Synopsis of the Ph. D. Thesis

“GEOMORPHIC ASSESSMENT OF PROBLEM OF SILTATION:
A CASE STUDY OF TAVARJA DAM IN LATUR DISTRICT, MAHARASHTRA”.

For the award of

DOCTOR OF PHILOSOPHY
IN GEOGRAPHY

Under the

SCIENCE FACULTY
UNIVERSITY OF PUNE-411007

CANDIDATE
ATUL M. ZETE

GUIDE
Dr. SUNIL W. GAIKWAD
Associate Professor in Geography
Department of Geography,
S. P. College, Tilak Road, Pune – 411 030.
(INDIA.)

Post Graduate Teaching and Research Centre, Department of Geography,
S. P. College, Pune – 411 030.

June, 2014
I. Preamble:

During the last hundred years or so, deforestation and wind water borne soil erosion have been steadily increasing and have now become the major geo-environmental problems, all over the world. Soils in general are degrading due to poor management and faulty land use at a rate faster than their natural degradation. Almost every reservoir is affected by sedimentation. The world commission on dams WCD estimated that each year around 1% of worldwide storage capacity is lost due to this effect. Without further action one quarter of all dams in the next 25 to 50 years will lose their storage capacity by sedimentation. (WCD, 2011). As a result of runoff from rainfall, soil particles on the surface of watershed can be eroded and transported through the process of sheet, rill and gully erosion. Once eroded, sediment particles are transported through river system and are eventually deposited in the reservoir or dams. (Yang et.al.1998).

Siltation of dams is the most grievous problem faced by scientist, engineers and researchers in the country these days. De-siltation or dredging of dams has not been attempted in our country so far. Sedimentation and siltation in water supply dams are wide spread problems affecting the viability of the water sediments carried by rivers and cause a number of problems such as rapid reduction of the ability to store the maximum quantity of water and promotion of weed growth on the increased area of shallow margins which might affect water quality. This can lead to the potential destabilation of the dam structure, and the problem with water intake and distribution system and higher frequency of acceptable tributary of water. (Brasillia, DF, 2011)

Dams located in semi-arid regions are most severally affected by sediment accumulation in Maharashtra. Land Use Land Cover (LULC) in the study area rapidly changed during the last 20 years. It changed from forest land to agricultural land. Sediment particles originating from erosion processes in the catchments are propagated along with the river flow and when the flow of a river is stored in a reservoir, the sediment settles in the reservoir and reduces its capacity. Reduction in the storage capacity of a reservoir beyond a limit hampers the purpose for which it was designed.

In several cases, the sediment load is associated with flood events, lack of vegetation coverage in drainage basin, lithological structure and nature of ground surface,
slope of the region, infiltration rate, denudation rate and high surface run off etc. Siltation in dam would create high loads in dam wall and thus safety of the dam becomes questionable. (Biswas et al 1999)

II. Study area:

The Tavarja dam catchment extends between $18^014'00''$ N to $18^024'00''$ N latitude and $76^015'00''$ E to $76^027'00''$ E longitude. It originates in between sub hill ranges of Balaghat covering Maharashtra plateau. The study area is located in Latur and Ausa tahsils of Latur district and Osmanabad tahsil of Osmanabad district.

Tavarja river drainage basin is one of the sub basins of the river Manjra (right hand tributary of Godavari river). The dam was constructed on river Tavarja in 1982 near Utti (Khurd) and Utti (Budrukh). It is a medium size dam having the catchment area of about 250.52 km².

III. Hypothesis:

'Litho-climatic factors have pronounced effects on the problem of siltation in central Maharashtra, knowledge of these factors can be useful to design a strategy to reduce the severity of the problem and in turn improve sustainability.'

IV. Aims and Objectives:

The basic aim of the present study of the Tavarja dam is to identify siltation and runoff areas to recommend prioritization of subwatersheds conservation and management plan for the same. In order to accomplish this goal, following objectives have been outlined:
1. To study the physical and chemical properties of the soil.
2. To perform terrain analysis pertaining to dominant physical determinants contributing sediment yield.
3. To estimate surface runoff using NRCS (SCS) curve number method, soil loss using USLE and sediment using SYI techniques to identify the priority for the sub basin areas.
4. To estimate siltation rate in Tavarja dam catchment.
5. To suggest the priorization of sub basins conservation planning using surface runoff, soil loss, USLE and SYI techniques.
V. Methodology:

In order to fulfill the objectives outlined above the following methodology is adopted in various stages.

1) The base map of the study is prepared with the help of 1:50000 SOI Toposheet.

2) The study of siltation in Tavarja dam is primarily based upon field investigations; frequent field surveys were organized.

3) Geomorphic attributes such as slope, absolute relief, relative relief, dissection index, geomorphic map are highlighted to get the idea about the overall relief of the study area and to infer the influence of the same on overall development of the area. In addition to this Terrain analysis software (TAS – Version 2.1) using the topographical sheet on the scale of 1:50000 (56 B/7, 56 B/8, 56 B/11, 56 B/12) and GSI map of the quadrangle has been used, as a base map.

4) Soil samples collected from various places in the study area were analyzed in soil lab to obtain sediment parameters.

5) The data regarding the climatic characteristics (Rainfall, temperature), land use etc. is collected from meteorological station of Latur District, census hand book, survey of India, Tavarja dam office and Tahsil headquarters.

6) Collection of soil samples performed by conducting soil surveys using GPS (by field survey) to cover the maximum possible representative slope segments. This is helpful in understanding the variability in soil properties according to slope units. The laboratory analysis of the soil is done to determine different soil parameters like soil texture and structure, bulk density, specific gravity, porosity, moisture variation etc. chemical properties, such as soil pH, organic matter, Organic carbon, hydraulic conductivity analysis have also been undertaken to know the general fertility status of the soil. In addition to this, infiltration capacity is directly checked in the field; this has become helpful in the determination of soil drainage classes. The study will also intend to check whether there is any change in the physico – chemical properties of soil according to seasons. This is helpful in suggesting some suitable measures according to variations in
physical attributes.

7) Run off analysis and soil loss estimation is undertaken to estimate the rate of erosion and siltation to delineate the areas of severe erosion and mapping of the same.

8) The mapping and analysis of the data is performed in GIS analysis. Grid wise data analysis has been carried out for preparation of maps applying GIS technique. Geomorphic attributes such as slope, absolute relief, relative relief, dissection index maps, and runoff and soil loss maps. Soil loss estimation of the area has been done by applying the USLE model of soil loss estimation

VI. Arrangement of the text:

The entire work is outlined in six chapters.

**First chapter** deals with the introduction of the subject of geomorphic assessment of problem of siltation and its significance of assessment of siltation problem in various projects and the recent observations regarding the problems that are made by different researchers. It also discusses aims and objectives, introduction to the study area and purpose of the present study. Finally a hypothesis has been put forth regarding the present study.

**The second** chapter gives detailed information about geographical and cultural position in the study area. This chapter also gives idea about data base and methodology adopted or applied for the present work. It also discusses the statistical and GIS techniques which are used in the present work.

Chapter three throws light on the relief characteristics and properties of soil environment, degradation of soil environment in the study area.

**The fourth chapter** seeks to find out the siltation of Tavarja river catchment. It also investigates the relationship between soil erosion and dam siltation. It also attempts spatio – temporal variation in siltation processes. The chapter also attempts to trace the causes and effects of siltation in the dam site. It also discusses the computation of siltation rates in the dam site. Assessment of land degradation and Siltation problem of Tavarja dam catchment also is carried out in this chapter.
The Fifth chapter is devoted to the assessment basin prioritization for watershed management and planning. It also gives the Estimation of surface runoff based on NRCS (SCS) curve Number Method. This chapter also emphasizes the importance of soil loss estimation using USLE and SYI techniques.

Chapter six summarizes the discussion, and moves towards the conclusion of the research work and provides suggestions.

Based on the results obtained, the conclusion, problems and major findings and suggestions are discussed in the sixth chapter.

VII. Conclusion:

Based on the analysis, observations and interpretations, the present study establishes following conclusions:

A quantitative assessment of soil loss and surface runoff on grid basis was made using the well-known USLE and NRCS (SCS) with a view to identify the critical erosion prone zones and potential surface runoff of study area respectively.

1. About 85% (212.38 km$^2$) of the study area is found out to be under severe to medium surface runoff. Areas covered by medium, high, very high and severe erosion potential zones are 24.72%, 14.74%, 25.26% and 20.06% respectively.

2. Estimated soil loss based on USLE technique is found out to be more than 20 kg/m$^2$/year for 39.18 km$^2$ (15.64%) area, while 15 to 20 kg/m$^2$/year soil loss is observed for 35.45 km$^2$ (14.15%) area, 10 to 15 kg/m$^2$/year soil loss for 69.01 km$^2$ (27.55%), 5 to 10 kg/m$^2$/year soil loss for 70.15 km$^2$ (28.00%) and less than 5 kg/m$^2$/year for 39.18 km$^2$ (15.64%).

3. Based on SYI, Runoff and USLE techniques only 2 sub basins require very high priority for conservation planning, while 27 sub basins require high priority, 32 sub basins require medium priority, 9 sub basins require low priority and only 1 sub basin require very low priority for conservation planning for Tavarja Dam Catchment.

4. Once the input information is entered into the GIS, analyses can be readily performed to yield accurate data without relying on tedious, expensive manual methods.
5. Thus, GIS and RS can assist in developing management scenarios and provide options to policy makers for handling soil erosion problem in the most efficient manner for prioritization of watershed areas for treatment.

6. The study of Tavraja dam siltation demonstrates that the siltation in dam site has become a serious problem in semi arid regions of India. Several dams become fully silted because the designers did not take into account correctly the soil erosion and sediment transport processes, and no soil conservation and watershed management practices was introduced.

VIII. Suggestions:

On the basis of relief, soil types, land use/land cover, the entire tahsils has been divided into three zones namely high elevated erosional area at West, North and South side, middle transportational and moderate sloping area and Eastern plain and siltation depositional area at the Tavarja dam. Each of the physiographic zones represent varying characteristics of geographical features and therefore pertaining to different geo-environmental problems, therefore watershed management and planning measures or models for each of the physio-graphic zones have been suggested.

1) Extensive watershed management programmes including afforestation should be initiated in this zone.

2. Construction of engineering structures like Bench terracing, gabion and drop structures, catch water drains, protection walls, and check dams etc. catchment treatment plans should be introduce for soil conservation.

3. Vegetation is effective natural measure in controlling soil erosion and dam siltation or sedimentation. It is therefore, plantation of natural or suitable species of trees may be taken up as an important ingredient of soil conservation programme in this catchment.

4. The active participation of the communities should be taken to control the sedimentation and to remove the silted part from the dam.

5 The sediment data is collected through sediment monitoring instrument and technique. There is no silt gauging stating in this catchment of Tavarja dam. It is, therefore, difficult
to assess quantitatively the impact of the soil conservation measures on sediment production in the watersheds. Hence, it is recommended that a gauging station for one out of the five watersheds should be installed before 2-3 years of the commencement of treatment. The data of siltation should be recorded systematically during the entire period of execution and continued hydrology and sedimentation unit must be established.

6. The grazing of government land should be controlled and this land should be used for forest land development to save the soil erosion and sedimentation at the dam site.
7. The sub-basin prioritization methods suggested for each of the land use/land cover categories may be helpful in the overall enrichment of soil environment and long-term benefits of the dam life.

Engineering Measures

Continuous Contour Trench (CCT)

The CCT are useful in arresting further erosion of depression, channels and gullies. In addition, retaining walls would be constructed to provide support at the base of threaten slopes. The main purpose of CCT is to break the slope and reduce velocity of runoff. This type of conservation measures has been suggested for the mainly in the upper reaches of watershed.

- Where there is sloppy land/ hill slopes.
- Degraded/ Waste lands
- Without treating the upper regions of watershed with other treatment options CCTs alone should not be constructed.

Contour bund (CB)

Contour bund (CB) are earth banks, 1.5 to 2 m wide constructed of small bund across the slope of the land on a contour so that the long slope is cut into a series of small ones and each contour bund acts as a barrier to the flow of water, thus making the water to walk rather than run, at the same time impounding water against it for increasing soil moisture. Contour bunds divide the length of the slope, reduce the volume of runoff water, and thus preventing or minimizing the soil erosion. In the study area contour bund is based on the contour intervals.
Contour Trenching
This consists of excavating shallow/ intermittent trenches across the land slope and forming a small earthen bund on the downstream side. Plantation is done on the bund to stabilize the bund. The trenches retain the runoff and help in establishment of the plantations made on the bund. Trenches are useful where the land surface is fairly porous and rainwater collected in trenches can quickly percolate into the ground. The spacing of trenches and their size i.e. length, width and depth should be adequate to intercept about 50% of the peak rainfall in semi-arid regions i.e. with annual rainfall of about 400-550 mm

Farm Ponds
There is very little qualitative difference between a pond/ tank, which usually serves the population of a village, and farm pond, which serves an individual agricultural field. Farm ponds greatly vary in size depending upon the rainfall. For example, these have only a few meters of length and width and are built across the flow path of natural drainage channels. Surplus water from one pond spills over to a lower pond. In some cases a series of farm ponds are built on one single stream. Each pond caters to the irrigation needs of one farm and also augments ground water recharge.

Gully Plugs
Gully plugs can be defined as stones placed across gullies, so as to capture nutrients, silt and moisture. Stones are often embedded into the upper surface of spillway aprons and wells to provide support for the next layer. The principle is to capture runoff from a broad catchment area, thus transferring low rainfall into utilizable soil moisture, and to prevent soil erosion. Slowing of the flow of water helps in settling down organically rich soil. A well maintained gully plug creates a flat, fertile and moist field, where high value crops and trees can be grown. Gully Plug is creating obstruction by placing used bags filled with sand. Gully Plug is the effective method to slow down the speed of flowing water of the stream in any area. It is a kind of stop made of empty cement bags filled with sand, clay and such other material and placed in the course of stream. Usually, there is erosion due to flow .The empty cement bags are filled with sand, clay and small pebbles. Such bags are then stacked one over the other in the channel of the stream which are not more than 15 meter in width. Two types of gully plugs were
suggested in the study area earthen gully plug and boulder gully plug.

**Earthen Gully Plug (EGP)**

Second order stream junction has been considered for EGP, which will reduce high peak flow of water in rainy season. EGP construction required more than 100m diameter of boulders. Here, farmers view shall be also taken into consideration. Generally first order channel junction has suitable for this type of construction.

**Boulder Gully Plug (BGP)**

BGP is proposed at the EGP section and it is drawn on treatment map of watershed. Farmer’s agreement should be considered for this intervention. The maximum numbers of BGP in drain area suggested on the basis of availability of construction material.

**Cement Bund**

A cement bund is an embankment or wall of brick, stone, concrete or other impervious material, which forms the perimeter and floor of a compound and provides a barrier to retain the flow of water. These bunds control the volume and velocity of runoff in each slope unit. The cement bunds are proposed at the end points of EGP and BGP in the study area.

**Farm Bund (FB)**

This is the most popular soil conservation structure in the country and it is practiced at large scale all over India. Farm bunds are constructed on agricultural land with the aim of arresting soil erosion and improving the soil moisture profile. Ideally, bunds on farms should be made on the contour line. It would lie along the boundary of the field. The farm bunds are suggested on the basis of the slope of the land and size of field. It would help to conserve the water in the field and maintain in situ moisture in the field. The erosion of the field is reduced. Farm bund structure of study area treatment plan is recommended for the lower slope, i.e. agricultural area. The farm bund size should be modified as per requirement. Farm bunds bring into line perpendicular to the slope. The net planning of farm bund should be finalized only in consultations with the farmers. Position and number of farm land will depends on requirement of farmers in their land. Farmer group, should be always involved while construction of farm bund in agricultural area.
Stream Bank Protection

Eroding stream banks not only damage adjoining agricultural lands but also contribute large quantities of sediment load to the river systems. Under the watershed management programme, bank protection of only small/ minor streams are included. However, works of this nature should only be taken up if the benefits justify the cost of construction. The works usually involved are in the nature of boulder pitching on banks of about 20-30 cm thickness after dressing the bank to a stable slope. Where the flow velocity of the stream is high (1.5 m/sec or more) gabion structures should be built at the toe of the bank with foundation firmly embedded in the streambed and bank.

Biological Measures

Afforestation

It should be implemented, especially along hill slope. This will lead to prevent surface as well as to increase to soil fertility. For this plant species, which has area resistant to erosion must be choose. In critically degraded areas plantation of locally useful diverse plant species such as timber plantation species, grasses, shrubs, medicinal and aromatic plants would be undertaken.

Fodder plantation

To overcome the problem of scarce availability of the fodder and fuel wood due to which the deforestation occurs at large scale, it is proposed to bring a substantial area under fodder plantation with suitable fast growing species. Considering the cattle population in the study area fodder plantation has been suggested almost for land segments where slope varies between 1.5% to 2%.

Restoration of Degraded Areas

LULC analysis exposes that, 38.66 sq.km i.e. (15.42%) of the total study area is wasted and can be regenerated by adopting treatment plan suggested in the earlier pages. The waste lands thus can be transformed applying these techniques like, continuous contour trenches, contour bunds, terracing and applying agroforestry as well as social forestry principles. These land surfaces however has to be kept for continuous modification, monitoring and feedback should be ascertained with certain time interval, possible outcome of these is reduction in the sediment yield and soil loss. In the waste land fruit crop can be cultivated.
**Brushwood check dams**

The main advantage of brushwood checkdams is that they are quick and easy to construct and are inexpensive as they are constructed by using readily available materials at the site. In brushwood checkdams, small branches preferably of coppiceable species are fixed in two parallel rows across the gully or nala and packed with brushwood between the rows of these vertical stakes. The vertical stakes are tied down with wires or fastened with sticks across the top. The important consideration in erecting brushwood checkdams is to pack the brushwood as tightly as possible and to secure it firmly. This type of checkdam is generally constructed over small gullys or at the starting stretch of gullys. In all, 240 brushwood checkdams/ vegetative spurs would be constructed to check gully erosion, stream bank protection and slope stabilization works.

**Forest land expansion**

Comprehensive programme of afforestation in the area should be taken, Tree plantation, Social forestry, agroforestry, Nursery raising, Horticultural, medicinal plant, rural fuel wood plant should be included in afforestation programme. Plantation can be used for wasteland, which will be helpful in regeneration of wasteland and decreasing in soil loss of the study area. Implementation of social forestry will provide fuel wood, small timber and employment opportunities to the local people; hence social forestry is also suggested. It is important to establish nursery on slightly sloping fertile land. It will be useful to improve economy of the people in the study area. Rural fuel wood schemes should be introduced. Horticultural and medicinal plants can be also raised which could be useful for restoration of degradation land as well as increased in the vegetation cover. Multipurpose plant species in this way certainly will help to enhance the quality of soil as well as land resources. Thus implementation of these techniques is a certainly for assured income as well as development of forest cover in the study.

Research student 

Mr. Atul M.Zete

Research Guide 

Dr.Sunil W. Gaikwad

Associate Professor in Geography

Department of Geography,

S. P. College, Tilak Road, Pune – 411 030.