CHAPTER 3: REVIEW OF LITERATURE

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3.1 Need of Watershed Approach: A Look Back

Prime soil resources of the world are finite, non-renewalable over the human time frame and prone to degradation through misuse and mismanagement as per **Lal (2000)**. He also calculated the global extent of soil degradation, where he reported that around 20.5 percent of land area was facing water induced degradation and 4.70 percent of land area was having wind-induced degradation. The chemical and physical degradation was present in 18.0 percent and 14.5 percent of land area under global scenario respectively.

Oldeman (1994) reported that out of a total degraded land area of 1965 mha, over 300 m ha (about the size of India) were strongly degraded on a world scale. These lands have loss their productive capacity as well as restoration and these can only be achieved through major investments and engineering works involving massive land reforming. Land degraded by water erosion and wind erosion constitutes 82 percent of the total strong and extremely degraded land area. On a global basis, rivers draining through very densely populated region of the world, i.e. Yellow river in China, Ganges in India, carry high sediment load. The problem of erosion and sedimentation are accentuated by misuse and mismanagement of resources within the watersheds of these river systems. A strategy based on watershed management is essential for effective erosion control and to stop simultaneous degradation of soils.

Eswaran *et al.* (2001) in his research article on land degradation expressed the adverse effect of soil erosion. Although from the view of an economist it seems that land degradation has a very minimal impact on economy in terms of productivity but a soil scientist and an agronomist always showed their concern in preserving non-renewable natural resource like soil, since that is non renewable in human time frame. As per the researchers on a global scale annual loss of 75 billion tons of soil costs the world about US$400 billion per year, or approximately US$70 per person per year.

According to **Singh (2000 b)**, rainfed agro-ecosystem, the so-called gray patches untouched by green revolution, occupies a very important position in the Indian agriculture. The rainfed agro ecosystem having annual rainfall from 500-1500 mm constitutes nearly 70 percent of the net cultivated area of the country, which certainly occupies some of those gray patches that did not encountered the boon of green revolution.

Acharya (2002) reported that even when the full irrigation potential of the country would be realized, 50 percent of the net sown area would continue to remain rainfed. Rainfed agriculture supports 40 percent of India's population and contributes 44 percent to the national food basket as per **Abrol *et al.* (1994).** He also reported that 70 percent of the oilseeds, 90 percent of the pulses and 70 percent of the true cotton were grown in rain fed agro-ecosystem.

The cropping intensities and crop fields (about 1 ton ha^{-1}) were low and unstable in the rainfed areas due to the unpredictable swings in rainfall, loss of biotic and abiotic stresses and adherence to age-old farm and crop management practices as notified by **Katyal *et al.* (1996).** The demand for food would continue to raise higher productivity from rain fed regions (2 Mg ha^{-1}), which emphasizes the critical importance of rain fed agriculture in Indian economy and food security of growing population.

In the present scenario *Upper Kasai* watershed was selected for critical or degraded area identification and subsequent micro-watershed selection through watershed prioritization for further land treatment. The watershed is situated in the rainfed agro-ecosystem of Eastern India.

Tiwari (2002) commented regarding the agriculture driven economy of India. The country may be considered as the home for one-sixth of mankind. The population has already crossed one billion and is increasing at the rate of 14-15 million per annum. National policies and program are geared towards producing the entire food and fibre needs for this growing population within the country. It is one of the outcomes of this goal to remain self- sufficient in food grains.

The watershed development program in India was implemented more than 20 years back during 1975-1983 (**Reddy and Rao, 1999**). By the ninth five-years plan a number of agencies have been involved in initiating and implementing and the watershed management program in almost all the agro-climatic zones in the country. Thus, watershed approach has been identified as a major route and a promising area for development, especially to rainfed agriculture and is receiving prior attention from union as well as state government and NGOs. Over the last 20 years of experience during the implementation of this program, several areas of success and shortcomings have been identified. However, for sustainable development of agriculture, the paper argues that unifying the municipality of watershed programs within the framework of an over-reaching national initiative is desirable in national interest.

3.2 Different Watershed Approaches: The Global Scenario

Aschman *et al.* (1999) clubbed nutrient management approach for watershed scale planning. The study indicated the development of watershed-scale models to examine dynamic phosphorous (P) flows into, out of, and within watershed using a mass balance approach. The "Watershed Ecosystem Nutrient Dynamics (WEND)" models track watershed P balances over time within each of the several land use sectors. Long term impact of various strategic policy decisions on P cycling both within and export form watersheds can be modeled. The *Winooski River Watershed* in Vermont, USA is a case watershed in which WEND was used to evaluate the impacts of long-term strategies on nutrient use efficiency. The model showed increased water quality impairment over 80 years under the status quo and development scenarios. Under the conservation scenario, P movement into the drainage network was significantly reduced. These suggest that the WEND model could be adopted as a tool for improved watershed-scale P management. In the present investigation the nutrient management schedule was proposed on the basis of macronutrient (N, P_2O_5 and K_2O) fertility data for the dominant variety of six selected crops of the micro-watershed locale.

Several other scientists undertook the study of major nutrients like P in the watershed level also. **Osei *et al.* (2000)** studied the results of computer simulations performed to assess the impact of various management practices on phosphorus losses from dairy farms in a watershed in north central Texas. The results show that moving from nitrogen to phosphorus-based waste application rates could significantly reduce phosphorus losses at moderate cost to producers. Composting solid manure for end used outside the impacted watersheds provides even greater phosphorus load reductions and requires less lands, but result in significantly higher cost to producers. The choice for each watershed depends on such key factors as available land area and the load reduction sought.

Watershed management is a multi-disciplinary approach combining different fundamental disciplines like agriculture, environment, **soil**, geology, engineering etc. The soil resource mapping was done in the present scenario to characterize and classify the soils of the watershed for further land use suggestion. Among few of the known scientists like **Cissel *et al.* (1999)** while studying in the *Blue River Watershed*, part of the Willamette national forest, Oregon approximately prescribed by historical information the timber harvest frequency, severity and spatial extent of past fires. Future harvest blocks were mapped and were used to project forest patterns 200 years forward and to map resulting landscape structure. It was suggested that landscape management plans incorporating key aspects of ecosystem history and variability might pose less risk to native species and ecological processes. The said group of scientists intermingled the forest management with the watershed management, which might be considered as a path of multi-directed watershed approach.

The development of a sub-regional water table map over 56 square kilometers for delineated watershed and sub watersheds (of Cape Cod, Massachusetts) was investigated by **Thomas and Eichner (1998)** with the help of plotting ground water flow paths, measured mass balance between recharge rates over riverine watershed segments as well as stream flows and characterized submarine ground water plus hydro geologic conditions at considered depth. This type of watershed characterization provides a firm basis for the development of no point source management option for coastal embayment.

Hatch *et al.* (2001) during an investigation in *Minnesota River Basin* suggested that watershed management in highly agriculture-dominated watersheds would be most effective when hydrologic watersheds were used as a framework that was complemented by agro eco-regions to identify the target regions where specific combinations of best management practices for agricultural sediment were most appropriate.

Jacobson *et al.* (1995) conducted a project to select, calibrate and validate a watershed scale model capable of evaluating the water quality impacts of the diversified cropping system and management practices in a watershed of North Carolina, USA. Soil Water Assessment Tool (SWAT) model was outlined to calibrate and validate data collection techniques. After calibration, the model adequately predicted monthly stream flow at the watershed outlet.

3.3 Watershed Development Under Indian Scenario:

Watershed development approach was widely adopted in India from early nineties when the National Watershed Development Projects for Rainfed Areas (NWDPRA) first kept its footstep to different Rainfed agro-ecological sub-regions like hot dry sun-humid belt of Puruliya district West Bengal (**Paul *et al.*, 1998**). Several scientists contributed a lot for the development of watershed projects from various aspects like agronomy, soil, geology, environment etc. to achieve better crop yield return from those rainfed sectors, as nearly 70 percent of Indian economy is rainfed (**Paroda, 1998**).

According to **Chennamaneni (1998)** a watershed management approach combining improved farming practices with soil / water conservation and appropriate land use offers scope for sustainable development of agriculture. The analysis showed a positive impact of modernized farming practices and soil water conservation measures on land use intensity, cropping pattern and crop yields, human labour utilization, creation of assets etc. However, problems such as a sectoral approach in implement, lack of different package options in tune with frame household strategies such as income diversification / stabilization and neglect of common property resources hamper the overall gains of watershed management.

Murthy (2000) studied the ground water potential in a semi-arid region of Andhra Pradesh through GIS approach. The method involves the creation of a systematic database of information from satellite imageries for reconnaissance survey before going for field exploration. False Colour Composite images from Landsat Thematic Mapper and Indian Remote Sensing Satellite (IRS) were used to interpret various thematic maps of *Varaha River Basin*, Andhra Pradesh. The topographic information was digitized and was analyzed through ERDAS IMAGINE software. Ground water potential zones were delineated through subjective weights assigned to interpreted thematic and derived topographic units according to their likely infiltration capacities. Seven categories of ground water potential ranging from very good to poor were derived from the study.

Singhal (1999) performed a case study regarding the importance of people participation in watershed management, while doing an investigation in the Nada village of Shivalik hills, Harayana, India. The study tried to elicit the level of people's participation in planning, implementation and monitoring of watershed activities.

Singh (1999) made a holistic approach to improve the socio-economic status of the farmers. The study was conducted in the *Chhajawa Watershed* and adjacent villages in Baron district of Rajasthan, India. The average family income, contributions of service sector and agricultural sector were 21.5 %, 7.64 % and 21.89 % higher inside the watershed, compared to the of the watershed area.

Varadan *et al.* (1998) worked in *Chembankuzhy* Watershed, Kerala, India. Observations of stream flow, rainfall, evaporation, ground water table fluctuations and soil moisture content were recorded for the period 1993-95 from two micro-watersheds, one with conservation treatments and another without treatment. The discharges in the streams of the treated and untreated watersheds were 0.246 and 0.06 m^3/s respectively in November. The ground water table decline was less in the treated watershed than in the untreated watershed. This indicated more surface water and ground water availability in the treated watershed due to conservation program. The soil moisture data during summer months also showed more moisture availability in the treated watershed.

Kumar *et al.* **(1998)** studied the effect of comprehensive watershed management program in Uttar Pradesh, India. He also reported that the impact of various soil and water conservation measures e.g. contour bunding, land leveling and smoothing, gully plugging, contour furrow, negative barriers and sunken structure were highly effective and resulted in an overall increase of 20-25 percent in the yields levels of wheat, barely, bengal gram [*Cicer aritimum*], pea, lentil, soybean, groundnuts and sorghum in the concerned watershed.

Adhikari (1993) monitored the effect of soil and water management in hydrological responses in a red soil watershed. Hydrological monitoring of a red soil in a semiarid watershed in Karnataka, India, over a three-year period showed that the average annual soil loss was 1 ton / ha. In the untreated areas of the same watershed the annual soil loss was estimated at between 5 to 10 tons /ha. Conservation measures included contour trenches, graded bunds, aforestation, stone checks and gully control water harvesting structures.

The effects of watershed management program on land and crop productivity in drought prone region of West Bengal was studied **(Zaman, 1993)**. The study was performed in 1988-90 with 6 rainy season crops {seeded and transplanted rice, arhar (*Cajanas cajan*), groundnuts, sesame as well as maize and 2 winter season crops (mustard and wheat)} on lateritic soil by giving improved agronomic practices like fertilizers and irrigation water management, plant protections, soil and water conservation. It was revealed that adoption of techniques in the favour of watershed management increases both land condition and crop productivity.

Sen *et al.* (1997) studied the rate of soil loss from fields sown with crop during the rainy season and to examine the factors determining the erosion rates in Pranmati watershed, which is characterized by, settled organic farming on terraced slopes. The author studied the effect of cultivation (with special reference to potato) on soil erosion. About 43 percent of the total agricultural land in the watershed was on low sloping terraces (<2°), 32 percent on medium sloping terraces (2-6°) and 25 percent on highly sloping terraces (6-10°). Potato was the most dominant crop, occupying 50.2 percent of the total cropped area. Although potato fields showed greater erosion (72.6 % of total soil loss from agricultural fields) compared to other tested crops like paddy, but people were more interested in potato cultivation due to its greater economic returns, in spite of having no fodder value of potato by products. Therefore the author suggested that it was needed a land use optimization policy to combat such dual problems.

In the present investigation several management practices like soil conservation, plantation, building of water harvesting structure, adoption of Fertility Management Practices etc. were proposed as a generalized action plan "In Totality" after identifying the patches suffering from the respective limitations.

3.4 Watershed Prioritization and Management: The GIS Approaches

Presently, the soil resource database was generated as an 'Information System' to locate critical and priority area for further land treatment, thereby generating thematic maps with the help of GIS tool indicating different problems and remedial or control measures as per requirement.

Das (1998) reviewed the criteria required for watershed development, both in the planning and strategy. It propose a soil and land information system for India, using GIS and notes the areas within which information are required to provide a sound database for natural resources management. **Suresh *et al.* (2004)** prioritized the sub-watersheds on the basis of sediment production rate in the *Tarai* development project area. The sediment production rates in the study area varies between 2.45 to 11.0 ha-m / 100km^2 / year. The remote sensing data has been utilized for generating land use/land cover data, which is an essential pre-requisite for land and water resources development, and planning. The remote sensing data can especially play significant role in collection of real time information from remote areas of river basins for generation of parameters required for hydrologic modeling.

The nine sub-watersheds of the major part of Nayagram block in the Midnapore district, West Bengal were studied for prioritization. The remote sensing techniques and GIS tools were efficiently used to identify the morphometric parameters such as stream length, bifurcation ratio, drainage density, stream frequency, texture ratio, form factor, circulating ratio and elongation ratio as the watershed prioritization index. The results suggested that the sub watershed numbered as '8' got the highest priority because of high erosion intensity considering the above-mentioned morphometric parameters **(Biswas *et al.*, 1999)**.

Richardson and Gatti (1999) prioritized wetland restoration activity within a Wisconsin watershed using GIS modeling. A GIS database was developed in southern Wisconsin in order to locate drained wetlands and their owners for field manager contacts and also to rank wetlands for restoration, based on their potential to improve water quality. In this study GIS was used to delineate the mini-watershed of each drained wetland basin, and estimated that could be trapped if the drained basin was restored.

Cox and Madramootoo (1998) developed conservation oriented watershed management by providing soil loss model or strategies on *St. Leila* by GIS approach. GIS provided a fast and efficient means of generating the input data required for the model and allowed for easy assessment of the relative erosion hazard over the watersheds under the different land management options. The model predicted substantial declines in soil loss under conservation oriented land management for both watersheds. The procedures developed will contribute to the evolution of a decision support system to guide agricultural and forestry planning in the study area.

A land use scheme for a hilly watershed, subject to soil erosion, in the Western Ghats, India using GIS was compiled by **Adinarayana and Krishna (1995)**. A remote sensing based physiographic soil map and a 'Digital Elevation Model (DEM)' were the sources of soil depth, slope steepness classes, respectively and were the information database for GIS analysis. The GIS was used to integrate and manipulate this database.

Fernandes *et al.* (1999) aimed to develop a computer program linking expert systems and geographical information system, in order to perform a rapid process for land use class definition, according to the FAO / Brazilian system, and the approach was applied to *Corrego Taquara Brance Watershed*. The results were presented as thematic maps, which illustrated the corresponding classes of land use at 3 levels of management and also the conflicts between actual as well as potential land use. The validation test shows that the system was 75 percent in agreement with the opinions of some of the experts consulted.

3.5 Soil / Land Resource Studies and Management in Different Watersheds

The soil / land resource studies and management on watershed basis is presently a boom issue of "Natural Resource Development" under Indian scenario. That is why the present article is mainly enriched with the references of Indian authors.

Soil / Land resource studies in order to generate the 'Information System' through mapping is essential to produce any 'Combat Measures' against land / soil limitations, thereby generating suitability studies for different crops as 'Action Plan'.

The cropland suitability analysis is a prerequisite to achieve optimum utilization of the available land resources for sustainable agricultural production. The evaluation of spatial variability of relevant terrain parameters was carried out in a geographic information system environment while assigning the land suitability for crops in the study area of *Kalayanakare sub-watershed* in Karnataka, India. Nine parameters (eight of soil and one of topography) were considered and suitability analysis was carried out by fuzzy membership classification with factors included to accommodate the relative importance of the soil parameters governing the crop productivity. According to the field information, the crop being grown in the maximum area is finger millet. However, the cropland evaluation indicated that the maximum area is potentially suitable for growing groundnut **(Ahamed *et al.*, 2000)**.

Soil samples from two depths (0-15 cm and 15-30 cm) in nine profiles of Alfisols under dry, wet, pasture and forest lands in *Kabbalanala* watershed, India were studied by **Murthy *et al.*** (1993) for particle size, organic matter, sesquioxides, water stable aggregates and aggregate stability coefficient. Forest and pasture soils had higher organic matter and sesquioxides than dry land and irrigated soils. Mean weight diameter increased with depth. Dry land and irrigated soils recorded lower mean weight diameter values than forest and pasture soils. Forest soils had an aggregate stability coefficient near one, which was conducive for root development. Clay significantly varied with soil series whereas, course sand, organic matter, sesquioxide, mean weight diameter and aggregate stability coefficient varied significantly with land use and soil series. The mean weight diameter correlated significantly with organic matter and sesquioxides. The aggregate stability coefficient was correlated with clay.

Vijaylakshmi *et al.* (1993) suggested that 'Runoff Farming' is a method of collecting surface runoff from a watershed and storing it in reservoirs for use. A model for estimating runoff on Alfisols in Hyderabad, India was compared with respect to observed values. Storage needs and irrigation requirements were evaluated. Using soil data analysis, it was inferred that a 180 m^3 pond, which could provide an irrigation of 15 mm in August to sorghum and 50 mm in October to castor bean, was an appropriate system for this region.

Chinchmalatpure *et al.* (2000) assessed soil-DTPA extractable micronutrients (Cu, Zn, Fe, Mn) in a micro watershed of *Wunna* catchment near Nagpur (Maharastra) and it was found that these micronutrients are present in adequate quantity (basalt derived soil). However soils developed on sand stone showed smaller amount of Cu and Zn cations. Available Cu was significantly correlated (1%) with Fe (r = 0.48), Mn (r = 0.57) and Zn (r = 0.49). Available Fe was negatively and significantly correlated with pH and lime content. DTPA- Mn had a negative correlation with sand (r = 0.44) and positive correlation with CEC (r = 0.69), organic carbon (r = 0.36) and clay content (r = 0.53). Zn and Cu were positively and significantly correlated with organic carbon and negatively with sand content.

Sharma ***et al.*** **(2004)** described a case study at Neogal Watershed in North-West Himalayas. The soil characterization and subsequent crop suitability was investigated. It was observed that the concerned soils were very deep, acidic (pH: 5.2-6.2), non-calcareous, coarse to fine textured (loamy) and were having mixed mineralogy {CEC: 4.9-14.3 cmol(+) kg^{-1}}. The Udorthents and Udipsamments were found in the Hill slopes, whereas, the gently sloping river terraces were enriched with Dystrudepts and Hapludulfs. The agricultural land showed land capability index III and irrigability 3 as well as 4. Paddy, maize, wheat and potato were the preferred crops and tea was the ideal plantation crop. The coefficient of improvement of soils varied from 1.7 to 3.2 for agricultural crops and 1.5 to 5.2 for plantation crops. It was also suggested by the concerned scientists that adoption of judicious soil and water management practices would sustain crop productivity of these soils.

Sidhu ***et al.*** **(2000)** worked for the various layers of maps for (*Upper Machkund* watershed, Andhra Pradesh) watershed and sub-watershed boundaries, hydro-geomorphology, soil, land use/cover, slopes prepared by interpretation of satellite data (IRS-1B bands 2, 3 & 4) and topographical maps were used for digitization and generation of a database on ARC/INFO GIS system. The version 5.0 / 6.0 ARC/INFO GIS software was used to digitize, edit, build, transform, display, analyze and plot the maps of a watershed in India. By using the 'Union' module, geomorphology soils, land use/land cover maps were combined to generate action plans. The results showed a well-established soil-landscape relationship in the area.

Bhaskar *et al.* (1996) evaluated the influence of various soil site parameters and climatic parameters for wheat yield on 6 different soils of *Saongi* watershed in Maharashtra. Among the climatic parameters, high temperature and low humidity coupled with high wind velocity were the most important factors in contributing to low yields through creating water stress. Soil factors, depth, clay content, cation exchange capacity (CEC), available water capacity (AWC) and organic carbon were correlated with grain yield. The effective range for soil depth was 65-100 cm, AWC was 170-200 m, clay content was 48-56 %, CEC was 43-53 cmol (+) kg^{-1} and organic matter content was 0.63 - 0.74 % while 3 soil types were satisfactory for high yields, the sites were moderately to marginally suitable for wheat because of the prevailing climatic condition. In the present context the similar study (like Bhaskar *et al.*, 1996 did) was performed with greater number of crops and soil parameters as well.

Yadav *et al.* (1995 a) conducted field experiments in a watershed near Nagpur, (Maharastra, India) on eight well defined and varied soil units to study the impact of soil characteristic on productivity of cotton, pigeon pea (*Cajanus cajan*), sorghum, groundnut and soybean grown under rainfed condition. The derived soil-climatic parameters plant available water capacity (PAWC), soil effective rainfall and the length of growing period (LGP) were directly associated with soil depth and clay content, and showed significant positive correlation values for all the five crops.

While working in the *Gomti* watershed, Kumaun, Uttar Pradesh, India **Bisht and Tiwari (1996)** studied in detail the traditional land use, regional agriculture system and the area prone to environment hazards by preparing large scale topographical forest and land record maps, field survey and mapping. The average slope was considered as the principal parameter of land capabiliity, the potential for landslides and the intensity of erosion. Recognizing the drastic changes that have taken place in the traditional land use, the watershed area has been proposed to be defined as protected forests (33.41%), community forests (32.86%), cultivation (23.33%) and horticulture (8.30%).

A diagnostic survey was carried out at the state government dairy of Ootacamund, Tamil Nadu, India at micro-watershed level by **Dwivedi *et al.* (1995).** Bench terracing, graded bunding, grassing of the watershed and trenching on steeper slopes were proposed as required watershed management, for that area. It was suggested that potato, cabbages, oats, beans, radishes would be the crop of choice for that area.

Yadav *et al.* (1997) conducted a field experiment at *Gondhkhari Watershed* near Nagpur, Maharashtra, India. In sorghum based cropping system, sorghum followed by wheat irrespective of soil type or sorghum followed by Indian mustard particularly in Typic Haplusterts produced higher return than gram, lentil, linseed or sunflower. Amongst the soybean–based cropping systems, soybean - Indian mustard produced the highest return followed by soybean-wheat or gram in Typic Haplustepts. On highly calcareous and moderately shallow soils (Typic Haplustepts) soybean-gram produced highest returns followed by soybean-wheat or Indian mustard. Therefore, sorghum based cropping system were more appropriate for Vertisols whereas, soybean based cropping system showed more promising result in Inceptisols.

Sano and Sakamoto (1998) effectively made watershed management plan considering the various viewpoints of land use. It cannot, however, deal with viewpoints that do not have enough quantities of information. The uses of such viewpoints were demonstrated using the landscape concept with GIS to make a watershed plan. The landscape level at which such viewpoints conflicts with others was clarified and the corresponding area omitted from whole watershed management plan. When it was difficult to specify the corresponding area, two alternative ways were used. One was omitting the area of the upper level of landscape that contains the area having the probability to conflict and which can be specified from the whole management area. Another way was allocating the cutting area before using goal programming and overlaying the area of the upper level of landscape.

Mandal *et al.* (2002) worked with the cotton growing soils of Nagpur district, Maharashtra, India. He emphasized on Riquor's parametric approach for estimating productivity index for its effectiveness in generalized land suitability estimation during reconnaissance soil survey. The modified criteria-based land suitability map depicted that 57.5 percent area was highly suitable, 28.5 percent area was moderately suitable, 5 percent area was marginally suitable and 9 percent area was unsuitable. Therefore the usually practiced crop of that area should be cultivated to the high to moderately suitable area. Rest of the area might be cultivated by the other suitable arable crop. The Sys's Index was more suitable than the Riquor's one when somebody considers the case of crop specificity as; it was taken care of in the present investigation.