CHAPTER 6
SUMMERY AND CONCLUSIONS

6.1 Summery of the Study

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 the large tracts of arid and semi-arid tracts of the country. Dryland areas also account for a significant proportion of the rural poor in the country. The poverty in this region found to be 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.

The developmental activities in India were carried out with sectoral approach rather than integrated approach in the past. Development based on administrative units such as district, taluk, block and village have resulted in imbalance and sometimes no overall development in some areas. In nature, all the resources are interlinked and thus, the integrated developmental approach is the best method for optimal development of any area. In view of this, the integrated approach of watershed development took prime importance during recent years. Many studies have shown that productivity / productions from watersheds have doubled due to interventions of developmental programmes in the dryland watersheds.

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,
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wasteland reclamation to establish vegetal cover, agro-forestry and agro-horticulture development, etc. The goal is to sustain the agriculture production without land degradation.

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. The satellite data can be effectively utilized beginning from i) prioritization work to ii) generation of natural resources data base and action plans in GIS environment and iii) finally for monitoring and impact evaluation of these watersheds between pre and post treatment periods. Therefore, 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 or better scale incorporating cadastral information.

The satellite image provides an excellent opportunity to monitor the land resources and evaluate the land cover changes and its impact on environment through a comparison of images acquired for the same area at different times. Changes in forest cover, cultivation area, water spread / levels, soil erosion status could be monitored using temporal satellite data.

GIS is an organized collection of computer hardware, software and geographic data, designed effectively to capture, store, update, manipulate, analyze and display all forms of geographically referenced data and is an important additional tool in monitoring and management of natural resources. GIS helps in handling voluminous data, updation of information on geographic features, which is helpful for natural resource management.

6.2 OBJECTIVES OF THE STUDY

Keeping the developments in the field of Watershed Management and Potentials and Developments 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
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Udupi District of Karnataka" was taken-up. The decision support system developed will help the district and taluk administration to tackle the very basic problems faced in implementing the various developmental schemes in the Western Ghat region. The watershed approach considers the development of water and vegetation resources development as the main goal by utilizing and protecting the available natural resource in the watersheds. In Western Ghat region, the natural vegetation development is not a main concern and the annual rainfall in the region is more than 3500 mm / year, which indicates that there is plenty of water available for development.

Most of the developmental schemes implemented on watershed basis in Udupi and Mangalore districts designed to tackle various land and water resources development considers particularly the objectives to provide drinking water during summer season and to provide supplemental irrigation to crops and horticulture plantation. Hence, the research is aimed at using RS and GIS techniques to prioritize the watersheds in the Udupi taluk, develop a natural resources database, create a decision support system for Udupi taluk, and conduct monitoring and evaluation of developmental programmes in the three identified watersheds treated during 2001-02 to 2006-07.

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 the taluk and selected sub-watershed comprising of selected watersheds using IRS LISS III + PAN Hybrid data

iv. Creation of non-spatial data base which include demographic, socio-economic, meteorological data collected at village / taluk level from different line departments / sources

v. Development of a Decision Support System for the taluk under GIS environment for the watershed management

pre-treatment and post-treatment satellite data and
vii. DEM generation using SRTM data, extraction of drainage and contour information and overlay of themes on SRTM DEM for better visualization for location of sites suitable for various activities.

6.3 STUDY AREA AND DATABASE USED

The entire Udupi taluk was taken-up for prioritization and creation of decision support system comprising of natural resources in the form of spatial layers and socio-economic, meteorological, demographic and other information available in non-spatial form. Three identified watersheds viz., Perdur, Bairampalli and Shirur out of 16 watersheds where implementation is in final stages falling within a sub-watershed and located in the western part of the taluk were considered for monitoring and evaluation using RS and GIS. The database used consists of reference maps in the form of SOI topo-sheets covering the Udupi taluk were used in the study during preparation of resources maps. Indian remote sensing satellites namely IRS 1C/1D /P6 LISS III and PAN data sets covered in path & row 98-64 of 1996, 2002 and 2006 were used for the completion of the study. The ground-truth data was collected for thematic mapping and watershed monitoring and maps were finalized.

6.4 METHODOLOGY ADOPTED

The methodology adopted for the creation of the decision support system is explained below under different sections.

6.4.1 Watershed Prioritization: The watershed prioritization of Udupi district was first carried-out using IRS LISS III satellite data of March 24, 1996 and other collateral data and employing the elimination techniques. The elimination technique is more suitable when the reliable information on natural resources data is not available on a detailed scale of 1:50,000 or better. Since the natural resources, information database is available on 1:50000 scale for the Udupi district generated under NRIS project, the criteria based technique was employed to prioritize the watersheds. The first stage of prioritization uses natural resources information and the second stage uses the socio-economic and / or demographic details for second level of classification as desired under the guidelines provided
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for that particular programme. The results of both the programmes were later compared.

6.4.2 Natural Resources Database Creation (Thematic & Action Plan Maps)

Visual interpretation techniques were adopted to delineate land use / land cover, soils, hydro-geomorphology, lithology, lineament using remote sensing data (LISS III + PAN merged) and SOI topo-sheets on 1:50,000 scale. Drainage & watershed map, transportation network, slope and its aspect maps are generated using SOI topo-sheets and updated using satellite data. Thematic mapping has been carried out strictly as per the "IMSD Guidelines," document of the NRIS project. Visual interpretation was carried out either using analog image or through the monoscopic interpretation of the digital data displayed on the colour monitor and thematic mapping was carried out through on-screen or heads-up interpretation using image interpretation keys, which are developed, based on ground truth and ancillary data. Semi automated approach was also followed for some of the themes. Resultant outputs from this approach are in digital GIS vector format, which supports complex GIS Analysis.

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 generated for identified watersheds. The 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 could 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 to ensure the technical feasibility and cultural acceptability.

6.4.3 Monitoring and Evaluation: The sequence of steps followed in the analysis are grid base generation, scanning of maps, registration of scanned maps (map grid generation), registration of satellite data, digitization of cultural features and other boundaries, generation of vegetation index, land use / land cover classification of satellite data, refinement, change analysis and generation of statistics and output generation. The Land use / Land cover and Biomass
changes are assessed and change statistics are generated.

6.4.4 DEM generation using SRTM data: In this study a methodology of automated DEM generation from SRTM data and extraction of terrain features such as drainage, slope, aspect and generation of derived outputs like shaded relief, painted relief and hill shade etc., of the study area have been adopted. An attempt was made in the present study to show the capabilities of SRTM based DEM for watershed management applications through the generation of some of the derived outputs and thematic overlays on the DEM for the better visualization of topography and natural resources. A morphometric analysis for the sub-watershed and the three micro-watersheds was carried out using SOI toposheets and derived information from remote sensing and GIS.

6.5 RESULTS AND DISCUSSION

Results obtained from the study are discussed below under the following sections.

6.5.1 Watershed Prioritization: The watershed priority maps of Udupi taluk were generated using elimination and criteria-based approaches respectively. The watershed classification system adopted follows an Alphanumeric codes consisting of a combination of alternating Arabic numbers and English capital alphabetic letters and have been used to designate alternate stages of delineation. By comparing the outputs of both the technique, it can be seen that they follow the same trend except for few changes. The elimination technique classifies the 100 watersheds in to five categories viz very high (21), high (19), medium (18), low (31) and very low (11). Similarly, the criteria based approach classifies the 100 watersheds in to five categories viz very high (16), high (10), medium (12), low (41) and very low (21).

6.5.2 Natural Resources Database Creation (Thematic / Action Plan Maps): The taluk consists of 4 hoblies, 108 Revenue villages, 24 other villages, 5 urban cities / towns and two municipalities. The sub-watershed falls in Perdur, Bairampalli and Shirur Panchyats and implementation areas are so selected that they fall well within the three revenue villages viz., Perdur, Bairampalli and Shirur. The Fig 6.1 and 6.2 shows the distribution of major natural resources viz., land use / land cover, soils groundwater potential areas and slope categories in the
form of Pi charts for Udupi taluk and the sub-watershed respectively.

6.5.2.1 Transport Network: National highway No. 17, which connects Mangalore to Panaji of Goa, passes through the taluk and runs through a distance of 56.68 km. The total length of the state highways comprising of four segments in the taluk is 47.34 km. Other types of roads in the taluk are district and village roads, cart tracks and footpath together have a length of 1000.2 km out of which 246.29 km is metalled. The Konkan railway line runs through a distance of about 49.15 km in the taluk. The total length of roads in sub-watershed is 82.57 km out of which one state highway runs through a distance of 9.24 km.

6.5.2.2 Slope Categories: Udupi taluk comprises slope classes ranging from moderately steep sloping to very steep sloping lands (15 – 35%) to nearly level lands (0 - 1%). Western part of the taluk covers level lands with gentle slopes, whereas undulating lands are observed in central part and moderately steep slopes are observed in western part of the taluk. Terrain of the taluk consists of six classes of slope. Nearly level lands cover 53.82% followed by very gently sloping by 13.70%, gently sloping by 3.61%, moderately sloping by 1.07% strongly sloping by 22.45% and moderately steep sloping to steep sloping by 5.35%. Western part of the sub-watershed covers level lands with gentle slopes, whereas undulating lands and moderately steep slopes are observed in central and eastern parts of the sub-watershed. The extent and distribution of various slope categories helps in planning land development activities and in suggesting alternate land use practices.

6.5.2.3 Drainage and watershed: The entire taluk lies in the West flowing rivers basin. The main rivers of Udupi district are Sita, Swarna and Kollur. The drainage network is dense in the Ghats. The ordering of rivers / streams was also completed so that morphometric analysis can be carried out for any watershed falling within the Udupi taluk.

There are no major tanks and reservoirs in the taluk except for few small irrigation tanks and ponds. The taluk falls under the water resource region of The Arabian Sea (Region 5) drained by the basin Cape Comorin to Sharavati. It is further delineated into 1 catchment, 2 sub-catchments and 4 Major watersheds. These 4 Major watersheds have been further delineated into 9 sub-watersheds and 100
micro-watersheds. Streams of 1st to 5th order can be observed in the sub-watershed. The study of drainage pattern helps in taking proper conservation measures for arresting runoff and soil loss, further it is used in locating sites for water harvesting structures.

6.5.2.4 Hydro-geomorphology: The major rock types of the Udupi taluk consist of Pink hornblende granite and Hornblende biotite gneiss (Bababudan Rock Type) covers an area of about 48.08% of the total geographical area. Quartzite / Sillimanite / Fuchsite / Migmatite and granodiorite-Tonalite gneiss (Sargur / Satyamangalam) covers an area of about 0.08% of the total geographical area, Crystalline Charnokite rocks cover about 39.45% of total geographical area. Residual capping of Laterite covers an area of about 8.42% of the total geographical area. Unconsolidated sediments consisting of Alluvium / Beach sand, alluvial soil covers about 3.97% of the total geographical area.

The hydro-geomorphological characteristics of the taluk indicate that the coastal plain, channel island, alluvial plain, tidal flat, marine island and valley / valley fills have very good to good ground water potential and Intermontane valley have good ground water potential. These units are highly favourable for ground water exploration and development in this taluk. Shallow weathered Pediplain and lateritic plain shallow have good to moderate ground water potential respectively. Lower plateau (lateritic) have moderate ground water potential. The pediment have moderate to poor ground water potential. The dissected pediment and pediment inselberg complex have poor ground water potential. The denudational hill, linear ridge, inselberg, residual hill, structural hill, butte, dyke ridge, escarpment slope, messa, in different geological formation due to high relief and slope, these units mainly act as runoff zones and grouped under poor to nil ground water prospect zones. The per cent area under very good to good prospect zone in Udupi taluk is 36.32, followed by good to moderate by 16.98, poor by 39.07, poor to nil by 2.78, saline by 0.06 and saline but good by 0.16. Similarly in the sub-watershed, the per cent area under very good to good prospect zone is 27.01, followed by good to moderate by 14.79, poor by 52.15, poor to nil by 2.68. The map as a whole facilitates in understanding the occurrence and movement of ground water and its potential.
FIG 6.1: Major Resources Distribution in Udupi Taluk as Derived from Satellite Remote Sensing and GIS
FIG 6.2: Major Resources Distribution in Sub-Watershed as Derived From Satellite Remote Sensing and GIS
6.5.2.5 Soils: The soils were mapped at series level and the associations of soil series formed the soil-mapping units. Twenty-six soil series were identified using the major differentiating characteristics arrived after laboratory analysis and 32 soil associations were mapped. Each soil map unit includes up to about 15 per cent of other soils as inclusions or impurities. Majority of the taluk area is covered by three-soil associations viz., Kudichar – Nadabettu - Derulakatte by 34694.82 ha (37.39%), Kandlur -Halanadu –Kollur by 14167.98 ha (15.27%) and Kalladi – Atradi – Vandse by 9657.46 ha (10.41%).

About 83.62 per cent of the area in Udupi taluk is suitable for agriculture; the remaining 16.38 per cent is not suitable for agriculture but well suited to forestry, pasture, silvi-pastural system, quarrying, wild life and recreation. Of the land suitable for agriculture, about 43.8 per cent has good cultivable lands (Class II) with minor soil limitations of soil erosion & clayey texture, problems of drainage (wetness) is present followed by about 25.68 per cent has moderately good cultivable lands (predominantly Class III) with problems of drainage (wetness), shallow rooting depth and moderate slopes and about 14.14 per cent has fairly good lands with severe limitations of shallow rooting depth, gravelliness, stoniness, moderate slopes, and clayey texture. Of the lands not suitable for agriculture, less than 8.26 per cent are well suited to forestry, pasture and silvi-pastural systems. The information thus obtained was valuable to understand the productive potentials and this was used as an important input in suggesting an alternate land use practices. The soil-mapping units of Udupi taluk have been grouped into seven associations of land irrigability subclasses. Nearly 85.85 per cent of the area is suitable for irrigation, about 10.18 per cent is not suitable and remaining 4.11 % of land is under water bodies.

6.5.2.6 Land use / Land cover: Land use / land cover map was prepared using three season satellite data. Six major classes viz., built-up land, agriculture land, forest, wastelands, water bodies and other categories were delineated. These are further classified up to level III categories. The major classes observed in the taluk include Kharif cropland, mixed vegetation, tree groves, water bodies and wastelands. The study of land use pattern help in understanding the present use of land to identify thrust areas of priority for development. The map helps in formulating alternate land use plan (using national / state policy, if required can
be considered) based on the potentials and limitations of existing natural resources.

The collateral data such as demography, socio-economic status, meteorological data, demand and supply of food grains, fodder and fuel wood was collected and a database has been built up. This information helps in deciding an alternate land use practices, which satisfied the needs of the people based on their requirement and present condition.

The details of the final implementation works taken-up in the three identified micro-watersheds in a phased manner from 2001-02 to 2006-07 include construction of Nala Bunds, Vented Dams, Farm Ponds, Desiltation of Tanks, Horticulture development, Afforestation and Social Development works like construction of Ranga Mandira and Public Health Centre etc. The statistics relating to the implementation programmes in the three identified watersheds are given in the Tables 5.26 and 5.27.

6.5.3 DEM generation using SRTM data: In this study a methodology of automated DEM generation from SRTM data and extraction of terrain features such as drainage, slope, aspect and generation of derived outputs like shaded relief, painted relief and hill shade etc., for the study area have been adopted. An attempt was made in the present study to show the capabilities of SRTM based DEM for watershed management applications through the generation of some of the derived outputs and thematic overlays on the DEM for the better visualization of topography and natural resources. With the availability of the SRTM DEM for the entire taluk, the watersheds to be treated in future can be analysed to understand and visualize the topographic attributes, distribution of natural resources information derived using RS techniques and systematically plan and manage the implementation programmes to achieve a better result and improve the natural resources condition in the watershed. The 3-D views helps in the location of soil / water conservation structures, sites for horticulture and afforestation programmes and also for evaluating their site suitability with respect to topographic and natural resources conditions present at the location.

It can be very well seen that drainage extracted from SRTM DEM is very much similar to that extracted from 1:50,000 scale SOI maps except where the river
courses are broader and contain perennial water. The contour pattern generated from the SRTM DEM closely matches with that of SOI extracted contour pattern when the area considered is large and contour intervals are above 10 m. The contours require smoothening as they are derived from raster DEM and hence contain typical step pattern.

6.5.4 Soil Conservation Service (SCS): Soil Conservation Service (SCS) model has been applied in the present study for the estimation of runoff from an agricultural watershed viz., sub-watershed. This method involves generation of various types of information related to hydrologic soil Group, vegetation and antecedent moisture condition of the watershed. The soil map and land use maps have been prepared using IRS satellite data (LISS III + PAN merged Hybrid Data set) following standard procedures. The SCS model was then applied to estimate the runoff for monthly storm and was validated. The USDA curve number table, modified for Indian condition was used for the determination of the curve number for the watershed. By intersecting the land use map and soil map, the curve number was assigned to the each combination of land use and soil type. Weighted value of CN was found out for AMC II condition. The monthly rainfall data for the year 2001 was collected and the weighted curve number of the watershed was used for the estimation of runoff. The calculated runoff value is 31,960 cubic meters for the sub-watershed for the year 2001.

6.5.5 Morphometric Analysis: The morphometric analysis carried-out indicates that the Perdur watershed has high runoff and prolonged peak discharge whereas the Shirur and Bairampalli watersheds have high runoff but quick peak runoff. The undulating terrain with moderate slope and geomorphology set-up leads to high runoff and low infiltration in all the watersheds. The soils of these watersheds are lateritic in nature leading to large-scale sub surface flows and hence call for special types of recharge structures and structures required for safe disposal of water for avoiding the wetness condition in the broad valleys.

6.5.6 Watershed Monitoring and Evaluation: The detailed result of the impact analysis of the developmental activities in the sub-watershed and three micro-watersheds viz., Perdur, Bairampalli and Shirur where implementation was carried out is summarized in the Tables 5.29 to 5.36 and the statistics are presented in Fig 5.34 and 5.35.
6.5.6.1 Cropped Area: The Cropped Area (Agriculture) comprises of area sown as dryland (Kharif crop area) and irrigated lands. The main crops grown in the watershed include Paddy and Pulses like Cowpea, Green gram, Horse gram and Urad Dal. Paddy is the main crop under rainfed area and is grown in the broad valleys of the watershed. Vegetables and fruit crops are grown under well irrigation. The total area under this category during pretreatment period in the sub-watershed, Perdur, Bairampalli and Shirur was 3625.60 (44.42%), 253.81 (47.08%), 558.30 (53.91%) and 333.56 (42.90%) ha respectively. Similarly, total area under this category during post treatment period in the sub-watershed, Perdur, Bairampalli and Shirur is 2435.51 (29.84%), 200.74 (37.23%), 369.37 (35.67%) and 217.81 (28.02%) ha respectively. The corresponding change in cropped area after the treatment in the sub-watershed, Perdur, Bairampalli and Shirur is found to be decreased by 1190.09 (-14.56%), 53.07 (-9.85%), 188.93 (-18.24%) and 115.75 (-14.88%) ha. This indicates decrease in the spatial distribution of cropland and the trend observed is same in all the watersheds.

6.5.6.2 Cropping Pattern and Crop Yields: The major source of water is surface (perennial streams, tanks / ponds) water and ground water. The exploitation of ground water to raise horticulture and intensive crops was observed in very few locations along valleys. More lands have been brought under irrigation during treatment period. The major crops grown before treatment were paddy and other pulses. During the post treatment period there is likely to be a change in cropping pattern. Farmers are likely to adopt intensive cropping and agro-horticultural system. The production levels of all crops have gone up. The crop cutting experiments conducted and from the experiences of farmers and officials, it can be concluded that there is considerable increase in crop yields.

6.5.6.3 Agro-Horticulture / Plantation: The major plantation trees observed in the watershed include Mango, Cashew nut, Coconut, Areca nut, Sapota and Teak. The analysis of satellite data indicates a very insignificant increase or decrease of plantation area as the Spectral signatures are similar to tree groves and / or mixed vegetation. The field data collected indicates that farmers are adopting Agro-horticulture / Agro-forestry as an improved cropping pattern in the watershed. Small patches of Areca nut, Mango and Cashew plantation introduced by the farmers in the watershed is observed. There are few afforestation works taken-up in community and private lands but could not be identified as it mixes
with the neighboring mixed vegetation or tree groves categories. During ground-truth data collection, some of the sites where soil and water conservation, afforestation and horticulture works taken-up were visited to observe the changes around these implementation works in all three micro-watersheds. The ground information on different land use / land cover categories and activities under watershed development program were collected by visiting the sample areas in the watersheds along with satellite imagery. The fieldwork was carried-out along with concerned line department officials during August 08-09, 2007 (Kharif season). The field details were collected from farmers as well as officers concerned in the watershed. Satellite imageries and topographical maps were utilized during ground-truth data collection.

6.5.6.4 NDVI Image: The NDVI images generated for pre-treatment and post-treatment periods indicate the changes in the biomass levels. The pre-treatment year 2001-02 received better than normal rainfall and hence vegetation vigour is good as indicated by the pre-treatment NDVI image. During post-treatment year, the rainfall received is above normal. The satellite image acquired is relative towards the end of the season during the post treatment year 2006. NDVI image of post treatment indicate good vigour in the standing vegetated areas. Over all, there is a decrease of area under first three lower categories i.e. No vegetation, poor and moderate Biomass Levels and increase of area under Good and Very Good Biomass level classes in Perdur, Bairampalli and Shirur micro-watersheds due to implementation of watershed programmes whereas the area under Very good category has decreased by 8.39% in the sub-watershed.

6.5.6.5 Live Stock: Live stock activities are taken up in all the micro-watersheds. There is no separate pasture or grazing land in the watersheds. Generally the nearby uplands and degraded forests are used for cattle rearing. The major source of fodder is forest trees / shrubs and agriculture waste.

6.5.6.6 Drainage line treatment: Some of the drainage lines are treated and stabilized through planting of trees like teak and other fuel wood species etc., and construction of loose boulder checks with vegetative support. This has helped in recharging of area and increasing ground water level. Farm ponds, Nala Bunds and Vented Dams of impounding type are also constructed along drainage lines. A number of existing small tanks and ponds are desilted.
6.5.6.7 Wastelands: The analysis indicates that area under this category has come down in all the micro-watersheds and sub-watershed. The total area under this category during pre-treatment period in the sub-watershed, Perdur, Bairampalli and Shirur was 817.21 (10.38%), 79.77 (14.79%), 97.24 (9.39%) and 48.79 (6.28%) ha. Similarly, total area under this category during post treatment period in the sub-watershed, Perdur, Bairampalli and Shirur is 766.55 (9.39%), 66.16 (12.27%), 88.66 (8.56%) and 54.62 (7.02%) ha respectively. The corresponding change in wasteland area after the treatment in the sub-watershed, Perdur, Bairampalli is found to be decreased by 50.66 (-0.99%), 13.61 (-2.52%), 8.58 (-0.61%) and increased by 5.93 (-0.74%) ha in Shirur watershed. This indicates decrease in the spatial distribution of wasteland except in Shirur watershed where there is slight increase in the wasteland category.

6.5.6.8 Water Bodies: This class mainly includes tanks, ponds and major drainage (river). The analysis indicates that the water spread in tanks is better in the year 2006 compared to 2002. The change in water bodies extent is very insignificant i.e. less than 1%. The new structures could not be located on imagery, as they were too small and enclosed by mixed vegetation classes and due to scale limitations.

6.5.6.9 Others: This class mainly includes the tree groves and mixed vegetation categories. The analysis indicates that area under this category has increased in all the micro-watersheds and sub-watershed. The total area under this category during pre-treatment period in the sub-watershed, Perdur, Bairampalli and Shirur micro-watersheds was 3547.81 (43.12%), 203.51 (37.61%), 365.00 (35.24%) and 390.68 (50.22%) ha.

The Sub-watershed analysis indicates an increase of tree groves by 10.69% and Mixed Vegetation by 4.59%. The analysis of Perdur watershed indicates an increase of tree groves by 20.29% and mixed vegetation area by 0.85%. During the analysis of Bairampalli watershed, it was found that there is an increase tree groves area by 18.43% mixed vegetation by 0.41%. Similarly, the analysis of Shirur watershed indicates a decrease of tree groves area by 0.24% and an increase of mixed vegetation by 0.14.26%.
Overall, satellite based Remote Sensing data analysis has indicated an improvement of 15.46, 12.39, 18.85 and 14.88 per cent in sub-watershed, Perdur watershed, Bairampally watershed and Shirur watershed respectively indicating the benefits obtained due to the adoption of holistic watershed based approach of land and water resources management. The overall positive biomass development observed in sub-watershed, Perdur watershed, Bairampally watershed and Shirur watershed respectively are 18.72, 21.11, 28.84 and 17.95 per cent of the geographical area.

6.7 CONCLUSIONS

The highly undulating lands with moderate to steep slopes, thick vegetation, heavy rainfall during June to November, inaccessibility of the terrain in rural area, lack of transportation facilities in such watersheds hinders carrying-out field surveys and implementation programmes in major part of the year. The district administration finds that the remote sensing derived thematic / action plan maps are very useful as it gives a better visualization of the field conditions during both planning / implementing and monitoring phases of the watershed. The decision support system will definitely help them to effectively implement the programmes and progressively monitor throughout and after the project.

The decision support system requires a very good GIS package like Arc-GIS, which can handle large volumes of both spatial and non-spatial data. GIS is a computer-based tool, helps in capturing, storing, integrating, analyzing and displaying the spatial and non-spatial data. The thematic information of any particular area could be extracted and studied in detail for evolving detailed developmental plans. Thus, GIS paves way for analyzing the natural resources information of large areas.

The elimination technique is more suitable when the reliable information on natural resources data is not available on a detailed scale of 1:50,000. If the natural resources information is available on 1:50,000 scale, the criteria based technique can be adopted. The first stage of prioritization uses natural resources information and the second stage uses the socio-economic and / or demographic details for second level of classification as desired under the guidelines provided for that particular watershed development programme. The priority maps helps
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the district or taluk administration to select the watersheds for treatment on a scientific method and convince the administration and locals involved, thereby avoiding conflicts in selecting the watersheds. The maps also help the district administration to quickly identify watershed and forward the proposals for clearance within a week as compared to routine conventional technique, which requires 3-4 weeks. It is observed that such maps help to select different priority watersheds as per the requirements of the programme guidelines of that particular scheme.

Agriculture being predominantly rainfed in the taluk, the low productivity in these areas was due to heavy rainfall leading to drainage problems (wetness), poor soil and water conservation measures, lack of water storage structures like tanks and ponds, adoption of old, traditional practices, and poor economic condition of farmers. In order to improve the productivity from these lands, inventory of natural resources are essential and goes a long way in checkmating the fragile ecosystem by suitable land and water management programmes.

Hence, database on natural resource was created using advanced remote sensing techniques and Geographic Information System. The information thus generated in the form of maps were integrated along with collateral data viz., meteorological data, socio-economic data, information on food grains, fodder and fuel wood, to arrive at meaningful and workable water and agriculture resource development plan for the taluk to bring the glory of sustainable agriculture.

For many of the selected NWDPRA watersheds falling in Udupi taluk, the thematic and action plan maps were generated based on above principles under GIS environment and provided for implementation. Training was also given to the taluk officials for reading the maps and preparing the final action plan maps by giving due weightage to the local requirements, site feasibility, funds available and the guidelines of the scheme under which the implementation is taken-up. Few workshops were conducted to familiarize the officials in Udupi taluk. Under the soil and water conservation measures, the area treated during 2001-02 to 2005-06 is approximately 725 ha in each of the three micro-watersheds selected for monitoring and evaluation. The runoff management structures like vented dam / check dams / sunken ponds / farm ponds are constructed to improve in-situ soil moisture conservation, ground water recharge and runoff / rainwater harvesting.
Watershed Management

The drainage line treatment, nala bund stabilization and filter strips/diversion channels are other major works carried out in the watershed. The community development works like Ranga Mandira or Public Health Centre works were also taken-up.

With the availability of the SRTM DEM for the entire taluk the watersheds to be treated in future can be analysed to understand and visualize the topographic attributes, distribution of natural resources information derived using remote sensing techniques and systematically plan and manage the implementation programmes to achieve a better result and improve the natural resources condition in the watershed.

In water resource development plan, drainage line treatments such as vented dams/check dam, nala bund, rubble check, boulder check, staggered trenches, gully control structures, sub surface dykes, vegetative checks, etc., in addition to moisture conservation measures like contour bunds, contour farming and strip cropping were also suggested. An attempt was also made to prioritize the tanks for taking up desiltation programme on priority basis and measures to improve water quality were recommended. These practices if implemented properly would help in achieving overall development of water resources.

Providing drinking water to the humans and cattle and supplemental irrigation is essential for the survival of humans (drinking water needs), agricultural and horticultural crops in the summer season. This is the major task or objective in most of the land and water resources programmes implemented in the Udupi taluk. Therefore, excess rainfall has to be conserved or stored in order to recharge the ground water for later use.

The natural resource information system thus generated for the taluk acts as a decision support system to the land users, policy makers and administrators. Utilizing the information, the farming section can act accordingly and achieve the projected objective of sustainable development of agriculture.

The importance is given for overall development of both agriculture and non-agricultural areas for the up-liftment of socio-economic conditions of the local people through the adoption of latest techniques of farming, use of hybrid varieties, pest & disease management, introduction of improved cropping
techniques (agro-horticulture / agro-forestry / intensive cropping), exploitation of ground water and soil & water conservation measures. Importance is also given for developing animal husbandry, inland fishing, mulberry cultivation and other non-agricultural activities to help landless laborers.

Under the monitoring and evaluation of three micro-watersheds, the field observation and satellite data analysis and schemes implemented clearly indicate that due to intervention of implementation of watershed activities, there is increase in Biomass / production. There is no significant change in spatial distribution of block plantation areas, which can be identified on satellite data. Improved cultivation both in dry land and in wetland was observed. Still there is lot of scope to improve the dry land as well as irrigated valleys by exploiting ground and surface water and introduction of block horticulture and forest plantation in the dry land areas.

There is good response from the farmers for all the activities including training /demonstration and for adopting new techniques / practices for getting improved and sustainable production from their lands. The implementation of watershed programs had lead to increase in employment opportunities, increase in ground water level, increase in productivity of paddy and pulses, improvement in socio-economic condition etc. Under household production scheme the items like improved implements for blacksmith, carpenter and people involved in basket and rope making have been distributed to improve the condition of landless labourers / farmers. This indirectly helped in increasing the use of more and better agricultural inputs.

Overall, satellite based remote sensing data analysis has indicated an improvement of 15.46, 12.39, 18.85 and 14.88 per cent in sub-watershed, Perdur watershed, Bairampally watershed and Shirur watershed respectively indicating the benefits obtained due to the adoption of holistic watershed based approach of land and water resources management. The overall positive biomass development observed in sub- watershed, Perdur watershed, Bairampally watershed and Shirur watershed respectively are 18.72, 21.11, 28.84 and 17.95 per cent of the geographical area.

The experience indicates that the remote sensing technology is quite cost
effective to assess the status of watershed programmes. Many studies have shown that the cost of data base creation, prioritization of watersheds and monitoring and status assessment of watersheds is about one-fifth the cost of such effort using conventional techniques. The watershed development authorities find RS & GIS techniques as an appropriate tool to monitor and evaluate the impact of watershed development programmes, as it provides more accurate, timely reliable and objective information.

6.8 RECOMMENDATIONS FOR IMPLEMENTING AGENCIES

The recommendations given to implementing agencies in the taluk are

i. Adopt a holistic approach such as a convergence model that demands the collective efforts of watershed stakeholders to address complex problems of the watershed. Action should be initiated for improving rural livelihood for all sections of people in the watershed promoting activities in the sectors of Agriculture, Horticulture & Forestry, Poultry, Fishery and small enterprise in the watershed through value addition to the products and improving the efficiency of operations etc.

ii. Many of the programmes indicate that 80 per cent of the stakeholders are not benefited in such programmes. Hence, there is a need to adopt a participatory approach involving all the stakeholders of the watershed.

iii. The implementation programme needs to be a demand driven rather than supply driven. It is required to identify drivers of success, ways and means to prevent bottlenecks and adoption of better technological interventions, funding pattern and implementing guidelines.

iv. Priority should be given to empowerment of community and stakeholders of the watershed. Emphasis should be given to provide saving linked financial assistance, to ensure employment to local people, equal pay for men and women, creation of additional income earning opportunities particularly to landless labourers and women in the watershed.

v. Villages selected for the watershed development work should have history of coming forward to a common cause, demonstrated concern towards natural resources conservation, ready to ban felling of trees & free grazing, reduce live stock population, ready to adopt water saving (drip irrigation) and energy saving (Bio-fuels), reduce growing of water intensive crops and
introduce crop diversifications.

vi. Efforts should be made to free the field functionaries from rigidity and encourage them to be more innovative and adoptive to local requirements, to bring mechanism of co-ordination and synergy between different agencies involved in implementation and also to bring public private partnership in some of the fields like regeneration of wastelands for production of Bio-fuel etc.

6.9 FUTURE SCOPE OF THE STUDY

To encourage and bring watershed stakeholders to come forward to contribute 10 percent of the project fund except poor and landless labourers, contribute towards building up of maintenance fund and constitute a village committee to take care of the assets created by the program.

To attempt mapping of natural resources on larger scale i.e., 1:12,500 using high-resolution satellite data [LISS IV + Cartosat (1 or 2) merged data / Quick Bird / Spot].

To attempt Decision Support System / digital database creation on natural resources to study smaller sub-watersheds / micro-watersheds in detail, as these techniques are quick, reliable and provides accurate information.

To attempt overlay of cadastral boundary map with survey numbers on the resource maps which helps in identifying target areas easily.

To attempt development of panchayat wise land & water resources information system using RS & GIS. Using the generated database on natural resources, micro watersheds can be prioritized using criteria based approach based on sediment yield index values and matching the requirements of the individual scheme for taking up catchment area protection measures.

Development of improved Digital Elevation Model (DEM) by using high-resolution data for designing and locating sites for water harvesting structures and soil mapping using semi automated digital techniques.