PROJECT REPORT

APPLICATION OF GIS IN WATERSHED MANAGEMENT

Submitted to:

School Of Good Governance & Policy Analysis
(An Autonomous Institution of Government of Madhya Pradesh)

and

Rajiv Gandhi Mission for

RAJIV GANDHI MISSION FOR WATERSHED MANAGEMENT, MADHYA PRADESH

Submitted by;
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References

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### Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tr>
<td>RGM</td>
<td>Rajiv Gandhi watershed mission</td>
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<tr>
<td>ST</td>
<td>Schedule Tribe</td>
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<td>DEM</td>
<td>Digital Elevation Model</td>
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<tr>
<td>PIA</td>
<td>Project Implementation Agency</td>
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<tr>
<td>GPS</td>
<td>Global Positioning System</td>
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<tr>
<td>DPI</td>
<td>Dots per inch</td>
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<td>DXF</td>
<td>Drawing exchange format</td>
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<td>GIS</td>
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<td>CAD</td>
<td>Computer Aided Design</td>
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<td>GIS</td>
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<td>Self Help groups</td>
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<td>EAS</td>
<td>Emergency Alert System</td>
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<td>DPAP</td>
<td>Drought Prone Area Programme</td>
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<td>IWDP</td>
<td>Integrated Watershed Development Project</td>
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Rajiv Gandhi Watershed Mission

Certificate

To whomssoever it may concern

This is to certify that Mr. Dhiraj Kumar, an intern from MBA Program of Indian Institute of Technology, Kanpur was associated with the Rajiv Gandhi Mission for Watershed Management, Madhya Pradesh, under the summer internship scheme of School of Good Governance and Policy Analysis.

He has undertaken a study on "Application of GIS in watershed management" assigned to him by Rajiv Gandhi Mission for Watershed Management department of Madhya Pradesh government. He was associated with the department for a period of two months starting from 10\textsuperscript{th} May, 2010.

The work has been successfully completed by the intern and a copy of the report has been received. During the internship he has worked satisfactorily and added value to himself as well as to the department.

We wish him all the very best for his future endeavors.

Shri. Umakant Umrao (IAS)
Director
Rajiv Gandhi Watershed Mission
Madhya Pradesh Government
Introduction

A watershed can be defined as the drainage basin or catchment area of a particular stream or river. Simply put, it refers to the area from where the water to a particular drainage system, like a river or stream, comes from. It also resembles a drainage basin or catchment as it drains water from small streams into a common stream, thus in the process recharging the ground water and irrigating the plantation that falls in that watershed. By dividing the big landscape into small watersheds, we can make them more manageable and suitable for the purpose of ground water recharge, thereby reducing erosion of soil and benefiting the people living in the vicinity. The sole purpose of developing watershed is to decrease the velocity of water and improve the absorption of water by the soil. It also takes into consideration that soil erosion is checked and water table of the area increases by making more and more use of the natural rain fall. Thus the basic principal of the watershed management is that the more water that is used for the replenishment of soil and storage from the rainfall, the better it is for the all round growth in yielding capacity of crops and availability of water for normal use - thus directly affecting the livelihood of the people.

In other words, watershed management implies, the judicious use of all the resources i.e. land, water, vegetation in an area for providing an answer to alleviate drought, moderate floods, prevent soil erosion, improve water availability and increase food, fodder, fuel and fiber on sustained basis.. The task of watershed management includes the treatment of land by using most suitable biological and engineering measures in such a manner that, the management work must be economic and socially acceptable.

The watershed profile divides the terrain into unequal segments with diverse terrain characteristics, varied endowment of nature and distinctly different susceptibility to the natural environmental constraints viz. flood, water logging, riverine erosion, drought and soil erosion. The livelihoods of the local population mainly rural largely depend on these natural resources as well as constraints. Development of the watershed/s needs better understanding about the various natural resources their relations with each other and their relations with livelihood of the stakeholders. Geo-scientific studies of the terrain, socio-economic appraisal of the stake holders and knowledge about local practices aimed at providing well coordinated and synthesized information on the overall watershed area are the need of the hour for the watershed development.

GIS is a very powerful tool for development of the watershed area with all natural and socio-economic facets for better planning, execution and monitoring of the project. It gives a clear perspective for analysis at various levels to different partners of the watersheds. Proper emphasis on the utilization of the surface run off through better measures suitable for the target region is needed at the planning stage to all partners of watershed. A GIS based model of the terrain with all relevant spatial data related to natural resources, infrastructure and administrative boundaries attached with relevant attribute data will enable the planners, stake holders and funding agencies to develop the watershed keeping in mind the fulfillment of stakeholders’ need in the backdrop of natural resources potential as well as limitations. Geo-technical appraisal of all the surface water irrigation projects necessary to avoid unfavorable natural conditions will be easier to develop through participatory method. This model provides a holistic picture to enable to share the natural resources and protect them for the betterment of the watershed.
GIS can play critical roles in all aspects of watershed management, from assessing watershed conditions through modeling impacts of human activities on water quality and to visualizing impacts of alternative management scenarios.

GIS combines these maps and data in an interactive scene based thematic maps which are much more interactive than normal maps. The multiple layers are created which can be seen in isolation or in groups. It also combines the latest remote sensed information and also provides the functionality of zooming into small areas.

One of the most important phases of any watershed project is its planning. When faced with challenges involving water quantity due to natural as well as human-induced hazards (e.g., droughts, soil erosion, floods), planning becomes extremely important so as to mitigate their impacts and ensure optimal utilization of the available resources. Information obtained from characterization and assessment studies, primarily in the form of charts and maps can be combined with other data sets to improve understanding of the complex relationships between natural and human systems as they relate to land and resource use within watersheds.

Project Implementation Agencies (PIA) are responsible for planning, execution and consideration of projects. They have a huge task of understanding the problem accurately and identifying the most suitable site for treatment, so that maximum impact will appear from such treatment. The success or failure of the project depends mostly on their acumen of identifying the correct site and their past experience in executing such projects. These activities require great deal of planning while the planning itself requires great deal of information and data about the area. Before the advent of GIS, they have the tremendous task of going through the large tables, complex descriptions, random photographs, random surveys and maps of khasra, toposheet, land and soil use etc.

Most of the information available about the socio-economic factors of the village like income, population, crop yield, and literacy rates are available in complex tables; excel sheets and word files which are not user friendly. Add to this, the maps of khasra and toposheet procured from Archeological Survey of India (ASI) are not on the same scale. Most of these maps have become outdated to certain extent as they don’t reflect the actual structure present in the area. With the passage of time, most of the water bodies have either changed their shape or have completely vanished from the landscape. This phenomenon necessitates the use of latest remote sensing images taken from the satellites, in conjunction with the olden maps available. Without GIS, PIA has to go through each of these maps individually along with other subjective data available about the village. This process is tedious and time taking there by introducing the possibility of mistakes or overlooking some important facts due to human error, which may eventually have a huge bearing on the success of projects.

In India watershed-based development has been the strategy for growth and sustainability of agriculture in the vast semi-arid and dry sub-humid regions popularly called rain-fed regions. Watershed Development Projects have been undertaken to enhance agricultural production, conserve natural resources base and ensure rural livelihood since 1980s. Initially soil and water conservation was the primary objective of the program which attracted large public investments in the last 25 years. Subsequently, egalitarian principles of equity and enhancing rural livelihood were given prominence; more recently the principle of sustainable development with emphasis on tenets of development economics like cost of degradation of fragile land and economic ecology like valuation of ecological services have gained emphasis. Large investments have been assigned for watershed based development in the National Five-Year Plans since 1990s and more investments have been earmarked till 2025.
Rajiv Gandhi Mission on Watershed Development was started in October, 1994. Presently 249 micro watersheds have been taken up under the schemes of EAS, DPAP, IWDP and IJRY. Total of 1, 47,066 hectares has been taken under integrated watershed development with an estimated project cost of Rs 5277.00 lakhs. In order to effectively launch the project, 12 governmental and 8 NGO Project Implementing Agencies (PIA) were carefully selected. Using RRA/PRA techniques and thematic maps from remote-sensing, action plans were prepared by P.I.A’s for every micro watershed. Furthermore, the following activities were also taken up:

Rajiv Gandhi Mission for Watershed Management is an ambitious Programme of Government of Madhya Pradesh, for sustainable development of area on watershed basis. It not only aims at conservation of natural resources like land and water, but also attempts to improve economic conditions of villagers by enhancing their employment opportunities in their village. This Programme has innovated the approach of watershed management through community participation. At present, this Programme is being implemented in all 313 blocks of M.P. in an area of about 3.2 million hectares.

Out Of a total geographical area of M.P. almost 70% of the net sown area is dependent on rainfall. Unpredictable variations in agricultural productivity in rain fed areas coupled with increased biotic pressure on the natural resources has led to an increasingly fragile ecosystem. It was realized that only a strategy, which looked at these interlinkages would provide for sustainable and holistic development in these areas. Livelihood opportunities of the people dependent on rain fed agriculture can be improved by conserving the soil and water resources and optimizing their use which would ultimately manifest in healthy regeneration of natural resources and increased agricultural productivity. Watershed management is a labor intensive and scientific approach towards this end. The departments are directly working under Department of Land Resources (DOLR) and Minister of rural development (MORD) of government of India. RGM is solely responsible for planning, implementation and consideration of all the watershed projects in every district of Madhya Pradesh.

RGM activities in Bhopal district

1. Creation of Watershed Committees
Watershed advisory committee which comprises collector, PIAs, district level relevant departments and representatives of people are entrusted with the responsibility of monitoring and resolving any shortcomings in the watershed projects. Watershed Development Teams for each PIA is formed which consists of block level officials. The PIAs have helped in forming self help groups and user groups in watershed villages.

2. Preparation of Action Plan and Community Organization
Self help groups and user groups were mobilized to enlist their support and help in watershed activities. Literacy campaign was launched to find geographical, geomorphologic and geo-hydrological problems and situations and socio-economic perception of the villagers.
3. Soil and Water Conservation Works
A thoughtful and targeted approach of ridge-to-valley has been followed while building watershed structures like contour trenches, earthen embankment, nalla bunds, sub-surface dykes, staggered pits, drainage line treatment and percolation tanks.

4. Fodder Development
A large amount of land has been identified for fodder production which includes private and public land, while giving emphasis to Grassbeds, silvi-pasture and pasture development, thus providing immediate return to the farmer community with the help of biomass generation and soil conversation.

5. Plantation Activities
Plantation of saplings which includes Jatropha (Ratanjot), Anona squamosa (Sitaphal), Moringa oleifera (Moringa) and fruit bearing species like Mengifera indica (mango), Emblica officianalis (Amla), Zizyphus jujuba (Ber), Psidium gujava (Guava) etc. have been taken up on private lands. Multipurpose trees like Bombax cieba (Samel) Pethocellebium dulce (jungle jalebi), Dendrocalamus strictus (Bamboo), Eucalyptus spp., Citrus limon (lemon) have been taken up in the gardens of SHG, SHG nurseries and PIA nurseries.

6. Artificial Recharge of Groundwater
To artificially recharge groundwater, percolation tanks and subsurface dykes have been constructed, which substantially increased the water table of the area.
Objective

To prepare vector layers of drainages, land-use and contours with the help of cadastral map and toposheet.

To identify and assess the existing watershed structures by taking help of GIS after attaching the database and created thematic maps to the vector layers.

To develop a three dimensional Digital Elevation Model of the landscape with the help of identified contours and slopes in order to help in the planning of the watershed structures.
Study Area

Bhopal District is a district of Madhya Pradesh state in central India. The city of Bhopal serves as its administrative headquarters. The district has an area of 2,772 km², and a population 1,836,784 (2001 census). The population of Bhopal District increased by 51% from 1981 to 1991 and by 36% from 1991 to 2001. Bhopal District is bounded by the districts of Guna to the north, Vidisha to the northeast, Raisen to the east and southeast, Sehore to the southwest and west, and Rajgarh to the northwest.

Location - Bhopal is the capital of the Indian state of Madhya Pradesh and the administrative headquarters of Bhopal District and Bhopal Division. Bhopal is also known as the Lake City-(or City of Lake) for its various natural as well as artificial lakes.

Location map of Jhirniya Micro-Watershed
Topography - Bhopal has an average elevation of 499 meters (1637 ft). Bhopal is located in the central part of India, and is just north of the upper limit of the Vindhya mountain ranges. Located on the Malwa plateau, it is higher than the north Indian plains and the land rises towards the Vindhya Range to the south. The city has uneven elevation and has small hills within its boundaries. The major hills in Bhopal comprise of Idgah hills and Shyamala hills in the northern region and Arera hills in the central region.

The municipality covers 298 square kilometers. It has two very beautiful big lakes, collectively known as the Bhoj Wetland. These lakes are the Upper Lake (built by King Bhoj) and the Lower Lake. Locally these are known as the Bada Talab and Chota Talab respectively. The catchment area of the Upper Lake is 361 km² while that of the Lower Lake is 9.6 km². The Upper Lake drains into the Kolar River. The Van Vihar National Park is a national park situated besides the Upper Lake.

Bhopal has a humid subtropical climate, with mild, dry winters, a hot summer and a humid monsoon season. Summers start in late March and go on till mid-June, the average temperature being around 30 °C (86 °F), with the peak of summer in May, when the highs regularly exceed 40 °C (104 °F). The monsoon starts in late June and ends in late September. These months see about 40 inches (1020 mm) of precipitation, frequent thunderstorms and flooding. The average temperature is around 25 °C (77 °F) and the humidity is quite high. Temperatures rise again up to late October when winter starts, which lasts up to early March. Winters in Bhopal are mild, sunny and dry, with average temperatures around 18 °C (64 °F) and little or no rain. The winter peaks in January when temperatures may drop close to freezing on some nights. Total annual rainfall is about 1146 mm (46 inches).

Jhirniya Village:-

Jhirniya is one of the small villages in Phanda block on the western side of Bhopal district which lies in the micro-watershed number 4H3C8a2d and 4H3C8a2e. The total area of the village is 306 hectares and of which 26 hectares is cultivable. In this village around 121 hectares of land falls under cultivable waste category. The total number of households in the village is 26, with the population of the village 157, out of which 124 people fall under ST category.
Methodology

Stage 1: During the very first stage of the study basic information about different types of watershed structures are studied and seen in the field. Then the application of GIS software for watershed development was studied in detail. This was necessary to build a basic understanding of the problems faced by the planners of watershed structure in planning of a new structure.

Stage 2: In this stage, gathering of all the data which is required for the process of developing a watershed plan took place. This included collection of scanned image of khasra and scanned image of a toposheet in which the khasra lies.

Stage 3: In this stage geo-referencing of the toposheet and the khasra were carried out. This stage is of high importance as it makes sure that the work done on the scanned images truly coincide with their spatial position on the ground.

Stage 4: During this stage digitization of the entire khasra map with the help of AutoCAD software took place. The digitization of raster image was done by hand tracing all the boundaries which were visible on the khasra map. This included khasra boundaries, roads, rivers, drainage and village boundary. This stage also required for the digitization of the study area (khasra) that fell in the toposheet. The digitization of toposheet involved digitizing contour lines and drainage lines which were later to be used in the process of developing a Digital Elevation Map. The digitization resulted in the creation of vector layers of khasra boundaries, roads, rivers, drainage and village boundary, which could be seen either in isolation or in a combination of two or more layers.

Stage 5: Superimposition of khasra map on the toposheet is carried out in this stage and contour and drainage lines from the toposheet were transferred on khasra map.

Stage 6: In this stage preparation of khasra map was carried out which included delineation of drainage lines, slope and creation of resource maps. In the same stage data related to soil, crop pattern and socio-economic factors like population, literacy rate and income were attached to the khasra map.

Stage 7: Thematic maps were generated which included maps of land ownership, land use, land cover, soil and resources.

Stage 8: In this stage an action plan was created for the treatment of watershed. The treatment took into consideration all the thematic maps generated in the previous stage, thus made sure that the suggested treatment fell in line with the topographical as well as socio-economic condition of the area.
Process Level Diagram of the stages of the Methodology

Figure-1

**Stage 1**
- Collection of secondary data about use of GIS in watershed planning and development
- Information gathering about the work culture of RGM and strategy devised for the planning, implementation and monitoring of the watershed projects

**Stage 2**
- Collection of scanned maps of khasra and toposheet
- Loading them in the software for further processing

**Stage 3**
- Geo-referencing of khasra map and toposheet
- Rectification of toposheet

**Stage 4**
- Digitization of khasra map and toposheet
- Creation of vector layers

**Stage 5**
- Superimposition of khasra map on toposheet
- Transfer of contour and drainage over Khasra Map
Stage 6
- Preparation of Khasra map (Drainage, slope and resource map)
- Attachment of soil data, crop pattern, land use data and socio-economic data to the Khasra map

Stage 7
- Generation of thematic maps

Stage 8
- Creation of action plan for the watershed treatment based on all thematic maps
- Creation of DEM by feeding the elevation data from contours of the toposheet
Application of GIS in watershed Management

Raster and Vector maps

Before we proceed further, it’s important to understand the difference between raster and vector maps. Raster and vector are the two basic data structures for storing and manipulating images and graphics data on a computer. All of the major GIS and CAD software packages available today are primarily based on one of the two structures, either raster based or vector based.

Raster image comes in the form of individual pixels, and each spatial location or resolution element has a pixel associated where the pixel value indicates the attribute, such as color, elevation, or an ID number. Raster image is normally acquired by optical scanner, remote sensing sensors or other raster imaging devices. Its spatial resolution is determined by the resolution of the acquisition device and the quality of the original data source. Because a raster image has to have pixels for all spatial locations, it is strictly limited by how big a spatial area it can represent. When increasing the spatial resolution by 2 times, the total size of a two-dimensional raster image will increase by 4 times because the number of pixels is doubled in both X and Y dimensions. Same is true when a larger area is to be covered when using same spatial resolution.

Vector data comes in the form of points and lines that are geometrically and mathematically associated. Points are stored using the coordinates, for example, a two-dimensional point is stored as (x, y). Lines are stored as a series of point pairs, where each pair represents a straight line segment, for example, (x1, y1) and (x2, y2) indicating a line from (x1, y1) to (x2, y2). In general, vector data structure produces smaller file size than raster image because a raster image needs space for all pixels while only point coordinates are stored in vector representation. This is even truer in the case when the graphics or images have large homogenous regions and the boundaries and shapes are the primary interest. Besides the size issue, vector data is easier than raster data to handle on a computer because it has fewer data items and it is more flexible to be adjusted for different scales.

Collection of cadastral map

Cadastral maps are the most basic of all maps which are prepared for every village. They are on a scale of 1:5000 and are made for the purpose of indicating ownership of public and private land inside a village. These maps are kept with patwari. Some of the features like drainage and roads are permanent in these maps while the ownership of the land changes from time to time. Sometimes the same amount of land is divided between two or more people from the same family which requires for its updating with the passage of time.

Use of cadastral maps for watershed management is of two fold.

On the one hand, cadastral maps help the planners of watershed management in identifying the owners of the land i.e., on whose land the micro-watershed is to be developed. This is important from the
perspective of the community officer of the PIA, whose job is to mobilize those people who are going to become the ultimate beneficiary of the watershed projects.

On the other hand the cadastral map helps in showing the watershed boundaries like drainage, rivulets and river. Some of the watershed bodies like drains, that fall inside a village rarely change in shape or size. However, the other watershed bodies like rivulet, river and lakes change their shape with the passage of time. The course of some of the rivers also changes drastically, thus necessitating the use of latest remote sensing images.

The cadastral map was collected from patwari and its photocopy was taken. The photocopy was later scanned to get a digital image of the village in tiff file format.

**Khasra Map of village Jhirniya**

![Figure-2](image-url)
Registration/ Georeferencing and Scaling of Toposheet

Georeferencing is the process of scaling, rotating, translating and de-skewing the image to match a particular size and position. In simple terms Georeferencing means to define its existence in physical space. This procedure is thus imperative to data modeling in the field of GIS. When data from different sources need to be combined and then used in a GIS application, it becomes essential to have a common referencing system which is done with the help of Georeferencing.

Why is it necessary?

A raster image is made up of pixels and has no particular size. Without Georeferencing, the vectorised CAD/GIS drawing size is determined by the raster's pixel dimensions (the width and height of the raster in pixels). This is in turn determined by the image resolution (DPI). This image sizing will usually bear no relationship with the dimensions of the drawing that the raster represents.

Here is an example:

We might scan a drawing at 100dpi and get a raster that is 1000 pixels wide by 1000 pixels high, then after vectorisation, the exported DXF drawing will be 1000 units wide by 1000 units high (the units can be set in meters or inches). Then if we scan the same drawing at 200dpi we will get a raster that is 2000 pixels wide by 2000 pixels high, and the resulting vectorised DXF drawing will be 2000 units wide by 2000 units high. In both cases the vectorised drawing is from the same original, but we get two different sized DXF drawings depending on the scanning resolution. In addition, it is likely that neither DXF drawing is the size that we actually wanted it to be.

Thus it becomes necessary to extrapolate the pixels on the raster image to the actual coordinates of the vector drawing. Thus in the process of registering a raster image, a pixel is selected and exact coordinate in terms of latitude and longitude is specified. This makes the raster image a true representative of the actual spatial details on the ground.

In case of the toposheet three pixels on the three extreme corners were picked and the latitude and longitude, which were written in the toposheet, were fed to the software. The fourth coordinate gets automatically computed by the software, thus making the process of Georeferencing complete.
Process flow diagram of Georeferencing of toposheet

Figure-3

Scan toposheet image

Open toposheet in tiff file format

Define Projection System
- Geographic Latitude/Longitude
- WGS 84

Locate four points on the toposheet in clockwise direction, whose lat/long is given

- Enter lat/long and save the file
- Registration completed

Output

Figure-4
Registration of khasra map

Registration of khasra map was done in the same way as was done for the toposheet except for the fact that, points that were selected on the khasra map didn’t have their latitude and longitude. These points are intersection of natural and man-made objects, like intersection of a river and road or intersection of a drainage and road. The same sets of points were also located in the toposheet which was earlier registered. These points are also termed as ground control points which help in the registration of cadastral maps. Once the ground control points were chosen and marked in both the cadastral map and the toposheet, the cadastral map got automatically digitized according to the latitude and longitude of the toposheet.

Process flow diagram of registration of khasra map

- Scan Khasra map
- Open khasra map in tiff format

Locate four Ground Control Points which are intersections of manmade and natural structures

Locate the same points in toposheet

Save the file

Registration of Khasra map completed
Digitization of cadastral Map (Raster Image)

Digitization of cadastral map was done with manual hand tracing of the lines on the computer screen, using the scanned raster image in the backdrop. The accuracy level is enhanced by making sure that the raster image of the cadastral map was scanned at high resolution. Zoom in and zoom out functionality of the display monitor was used to digitize at a higher accuracy level. The main advantage of this form of interactive tracing is the flexibility of tracing lines selectively and better manual control.
Process flow diagram of digitization of cadastral map

Figure-7

1. Open raster layer of village map
2. Create vector layers of road, rivers, khasra boundary, drainage and village boundary by hand tracing with the help of a mouse
3. Color code different vector layers with different colors for ease in understanding
4. Save the digitized image of the village
Comparison of Raster and Vector Image

Figure-8

It can be seen from the digitized image of the cadastral map that, different vector layers are color coded for ease in understanding. For e.g. roads are drawn in red lines, river in blue, village boundary in rugged dark lines while the khasra boundaries in this lines.
After digitization Khasra Map (Base Map)

Figure-9

Superimposing or transforming of Khasra Map on registered Toposheet

After the digitization and proper geo-referencing of khasra map and toposheet, the khasra map is superimposed on the toposheet. After superimposing we can see whether both the maps are exactly fitting on top of one another or not. This can be done by the ‘blend’ and ‘swipe’ functionality of the software, which allows us to see only some portion of khasra and the rest of the portion can be seen from the toposheet. Some features like roads and rivers which are present in both khasra map and toposheet become the guiding tools to confirm the correct superimposition.

Superimposition has one very important function, which is transfer of contour and drainage from toposheet to the khasra map. Contour lines are only present in the toposheet and once it got transferred to the khasra map, we could see the entire topography of the village. However, there is one drawback to this form of contour generation. The khasra map is built at a scale of 1:5000 whereas the toposheet is at a scale of 1:25000, thus contours on the toposheet are spaced at 20 meters interval and therefore these contours when superimposed on the khasra map, can only give a general view of the slopes. To get a clear picture of the actual slopes, we need remote sensing image of very high resolution. To get the clear picture of spatial condition on the ground these images have to be fairly recent because of the constant changes in the topography of the landscape due to manmade and natural changes.
Process flow diagram of superimposition of khasra map on toposheet

Figure-10

1. Open registered toposheet in GIS software
2. Open khasra map on top of toposheet
3. See whether drainage and river on the toposheet are fitting exactly on top of khasra map
4. If the features on both khasra map and toposheet are matching, registration is properly done
5. Use blend and swipe function of the software to confirm the superimposition

Result

Figure-11
Thematic maps

A thematic map is a map that emphasizes a particular theme or special topic such as the average distribution of rainfall in an area. They are different from general reference maps because they do not just show natural features like rivers, cities, political subdivisions and highways. Instead, if these items are on a thematic map, they are simply used as reference points to enhance one's understanding of the map's theme and purpose.

However, all thematic maps use maps with coastlines, city locations and political boundaries as their base maps. The map's specific theme is then layered onto this base map via different mapping programs and technologies. In contrast to general maps, these maps emphasize on geographic areas of a particular region for data analysis. These maps provide information or data related to the percentage unemployed, population explosion, and climate or soil type of a particular area.

Resource map

After attaching data related to different kinds of resources like anganwadi, primary school, panchayats bhavan and number of wells, a thematic map was generated. In this thematic map we can see these resources represented in terms of symbols which are scattered all across the village. Other data related to demographic information, livestock population, socioeconomic data, climatic data and irrigation facilities were also added to produce thematic maps of soil use, land problem and geology.

Figure-12
Land use and Land Cover Maps of Jhirniya Micro-Watershed

Figure-13

Figure-14
Land Ownership Maps of Jhirniya Micro-Watershed

Figure-15

Soil map of Jhirniya micro-watershed

Figure-16
Digital Elevation Model (DEM)

Digital elevation models (DEMs) are collections of elevation points for an area. Among other things, certain software can display DEMs to show the terrain surface in three dimensions and from a choice of viewpoints. DEMs are created by collecting elevations and referencing them to corresponding points in the mapped area. The elevations add a Z value to the ground's X and Y horizontal coordinates.

There are two ways in which elevation for DEM model can be collected. One is manual collection of elevation by actually going to the area of study and the other is through remote sensing images. It is advisable to go for the latter option but it entails for satellite images with very high resolution in order to clearly depict the elevation on the ground. In other cases when there is no such constraint of clarity and a rough estimate of the spatial details are required, contour lines of pre-existing maps like toposheet could be used for generating the digital elevation modal.

In whichever case the spacing and the density of the elevation directly affects the accuracy of the DEM. The higher the density of points, higher is the accuracy of the DEM. This puts enormous pressure on the data recording capacity of the Global Positioning System and requires more work and more demand for data storage thus leads to a higher cost.

A major issue in building a DEM is in selecting points. If we select more points in an area which is relatively flat then it would be a waste of resources and effort. On the other hand collecting a few points in a hilly area with undulating terrain would provide us very few details of the actual slope. Hence a very dense matrix of points is needed to adequately capture the variations in the land surface. In this case the two ways of data collection, viz. systematic grid pattern or a stratified method of data collection comes very handy. In stratified method of data collection, the GPS can actually be instructed to collect more data in areas of increased relief variation, such as along ridges, mountains, and valleys.

A pictorial representation of a 2D map converted into 3D DEM

Figure-19

2D Topographic Maps VS 3D DEMs
3D Map of the Jhirniya Micro-watershed

Figure-20

Action plan for watershed treatment

Figure-21

**PROBLEM:**
Northern part of the village observes intensive soil erosion, which is leading to washing away of topsoil, silt formation in the lower portion, etc.

**SCOPE OF TREATMENT:**
It may be seen from the ownership map of the village that the majority of the area is Govt./community land, hence it can be used for large area treatment.
Constraints

Although GIS has a lot of functionality that can aid in the planning, evaluation and monitoring of watershed management but there is a cost factor involved in it. Most of the data that we have, are on a very high scale except for cadastral maps which is on a scale of 1:5000. The toposheet which is available from the Survey of India is on a scale of 1:25000, thus the contours that are visible on a toposheet are at intervals of 20 meters. This puts serious impediment on the slopes generated in 3D elevation model. The slopes generated in the 3D DEV model are spaced at 20m intervals; hence miss out on finer ridges and terrains which are smaller in size. The drainage line which is only visible on the toposheet is also outdated. Some of the drainage line have either completely altered their path with due course of time or are completely wiped off the landscape. The reason for these could be natural phenomena like draught, flood, run off due to excessive rain or it could be new constructions by mankind. Owing to this, one of the most critical problems faced by planners while deriving contours and drainage from toposheet is that the slopes generated or watershed marked on the digital maps does not represent the true reality on the ground. Even though the contours and drainage on the toposheet sometime manage to show the true reality, they are on a very high scale and miss out on finer details because most of the watershed structures are of small size. The average height, top width and bottom width of watershed structures are 2m, 1m and 1.5m respectively. Hence it is imperative for the planner to buy DEM elevation data of high resolution in which 2 meter contours should be visible. At present to procure, 81 sq km of data with such accuracy costs Rs 10,000. This data could be either purchased from National Remote Sensing Center or from BirdView.

In addition to cost of procuring satellite imagery, digitization work needs to be carried out which requires money. For digitization, creation of DEM and thematic maps trained GIS professional are needed, which calls for heavy investment. GIS also requires investment in terms of collecting demographic data on the grass route level which is often more time taking than any other work. Often many field surveys have to be done to cover the whole area with at least a detailed topographical map. Sometimes the information about natural resources like soils and vegetation, climate and geology are not available in which case a survey of the area needs to be conducted and then the data generated afterwards need to be fed to the GIS system.

Because of this, planners of watershed management face a daunting task of first implementing the entire setup before they can gain any fruit of GIS and its allied applications. The entire data needs to be updated in the database of GIS and then only it could be of any help for the purpose watershed management. The initial cost of setting up of GIS is also very high, add to it the infrastructure cost and the cost of software make GIS all the more capital intensive and time consuming proposition. The other constraints are scarcity of trained resources in GIS.

Having said all that, the power and the benefit, it can bring can not to underestimated, hence it is better to start with a minimal solution for a GIS and get a knowhow of the software than waiting for the all or nothing.
Conclusion

We often see development being done at the cost of environment. As a result our environment has to increasingly bear the brunt of constant degradation. The most affected among all is water which is intricately linked to our survival and day to day activities. Watershed management is a noble initiative taken in this respect to conserve this valuable resource for the betterment of the entire society. Rajiv Gandhi Mission for Watershed Management has done a commendable job of conserving this natural resource by bringing in all stakeholders together under a common ambit and providing them with expertise and resource to build and maintain water harvesting structures. The stakeholders are mainly the villagers, administration and government at large. This initiative could be further strengthened by the help of GIS. GIS can be play a pivotal role in solidifying the interaction between the administration and watershed boundaries and it could also help in the proper allocation of financial resources with respect to the watershed boundaries. The other use of GIS could be in locating the water-harvesting structures which are a common feature in the watershed management programme. Both these activities are of crucial importance for the success of any watershed project as it leverages the power of technology in order to produce error free, efficient and expedited results.

GIS not only helps in giving a clear picture of the entire landscape but it also helps in finding out the correct structure suitable for the treatment of watershed. The spatial tools available in GIS helps in estimating water spread area and available water storage capacity at that location, which are extremely important to find out the viability of the project. In addition to this, GIS can also be used in monitoring and evaluation of the watershed programmes.
Recommendations

GIS software is extremely powerful software and it could be of immense help in the planning, evaluation and monitoring of watershed structures.

During the course of my study I have observed that a lot of departments in Madhya Pradesh government have shown inclination towards the using GIS, be it Forestry department or Rajiv Gandhi Watershed mission. Most of these interests stems from the fact that GIS is software which brings the spatial and socio-economic reality at the ground level to the finger tips of the administration. Therefore, it is high time that Madhya Pradesh government take the noble initiative of digitizing every village under its purview. There are approximately 55,393 villages in Madhya Pradesh out of which only 3276 are inhabited.

Cost and time for digitization of villages

On an average it takes approximately two to three hours of time for a GIS operator to manually hand trace and digitize a village. That means approximately 1.38 lac man hours is needed to digitize almost all villages of Madhya Pradesh. On an average the cost of digitizing a village is Rs 750, provided the village has 300 to 350 khasra. The cost of digitization increases with the increase in the number of khasra. For the sake of simplicity the cost of digitization a single village has been taken as Rs 1000 which should even out the effect of relatively smaller villages having lesser than 300 khasras and larger villages having more than 300 khasras.

If RGM can set up or outsources the service of one hundred GIS operators and form a team, which works for forty hours a week then it would take the entire team to finish the digitization work in approximately thirty five weeks. This is approximately nine months of time. However, the time taken could be drastically reduced by half if instead of hundred people; two hundred people were employed or outsourced for the digitization of all the villages of Madhya Pradesh. In both the cases of digitization, the entire cost turns out to be approximately Rs 5.5393 Crore. The benefit of this would not only come to RGM but could be availed by other departments in issues related to governance and town planning.

<table>
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<tr>
<th>Time taken for digitization(man hrs)</th>
<th>Cost</th>
<th>Number of days required for a 100 member team, working 40 hrs a week, to finish digitization</th>
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<td>For one village</td>
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<td>1000 Rs</td>
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<tr>
<td>For 55,393 villages</td>
<td>138482.5</td>
<td>5.5393 Crore</td>
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</tbody>
</table>

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Cost for procurement of DEM elevation data and preparation of 3 D slope data

The cost of procuring 9*9 sq km (81 square kilometer) of DEM elevation data from National Remote Sensing Center is approximately Rs 10,000. This data can cover five to six milli-watersheds which is equivalent to forty to fifty villages. The cost of preparing a three dimensional DEM model for a khasra, which would show elevation with contours at two meter intervals, is Rs 3500 to Rs 4000. Hence the cost of preparing three dimensional models would be 1.6875 lacs for approximately 45 villages. By adding the cost of digitization to it, we get a total cost of Rs 2, 23,750 for digitization as well as preparation of DEM of 45 villages. In a single milli watershed approximately ten villages are covered. Thus the cost of digitizing a single milli watershed and then preparing its DEM with slopes visible would be approximately Rs 40,681.

Table-2

<table>
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<th>Cost of digitization (Rs)</th>
<th>Cost of procuring DEM elevation data(Rs)</th>
<th>Cost of preparing DEM elevation map(Rs)</th>
<th>Total cost of preparing 3 D model with slopes(Rs)</th>
</tr>
</thead>
<tbody>
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<td>4,972</td>
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<td>45 villages(five to six milli watersheds)</td>
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<td>10,000</td>
<td>1,68,750</td>
<td>2,23,750</td>
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<td>For a single milli watershed</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>40,681</td>
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</tbody>
</table>

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