RS&GIS Applications in Planning and Conservation of Resources in Rainfed Watersheds

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Introduction

Space technology in India, has come a long way in providing valuable information, in spatio-temporal domains, for the development of various sectors like agriculture, forestry, water resources, ocean resources, etc. that have direct relevance to the economic development of the nation. The achievements in the applications of space technology towards societal benefits are numerous and impressive. The major applications of this technology towards agricultural development in rainfed areas include timely assessment of crop condition and production, surface and ground water potentials, status of soil productivity and land degradation, monitoring of land use, road connectivity in rural areas and inputs for development of action plans for sustainable agriculture.

About 70% of Indian agriculture is rainfed where soil and water play a significant role in crop production. Spatial and temporal variations of resources, coupled with mismanagement, result in inefficient utilization of these resources for production purposes. Management of these resources on watershed basis has long been identified as more scientific, sustainable and is the only viable alternative to prevent the food shortage and check environmental degradation. Watershed management Programme in India is about 5 decade old. Various guidelines for watershed development programmes have been framed from time to time which have dealt in detail the objectives, criteria for selection of priority watersheds, ensuring the participation of the beneficiaries, implementation methodology and monitoring strategies.

Space technology has now reached a stage, where natural resources can be continuously monitored either at nation, state, district or at watershed basis. Thus, various facets of sustainable development ranging from global processes to watershed development, remote sensing can play a vital role in generating information at various scales. Integration of the research information for solving the resources problems and providing specific action plans for land and water resources development using space inputs enables better management of agricultural resources to meet the current and future basic requirements, besides improving the quality of life in rural areas.

Historical perspective of Watershed Development Programmes

Watershed offers a scientific basis for agricultural development as it facilitates accurate measurement and monitoring of components of water balance in hydrologic cycle, sediment, energy, pollutants and nutrients, as it is the smallest and complete entity in an ecosystem. Watershed development encompasses control of soil erosion and land degradation, moisture conservation, land use revisions in tune with land capability, optimal management of crop lands,

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grasslands, forest conservation, harvesting and management of water resources, etc. It leads to optimal biomass production and consequent economic and social well being of the populace in the watershed.

The soil and water conservation activities can be executed on an individual field basis or within the administrative boundary of a village/block/tehsil. However, this does not help in assessing the water balance and particularly the rainfall-runoff relationships which are crucial for assessing the water requirements of a given locality or region. The watershed as a unit of planning helps in assessing the rainfall-runoff relationships and other related parameters in a quantifiable manner. Further, the watershed approach helps in managing the flow of water from up slope to down slope and particularly from the water divide line/watershed boundary/ridge line to the valley portion efficiently and convey it safely through the outlet.

Organized governmental efforts initiated during 1930's under the banner of dry farming research had substantial component of watershed management. After independence in 1947, five-year plans were initiated to address all development issues. Variety of programmes was created to tackle problems like soil erosion, soil moisture depletion, run off, deforestation etc. In 1949-50, a multidisciplinary soil conservation department was set up at Hazaribagh under Damodar Valley Corporation for watershed management and land reclamation. The Central Soil Conservation Board was established in 1954. In the First Five Year Plan (1951-56), a chain of Soil Conservation Research, Demonstration and Training Centres was established in 1954. These centres were reorganized under Central Soil & Water Conservation Research and Training Institute (CSWCRTI), Dehradun in 1974.

Union Agriculture Ministry launched Soil conservation scheme in river valley projects in 1961-62 for watershed protection in 27 catchments. Watershed technologies were first demonstrated in actual field settings through integrated watershed management techniques in mid-seventies through the Operational Research Projects (ORPs) on watersheds by CSWCRTI. During 1980-81, watershed programs were initiated for Flood Prone Rivers by Agriculture Ministry. Forty seven model watersheds were developed in different agro-ecological regions of the country in 1983 jointly by the Central Soil and Water Conservation Research and Training Institute (CSWCRTI), Dehradun and Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad of the Indian Council of Agricultural Research, in collaboration with State Governments and State Agricultural Universities. The Ministry of Rural Development has developed number of projects in 1987-89 like DPAP, DDP,IWDP to address needs of the backward and needy regions using watershed approach. Ministry of Agriculture has developed NWDPRA during eighth plan, a watershed to treat ranfed areas. The watershed atlas of India published by AISLUS on 1:1,000,000 scale in 1988 was a landmark development. The atlas presented a methodology of watershed delineation and nomenclature for the country.

Western Ghats Development Programme of Union Planning Commission spread over an area of 16 M ha in the States of Maharashtra, Goa, Karnataka, Tamil Nadu and Kerala also started following integrated watershed based approach since 1987-88 for eco-restoration including Hill Area Development Programme (HADP). World Bank, DANIDA, EEC, Indo-German, Indo-Swiss and Japanese aided Watershed Projects were also initiated as externally funded watershed programmes. Apart from these national/international level programmes, a number of State Governments sponsored and NGOs supported watershed programmes were subsequently started during eighties and nineties and these efforts continue to increase.

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In 1994 Dharia committee was constituted to study wasteland development and had analyzed and recommended that SWC encompass degraded and non-degraded lands, insisted on more integrated watershed development and need for a single agency to address all conservation issues. Ministry of Rural Development had revised the guidelines of Hanumantha Rao committee (1995) for watershed selection by implementing HARIYALI guidelines in 2003 that are simpler to follow.

In summary, the watershed development programme in India has evolved through various stages. The first generation programmes were highly centralized, with major emphasis on technical aspects. The second generation projects were redesigned with community participation as the central theme, together with major decentralization of procedures and emphasis on indigenous technologies. While the restructured second-generation projects are resolving the sustainability concerns to a large extent, they have begun to throw up a host of other policy, institutional and technology issues related to efficient management of water resources.

Watershed development needs and gaps

One important observation emerging from various experiences and past efforts in watershed development is that home expertise is available in the country to address all dimensions of watershed development but the line departments prepare their own plans and often there is no inter department coordination. Secondly, people's participation and social perspectives are absent and thirdly, there has been no systematic attempt to study the impact of watershed schemes. In recent years, some of these issues are addressed in a sporadic way but a more structured effort is needed. The watershed codification up to micro-watershed level for the entire country is not complete. Currently, watershed selection is done with little use of natural resource inventory and socio economic data. Action plans are not prepared on scientific basis using natural resource data. The watershed monitoring and impact assessment is not done for most of the watersheds. This leads to somewhat haphazard approach to treatment and monitoring.

Natural resources base for watershed development

In this backdrop, the Department of Space has launched a national level programme for watershed development, entitled, "Integrated Mission for Sustainable Development (IMSD)", covering 184 districts and 175 M ha. It was envisaged to build a comprehensive scientific database on the natural resources of the watershed as a first step. Seven vital layers of information for each of these watersheds were mapped using the state-of-the-art remote sensing techniques and the integrated information thus derived was used to develop action plans for development of watersheds. Several action plans were demonstrated and a guided development was ensured. A large number of organizations participated in this effort and it turned out to be the largest remote sensing application experiment ever done in the world using a meticulous participatory approach.

Feedback from the IMSD project has been highly rewarding to further improve the realization of the benefits of the watershed development programmes. The feedback indicated that the action plans are more generic and the user was ill equipped to make use of the more technical inputs, thus resulting into poor participation of the community. In the subsequent watershed developoment programmes, several of these issues have specifically been covered.

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Traditionally, watershed management needs are met through conventional surveys, which are tedious, expensive and slow. Planners had to contend with topographic maps and cadastral maps. In the absence of natural resources information (soil, land use, slope ground water etc), decision-making becomes unscientific. In the mid sixties, Aerial Photo Interpretation techniques came into vogue and were effective in soil survey and watershed studies. Satellite remote sensing became a logical extension to aerial surreys by virtue of its synoptic coverage, multi-spectral, multi-temporal and spatial resolution capability as it was even more flexible and efficient in resource inventory and monitoring. Remote sensing plays a vital role in watershed management as it helps in watershed delineation, resource inventory, develop action plans through analysis of maps, action plan implementation, monitoring and impact assessment. In recent years the technology has taken a big leap and with the availability of superior sensor system in CARTOSAT and RESOURCESAT enabling improved natural resource inventory, action plans prescriptions and monitoring. The CARTOSAT mission has also ushered a new era in DEM applications. In addition Global positioning Systems (GPS) have furthered use of remote sensing as they enable accurate estimation of location and height.

Remotely sensed data is used to prepare theme maps such as land use/land cover, soils, geomorphology, forest cover etc., for designing management strategy. In watershed management, these theme layers are overlaid in GIS environment and through spatial analysis; action plan prescriptions are arrived for implementation. NRSA/DOSA have developed methodologies for operational use of remote sensing in watershed management. Legends for various scales of mapping have been designed and standard codes developed under NNRMS. DOS has also developed digital database standards and transfer protocols for thematic/non thematic maps at various scales. Programs like NRIS and NRCENSUS have been taken up to meet state/district level database needs at different scales. With the availability of High-resolution remotely sensed data, valuable inputs for watershed characterization can be extracted with finer detail and higher accuracies. Satellite stereo data available currently through CARTOSAT can be used to derive Digital Elevation Model (DEM) for terrain analysis. Further, remotely sensed data is being used in special studies on modeling water balance, erosion and runoff.

For integrated planning, a large number of thematic maps need spatial overlay to derive integrated land units for their potential, limitations and usage. Geographic Information System (GIS) is a pragmatic tool for geo-relational database management, be it data retrieval, updating or manipulation capability. The integrated database can be stored and queried for decision alternatives and decision-making. It is possible to prioritize activities for watershed health, socio-economic well-being and development of the populace.

Information System & Automation

A natural resources information system was developed to generate land and water resources development action plans in an automated manner for desertic areas, covering 76257 sq. km., spread across 40 districts, under Integrated Resources Information System for Desertic Areas. Spatio-temporal databases generated for watershed development in these are digitally organized for monitoring the changes consequent to the implementation of the action plans, which in turn enable decision making for appropriate interventions to achieve the desired response.

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Watershed information system is a tool that can be developed to assist planners in decision making and implementing all watershed programs. The watershed Information System (WIS) enables the user to store, retrieve, and view watershed data with an easy to use user-interface. The use of Geographic Information Systems allows combined analysis of multiple datasets such as soils land use, geology, geomorphology, slope, socio- economic data etc. Such analysis enables development of action plans for land and water resource management, which can be used in watershed implementation. The WIS design and implementation will be within GIS environment with functionality that provides a potential user with an easy access to the Watershed data for a specific Location/area. In a watershed program, it is necessary to know the status of watershed in relation to other watersheds. The functionality for data-retrieval and viewing of specific information on certain areas, watershed parameters enable the user to get a spatial insight in the soil information and regional differences in soil quality. Information on soil can be analyzed in combination with other spatial data and thus incorporated integrally with other types of information in the development of complex plans and the taking of far reaching decisions. . The system should offer the user extensive possibilities to read data from different sources and forms such as tabular, raster and vector data. This makes it possible to, integrate the seamlessly with available data files and also to interface with other existing systems.

A complete system comprises of the following elements:
(a) Natural resource database layers consisting of Soils (data. site data, soil profile description data, soil taxonomic and mapping units, and laboratory analyses) with land degradation, land capability / irrigability information, slope, existing land use/land cover, slope, geology and ground water prospects etc.
(b) Information on climate and rainfall
(c) Socio economic data consisting of population, literacy, land holdings, employment, income, irrigation, drinking water facility etc.
(d) Package of practices for agriculture development and soil-water conservation and management.
(e) Village wise information on watershed treatment status, expenditure, agencies/NGOs involved, spatial location of structures constructed, spatial irrigated area information,Year of treatment etc
The entire database can be organized in a Geodatabase embedded in RDBMS like ORACLE. Query shells are to be developed to answer questions like:
- What types of soils/land use practices exist in a watershed?
- List the villages without drinking water facility
- Show towns/villages with fertilizer outlets
- When was a watershed treated and by whom?
- Give details of expenditure.
- What are the optimum cropping practices given a set of conditions?

Metadata (data about data) for all spatial layers and non-spatial data shall be generated to conform to ISO standards for data description. The inter-operable database will be installed at district level offices and trained manpower shall operate these facilities for meeting the wider needs of the public. Detailed operations can be spelt out in a technical manual.

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Production System Approach & Microwatersheds

Micro-watersheds of typically about 500 ha are delineated for watershed development by the line departments, primarily, due to convenience in management. This necessitates natural resource information on maps of 1:12500 or larger scales. Action plans also are centered around crop production systems. These twin issues were jointly addressed in one National Agricultural Technology Project, wherein critical areas have been mapped on 1:12500 scale using IRS Pan sharpened LISS-III data and locale specific action plans have been implemented based on the resource constraints for containing soil erosion, harvesting run off and improving overall crop productivity with the technology developed by the State Agricultural Universities and the ICAR. The impact assessment revealed that the space inputs coupled with GIS and ICAR research findings on crop improvement, land and water resources development could be successfully used for the benefit of farmers in the micro-watersheds.

Monitoring and Evaluation

Monitoring and Evaluation (M&E) in watershed development projects has assumed greater significance in recent years with the developments in the technology. A community driven, participatory watershed development project, SUJALA, is being implemented in 854 micro watersheds distributed across 38 taluks in five districts of Karnataka State. The monitoring system adopted in SUJALA project has a blend of modern technologies like Remote Sensing (RS), Geographical Information System (GIS), Management Information System (MIS) with conventional ground based monitoring system and has three components viz., input – output monitoring, process monitoring and impact assessment. The integrated approach of M&E answers questions about progress against broad development indicators. It has enabled appropriate policy formulation, implementation of suitable strategies /action plans, assessing the impacts, resulting in mid course corrections and increased transparency/accountability in the project.

Village Resource Centres

Spaces based services, emanating from Satellite Comunication (SatCom) and earth Observation (EO) satellites, hold the capacity to transform the village community. In this regard, EO enables community centric spatial information in terms of geo-referenced land record, natural resources, suitable sites for potable / drinking water as well as recharge, spatial distribution and type of wastelands, for reclamation through rural employment creation, watershed attributes, environment and infrastructure related information. Synthesizing spatial information with other collateral and weather information, EO also facilitates locale specific community advisory services. India has demonstrated operationally these SatCom and EO applications and successfully could integrate space based community centric services down the line at the grassroots.

Conclusions

- Use of geospatial technologies like remote sensing, Geographic Information System and Global Positioning System should be made mandatory in all watershed programmes in the country for effectively monitoring the watershed programmes.

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- The technical parameters like soil loss, scarcity of water for irrigation and domestic use, remoteness of area from approach road may be given more weightage in selection of watershed against the social aspects, viz; population of scheduled castes/scheduled tribes, landless families etc. The watershed area of about 500 ha is logical for treatment from management point of view. The families residing within a watershed of this size can have better participatory index than a larger watershed area. The watershed project duration of five years is sufficient for planning and execution.
- Base map is required on 1:5000 scale which should be prepared using the existing toposheet of SOI on a scale of 1:50,000 or 1:25, 000 along with high resolution satellite data. As there may be about 6 lakh such watersheds in the country, hence it may not be possible for a single agency to undertake this work. Each state is having its own "State Remote Sensing Centre", which is equipped with GIS and other suitable softwares and trained manpower related to RS/GIS. These centres may be strengthened with an additional responsibility of preparing and providing base maps on 1:5000 scale.
- Watershed planning requires analysis of the problems of the area and develop appropriate solutions within the available resources of the watershed. This calls for resource inventory of micro-watershed at 1:10,000 scale all the major watershed programmes in the country for identification of problem areas and development of action plans. There is a need to prepare Integrated Tool Kits (ITK) for watershed development for different Agro-Ecological Sub Regions Use of high-resolution satellite data for group of villages / micro-watersheds aid in resource inventory and monitoring is cost effective.
- There should be an in-built mechanism of evaluation and monitoring and provision for post-project maintenance and repair. It should be carried out by an independent outside organization not connected with the watershed in any manner so as to avoid any biasness. The quantitative indices of monitoring and evaluation should be employed. For example, the indices such as LDI, CPI, CDI, CLUI, PWDI etc. developed by CSWCRTI, Dehradun can be used for this purpose. For monitoring and evaluation, the high resolution remote sensing data of pre-treatment phase and post- treatment period should be used for impact assessment of various programmes implemented in the watershed.
- Awareness may be created among stake holders about finiteness of time frame of the project and the financial support beyond which it would be managed by them. Stake holders may be informed at least two years before proposed withdrawal which should be in a phased manner. Strong groups/institutions should be constituted to maintain watershed infrastructure independently during last one quarter life of the project. Capacity building at all levels is a must to protect and maintain the infrastructure created.

The experience of India indicates that the best benefits of the space inputs could be realized through motivated participation of the community in the development programme, right from selection of the watershed upto implementaion, propped up by the automated monitoring and evaluation mechanisms. This is certainly possible with the effective means for enahanced timely outreach of easily understandable information, via digital connectivity through information kiosks in joint public – private partneship endeavours.

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Acknowledgement

I sincerely acknowledge all the original contributors of the studies mentioned here which have been carried out at ISRO/DOS over the years.

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