CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Rainfed agriculture is the major future challenge for the country’s agricultural economy. Food grain production in the country stood at 210.4 million tons during 2004-05 from the net cultivated area of 142 Mha. It is estimated that nearly an area of 56 Mha (40%) is irrigated which contributes 58% of the total food production, whereas remaining 85 Mha i.e. 60% of the rainfed areas accounts for 40% of the production. At present rainfed areas contribute to the production of approximately 90% of oilseeds and pulses, 70% of coarse cereals and supports 66% of cattle and 40% of population.

India is home for 221 million out of 852 million hungry people in the world and has to take urgent step to meet the goal of halving the number of hungry people by 2015. Eighty per cent of the hungry people are in rural areas, 50% are small landholders, 22% are landless and 8% are pastoralists and forest dwellers (Sanchez et al. 2005). There is an urgent need to increase the agricultural productivity of food-insecure farmers through improving soil health, adopting improved and expanded small-scale water management schemes, improved access to better seeds, diversified farm enterprises and establishing the effective extension services. Rainfed agriculture in India occupies an important place in the developmental issues as 69% of 142 Mha arable land is rainfed, and productivity is low (< 1 ton/ha), although the potential is much high. In India, rainfed agriculture generates nearly half of the total value of agriculture output.

Emphasis is on spread of irrigation has led to enhancement of the irrigated area by one Mha every year. With current efforts, if optimally pursued it may take 20 years to bring additional 20 Mha area under irrigation and as such dryland / rainfed agriculture continue to be the main stay of Indian agriculture. Erratic rainfall, degraded land, extremely harsh climate and very low productivity along with very poor socio-economic condition of farmers in the rainfed areas are the major features of arid and semi-arid tracts of the country. Dry land areas also account for a significant proportion of the rural poor in the country. The poverty in

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this region is compounded by the severe resources degradation. Continued degradation of rainfed areas is an environmental and social hazard. Hence, comprehensive watershed development may be a long enduring answer to the sustainability of rainfed areas.

Dryland agriculture or rainfed farming is practiced on almost 63% of 144 Mha land under cultivation in India. The dictum that Indian Agriculture is a gamble with monsoon really applies to dryland agriculture. According to the Indian Agricultural Atlas (1971), dryland agriculture areas generally include the zones having an annual rainfall of less than or around 750 mm. These areas are impoverished, deficient in plant nutrients; suffer from various forms of land degradation. The crop production on these lands is dependent entirely on natural precipitation that is highly erratic in terms of spatial and temporal distribution during the crop-growing season. Dryland agriculture is also affected by the socio-economic conditions of smallholding, expensive credit, low fertilizer use and poor infrastructure.

Keeping in view the conservation, protection and improvement of available arable and non-arable land, action plans are generated and implemented jointly by the concerned sectors in an integrated approach from ridge to valley. The program is being implemented scientifically based on systematic assessment of physical capability, social acceptability, economic viability, technical feasibility and institutional sustainability.

The holistic approach starts with a base line survey of selected watersheds and preparation of development master plans. The watershed is divided into many sub-watersheds and action plans are generated. This is done for administrative convenience and systematic implementation of action plans in a phased manner.

The action plan suggests changes in cropping pattern, cropping intensity and crop husbandry practices, soil conservation measures required on private as well as public lands. Suitable measures are recommended for stabilization and improvement of drainage system, construction of water harvesting structure, wasteland reclamation to establish vegetal cover, agro-forestry and agro-
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horticulture development, etc. The goal is to sustain the agriculture production without land degradation.

Under the centrally sponsored schemes like National Watershed Development Project for Rainfed Areas (NWDPRA), Drought Prone Area Development Project (DPAP), Jawaharlal Rozgar Yojana (JRY) and other external funded projects, the Agricultural Department has accorded high priority to the sustainable integrated farming systems of rainfed areas on watershed basis. The development efforts are concentrated on both arable and non-arable lands including treatments of natural drainage lines. The watershed approach represents the principal vehicle for transfer of rainfed agriculture technology. The National agriculture policy seeks to promote the integrated, holistic and harmonious development of rainfed areas through the conservation of rainwater and soil and augmentation of biomass production through agro and farm forestry with the active involvement of the watershed community.

The emphasis is on food production, reduces regional disparity between irrigated and rainfed areas, increased employment opportunities, restoration of ecological balance and reduced need for migration within the watershed through integrated approach. The project aims at in-situ moisture conservation primarily through vegetative measures to conserve rainwater, control soil erosion and generate the green cover both on arable and non-arable lands. The scheme is implemented at the field level by an inter-disciplinary team of members from line departments of state government and the beneficiaries of the watersheds. Today the thrust of the watershed approach is on low cost and location specific technologies, which are more knowledge based and give room to local innovation rather than capital and chemical intensive programs.

Dryland farming areas largely constitute the overall production of coarse grains, pulses, oilseeds and cotton in the country. Millets like Bajra, Maize and Sorghum; pulses like Red gram and Green gram; fodder like Cowpea and some crop mixtures like Red gram with Sorghum or Green gram are popular cropping pattern. In certain areas where the soil is suitable, commercial crops like Cotton, Groundnut, Castor, Soybean, etc. are also grown. Mixed cropping is also a common practice to guard against wholesale crop loss. The yield and productivity
of crops in dryland areas are significantly lower as compared to irrigated crops. Major constraints and problems in these areas are:

i. Uncertain, erratic and uneven distribution of rainfall
ii. Degradation of forests and natural tree cover
iii. Low soil fertility and soil depth
iv. Shortage of drinking water and assured irrigation for crops
v. Considerable area under wastelands
vi. Cultivation of marginal lands due to population and animal pressure
vii. Lack of infrastructure and facilities
viii. Shortage of fuel wood and fodder
ix. Continuance of traditional varieties and management practices
x. Improper management of community lands
xi. Frequent occurrence of drought

1.2 OBJECTIVES OF WATERSHED DEVELOPMENT

The broad objectives of the Watershed Development are

i. Conservation, development and sustainable management of natural resources including their use.
ii. Enhancement of Agricultural Productivity and production in a sustainable manner.
iii. Restoration of ecological balance in the degraded and fragile rainfed ecosystems by greening these areas through appropriate mix of trees, shrubs and grasses.
iv. Reduction in regional disparity between irrigated and rainfed areas.
v. Creation of sustained employment opportunities for the rural community including the landless laborers.

To address the problems of dryland, watershed was considered an appropriate geo-hydrological unit in which rainfall occurring on the highest point of the area (ridgeline) drains at a common point. The Government of India has accorded high priority to this holistic approach for development of rainfed areas through National Watershed Development Project for Rainfed Areas (NWDPRA) and other
externally aided watershed development projects. So far, about 46 lakh hectares of area has been treated. However, studies show that, at the current pace of watershed management, it would take enormous time to cover all the rainfed areas of the country and involves the efforts of various departments and considerable budget.

1.3 WATERSHED DEVELOPMENT - A HOLISTIC APPROACH

Integrated watershed development program has been conceived and adopted for holistic development of rainfed farming in recent years. Watershed management is fast becoming a blue print for agricultural development in most parts of the country today. This program aims at conserving soil and moisture, as well as to put the lands to use according to their capabilities to improve the overall productivity of catchment. The major objective of the project is to increase / stabilize production of crops, forage, fruits, fuel and timber in rainfed areas by introduction of improved soil and moisture conservation measures, better crop and rangeland management practices, animal husbandry and afforestation. The ultimate goal of watershed management is to achieve and maintain a balance between resources development for welfare of the population and to safeguard resources for future exploitation to maintain ecological diversity - both for ethical reasons and as an assumed prerequisite for the survival of mankind.

1.4 ACTIVITIES OF WATERSHED DEVELOPMENT

The watershed development project is aimed at achieving the following specific objectives:

i. Treatment of non-arable lands for soil and moisture conservation and biomass production through afforestation, horticulture and pasture development.

ii. Treatment of arable lands for better in-situ soil and moisture conservation and to enhance production through cost effective, sustainable and replicable cropping techniques with minimum infrastructure and soil conservation measures.
iii. Adoption of alternate land use to prevent ploughing of steep slopes and thereby reducing runoff and soil erosion by taking up horticulture, silvi-culture and silvi-pasture.

iv. Development of water resources and improve recharge of underground aquifers.

v. To increase the average income of small and marginal farmers and landless families through increased casual employment on marketable surplus of agricultural and dairy produce and by growing cash crops like vegetables.

vi. To improve the social status and living standard of watershed inhabitants.

Under watershed development program, various soil and water conversation measures such as conservation of moisture, vegetative filter strips upstream of diversion drains, contour vegetation hedges supported by trenches / ridges or bunds with small cross-section on sloping areas have been performed. Gully control measures with vegetative support or supported with small structural measures wherever necessary, opening of contours dead furrows and contour cultivation has been done. Besides this to store excess run off water, water storage structure like small dugout structure and ponds of suitable dimensions have been constructed to provide life saving irrigation in Kharif and partial irrigation in Rabi to ensure reasonable good crops even when rains are not favorable.

Soil and water conservation program also includes dryland horticulture, grassland development, silvi-culture and agro-forestry which play significant role in controlling run off and restoring ecological balance as well as create potential to meet requirement of timber, fuel, fodder, fiber, grasses and fruits etc. It was envisaged that the program of National watershed development would have following benefits:

i. Drought proofing

ii. Erosion control

iii. Increase in agricultural production.

iv. Increased availability of fodder, fuel and timber.

v. Ground water recharge.
vi. Creation of durable assets
vii. Restoration of ecological balance
viii. Employment generation
ix. Ensuring desired cropping intensity in rainfed agriculture.
x. Protection of the tableland and stabilization of gullies.

1.5 ROLE OF RS & GIS IN WATERSHED MANAGEMENT

Watershed as a unit for developmental planning is the natural choice of present time. The sustainable development of natural resources in a watershed is based on maintaining the fragile balance between productivity functions and conservation practices through monitoring and identification of critical areas, existing agricultural practices, crop rotation, energy efficient farming methods and reclamation of under utilized lands. Watershed management is fast becoming the blue print for dry land agriculture development in our country. This programme aims at conserving soil and moisture, as well as to put the lands to use according to their capabilities to improve the overall productivity of the catchment. The major emphasis is on increase of food production, reduction in regional disparity between irrigated and dry land / rainfed areas, increasing employment opportunities and restoration of ecological balance within watershed through integrated approach. The goal of watershed development is to sustain the agriculture production without land degradation. Under watershed development, suitable measures are recommended for stabilization and improvement of drainage system, construction of soil and water harvesting structures, wasteland reclamation to establish vegetation cover, agro-forestry and agro-horticulture development etc.

Realizing the importance of dryland development both Government of India and Government of Karnataka have accorded high priority for development of rainfed areas through adoption of various watershed development projects such as DPAP, NWDPRA, JRY, Hill Area development Programme, Sujala - a World Bank Assisted concurrent Monitoring Programme etc..

As the watershed development project involves the efforts of various departments and considerable budget, we advocate use of remote sensing and GIS as useful
tools in prioritizing the watersheds, developing natural resources database and generating action plan maps in GIS environment and finally as a monitoring and evaluating tool. For effective planning and implementation of watershed development, information on nature, extent, magnitude and spatial distribution of land, including its potential and limitations and temporal behavior is paramount important. Remote sensing data hold great potential for deriving timely and reliable information.

With the launch of indigenous Indian Remote Sensing (IRS) satellites, satellite data is available from 1986 onwards. Currently, IRS 1A/1B, IRS P2, IRS-P3, IRS-1C/1D, Resourcesat, Cartosat 1 & 2, Landsat, spot satellite data are available. The spatial resolution has significantly improved and the spectral coverage increased to cover middle infrared, thermal and microwave wavelength regions and repetivity increased with multiple satellites. Microwave remote sensing is helping to see through clouds enabling monitoring through monsoon clouds. The availability of high-resolution data with the capability to provide unbiased, holistic and synoptic view has facilitated the generation of basic inputs required for taking up prioritization of watersheds, generation of natural resources database in GIS environment and action plans for watershed development and impact assessment and evaluation of implementation of watershed programmes. As demonstrated under many national level projects and other user-funded projects, the satellite data provides required / essential information on current land use / land cover, hydro-geomorphic conditions, soil characteristics, status of drainage and surface water bodies etc., which are vital for watershed management. The IRS 1C/1D provides multi-spectral LISS III data with 23m and PAN data with 5.8m resolution. The composite hybrid data of (LISS III + PAN) not only improves the identification of features but also helps in mapping at cadastral level providing detailed information on 1:12,500 scales. Currently Cartosat -1 satellite provides panchromatic data at 2.5m resolution and Cartosat - 2 satellite provides panchromatic data at better than 1m resolution. The hybrid data generated using Resourcesat LISS IV data and Cartosat data helps mapping at cadastral level providing detailed information on 1:4000 scale. Thus, the high-resolution data provides ample scope to map the natural resources data and monitor the
activities at farm level with frequent intervals for tracking implementation, apply mid-course corrections and assessing effectiveness of implementation.

Over exploitation of natural resources for meeting requirements of ever-growing population for food, fuel and fiber has lead to serious environmental degradation. Sustainable development calls for optimal utilization of available natural resources based on their potential and limitations. Planning for wasteland calls for up-to-date information on their geographical location, areal extent and spatial distribution, besides other inputs like slope, water availability, soil feasibility etc. In addition, we need to have the capability to monitor the wasteland reclamation process. Conventional methods of wasteland information generation are arrived by compilation of village records, which is primarily in statistical nature. These techniques are labour intensive and time consuming and are done relatively infrequently.

Out of 329 Mha geographical area of our country, nearly 175 Mha land is subjected to some kind of land degradation. Recent studies indicate that the areas affected by water and wind erosion are about 150 Mha, salinity and alkalinity is about 60 Mha and shifting cultivation constitutes about 4.0 Mha respectively. Vast stretches of lands suitable to be put under non-agricultural use and for reclamation for better productive use are available in the country. Not less than 37.5 Mha of such lands are expected for viable treatment.

The availability of high-resolution, multi-sensor and multi-frequency satellite data with the capability to provide un-biased, holistic and synoptic view has facilitated the generation of basic inputs required for taking up developmental works on watershed basis as well as it has provided a means for monitoring the implementation works in the watersheds. As demonstrated in many studies the satellite data provides required / essential information on current land use / land cover, hydro-geomorphological conditions, soil characteristics, status of drainage and surface waterbodies, slope and aspect, etc., which are vital for the prioritization of watershed in a given study area. Watershed approach of conserving and developing the natural resources of an area or a region is accepted as the most appropriate method. State / District administration are carrying out developmental works on watershed basis under several schemes.
like JRY, DPAP, NWDPRA, RVP" etc. In the changed scenario of equity, it is mandatory to identify at least 2 to 3 watersheds of size 500-1000 ha in each taluk every year and treat them over a period of two to three years rather than selecting a large single 20,000 ha sub-watershed and treat over a period of 5-6 years. The district administration finds it difficult to identify such critical watersheds in each taluk and hence desired to use remote sensing and GIS techniques to get a quicker and reliable solution of prioritizing the watersheds on scientific basis.

The information on natural resources with regard to their nature, extent, spatial distribution and potential and limitation is a pre-requisite for optimal land use planning and for initiating any other developmental activities at district / taluk / watershed level. The optimal land utilization of available land and water resources based on their potential and limitation is a key to sustainable development in a watershed. Space borne multi-spectral data is available since Landsat–1 in 1972, for generating information on natural resources and subsequently for preparing optimal land use. By virtue of large area coverage at frequent intervals, the satellite data have immense potential for providing timely, reliable and cost effective information on various natural resources and environment.

The methodology adopted involves generation of thematic maps showing current land use / land cover, types of wastelands, forest cover / types, surface water resources, drainage system / pattern, potential ground water zones, land forms (geomorphology), geology (rock types, structural features, mineral occurrence), soil resources maps (soil type, irrigability, land capability, crop suitability maps) etc., using Indian Remote Sensing Satellite (IRS) data. In addition, maps like slope, village location, boundary and transport network maps were generated using Survey of India (SOI) topographic maps and other collateral information. Socio-cultural, socio-economic, demographic and meteorological data were collected from available existing databases.

By integrating all these information in a GIS environment, derivative maps called composite mapping units showing resource availability of individual land parcels, land characteristics, status of land erosion / limitations etc., are prepared. These
Watershed Management maps are validated through adequate field checks and by using authentic existing information. Specific developmental plans in the form of action plans for water resources development and alternate land use development can be generated on watershed basis in consultation and close coordination between space scientists, state line department / watershed officials, agricultural universities / research centers and local farmers so as to ensure the technical feasibility and cultural acceptability. Under the National project "Integrated Mission for Sustainable Development" coordinated by National Remote Sensing Agency, Hyderabad in collaboration with State Remote Sensing Service Centres, Regional Remote Sensing Service Centres, Private Agencies and other Central / State Organizations, the natural resources data base creation and action plan generation for taking up developmental work was successfully completed for 19 districts completely and one block in each of the 80 districts identified by Ministry of Rural development.

The GIS data creation was carried-out under Arc-Info environment for most of these districts and blocks identified. This work was undertaken under the National project "Natural Resources Information System" through the participation of concerned State Remote Sensing Centres and Regional Remote Sensing Service Centres of ISRO. The hard copy outputs on all natural resources and action plan maps have been handed over to the district administration for further utilization. As desired by many district administrations in many districts / taluks, watershed wise maps on natural resources and action plans were generated and handed over to them for taking up watershed development programmes.

The implementation of such action plans have been reported from many taluk / districts from the states of Karnataka, Andhra Pradesh, Gujarat, Rajasthan, Uttar Pradesh, Maharashtra, Madhya Pradesh, Orissa etc., on watershed basis. In Bijapur district of Karnataka at least 8 watersheds have been identified and implementation of watershed programmes were entrusted to NGO's by Zilla Panchayat, Bijapur using the natural resources data base created under IMSD, action plans were generated in close interaction with the Remote Sensing scientists, department officials, scientists from Research centers, field functionary etc. The same action plans for water resource development and alternate
agriculture resources development generated through RS & GIS were successfully implemented and monitored.

The repetitive coverage of the satellite provides us an excellent opportunity to monitor the land resources and evaluate the land cover changes and its impact on environment through the comparison of images acquired for the same area before and after the treatment period. Changes that could be derived through satellite data include:

i. Cropped area (change in areal extent of agricultural crops, cropping pattern, extent of wet land / irrigated croplands)
ii. Plantations (increase / decrease under horticulture and forest plantations)
iii. Wastelands (change in areal extent)
iv. Alternate land use (switchover from marginal lands to agro-horticulture / agro forestry)
v. Waterbody (change in number and areal spread) and Biomass (overall change in productivity).

However, the socio-economic indicators like land value, employment opportunities, changes in ground water levels, agro based and allied industries, migration of labour and cattle etc., are collected from field survey.

This monitoring and evaluation study would provide insight in to the impact of developmental activities in the watershed and provides feedback for making necessary modifications, plan revisions and preparation of fresh watershed developmental projects.

The study conducted over a number of watersheds indicated increased area under forest / horticulture plantation, expansion of area under cultivation, change in cropping pattern, increase in the irrigated area, alternate land use practices (i.e. increase in area under agro-forestry / agro-horticulture), more number of waterbodies, change in water spread area, reclamation of wastelands for productive use, more area under fruit crops and forest.

The experience indicates that the remote sensing technology is quite cost effective to assess the status of watershed development. It is observed that the
cost of monitoring and status assessment is about one-fifth the cost of such assessment using conventional techniques. The watershed development authorities find RS & GIS techniques as the appropriate tool to monitor and evaluate the impact of watershed development programmes, as it provides more accurate, timely reliable and objective information.

The studies so far carried-out indicates that there is a greater need to streamline the implementation process by increasing manpower of the department, better co-ordination between identified inter-disciplinary team from various participating departments, utilization of better maps for preparation of implementation plans and record keeping and greater need for protection, maintenance and conservation of developmental works. In Karnataka, a sound beginning has been made in many watershed programmes like World Bank aided ‘SUJALA’ watershed development programme. In this project NGO’s and local committees are involved in actual plan preparation and implementation making use of Remote Sensing derived maps as well as GIS for integrating all the information and monitoring the entire process of implementation at cadastral level. This approach makes the watershed management more meaningful and productive.

Finally, it can be concluded that the availability of high-resolution satellite data at frequent intervals for IRS satellites and other foreign satellites (landsat and spot) provides sufficient timely reliable information for the watershed development beginning from prioritization work to generation of natural resources data base and action plans in GIS environment and finally for monitoring and impact evaluation of these watersheds between pre and post treatment periods. So, the technology allows planner to evaluate the watershed development programmes continuously and apply midcourse corrections if required. Many studies have indicated that the mapping and monitoring can be carried out on 1: 12,500 scales incorporating cadastral information.

Keeping these developments in the watershed management and potentials of latest technologies like Remote Sensing, Geographical Information System, Global Positioning System and other Information Technology in mind the present research work on “RS and GIS approach for creation of Decision Support System for the Development of Identified Micro-watersheds in Udupi Taluk"
District of Karnataka was taken-up. The research is aimed at using RS and GIS techniques to prioritize the watersheds in the Udupi taluk, develop a natural resources database and create a decision support system for the Udupi taluk and conduct monitoring and evaluation for three identified watersheds to assess the progress of implementation of developmental programmes between pre-treatment (2001-2002) and post-treatment (2006-2007) periods.

1.6 OBJECTIVES OF THE STUDY

The objectives of the present study include:

i. Prioritization of watersheds of Udupi taluk using satellite data.
ii. Characterization of selected watersheds.
iii. Generation of Natural Resources layers viz., Current Land Use / Land Cover, Soils, Hydro-geomorphology, Slope, Drainage & Watershed, Transport and Village Boundary for selected watersheds using IRS LISS III + PAN Hybrid Data.
iv. Creation of Non-Spatial database that include Demographic, Socio-economic,
v. Meteorological data collected at village/ taluk level from different line departments / sources.
vi. Development of a decision support system for the taluk under GIS environment for the watershed management.
vii. Generation and Implementation of action plan maps for water resources development for the selected priority watersheds.
viii. Monitoring and evaluation of three treated and selected NWDPRA watersheds in Udupi taluk using pre and post treatment satellite data.
ix. Generation of SRTM DEM and derived outputs.

1.7 BRIEF DESCRIPTION OF THE CHAPTERS

The Chapter I on Introduction explains the background for the research work, objectives and scope of watershed development, activities carried-out in the watershed, role of RS & GIS in watershed development and management and the objectives of the present research work.
In the Chapter II on Review of Literature, the research works carried-out in the field of watershed management using satellite remote sensing and GIS techniques have been reviewed and discussed covering the history of watershed development, prioritization of watersheds, generation of thematic and developmental action plans and monitoring and evaluation of watersheds.

The description of the study area, details of the three identified watersheds covering their location, socio-economic & meteorological conditions, land utilization patterns, implementation details and the materials used for the study including satellite data and collateral data used is described in the Chapter III on Study Area and Materials Used.

Methodologies adopted for prioritization of watersheds, delineation of different resources themes using remote sensing approach, generation of attribute data, action plans for water and agriculture resource development plans and monitoring of the developmental works carried-out in three identified watersheds of Udupi district during 2001-02 to 2006-07 have been described in the Chapter IV on Methodology. In addition, the methodology adopted for the generation of DEM using SRTM data is briefly described.

The results obtained on i) the prioritization of micro-watersheds using two techniques viz., elimination technique and Criteria based model using RS & GIS, ii) the resources thematic mapping in the study area with respect to surface water & watershed, slope, transport network and settlement location maps, soil resource inventory, hydro-geomorphology, land use / land cover, generation of socio-economic database and analysis of meteorological data and iii) monitoring and evaluation of impacts of watershed development programmes in three identified NWDPRA watersheds are presented in the Chapter V.

The Chapter VI on Summery and Conclusions briefly explains the watershed management, objectives of the present research work, methodology adopted, results obtained particularly on i) the prioritization of micro-watersheds using two techniques viz., elimination technique and Criteria based model using RS & GIS, ii) the resources thematic mapping in the study area with respect to surface water & watershed, slope, transport network and settlement location maps, soil
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resource inventory, hydro-geomorphology, land use / land cover, generation of socio-economic database and analysis of meteorological data and iii) monitoring and evaluation of impacts of watershed development programmes in three identified micro-watersheds. The Chapter also describes the conclusions of the research work, recommendations given to the implementing agencies on land and water management in the Udupi taluk and future scope of the research work. A well-organized reference list is provided in Chapter VII.