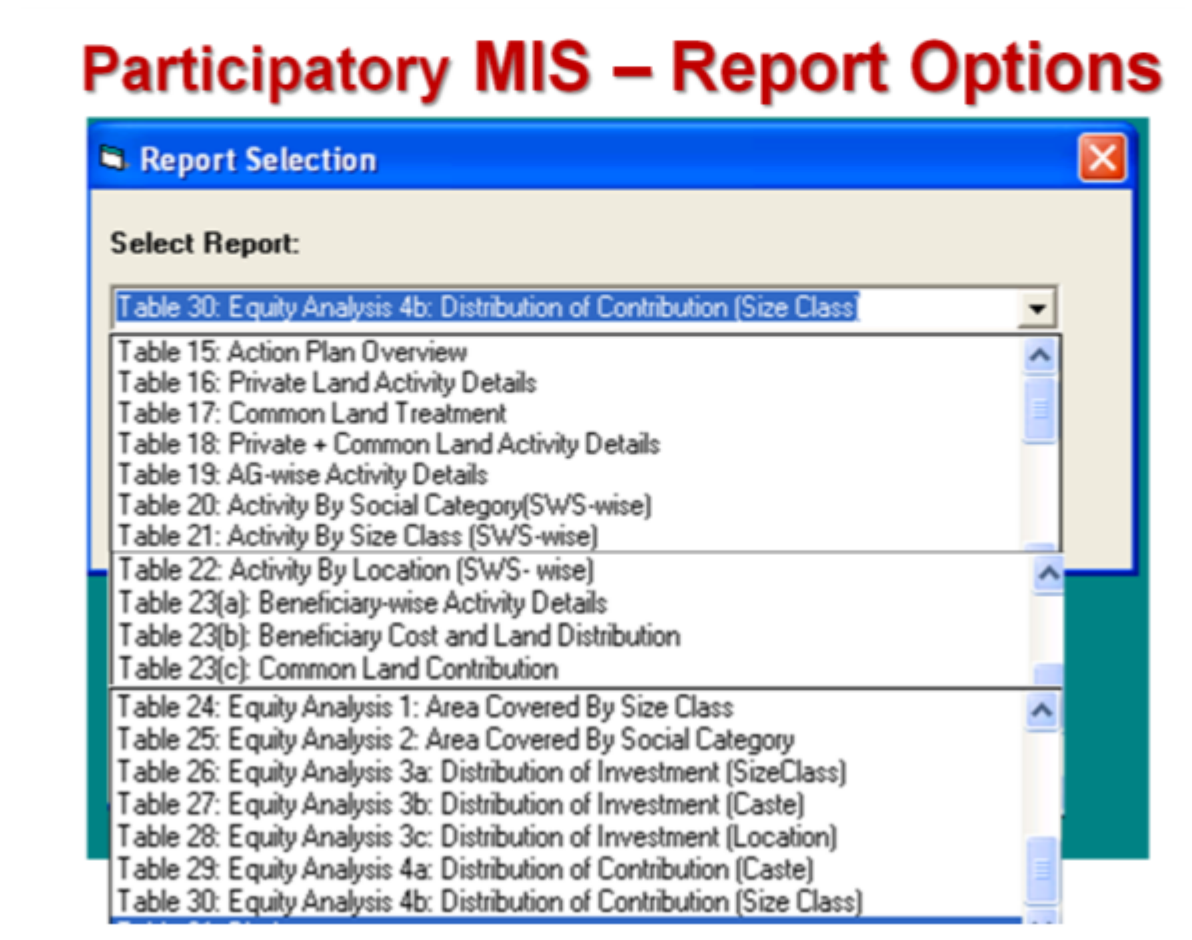


Fig. 7.14 Participatory MIS – Reports & analysis for decision making

The software design provides various options for creating detailed database at micro-watershed level that helps stakeholders to prepare micro-watershed development plans. Varieties of reports are also generated that includes analysis and decision making tools (Fig 7.14). This includes action plan overview, private land activities, common land treatment, private & common land details, user group wise activity details, activity by social categories, land-holding size class, gradient-based location and Equity analysis. Since these reports are exhaustive in content, a few sample reports and outcome are presented in Fig 7.15 and Fig 7.16 respectively. These reports represent analysis related to inclusiveness and equity of the action plan prepared at micro-watershed level.

Percentage of Area and Families Covered by Social Category

Mallikarjuna

SWS ಮಲ್ಲಿಕಾರ್ಜುನ

	Vulnerable groups		Others	
Caste	ಪ. ಜಾತಿ	ಪ. ಪಂಗಡ	ಇತರೆ	Total
Area Proportion	376.57	114.03	142.18	141.48
Farmer Proportion	300.00	130.88	137.74	137.77

Fig. 7.15 Analysis Report – Inclusiveness with respect to social categories

Distribution of Investment by Social Category Groups

SWS ಆಂಜನೇಯ

	ಪ. ಜಾತಿ	ಪ. ಪಂಗಡ	ಇತರೆ	Total
Area	6.21	9.69	348.06	363.96
Investment	30444.60	71402.30	2258264.53	2360111.43
No of Farmers	9	89	719	817
% of Farmers	1.10	10.89	88.00	100.00
% Area	1.71	2.66	95.63	100.00
Investment	1.29	3.03	95.68	100.00
Cost / Hectare	4902.51	7368.66	6488.15	6484.54

SWS ಆಂಜನೇಯ

	ಪ. ಜಾತಿ	ಪ. ಪಂಗಡ	ಇತರೆ	Total
Area	17.74	78.80	929.27	1,025.81
Investment	95721.10	519578.10	4555890.30	5171189.50
No of Farmers	9	89	719	817
% of Farmers	1.10	10.89	88.00	100.00
% Area	1.73	7.68	90.59	100.00
Investment	1.85	10.05	88.10	100.00
Cost / Hectare	5395.78	6593.63	4902.66	5041.08

Fig. 7.16 Analysis Report – Equity with respect to social categories

The type of reports generated from the package for planning and decision making are summarized, such as the specific works chosen by the community on soil and water conservation, afforestation, horticulture, drainage line treatment etc., as part of participatory watershed development activity. For each activity, important parameters that are useful for administration and management, community level database is created. Similarly, parameters on farmer groups and their activities, social and vulnerable groups, action plan implementation, beneficiary-wise information, such as, Beneficiary name, category of farmer (Small/ Marginal/ Big), social group, cadastral number, location of watershed (Ridge/ middle/ valley), activity chosen etc. are also captured by the package and reports are generated for management and monitoring.

Fig 7.15 and 7.16 present a report that highlights specific analysis related to inclusiveness and equity with regard to developmental plans at micro-watershed level. That is, participation of farmers with respect to different social groups and the equitable nature of developmental activities with regard to area coverage, investments and their participation. Such analysis guides the administrators in making important assessments on the nature of participatory processes followed by the local level decision making bodies and the way the poor and vulnerable communities get benefitted by such developmental plans.

7.5 Remote sensing based monitoring

Multi-temporal satellite images are also used to monitor implementation works. Use of Image fusion on high spatial resolution data enables interpretation of activities like bunding, bund stabilization, water ponds, horticulture, agro-forestry etc. Fig 7.17 shows one such activity of watershed development. The image highlights treated area as against untreated areas of a micro-watershed. The signatures within the treated area and outside the treated area are differentiated with reference to the linear features that highlight bunding and bund stabilization activities carried out compared to the untreated areas where such features are not visible.

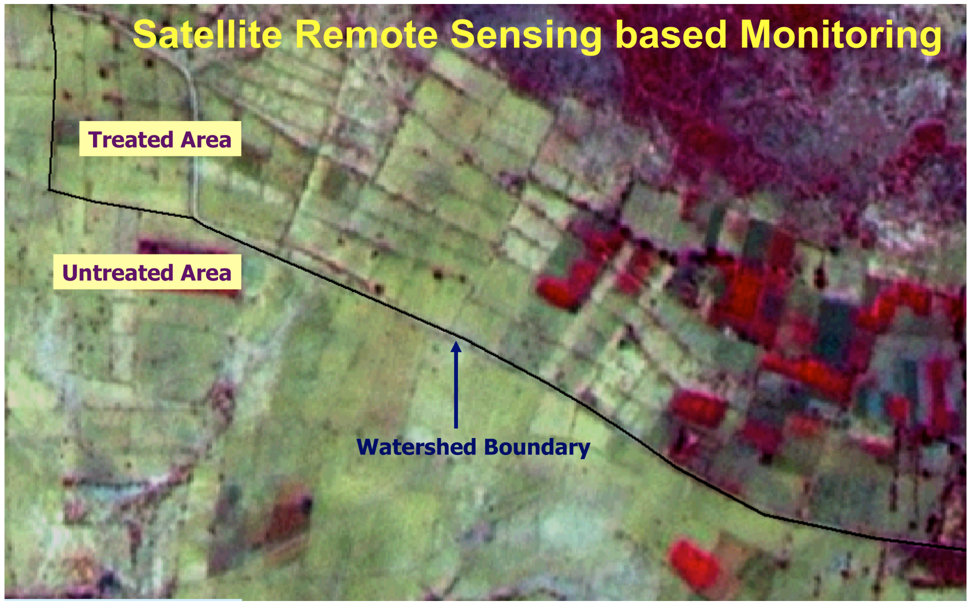


Fig. 7.17 Image fusion for Bund Stabilization monitoring

Similarly, **Fig 7.18** demonstrates pre and post implementation images that clearly highlights the field bund stabilization and repair activities taken up in the watershed. Fig 7.19 and 7.20 shows two important monitoring possibilities, namely, i) Farm ponds and percolation ponds and ii) Agro-horticulture and Afforestation activities.

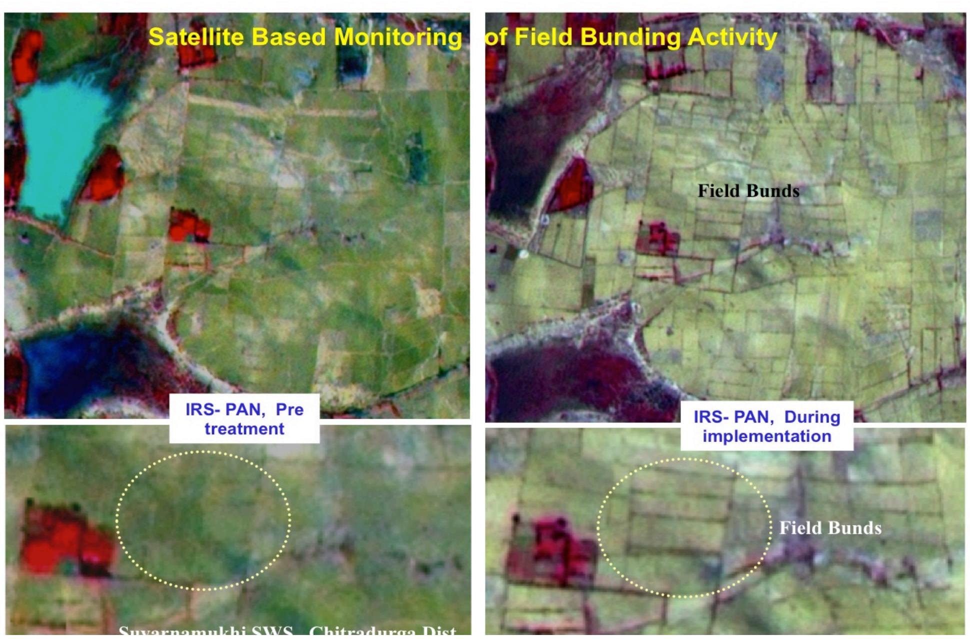


Fig. 7.18 Image Fusion highlighting the improvements in Field Bunds

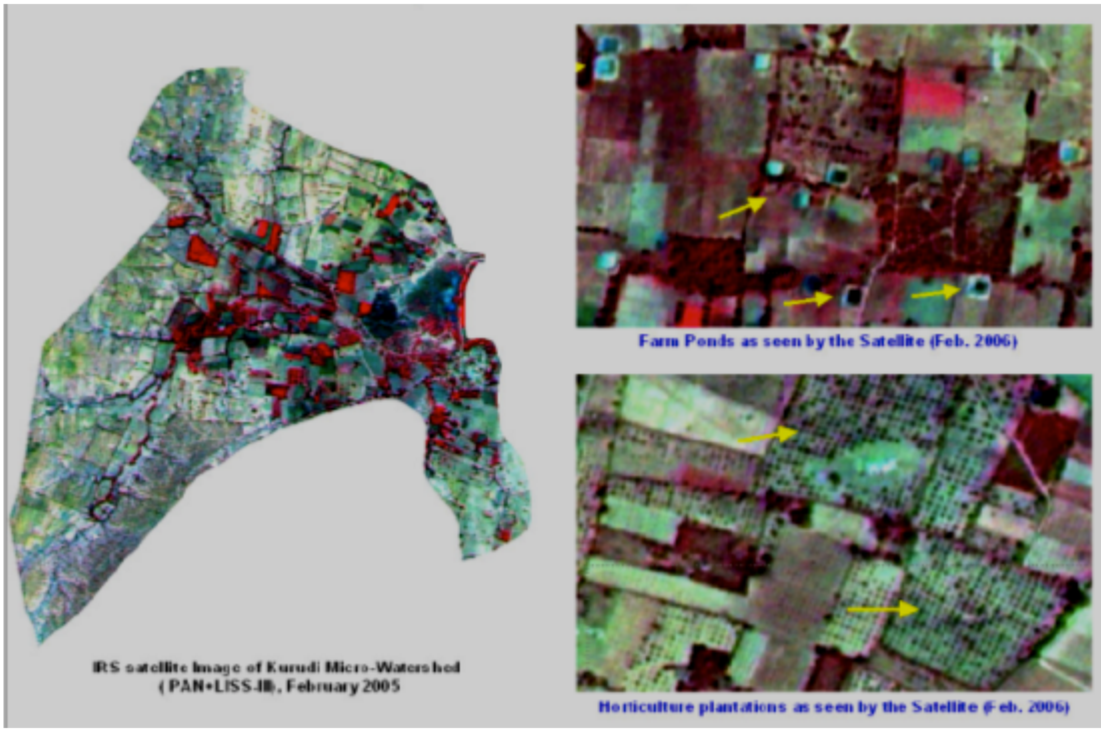


Fig. 7.19 Monitoring of water ponds, Agro-horticulture & Afforestation

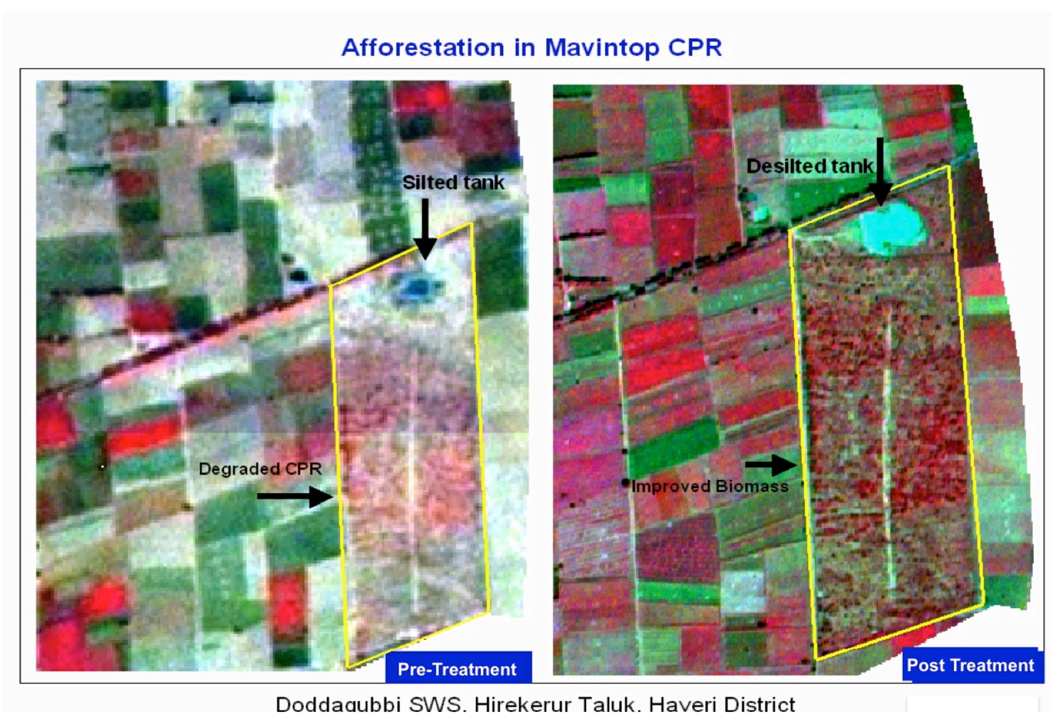


Fig. 7.20 Monitoring of Cropping pattern, Cropping intensity & Agro-biodiversity

7.6 Web-based MIS tool for concurrent monitoring

A few watersheds, in a given area, can be efficiently managed and monitored using field-based conventional methods. However, for large scale watershed development programmes, that needs close monitoring of many developmental activities and indicators simultaneously, it is essential to obtain periodic information, which makes it more challenging. The present study highlights such a situation and the need for monitoring various processes on a concurrent basis. Considering the requirements and the best possible options available in the domain of information technology, a web-based software design is developed to provide online near real-time inputs on various indicators of all micro-watersheds across the entire study area. Facility for online data entry is provided through simple client-server software design that allows facilitators at micro-watershed level to provide data on a regular basis. Standardization of Common monitoring indicators for all watersheds is evolved so as to use these indicators for monitoring, management and cross comparison of all micro-watersheds across the study area.

The web-based tools allow data capture on a near real-time basis on various activities that enables close monitoring of developmental processes. The online data capture and reporting enabled a close watch on the outcome of various processes followed at the field level. For example, the field validation and reporting, carried out by process monitoring groups, effectively use these online tools as a guiding factor to select field samples for validation on random basis. This mechanism has ensured proper monitoring of the quality of the works, nature of reporting, near-real-time information on field realities and online information updates.

7.6.1 Web Technology for large number of watersheds

The Web-based MIS is designed and developed based on a set of indicators for monitoring. Initially the package is deployed at a few micro-watersheds for testing with an intention of scaling it across all districts and taluks using internet and wireless connectivity. On successful validation, the WebMIS is enabled for all locations in the entire study area. Stand-alone or offline version of the packages are also deployed for those areas where proper connectivity does not exist. These locations use special software packages to provide the data in the same format for synchronization with the server at central location.

7.6.2 Use of Web-based MIS

The package is used at 742 micro-watersheds across 5 Districts to provide near real-time data on field implementation on a regular basis. The requirement is to monitor the progress of works and the processes on a weekly basis from the Districts and Central locations through online data entry on WebMIS and audio conferences. Since the package gets used at all locations on same set of indicators, monitoring and cross comparison on performances are easily assessed. Reviews and interactions with the field functionaries or village community are further enhanced, through video or audio conferences, due to the online MIS for monitoring. The entire procedure helps the decision makers to be more efficient and vigilant, particularly while handling a large programme, which is geographically spread out and difficult to monitor otherwise.

Following are some of the results generated from the package through online operations for one of the micro-watershed. Mudianur micro-watershed, Mulbagal, Kolar District is one such area considered to demonstrate the online monitoring and outcome of such package under watershed development programme.

Basic information about the group formation with regard to farmers and self help groups (SHGs) is shown in Fig 7.21 and 7.22. An example of monitoring the performance of Self Help Groups (SHGs) through several parameters related to micro-credits is shown in Fig 7.23. An example of SHG-wise bank linkages and group dynamics is presented in Fig 7.24. Online monitoring of land and water development activities, extracted from the package highlighting major activities for private and common lands is presented in Fig 7.25. The capabilities of generating online charts or graphical analysis, like, pie charts and bar charts are also presented from the online data as part of interactive analysis capability (Fig 7.26). A stacked bar chart that highlights the investments in different sectors for a given period of time is shown in Fig 7.27. Several charts including trends of investment in different sectors of development, including trend analysis are shown in Fig 7.28. These are some of the capabilities of the package and the results generated helps implementing agency in appropriate decision making while implementation.

District: Kolar
Taluk: Mulbagal
Subwatershed: Uttanur
FNGO: Prakruti

User Group Formation

AG Name	Date of formation	Villages covered	No. of members						Category of farmers					Area covered (in hectares)						Meeting Frequency
			M	F	SC	ST	O	Tot	M	S	Md	SM	B	M	S	Md	SM	B	Tot	
Mudiyanur																				
Sri Chamundeshwari JKG	Dec 27 2002	Bestharahalli	45	5	0	0	0	50	17	14	15	4	0	5.6	9.2	23.6	10.8	0	49.2	Fortnightly
Sri Chowdeswari JKG	Oct 23 2002	Bestharahalli	45	5	0	0	0	50	10	15	16	5	4	2.8	9.2	23.2	14.4	31.2	80.8	Fortnightly
Maruthi JKG	Nov 13 2002	J.Vommasandra	25	1	0	0	0	26	1	2	6	14	3	0.04	1.2	6.88	4.32	20.4	32.84	Fortnightly
Venugopalaswmy JKG	Oct 16 2002	Balashettihalli	20	4	0	0	0	24	7	4	6	4	3	1.88	2.52	6.9	6.8	24.52	42.62	Fortnightly
Veeranjaneya JKG	Nov 06 2002	Chikkanahalli	39	1	0	0	0	40	3	11	11	9	6	0.8	6.88	13.32	21.2	76.88	119.08	Fortnightly
Yallamma JKG	Feb 01 2003	Gujjanahalli	53	3	0	0	0	56	15	11	13	10	7	11.38	5.69	17.07	5.76	17	56.9	Fortnightly
Total			227	19	0	0	0	246	53	57	67	46	23	22.5	34.69	90.97	63.28	170	381.44	
Grand Total			**227**	**19**	**0**	**0**	**0**	**246**	**53**	**57**	**67**	**46**	**23**	**22.5**	**34.69**	**90.97**	**63.28**	**170**	**381.44**	

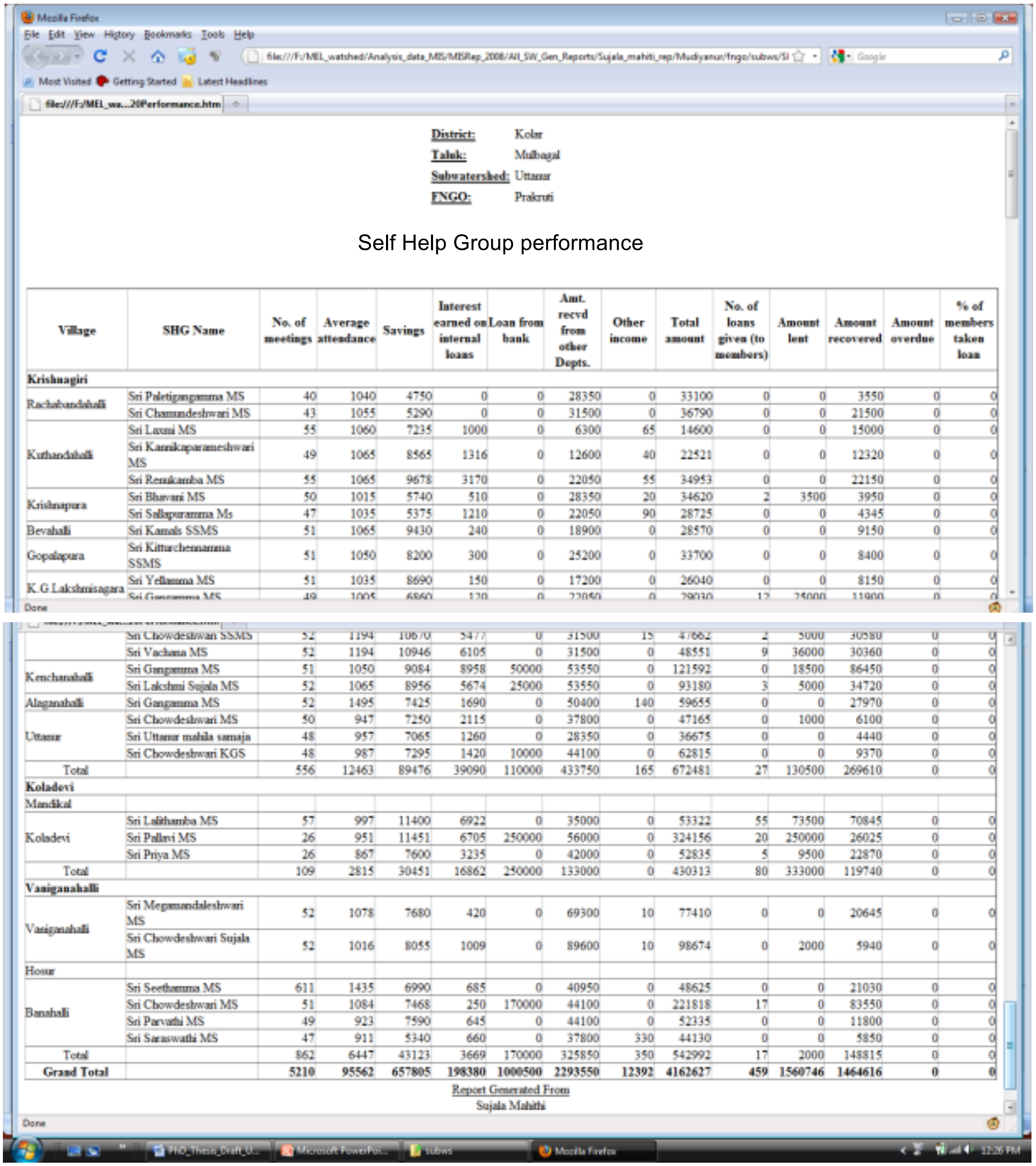
Fig. 7.21 User Group Formation

District: Kolar
Taluk: Mulbagal
Subwatershed: Uttanur
FNGO: Prakruti

Self Help Group formation

Village	No. of vulnerable HH as per PRA	Self Help Groups		No. of vulnerable HH covered under SHG							No. of SC HH	No. of ST HH
		Trgt.	Ach.	LL	M	S	Md	SM	B	Tot		
Mudiyanur												
Chikkanahalli	18	0	1	5	3	5	4	3	0	20	0	0
Balashettihalli	20	0	1	2	5	4	3	2	0	16	3	0
Bestharahalli	43	0	2	4	6	13	8	4	0	35	41	8
J.Vommasandra	17	0	1	1	1	3	6	8	0	19	8	0
Gujjanahalli	71	0	5	12	25	34	0	0	0	71	39	0
Total	169	0	10	24	40	59	21	17	0	161	91	8
Grand Total	**169**	**0**	**10**	**24**	**40**	**59**	**21**	**17**	**0**	**161**		

Fig. 7.22 Self Help Group Formation



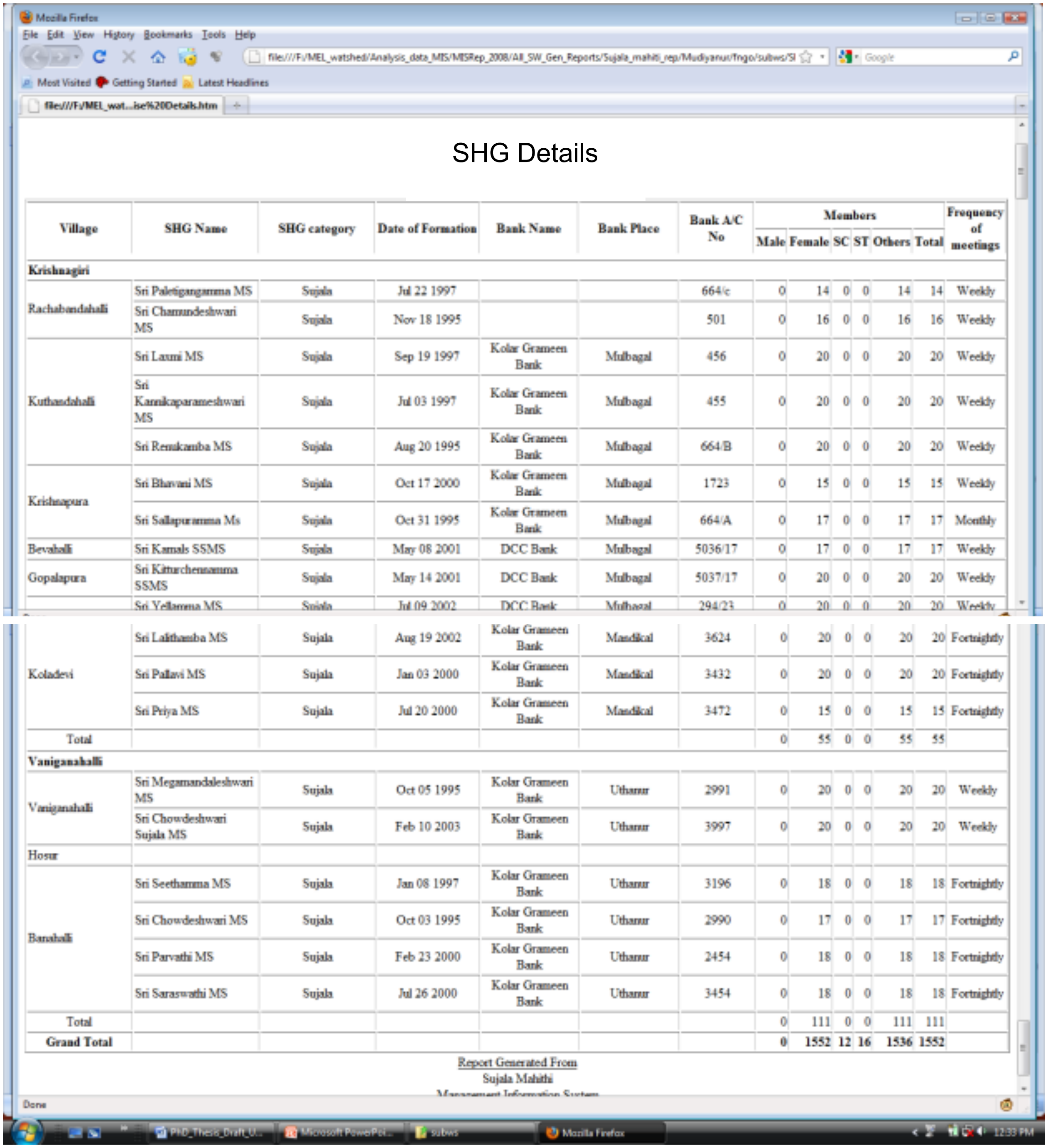
District: Kolar
Taluk: Mulbagal
Subwatershed: Uttanur
FNGO: Prakruti

Self Help Group performance

Village	SHG Name	No. of meetings	Average attendance	Savings	Interest earned on internal loans	Loan from bank	Amt. recvd from other Depts.	Other income	Total amount	No. of loans given (to members)	Amount lent	Amount recovered	Amount overdue	% of members taken loan
Krishnagiri														
Rachabandahalli	Sri Paletigangamma MS	40	1040	4750	0	0	28350	0	33100	0	0	3550	0	0
	Sri Chamundeshwari MS	43	1055	5290	0	0	31500	0	36790	0	0	21500	0	0
Kuthandahalli	Sri Laxmi MS	55	1060	7235	1000	0	6300	65	14600	0	0	15000	0	0
	Sri Kannikaparameshwari MS	49	1065	8565	1316	0	12600	40	22521	0	0	12320	0	0
	Sri Renukamba MS	55	1065	9678	3170	0	22050	55	34953	0	0	22150	0	0
Krishnapura	Sri Bhavani MS	50	1015	5740	510	0	28350	20	34620	2	3500	3950	0	0
	Sri Sallapuramma Ms	47	1035	5375	1210	0	22050	90	28725	0	0	4345	0	0
Bevahalli	Sri Kamals SSMS	51	1065	9430	240	0	18900	0	28570	0	0	9150	0	0
Gopalapura	Sri Kitturchennamma SSMS	51	1050	8200	300	0	25200	0	33700	0	0	8400	0	0
K.G.Lakshmisagara	Sri Yellamma MS	51	1035	8690	150	0	17200	0	26040	0	0	8150	0	0
	Sri Gangamma MS	49	1005	6860	120	0	22050	0	29030	12	25000	11900	0	0
	Sri Chowdeshwari SSMS	52	1194	10670	5477	0	31500	15	47662	2	5000	30580	0	0
	Sri Vachana MS	52	1194	10946	6105	0	31500	0	48551	9	36000	30360	0	0
Kenchanahalli	Sri Gangamma MS	51	1050	9084	8958	50000	53550	0	121592	0	18500	86450	0	0
	Sri Lakshmi Sujala MS	52	1065	8956	5674	25000	53550	0	93180	3	5000	34720	0	0
Alaganahalli	Sri Gangamma MS	52	1495	7425	1690	0	50400	140	59655	0	0	27970	0	0
Uttanur	Sri Chowdeshwari MS	50	947	7250	2115	0	37800	0	47165	0	1000	6100	0	0
	Sri Uttanur mahila samaja	48	957	7065	1260	0	28350	0	36675	0	0	4440	0	0
	Sri Chowdeshwari KGS	48	987	7295	1420	10000	44100	0	62815	0	0	9370	0	0
Total		556	12463	89476	39090	110000	433750	165	672481	27	130500	269610	0	0
Koladevi														
Mandikal														
Koladevi	Sri Lalithamba MS	57	997	11400	6922	0	35000	0	53322	55	73500	70845	0	0
	Sri Pallavi MS	26	951	11451	6705	250000	56000	0	324156	20	250000	26025	0	0
	Sri Priya MS	26	867	7600	3235	0	42000	0	52835	5	9500	22870	0	0
Total		109	2815	30451	16862	250000	133000	0	430313	80	333000	119740	0	0
Vaniganahalli														
Vaniganahalli	Sri Megamandaleshwari MS	52	1078	7680	420	0	69300	10	77410	0	0	20645	0	0
	Sri Chowdeshwari Sujala MS	52	1016	8055	1009	0	89600	10	98674	0	2000	5940	0	0
Hosur														
Banahalli	Sri Seethamma MS	611	1435	6990	685	0	40950	0	48625	0	0	21030	0	0
	Sri Chowdeshwari MS	51	1084	7468	250	170000	44100	0	221818	17	0	83550	0	0
	Sri Parvathi MS	49	923	7590	645	0	44100	0	52335	0	0	11800	0	0
	Sri Saraswathi MS	47	911	5340	660	0	37800	330	44130	0	0	5850	0	0
Total		862	6447	43123	3669	170000	325850	350	542992	17	2000	148815	0	0
Grand Total		**5210**	**95562**	**657805**	**198380**	**1000500**	**2293550**	**12392**	**4162627**	**459**	**1560746**	**1464616**	**0**	**0**

Report Generated From
Sujala Mahithi

Fig. 7.23 Self Help Group Performance



SHG Details

Village	SHG Name	SHG category	Date of Formation	Bank Name	Bank Place	Bank A/C No	Members						Frequency of meetings
							Male	Female	SC	ST	Others	Total	
Krishnagiri													
Rachabandahalli	Sri Paletigangamma MS	Sujala	Jul 22 1997			664/c	0	14	0	0	14	14	Weekly
	Sri Chamundeshwari MS	Sujala	Nov 18 1995			501	0	16	0	0	16	16	Weekly
Kuthandahalli	Sri Laxmi MS	Sujala	Sep 19 1997	Kolar Grameen Bank	Mulbagal	456	0	20	0	0	20	20	Weekly
	Sri Kannikaparameshwari MS	Sujala	Jul 03 1997	Kolar Grameen Bank	Mulbagal	455	0	20	0	0	20	20	Weekly
	Sri Renukamba MS	Sujala	Aug 20 1995	Kolar Grameen Bank	Mulbagal	664/B	0	20	0	0	20	20	Weekly
Krishnapura	Sri Bhavani MS	Sujala	Oct 17 2000	Kolar Grameen Bank	Mulbagal	1723	0	15	0	0	15	15	Weekly
	Sri Sallapuramma Ms	Sujala	Oct 31 1995	Kolar Grameen Bank	Mulbagal	664/A	0	17	0	0	17	17	Monthly
Bevahalli	Sri Kamals SSMS	Sujala	May 08 2001	DCC Bank	Mulbagal	5036/17	0	17	0	0	17	17	Weekly
Gopalapura	Sri Kitturchennamma SSMS	Sujala	May 14 2001	DCC Bank	Mulbagal	5037/17	0	20	0	0	20	20	Weekly
	Sri Yellamma MS	Sujala	Jul 09 2002	DCC Bank	Mulbagal	294/23	0	20	0	0	20	20	Weekly
Koladevi	Sri Lalithamba MS	Sujala	Aug 19 2002	Kolar Grameen Bank	Mandikal	3624	0	20	0	0	20	20	Fortnightly
	Sri Pallavi MS	Sujala	Jan 03 2000	Kolar Grameen Bank	Mandikal	3432	0	20	0	0	20	20	Fortnightly
	Sri Priya MS	Sujala	Jul 20 2000	Kolar Grameen Bank	Mandikal	3472	0	15	0	0	15	15	Fortnightly
Total							0	55	0	0	55	55	
Vaniganahalli													
Vaniganahalli	Sri Megamandaleshwari MS	Sujala	Oct 05 1995	Kolar Grameen Bank	Uthanur	2991	0	20	0	0	20	20	Weekly
	Sri Chowdeshwari Sujala MS	Sujala	Feb 10 2003	Kolar Grameen Bank	Uthanur	3997	0	20	0	0	20	20	Weekly
Hosur													
Banahalli	Sri Seethamma MS	Sujala	Jan 08 1997	Kolar Grameen Bank	Uthanur	3196	0	18	0	0	18	18	Fortnightly
	Sri Chowdeshwari MS	Sujala	Oct 03 1995	Kolar Grameen Bank	Uthanur	2990	0	17	0	0	17	17	Fortnightly
	Sri Parvathi MS	Sujala	Feb 23 2000	Kolar Grameen Bank	Uthanur	2454	0	18	0	0	18	18	Fortnightly
	Sri Saraswathi MS	Sujala	Jul 26 2000	Kolar Grameen Bank	Uthanur	3454	0	18	0	0	18	18	Fortnightly
Total							0	111	0	0	111	111	
Grand Total							**0**	**1552**	**12**	**16**	**1536**	**1552**	

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Fig. 7.24 Self Help Group wise details & Bank linkages

District: Kolar
Taluk: Mulbagal
Subwatershed: Uttanur
Microwatershed: Mudiyanur

Land treatment summary report

Sl. No.	Activity Name	Unit	Achievement for the Selected Period						Cumulative Achievement					
			Phy	Fin	Contribution				Phy	Fin	Contribution			
					Cash	Kind	Labour	Total			Cash	Kind	Labour	Total
Private Land Treatment														
Soil and Water Conservation														
1	Farm Pond Desilting	No	600.5	282516.00	19503.00	0.00	0.00	19503.00	600.5	282516.00	19503.00	0.00	0.00	19503.00
2	Desilting of Tank	No	0	5300.00	400.00	0.00	0.00	400.00	0	5300.00	400.00	0.00	0.00	400.00
3	Earthen Bund	Rmt	223.795	389490.00	32475.00	0.00	0.00	32475.00	223.795	389490.00	32475.00	0.00	0.00	32475.00
4	Farm Pond	No	35	731538.00	64120.00	0.00	0.00	64120.00	35	731538.00	64120.00	0.00	0.00	64120.00
5	Henata Seeding	Ha	2000	78000.00	3900.00	0.00	0.00	3900.00	2000	78000.00	3900.00	0.00	0.00	3900.00
6	Recharge Pits	No	36	757868.00	54020.00	0.00	0.00	54020.00	36	757868.00	54020.00	0.00	0.00	54020.00
	Soil and Water Conservation Total			*2244712.00*	*174418.00*	*0.00*	*0.00*	*174418.00*		*2244712.00*	*174418.00*	*0.00*	*0.00*	*174418.00*
Drainage Line Treatment														
7	Boulder Checks / LBC with Vegetative Support	No	18	17750.00	400.00	0.00	0.00	400.00	18	17750.00	400.00	0.00	0.00	400.00
8	Gokatte	No	3	68250.00	2600.00	0.00	0.00	2600.00	3	68250.00	2600.00	0.00	0.00	2600.00
9	Nala Revetment	No	127	47000.00	5573.00	0.00	0.00	5573.00	127	47000.00	5573.00	0.00	0.00	5573.00
	Drainage Line Treatment Total			*133000.00*	*8573.00*	*0.00*	*0.00*	*8573.00*		*133000.00*	*8573.00*	*0.00*	*0.00*	*8573.00*
Horticulture														
10	Horticulture	Ha	13412	437586.00	41008.00	0.00	0.00	41008.00	13412	437586.00	41008.00	0.00	0.00	41008.00
	Horticulture Total			*437586.00*	*41008.00*	*0.00*	*0.00*	*41008.00*		*437586.00*	*41008.00*	*0.00*	*0.00*	*41008.00*
Forestry														
11	Agro Forestry	Ha	20795	322889.00	19909.00	0.00	0.00	19909.00	20795	322889.00	19909.00	0.00	0.00	19909.00
12	Earth Work - Forestry	Ha	7722	289046.00	33637.00	0.00	0.00	33637.00	7722	289046.00	33637.00	0.00	0.00	33637.00
	Forestry Total			*611935.00*	*53546.00*	*0.00*	*0.00*	*53546.00*		*611935.00*	*53546.00*	*0.00*	*0.00*	*53546.00*
Others														
13	Silt Application	Ha	7.09	49768.00	9505.00	0.00	0.00	9505.00	7.09	49768.00	9505.00	0.00	0.00	9505.00
14	Fodder Development	Ha	3	55490.00	5000.00	0.00	0.00	5000.00	3	55490.00	5000.00	0.00	0.00	5000.00
	Others Total			*105258.00*	*14505.00*	*0.00*	*0.00*	*14505.00*		*105258.00*	*14505.00*	*0.00*	*0.00*	*14505.00*
Livestock														
	Livestock Total			*0.00*	*0.00*	*0.00*	*0.00*	*0.00*		*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Demonstrations														
	Demonstrations Total			*0.00*	*0.00*	*0.00*	*0.00*	*0.00*		*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
	Private Land Total			**3532491.00**	**292050.00**	**0.00**	**0.00**	**292050.00**		**3532491.00**	**292050.00**	**0.00**	**0.00**	**292050.00**
Common Land Treatment														
Soil and Water Conservation														
1	Gokatte Repairs	No	0	0.00	3060.00	0.00	0.00	3060.00	0.00	0.00	3060.00	0.00	0.00	3060.00
2	Farm Pond Desilting	No	2	20000.00	4270.00	0.00	0.00	4270.00	2.00	20000.00	4270.00	0.00	0.00	4270.00
3	Desilting of Tank	No	2	20640.00	1384.00	0.00	0.00	1384.00	2.00	20640.00	1384.00	0.00	0.00	1384.00
	Soil and Water Conservation Total			*40640.00*	*8714.00*	*0.00*	*0.00*	*8714.00*		*40640.00*	*8714.00*	*0.00*	*0.00*	*8714.00*
Drainage Line Treatment														
	Drainage Line Treatment Total			*0.00*	*0.00*	*0.00*	*0.00*	*0.00*		*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Horticulture														
	Horticulture Total			*0.00*	*0.00*	*0.00*	*0.00*	*0.00*		*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Forestry														
4	Earth Work - Forestry	Ha	0	5000.00	1700.00	0.00	0.00	1700.00	0.00	5000.00	1700.00	0.00	0.00	1700.00
5	Planting - Forestry	Ha	0	0.00	1500.00	0.00	0.00	1500.00	0.00	0.00	1500.00	0.00	0.00	1500.00
6	Agro Forestry	Ha	2000	81601.00	5900.00	0.00	0.00	5900.00	2000.00	81601.00	5900.00	0.00	0.00	5900.00
	Forestry Total			*86601.00*	*9100.00*	*0.00*	*0.00*	*9100.00*		*86601.00*	*9100.00*	*0.00*	*0.00*	*9100.00*
Others														
	Others Total			*0.00*	*0.00*	*0.00*	*0.00*	*0.00*		*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Livestock														
	Livestock Total			*0.00*	*0.00*	*0.00*	*0.00*	*0.00*		*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Demonstrations														
	Demonstrations Total			*0.00*	*0.00*	*0.00*	*0.00*	*0.00*		*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
	Common Land Total			**127241.00**	**17814.00**	**0.00**	**0.00**	**17814.00**		**127241.00**	**17814.00**	**0.00**	**0.00**	**17814.00**
	Grand Total			**3659732.00**	**309864.00**	**0.00**	**0.00**	**309864.00**		**3659732.00**	**309864.00**	**0.00**	**0.00**	**309864.00**

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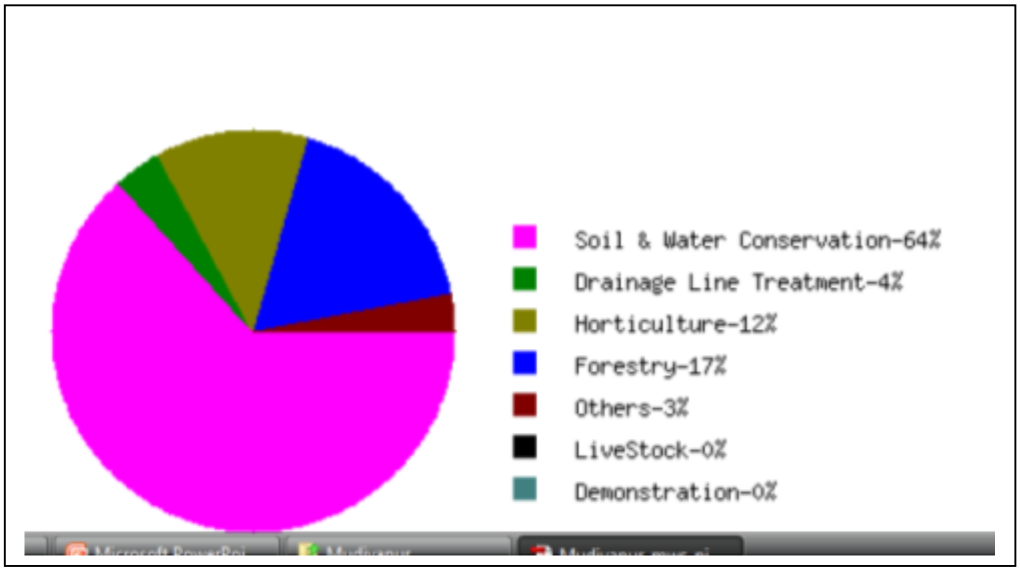
Fig. 7.25 Sample report on Land Treatment Monitoring

Investment Analysis

District	:	Kolar
Taluk	:	Mulbagal
Subwatershed	:	Uttanur
Microwatershed:		Mudiyanur



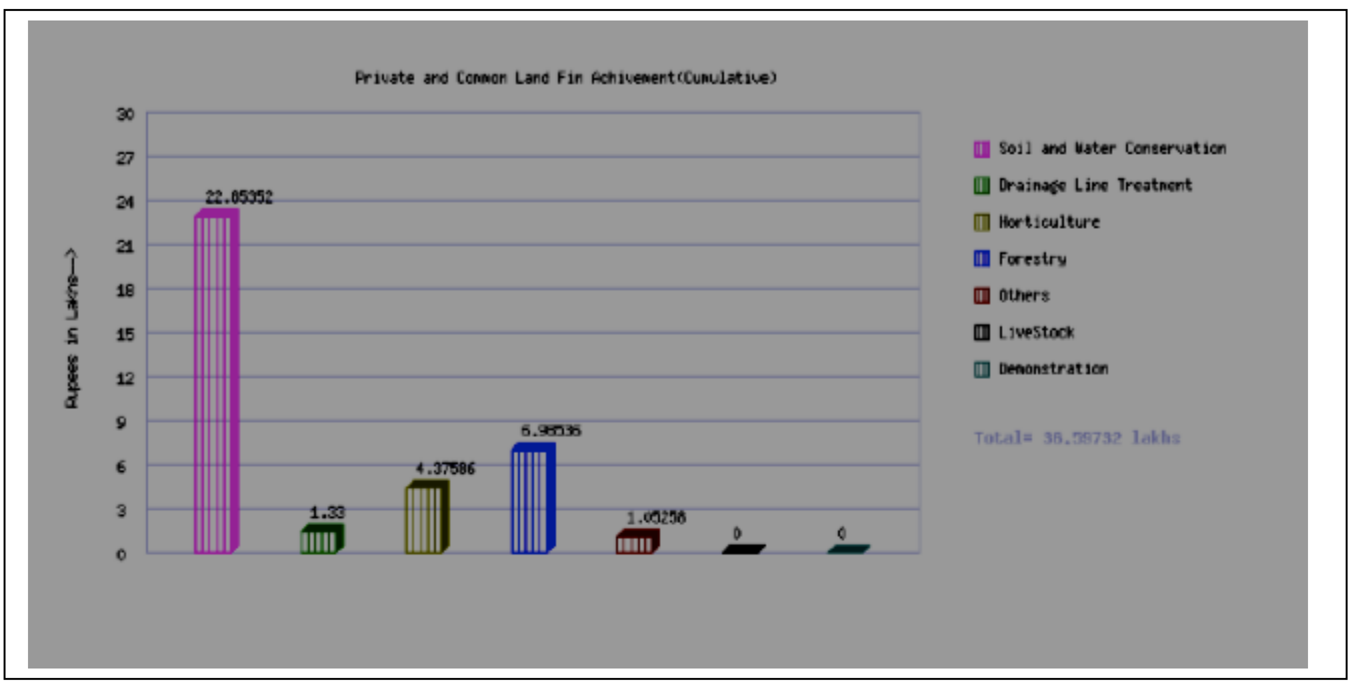


Fig. 7.26 Online Graphic analysis – Pie & Bar charts depicting financial investments

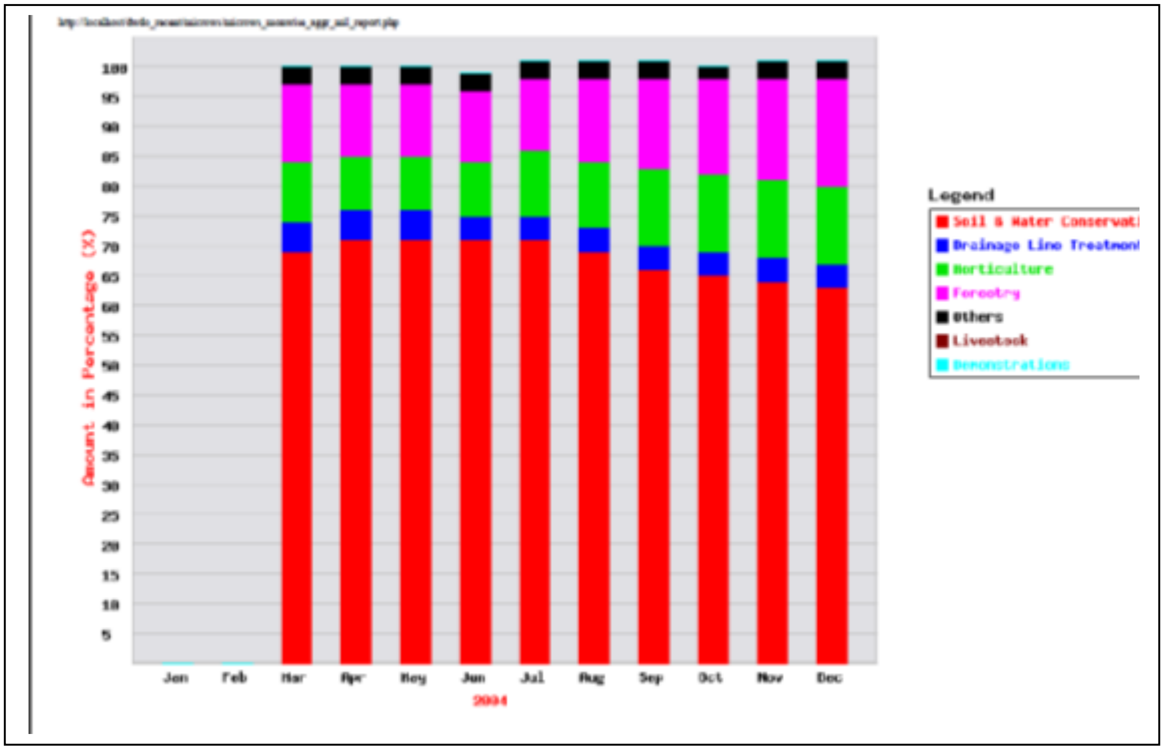


Fig. 7.27 Stacked Bar chart for month-wise investment analysis

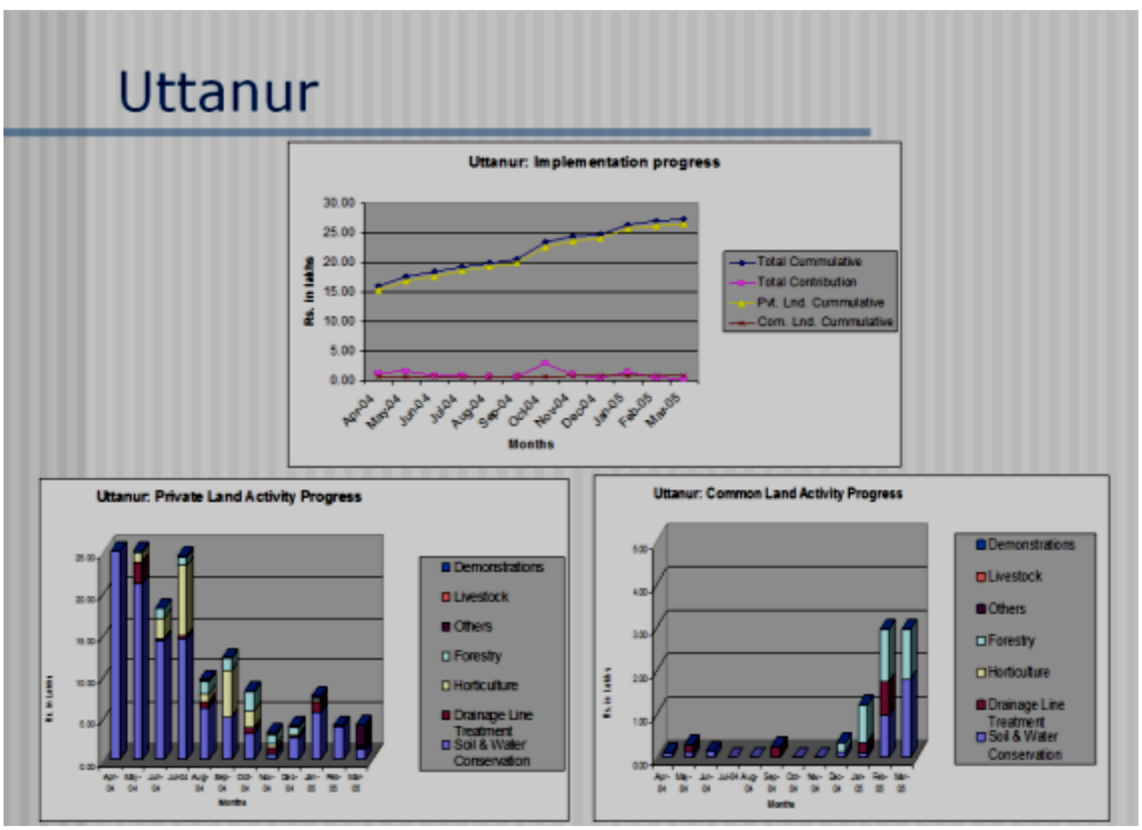


Fig. 7.28 Subwatershed level monitoring - Online Graphic presentation of concurrent investment monitoring:Uttanur subwatershed, Kolar District.

The database structure and coding scheme adopted in the design facilitates data organisation and analysis with respect to administrative hierarchy, like, District, Taluk, Sub-watershehd or Micro-watershed for analysis and online reports for decision making. There are other indicators related to SHGs and micro credits for which reports on the performance can be generated at stakeholders' level.

As the implementation is in 5 districts, covering different agro-climatic zones, a simple tool for aggregation of results based on such zonal criteria and timeframe is also developed as a part of the package for evaluation. Performance with respect to different agro-climatic zones is monitored through simple graphic analysis tools as shown in Fig 7.29. Decision makers can generate such reports for analysis and inferences.

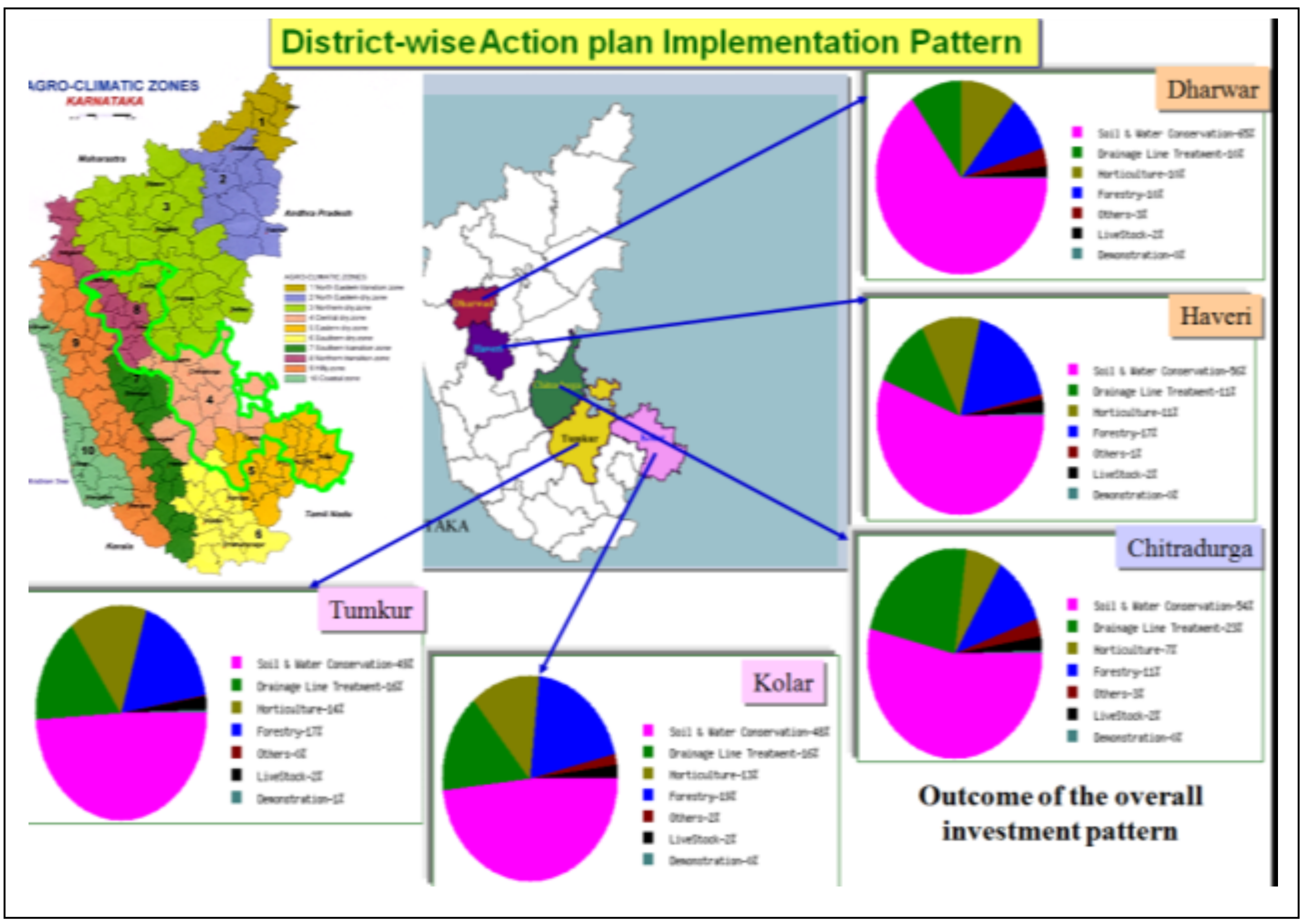


Fig. 7.29 District-wise Action Plan implementation pattern

It can be inferred from Fig 7.29, that the implementation trends are different in each districts. It is seen that for Kolar, Tumkur and Chitradurga districts, the sectors of investments are similar while they are different for Haveri and Dharwar districts. It is observed that investments on soil and water conservation activities are dominant in all districts, but drainage line treatment is seen to be of greater preference in Kolar, Tumkur and Chitradurga.

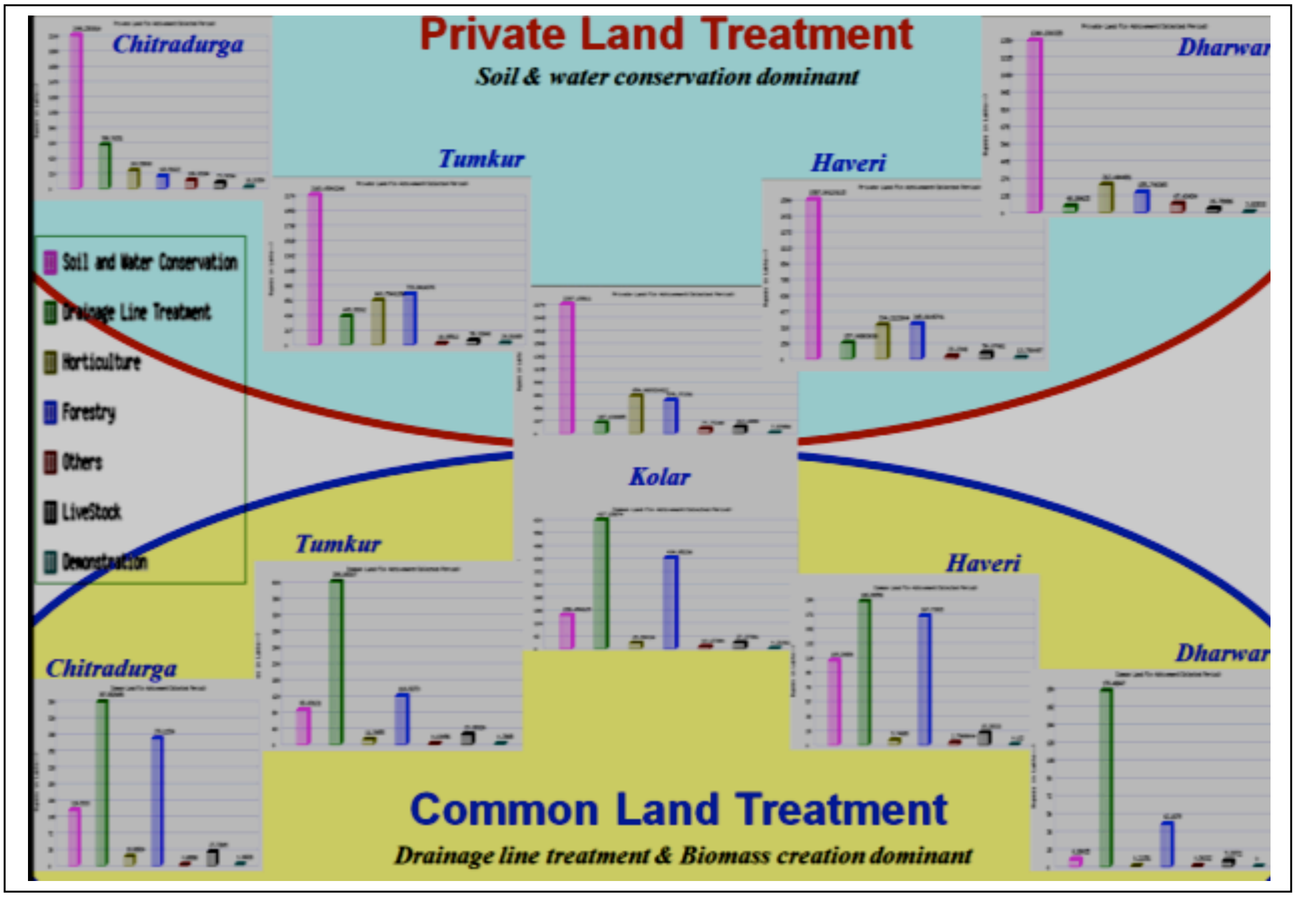


Fig. 7.30 District-wise Action Plan implementation pattern amongst private and common land

It is also seen from Fig 7.29 that more than 50% of the community spending has opted for soil and water conservation activities to reduce run-off and improve infiltration. While Kolar and Tumkur districts have taken up greening activities, that is forestry, horticulture, agro-forestry (ie., about 30% of total investment), Haveri and Dharwar districts have invested about 21% for similar activities in their region. This pattern also clearly brings out the priorities in these areas which are purely driven by the local conditions of the soil, slope, rainfall pattern etc.

Similarly, Fig. 7.30 highlights the pattern in which farmers have implemented developmental activities in private and common land. While the Private land development has predominantly focused on soil and water conservation measures, they have opted for drainage line treatment and afforestation / biomass development for common property resources (CPRs). Reasoning is quite obvious, the community has the stakes to use the CPRs and hence they have opted for fuel wood and fodder development to sustain their livestock and energy requirements. At the same time the investments on drainage line treatment in CPRs is also observed to be significant, which provides benefits during rainy days and also helps in soil conservation.

The other type of data analysis pertains to implementation of activities in phases. That is, developmental activities taken up across different agro climatic zones are done in 3 phases. 10 sub-watersheds are taken up in the initial phase as compared to 20 in phase 2 and 47 in phase 3. This is done to facilitate better learning amongst farming community from the previous phases and to improvise upon developmental activities. Data and information is gathered using WebMIS package in all 3 phases covering all watersheds. The findings are summarised with respect to each of the districts and mode of implementation, including learning from previous phases, as shown in Fig. 7.31. Two types of comparisons are possible, (a) district-wise comparison across different phases and (b) phase-wise comparison amongst group of districts with respect to agro-climatic conditions.

All districts have adopted progressively diversified activities in successive phases of implementation due to learning from previous phases. This has been possible due to the new concept of "Farmers' Field Schools (FFS)", that is, successful farmers from the previous phases providing information from their experience to the next phase stakeholders, in addition to critical analysis and scrutiny of action plans before implementation and approval. For example, Kolar and Tumkur districts could adopt changes and have moved ahead in more diversified activities compared to other districts in a progressive manner.

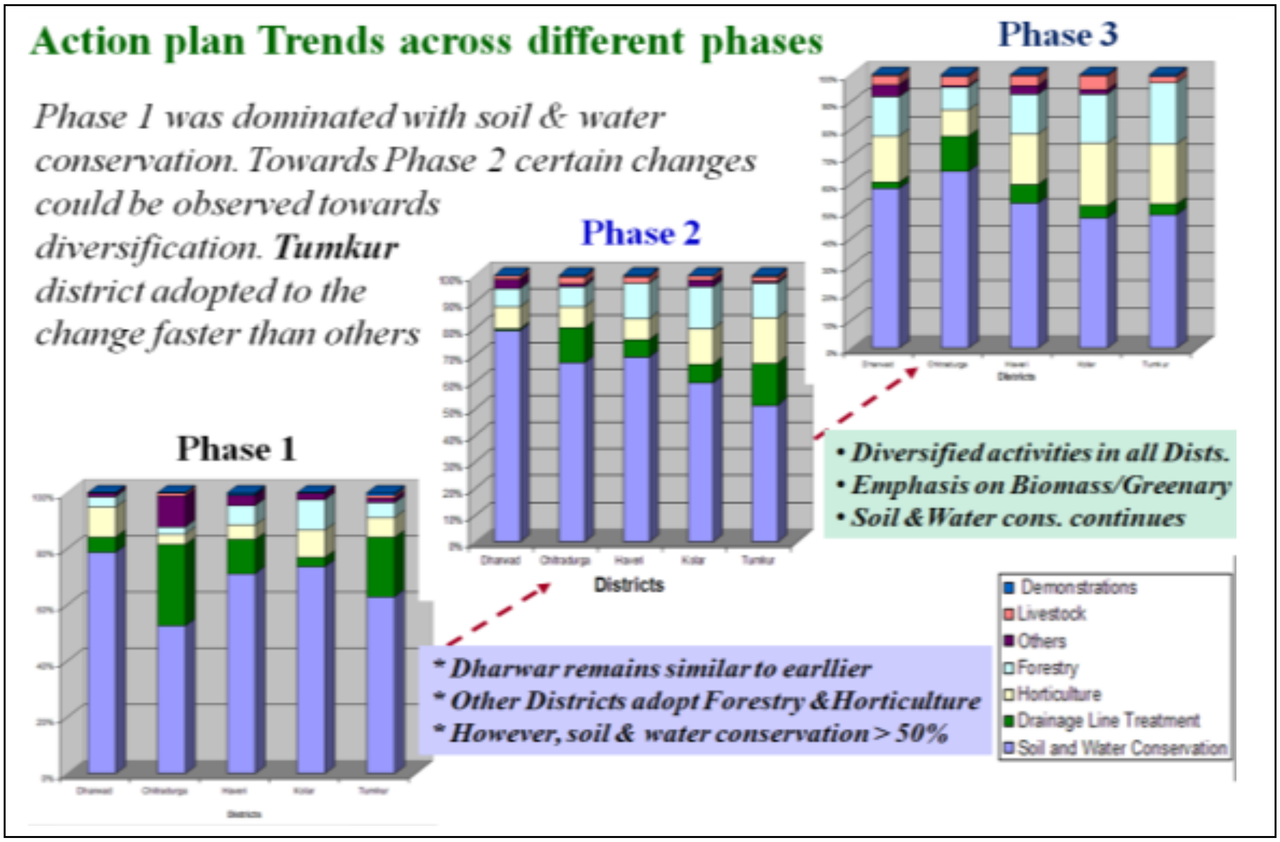


Fig. 7.31 Community learnings from previous phase implementation

Fig 7.31 brings out the fact that the quality of action plans prepared across different agro-climatic zones turned out to be progressively diversified with time due to adaptive learning amongst the village community. From phase 1 through phase 3, it can be seen that there is a significant increase in greening activities through horticulture and forestry, in addition to soil and water conservation. Hence, from the above illustration it is inferred that developmental efforts are equitably adopted based on learning from activities of previous phases and adaptability with respect to agro-climatic conditions.

The software package developed, not only facilitates post-facto analysis of the trends and nature of implementation (which results in better learning and planning for the future), but also provides online tracking of plan execution for the entire study area and across different phases. In particular, the online data has provided much needed mechanisms for effective monitoring of watershed development through the online involvement of functionaries from village clusters and districts with the state level decision makers for dynamic decision making and applying mid-course corrections to processes as required.

7.7 Impact Assessment

Integrated watershed development is expected to yield results that need to be seen from various perspectives, like, social, economic and environmental. These impacts depend much on the methods employed in planning and implementation, types of processes adopted and extent of participation of the local communities. Several scientific methods have been adopted in implementation of the programme. Impact assessment has been done using the data collected different sources and analysis is carried out. The different sources are sample field survey of household, satellite remote sensing, and data collected from MIS – GIS software solutions. Impact analysis is done using these data sets and details are brought out in the following sections.

7.7.1 Land Use/ Land Cover Transformation–Southern Dry Zone (SDZ)

The study clearly brings out the improvements in land resources due to various developmental activities taken up by the local community. Mudiyanur micro watershed, Uttanur, Kolar District covering an area of about 670 Ha, is considered to asses the impacts using remote sensing and GIS techniques. The data collection and analysis are done using two-time satellite data, one at the beginning and the other after implementation, along with sample field data.

Analysis of the data collected indicates that an integrated approach involving agriculture, horticulture, forestry, sericulture, pisciculture and other interventions is adopted in the micro watershed. The arable and non-arable land parcels have been treated suitably with soil and moisture conservation activities. Alternate land use is adopted according to capability and potential of the land, in due consultation with experts and the scientific inputs.

The works related to soil and water conservation, such as, earthen bunds, construction of farm ponds, nalla revetment, boulder checks, gokatte (water storage for cattle), desilting of tanks, creation of farm-ponds and recharge pits are some of the major activities implemented at different suitable areas (parcel number-wise), as per approved plan. Extensive rainwater harvesting activities are taken up by the community for supplementing irrigation facilities with an intension to improve sub soil moisture conditions and ground water recharge. As a part of land use and land cover transformation, large tracts of land are treated for agro-horticulture and agro-forestry. Mango, Sapota, Silver-oak, Eucalyptus, and Pongamia are some of the species planted, as verified through sample field data collection.

Impact assessment using Remote sensing and GIS is done as follows:

I. The satellite data pertaining to pre and post treatment periods are initially georeferenced and co-registered for further analysis (Fig 7.32).

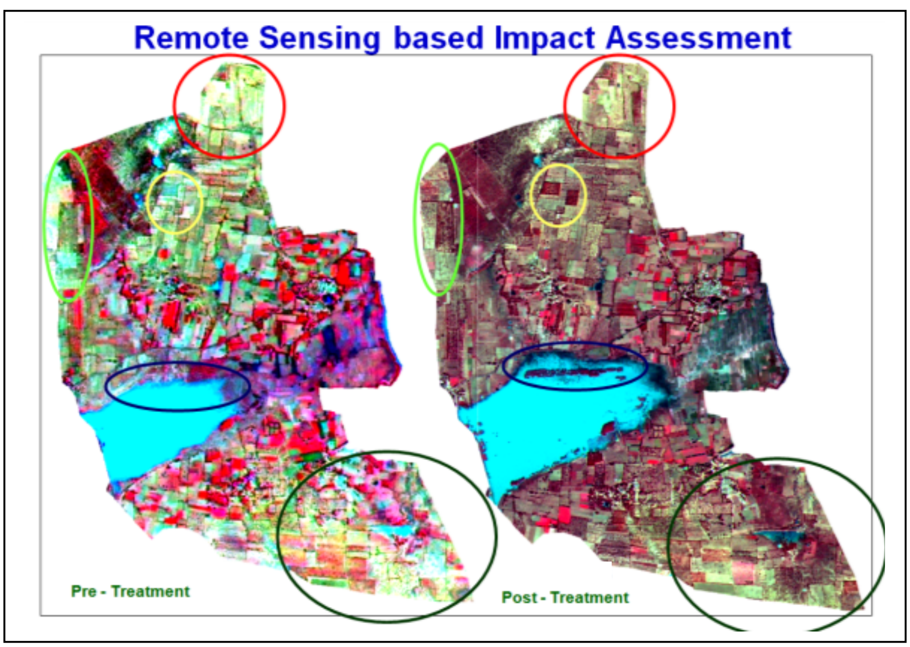


Fig. 7.32 Pre & Post treatment images highlighting changes

Visual inspection of these Images gives an indication of the kind of changes that have occurred over a period of 4 years. Tank fore-shore plantations (Fig 7.33), clearly visible as a linear patch within the tank as a post-treatment image, is a significant contribution by the community. The northern, western and southern corners of the pre-treatment image do indicate large tracts of degradation, which are restored and brought under green cover. This is clearly visible in the post-treatment image. This shows that the micro-watershed has gone through a significant positive transformation.

II. The pre and post treatment images are classified by using corresponding sample ground truth data. The outcome of such a process is shown in Fig 7.33. These are further transformed into Raster GIS for further analysis.

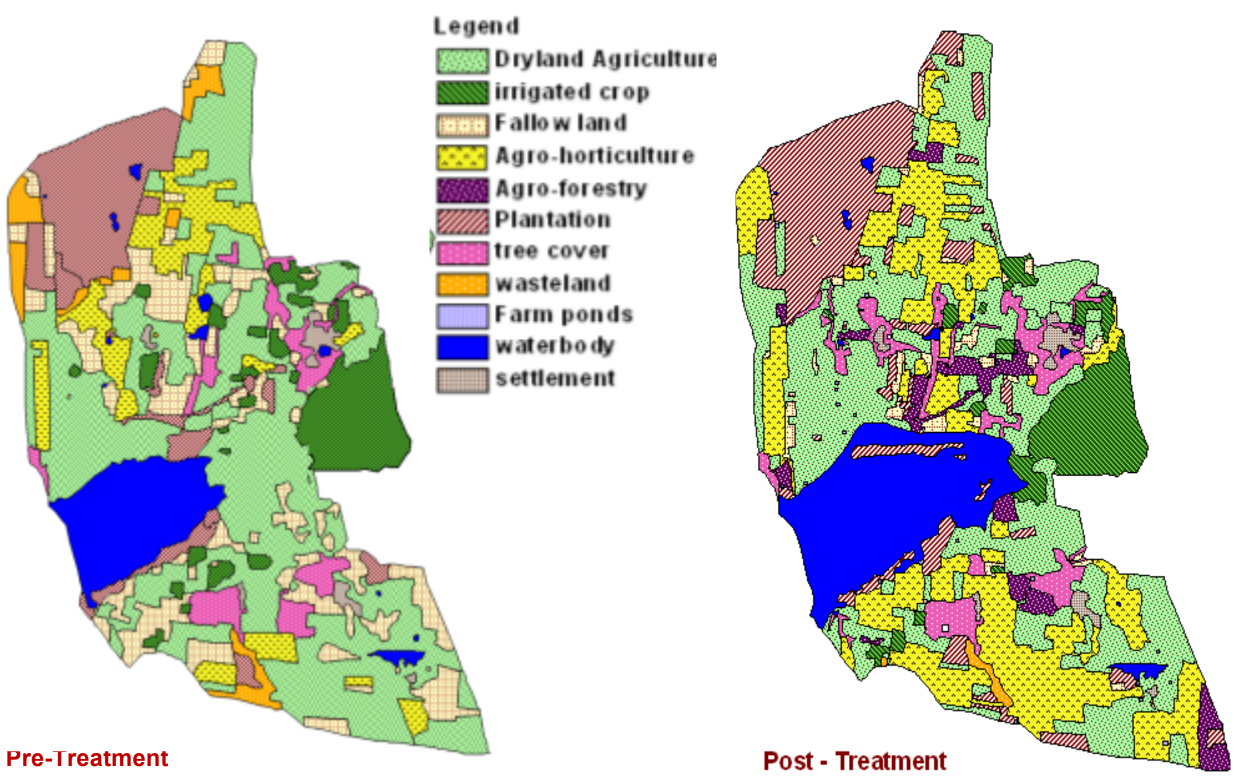


Fig. 7.33 Pre & Post Classified images

III. Change Detection - Rule based automatic change detection, with respect to co-registered pixels, is used to derive change image (Fig 7.34).

Simple logical rules are used for pixel level comparison amongst the 2-time classified images, to assess the extent of changes that has occurred. The classification codes and legends are maintained identical between the two classified images as a part of the change detection logic. A "Truth-Table" for two-time image comparison is used for deriving change image (Table 7.4).

Table 7.4 Truth Table for Change Detection

Sl. No.	***If*** *(Pre-treatment Pixel)* ***is***	***If*** *(Post-treatment Pixel)* ***is***	***Then*** *(Rule for outcome Pixel)* ***is***
1	*Class A*	*Class A*	**No-Change Pixel**
2	*Class A*	*Class B*	**New Class A → B or B ← A,** resulting in land cover transformation. The change pixel could be progressive or retrogressive.
3	*Class B*	*Class A*	

There are 11 broad classes in both the classified images with settlement being a static class in both images. While carrying out the change analysis using the truth-table (Table 7.4), there are many combinations of land cover transformations that may occur in the nature, which can automatically be selected by the system in the process of comparison. Hence, the concept of "Truth-Table" with a-priori coding scheme based on possible outcome is adopted using raster GIS environment to derive change image and corresponding statistics (Table 7.5). The class codes are determined in such a way that progressive and retrogressive transformations are identified and classified with unique coding scheme, while pixels with no-change are retained as no-change category.

IV. <u>Change Analysis</u> **-** The change image, derived as a part of change detection analysis, shows significant positive improvements due to different interventions, as shown in Fig 7.34. The analysis indicates significant progressive transformations that have taken place in the micro-watershed as given in Table 7.5 and graphically presented in Fig 7.35. Although the area under agriculture has reduced from 288 ha to 217 ha, (a) the agricultural land use pattern has changed, that is, un-irrigated area is converted to irrigated tracts due to water availability, (b) single crop area is found to be supporting double cropping due to better water availability, (c) mono cropping areas have facilitated for mixed cropping and changes are observed in the dominant crops and the cropping pattern. It may also be observed from the Fig 7.34 that 235.5 ha has remained unchanged.

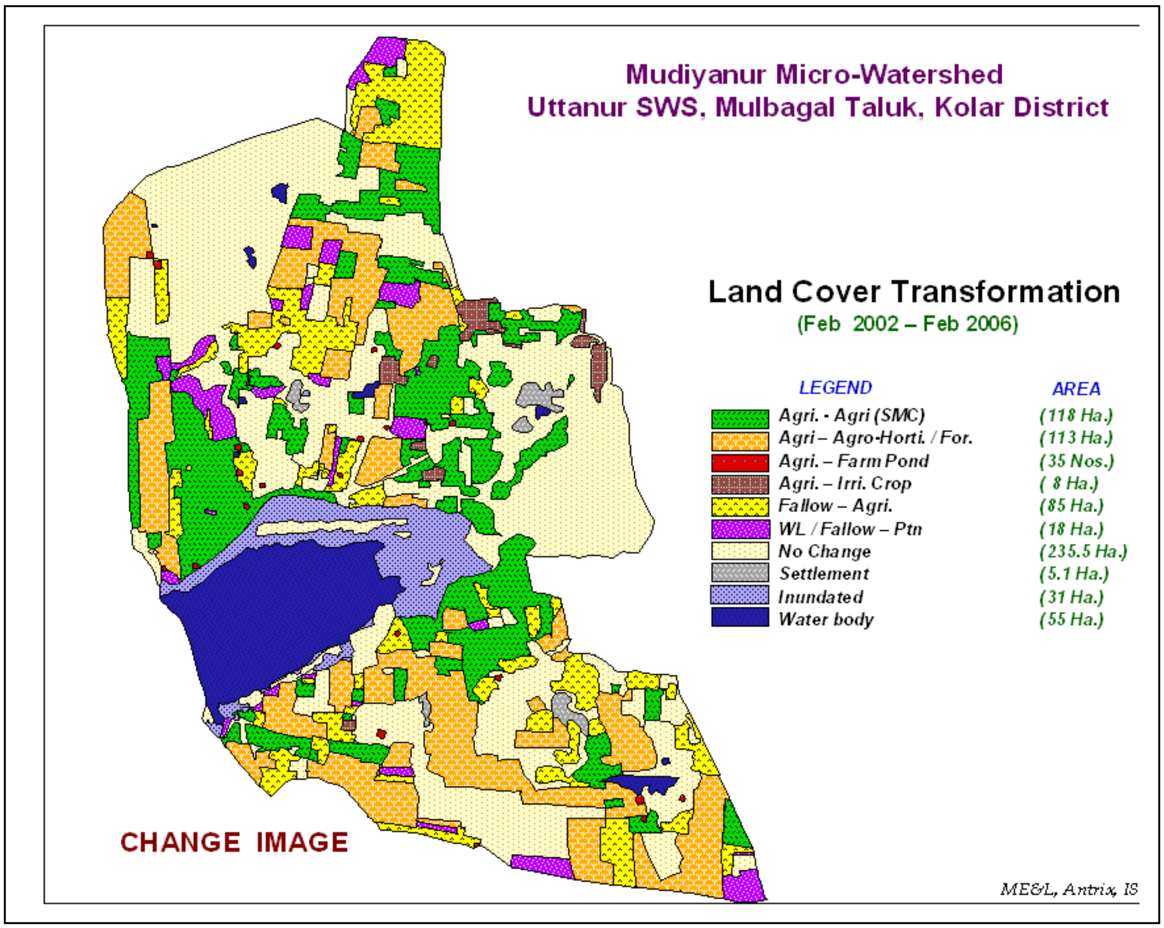


Fig. 7.34 Analysis of classified images - Change Image

A switchover from traditional single cropping to agro-horticulture is quite substantial (93 ha), thereby increasing the area under fruit crops. Forestry species have been taken up in the agricultural lands (about 20 ha) including the field bunds as a part of agro-forestry activity, which has increased the biomass in the village. Reduction in the spatial extent of wastelands and fallow lands has also been observed, particularly in the degraded areas along the peripheries of the watershed. About 100 ha are reclaimed and brought to productive use. Afforestation along the nalas and streams, around farm ponds have improved the overall tree-cover in the area. The area under forest plantations has also increased by about 12 ha. The satellite data has provided required information on bio-physical parameters for monitoring and assessment of changes.

Table. 7.5 Statistics of Change Analysis

Sl. no.	Description	Pre-treatment area (in Ha)	Post-treatment area (in Ha)	Change (in Ha)	Change (in %)
1	**Agriculture**	287.7	216.6	-71.1	-10.6
2	**Irrigated Crops**	39.2	47.6	8.4	1.3
3	**Agro-horticulture**	57.4	150.0	92.6	13.8
4	**Agro-forestry**	5.4	24.9	19.5	2.9
5	**Forest Plantation**	82.4	95.3	12.9	1.9
6	**Tree Cover**	25.0	37.2	12.2	1.8
7	**Fallow land**	98.0	13.0	-85.0	-12.7
8	**Wasteland**	20.1	2.5	-17.6	-2.6
9	**Water Spread**	54.8	82.9	28.1	4.2
10	**Total**	670.0	670.0		

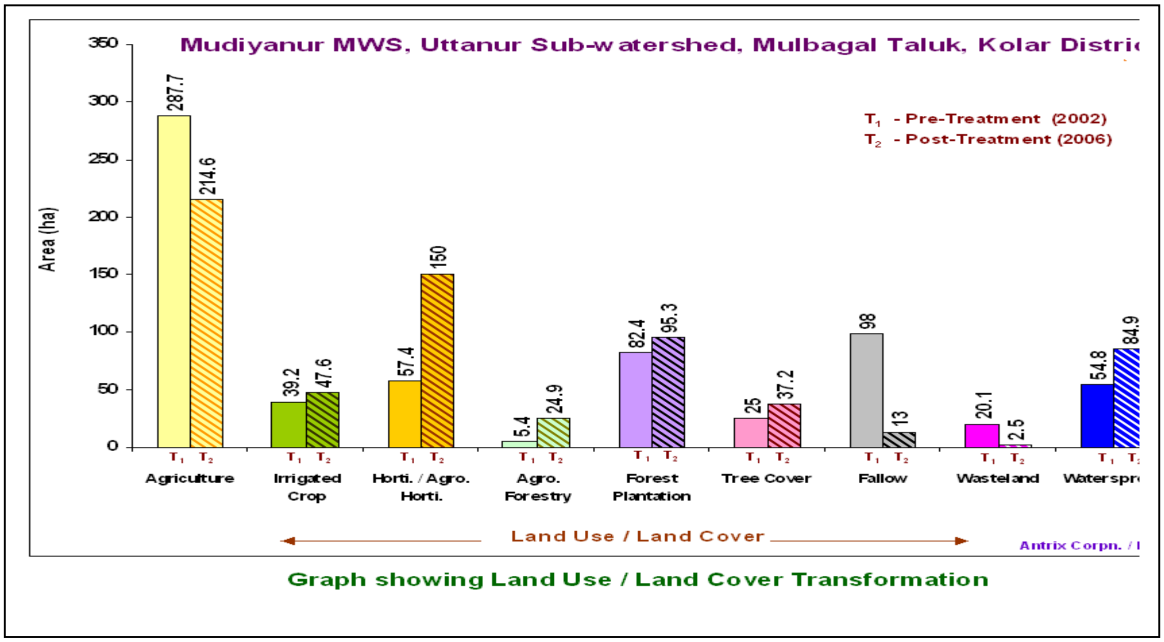


Fig. 7.35 Graphical representation of change Analysis

7.7.2 Rapid Assessment of Impacts

An attempt is also made to carry out rapid change analysis, using coarser spatial resolution data of IRS LISS 3 with 23 m spatial resolution. This is particularly found useful for monitoring impacts covering large areas with many watersheds simultaneously as the swath of LISS 3 sensor is 141 x 141 km. Benakanakatti micro-watershed, Managundi subwatershed, Dharwar District covering Northern Transition Zone with a geographical area of 825 ha is considered with a temporal resolution of 5 years (Fig 7.36A). The land utilization pattern with respect to pre and post treatment of watershed is analysed with different types of land cover changes.

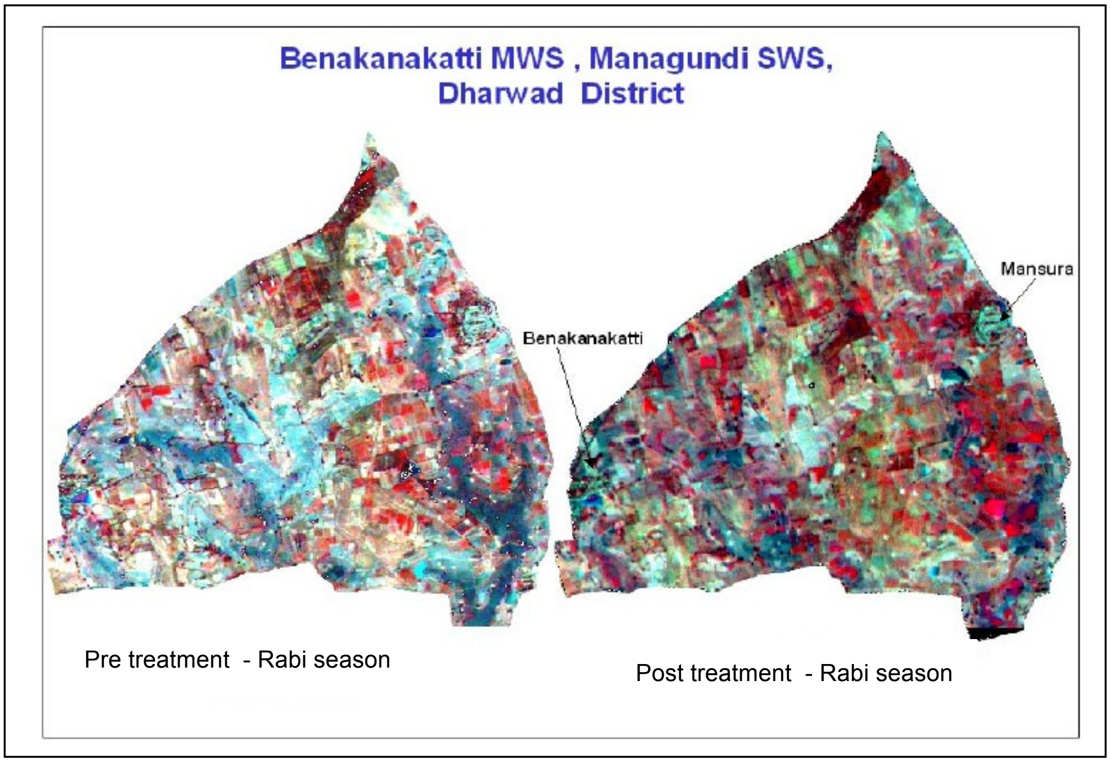


Fig. 7.36A Georeferenced IRS LISS 3 images of the study area.

It can be seen from Fig 7.36A that a substantial area has been brought under biomass in western, central and north-eastern portion of the study area. The cadastral boundaries overlaid on satellite image as shown in Figure 7.36B that highlights horticultural activities in the marginal agriculture land with increased biomass due to agro-forestry and other agricultural activities.

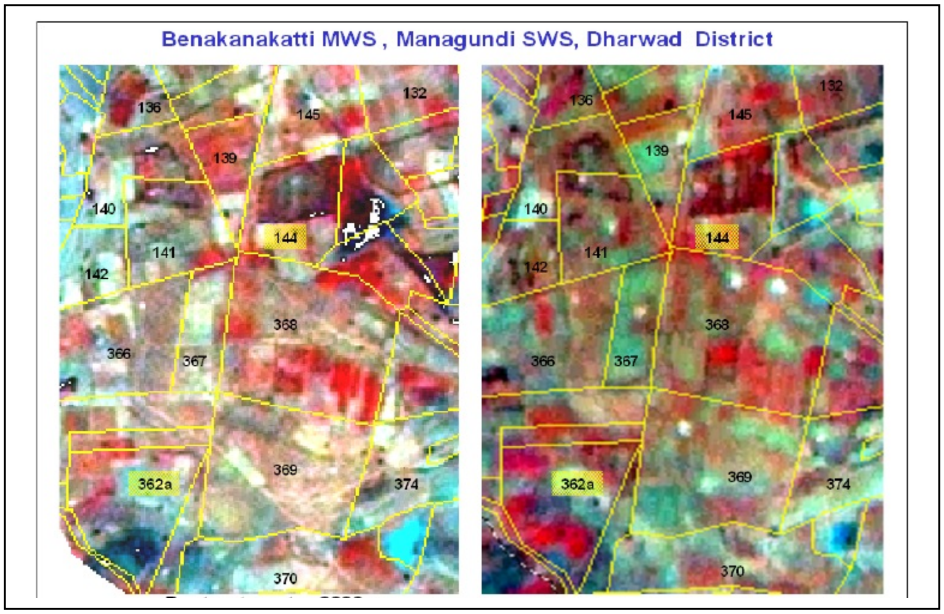


Fig. 7.36 B Cadastral overlay on False Color Composite

Normalised difference vegetation index (NDVI) image, is an effective indicator for understanding the status of vegetation with respect to its greenness and healthyness. This is derived using band ratio of Infrared and Red bands with normalization principle. This also helps to establish the status of biomass (Fig 7.37**)**. The improvement in high and moderate vegetation indices is observed to an extent of 5.7% and 5.9% respectively as compared to baseline (pre-treatment) figures (Table 7.6**)**.

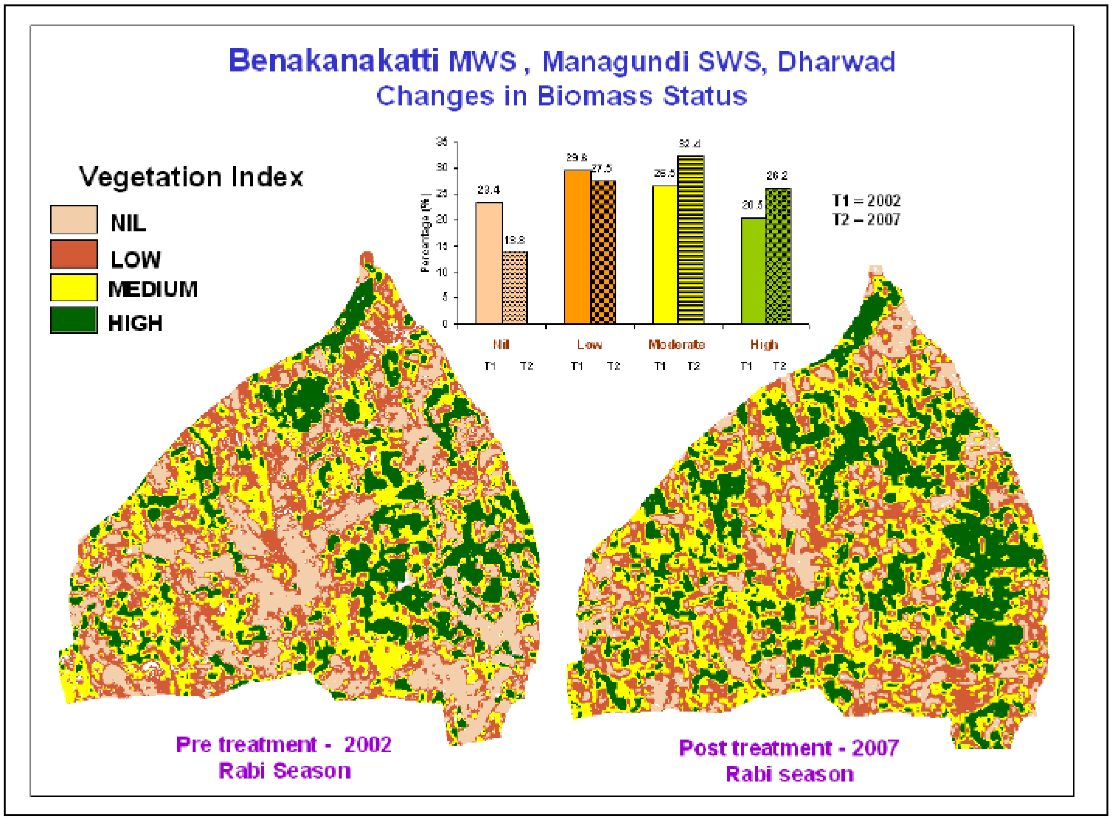


Fig. 7.37 NDVI based biomass changes in Benekanakatte MWS

Table 7.6 Change in Biomass as observed from pre and post treatment periods

Biomass	Pre-Treatment	Post-Treatment	% Change
Negligible	23.4	13.8	-9.6
Low	29.6	27.5	-2.1
Moderate	26.5	32.4	+5.9
High	20.5	26.2	+5.7

The satellite data has also provided information on biophysical parameters for carrying out monitoring and assessment of changes at a coarser resolution. The vegetation index based observations reveal that there is a positive impact in the form of significant gain in biomass.

7.8 Hydrological impacts

Hydrological impacts, attain unique importance due to extensive soil and water conservation activities undertaken as part of interventions. Based on the nature of activities taken up, both on surface and sub-surface elements of watersheds are affected. An attempt is made to asses hydrological impact on the watersheds using well established SCS-CN (Soil Conservation Services-Curve Number) method. The results have shown increased infiltration indicating better recharge of ground water.

7.8.1 Runoff Analysis – Use of Remote Sensing and GIS

The SCS curve number method that calculates the runoff as a function of soil and the vegetation cover is adopted in the present study. The Curve Number (CN) represents the watershed co-efficient, which is a combination of hydrological effect of soil, land use, hydrological condition and antecedent soil moisture condition. Remote sensing and GIS techniques allow integration of spatially variable geomorphologic parameters, such as, rainfall, soil characteristics, changes in land use, etc., as prerequisites for computation. GIS is used to integrate such layers both spatially and temporally to analyse and estimate the runoff for a given area.

The land use & land cover (LULC) maps for pre and post treatment periods are generated using high spatial resolution satellite data from Indian Remote sensing Satellite (IRS) pertaining to summer (March – April) 2002 and 2005 respectively. The digital soil database is used to group the soil type based on their structure and textural information and with respect to hydrological soil grouping. The details are presented in Table 7.7**.**

The GIS layers of soil and LULC are further intersected to obtain the Soil–Vegetation Complex (SVC) layer. The curve numbers are assigned to each Soil–LULC pair based on available lookup table (Table 7.8). The weighted average CN (WCN) are calculated for the entire micro-watershed. The average curve numbers are used to calculate the runoff depth (Q) and runoff volume in cu. m. This is adapted to Indian conditions by computing the Q, using the formulae developed for the Indian conditions (Zade et al, 2005).

Table 7.7 Standards for Hydrological Soil Grouping

Soil group	Description	Soil characteristics	Infiltration rate (cm/hr)
Group A	High infiltration rates, soils are deep ,from well drained to excessively drained sands and gravels	Deep sand, deep losses and aggregated soils	0.76
Group B	Moderate infiltration rates, deep and moderately deep, moderately well drained soils with moderately coarse textures	Shallow losses and sandy loam	0.38-0.76
Group C	Slow infiltration rates, soils with layers impeding downward movement of water or soils with moderately fine or fine texture	Clay loam, shallow sandy loam, soil in organic content and soils usually high in clay	0.13-0.38
Group D	Very slow infiltration rates soils are clayey and have a high water table or are shallow to an impervious layer	Soil that is well up to wetting heavy plastic clays and certain saline soils	0.0-0.13

Table 7.8 Soil – Vegetation - CN Lookup Matrix

Land use	Hydrologic soil group			
	A	**B**	**C**	**D**
Agriculture – Single Cropped Area without conservation	72	81	88	91
Agriculture – Single Cropped Area with conservation	67	75	81	83
Double Cropped Area	62	71	88	91
Plantations	45	53	67	72
Scrubland	36	60	73	79
Wasteland (Stony/rocky/eroded)	45	66	77	83
Fallow land	39	61	74	80
Settlement	57	72	81	86
Water Body	100	100	100	100

7.8.2 Runoff Analysis – Impact of the changed scenairo

Remote sensing and GIS technology with necessary ground sampling has been effectively used in establishing various parameters related to runoff and infiltration for selected watersheds across different agro-climatic regions within the study area. Following results illustrate the fact that the use of such methods in establishing hydrological parameters could be of practical use for effective monitoring of large scale watershed intervention programs.

GIS outputs and outcome of geospatial analysis for Mansur micro-watershed, Dharwar district that represents northern transition zone (NTZ) are presented in Fig. 7.38. Similar exercise is also done for selected micro-watersheds from other agro-climatic zones, namely, Central Dry Zone (CDZ) and Eastern Dry Zones (EDZ) respectively. While geospatial illustrations are shown for only Mansur micro-watershed, the quantitative results of analysis for sample watersheds from other agro-climatic zones are given in Table 7.9 and 7.11 respectively. The images of Mansur micro-watershed (Fig 7.38) indicate the study area in the pre and post treatment periods respectively.

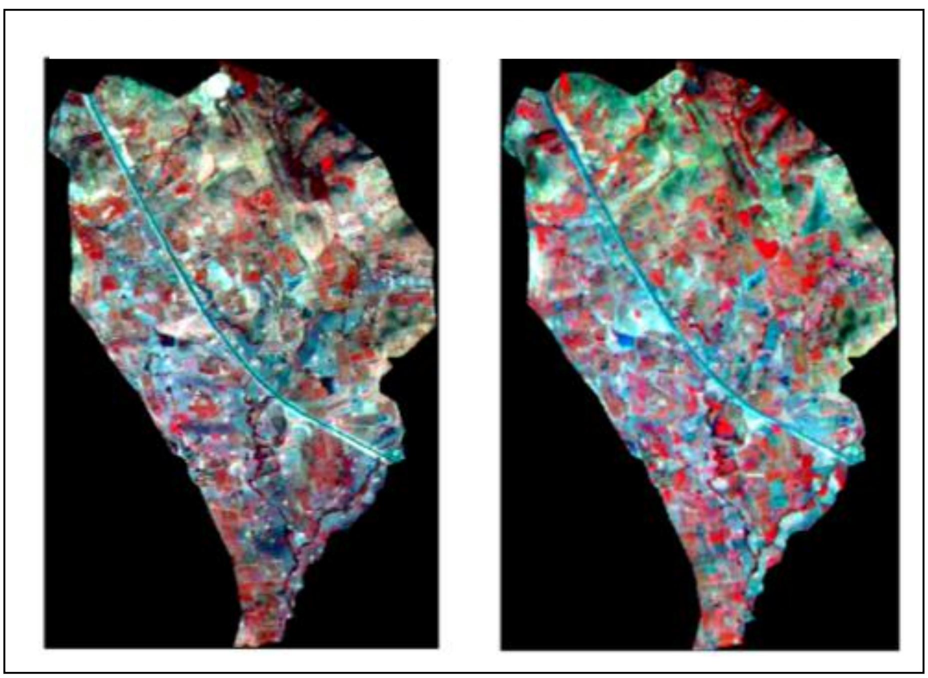


Figure – 7.38: Satellite image of Mansur (NTZ)

Geospatial database elements, such as, Soil, Slope, Hydro-geomorphology, land use & land cover and other inputs are used for spatial computation of runoff and infiltration components for the micro-watershed. Action plans are prepared as a part of developmental process, by the community (Fig. 7.39), which is a result of consultative and decision-making process. These maps, after technical validation are used for implementing necessary interventions that are intended to result in changes with respect to land use and land cover. Hence, the land use and land cover maps are prepared for pre and post implementation phases to study the impact on runoff and infiltration.

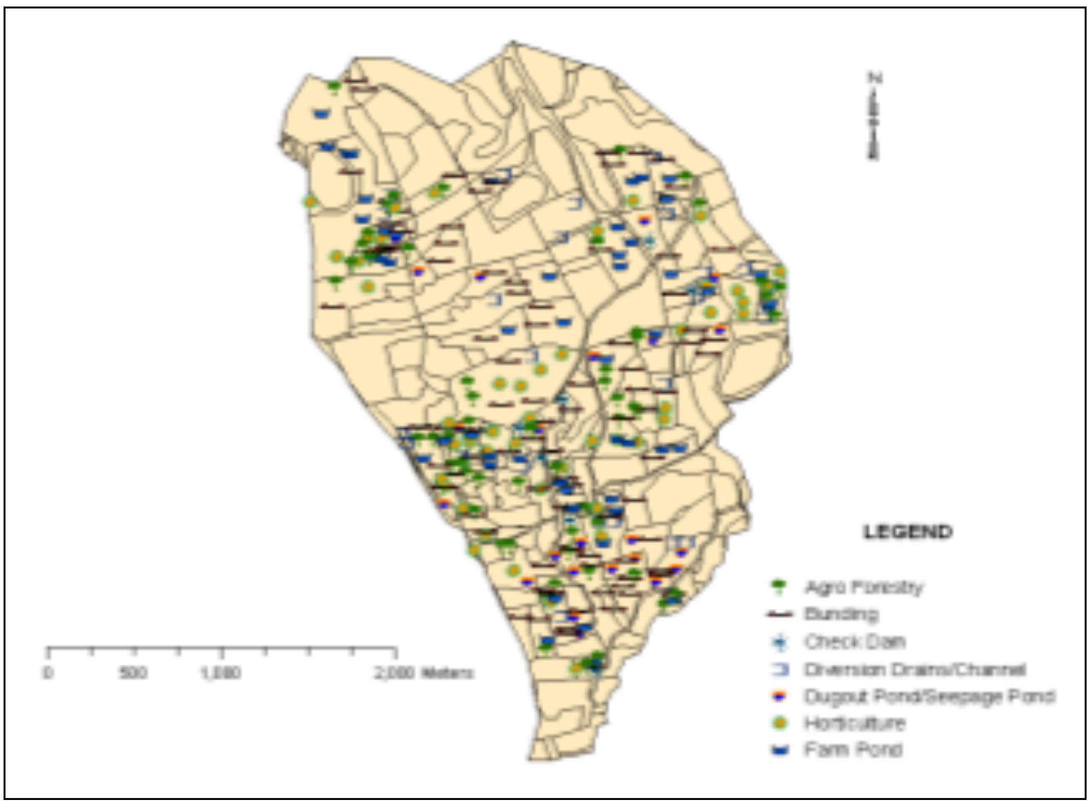


Fig. 7.39 Participatory Action plan

The action plans are implemented over a period of 3 years. The interventions are broadly categorized into soil and water conservation measures, biomass development (agro-forestry and agro-horticulture), improved agricultural practices etc. that result in changes with respect to land use and land cover as presented in Fig 7.40. While biomass development goes through a longer process of development, the other measures do yield results in shorter timeframe. Hence, a 3-year period is chosen to observe the impact of action plans.

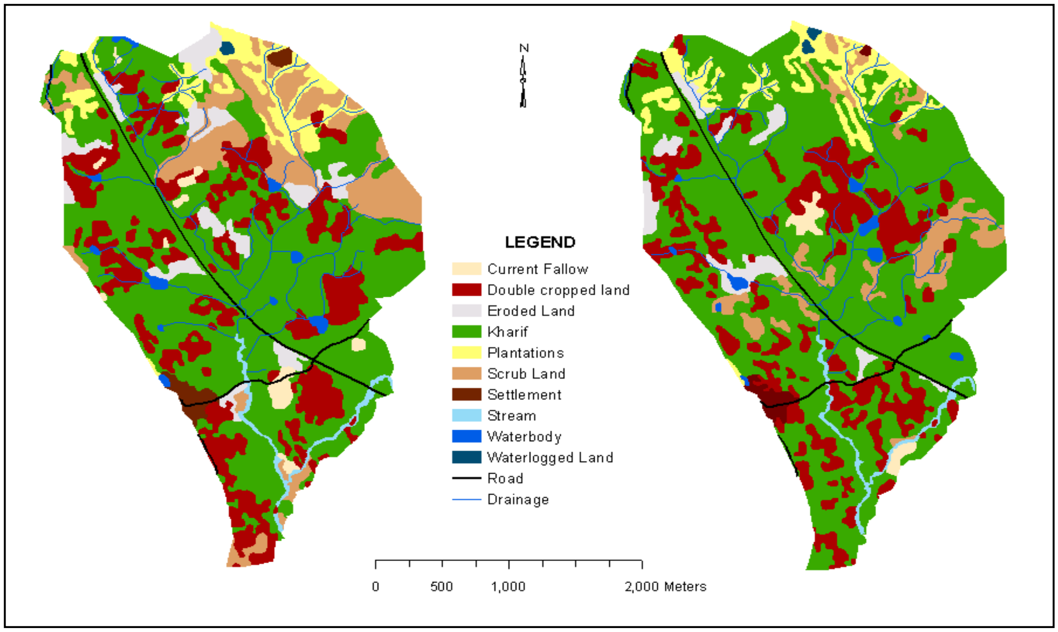


Figure 7.40: Pre & post treatment Classified images of Mansur

The geospatial comparison shows noticeable changes that have occurred as a result of implementation of various activities. They are mainly with respect to agriculture, plantations, scrubland and wastelands. The changes are also due to the soil and water conservation activities that are implemented in the micro-watershed.

Randomly selected watersheds of other agro-climatic zones, that is, Baradi from NTZ, Venkal Gudda (VK Gudda) from CDZ, Echalahalla, boothappanakatte and Kurudi from EDZ are also considered for comparative analysis. Comparison of land use and land cover statistics with respect to pre and post implementation phases are presented in Table 7.9. It is seen that, in most of the cases, the area under agriculture and plantations have increased, while the wasteland and scrubland area has been decreased, due to watershed interventions.

Table 7.9 Pre & Post Treatment extent (%) and Change in LU / LC classes

LULC	Mansur - NTZ			Baradi – NTZ			VK Gudda - CDZ		
	PreTrt	PostTrt	Change	PreTrt	PostTrt	Change	PreTrt	PostTrt	Change
Single crop Area	51.06	61.69	**10.63**	63.09	62.19	-0.91	62.13	67.19	**5.06**
Double Crop Area	20.86	18.45	**-2.41**	7.15	7.22	0.07	0.97	2.13	1.16
Plantations	5.86	6.17	0.30	3.03	10.11	**7.09**	0.18	0.22	0.03
Fallow land	1.43	1.02	-0.41	2.08	2.84	0.76	5.57	0.84	**-4.73**
Scrub Land	11.65	5.75	**-5.90**	17.84	11.72	**-6.12**	23.87	24.05	0.17
Wasteland	5.72	3.50	**-2.22**	2.51	1.62	-0.89	6.23	4.54	-1.69
Settlement	1.25	1.25	0.00	2.33	2.33	0.00	--	--	--
Waterbody	2.17	2.17	0.00	1.97	1.97	0.00	1.05	1.04	-0.01
Eastern Dry Zone – EDZ									
LULC	**Echalahalla**			**Boothappanakatte**			**Kurudi**		
	PreTrt	**PostTrt**	**Change**	**PreTrt**	**PostTrt**	**Change**	**PreTrt**	**PostTrt**	**Change**
Single Crop Area	19.58	18.80	-0.78	72.58	70.83	-1.76	57.47	59.08	1.61
Double Crop Area	0.72	0.61	-0.11	3.88	3.58	-0.30	1.02	1.77	0.75
Plantations	4.13	4.45	0.33	2.79	5.76	**2.97**	15.39	13.32	**-2.07**
Fallow land	--	1.35	1.35	0.87	0.64	-0.22	0.92	0.58	-0.34
Scrub Land	71.69	71.95	0.27	7.84	8.81	0.97	15.67	16.80	1.13
Wasteland	1.68	0.63	-1.05	7.17	5.48	-1.68	3.20	2.13	-1.08
Settlement	0.12	0.12	0.00	3.35	3.38	0.02	1.15	1.13	-0.02
Waterbody	2.09	2.09	0.00	1.51	1.51	0.00	5.18	5.19	0.01

The increase in the extent of cropped area is observed to be significant in Mansur micro-watershed. Similarly, increase in plantations is also observed in Baradi and Boothappankatte micro-watershed respectively. The scrubland, fallow and other wastelands have decreased in Mansur, Baradi and VK gudda micro-watersheds respectively.

7.8.3 Runoff Analysis – Potential zones

It is observed that action plan Implementation has resulted in changes in land use and land cover. Runoff potential is computed using both pre and post-treatment images based on the input GIS layers, as detailed above and the outcome is presented in Fig. 7.41. It is observed that many areas with very high runoff potential have transformed to low and medium runoff potential due to changes in LULC. Most of the northern portions of the micro-watershed fall under low and medium runoff potential category. This also provides a means to record the impacts due to watershed interventions.

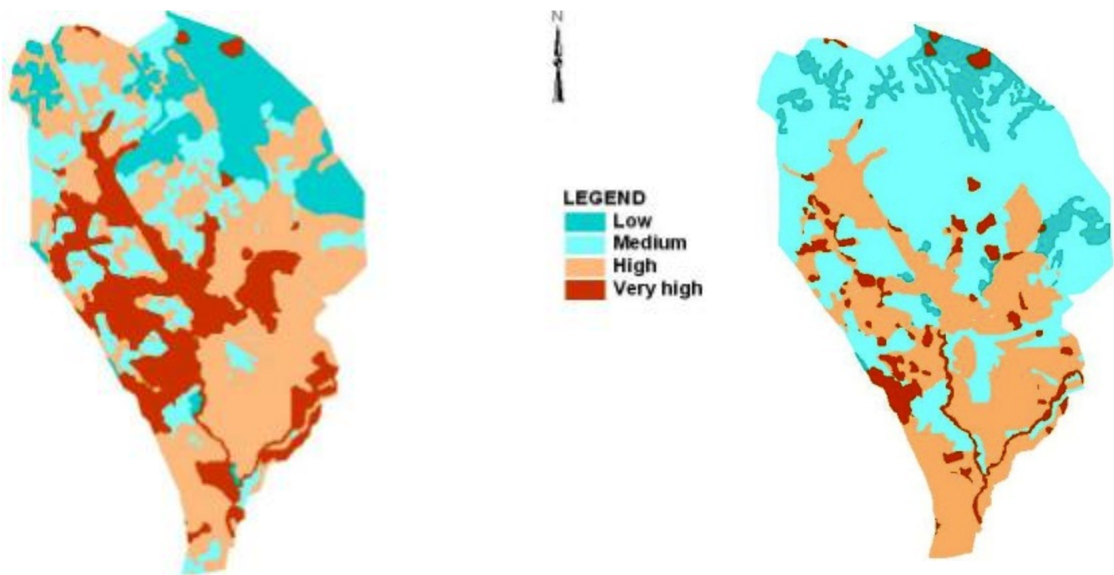


Figure 7.41: Runoff Potential based on CN for the Pre and Post-treatment periods

7.8.4 Runoff Analysis - Impact due to Agro-Climatic Conditions

A comparative analysis of runoff and infiltration with respect to different agro-climatic zones is done to study the impacts. The computation has resulted in runoff and infiltration from the respective micro-watersheds with respect to agro-climatic zones. It is observed that, the rainfall and the runoff are higher in NTZ as compared to CDZ and EDZ. However, it is seen that there is an overall increase in infiltration, as shown in Fig 7.42, and reduction in runoff in all micro-watersheds irrespective of agro-climatic zones.

7.8.5 Runoff Analysis - Impact on Infiltration

The infiltration 'S' has increased consistently in all agro-climatic regions with treatment (Fig 7.42). The average increase is about 18 mm. The least increase is in Mansur micro-watershed and the maximum in VK gudda.

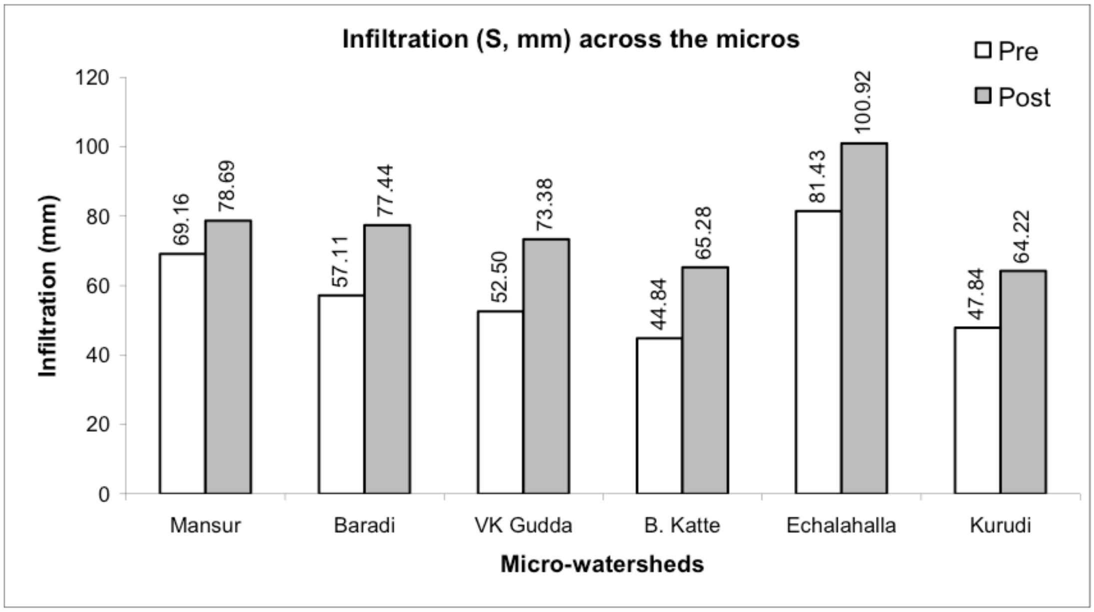


Fig. 7.42 Changes in the Infiltration value across the micro-watersheds

7.8.6 Runoff Analysis – Quantitative changes

Pre and post treatment runoff depth information in different micro-watersheds are presented in Fig. 7.43. It can be seen that, on an average, the runoff depth has decreased by about 16 mm, with Mansur recording the least decrease and Boothappanakatte the highest.

The estimated runoff volume has decreased across different agroclimatic zones. The details are summarized in Table 7.10. The change translates into an average reduction of about 180 cu. m / ha across different agro-climatic zones. Runoff, measured as percent of rainfall, has shown a fairly good decrease in Kurudi (4%) as compared to VK gudda (3.7%) and Boothappanakatte (3.1%). The least decrease is observed in Mansur (1.3%) and Echalahalla (2.8%) respectively.

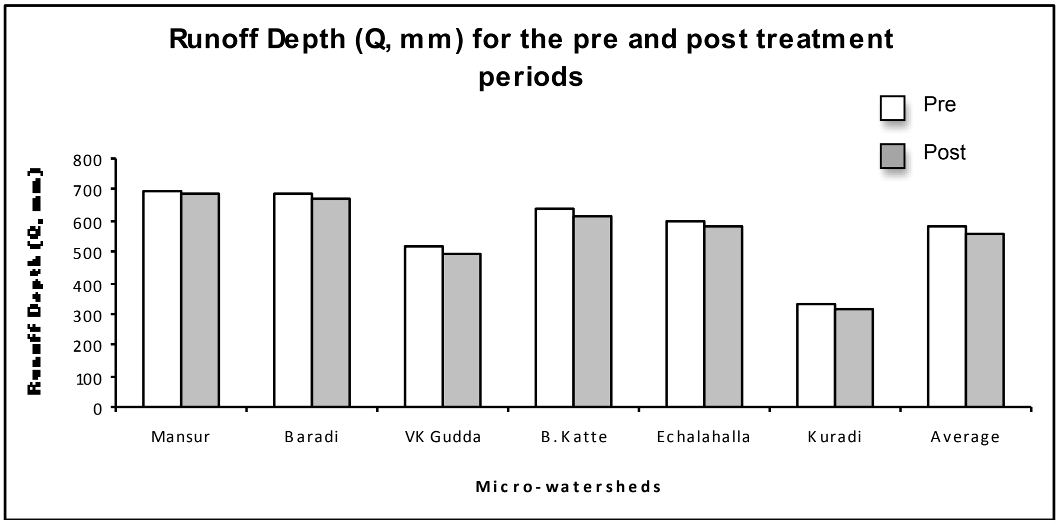


Fig. 7.43 Changes in Runoff Depth (Q, mm) across the micro-watersheds

Table 7.10 Changes in Runoff depth (Q) and volume (cu. m) across the micro-watersheds

MWS	Area (ha)	Rainfall (mm)	Total Rainfall (cu.m)	Runoff vol. (cu.m)				Runoff (% Rainfall)	
				Pre	Post	Change	Change /ha	Pre	Post
Mansur	790	772	6098800	5489035.30	5411407.60	-77627.70	- 98.26	90.00	88.73
Baradi	879	753	6618870	6052355.40	5866735.20	-185620.20	-211.17	91.44	88.64
Venukalgudda	870	573	4985100	4475965.60	4293177.70	-182787.90	-210.10	89.79	86.12
Boothappana-katte	625	689	4306250	3987289.40	3852560.60	-134728.80	-215.57	92.59	89.46
Echalahalla	898	689	6187220	5388714.80	5218500.70	-170214.10	-189.55	87.09	84.34
Kurudi	656	386	2532160	2190974.40	2088441.60	-102532.80	-156.30	86.53	82.48
Average	**786.33**	**643.67**	**5121400**	**4597389.15**	**4455137.23**	**-142251.92**	**-180.16**	**89.57**	**86.63**

The above analysis clearly shows the Agro-climatic zone wise impacts on the runoff parameters, which is presented in Table 7.11. The table highlights major types of activities taken up and its impact on land use and land cover. Correspondingly, the CN and Runoff details provide details on the correlation of activities against the impacts at field level. The soil types are different and so is the climatic variability across different agro-climatic zones. Within NTZ and amongst 2 micro-watersheds, there is relatively large difference between CN and Runoff. While Baradi has invested on Horticulture and forestry, in addition to field bunds, the same is not observed in Mansur. Mansur farmers have invested more on bunds and drainage line treatments. The difference in impact may be due to types of activities chosen for implementation as part of action plan. Hence, remote sensing, GIS tools and empirical model based runoff and infiltration acts as good indicative combination of tools for measuring impact due to watershed interventions.

Table 7.11 Summary of the Runoff and SCS-CN estimation - Agro-climatic zone wise.

Agro-climatic Zones	District / Watershed	Major Activities taken up	Impact		
			Land Use	CN	Runoff (Cu. m/ha)
North-Transition Zone	Dharwad / Mansur	Bunding, Drainage Line treatment	Increased Agricultural. Area, decrease in wastelands	-1.91	-98.26
	Haveri / Baradi	Bunding, Horticulture, Forestry	Increased Agri. area, Increase in Plantations, decrease in wastelands	-5.01	-211.17
Central Dry Zone	Chitradurga / VK Gudda	Bunding, Drainage line treatment, Horticulture, Agro-forestry	Increased Agri. Area, reduced fallow land	-5.28	-210.10
Eastern Dry Zone	Tumkur/ B.Katte	Bunding, land leveling, Drainage line treatment, Horti., forestry	Increased Plantations	-5.44	-215.57
	Tumkur/ Echalahalla	Bunding, Drainage line treatment, Forestry, Horticulture	Increased Plantation Area	-4.16	-189.55
	Kolar / Kurudi	Bunding, Farm ponds, Horti., Forestry	Increased Agri. Area, decrease in wastelands	-4.34	-156.30

7.9.7 Runoff Analysis - Salient findings

The study has shown that the investments and treatments carried out in the watersheds have produced noticeable changes in the land use and land cover of the watersheds and in turn resulted in reduced runoff and increased infiltration. This corroborates with the observations made through MIS database that more than 50% of the investments are done in soil and water conservation. In addition to the conservation, the general trend in investment also shows increased agriculture, biomass and vegetation cover in all micro-watersheds.

The Curve number method is chosen in the study as it helps to overcome the limitation on lack of field data on runoff and infiltration at micro-watershed level. The decrease in CN value represents percent decrease in the runoff potential as a function of soil and land use. The changes in the CN can therefore be directly linked to the soil and land use of the area under study. Least CN variation observed in Mansur area may be due to the predominant presence of black cotton soil and increased agriculture activities. However, the decrease in runoff as observed in other micro-watersheds, may be due to a greater shift towards plantations, conservation measures and also the gravelly and sandy nature of the soil, which allows higher percolation or infiltration. However, Mansur micro-watershed depicts relatively less infiltration rates and the reason could be due to low variation in runoff depth and volume observed. Hence, the SCS-CN method brings out positive impacts due to development in the hydrological domain, which is an important observation for further sustenance.

The advantage of using SCS CN method is its repeatability at frequent intervals to assess the impacts on hydrological parameters of the micro-watersheds with minimal geospatial updates.

7.10 Results from sample field data analysis

The sample field data, collected on various aspects of watershed development, are systematically organized in time scale and analysed to bring out specific impacts.

7.11 Agricultural Impacts

Agriculture is one of the major sectors that directly gets addressed as part of developmental activities in a watershed. Depending on the type of interventions and conservation measures adopted, the changes are expected to occur with regard to aspects. The impact on agriculture sector is analysed here.

7.11.1 Crop Yield

Crop yield is one of the parameters examined, agro-climatic Zones wise, considering some of the major crops grown in the areas, namely, Ragi, Jowar, Maize, Cotton, Groundnut and Sunflower. A comparative analysis is done using data from treated and control (untreated) areas of implementation. The estimates drawn from pre and post treatment areas are compared with that of control areas to analyse the actual impacts due to development. The result shows an increase in average crop yield (quintals/acre) for major crops in all three agro-climatic zones (Table 7.12).

The impact assessment with "control areas" strategy, adopted in the study, provides information for not only before-after scenario, but also enables evaluation of with and without treatment scenario. This helps in eliminating the bias in estimation due to variable weather conditions like rainfall, sunny-days, etc., in the watersheds during baseline and post-treatment periods, as corresponding control areas are also evaluated under similar conditions.

The average increase in crop yield of watersheds taken up in both phases is 19.83% and 17.16% respectively as compared to the control areas. Similarly, the treated areas in phase 1 shows an average increase in yield of 35% with respect to baseline as compared to only 15.16% in the control areas, while for Phase 2 it is observed to be 38.6% as compared to 21.43% in the control areas.

Table 7.12 Agro climatic zone wise crop yields (in quintals / acre)

Zone	Crops	Phase – I							Phase – II						
		Treated Area			Control			A-B	Treated Area			Control			P-Q
		Baseline (T1)	(T2)	((T2-T1)/ T2)*100 (A)	Baseline (T1)	(T2)	((T2-T1)/ T2)*100 (B)		Baseline (T1)	(T2)	((T2-T1)/ T2)*100 (P)	Baseline (T1)	(T2)	((T2-T1)/ T2)*100 (Q)	
CDZ	Ragi	2.8	5.2	46.2	3	4.6	34.8	11.4	3.7	6.8	45.6	2.5	3.7	32.4	13.2
	Jowar	3.7	5.3	30.2	4.1	4.9	16.3	13.9	4.2	6.4	34.4	4.9	5.5	10.9	23.5
	Maize	9.6	13	26.2	7.8	8.4	7.1	19.1	7.2	11.6	37.9	6.5	8.6	24.4	13.5
	Cotton	1.9	3.3	42.4	1.6	1.8	11.1	31.3	1.5	2.2	31.8	0.9	1.2	25.0	6.8
	Ground Nut	3.1	4.8	35.4	2.3	2.8	17.9	17.5	2.8	7.4	62.2	2.5	3.2	21.9	40.3
	Sunflower	3.1	4.8	35.4	2.4	2.9	17.2	18.2	2.8	3.5	20.0	3.2	3.5	8.6	11.4
	Average	**4.0**	**6.1**	**36.0**	**3.5**	**4.2**	**17.4**	**18.6**	**3.7**	**6.3**	**38.6**	**3.4**	**4.3**	**20.5**	**18.1**
EDZ	Ragi	3.1	5.3	41.8	3.9	4.8	18.8	23.1	5.5	7	21.4	4.7	5.2	10.6	10.8
	Jowar	3.8	5.8	34.5	4.1	4.6	10.9	23.6	4.3	8	46.3	4.2	5.4	28.6	17.7
	Maize	12.5	16.6	24.6	10.2	10.8	5.6	19.0	8.5	11	22.7	8.5	9.2	8.2	14.5
	Cotton	2.3	3.4	33.8	1.9	2.3	17.4	16.4	0	0	0.0	0	0	0.0	0.0
	Ground Nut	3.5	5.2	32.6	2.8	3.2	12.5	20.1	3.8	7.8	51.3	3.5	4.4	25.7	25.6
	Sunflower	3.6	5.2	30.8	2.8	3.2	12.5	18.3	1.7	2.8	39.3	1.8	2.2	22.2	17.1
	Average	**4.8**	**6.9**	**33.0**	**4.3**	**4.8**	**12.9**	**20.1**	**4.8**	**7.3**	**36.2**	**4.5**	**5.3**	**19.1**	**17.1**
NTZ	Ragi	3.1	4.8	35.4	2.8	3.5	20.0	15.4	2.5	4.2	40.5	3.1	3.8	22.6	17.9
	Jowar	4	6.1	34.4	4.6	5.1	9.8	24.6	5.7	7.2	20.8	5.4	5.9	9.3	11.6
	Maize	12.5	16.8	25.6	9.6	10.2	5.9	19.7	8.5	13.7	38.0	8.2	10	22.0	16.0
	Cotton	2.2	3.3	33.3	1.5	1.9	21.1	12.2	2	4.2	52.4	1.8	2.6	44.4	7.9
	Ground Nut	3.1	5.2	40.4	2.9	3.3	12.1	28.3	2	4.4	54.5	2.8	3.5	25.0	29.5
	Sunflower	2.6	4.9	46.9	2.8	3.6	22.2	24.7	1.5	2.5	40.0	1.2	1.5	25.0	15.0
	Average	**4.6**	**6.9**	**36.0**	**4.0**	**4.6**	**15.2**	**20.8**	**3.7**	**6.0**	**41.0**	**3.8**	**4.6**	**24.7**	**16.3**

The comparison amongst agro-climatic zones shows that reasonable increase in crop yield is observed in all regions. For example, cotton crop in CDZ, ragi and jowar in EDZ and groundnut, sunflower and jowar in NTZ are significant in phase 1, while groundnut and jowar in CDZ, groundnut in both EDZ and NTZ are significant in phase 2 implementations. It is inferred that the dry-lands selected for developmental activities have provided consistently better yield in both phases.

7.11.2 Cropping Intensity

It is a common phenomenon that the farming activities in rain fed areas are mostly confined to kharif season (rainy or monsoon) only, particularly the regions considered under the study. Different conservation measures, such as, farm ponds, nala bunds, check dams, recharge pits, field bunds, greening/ plantations, varieties of restoration works etc., have resulted in improved local conditions for farming activities. With the improvement in field conditions, the local community has further intensified the field activities.

On an average, the field data pertaining to Baseline, Midterm and Post-treatment periods are analysed and the outcome shows that there is a positive trend with respect to the crop intensification (Table 7.13).

Table 7.13 Cropping Intensity (Average Area) across Agro-climatic zones

Zone	Village	Period	Kharif (ha)	Rabi (ha)	Summer (ha)	Gross Crop Area (ha)	Crop Intensity (%)
CDZ	Control	Baseline	120.0	45.0	0.0	165.0	**137.5**
		Midterm	108.0	38.2	0.0	146.2	**135.4**
		Post Trt	112.0	43.0	0.0	155.0	**138.4**
	Treated	Baseline	460.9	205.2	20.5	686.6	**149.0**
		Midterm	560.1	238.6	45.6	844.3	**150.7**
		Post Trt	580.0	268.4	52.2	900.6	**155.3**
EDZ	Control	Baseline	139.3	22.9	4.0	166.2	**119.3**
		Midterm	143.8	25.1	0.0	168.9	**117.4**
		Post Trt	153.9	28.2	0.0	182.0	**118.3**
	Treated	Baseline	694.7	102.5	5.0	802.2	**115.5**
		Midterm	719.0	177.2	4.0	900.2	**125.2**
		Post Trt	712.3	201.3	14.5	928.1	**130.3**
NTZ	Control	Baseline	109.0	26.4	0.0	135.4	**124.2**
		Midterm	60.0	14.8	0.0	74.8	**124.7**
		Post Trt	59.7	16.3	0.0	76.0	**127.2**
	Treated	Baseline	653.8	186.3	1.5	841.6	**128.7**
		Midterm	806.0	237.0	11.9	1054.9	**130.9**
		Post Trt	855.5	290.9	15.4	1161.8	**135.8**
Over all	Control	Baseline	368.3	94.2	4.0	466.6	**126.7**
		Midterm	311.8	78.1	0.0	389.9	**125.0**
		Post Trt	325.6	87.4	0.0	413.0	**126.9**
	Treated	Baseline	1,809.4	494.0	27.0	2,330.4	**128.8**
		Midterm	2,085.1	652.8	61.5	2,799.4	**134.3**
		Post Trt	2,147.8	960.5	82.1	3,190.4	**148.5**

Note: *Crop Intensity = (Gross Crop Area/ Area under Kharif) * 100*

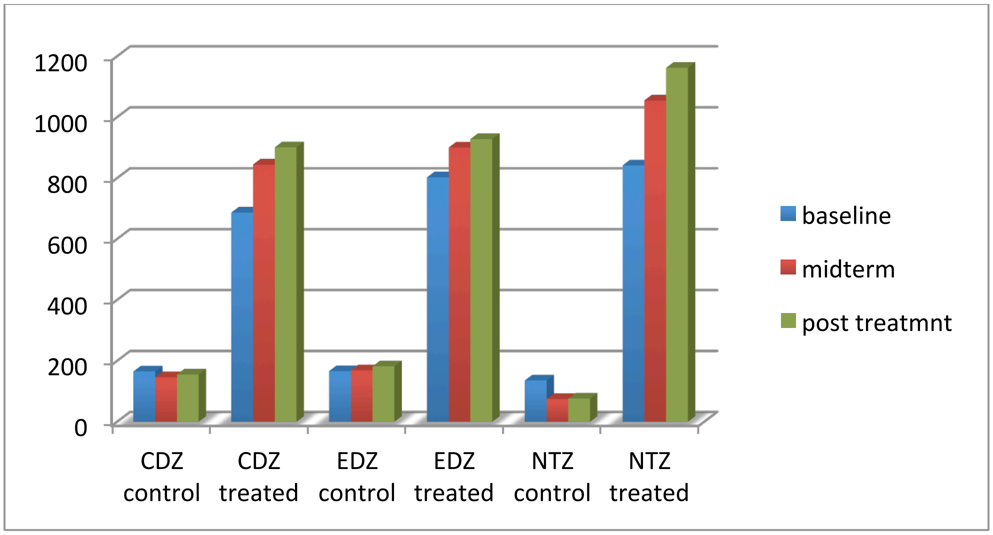


Fig. 7.44 Temporal comparison of Gross Cropped area

It can be seen from Table 7.13 and the depiction in Fig 7.44 that there is a significant increase in the gross cropped area amongst treated watersheds as compared to the control areas, particularly in NTZ. It is seen that there is a consistent increase in cropping intensity amongst all Agro-climatic zones. It is observed that cropping activities are taken up in the rabbi season also, though to a limited extent, thereby marginally improving the cropping intensity. The baseline versus post implementation period data in the treated areas also shows a significant improvement in the gross-cropped area. This clearly shows the impact on cropping intensity due to developmental activities in watersheds.

Thus, on an average, an increase in the cropping intensity is seen to be ranging from 129% to 149% with an increase by about 20% with respect to the baseline (Table 7.13), whereas in the control areas, there is no significant change in the cropping intensity.

7.12 Common Property Resources (CPRs)

CPRs development and maintenance is very important from the view-point of integrated holistic development of all village resources. CPRs are basically Government lands, like, community forests or Gomal land or any other form of land used for the community purposes. Village community is encouraged to develop such areas and also evolve a mechanism to share the produce equitably amongst poorer sections, particularly the marginal or landless farmers. Hence, the CPRs assume unique importance for overall development of watersheds and to practice equity and inclusiveness.

In order to evaluate the performance of CPR development, sample field data is collected and analysed. The result is presented in Table 7.14 and Fig 7.45. There is a reduced dependency of the community on CPRs for fuel wood in the treated watersheds, that is, by 18.2% in Phase-I and 27.4% in Phase – II, irrespective of agro-climatic zones. Also, a marginal increase by 6.5% and 2.9% is observed in the control areas of phase-1 and phase-2 respectively. This has demonstrated a positive trend towards sustainability of common lands in the watersheds. It is primarily due to awareness building exercises, conducted as a part of development processes, for the locals to judiciously utilize CPRs in a sustainable manner.

The dependency on CPR lands for fodder is also found to have decreased by 36% in treated areas of phase-I and 27.6% in phase-II, while for control area there is an increase by 11.8% iand 12.0% in phase 1 and 2 respectively. The observations in the treated areas are significant, primarily due to increase in fodder yield, implementation of watch and ward by community and also availability of fodder in their own private lands. This not only helps in optimum utilization of common property resources but also helps in biomass generation and ecological conservation

Table 7.14 Fuel wood and Fodder dependency in CPRs (in %)

Phase	Sample collection	Livelihood	CDZ		EDZ		NTZ		Overall	
			Control	Treated	Control	Treated	Control	Treated	Control	Treated
Phase I	Baseline-T1	Fuel wood	72.1	68	63	74	61.2	58.3	65.4	66.8
		Fodder	32.2	35.2	31	32.3	41.1	27.8	34.8	31.8
	Midterm-T2	Fuel wood	74.8	65.1	60	70.1	62.8	56	65.9	63.7
		Fodder	35	32.4	33	27	37.6	26.4	35.2	28.6
	Post Treatment -T3	Fuel wood	81	54.2	65	65.9	64	49.3	70.0	56.5
		Fodder	39	28	38	21	41.2	21.1	39.4	23.4
	((T3-T1)/T3)*100	Fuel wood	**11.0**	**-25.5**	**3.1**	**-12.3**	**4.4**	**-18.3**	**6.5**	**-18.2**
		Fodder	**17.4**	**-25.7**	**18.4**	**-53.8**	**0.2**	**-31.8**	**11.8**	**-35.9**
Phase II	Baseline-T1	Fuel wood	77.2	40	65.4	65.6	41.8	31	61.5	45.5
		Fodder	16.5	22.2	13.35	27.8	32.7	23.5	20.9	24.5
	Midterm-T2	Fuel wood	79.2	36.6	66.3	55.2	43.3	28.2	62.9	40.0
		Fodder	20.5	20.6	16.1	24.2	36.2	20.1	24.3	21.6
	Post Treatment -T3	Fuel wood	80.1	34.6	64.7	45.9	45.2	26.7	63.3	35.7
		Fodder	21	19.3	15.4	20.7	34.7	17.6	23.7	19.2
	((T3-T1)/T3)*100	Fuel wood	**3.6**	**-15.6**	**-1.1**	**-42.9**	**7.5**	**-16.1**	**2.9**	**-27.4**
		Fodder	**21.4**	**-15.0**	**13.3**	**-34.3**	**5.8**	**-33.5**	**12.0**	**-27.6**

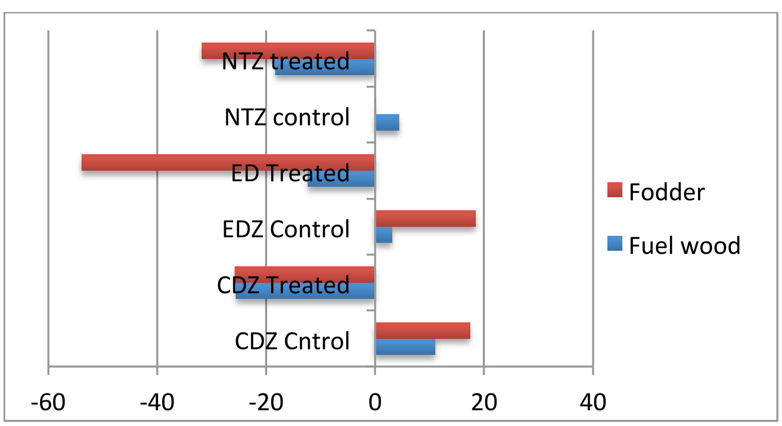


Fig. 7.45 Use of Fuel wood and fodder as CPR

7.13 Socio-Economic Analysis

Community participation in the process of watershed development is one of the basic requirements for achieving set goals. In addition, transparency and social Inclusiveness are the other two important elements. These are amicably addressed as a part of societal development. The community participation is facilitated through groups at village or micro-watershed level, ensuring collective participation. Some of the social aspects related to development of watersheds are addressed here.

7.13.1 Formation of Community Based Organizations (CBO)

The formation of CBOs and training of these communities through facilitators on social and natural resources conservation aspects have been attempted. The field level data collection has provided information on the peoples' participation or community based organizations, which are responsible for implementation of all activities carried out as a part of watershed development. The total number of member in Self Help Groups (SHGs), User Groups (UGs) and Watershed Committees (WCs) formed during the 2 phases are 2315, 1160, and 254 respectively. Table 7.15 gives details of all phases.

Table 7.15 CBOs formed during 3 phases of implementation

District	Self Help Groups	Area Groups	Watershed Societies
Kolar	1774	1205	211
Tumkur	1816	1187	202
Chitradurga	1173	787	131
Haveri	1107	719	118
Dharwad	778	496	80
Total	**6648**	**4394**	**742**

7.13.2 Self Help Groups (SHGs)

The SHGs, formed as a part of the watershed development, are sustaining and carrying out their activities effectively even after implementation of developmental activities. They are basically social affinity groups formed more on social affiliations and social bondages. These are mostly women groups who are landless or coming from poorer sections of the society and marginal farmers' family. The economic super structure is built on the social foundation through income generation activities along with financial linkages, particularly the micro credits schemes at local level. Thus the main agenda for SHGs is to pursue long-term alternative livelihood options, rather than limited short-term gains.

About 60% of SHGs formed, belong to landless category. Besides, 90% of these SHGs are Women groups who are involved actively in development. 100 % of male SHGs, comprising of landless labourers category, have participated actively in the natural resources assets building. Thus, active involvement of all sectors of the society is observed in these watersheds, which is a positive indicator for comprehensive watershed development.

7.13.3 Household income

Sample data collection with respect to village families to assess household income is done at various stages of implementation to evaluate the impact of development on their livelihood. It is found that the average annual household income increased by about 20.39% with reference to the baseline data in phase 1 watersheds, while the increase is observed to be 19.27% in phase 2 (Table 7.16). The table highlights different categories of farmers' income at various stages of developmental processes, taken up in phase1, 2 across the agro-climatic zones. Significant increase in household income, during midterm and post treatment period, is observed amongst different land holding classes and across different agro-climatic zone, as compared to baseline figures. The positive trend observed in their earnings is due to all-round development in all sectors including income generation activities.

Employment opportunities created during the implementation of the programme have become very beneficial for landless and vulnerable groups in the watershed. As a result, significant increase in the income levels of this class of people has been observed. The increase in income is about 2.5 times on an average, particularly amongst the landless category. Also, increase of income by about 1.7 times for the marginal farmers and 1.8 times for small farmers are observed, which are also a positive indicators for livelihood development in the villages. Fig 7.46 gives graphic presentation on the income levels of different categories of farmers at midterm and post treatment of watersheds with respect to the baseline figures. This clearly establishes the increase in income levels of the community because of the developments that have taken place in the watersheds.

Table 7.16 Average of annual income (Rs)

Agro climatic zone	Land Holding classes	Phase - I Treated area					Phase - II Treated area				
		Baseline (T1)	Midterm (T2)	Post Treatmentt. (T3)	(T2-T1)/ T2*100	(T3-T2)/ T3*100	Baseline (T1)	Midterm (T2)	Post Treatmentt. (T3)	(T2-T1)/ T2*100	(T3-T1)/ T3*100
Central Dry Zone	**LL**	5,320.00	9,053.00	11,006.56	41.23	51.67	9,100.00	16,250.00	20,950.00	44.00	56.56
	MF	7,750.00	11,625.00	14,608.77	33.33	46.95	20,253.00	33,333.33	40,961.11	39.24	50.56
	SF	11,463.64	18,759.00	23,538.46	38.89	51.30	25,700.00	44,435.00	56,125.00	42.16	54.21
	BF	16,796.67	27,160.00	36,504.24	38.16	53.99	42,200.00	80,204.55	110,711.36	47.38	61.88
		10,332.58	**16,649.25**	**21,414.51**	**37.94**	**51.75**	**24,313.25**	**43,555.72**	**57,186.87**	**44.18**	**57.48**
Eastern Dry Zone	**LL**	4,752.07	9,296.55	11,592.00	48.88	59.01	12,114.00	19,600.00	25,214.29	38.19	51.96
	MF	10,003.33	13,460.42	16,658.66	25.68	39.95	14,089.00	21,987.98	29,341.79	35.92	51.98
	SF	14,795.95	21,022.97	28,254.08	29.62	47.63	20,055.00	36,048.15	44,930.19	44.37	55.36
	BF	20,326.32	37,515.09	57,889.12	45.82	64.89	37,022.00	64,548.48	78,321.21	42.64	52.73
		12,469.42	**20,323.76**	**31,477.89**	**38.65**	**60.39**	**20,820.00**	**35,546.15**	**44,451.87**	**41.43**	**53.16**
Northern Transitional Zone	**LL**	7,575.00	14,836.67	21,002.30	48.94	63.93	14,104.00	27,880.56	40,283.33	49.41	64.99
	MF	10,750.00	18,970.00	25,859.09	43.33	58.43	19,064.00	35,330.53	41,030.00	46.04	53.54
	SF	14,944.57	29,106.18	36,464.64	48.65	59.02	25,246.00	44,627.50	56,500.00	43.43	55.32
	BF	21,507.00	40,604.31	77,633.13	47.03	72.30	83,666.00	166,136.55	220,622.41	49.64	62.08
		13,694.14	**25,879.29**	**41,108.84**	**47.08**	**66.69**	**35,520.00**	**68,493.78**	**89,608.94**	**48.14**	**60.36**
Overall	**LL**	5,882.36	11,062.07	14,533.62	46.82	59.53	11,772.67	21,243.52	28,815.87	44.58	59.15
	MF	9,501.11	14,685.14	19,042.18	35.30	50.10	17,802.00	30,217.28	37,110.97	41.09	52.03
	SF	13,734.72	22,962.72	29,419.06	40.19	53.31	23,667.00	41,703.55	52,518.40	43.25	54.94
	BF	19,543.33	35,093.13	57,342.16	44.31	65.92	54,296.00	103,629.86	136,551.66	47.61	60.24
		12,165.38	**20,950.77**	**31,333.75**	**41.93**	**61.17**	**26,884.42**	**49,198.55**	**63,749.22**	**45.36**	**57.83**

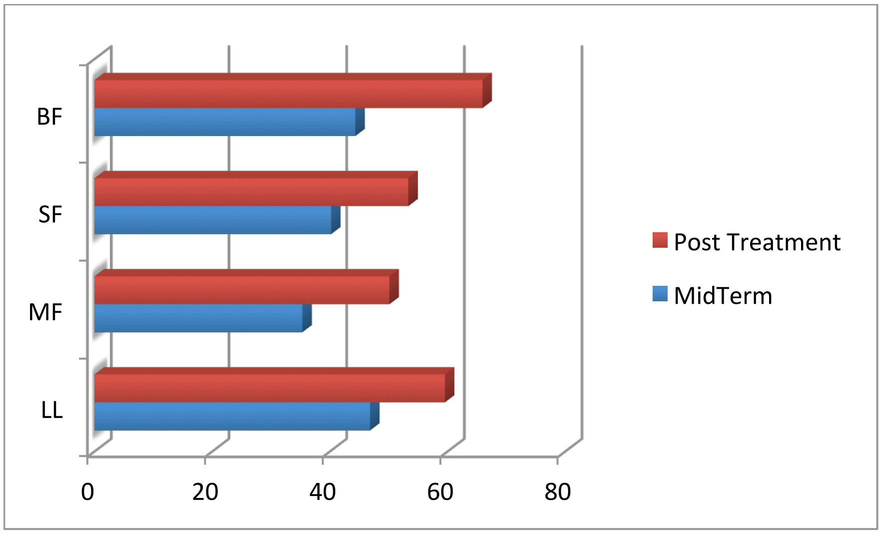


Figure - 7.46: Trend in Income levels at midterm and post treatment

7.13.4 Milk Yield

Livestock management is an important livelihood activity for majority of the landless village community. For successful development of watersheds it is necessary to improve natural resource conditions, provide alternative livelihoods and institutionalize a well-organized livestock management. Particularly, for optimal livestock management it is necessary to inculcate strategies to sustain common property resources to meet fodder requirements for the livestock. It is also observed that, with better income generation, the community is enabled to procure hybrid varieties of cows and buffaloes resulting in increased milk yield. The attempt made to assess the outcome of livestock management activities, across different agro-climatic zones, with milk yield as the indicator from both the phases of watershed development has clearly shown significant increase in milk production. The sample data collected and the analysis are given in Table 7.17.

The milk yield comparison with the baseline data, in phase 1 watersheds, shows an average increase of about 1.7 and 0.9 liter per animal per day for hybrid and local varieties respectively, while the control villages do not show similar trend during the same timeframe. Overall, there is an increase in the milk yield to the extent of 18 to 22% in the treated areas.

Table 7.17 Average Milk Yield (liter/animal/day) Phase - 1

Zone	Type	Live stock	Baseline (T1)		Midterm (T2)		Post treatment (T3)	
			Control	To be Treated	Control	Treated	Control	Treated
CDZ	Hybrid	Cow	6.5	6.0	6.2	7.8	6.5	7.6
	Local	Buffalo	1.5	1.8	1.3	2.0	1.4	2.4
		Cow	1.6	1.9	1.5	2.2	1.5	2.6
EDZ	Hybrid	Buffalo	6.2	6.2	6.4	8.6	6.6	7.9
		Cow	6.3	6.4	6.2	8.0	6.5	8.2
	Local	Buffalo	1.5	1.6	1.5	1.9	1.8	2.5
		Cow	1.8	1.5	1.5	2.0	1.8	2.6
NTZ	Hybrid	Cow	6.8	6.4	7.0	7.8	7.5	8.2
	Local	Buffalo	1.6	1.6	1.4	2.0	1.8	2.5
		Cow	1.8	1.5	1.2	2.2	1.9	2.8
Average	Hybrid		**6.5**	**6.3**	**6.5**	**8.1**	**6.8**	**8.0**
	Local		**1.6**	**1.7**	**1.4**	**2.1**	**1.7**	**2.6**
Average Increase	Hybrid	T3-T1	0.3	1.7	**T1 - Baseline, T3-Post treatment**			
	Local	T3-T1	0.1	0.9				

This can be attributed to the interventions in the common land development and capacity building towards procurement of better and hybrid varieties of cattle and also due to other livestock development plan. A progressive trend is observed in the milk yield across different agro-climatic zones.

Similar analysis is carried out for the sample data collected from different agro-climatic zones of phase 2 watersheds. The results are summarized in Table 7.18. The average milk yield per animal per day showed an increase by about 19.15% for hybrid variety and 34.5% for local species respectively, in the treated areas. At the same time, the control villages do not show similar trend during the same period.

Table 7.18 Average of Milk Yield (liter/animal/day) Phase - 2

Zone	Type	Live stock	Baseline		Midterm		Post treatment	
			Control	Treated	Control	Treated	Control	Treated
CDZ	Hybrid	Cow	6.5	6.8	6.2	7.6	6.5	9.5
	Local	Buffalo	1.5	1.9	1.7	2.1	2.2	3
		Cow	1.8	2	1.9	2.2	2.3	3.3
EDZ	Hybrid	Buffalo	-	8	-	8.6	-	9.4
		Cow	5.8	8.2	6.2	9.6	6.5	10.6
	Local	Buffalo	2	1.9	2.1	2.3	2.5	2.9
		Cow	1.8	1.8	2	2.2	2.2	2.6
NTZ	Hybrid	Cow	6.8	7.2	7	7.8	7.5	8.2
	Local	Buffalo	1.6	1.7	1.8	2.4	2.5	2.8
		Cow	1.8	1.8	2.1	2.6	2.4	3
Average	Hybrid		**6.4**	**7.6**	**6.5**	**8.4**	**6.8**	**9.4**
	Local		**1.8**	**1.9**	**1.9**	**2.3**	**2.4**	**2.9**
Average Increase	Hybrid	T3-T1	0.5	1.8	**T1 - Baseline, T3-Post treatment**			
	Local	T3-T1	0.6	1.0				

7.13.5 Livestock Management

The importance of livestock and its management received a special emphasis in phase 2 due to the feedback from implementation in phase 1 watersheds. The success is also due to well organized approach towards empowerment of local community on livestock management. Special training to youth volunteers to take care of basic health parameters of livestock at village level, activities like Village Based Trainings (VBT), Livestock health camps, etc., have helped in producing many local level youngsters to help in monitoring and management of livestock within the village community.

The Fodder mini kits and crop border plantation, fodder nurseries, silvi-pasture system are also promoted as a part of requirement for livestock management. A total of about 3,695 Ha of land is brought under improved fodder production and tree plantations. More than 1.1 lakh livestock population are treated in about 2300 animal health camps and about 65,000 people from the farming community and also the landless category went through VBT in livestock management.

An increase in livestock holdings is observed, with many rural folks opting for hybrid cows as a part of livestock management. The cattle population and the number of milk yielding cows and buffaloes increased significantly with time. An overall increase of about 17% in fodder production in private lands is observed due to increase in livestock. Notably, an impressive reduction in the mortality rate amongst livestock is also observed due to awareness of health management and help rendered by village volunteers. These observations and field realities have provided greater awareness and improvement in livestock management amongst local farming community and better milk production.

One of the inferences drawn from the above observations is that watershed development leads to multiple gains, especially when it is holistic and comprehensive in approach. For instance, the involvement of SHGs, landless and marginal farmers in a equitable manner, providing specific activities under watershed development has resulted in many gains. Particularly, employment in the form of labour, development of CPR areas and livestock management good examples of self employment but indirectly contributes to the overall well-being due to better management of CPR for fuel and fodder and self sustenance of livestock.

7.14 Benefits on account of technology usage

The various process-level interventions attempted at different stages of development have resulted in unique benefits from the programme. They are summarized here:

- High spatial resolution geospatial data created for study area served as the natural resources baseline. The data is used for comparison during plan implementation and also for impact evaluation.
- The geospatial databases also served the purpose of action plan preparation at micro-watershed level. All the GIS layers prepared and made available to micro-watersheds are used as input tool for training and capacity building at stakeholders' level, particularly the importance of soils, slopes, land use and other terrain features for plan preparation.

- IT solution with local language interface, accompanied with participatory GIS tools, has enabled total transparency in action plan preparation. The process also ensured that peoples' aspirations are properly documented as part of action plan.
- The participatory GIS tool for action plan preparation turned out to be input data for improved Participatory Rural Appraisal (PRA) process at field level. It is felt that PRA is one of the most important processes at field level for effective action plan preparation and to ensure sustainability of actions.
- The action plan reports and GIS-based maps generated from these packages, in local language, are popular amongst the stakeholders. The approved document is a commitment for development in the private and common land. The community used this input to followup with the implementing authorities for actual field implementations.
- "Spin-off effect from Participatory MIS" - Wall paintings in each of these micro-watersheds are special features to ensure transparency in implementation. As a part of self-monitoring of action plan implementation, the action plan details were painted on walls, highlighting farmer's name, list of activities, funds sanctioned or released, status of implementation etc. Activity status and details are regularly updated for the entire village to bring about awareness of the field-happenings. Inputs for wall paintings are drawn from the approved action plan.
- Approved action plan report is an important input for the web-based MIS. The logical action plan and target-fixing exercise are done based on this input.. The implementation authorities are able to fix targets, allocate estimated funds, and track the implementation based on the targets through regular WebMIS updates.
- The online Web-based MIS system is accessible from all micro-watersheds to provide weekly inputs on the various implementation processes. The data-flow is regularly monitored at Sub-watersheds, Districts and at State level with respect to activities carried out and funds utilization. WebMIS ensures a common database

for generating all reports for all micro-watersheds, ensures paper-less reporting system and e-reporting.

- Random field observations carried out by a separate process monitoring team (field data collection team) effectively used the online WebMIS on a regular basis to plan their field strategies for monitoring. This enabled monitoring the quality of implementation at field level.
- The decision maker at State level use WebMIS inputs to conduct regular Audio-conferences on a weekly basis with corroborated field data. This helped in online monitoring of action plan implementation and quality aspects.
- Satellite images are randomly used at different points of time for tracking and monitoring of implementation. The method proved to be an effective mechanism to monitor large areas of implementation due to the synoptic viewing capability from space.
- As a part of post-treatment impact assessment, satellite images proved to be particularly useful for bringing out changes in land use and land cover due to various developmental activities.

While some of the major spin offs from the technology adaptation at various stages of watershed development processes are brought out, there are many other benefits that accrued at the grass root level. The mere fact that satellites from space are able to provide field status at any point of time made the local authorities, facilitators and farming community to be more vigilant in implementation. The entire reporting system and standards are proved to be more efficient than any other programmes. All stakeholders of the programme, at the end, felt that they got benefitted from such a system, which provided information concurrently.

CHAPTER 8

SUMMARY AND CONCLUSION

8.0 SUMMARY

The objective of the present study is to develop a better process based watershed development model with key features of participatory approach and technology inputs. Accordingly, the conventional method is analysed and an improved set of processes are defined and proposed for development. An optimum combination of participatory geomatics tools, which includes remote sensing data processing and geospatial technologies, information technology and web-based technology for concurrent monitoring software tools are designed and developed with appropriate blending of conventional methods. These technologies are systematically incorporated into the proposed process based watershed development model tested in its final form after successful testing under real life scenario (Fig. 8.1).

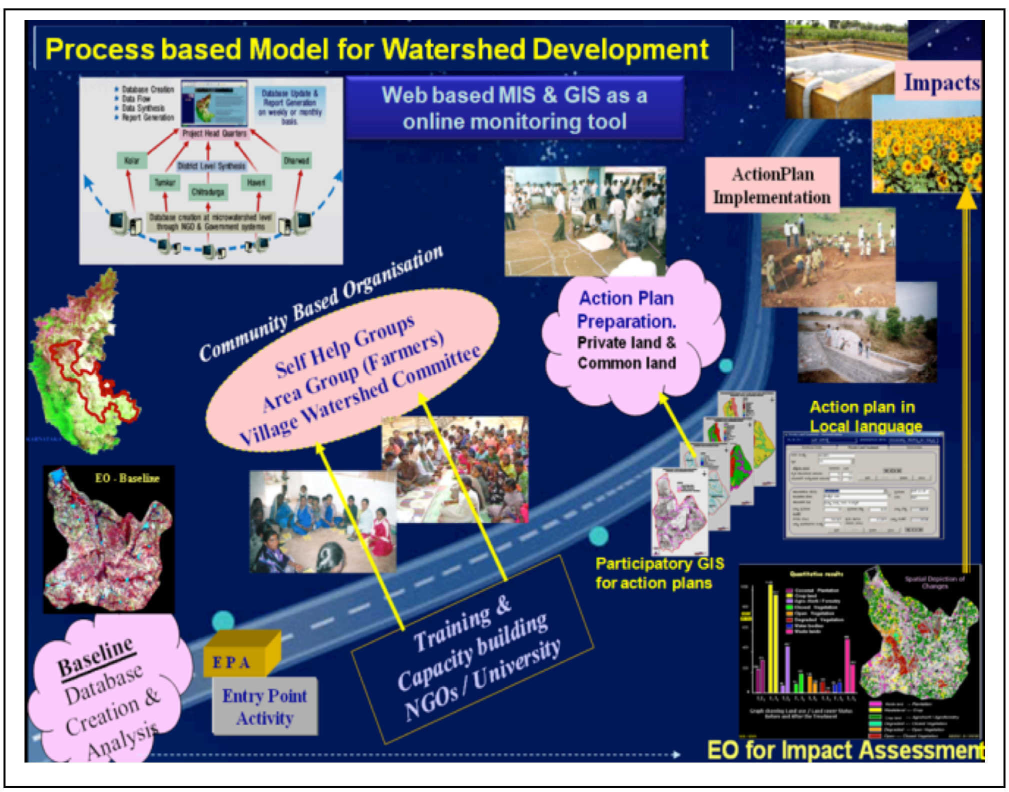


Fig. 8.1 Process based model for watershed development

The illustration shows the achievement of the present study in comparison with the proposed model as illustrated in Fig.3.3.

The new process based model is tested with one of the watershed development programme in Karnataka, India. The programme consists of 77 sub-watersheds with 742 micro-watersheds, spread across 5 rain fed districts and cuts across 3 major agro-climatic regions. The tools and technologies are programmatically deployed at the field level with required customization, including the concurrent monitoring tools as a part of testing the model for its performance. The outcome of such a model highlights many positive aspects of development, particularly with respect to the participatory methods, advantages of using technology as an intervention and importance of using process based approach for watershed development. The salient outcomes and benefits of such a model is brought out here and the conclusions specifically bring out major achievements and advantages of using such a model for development.

8.1 CONCLUSIONS

The proposed process based model with participatory methods and technology elements has been successfully implemented. The salient findings and conclusions on field-testing the model in a near real-time watershed development programme are presented here.

8.1.1 Conventional Watershed Development

- The suggested improvements and the innovative methods to the conventional watershed development procedure, with suitable and appropriate technology interventions, is found to give better results.
- The suggested technological interventions and participatory processes practiced in the implementation of the programme have resulted in bringing out many positive outcomes in the watershed as well as amongst village community.
- The systematic adaptation in terms of agro-climatic factors, scientific inputs for watershed delineation, customized solution in local context and other innovative methods have helped in obtaining anticipated results.
- It can be said that the proposed modifications and improvements on various components of the conventional approach are found to be effective. Hence, it can be said that the present model is a better one for adaptation in watershed

development and is found to be replicable irrespective of different agro-climatic regions and local conditions.

8.1.2 Geomatics solution

- Remote sensing data processing for value added product generation is attempted. Four major Image fusion methods are compared and it is found that Discrete Wavelet Transforms is the most suitable technique for different conditions and hence the same is adopted in the present study. The technique is extensively used in producing high quality fused products using IRS 1C, 1D Panchromatic and LISS 3 data at 5.8 m spatial resolution and CARTOSAT 1 and RESOURCESAT 1 LISS 4 data for 2.5 m spatial resolution products.

- These products are found to be very useful. The fusion technique adopted here is better suited for deriving high quality value data product for village community to utilize for planning.

- Large-scale mapping for generation of community level land use / land cover maps is also attempted. Three methods are considered that include digital classification using maximum likelihood, ANN classifiers and manual digital mapping on GIS domain.

  - Considering the challenges of ground truth sample labeling for supervised classification, a new hybrid method is proposed and developed as a part of ANN classifier. This semi-automatic object based ground truth sample labeling technique is successfully tested using RESOURCESAT LISS 4 (5.8 m spatial resolution) data and compared with maximum likelihood classifier with improved classification accuracy.

- The proposed method here is found to be very useful in efficient digital mapping of high-resolution data. The proposed hybrid classification technique, with ANN classifier, is particularly useful when the input data does not follow Gaussian distribution and hence maximum likelihood classifier proves to be inefficient. The proposed method, with improved ground trothing feature, is a good alternative for high-resolution mapping.

- The high-resolution satellite data and the GIS data are made available to all micro-watersheds. This has provided effective basic input for planning and decision-making, including meeting of the baseline data requirements. This is further found to be successful as a reference for the impact assessment, both in terms of qualitative and quantitative analysis. A GIS database repository created with a customized software tool that supports simple query and analysis for the implementing agency has become very useful tool for specific decision making.

8.1.3 Participatory methods

- Participatory MIS and GIS software tools are designed and developed for creation of micro-watershed level action plans. These tools are found to be successful for all micro-watersheds of the study area in adopting participatory approach.

- The success has been primarily due to the local language interface, depiction of stakeholders' fields with information of prospects and drawbacks. Expert's remedies at the field level for the drawbacks. It can also be attributed to ensured focus on their participation in planning and due considerations given to their aspirations. Online creation of action plan covering private and common land along with assured benefit from the plan. The criteria of equity and inclusiveness in plan preparation have specially made a positive impact on the poor and marginal farmers.

- The Geomatics and local MIS solution have successfully produced the much-needed systematic documentation of action plans. Geomatics tool has helped in guiding the people on various natural resources information at local level for decision-making. The participatory MIS has effectively provided online documentation of developmental plans.

- Participatory Geomatics solution, used at the stakeholder level, has resulted in unprecedented transparency in the entire process of planning and development. This has demonstrated the effective role of Geomatics as a technology intervention in the process based watershed development programme.

8.1.4 Online Monitoring Tool

- The Web-based MIS solution is successfully used for concurrent monitoring during the entire project lifecycle. This has helped the implementing agency to closely monitor the various investments made in the programme. The online data services have played a major role in the programme tracking on the basis of regular updates.

- The process monitoring teams have effectively used the online data, across the entire study area, for assessment of quality in implementation. The unique online analysis capabilities of the webMIS have helped managers in taking many management decisions during implementation.

8.1.5 Impact Assessment

- Remote sensing data is extensively used for impact assessment in the post-implementation scenario. The change detection analysis has demonstrated the effective assessment of land use / land cover transformations. Trends such as switchover from mono cropping to mixed cropping, single cropping to double cropping, reduction in wastelands and fallow lands, adaptation of agro-horticulture and agro-forestry are effectively demonstrated.

- The impact assessment carried out has successfully demonstrated the results, highlighting multi-tier concepts like agro-horticulture and agro-forestry effectively. The example of Mudiyanur micro-watershed of kolar district shows an increase of 13.8% and 2.0% in agro-horticulture and agro-forestry respectively. The results also show a decrease in fallow land by 12.7% as compared to pre-treatment.

8.1.6 Outcome Of Good Practices

- Online webMIS and remote sensing based monitoring have effectively served the entire process of implementation. This has facilitated the stakeholders with necessary updates on field activities. The implementing agency used the tool for tracking all developments and results of their investments. This has significantly contributed to the all-round development of selected watersheds.

- The MIS data shows that more than 50% of the community spending has been on soil and water conservation activities. Due to such an investment, significant positive trends are recorded both in runoff and infiltration computation in all the three agro-climatic regions. Six micro-watersheds selected across these regions have shown that infiltration has increased by 18 mm and the runoff has decreased by about 14,000 cu m per ha in a span of about 3 years. The results are encouraging, irrespective of agro-climatic conditions. It can be said that the model developed is highly replicable under different conditions.

- The crop yield assessment shows an average increase of about 18% across different agro-climatic zones with respect to control areas. The average increase in yield is about 36% in treated area as compared to an increase of about 18% in control area. This shows that the model has also given positive impacts in agricultural activity.
- The average crop intensity has shown an increase of 20% with respect to the baseline data in the treated areas. During the same period, the control area has not shown any significant change. This demonstrates the success of the model adopted for development.
- The dependency on Common Property Resources (CPR) for firewood has reduced by 23% in the treated area while in the control areas the dependency has increased by about 4%. Similarly, dependency on fodder has decreased on an average by 32% in the treated areas while in control area there is an increase by 12%. This is the result of training and capacity building initiated in the study area, as a part of participatory approach adopted in the model.

8.1.7 Socio-Economic Outcome

- A large number of Community Based Organizations (CBOs) have been formed with a series of training and capacity building on various aspects of watershed development. A total of 6648 Self Help Groups and 4394 User Groups are formed in the watersheds considered for implementation of the programme.
- Active participation of these groups in the natural resources development along with the technology inputs has resulted in efficient implementation of the programme. Participation of the community through CBOs in process based watershed development programme plays an important role in improving the socio-economic conditions of the society
- Employment opportunities have been increased considerably due to the treatment provided in the watersheds. The opportunities for the vulnerable groups have been increased significantly. The field sampling data shows an increase in income by about 2.5 times for landless, 1.7 and 1.8 times for the marginal and

small farmers respectively. This is another major outcome and it can be attributed to the new approach considered in the model and their successful implementation.

- Specific sensitization provided on the livestock development and optimal utilization of CPRs, have reflected on the livestock management and its impact. The impact is measured through the observations on the milk yield from the watersheds. There is an average increase in the milk yield to the tune of 18 to 22% in the treated areas. However, such a trend is not reflected in the control area. This demonstrates another self-employment opportunity created for the locals on account of the model adopted for watershed development.

- The training and capacity building programmes in the villages resulted in bringing awareness on the maintenance of good health of the livestock. About 2300 animal health camps organized in the watersheds have provided opportunity to treat about 1.1 lakh livestock population in a span of about 5 years. This has led to better management of livestock and hence proved to be a better livelihood alternative. Particularly, the small, marginal and landless poor in the society enjoyed direct benefit from effective livestock management.

Thus, it can be observed from above that an improvised process based model for watershed development is able to provide rich benefits not only to the landowners but also to those who are vulnerable and belong to economically weaker sections in the society. The objective of the proposed model of addressing an all-round development through a well orchestrated and designed watershed development programme can be considered as successfully achieved.

The model developed in the present study and tested in Karnataka, India has shown many positive results, such as, creation of a strong community based organizations, creation of employment opportunities, increase in farm output, improved land water resources status, increase in individual income level, availability of labour, better living conditions, improved livestock management. It has also provided sustainable alternative for landless poor.

The objective of the study has been to implement a watershed development model through participatory approach with the blend of technology and conventional methods.

While this is successfully achieved and demonstrated, it is also seen that the measures included in the development programme has reaches the common man in many aspects, addressing the basic needs and moving towards the “Social Well-Being” of the society.

The model has demonstrated an ideal way of implementing watershed development with participatory approach and geomatics tools. It can be said that the model has set new standards for implementing watershed development programme for comprehensively uplifting rural society.

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