Ministry of Rural Development
Government of India

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YUKTDHARA

A New Era in Gram Panchayat Planning

Technical Training Manual

Ministry of Rural Development
Government of India

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1. WATERSHED

Introduction

Water is a vital natural resource essential for life on Earth. It is crucial for drinking, agriculture, industry, and sustaining natural ecosystems. Every living organism relies on water for survival, and it plays a fundamental role in food production, sanitation, and economic growth. A clean and adequate water supply is essential for public health, development, and environmental balance. But India is facing a severe water crisis. According to NITI Aayog (2018), nearly 600 million people in India are dealing with high to extreme water stress, and 21 major cities (including Delhi, Bengaluru, and Chennai) could run out of groundwater by 2030. India's growing population has led to an increasing demand for water. The country has 18% of the world's population but only 4% of the world's freshwater resources. However, groundwater is being overused, especially in agriculture, which accounts for nearly 80% of India's water consumption. According to the Central Ground Water Board (CGWB), groundwater levels are declining in 70% of India's wells. Many rivers and lakes are also polluted due to industrial waste, sewage, and excessive use of chemical fertilizers. Studies show that over 70% of surface water in India is contaminated, making it unsafe for drinking and other uses. Additionally, climate change has made rainfall patterns unpredictable, leading to frequent floods in some areas and droughts in others. As a result, millions of people face water shortages, and agricultural productivity is declining. Many cities and villages are struggling to get clean drinking water, and farmers are finding it difficult to irrigate their crops. This crisis is caused by overuse of water, pollution, and climate change. One effective way to solve this problem is by improving watershed management. In this tutorial, we will explore what is the watershed and what is the scope of watershed management.

A watershed is a land area that collects and directs rainfall and snowmelt to a single waterbody, such as a river, stream, lake, or wetland (Figure 1.1). Watersheds can be as small as a footprint or as large as thousands of square miles. Watersheds are also known as drainage basins or catchments. You can think of it like a funnel! Just like a funnel collects and directs water to a single point, a watershed gathers rainwater and channels it into a specific water body (Figure 1.2).

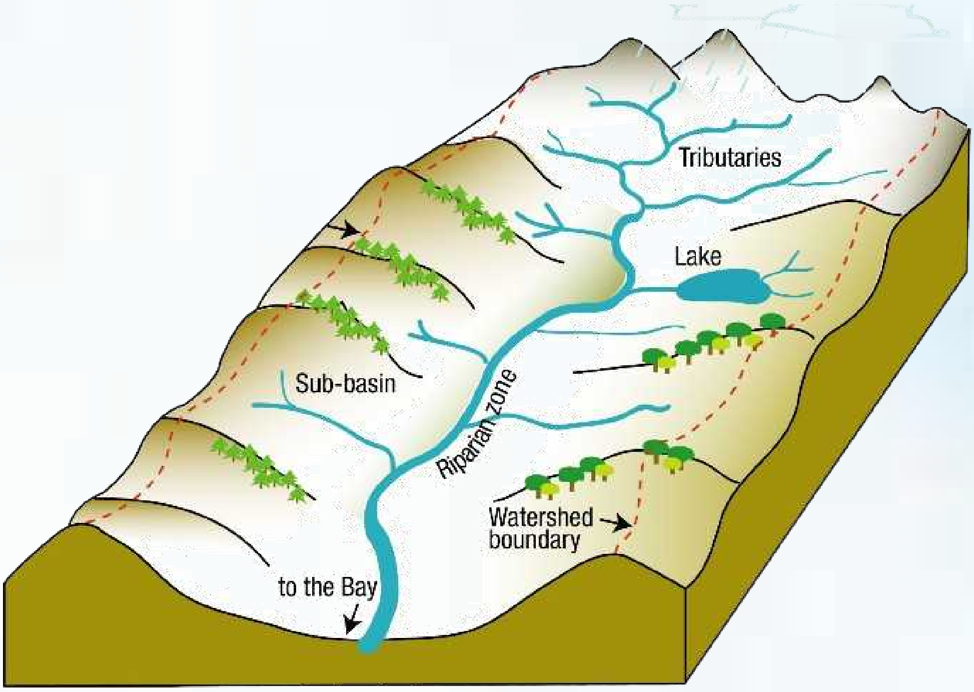


Figure 1.1

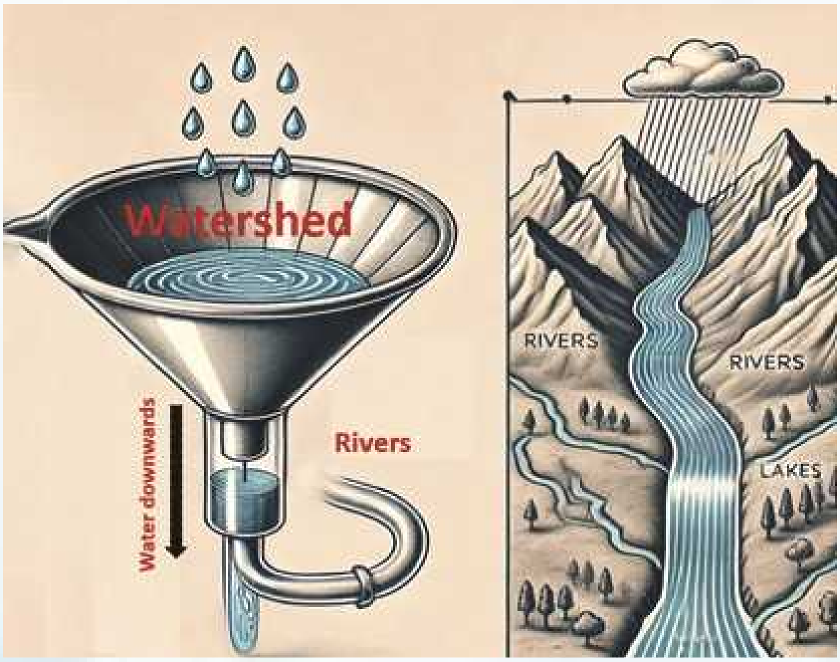


Figure: 1.2

Watershed, you can think of it like a funnel!

Imagine you have a big funnel that collects rainwater and directs it into a bottle. A watershed works the same way, but instead of a bottle, it channels rainwater into rivers, lakes, and underground storage. When rain falls, it flows down hills and through streams, just like water moving through a funnel's narrow opening. Along the way, plants and soil help clean the water, making it safe for drinking and wildlife. If trash or pollution blocks the funnel, the water becomes dirty—just like how pollution harms watersheds. Keeping watersheds clean ensures fresh water for everyone, just like maintaining a clean funnel keeps water pure.

Unlike traditional maps, CGIS allowed the storage of multiple layers of geographic information in a digital format, setting the foundation for modern GIS technology. Around the same time, research institutions and government agencies in the United States and Europe also began experimenting with computer-based mapping systems.

Watershed Classification with Sizes and Example

A watershed is an area of land where all rainwater and runoff drain into a common water body such as a river, lake, or ocean. Watersheds are classified based on their size, which helps in effective water management and conservation (Table: 1.1). Below is a detailed explanation of watershed classification, including their area range and real-life examples from the Ganges River Basin.

Table:1.1 Classification of watershed based on size

Classification	Size(in hectares)	Description
Watershed	50,000 – 2,00,000	The largest category; includes vast areas like river basins or large drainage basins.
Sub-watershed	10,000 – 50,000	A subdivision of a large watershed, focusing on smaller streams or tributaries within the main watershed.
Milli-watershed	1,000- 10,000	A smaller section of a sub-watershed, usually covering small river systems or a few streams.
Micro-watershed	100 – 1,000	Focuses on even smaller drainage areas like village streams or small ponds.
Mini-watershed	10 - 100	The smallest category, such as small catchment areas around a specific field or small water body.

Watershed– Ganges River Basin

A watershed is the largest category, covering major river basins or large drainage areas. The Ganges River Basin is an example, covering parts of India, Nepal, and Bangladesh. All smaller rivers, lakes, and streams in this vast region drain into the Ganges River, making it the primary watershed. Managing large watersheds like this is essential for flood control, water storage, and ecosystem balance.

Sub-Watershed – Yamuna River Basin

A sub-watershed is a smaller section within a large watershed, focusing on major tributaries. The Yamuna River Basin is a sub-watershed within the Ganges Basin. It covers parts of Delhi, Haryana, and Uttar Pradesh and collects water from smaller rivers and streams before flowing into the Ganges. Managing sub-watersheds helps in monitoring water quality, preventing pollution, and ensuring sustainable water use.

Milli-Watershed – Hindon River Basin

A milli-watershed is a division of a sub-watershed that includes small river systems or a few streams. The Hindon River Basin, a tributary of the Yamuna, falls into this category. It drains water from parts of Western Uttar Pradesh and carries it to the Yamuna. Proper management of milli-watersheds helps in reducing soil erosion, controlling sediment flow, and protecting local water sources.

Micro-Watershed – Hindon River Micro Watershed

A micro-watershed is an even smaller section within a milli-watershed, covering local drainage areas like village streams, small ponds, or small river sections. The Hindon River Micro Watershed collects water from small fields, urban areas, and local streams before flowing into the Hindon River. These micro-watersheds play a crucial role in groundwater recharge, improving irrigation, and managing water supply at the village level.

Mini-Watershed – Farm Pond Catchment

At the smallest level, a mini-watershed covers tiny catchment areas such as farm ponds, small fields, or village drainage systems. A small farm pond near the Hindon River serves as a mini-watershed, collecting rainwater before it drains into the nearby river. These mini-watersheds are vital for local water conservation, irrigation, and improving soil moisture for farming.

This hierarchy—from the vast Ganges river basin down to a local farm pond—illustrates how water collects and moves through interconnected systems, each nested within a larger one. For a visual representation of these watersheds, you can refer to the following map (Figure:1.3):

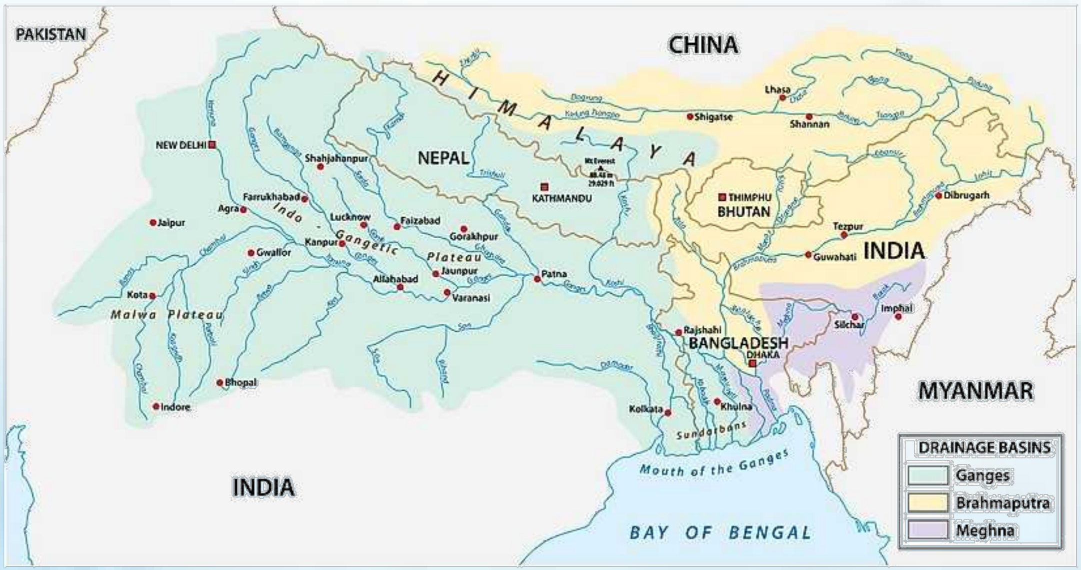


Figure: 1.3

Why Watershed Classification is Important

Understanding different levels of watersheds helps in better water management, flood control, and agricultural planning. Managing watersheds from large river basins to small farm ponds ensures sustainable water use and prevents shortages. Proper watershed management is essential for ecosystem protection, water conservation, and long-term sustainability. Among these, micro-watersheds (100 – 1,000 hectares) play a crucial role in managing water at the local level and ensuring sustainability. Below is a detailed explanation of watershed classification and why micro-watersheds are particularly important.

Importance of micro-watershed

A micro watershed is a small area of land where rainwater collects and flows into a nearby stream, pond, or river. Although they may seem small, micro watersheds play a key role in maintaining a healthy environment. Let's explore why they are so important:

Ensuring a Reliable Water Supply

Micro watersheds help store and distribute freshwater, which is essential for drinking, farming, and industries. By managing them properly, we can ensure a continuous supply of clean water, even during dry seasons. Without healthy micro watersheds, communities may struggle with water shortages and poor water quality.

Flood Control

Healthy micro watersheds absorb rainwater and release it gradually into rivers, lakes, and groundwater systems. This reduces the risk of sudden flooding and minimizes damage to infrastructure, farmland, and communities during heavy rains.

Water Quality

Micro watersheds naturally filter water as it flows through soil and vegetation. This process removes pollutants, sediments, and harmful substances, improving the quality of water for both human consumption and aquatic life.

Protecting Nature and Wildlife

Micro watersheds provide habitats for plants and animals while maintaining biodiversity. By filtering pollutants and mitigating flood impacts, they play a key role in sustaining ecosystems, supporting wildlife, and maintaining balance in the natural environment.

Economic Benefits

Micro watersheds contribute to the economy by supporting activities like farming, fishing, tourism, and recreation. Clean and healthy water systems add value to nearby properties, attract tourists, and provide livelihoods for local communities.

MICRO-WATERSHEDS AND MGNREGA

The Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) is a program that provides jobs to rural people by involving them in building useful infrastructure. One of the best ways MGNREGA helps both people and the environment is through micro watershed projects. These projects focus on soil and water conservation, creating jobs while also improving water availability, farming, and overall rural development.

Examples of few MGNREGA works in micro-watersheds

Building Check Dams

These small structures slow down the flow of water, allowing it to be stored and recharge the groundwater. This is especially useful for irrigation, as it ensures a reliable water source during dry periods.

Digging Farm Ponds

Farm ponds are small reservoirs that collect rainwater. They provide water for crops and livestock when there's not enough rainfall, helping farmers during dry spells and reducing their dependence on external water sources.

Planting Trees (Afforestation)

Trees are planted in areas prone to soil erosion to hold the soil in place. This prevents the soil from washing away during heavy rains, ensuring better land quality for farming.

Creating Contour Trenches

Trenches are dug along the slopes of hills to capture rainwater and prevent it from running off. The collected water helps with irrigation, enabling villagers to grow crops like grass and vegetables even in areas with limited water.

Desilting Tanks

Over time, water tanks collect dirt and debris, reducing their capacity. Desilting clears this material, allowing tanks to hold more water, ensuring a stable water supply, particularly in dry seasons.

Example: A study conducted by the Central Arid Zone Research Institute (CAZRI) in Jodhpur, Rajasthan, highlighted the positive impact of MGNREGA activities, such as the construction of farm ponds and contour bunds. These structures facilitated rainwater storage, enabling farmers to cultivate vegetables even in the dry season. As a result, the socio-economic and ecological conditions of desert communities were significantly improved. The study found that these interventions led to enhanced water availability, increased agricultural productivity, and better livelihoods for the local population.

This example illustrates how micro-watershed development under MGNREGA can effectively improve both livelihoods and the environment in arid regions like Rajasthan.

Importance of watershed management

1. Watersheds are areas of land where all the water drains into a common body of water, like a river or lake. They are essential for sustaining life because they provide water for drinking, agriculture, and ecosystems. Healthy watersheds help regulate water flow and maintain water quality, supporting plants, animals, and human communities. By managing watersheds properly, we ensure a reliable water supply for all living things on Earth.

2. It helps to identify the stream orders (hierarchy of streams based on their position in the watershed) that is smaller streams (tributaries) combine to form larger streams. Through which we can understand the availability of water and where all we can save/ store water by creating different conservation structures like recharge pits etc.

3. The relationship between watersheds and floods is that a watershed is the area that funnels water to rivers, and if there's too much water in the watershed due to heavy rainfall or other factors, it can result in flooding. Managing watersheds effectively can help minimize the impact of floods.

4. A watershed is a key geographic unit that influences the health of ecosystems by regulating water flow, supporting nutrient cycling, and providing habitats for a variety of organisms. The health of a watershed directly impacts the well-being of the ecosystems it supports, and vice versa.

5. Conservation and management efforts, such as protecting wetlands, restoring riparian zones (areas along rivers and streams), or reducing pollution, are essential for maintaining healthy watersheds and ecosystems.

6. Many communities rely on watershed resources for their livelihoods, including agriculture, fishing, and tourism. Proper watershed management ensures these resources are available and sustainable.

Watershed Management

Watershed management is the process of planning and managing the land and water in an area where all rain and surface water flow to the same place, like a river, lake, or ocean. This area is called a watershed. For example, rain falling on a mountain might flow into small streams, which then join bigger rivers before reaching a lake or sea.

Inside a watershed, there is a drainage network, which is like nature's plumbing system. It includes small streams, rivers, and channels that move water, nutrients, and soil from one part of the watershed to another. For instance, a small stream in a village may flow into a larger river that supplies water to nearby towns.

When activities like cutting down trees (deforestation), throwing waste into rivers (pollution), or over using land happen, they can damage the drainage network. This can lead to problems like muddy rivers, impure drinking water, or flooding in low-lying areas.

Watershed management helps protect and fix these problems. For example, planting trees can reduce soil erosion, and building small dams can store water for farming. By working together to care for the watershed and its drainage network, we can ensure clean water, protect plants and animals, and help communities prepare for changes like heavy rains or droughts.

A Yatra towards conserving soil and water

Water and soil are the lifelines for agriculture, and their preservation is our responsibility. Watershed yatra is a moment dedicated to addressing one of the most pressing challenge of our time – ensuring fertile soil and abundant water for sustainable farming.

Scope of Watershed Management

The concept of watershed management in India has its roots in the country's traditional ways of conserving water. In the past, people used innovative techniques like building stepwells, tanks, and smart irrigation systems to store and use water efficiently for farming and daily needs.

However, as the population grew in the 20th century, new problems arose. Water became scarce, forests were cut down, soil was eroded, and land quality worsened because of unsustainable practices and agricultural expansion. To tackle this issue, India launched the MGNREGA act 2nd February 2006 by the Government of India, the program aims to reduce poverty, ensure livelihood security, and empower rural families by offering them a stable source of income. India launched its first watershed management program, the Community Development Program, in the 1950s, focusing on conserving soil and water. Later, in the 1980s, the Watershed Development Project further improved these efforts by involving local communities in managing their natural resources.

Components of Watershed Management

Drainage

Drainage is the process by which water flows naturally or through man-made systems from higher areas to lower areas, eventually reaching rivers, lakes, or oceans. It includes all streams, rivers, and channels that carry water across the land

Drainage Order

Drainage order is a way of organizing streams based on their size and how they join together. It starts with small streams (first-order) and moves up to bigger streams (second-order, third-order, and so on) as they combine.

Importance of drainage order

Understanding drainage order helps us manage water better. It allows us to plan activities to prevent floods, keep water clean, and protect the environment. By knowing how water flows, we can take steps to manage the land and water more effectively, which benefits farming, wildlife, and communities.

First-order stream

A first-order stream is the smallest type of stream. It doesn't have any other streams flowing into it. For example, imagine a small stream that starts on a hill. When it rains on a mountain, the rainwater flows down and forms tiny streams. These small streams are called first-order streams. By knowing about drainage order, we can plan activities in the area to keep water clean, avoid floods, and protect nature. First-order streams are close to the land, so they can get polluted or eroded easily. Protecting these streams, like planting trees around them, helps keep the whole system healthy.

Second-order stream

A second-order stream is formed when two first-order streams meet. For example, when two small streams from hills come together, they form a bigger stream. Later, when two second-order streams combine, they create an even bigger stream. Second-order streams carry more water, so managing them can help store water for farming or reduce the flow of dirt and debris. Building small dams can slow down the water and reduce flooding.

Third-order stream

A third-order stream is formed when two second-order streams come together. For example, this is like a small river. When two second-order streams join, they create a third-order stream, which is a small river that can flow into a lake or sea. Third-order streams are bigger, and managing them is important to help control flooding and provide clean water for people and animals.

Lowest and highest order streams

When a small stream (lowest order) joins a big stream (highest order), the new stream is classified based on the bigger stream's order. For example, if a first-order stream (the smallest) joins a second-order stream, the new stream is classified as a second-order stream because two first-order streams combine to make a second-order stream.

By understanding drainage order, we can plan activities in the watershed to keep water clean, prevent floods, and protect the environment.

Vegetation

Plants are really important for keeping watersheds healthy. The roots of plants, like trees and grass, grow deep into the soil, which helps hold the soil in place. This stops the soil from washing away when it rains, which is called erosion. Without plant roots, the soil would easily get carried away by rainwater and flow into streams, making the water dirty.

The leaves and branches of plants also help protect the soil. When it rains, the leaves and branches slow down the raindrops before they hit the soil. This helps prevent the soil from getting disturbed or washed away. The leaves and branches also shield the soil from direct sunlight, keeping it cooler and helping it hold more moisture.

For example, when trees and grass are planted on a hillside, rainwater doesn't just rush down and carry away the soil. Instead, it seeps into the ground, replenishing underground water and slowing the flow of storm water. This process also reduces flooding and creates reservoirs and streams, which provide clean water for people and farming.

Healthy watershed

A healthy watershed is a place where the land, water, and plants all work together to keep the environment in good condition. A healthy watershed, often called a "green watershed," has very little or no soil erosion, which means the soil stays in place and doesn't wash away. This is important because it helps keep the water clean and prevents land from being lost.

In a healthy watershed, there is plenty of both groundwater and surface water. Groundwater is the water found beneath the ground, while surface water is the water in rivers, lakes, and streams. A healthy watershed has enough water in both of these sources to support plants, animals, and people.

Additionally, most of the natural resources in a healthy watershed are well-preserved. This means that the plants, animals, and soil are protected, and the environment is in good shape for future generations. In short, a healthy watershed is one that is full of plants, has enough clean water, and keeps its natural resources safe.

Example of health watershed

An example from Karnataka would be the Kabini Watershed, located in the Western Ghats (Figure:1.4). The area is known for its rich biodiversity, forest cover, and effective water management practices, which help maintain a healthy ecosystem. Similarly, in Andhra Pradesh, the Nallamalai Hills watershed, part of the Krishna River basin (Figure:1.5), has efforts underway to conserve forests and water, leading to improvements in water availability and biodiversity.

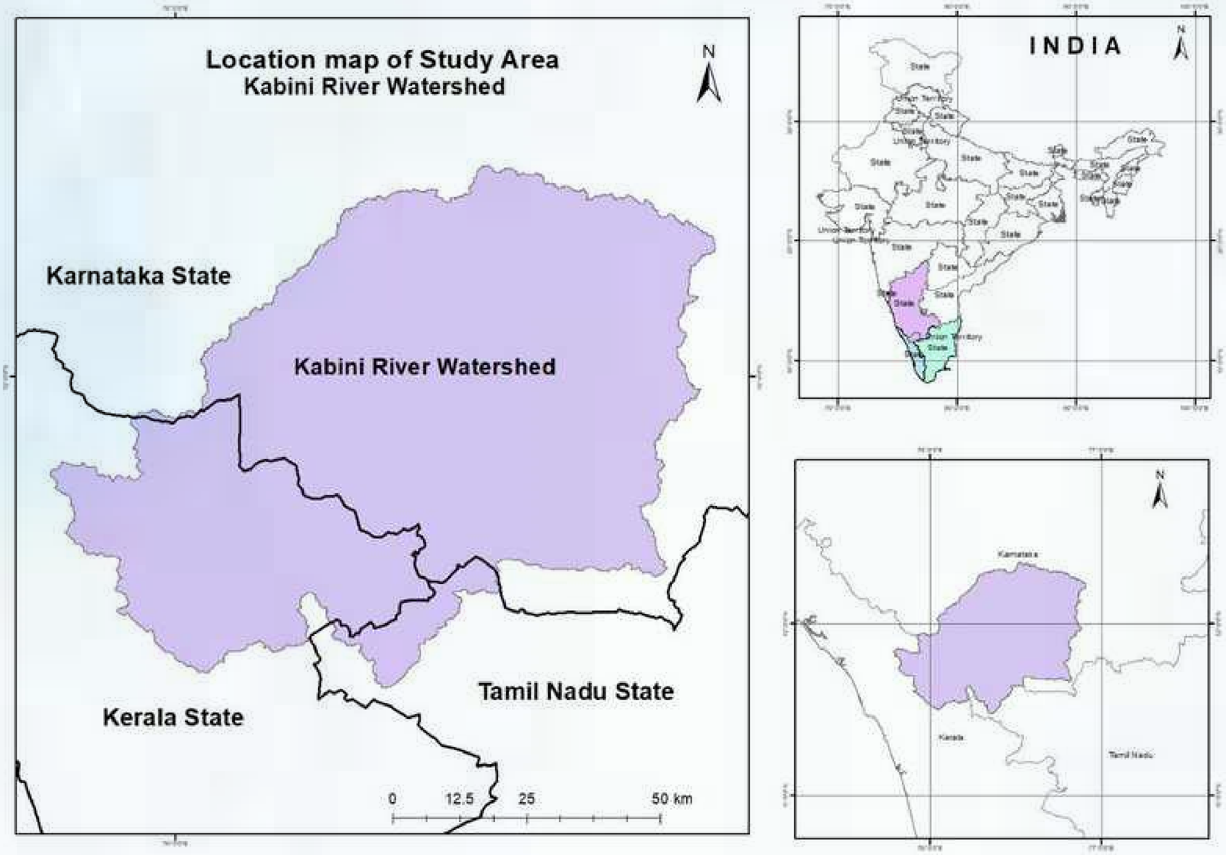


Figure: 1.4

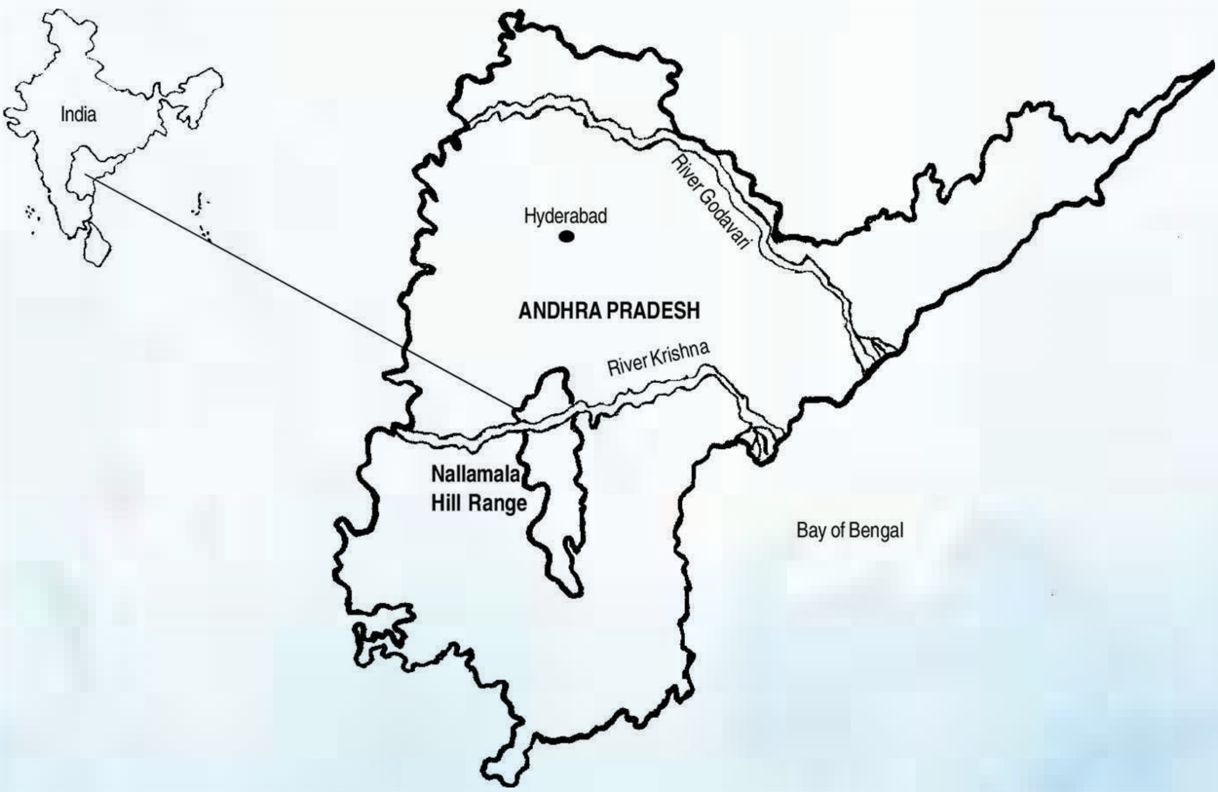


Figure: 1.5

Now, imagine a village near a river. Without proper care, rain washes away the topsoil, making the land barren. But if the villagers plant trees and build small dams, they can slow down the water, save the soil, and store water for the dry season. Over time, the area becomes fertile, and the river flows steadily.

Soil

Soil is a key component of a watershed, as it influences how water flows, infiltrates, and nourishes plants and ecosystems. Healthy soil helps regulate water movement, reduce erosion, and support sustainable land use, making soil management essential for effective watershed management.

Soil management helps in creating MGNREGA activities by focusing on preserving soil health, conserving water, and preventing soil erosion. The type of soil in a watershed area determines which soil management activities are most effective. For example, sandy soils need more water retention structures, while clayey soils benefit from improved drainage. By understanding the soil types and implementing appropriate MGNREGA activities, watershed management can improve both the environment and livelihoods in rural areas. Here's a simple table explaining the MGNREGA activities in relation to soil types and their benefits:

Here's a simple table explaining the MGNREGA activities in relation to soil types and their benefits:

Table:1.2 MGNREGA activities based on soil type

Activity	Soil Type	How It Helps	Example
Erosion Control & Terracing	Loamy & Sandy Soils	Terraces stop soil from washing away by slowing water flow.	In hilly areas with loamy soil, workers create terraces to reduce soil loss and improve water retention.
Water Conservation Structures	Clayey & Sandy Soils	Check dams and ponds store water; prevent water loss or flooding.	In sandy soil regions, check dams store water, preventing rapid runoff.
Afforestation & Vegetative Cover	All Soil Types	Trees and grass prevent soil erosion and improve soil health.	In loamy soil areas, diverse plants improve soil. In sandy soil, drought-resistant plants protect the soil.
Gully Plugging	Loamy & Sandy Soils	Blocks or redirects water to stop erosion and protect soil.	Workers in loamy or sandy areas use rocks, concrete, or plants to block water and stop soil from washing away.
Watershed Management	All Soil Types	Combines various activities to improve water flow and soil health.	In a watershed area, workers use a mix of terracing, check dams, and planting trees based on soil types to improve water and soil.

Slope

Slope plays a crucial role in how water, soil, and nutrients move in a watershed. Steeper slopes cause faster water flow, which can lead to problems like soil erosion and flooding, while gentle slopes slow water down, helping water soak into the ground and preventing damage.

In watershed management, managing the slope is important to prevent soil erosion and help water soak into the ground. Here's how MGNREGA helps with this:

Steeper Slopes

On steep slopes, water flows quickly and can wash away soil. To prevent this, MGNREGA workers build terraces (steps on the hillside) to slow down water. They also plant grass and trees to hold the soil in place. Check dams are built to control water flow and stop flooding.

Example: In hilly areas, workers create terraces and plant trees to keep the soil from washing away when it rains.

Gentler Slopes

On gentler slopes, water flows slowly but can still be better managed. MGNREGA workers can build ponds to collect water and use it later. They also plant trees and grass to help the soil absorb more water.

Example: In flatter areas, workers might dig small ponds to store water for farming and other uses.

In simple terms, on steep slopes, workers build terraces and plant trees to stop soil from washing away, and on gentle slopes, they collect water in ponds and plant more vegetation to help the soil.

The Goal of Watershed Management

Watershed management aims to balance how we use and protect natural resources like soil, water, and plants. It's a sustainable approach that ensures these resources are available for future generations while meeting current needs.

The way to achieve this goal is by using the ridge-to-valley approach, which looks at the entire area from the top (the ridges) to the bottom (the valleys). By managing the watershed from the highest point to the lowest, we can make sure water is protected and used wisely, prevent soil erosion, and keep the environment healthy at every level.

In simple terms, the goal is to manage the whole watershed, from the ridges to the valleys, to ensure clean water, stable land, and healthy ecosystems for everyone.

References: All India Soil and Land Use Survey (AISLUS, 1990): This classification formalized the size categories for effective planning and management.

Source: Krishi ICAR

2. RIDGE TO VALLEY

Background

India is highly vulnerable to drought, with approximately 68% of its total land area classified as prone to drought. Out of this, 33% falls under chronically drought-affected regions, where droughts occur frequently, severely impacting agriculture and water availability. The worst-affected states include **Rajasthan, Karnataka, Maharashtra, Andhra Pradesh, Telangana, Madhya Pradesh, and Tamil Nadu,** which together constitute a significant portion of India's dryland **(Figure 2.1).**

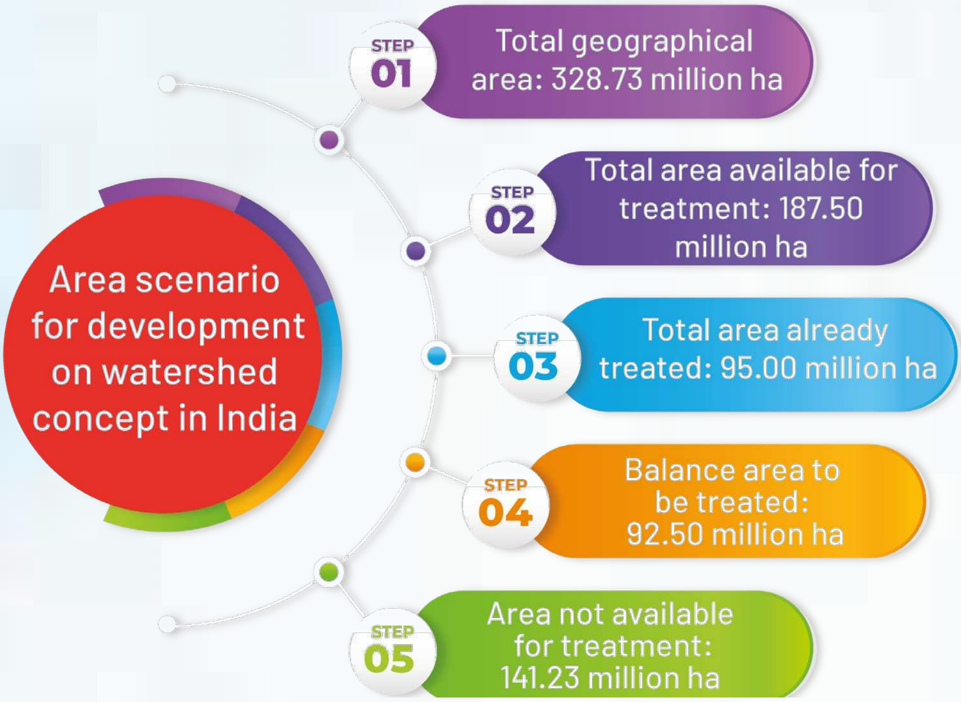
Figure 2.1

Rainfed agriculture covers about 55% of India's net sown area, making it highly dependent on monsoon rains. However, 40% of this rainfed area receives less than 750 mm of annual rainfall, making it highly susceptible to water shortages. Drought frequency has increased due to climate change, with some regions facing severe droughts every 3 to 5 years. In recent years, erratic monsoons have caused both droughts and floods, damaging crops and worsening the livelihood crisis for millions of farmers.

In recent years, changes in rainfall patterns have not only led to droughts but also increased the risk of floods, which further damage crops and soil. Karnataka has the second-largest area of dry land in India, after Rajasthan. This land has been the main source of livelihood for a large rural population over many years. However, due to poor land management, there has been significant soil erosion, loss of soil fertility, declining agricultural productivity, depletion of water resources, deforestation, and damage to natural pastures. These environmental issues have led to economic challenges for people living in rainfed areas.

Importance

India has a total of 328.73 million hectares of geographical area, out of which 187.50 million hectares are available for watershed treatment. Currently, 95 million hectares have been treated, and there is still a significant portion (92.50 million hectares) that requires treatment. However, 141.23 million hectares of the land is not available for treatment due to various reasons.



To address these issues, it is necessary to implement a scientific and integrated approach to watershed development. This approach should include both land-based and non-land-based interventions to ensure sustainable soil fertility and efficient use of natural resources.

In 1994, the Government of India launched the Participatory Watershed Development Program, which adopted the ridge-to-valley approach. This initiative aimed to treat degraded lands using low-cost, locally accessible technologies, focusing on in-situ soil and moisture conservation measures and afforestation. The program emphasized community involvement to ensure sustainable development. Subsequently, the Integrated Watershed Management Program (IWMP) was introduced, continuing the emphasis on the ridge-to-valley methodology. The IWMP's primary objective is to conserving, and developing degraded natural resources such as soil, vegetative cover, and water.

In India, the **Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA)** has been instrumental in promoting watershed management through activities such as soil and water conservation, afforestation, and irrigation development. Integrating the Ridge to Valley approach with MGNREGA projects can significantly enhance environmental sustainability and rural livelihoods. **The adoption of the ridge-to-valley approach in these programs aims to:**

- Reduce soil erosion.
- Enhance water conservation.
- Promote afforestation.
- Improve the socio-economic conditions of resource-poor communities.

By managing water flow from the ridge to the valley, this approach ensures effective conservation of moisture, leading to sustainable agriculture and strengthened durability of soil and water conservation structures.

Approach

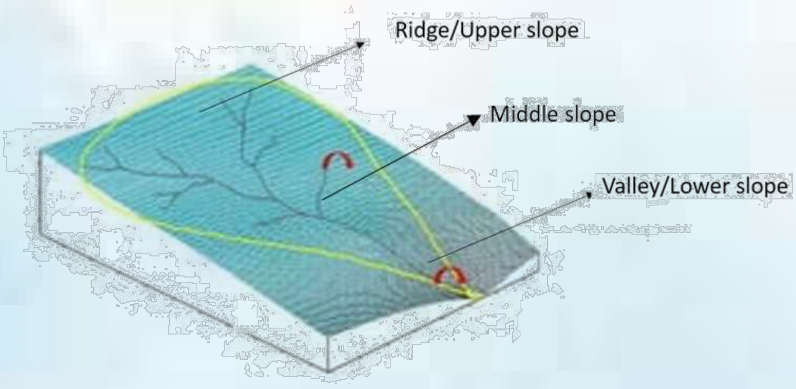
The Ridge-to-Valley concept is a scientific approach to watershed management that focuses on conserving water, reducing soil erosion, and improving land productivity. The approach must begin at the highest point of the landscape, known as the ridge or upper slope, and progress downward toward the lowest points (valley or lower slope) valley. This method is known as the ridge-to-valley approach. The idea is to slow down and capture water at different levels, ensuring sustainable natural resource management.

Natural Resource Management (NRM) under MGNREGA includes activities focused on soil and water conservation, afforestation, and sustainable agriculture to improve land productivity, enhance groundwater recharge, and reduce erosion. Key NRM interventions include contour trenching, afforestation, check dams, farm ponds, field bunding, and percolation tanks across different watershed zones (ridge, middle slope, and valley). In contrast, Non-NRM works under MGNREGA involve livelihood enhancement, skill development, and infrastructure support that complement NRM efforts by generating rural employment, promoting farmer cooperatives, training in sustainable practices, and improving market access. Together, NRM and Non-NRM interventions create a comprehensive watershed management approach, ensuring environmental sustainability and economic resilience for rural communities. Here's a table representation of NRM vs. Non-NRM in MGNREGA for easy understanding **(Table 2.1).**

Table 2.1: MGNREGA Works

Natural Resource Management (NRM)		**Non-NRM Works (Infrastructure & Livelihood) (2 more examp)**	
Water Management	**Land Development**	**Rural Infrastructure**	**Community Facilities**
Ponds	Contour Bunds	Roads	Schools
Check Dams	Terracing	Toilets	Panchayat Buildings
Canals	Plantation	Housing	Livelihood Support
Percolation Tanks	Agroforestry	Storage buildings	Cross drainage works
Recharge Pits	Field Bunding	Kitchen shed	Cattle shelter

The NRM and Non NRM works in the watershed are suggested based on ridge to valley approach and it is divided into three major zones: the ridge or upper slope, the middle slope, and the valley or lower slope **(Figure 2.2).** Each of these zones has unique characteristics and requires specific interventions to achieve effective watershed management.



Ridge or upper slope

The ridge is the highest point in a landscape and serves as the starting point of water flow. This area often consists of degraded lands, barren hills, and forested zones that experience significant soil erosion due to wind and water runoff. Since water flows downward from this point, any conservation measures taken here have a cascading effect on the middle and lower slopes. The main goal at this level is to slow down water flow and allow more absorption into the soil.

In the ridge areas, activities such as afforestation, contour trenching, and soil moisture conservation are prioritized. Planting trees and grass species helps in stabilizing the soil, reducing erosion, and promoting groundwater recharge. Under MGNREGA, rural workers are engaged in constructing continuous contour trenches (CCTs), staggered trenches, and gully plugs, all of which help in controlling surface runoff and improving water infiltration. These activities not only provide employment opportunities but also contribute to the long-term sustainability of natural resources.

Middle slope

The middle slope is the transition area between the ridge and valley. It consists of agricultural fields, grazing lands, and some settlements. If water is not managed properly here, it can cause further erosion and siltation in the lower areas. The aim is to regulate the flow of water while improving soil fertility.

To address these challenges, various soil and water conservation techniques are applied under MGNREGA. Field bunding, stone bunding, and check dams are commonly constructed to slow down water movement and retain moisture in the soil. Additionally, agroforestry and horticulture-based interventions are encouraged to enhance productivity while maintaining ecological balance. Farmers in these regions benefit from water availability and improved soil health, leading to increased crop yields and economic stability.

Valley or upper slope

The valley or lower slope is the lowest part of the watershed where water accumulates. It includes riverbeds, ponds, and fertile agricultural lands. his area often has fertile soil but can suffer from waterlogging and sediment deposition if upstream activities are not managed well. However, with proper management, the valley areas can become highly productive for agriculture and water storage.

In the lower slopes, MGNREGA plays a crucial role in creating and restoring water harvesting structures such as farm ponds, percolation tanks, and check dams. These structures help in storing excess water, reducing flooding, and improving irrigation facilities for farmers. Desiltation of water bodies is another important activity undertaken under MGNREGA to enhance water storage capacity and maintain ecological balance.

The ridge-to-valley approach is closely linked to MGNREGA activities, as it provides a framework for sustainable watershed management while directly supporting rural communities. MGNREGA initiatives such as afforestation, construction of contour trenches, and water harvesting structures play a crucial role in implementing this approach. By addressing water flow, soil erosion, and land productivity through local labor, MGNREGA helps restore degraded landscapes, improve agricultural yields, and enhance water availability. This integrated approach ensures long-term ecological balance, benefiting both the environment and the livelihoods of rural populations.

Types of Treatment

With an intension to conserve every drop of water starting at the ridge and reduce to a considerable extent both the surface runoff volume and the velocity of water, the ridge to valley approach seeks to detain, divert, store and use available rain water. This allows better management of water flowing from the ridge to the valley and ensures conservation of rainwater, which in turn, bring agricultural and economic stability. This approach also helps in strengthening the durability of soil and water conservation structures downstream. Under ridge to valley approach, the soil and water activities can be taken up into two main aspects:

1. Area treatment (Soil moisture conservation and agricultural land management)
2. Drainage line treatment (watercourse stabilization and flow management)

Each of these treatment is further divided based on **Ridge, Mid-Slope, and Valley interventions.**

Area treatment

Area treatment involves a series of soil and water conservation techniques designed to minimize soil erosion, enhance water retention, and improve land productivity. By managing surface runoff effectively, this approach helps in groundwater recharge and vegetation growth, leading to sustainable land and water management and is broadly classified into arable land treatment and non-arable land treatment, depending on whether the land is suitable for agriculture.

Arable land treatment

It focuses on agricultural lands where crops are cultivated. The main goal is to prevent soil erosion, conserve moisture, and enhance soil fertility to improve agricultural productivity. Some common activities used in arable land treatment include:

Contour bund

These are trapezoidal earthen or loose boulder embankment constructed along the contours of arable lands to slow water runoff and improve soil infiltration **(Figure 2.3).** Bunds of small cross section (0.05 m2) laid at 0.3 to 1.0 m vertical interval on hill slopes are used as conservation measures

Figure 2.3

Terracing

A bench terrace is a method used to convert steep slopes into level platforms, making them suitable for crop cultivation. The process involves cutting into the slope to create wide, flat terraces, which help reduce the speed of water runoff. By slowing down the water, bench terraces prevent soil erosion and improve water retention, creating a more stable environment for farming **(Figure 2.4).**

Figure 2.4

Farm pond

refers to a system where a farm pond is strategically built at the lower end of a sloping terrain, collecting rainwater that has been carefully channelled from the higher "ridge" areas through various soil conservation structures, like contour trenches and check dams, as part of a "ridge to valley" watershed management strategy, maximizing water harvesting and minimizing soil erosion **(Figure 2.5).**

Figure 2.5

Field bunding

Field bunds are soil conservation structures built around fields to reduce runoff and prevent erosion. Deep-rooted crops like trees or vegetables are planted on bunds to enhance stability and soil fertility (Figure 2.6). Under MGNREGA, field bunding is promoted for land development, improving soil health, and supporting rural livelihoods through sustainable farming practices.

Figure 2.6

Waterways

It involves constructing channels or drains along slope to guide excess rainwater from ridges to valleys in a controlled manner, ensuring proper water distribution across the landscape. By slowing down runoff, waterways help recharge groundwater, reduce soil loss, and improve water ava liability for agriculture

Figure 2.7

Vegetative bund

Across the slope, where deep-rooted plants like vetiver grass or shrubs are planted along contours to reduce erosion, slow runoff, and improve soil moisture (Figure 2.7). These barriers act as natural filters, trapping sediments, enhancing groundwater recharge, and stabilizing sloped lands for sustainable agriculture. Under MGNREGA, vegetative barriers are promoted as a low-cost, eco-friendly solution to restore degraded lands, support rural livelihoods, and improve long-term water management

Non-arable land treatment

It is implemented on lands that are unsuitable for cultivation, such as forests, wastelands, and steep slopes. The primary goal is to control erosion, improve groundwater recharge, and restore ecological balance. Some key techniques include

Contour trench

These trenches are shallow, dug along the contour lines of more than 3 % sloped land to capture rainwater, slow its flow, and allow more infiltration into the soil. They help prevent erosion, restore degraded lands, and improve soil moisture, making them beneficial for agriculture and afforestation **(Figure 2.8).** They are established for development of trees and grass species and are adoptable in area with annual rainfall upto 950 mm.

Figure 2.8

Contour continues trench

These are designed to trap rainwater and prevent soil erosion in sloped or degraded lands **(Figure 2.9).** These trenches are dug along contour lines without breaks, forming an uninterrupted barrier that slows down water runoff, enhances groundwater recharge, and supports vegetation growth. These are opened at a distance of 5 to 10 meters with 0.45 meter depth and 0.6 meter width in the area where annual rainfall is less than 750 mm.

Figure 2.7

Staggered continues trench

These are discontinuous trenches dug along contour lines in a staggered pattern, meaning they are not connected but placed at intervals **(Figure 2.10).** This design helps slow down water runoff, reduce soil erosion, and improve groundwater recharge, especially in areas where continuous trenches are not feasible due to rocky terrain or uneven slopes. SCTs are particularly effective in semi-arid and degraded lands, where they trap moisture and support vegetation growth over time.

Figure 2.10

Afforestation

Afforestation in watershed management under MGNREGA plays a critical role in soil conservation, water management, and ecosystem restoration. Through afforestation projects, trees and vegetation are planted in degraded or deforested watersheds to reduce soil erosion, improve water retention, and enhance biodiversity. These activities not only restore ecological balance but also contribute to groundwater recharge and prevent flooding by slowing down water runoff.

Diversion channels

These are the artificial channels designed to redirect excess water from high-flow areas to prevent erosion, flooding, or damage to crops and infrastructure. These channels are built along contour lines or specific pathways to guide water from ridges to valleys or away from vulnerable areas, ensuring that water is efficiently distributed across the landscape. By managing water more effectively, diversion channels also promote groundwater recharge and improve water availability for agricultural activities. Under MGNREGA, they are implemented as part of watershed development projects to enhance water conservation and support sustainable land use in rural areas.

Drainage line treatment

Drainage Line Treatment refers to the practices aimed at managing natural drainage lines such as, streams, gullies, and riverbeds—where water naturally flows. The goal is to control surface runoff, reduce erosion, and manage sediment deposition. Common methods include constructing check dams, gully plugs, and desiltation, which help prevent flooding, waterlogging, and erosion, ensuring effective water management in vulnerable areas. This drainage line treatment is further divided based on **Ridge or upper reaches, Middle reaches, and Valley or lower reaches.**

Ridge or upper reaches treatment

In the upper reaches of a watershed, water flows from higher elevations into streams and gullies. The treatment here focuses on reducing runoff before it enters the drainage lines.

Boulder check dam

A Boulder Check Dam is a type of check dam made using large stones or boulders to restrict and slow down water flow in small streams, riverbeds, or gullies **(Figure 2.11).** These dams are designed to control surface runoff, reduce soil erosion, and increase water retention in a watershed, especially in areas prone to flash floods or heavy rainfall.

Figure 2.11

Brush wood check dam

Brushwood checks are erosion control structures made by laying branches or small trees across a waterway or slope in a watershed **(Figure 2.12).** They slow down water runoff, trapping debris, sediment, and water, which helps prevent soil erosion and sedimentation in downstream areas. These checks are placed in areas like hillsides, gullies, or streams where erosion is likely. While the brushwood decomposes over time, it encourages the growth of vegetation, which further stabilizes the soil and improves water quality.

Figure 2.12

Gabions

These are dams made of wire-woven baskets filled with stones placed in trench of suitable size across steep sloped gullies to trap erosion sediment during rain **(Figure 2.13).** They are adoptable in all areas of high slopes and high rainfall

Figure 2.13

Water recharge pit

Water recharge pits are shallow excavated structures designed to capture and store rainwater, allowing it to seep into the ground and replenish groundwater levels (Figure 2.14). Typically, 1 to 3 meters deep and filled with layers of gravel, sand, and stones, these pits reduce surface runoff, control floods, and improve soil moisture, benefiting agriculture and local ecosystems.

Figure 2.14

Middle reaches treatment

The middle slope is where water starts to flow downhill, gaining speed and causing significant erosion and sedimentation. The focus here is on slowing down water flow and stabilizing the soil.

Loose stone check dam

It is a low-cost, temporary structure made of stacked stones, built across small streams or gullies to slow water flow, reduce erosion, and promote groundwater recharge **(Figure 2.15).** It helps trap sediments, enhance soil moisture, and stabilize gullies, making it an effective watershed management tool. Constructed with large stones at the base and smaller ones filling gaps, it includes a central spillway to control overflow. While easy to build with local materials, LSCDs require periodic maintenance to prevent washout and ensure effectiveness in reducing sediment transport and improving land productivity.

Figure 2.15

Small sunken ponds

These are shallow, excavated depressions designed to capture and store runoff water in a watershed, enhancing groundwater recharge and soil moisture retention. Typically constructed in agricultural fields, degraded lands, or near water-scarce areas, they help reduce surface runoff, prevent soil erosion, and provide water for livestock, irrigation, and vegetation growth **(Figure 2.16).** These ponds improve local water availability, especially in dry seasons, and support biodiversity. Proper site selection, excavation depth, and protective vegetation around the pond ensure longevity and efficiency. Regular maintenance, such as desilting and embankment reinforcement, is essential for sustained benefits.

Figure 2.16

Gully plug

A Gully Plug is a small, low-cost structure built across gullies in a watershed to slow down water flow, prevent further erosion, and promote sediment deposition. Made from materials like loose stones, brushwood, or earth, gully plugs help stabilize eroded channels and enhance groundwater recharge **(Figure 2.17).** They are typically constructed in series along a gully to reduce water velocity and allow soil accumulation. Proper site selection, spacing, and maintenance (such as removing debris and repairing washed-out sections) are essential for their effectiveness in watershed conservation.

Figure 2.17

Valley or lower reach treatment

In the lower reaches, where water accumulates in valleys, the focus is on managing high water volumes and reducing the risk of flooding and sediment deposition.

Percolation tank

A percolation tank is a water storage structure designed to enhance groundwater recharge by allowing water to seep into the soil. It is typically built in permeable soil areas to reduce runoff, prevent erosion, and support agriculture by maintaining soil moisture. Constructed with an earthen or masonry embankment and a spillway for overflow control, it helps in flood mitigation and ensures water availability for wells and boreholes. While effective in groundwater replenishment, it requires regular desilting to prevent silt accumulation and works best in regions with good infiltration capacity.

Embankment

It is a raised barrier made primarily of compacted soil, designed to control water flow, store runoff, and prevent erosion in watershed areas. It is commonly used in dams, percolation tanks, check dams, and nala bunds to regulate water retention and enhance groundwater recharge. These embankments are built with gentle slopes to ensure stability and may include spillways to safely discharge excess water. Regular maintenance, such as vegetation planting and desilting, helps prevent breaches and improves long-term effectiveness. Earthen embankments are widely used in agriculture, flood control, and soil conservation projects.

Here is a comprehensive table dividing the MGNREGA activities into ridge activities, mid-slope activities, and valley activities, along with their purposes (Table 2.2)

Category	Characteristics	MGNREGA activities	Purpose
Ridge or Upper slope	Steep slopes, shallow soil, high runoff, and low vegetation cover.	- Contour trenches: Trenches dug parallel to contours.- Afforestation: Planting trees.- Stone bunds: Stone barriers to reduce water speed.	- Prevent soil erosion.- Reduce surface water runoff.- Recharge groundwater at higher elevations.
Mid-Slope	Moderate slopes, mixed land use (agriculture, forest), partial water retention.	- Field bunding: Earthen or stone bunds along fields.- Check dams: Small water storage structures.- Horticulture plantations: Fruit-bearing trees on slopes.	- Slow down water flow.- Improve soil moisture.- Recharge groundwater and reduce sedimentation.
Valley or lower slope	Gentle slopes, deep soils, high water accumulation, fertile land.	- Pond construction: Small water storage structures.- Drainage line treatment: Stabilizing drainage channels.- Irrigation canals: Structures for water distribution.	- Harvest water.- Prevent waterlogging and flooding.- Increase agricultural productivity.

Conclusion

The ridge-to-valley approach is a proven method for sustainable watershed management, crucial for reducing soil erosion, enhancing groundwater recharge, and improving agricultural productivity in drought-prone regions. By integrating area treatments (like contour bunding and afforestation) with drainage line treatments (such as check dams and percolation tanks), it ensures effective water flow management. Supported by programs like MGNREGA, it not only restores degraded lands but also generates rural employment. This holistic strategy strengthens livelihood resilience, promotes ecological balance, and secures water resources for future generations.

3. BASICS OF GIS

History: Evolution and key milestones

The concept of Geographic Information Systems (GIS) has been around for decades, evolving from simple cartographic methods to sophisticated digital mapping and spatial analysis tools. Before the advent of computers, maps were created manually and used primarily for navigation, land surveys, and urban planning. These traditional methods were limited in their ability to analyse and overlay different types of geographical information efficiently.

The modern GIS era began in the 1960s, when Dr. Roger Tomlinson, a Canadian geographer, developed the Canada Geographic Information System (CGIS). This was the first computerized GIS system designed to manage and analyze land-use data. Unlike traditional maps, CGIS allowed the storage of multiple layers of geographic information in a digital format, setting the foundation for modern GIS technology. Around the same time, research institutions and government agencies in the United States and Europe also began experimenting with computer-based mapping systems.

In the 1970s, GIS technology started gaining momentum with the advancement of computer processing power. The Harvard Laboratory for Computer Graphics and Spatial Analysis played a crucial role in refining GIS methodologies, leading to the development of software that could handle more complex spatial analysis. During this period, GIS was mainly used by government agencies for land management, transportation planning, and environmental studies. The 1980s saw the commercialization of GIS with the launch of ArcInfo by Esri, making GIS software accessible to industries like forestry, real estate, and urban planning.

By the 1990s, GIS had become more mainstream, thanks to the growth of the internet and improvements in satellite imaging. Web-based GIS applications started to emerge, allowing users to access and share spatial data more efficiently. The launch of open-source GIS software, such as GRASS GIS, further democratized access to geographic tools. Around this time, GIS began to play a key role in disaster management, environmental monitoring, and business intelligence.

In the 2000s, the rise of cloud computing, GPS, and mobile technology revolutionized GIS. Platforms like Google Earth made geographic visualization widely available, while advanced GIS software like ArcGIS online allowed for real-time spatial analysis. Companies like Uber and Ola leveraged GIS to optimize their ride-hailing services by integrating real-time location tracking, route optimization, and demand prediction.

Today, GIS is more powerful than ever, integrating artificial intelligence, big data, and machine learning to enhance spatial decision-making. It is widely used in smart city planning, climate change research, transportation systems, and precision agriculture. With continuous technological advancements, GIS is expected to play an even greater role in shaping the future of urban development, environmental conservation, and global connectivity.

Introduction

A geographic information system (GIS) is a computer-based system that stores, analyses, and displays data about the Earth. GIS can be used to create maps, charts, and 3D models of earth features. A GIS is basically like any other database, but with an important difference: all information in GIS must be linked to a geographic (spatial) reference (latitude/longitude, or other spatial coordinates).

GIS = G + IS

GEOGRAPHIC REFERENCE	+	INFORMATION SYSTEM
Data of Spatial coordinates on the surface of the earth (Map) - location data		Database of attribute data corresponding to spatial location and procedures to provide information for decision making

GIS = IS with geographically referenced data

GIS is an integral part of our daily lives and is widely used in applications like Ola, Uber, Google Maps, Swiggy, and Zomato. These platforms leverage GIS technology for real-time location tracking, route optimization, navigation, and efficient service delivery. Whether it's booking a ride, finding directions, or ordering food, GIS helps enhance convenience and accuracy in everyday tasks. The widespread use of GIS in everyday applications is made possible by its core components. Understanding these key components helps us to provides insight into how GIS operates and supports various industries.

Components

A Geographic Information System (GIS) is a powerful technology that enables the collection, storage, analysis, and visualization of spatial data. It consists of five essential components (Figure 3.1): Hardware, Software, Data, People, and Methods. Each of these components plays a vital role in ensuring the efficiency and accuracy of GIS applications.

People

People are the users of GIS, including analysts, researchers, and planners who collect, analyze, and interpret geographic data for applications such as urban planning, resource management, and business strategy. Their expertise ensures GIS data is effectively utilized for decision-making.

Data

Data is the foundation of GIS, categorized into spatial data (representing locations through vector and raster formats) and attribute data (descriptive details like population density and land use). Accurate data is crucial for reliable analysis and decision-making.

Hardware

It includes computers, GPS devices, drones, and printers, which support GIS operations. These tools enable data collection, processing, and visualization, ensuring efficient handling of spatial information.

Software

It provides tools for mapping and analysis, with platforms like ArcGIS, QGIS, and Google Earth Pro allowing users to overlay datasets, conduct spatial analysis, and generate insights for various applications.

Processes and Methods

It defines the workflows for GIS operations, including data collection, georeferencing, and spatial analysis techniques like buffering and overlay analysis. Standardized methods ensure accuracy, consistency, and efficiency in GIS applications.

Figure 3.1

In GIS, latitude and longitude serve as the foundation for spatial data, which is managed using key GIS components like data, hardware, software, people, and methods. The accuracy of GIS mapping depends on precise coordinate systems and data collection methods, ensuring reliable spatial analysis and decision-making. These GIS components work together to maintain accurate spatial representation, which is dependent on coordinate systems. As fundamental elements of geographic positioning, latitude and longitude play a crucial role in aligning GIS data with real-world locations.

Coordinate systems

A coordinate system is a framework used to define the precise location of geographic features on the Earth's surface. It consists of a Geographic Coordinate System (GCS), which uses latitude and longitude to represent locations on a three-dimensional sphere, and a Projected Coordinate System (PCS), which converts these coordinates into a two-dimensional map for accurate distance and area measurements. For more details, refer to Annexure 1. A coordinate system is a way to locate places on Earth using numbers. The most common system uses latitude, longitude and Accuracy, which are like a grid covering the planet.

Latitude & Longitude: The Earth's Address System

Latitude (Horizontal lines)

Think of the Earth as an apple. If you slice the apple horizontally, you create rings—these rings represent lines of latitude. Latitude measures how far north or south a place is from the Equator (0° latitude). The Equator is the imaginary line that divides the Earth into the Northern and Southern Hemispheres. Locations north of the Equator are measured in degrees north (°N), while locations south of the Equator are measured in degrees south (°S). The North Pole is at 90°N, and the South Pole is at 90°S (Figure 3.2).

Longitude (Vertical lines)

Now, imagine slicing the apple vertically from top to bottom. These slices represent lines of longitude. Longitude measures how far east or west a place is from the Prime Meridian (0° longitude), which runs through Greenwich, England. Longitude lines extend from 0° to 180° east or west, dividing the Earth into the Eastern and Western Hemispheres (Figure 3.2). Unlike latitude lines, which are parallel, longitude lines converge at the North and South Poles, forming a global coordinate system used for navigation and mapping.

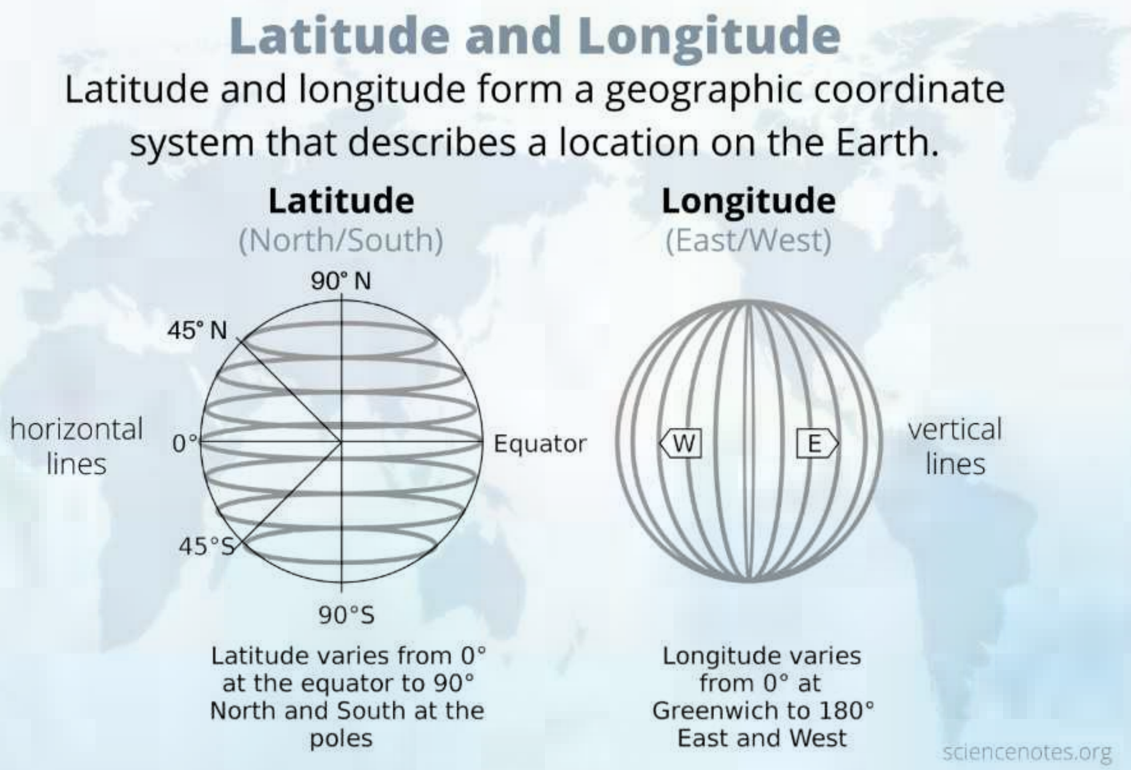


Figure 3.2

FINDING A LOCATION USING LATITUDE AND LONGITUDE

To find a place on Earth, you need both its latitude and longitude, like giving its "address" on the apple. For example, if you want to find where London is on your apple:

- Look for the latitude line that says "51.5 degrees North" (that's how far north London is from the Equator).
- Then, look for the longitude line that says "0 degrees" (that's how close London is to the Prime Meridian).
- Where those two lines cross is roughly where London is on your apple!

INTERESTING FACTS

- ✓ The Equator is the Longest Line of Latitude – At 40,075 km (24,901 miles), it divides the Earth into the Northern and Southern Hemispheres.
- ✓ The International Date Line Creates a Time Jump – Located at 180° longitudes, crossing it can make you gain or lose a day instantly!
- ✓ Antarctica Has No Official Time Zones – Since all longitude lines meet at the South Pole, time zones in Antarctica are often based on the country operating a research station.
- ✓ The Equator is considered the "Zero degree" latitude, making the dividing line between the northern and southern hemisphere.

Accuracy

The precision of latitude and longitude coordinates is determined by the number of decimal places used. More decimal places provide a finer level of accuracy, which is essential for various geospatial applications such as mapping, navigation, and surveying. This table shows the relationship between decimal places in latitude/longitude coordinates and the corresponding ground distance precision. This is useful when determining the necessary precision for mapping, GPS tracking, and geospatial analysis. The table below presents the accuracy chart for latitude and longitude precision (Table 3.1)

Table 3.1: Accuracy Chart for Latitude and Longitude Precision:

Decimal Places	Degrees	Distance
0	1	111 km
1	0.1	11.1 km
2	0.01	1.11 km
3	0.001	111 m
4	0.0001	11.1 m
5	0.00001	1.111 m
6	0.000001	111 mm
7	0.0000001	11.1 mm
8	0.00000001	1.11 mm

Practical Examples of Precision in GIS Applications

Let's think of latitude and longitude like a big grid on the Earth that helps us find places. The more numbers (decimal places) we use, the more precise our location is.

- If we only use whole numbers (0 decimal places), we can find a city, but not an exact place (about 111 km wide).
- If we use 2 decimal places, we can find a location close to a small town (1.11 km wide).
- With 5 decimal places, we can find a location very accurately, like inside a small room (1.1 meters wide).
- If we go up to 8 decimal places, we can pinpoint something as small as an ant (1.1 mm wide)!

More numbers = More precise location!

- 0 decimal places ➔ Finds a **Big City** (111 km wide)
- 2 decimal places ➔ Finds a **Small Town** (1.1 km wide)
- 5 decimal places ➔ Finds a **House or Room** (1.1 meters wide)
- 8 decimal places ➔ Finds an **Ant or a Grain of Rice** (1.1 mm wide)

Data types

Geographic Information Systems (GIS) use different data types and formats to store, analyze, and visualize spatial information. These data types are broadly classified into two main categories: Spatial data and Non spatial data, each with its own formats for efficient storage and processing.

Spatial data

Spatial data, also known as geometric data, represents the physical location, shape, and arrangement of objects on the Earth's surface. It is the core component of Geographic Information Systems (GIS) and helps to analyse geographical relationships. For example, a street address, place name, GPS co-ordinates, geotagged photos, tweets, location tags on Facebook and Instagram data all are spatial data, even your cell phone photos can have a location attached to it. Spatial data is classified into two major types: Vector Data and Raster Data.

Vector Data (Discrete Data)

Vector data is a type of spatial data used in Geographic Information Systems (GIS) to represent real-world features through geometric shapes. It consists of discrete points, lines, and polygons, which are defined by coordinate pairs (latitude and longitude or other coordinate systems) (Figure 3.3). This type of data is useful for mapping and analyzing spatial relationships between different features.

TYPES OF VECTOR DATA

Point data

A point in GIS represents a specific location with no dimensions—just a coordinate (x, y) or (latitude, longitude). Points are used to depict objects that are too small to be represented as lines or areas at a given scale. Since they lack length and area, they serve as markers for specific locations.

Example: The location of trees in a forest, the position of fire hydrants in a city, or the placement of weather stations in a region.

Line (Polyline data)

A line, or polyline, consists of two or more connected points and represents features that have length but no width. Lines are commonly used to model linear features such as roads, rivers, or pipelines. They can also represent movement paths, such as migration routes of animals or flight paths.

Example: Road networks, river systems, railway tracks, and power lines.

Polygon data

A polygon is a closed shape formed by three or more points connected by lines, representing features that have both area and perimeter. Polygons are used to model surfaces or regions, such as land use zones, water bodies, or administrative boundaries. Unlike points and lines, polygons enclose space and can be used to analyze area-based attributes.

Example: Land parcels, city boundaries, lakes, forests, and agricultural fields.

Raster data (Continuous data)

Raster data is a type of spatial data in Geographic Information Systems (GIS) that represents the Earth's surface using a grid of cells or pixels (Figure 3.3). Each cell has a specific value representing information such as elevation, temperature, or land cover. Raster data is commonly used for continuous data representation and spatial analysis.

Example: Satellite image, land use and land cover map, soil map

Non spatial data

Non-spatial data, also known as attribute data, refers to information that describes characteristics of spatial features but does not include geographic coordinates. It provides additional details about points, lines, and polygons in a GIS dataset, enhancing the analysis and interpretation of spatial data. Non-spatial data, simply, is data that contains 'what' instead of 'where'.

Example: Land use classifications, Temperature, District names and city population

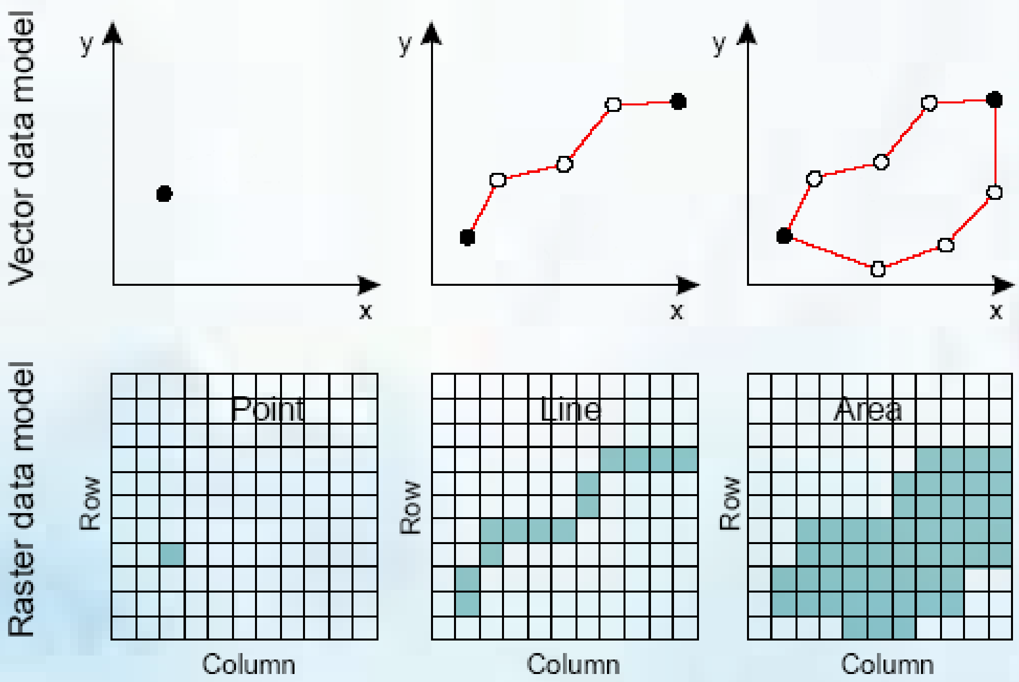


Figure 3.3

File formats

GIS data file formats are essential for storing, managing, and analyzing spatial and non-spatial data. These formats ensure compatibility between different GIS software and enable efficient handling of geographic information. GIS file formats are broadly categorized into vector data formats, raster data formats, and non-spatial data formats. Table 3.2 depicts the different data types for data file formats for different data types

Table 3.2: Types of file formats for different data types:

Data Type	Examples	File Types
Vector Data	Land parcels, city boundaries, lakes, forests, agricultural fields	- **Shapefile** (.shp, .shx, .dbf) – Widely used format for storing vector data with attributes. - **GeoJSON** (.geojson) – A web-friendly format using JSON for spatial data. - **KML/KMZ** (.kml, .kmz) – Used in Google Earth and online mapping. - **GeoPackage** (.gpkg) – An efficient, modern format for storing vector data.
Raster Data	Satellite images, land use and land cover maps, soil maps	- **GeoTIFF** (.tif, .tiff) – A high-resolution raster format with georeferencing. - **JPEG 2000** (.jp2) – A compressed format for efficient raster storage. - **ASCII Grid** (.asc) – Text-based format used for elevation and environmental modeling. - **ECW & MrSID** (.ecw, .sid) – High-compression formats for storing large aerial and satellite images.
Non-Spatial Data	Land use classifications, temperature, district names, city population	- **CSV** (.csv) – A plain text format for tabular attribute data. - **Excel** (.xls, .xlsx) – Used for managing attribute data in spreadsheets. - **DBF** (.dbf) – A database format used alongside shapefiles. - **SQL Databases** (.sqlite, .mdb, .pgdb) – For storing large attribute datasets.

GIS data types and formats work together to store, manage, and analyze spatial information. Vector formats like Shapefiles and GeoJSON store discrete features, Raster formats like GeoTIFF handle continuous data, and Non-spatial formats like CSV store descriptive attributes. The choice of format depends on the data type, required precision, and software compatibility, ensuring efficient GIS applications across various domains.

GIS software's

GIS (Geographic Information System) software is a type of computer program used to capture, store, analyse, manage, and visualize spatial or geographic data. It allows users to understand patterns, relationships, and trends by overlaying different layers of data on maps. software can be categorized (Figure 3.4) based on deployment models, licensing, and accessibility. Here's a breakdown of GIS software into different categories:

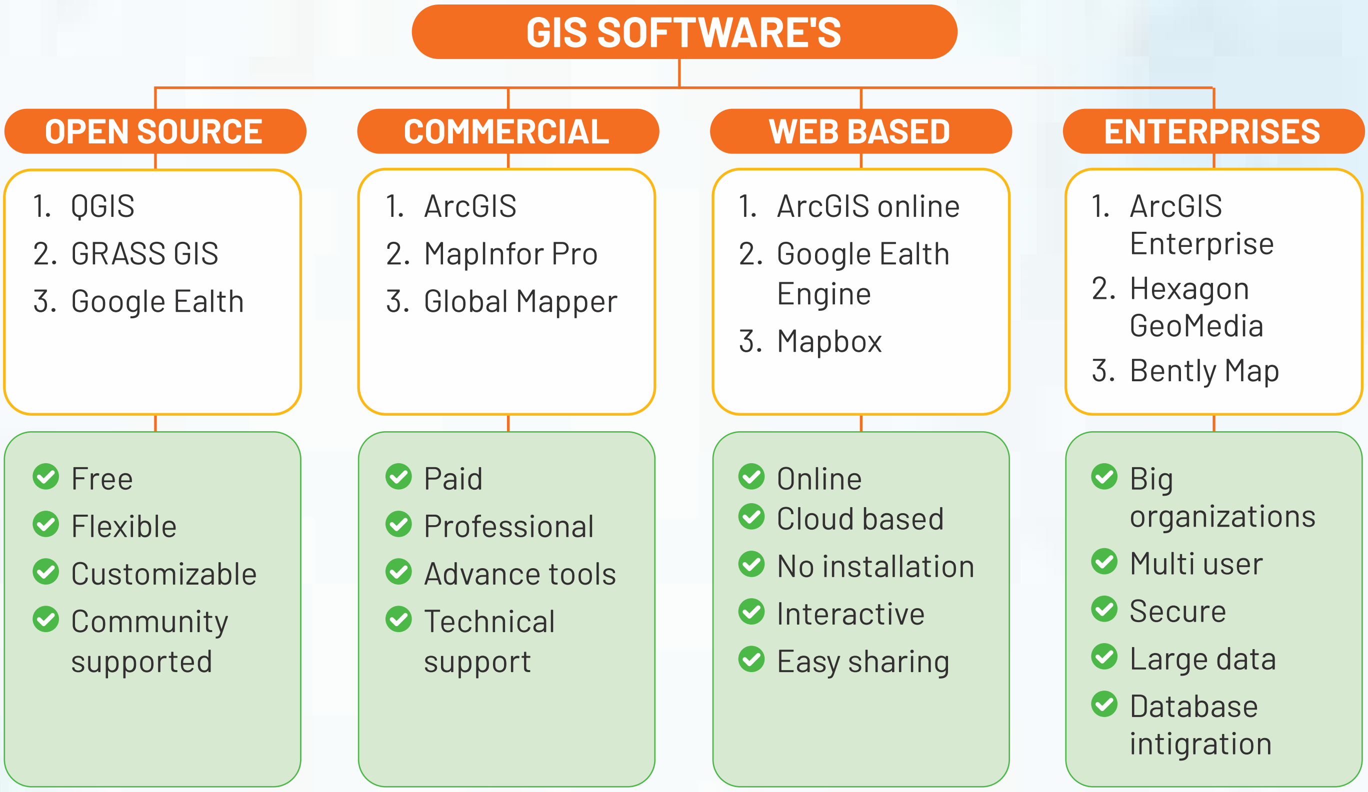


Figure 3.4

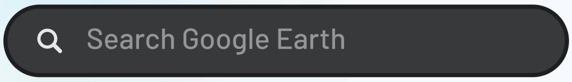
There are various types of GIS software, including open-source, commercial, web-based and enterprise. While commercial GIS software like ArcGIS offers advanced features, it often comes with high costs. Open-source alternatives such as QGIS provide flexibility but may require technical expertise. Web-based and enterprise GIS platforms enable large-scale data management, but they often involve subscription fees. Among these options, Google Earth stands out as a free and user-friendly choice. It allows users to explore geographic data through high-resolution satellite imagery, 3D visualization, and basic GIS functions. Whether accessed via desktop, web, or mobile, Google Earth provides an accessible and cost-effective solution for spatial analysis without the complexity or expense of other GIS software.

Google Earth

Google Earth is a powerful tool that provides a 3D representation of the Earth using satellite imagery, aerial photography, and geographic data. It allows users to explore different locations, view historical imagery, measure distances, and create custom maps (Figure 3.5). Google Earth can be used for various purposes, including education, environmental studies, urban planning, and travel exploration. The platform is available as a web-based application, a desktop version (Google Earth Pro), and a mobile app. Users can navigate using search, zoom, tilt, and rotate features, and they can also overlay data for analysis and visualization.

KEY FEATURES

Search Functionality



Users can quickly find places, landmarks, and addresses using the search bar. It instantly navigates to the desired location with latitude, longitude, and elevation details. The tool helps in research, travel planning, and navigation. It also provides information on nearby points of interest. This makes finding and analyzing locations easier.

Historical Imagery

Available in Google Earth Pro, this feature allows users to view satellite images from different time periods. It helps in studying changes in landscapes, urban expansion, and environmental shifts. Users can compare past and present imagery to track developments. This is widely used in research, conservation, and city planning. It provides valuable insights into long-term geographic changes.

Measurement Tools

Google Earth provides tools to measure distances, perimeters, and areas. Users can calculate the straight-line distance between two points or measure specific regions. This is helpful for urban planning, agriculture, and land analysis. It allows precise geographic measurements for various professional uses. The feature supports both small-scale and large-scale mapping needs.

Data Overlay & Import

Users can import and overlay GIS data, KML, and KMZ files for advanced analysis. This allows visualization of population density, climate data, and transportation networks. Researchers and planners use this feature for spatial analysis. It enables deeper insights into geographic and environmental studies. The ability to overlay data enhances decision-making in various fields.

Place mark & Annotation

Users can add custom markers, labels, and descriptions to locations. These annotations help in research, presentations, and geographic studies. Placemarks can include images, links, and notes for reference. This feature is useful for travelers, educators, and professionals. It makes location-based information easy to organize and share.

Street View

Users can explore locations at street level using 360-degree panoramic images. By dropping the Pegman icon, they can virtually walk through streets and landmarks. This feature is useful for navigation, real estate, and travel previews. It provides a real-world perspective without physically visiting a place. Street View enhances exploration with high-quality visuals.

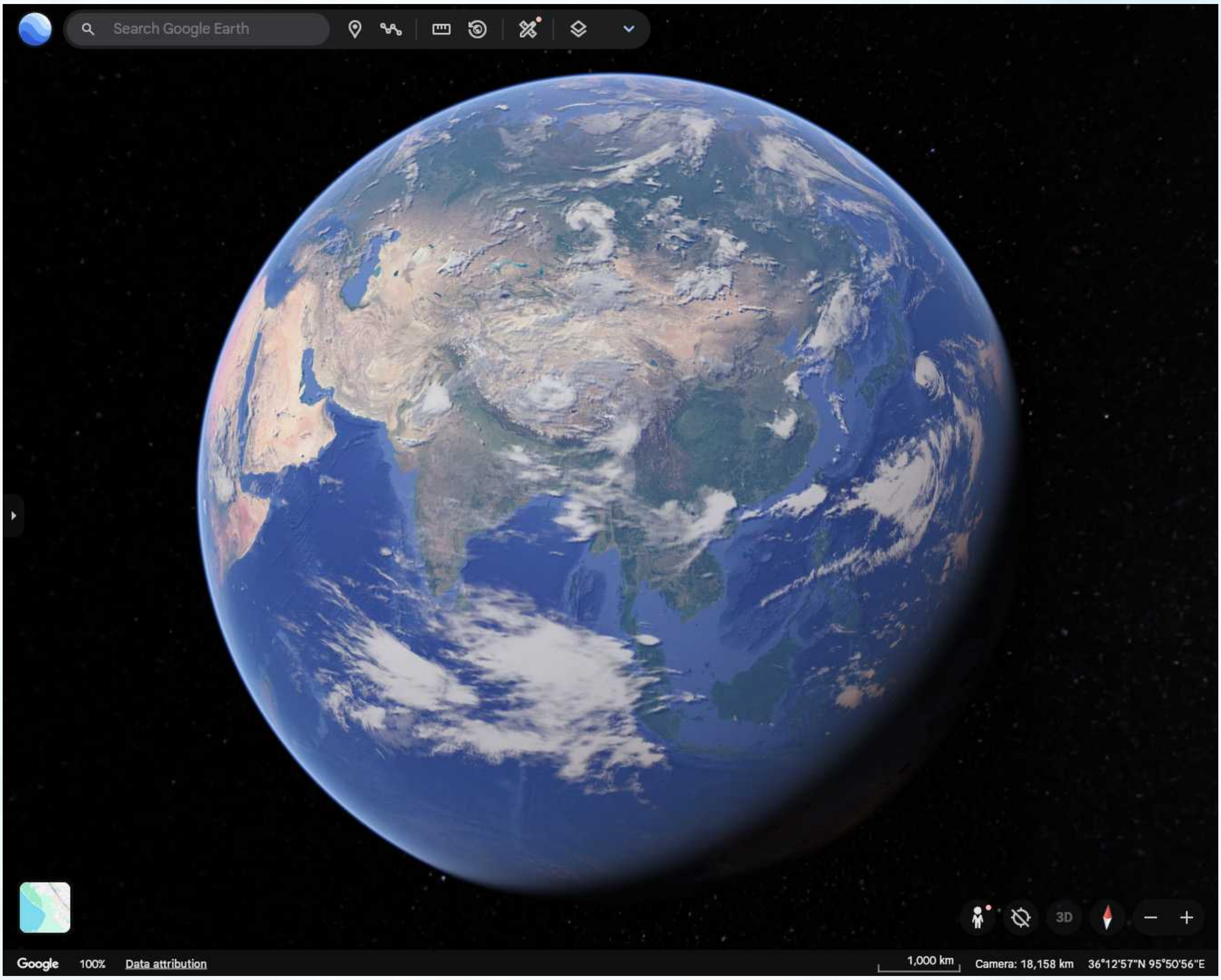


Figure 3.5

Conclusion

Geographic Information Systems (GIS) have advanced from manual mapping to modern digital tools powered by AI, big data, and cloud computing. These innovations make GIS essential for industries like urban planning, environmental management, and business analysis. By enabling data collection, analysis, and visualization, GIS supports informed decision-making and efficient resource management. As technology evolves, GIS will continue to play a vital role in solving real-world challenges. Next, we will explore GIS planning, a crucial step in implementing GIS strategies effectively.

ANEXURE-1

Coordinate systems

A GIS is to be created from available maps of different thematic layers (soils, land use, temperature, etc). in this GIS map, geographic information is correctly aligned with real world locations. The maps are in two-dimensions whereas the earth's surface is a 3-dimensional ellipsoid. Every map has a projection and scale. To understand how maps are created by projecting the 3-d earth's surface into a 2-d plane of an analogue map, we need to understand the coordinate systems: Geographic Coordinate System (GCS) and Projected Coordinate System (PCS).

TYPES OF COORDINATE SYSTEMS

Geographic Coordinate System (GCS)

A Geographic Coordinate System (GCS) works by using a grid of latitude and longitude lines to specify locations on the Earth's surface. It is a three-dimensional reference system that represents the Earth as an ellipsoid and assigns coordinates to each point based on angular measurements (Figure 3.6).

Latitude measures how far a location is from the Equator, which is the central horizontal line at 0° latitude. It is expressed in degrees, ranging from 90° North (North Pole) to 90° South (South Pole). Locations in the Northern Hemisphere have positive latitude values, while those in the Southern Hemisphere have negative values.

Longitude measures how far a place is from the Prime Meridian, the vertical line at 0° longitude that runs through Greenwich, England. Longitude values range from 180° East to 180° West. Unlike latitude, which has a fixed reference (the Equator), the Prime Meridian is an arbitrary line chosen for standardization.

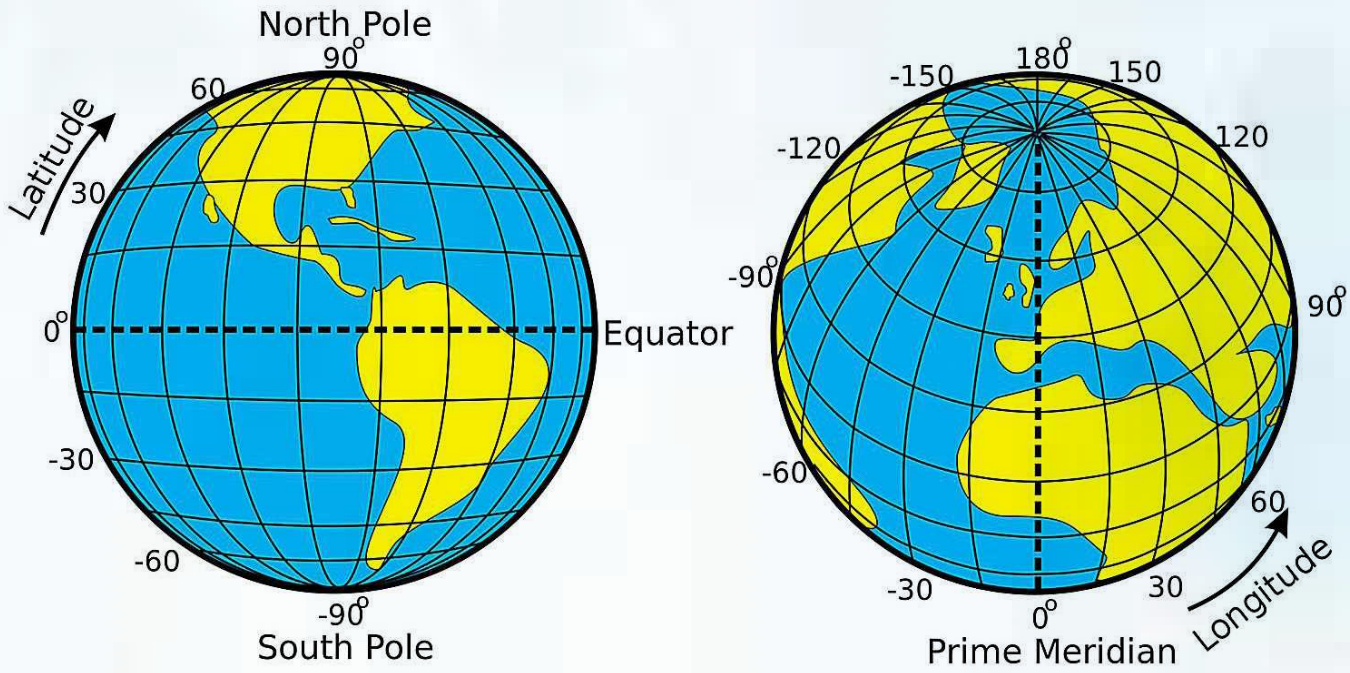
Together, latitude and longitude form a coordinate pair, which uniquely identifies any point on Earth. This system is essential for navigation, mapping, and geographic analysis in GIS applications.

Projected Coordinate System (PCS)

A Projected Coordinate System (PCS) represents the Earth's surface in a two-dimensional plane by converting geographic coordinates from a Geographic Coordinate System (GCS) (Figure 3.7). Unlike GCS, which uses latitude and longitude, PCS uses X and Y coordinates to accurately measure distance, area, and direction.

PCS relies on map projections to transform the curved Earth into a flat surface. Different projections serve specific purposes, such as preserving shape (conformal), area (equal-area), or distance (equidistant). Common projection systems include Universal Transverse Mercator (UTM) and State Plane Coordinate System (SPCS).

By using PCS, GIS professionals can create accurate and practical maps for urban planning, land surveying, transportation networks, and environmental studies, ensuring that spatial data is aligned correctly for analysis and decision-making.



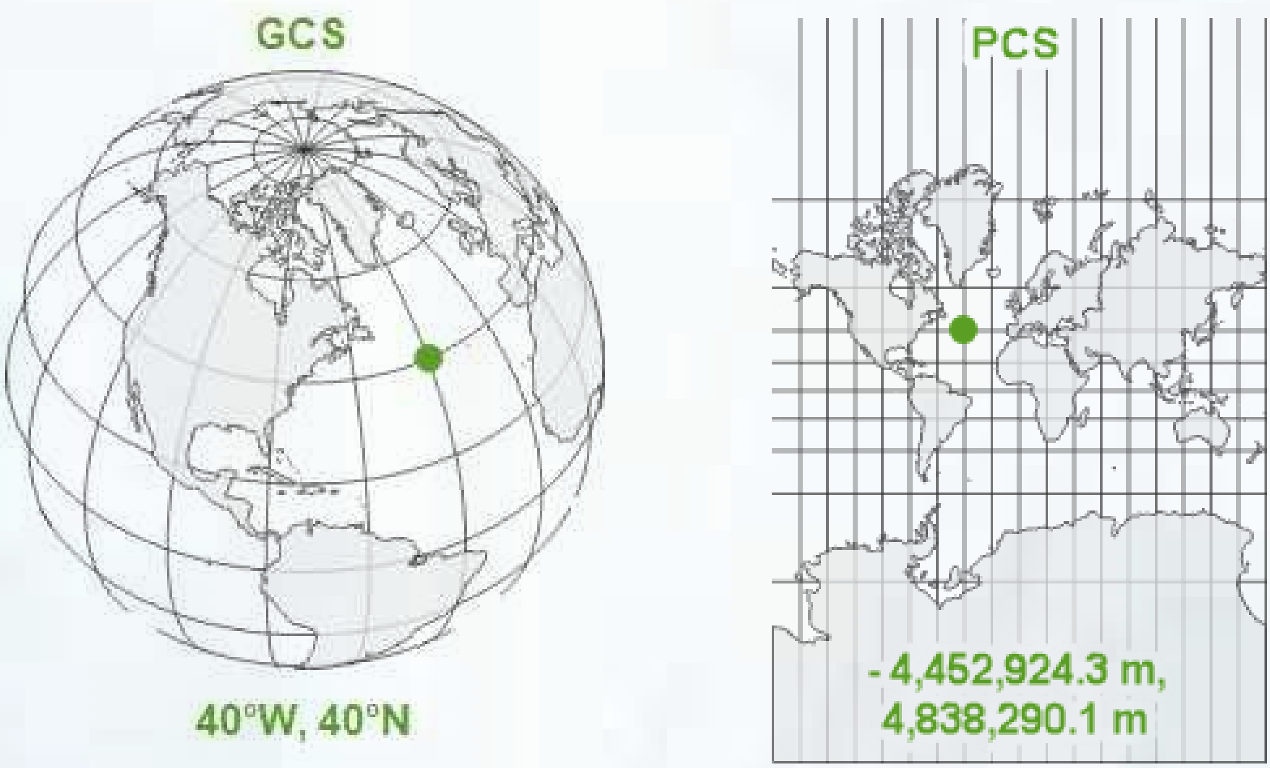


Figure 3.7 - A geographic coordinate system (left) measured in angular units is compared to a projected coordinate system (right) measured in linear units (meters) for the same location in the Atlantic Ocean.

4. THEMATIC LAYERS

Introduction

Thematic layers are digital map layers that represent specific themes or features of the Earth's surface. They are created by overlaying different datasets, which helps in analyzing spatial relationships and patterns. These layers play a crucial role in spatial planning, resource management, and decision-making by providing crucial geospatial information. In the context of MGNREGA (Mahatma Gandhi National Rural Employment Guarantee Act), thematic layers play a significant role in planning, monitoring, and evaluating rural development projects. They help in selecting project sites, assessing natural resources, and tracking asset creation under MGNREGA. MGNREGA utilizes GIS-based tools like Bhuvan to integrate thematic layers for effective decision-making.

Types of thematic layers

Different thematic layers are used for site selection, planning, and monitoring MGNREGA projects. These layers are broadly categorized into administrative layers, natural resource layers and socio-economic layers.

Administrative layers

Administrative layers in MGNREGA ensure efficient planning, fund distribution, and project monitoring at different governance levels, from districts to Gram Panchayats (GPs). This structured system ensures that resources reach the right beneficiaries, and local bodies like GPs can select projects based on community needs, promoting rural development.

These layers also improve monitoring and transparency through GIS-based platforms like GeoMGNREGA and regular social audits. They help in better coordination among government departments, ensuring smooth execution of projects like rural roads and water

Natural resource layers

These layers provide critical geospatial data on land, water, and vegetation to help plan soil conservation, water harvesting, and afforestation projects under MGNREGA.

Land Use and Land Cover (LULC)

The Land Use Land Cover (LULC) layer is a thematic GIS layer that classifies land based on its natural and human-made features (Figure 4.1). It helps in understanding how land is utilized (e.g., agriculture, forests, water bodies) and the types of surface cover (e.g., barren land, built-up areas). LULC layers in MGNREGA is categorized into various classes based on land use and land cover types. These categories help in understanding land suitability for different projects.

TYPES OF LAND USE AND LAND COVER

Built-up areas (urban & rural)

Built-up areas refer to land occupied by human settlements, infrastructure, and industrial or commercial structures. These include villages, towns, roads, and other constructed spaces. In the context of MGNREGA, built-up area mapping is crucial for planning rural roads, drainage systems, and public utility projects. It also helps avoid placing large-scale MGNREGA activities in areas already urbanized, ensuring better land utilization.

Agricultural land

Agricultural land includes all areas used for crop cultivation and farming activities. It is divided into cropland (actively cultivated land) and fallow land (temporarily uncultivated fields). Identifying agricultural land through LULC layers allows MGNREGA to support irrigation projects, farm ponds, soil conservation, and land leveling activities, which improve productivity and ensure sustainable farming practices.

Forest cover

Forest land consists of areas with dense, open, and degraded forests, which play a vital role in ecological balance. Dense forests have thick tree cover, open forests have scattered trees, and degraded forests have sparse vegetation due to deforestation or land degradation. MGNREGA uses these classifications to promote afforestation, reforestation, and eco-restoration projects, helping to improve biodiversity, carbon sequestration, and land productivity.

Wastelands (Barren & Uncultivable land)

Wastelands are areas that are infertile, degraded, or unsuitable for agriculture due to rocky terrain, erosion, or desertification. These lands are often targeted under MGNREGA for land reclamation, afforestation, and soil moisture conservation projects. By converting barren land into productive areas, employment is generated while improving environmental sustainability.

Water bodies (Rivers, Lakes, Ponds)

Water bodies include rivers, lakes, reservoirs, and small ponds, which are crucial for rural livelihoods. In MGNREGA, projects such as desilting ponds, constructing check dams, and developing rainwater harvesting structures are planned using LULC water body layers. These interventions enhance water conservation, irrigation, and groundwater recharge, making rural communities more resilient to droughts.

Wetlands

Wetlands are marshy lands, swamps, or areas with seasonal/permanent water accumulation. These ecosystems support biodiversity and act as natural flood regulators. MGNREGA uses wetland maps to implement restoration projects, flood control measures, and eco-friendly interventions, ensuring sustainable land management and ecosystem conservation.

Grazing land/pastures

Grazing lands or pastures are open lands used for livestock grazing. These areas are vital for rural community's dependent on animal husbandry. MGNREGA supports pastureland development, fodder plantations, and soil conservation projects to improve livestock productivity and prevent overgrazing-induced land degradation.

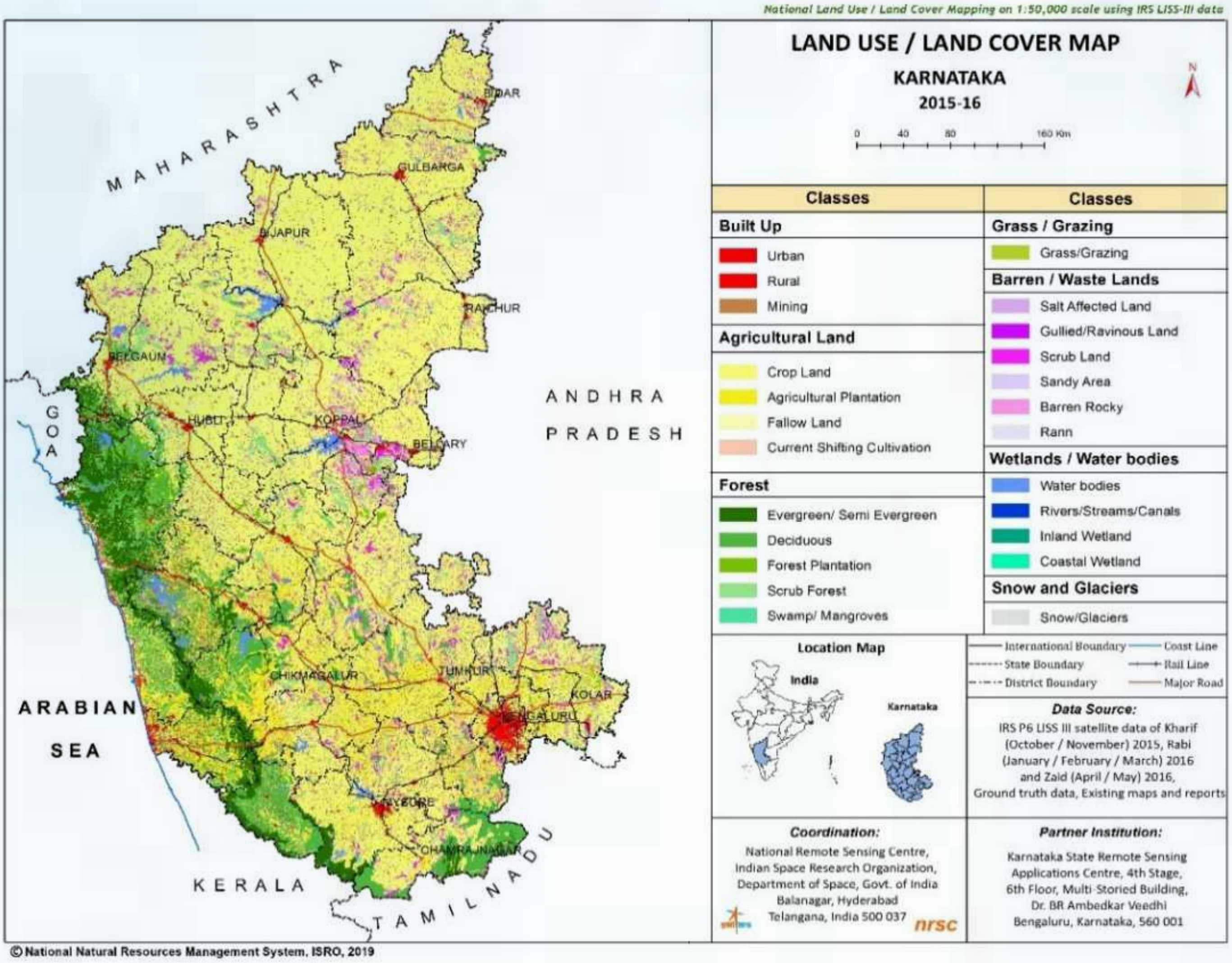


Figure 4.1

Digital Elevation Model (DEM)

A Digital Elevation Model (DEM) is a digital representation of the Earth's surface, providing elevation data for analyzing terrain features such as slopes, drainage patterns, and watersheds. It is widely used in hydrology, land management, and infrastructure planning.

In MGNREGA, DEM plays a vital role in watershed management by identifying suitable sites for check dams, ponds, and percolation tanks, improving groundwater recharge and soil conservation. It also aids in rural infrastructure planning, helping select sites for roads, embankments, and afforestation while supporting contour bunding and land levelling to enhance soil fertility. For disaster mitigation, DEM-based hydrological modelling assists in flood risk assessment and rainwater harvesting in drought-prone areas. Additionally, it supports project monitoring, enabling authorities to track completed works, assess their impact on groundwater recharge, and ensure transparency. Integrating DEM into MGNREGA enhances resource management and sustainable rural development.

UNDERSTANDING DEM VALUES AND THEIR INTERPRETATION

A Digital Elevation Model (DEM) represents the Earth's surface topography in a digital format, where each pixel's value indicates elevation in meters above mean sea level. For instance, a pixel value of 250 signifies that the terrain at that location is 250 meters above sea level. Higher values correspond to elevated terrains like hills or mountains, while lower or negative values represent plains or depressions. A zero (0) value represents areas at mean sea level (MSL). This typically includes: coastal regions, lakes, waterbodies and river deltas. If a DEM shows negative values, it means those locations are below sea level, which is rare in India but common in places like the Dead Sea region globally.

Example :
Consider the DEM map of India below(Figure 4.2), which showcases elevation variations across the country:

In this map:

- Green areas represent low-lying regions, such as the Indo-Gangetic plains.
- Yellow to brown areas indicate higher elevations, like the Deccan Plateau.
- Red regions correspond to the highest elevations, notably the Himalayan mountain range.

By interpreting the colour gradients and corresponding elevation values, one can understand the terrain's topography, which is essential for applications in hydrology, land management, and infrastructure planning.

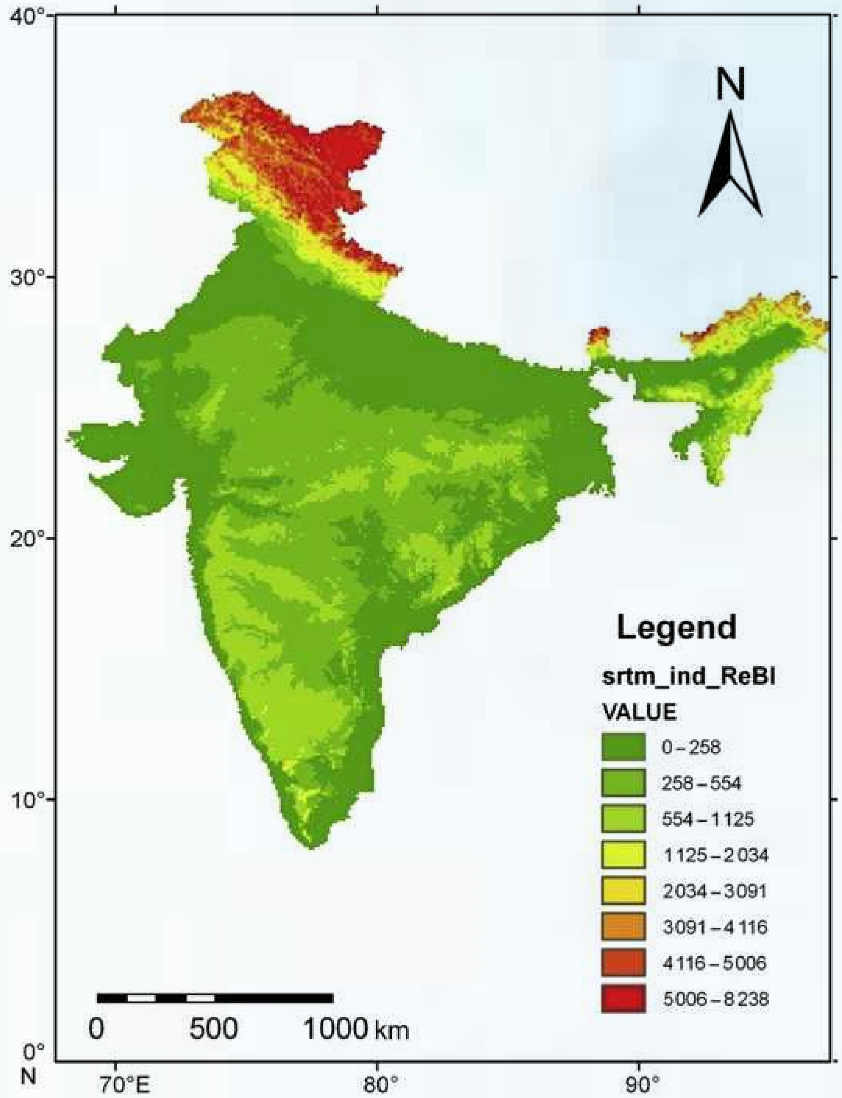


Figure 4.2

SLOPE

A slope map represents the steepness or gradient of terrain using data derived from a Digital Elevation Model (DEM) (Figure 4.3). It is an essential tool in MGNREGA for planning and implementing rural development projects, particularly in water conservation, infrastructure, and land development by identifying suitable sites for check dams, roads, and afforestation while preventing soil erosion. They also aid in flood control, drought management, and project monitoring, ensuring effective drainage, water harvesting, and sustainable rural development.

Different slope categories require different interventions to enhance productivity, prevent soil erosion, and manage water resources effectively. Table 4.1 depicts the different slope categories and their significance in MGNREGA

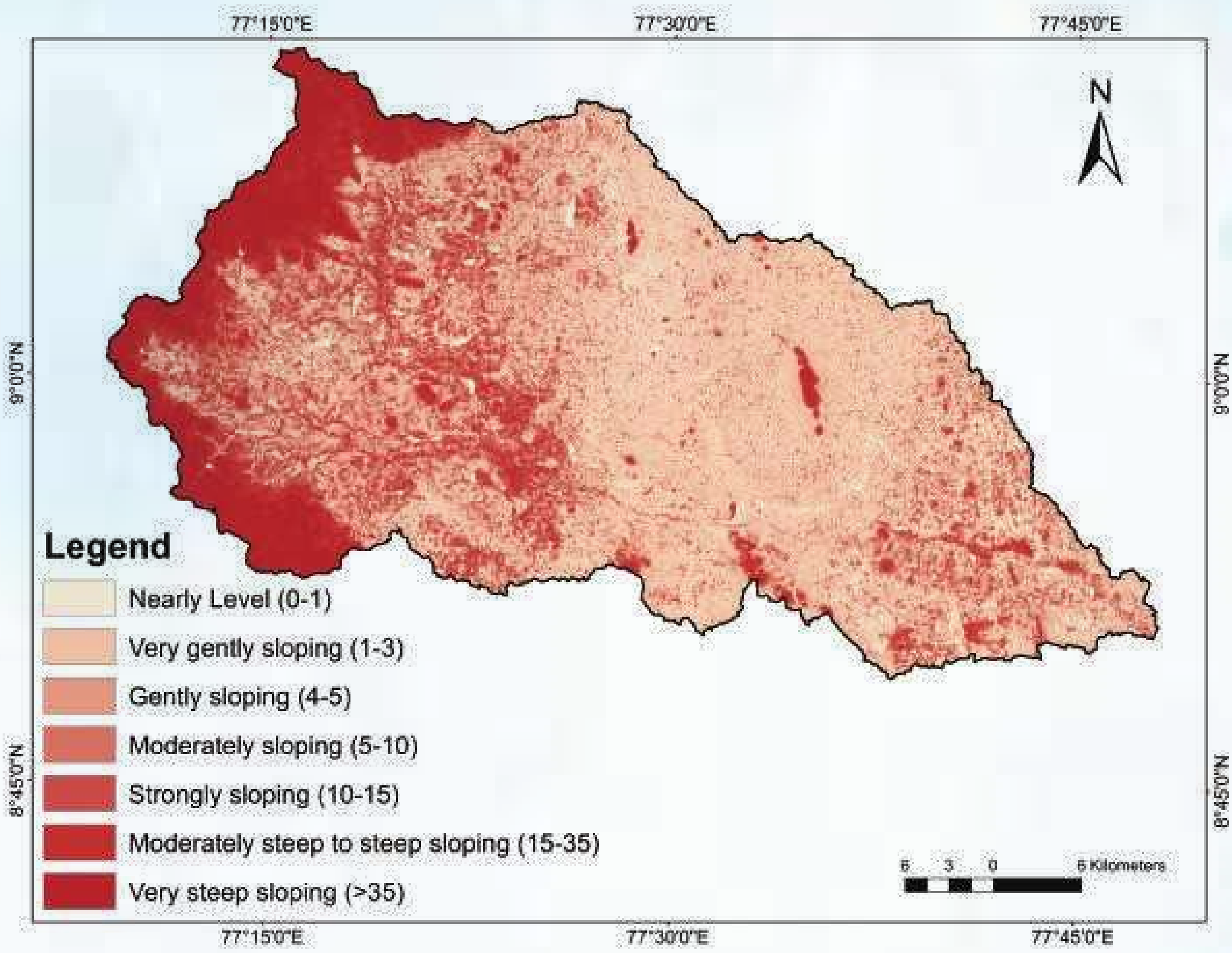


Figure 4.3

Table 4.1: Slope Categories and Their Significance in MGNREGA Interventions		
Slope Category	**Slope Percentage (%)**	**Significance in MGNREGA**
Nearly Level	0-1%	Suitable for agriculture, irrigation canal construction, and farm ponds. Soil moisture conservation techniques like field bunding are effective.
Very Gently Sloping	1-3%	Ideal for minor irrigation projects, graded bunding, and land shaping to reduce surface runoff and improve water retention.
Gently Sloping	4-5%	Requires contour bunding, agroforestry, and water harvesting structures to minimize soil erosion and enhance water infiltration.
Moderately Sloping	5-10%	Suitable for contour trenches, stone bunding, and terracing to reduce soil loss and manage rainwater effectively.

Table 4.1: Slope Categories and Their Significance in MGNREGA Interventions		
Slope Category	**Slope Percentage (%)**	**Significance in MGNREGA**
Strongly Sloping	10-15%	Needs continuous contour trenches (CCTs), vegetative barriers, and afforestation to prevent land degradation and soil erosion.
Moderately Steep to Steep Sloping	15-35%	Requires gully plugging, check dams, staggered trenches, and stone pitching to control runoff and improve groundwater recharge.
Very Steep Sloping	>35%	Not suitable for cultivation. Recommended interventions include forest conservation, afforestation, and landslide prevention measures.

Groundwater prospect

A Groundwater Prospect Map helps identify groundwater availability and potential yield, aiding water conservation under MGNREGA. It guides site selection for check dams, percolation tanks, wells, and borewells, ensuring groundwater recharge in water-scarce areas. These maps support irrigation planning and watershed management, boosting agricultural productivity in drought-prone regions. Additionally, they promote sustainable rural development by preventing groundwater depletion and ensuring equitable water distribution for drinking, farming, and livelihoods, fostering long-term water security and economic growth. It categorizes areas based on water yield capacity (measured in Liters Per Minute - LPM) and the required well depth (measured in meters) for groundwater extraction.

Example : India's groundwater prospects and MGNREGA implementation

India has diverse groundwater availability, ranging from high-yield alluvial plains (Ganga-Yamuna basin) to low-yield rocky terrains (Deccan Plateau). In Punjab and

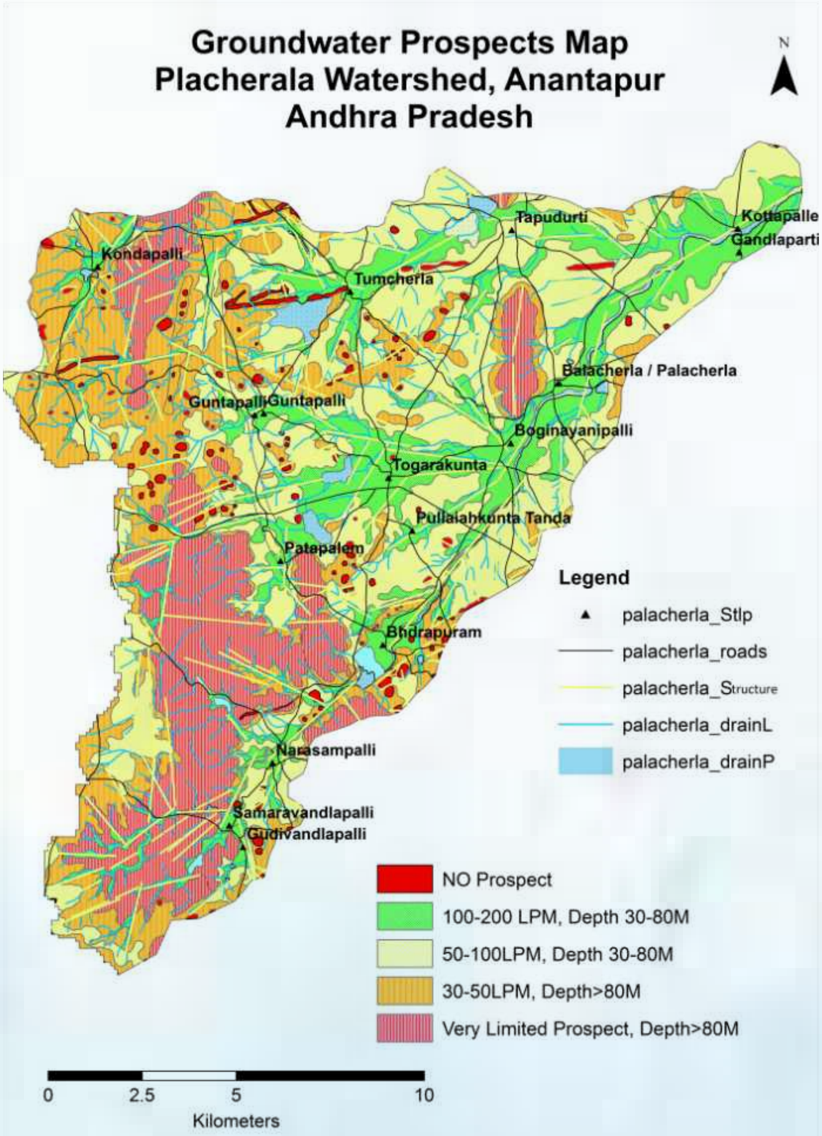


Figure 4.4

Uttar Pradesh, where groundwater availability is high (>800 LPM), MGNREGA projects focus on efficient irrigation methods like drip irrigation to prevent excessive water use. In contrast, states like Rajasthan and Madhya Pradesh, which have moderate to low groundwater availability (200-400 LPM), prioritize rainwater harvesting and check dam construction under MGNREGA to enhance recharge. The Groundwater Prospects Map of Placherala Watershed, Anantapur, Andhra Pradesh provides insights into groundwater availability and its potential yield across different areas. The map categorizes regions based on their groundwater prospect and depth of extraction (Figure 4.4), which is essential for water resource planning, irrigation, and MGNREGA-related water conservation activities.

Key Indicators on the Map:

LPM (Liters Per Minute) indicates the water discharge capacity of a well or borewell. Higher LPM values suggest better groundwater availability. Well Depth (Meters) determines how deep a well needs to be drilled to access groundwater.

- ✓ No Prospect (Red) – Areas where groundwater availability is extremely poor, making extraction unfeasible.
- ✓ 100-200 LPM (Green, Depth 30-80m) – Regions with moderate groundwater availability, suitable for borewells and irrigation.
- ✓ 50-100 LPM (Yellow, Depth 30-80m) – Areas with limited groundwater availability, requiring efficient water management.
- ✓ 30-50 LPM (Orange, Depth >80m) – Low-yield zones, where deep drilling (>80m) is needed.
- ✓ Very Limited Prospect (Pink, Depth >80m) – Areas with poor groundwater potential, making sustainable extraction difficult.

Watershed

The Watershed Layer in MGNREGA planning plays a crucial role in water conservation, soil protection, and sustainable irrigation by identifying micro-watersheds, sub-watersheds, and river basins for targeted interventions (Figure 4.5). It helps in selecting suitable sites for check dams, percolation tanks, and farm ponds, ensuring optimal groundwater recharge and drought mitigation. Watershed-based planning supports soil conservation measures like contour bunding and afforestation, reducing erosion and improving

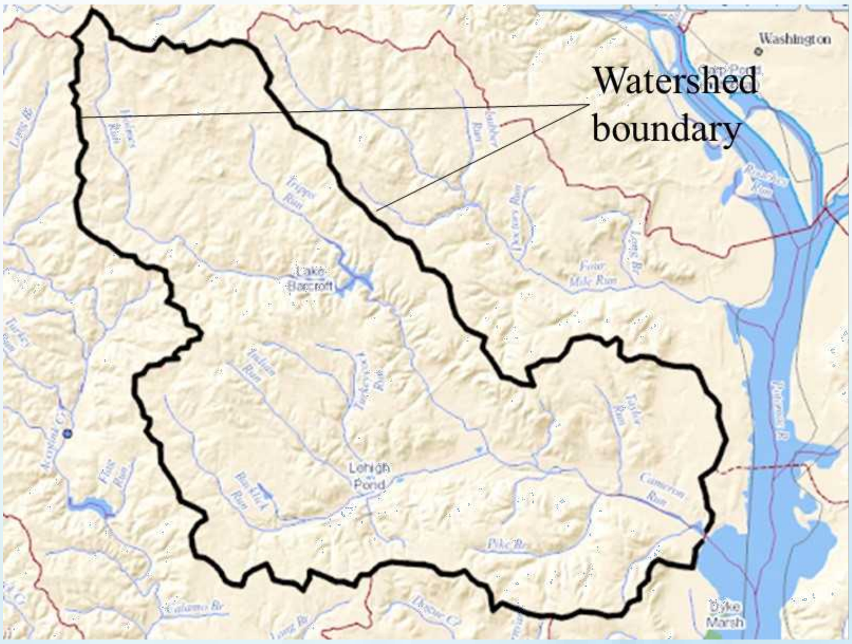


Figure 4.5

soil moisture retention. By analyzing water-stressed areas, the watershed approach enables rainwater harvesting and sustainable irrigation systems such as drip and sprinkler irrigation, improving agricultural productivity and rural water security. Integrating the Watershed Layer in MGNREGA ensures long-term water sustainability, climate resilience, and livelihood enhancement for rural communities.

Examples of Watershed-Based MGNREGA Implementation in India

- Hivre Bazar, Maharashtra – This village transformed from a drought-prone area to a water-sufficient region through watershed management under MGNREGA. By constructing check dams, percolation tanks, and contour bunds, groundwater levels improved, leading to higher agricultural productivity and reverse migration of farmers.
- Purulia, West Bengal – One of India's driest districts, Purulia adopted watershed-based planning under MGNREGA to implement rainwater harvesting structures and check dams. This led to better soil moisture retention, higher agricultural output, and enhanced water security for local communities.

Drainage

Drainage features refer to the natural and man-made pathways through which water flows, helping in irrigation, flood control, and water management. Based on the image legend, the following are the key drainage features (Figure 4.6):

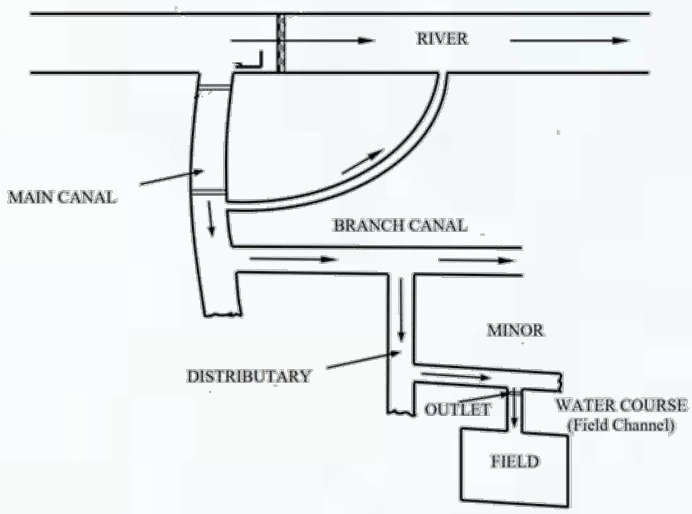


Figure 4.6

River (Natural primary water source)

A river is the primary natural water source in a drainage system. It originates from mountains, glaciers, or rainfall and serves as a crucial source for irrigation, drinking water, and hydroelectric projects. Rivers can be perennial, flowing throughout the year, or seasonal, carrying water only during certain periods. Many irrigation systems and reservoirs are built around rivers to harness their water supply for agricultural and domestic use.

Main canal (Artificial primary water channel)

The main canal is the largest artificial water channel that directly receives water from a river, dam, or reservoir. It serves as the backbone of irrigation systems, transporting large volumes of water to different regions. Main canals are often lined with concrete to prevent seepage and ensure efficient water flow. These canals act as the primary distribution channels, supplying water to branch canals and distributary networks.

Branch canal (Secondary water distribution)

A branch canal is a secondary channel that diverts water from the main canal to specific areas. These canals help distribute water over a wider region, ensuring that different agricultural zones receive adequate irrigation. They are smaller than main canals but still carry a significant volume of water. By branching off from the main canal, they improve water accessibility to multiple locations.

Distributary canal (Final water distribution for irrigation)

The distributary canal is the final artificial water channel in the irrigation network. It takes water from branch canals or directly from the main canal and delivers it to agricultural fields, small reservoirs, or irrigation ponds. These canals ensure that farmland receives a controlled supply of water for cultivation. They are usually the smallest canals in the system and provide localized water distribution.

Stream (Natural small water flow)

A stream is a small natural watercourse that carries water over short distances. Streams often originate from rainfall, springs, or melting snow and may flow seasonally or throughout the year. They can feed into larger rivers, lakes, or irrigation systems, playing a vital role in groundwater recharge and drainage. Streams are important for maintaining local ecosystems and often act as drainage pathways for excess rainwater.

Drain (Water removal system)

The drain is designed to remove excess water from roads, fields, and settlements. Drains can be natural or man-made and are essential for preventing waterlogging, soil erosion, and floods. In agricultural areas, drainage systems help maintain soil health by ensuring that excess water does not accumulate and damage crops. Proper drainage systems improve water management and protect infrastructure from water-related damage.

Together, these drainage features create a structured water management system that ensures efficient distribution, utilization, and removal of water.

Erosion

Erosion is the action of surface processes (such as water flow or wind) that removes soil, rock, or dissolved material from one location on the Earth's crust and then transports it to another location where it is deposited. Erosion mapping plays a crucial role in planning and implementing MGNREGA projects, as it helps identify vulnerable areas where soil degradation is a concern. By analyzing erosion patterns, MGNREGA can implement sustainable land development activities such as watershed management, afforestation, check dams, and soil conservation measures.

TYPES OF EROSION

SHEET EROSION

Sheet erosion is a form of soil erosion where a thin layer of topsoil is uniformly removed across a large area by rainfall or surface runoff (Figure 4.7). This process often goes unnoticed until significant soil loss has occurred, leading to reduced soil fertility and agricultural productivity.

Figure 4.7

Preventive Measures

To mitigate sheet erosion, several soil

conservation practices can be implemented:

- ✓ Contour Farming: Planting crops along the natural contours of the land to reduce runoff velocity.
- ✓ Cover Crops: Growing specific plants during off-season periods to protect the soil from erosion agents.
- ✓ Mulching: Applying a layer of organic or inorganic material on the soil surface to shield it from rain impact and retain moisture.

RILL EROSION

Rill erosion occurs when running water creates small, yet visible, channels on the soil surface, typically after heavy rainfall (Figure 4.8). These rills are a few centimetres deep and can develop into larger gullies if left unchecked. It is a transitional stage between sheet erosion and more severe gully erosion, often found on sloped agricultural land and construction sites where vegetation cover is minimal.

Figure 4.8

Preventive Measures

To control and prevent rill erosion, several soil conservation practices can be implemented:

- ✓ Contour Ploughing: Ploughing along the natural contours of the land helps slow down water flow and reduces soil displacement.
- ✓ Grassed Waterways: Establishing grass-covered channels helps direct excess runoff while stabilizing the soil.
- ✓ Terracing: Constructing terraces on slopes reduces water velocity and prevents the formation of rills.
- ✓ Crop Rotation and Cover Crops: Maintaining continuous vegetation cover protects the soil from direct water impact and strengthens its structure.

GULLY EROSION

Gully erosion is an advanced stage of rill erosion where surface runoff creates deep channels or gullies in the soil (Figure 4.9). It occurs when rills (small channels formed by running water) expand due to continuous water flow, removing large amounts of soil. This type of erosion is commonly seen in regions with loose, unprotected soil, steep slopes, and heavy rainfall.

Figure 4.9

Preventive Measures

- ✓ **Vegetative Barriers :** Planting grasses, shrubs, or trees on slopes to stabilize the soil.
- ✓ **Terracing :** Creating step-like structures on slopes to slow down water flow and prevent gully formation.
- ✓ **Check Dams :** Constructing small barriers in gullies to reduce water speed and promote sediment deposition.
- ✓ **Contour Ploughing :** Ploughing along the natural contours of the land to reduce runoff and prevent soil loss.
- ✓ **Gully Plugging :** Filling small gullies with stones or soil to halt their expansion.

Implementing these conservation techniques can help mitigate gully erosion, protecting land resources and ensuring sustainable land use.

Ravines

A ravine is a deep, narrow, and steep-sided landform created by continuous water erosion, typically formed by the prolonged action of surface runoff and gully expansion (Figure 4.10). Ravines are larger and deeper than gullies but smaller than valleys. They often develop in areas with loose, easily erodible soil and heavy rainfall, leading to rapid land degradation.

Figure 4.10

Preventive Measures

- ✓ Afforestation & Vegetation Growth: Planting trees and grasses stabilizes the soil and reduces erosion.
- ✓ Check Dams & Gully Plugging: Small structures in ravines slow down water flow and encourage sediment deposition.
- ✓ Terracing & Contour Ploughing: Agricultural practices that reduce surface runoff and prevent further deepening of ravines.
- ✓ Riverbank Protection Measures: Stone pitching, retaining walls, and bioengineering techniques can help stabilize ravine-prone riverbanks.

Geomorphology

Geomorphology is the study of landforms, their processes, history, and how they evolve over time due to natural and human influences. It examines the forces shaping Earth's surface, such as tectonic activity, erosion, sediment deposition, and climate effects. Understanding geomorphology helps in resource management, environmental conservation, and land-use planning. Geomorphology map helps in understanding landforms and their suitability for various activities like water conservation, afforestation, and soil erosion control.

ORIGINS OF LANDFORMS

Structural Origin

Structural origin refers to landforms shaped by natural forces like tectonic movements. Examples include hills, valleys, and plateaus. MGNREGA utilizes structural landforms for rural development by addressing soil erosion through check dams and afforestation, improving water storage with ponds and bunds, and supporting agriculture through terracing and soil conservation. It also enhances connectivity with rural roads and embankments while providing employment through land and water conservation projects, ensuring sustainable development.

Denudational Origin

Denudational origin refers to landforms shaped by weathering, erosion, and natural forces over time. This process creates hills, slopes, and eroded lands that often suffer from soil loss and water runoff, making them less suitable for farming and settlement.

MGNREGA helps restore denudational landscapes by preventing soil erosion through tree planting and check dams, improving water conservation with ponds and tanks, and reclaiming land for farming through terracing. It also builds roads and embankments to prevent landslides and improve access, while providing jobs and promoting sustainability.

Fluvial origin

The fluvial origin of soil and landforms refers to their formation through the action of rivers and streams. This process includes erosion, transportation, and deposition of sediments, shaping landscapes such as floodplains, river terraces, and alluvial deposits. MGNREGA initiatives in such areas focus on flood management through embankments and plantations, soil and water conservation via check dams and desilting, and agricultural enhancement through land leveling and irrigation maintenance. Watershed development, including afforestation and rainwater harvesting, further supports sustainable resource management. These efforts improve land productivity, water conservation, and rural employment.

Coastal origin

Coastal-origin landscapes, shaped by marine processes like waves, tides, and sediment deposition, include beaches, sand dunes, estuaries, lagoons, and mangroves. In such regions, MGNREGA plays a crucial role in enhancing coastal resilience, conserving natural resources, and generating employment through various interventions.

Under MGNREGA, shoreline protection measures such as plantation, dune stabilization, and the construction of seawalls or embankments help reduce coastal erosion and mitigate the impact of cyclones and rising sea levels. Water conservation efforts, including the rejuvenation of coastal wetlands and desilting of estuaries, support fisheries and biodiversity. Land development projects, such as bunding, and soil improvement, enhance agricultural productivity in coastal areas. Additionally, afforestation and watershed management in coastal zones improve groundwater recharge and ecosystem stability. By integrating MGNREGA with coastal-origin landscapes, rural communities benefit from disaster resilience, improved livelihoods, and sustainable resource management, ensuring long-term environmental and economic stability.

Aeolian origin

Aeolian origin refers to landforms shaped by wind-driven processes, primarily found in arid and semi-arid regions. These include sand dunes, loess deposits, and desert pavements, formed by wind erosion, transportation, and deposition of fine particles. Such landscapes are often prone to desertification, soil erosion, and water scarcity, making sustainable land management essential. Under MGNREGA, several initiatives help combat these challenges while generating employment. Sand dune stabilization through afforestation, grass plantation, and fencing helps prevent desert expansion. Soil and water conservation measures, such as the construction of check dams, contour bunding, and water harvesting structures, improve land productivity and water availability. Additionally, windbreaks and shelterbelts, created by planting trees in rows, reduce wind erosion and protect farmlands.

By integrating MGNREGA with aeolian-origin landscapes, rural communities benefit from land restoration, improved water security, and sustainable livelihoods, ensuring long-term environmental and economic stability.

Glacial origin

Glacial-origin landscapes, shaped by glaciers, include moraines, glacial lakes, and U-shaped valleys, often facing water scarcity, erosion, and flash floods. Under MGNREGA, interventions like embankments and early warning systems help reduce glacial lake outburst flood (GLOF) risks. Water conservation through artificial glaciers and check dams improves availability, while afforestation and bunding stabilize slopes. Pasture development and cold-resistant crops support local livelihoods. These efforts enhance disaster resilience, water security, and sustainable development in high-altitude regions.

Karst origin

A karst landscape forms when water slowly dissolves soft rocks like limestone, creating caves, sinkholes, and underground rivers. Because water drains quickly through cracks and holes in the ground, these areas often suffer from water shortages, unstable soil, and difficulty storing groundwater. MGNREGA helps karst regions, where water drains quickly, causing water shortages and soil erosion. To address this, it builds check dams, ponds, and recharge wells to store water and refill groundwater. It also plants trees and grasses to prevent soil erosion and strengthen the land. Additionally, MGNREGA supports eco-tourism, better farming, and pasture development, helping people earn a livelihood while protecting the environment. These efforts improve water availability, land stability, and job opportunities, ensuring a sustainable future for rural communities.

Volcanic origin

Volcanic-origin landscapes are formed by lava flows, ash deposits, and volcanic eruptions, creating landforms like plateaus, mountains, and fertile plains. These regions often have fertile soil, but they may also face challenges such as soil erosion, water scarcity, and land instability.

MGNREGA helps in volcanic regions by building check dams, ponds, and recharge wells to store water and improve groundwater availability. It also supports afforestation and soil conservation to prevent erosion and maintain soil fertility. Additionally, MGNREGA promotes agriculture, pasture development, and eco-tourism, providing livelihoods while ensuring environmental sustainability.

These efforts help protect land, improve water resources, and create jobs, making volcanic-origin areas more resilient and productive for rural communities.

Impact origin

Impact-origin areas are formed when large space rocks (meteorites) hit the Earth, creating big craters and rocky land. These places often have poor soil and problems storing water, making farming and daily life difficult.

MGNREGA helps by building ponds, check dams, and wells to store water and improve groundwater levels. It also plants trees and grasses to stop soil from washing away and make the land stronger. In addition, MGNREGA supports farming, eco-tourism, and livestock grazing, giving people jobs while taking care of nature. These efforts make impact-origin areas better for living, farming, and working, helping rural communities grow.

Lacustrine origin

Lacustrine-origin areas are formed by lakes that have dried up or changed over time, leaving behind flat land with fertile soil. These places are good for farming but may face water shortages, soil erosion, and drainage issues.

MGNREGA helps by building ponds, check dams, and recharge wells to store water and improve groundwater levels. It also plants trees and grasses to protect soil from erosion and keep the land strong. Additionally, MGNREGA supports better farming, fishery projects, and eco-tourism, creating jobs while protecting nature. These efforts make lacustrine areas more productive, water-secure, and sustainable for rural communities.

Anthropogenic origin

Anthropogenic-origin areas are landscapes changed by human activities, such as mining, deforestation, construction, and agriculture. These activities often lead to soil erosion, water pollution, and land degradation, making it difficult for people to use the land properly.

MGNREGA helps by building ponds, check dams, and wells to store water and improve groundwater levels. It also plants trees and grasses to prevent soil erosion and restore damaged land. Additionally, MGNREGA supports land reclamation, eco-tourism, and sustainable farming, creating jobs while protecting the environment. These efforts help make human-affected areas healthier, greener, and more useful for rural communities.

Waterbodies

Waterbodies, such as rivers, lakes, ponds, and wetlands, are essential for drinking water, farming, fishing, and groundwater recharge. However, they often face issues like drying up, pollution, and sediment build up, reducing their ability to store and provide water.

MGNREGA helps by desilting and deepening ponds, lakes, and canals to increase water storage. It also builds check dams, embankments, and recharge wells to improve water availability. Additionally, planting trees around waterbodies prevents soil erosion and protects water quality. These efforts help restore water sources, improve irrigation, and support local livelihoods, ensuring sustainable water management for rural communities.

Lineament

A lineament map represents linear features on the Earth's surface, which can be geological (faults, fractures, shear zones) or geomorphic (ridges, drainage patterns, scarps) (Figure 4.11). These features are often identified using remote sensing and GIS techniques. Lineament mapping supports MGNREGA by aiding water conservation, soil protection, and infrastructure planning. It helps identify groundwater zones for wells, guides the placement of check dams and watershed projects, and assists in erosion control through contour bunding and terracing. Structural lineaments ensure safe locations for roads and embankments, enhancing resource management, sustainability, and rural development.

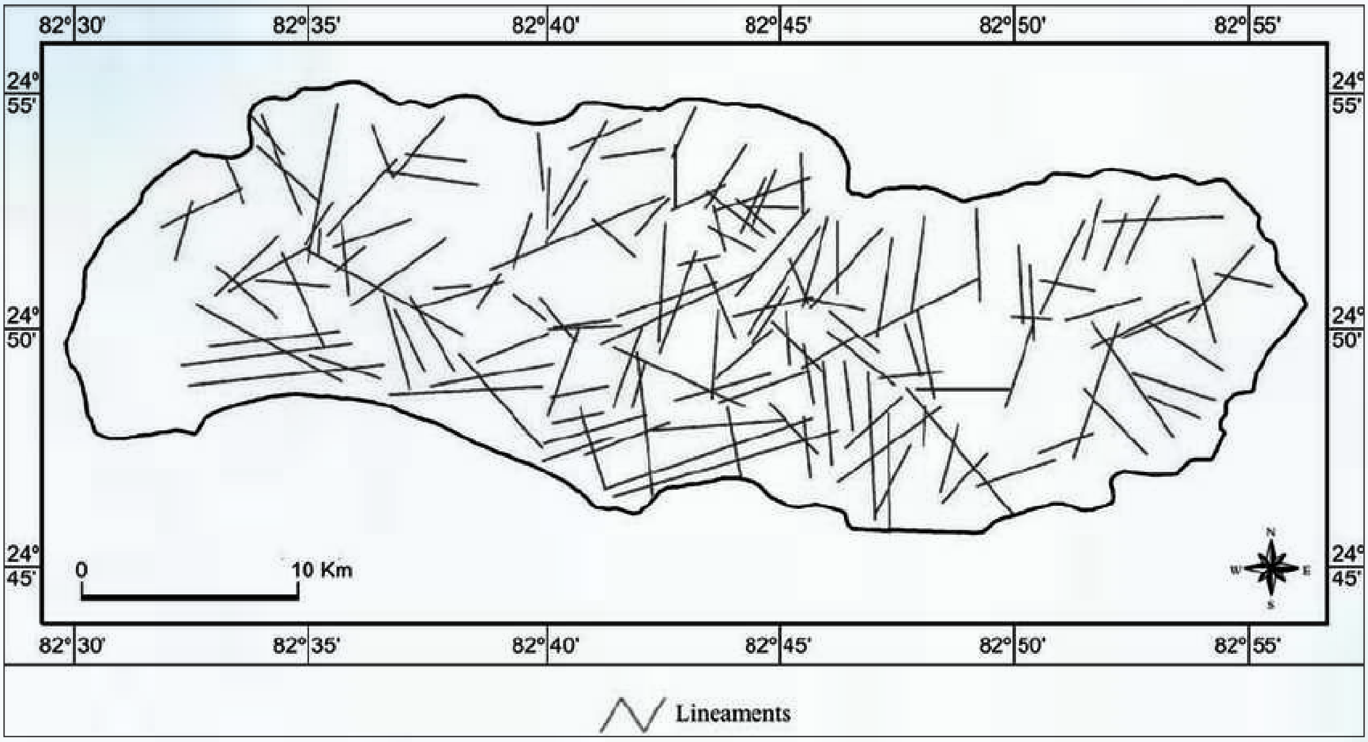


Figure 4.11

Wasteland

Wasteland is the unproductive, underutilized, or environmentally damaged due to natural or human activities. These lands include gullied and ravenous land, scrub land, waterlogged areas, salt-affected areas, shifting cultivation zones, degraded forests, degraded pastures, sandy areas, mining waste, barren rocky regions, and glacier-covered areas (Figure 4.12).

TYPES OF WASTELAND

Gullied and Ravenous Land

These areas are affected by severe soil erosion, forming deep channels and ravines. Under MGNREGA, soil conservation methods like contour bunding, check dams, and reforestation can help restore these lands.

Scrub land

These lands have sparse vegetation and low fertility. MGNREGA initiatives can promote afforestation, agroforestry, and soil enrichment to make them productive.

Waterlogged area

Water stagnation reduces land usability. Drainage improvement, pond construction, and groundwater recharge projects under MGNREGA can help manage excess water effectively.

Salt affected area

Excess salt in soil makes agriculture difficult. Soil amendment techniques, organic farming, and plantation of salt-tolerant crops can be implemented through MGNREGA.

Shifting cultivation

This practice depletes soil fertility. Contour farming, agroforestry, and sustainable land management can be promoted under MGNREGA to stabilize these lands.

Degraded forest

These areas have lost vegetation cover. MGNREGA can support afforestation, assisted natural regeneration, and biodiversity restoration to improve ecosystem health.

Degraded pasture/Grazing land

Overgrazing leads to land degradation. MGNREGA projects can encourage grassland development, rotational grazing, and fodder crop cultivation to restore pasture quality.

Degraded land under plantation

These lands have lost productivity due to poor management. Soil conservation, agroforestry, and replantation programs under MGNREGA can improve their condition.

Sandy area

Loose sand makes farming difficult. Windbreaks, shelterbelts, and soil-binding vegetation can be planted to control erosion and improve fertility.

Mining/Industrial waste

Mining and industrial activities leave barren land. Land reclamation, topsoil restoration, and ecological restoration projects can make these lands usable again.

Barren rocky area

Hard, rocky land is unsuitable for farming. MGNREGA can support soil improvement, afforestation, and alternative land-use projects like solar farms or eco-tourism.

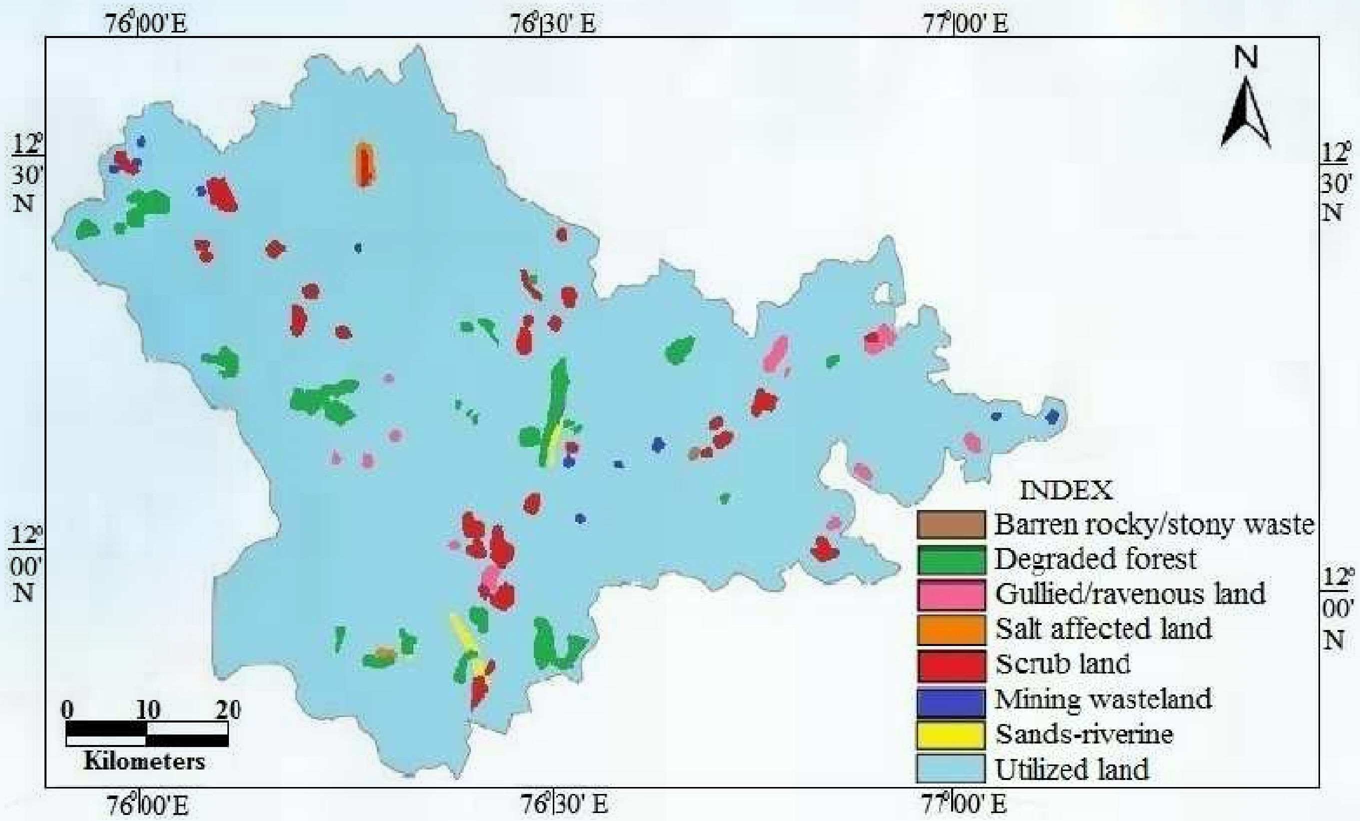
Snow covered/Glacier area

These areas are unsuitable for direct intervention, but MGNREGA can focus on watershed management and afforestation in lower regions to protect water resources.

Non wasteland area

These lands are already productive and may require only minor interventions like soil conservation and water resource management under MGNREGA.

By identifying and addressing different types of wastelands, MGNREGA can restore land, improve water resources, and enhance rural employment opportunities, making these lands productive and environmentally sustainable.



Satellite imagery is an advanced technology used for monitoring and planning developmental projects (Figure 4.13). In India, it plays a crucial role in the Mahatma Gandhi National Rural Employment Guarantee Act(MGNREGA) platform by enabling efficient planning, monitoring, and transparency in rural development projects. It helps identify suitable locations for initiatives like afforestation, soil conservation, and water body rejuvenation. By providing before-and-after comparisons, satellite images allow authorities to track project progress and assess their impact. The technology also ensures accountability by offering verifiable proof of completed work and reduce the duplication of work. Additionally, Yuktdhara integrates various satellite layers, such as land use maps, digital elevation models, soil moisture indices, and hydrological data, to support scientific decision-making for sustainable resource management.

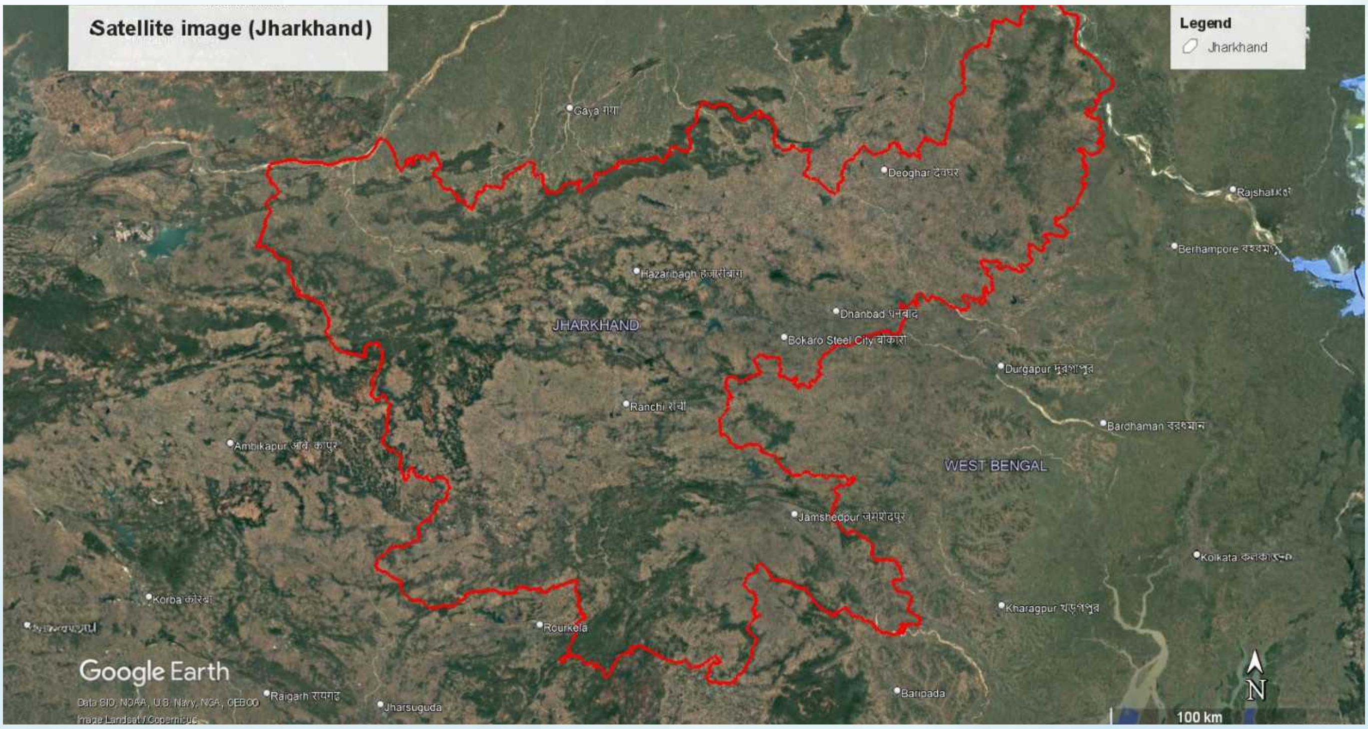


Figure 4.13

Socio-economic layer

These layers help in identifying vulnerable regions, ensuring employment distribution, and preventing duplication of MGNREGA assets.

Geotagged assets/MGNREGA Assets layer

The Geotagged Assets Layer in MGNREGA is a digital mapping system used to track and monitor assets created under the scheme. Each asset, such as roads, ponds, and water conservation structures, is assigned geographical coordinates (latitude and longitude) to ensure transparency and accountability. This geotagging process helps in preventing fraud, improving monitoring, and ensuring that resources are allocated effectively. Through platforms like GeoMGNREGA, both government officials and the public can verify the existence, progress, and quality of MGNREGA projects, making the system more transparent and efficient.

Geotagging is carried out in three phases—at the start, mid-stage, and completion of a project—using the Bhuvan-MGNREGA mobile app, developed by ISRO's National Remote Sensing Centre (NRSC). The collected data is then integrated into a GIS-based portal, allowing real-time tracking and analysis. This ensures that only genuine, functional infrastructure is recorded and funds are utilized appropriately. By enhancing project efficiency, supporting disaster management, and strengthening government accountability, geotagging plays a crucial role in ensuring the success and sustainability of MGNREGA projects.

Infrastructure layer

The Infrastructure Layers represent natural and man-made features that impact MGNREGA projects. These layers include road networks, which help in planning rural connectivity improvements, and settlements, which show the location of villages and towns where projects are implemented. Water bodies, such as rivers, lakes, and reservoirs, are also mapped to assist in planning water conservation and irrigation projects. Understanding these features helps in selecting the right locations for new infrastructure and avoiding conflicts with existing structures.

conservation. Additionally, they ensure timely wage payments by tracking work progress, reducing delays, and upholding MGNREGA's employment guarantee.

Sources for thematic layers

Here's a tabular representation of different GIS data layers and their sources for MGNREGA (Table 4.2):

Table 4.2: GIS Data Layers, Descriptions, and Source Websites

GIS Data Layer	Description	Source Websites
Administrative Layers	Districts, Taluks, Villages, Gram Panchayats (GPs)	Survey of India (SOI), Bhuvan (NRSC), OpenStreetMap (OSM)
Land Use and Land Cover (LULC)	Classification of land (agriculture, forest, urban, etc.)	Bhuvan LULC (ISRO), USGS Landsat, NRSC

Digital Elevation Model (DEM) & Slope	Terrain elevation & slope analysis	USGS Earth Explorer, Bhuvan CartoDEM (ISRO), NASA Earthdata
Groundwater Prospect & Watershed	Groundwater availability & watershed boundaries	CGWB, Bhuvan Groundwater (ISRO), India-WRIS
Drainage, Erosion & Geomorphology	River systems, erosion-prone areas & landforms	NBSS&LUP, Bhuvan Thematic Data, IIRS
Waterbodies & Lineament	Lakes, rivers, and fault lines	NWIC, Bhuvan Water Resources, HydroSHEDS
Wasteland & Satellite Imagery	Unutilized land and satellite imagery	Wasteland Atlas (NRSC), USGS Landsat, NRSC
Geotagged Assets (MGNREGA Assets Layer)	MGNREGA project locations with geotags	GeoMGNREGA, Bhuvan-MGNREGA
Infrastructure Layers	Roads, bridges, community buildings	Bharat Maps, PMGSY GIS, Open Government Data (OGD)

Conclusion

Thematic layers play a crucial role in spatial analysis, resource management, and decision-making, particularly in the context of MGNREGA. By integrating diverse datasets such as administrative boundaries, land use, water resources, and socio-economic conditions, GIS-based planning enhances the effectiveness of rural development initiatives. The use of GIS tools like Bhuvan enables precise site selection, real-time monitoring, and efficient asset management. Furthermore, thematic layers support sustainable natural resource utilization by aiding in soil conservation, water harvesting, afforestation, and erosion control. By leveraging GIS planning, MGNREGA ensures data-driven decision-making, transparency, and optimized resource allocation, contributing to long-term rural development and environmental sustainability.

5. GIS PLANNING

Introduction

Rural development in India has undergone significant changes over the years, with technology playing a crucial role in improving planning and implementation. One of the major milestones in this progress was the introduction of the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) in 2006. This initiative was designed to provide employment opportunities and enhance livelihood security for rural communities. In the early stages, MGNREGA planning relied on manual surveys, paper maps, and local knowledge. While these traditional methods provided useful insights and with the integration of Geographic Information System (GIS) technology, MGNREGA planning has been further enhanced. GIS enables data-driven decision-making and real-time project monitoring, improving the overall efficiency of planning and implementation

Between 2015 and 2020, the Government of India incorporated GIS tools into the MGNREGA framework with the support of the Bhuvan Portal, developed by the Indian Space Research Organisation (ISRO). In 2022, the introduction of the Yukthadara GIS Portal further strengthened the system, allowing for even more precise and effective planning.

GIS technology enables planners to use spatial data and thematic layers to accurately identify project locations. These layers provide essential environmental information, including land use, soil types, and water resources. By integrating this data, planners can design sustainable projects that align with natural resource availability, ensuring optimal utilization and long-term benefits.

Role of GIS in MGNREGA Planning

GIS-based planning is a data-driven approach that enhances the efficiency of resource management. It provides decision-makers with powerful tools to:

- Understand geographical patterns: GIS allows users to visualize land features and the distribution of natural resources, enabling better planning decisions.
- Identify optimal project locations: Using spatial data, planners can determine the best sites for MGNREGA projects such as ponds, check dams, roads, and soil conservation structures, ensuring they are placed where they will have the greatest impact.
- Monitor ongoing activities: GIS technology enables real-time tracking of project progress, ensuring transparency and efficiency in implementation.

By 2016, the integration of Remote Sensing (RS) and GIS revolutionized MGNREGA asset management. GIS provided a unified view of asset information across rural India, allowing planners to collect, store, and analyse the data efficiently. This advancement made it possible to map, visualize, and optimize key assets such as watershed locations, farm ponds, percolation tanks, and irrigation channels, leading to improved decision-making at the grassroots level.

In 2021, pilot projects introduced GIS-based planning at the Gram Panchayat level, where four GIS-based plans per block were developed. This initiative laid the foundation for data-driven, geospatially informed decision-making in rural development. GIS technology continues to play a vital role in MGNREGA, ensuring that projects are planned scientifically, implemented efficiently, and effectively monitored. This approach enhances transparency, maximizes resource utilization, and contributes to sustainable rural development.

Key components
Scientific planning

GIS plays a critical role in ensuring that MGNREGA projects are selected based on scientific data and real-world data. Instead of relying solely on traditional methods, GIS helps authorities to identify the most suitable locations for activities such as ponds, check dams, roads, and soil conservation structures.

By analysing multiple thematic layers like:

- **Topography:** The land's shape and features.
- **Water availability:** To ensure that projects are focused on areas with adequate or limited water resources.
- **Population density:** Ensuring that projects serve communities that need them the most.

By analysing these factors, GIS ensures that projects like ponds, roads, and check dams are strategically placed for maximum benefits.

Climate - resilient development

One of the challenges in rural development is climate change. GIS helps to design the climate-resilient projects by identifying the areas that are prone to drought, soil erosion, and floods. With this data, planners can:

- Implement water conservation measures.
- Establish afforestation programs.
- Apply soil conservation techniques in regions at risk.

For example, GIS can help authorities to plan the construction of check dams and percolation tanks in water-scarce areas, improving groundwater recharge and supporting rural communities to adapt to climate change.

Real-Time Transparency and Accountability

GIS enhances transparency and accountability in MGNREGA projects through real-time tracking and monitoring. Key technologies such as:

- Geotagging: Assigning geographic coordinates to project sites.
- Satellite-based tracking: Using satellite images to track project progress.
- Mobile GIS applications: Enabling field staff to capture real-time data on-site.

Assigning GPS coordinates to project sites allows easy verification and monitoring, ensuring systematic execution. Additionally, satellite imagery and remote sensing help officials oversee project progress efficiently, contributing to sustainable rural development.

Efficient Resource Utilization

GIS also plays a role in optimizing resource use. By mapping and analysing existing resources, GIS helps avoid redundant construction and promotes the improvement of existing infrastructure. For example:

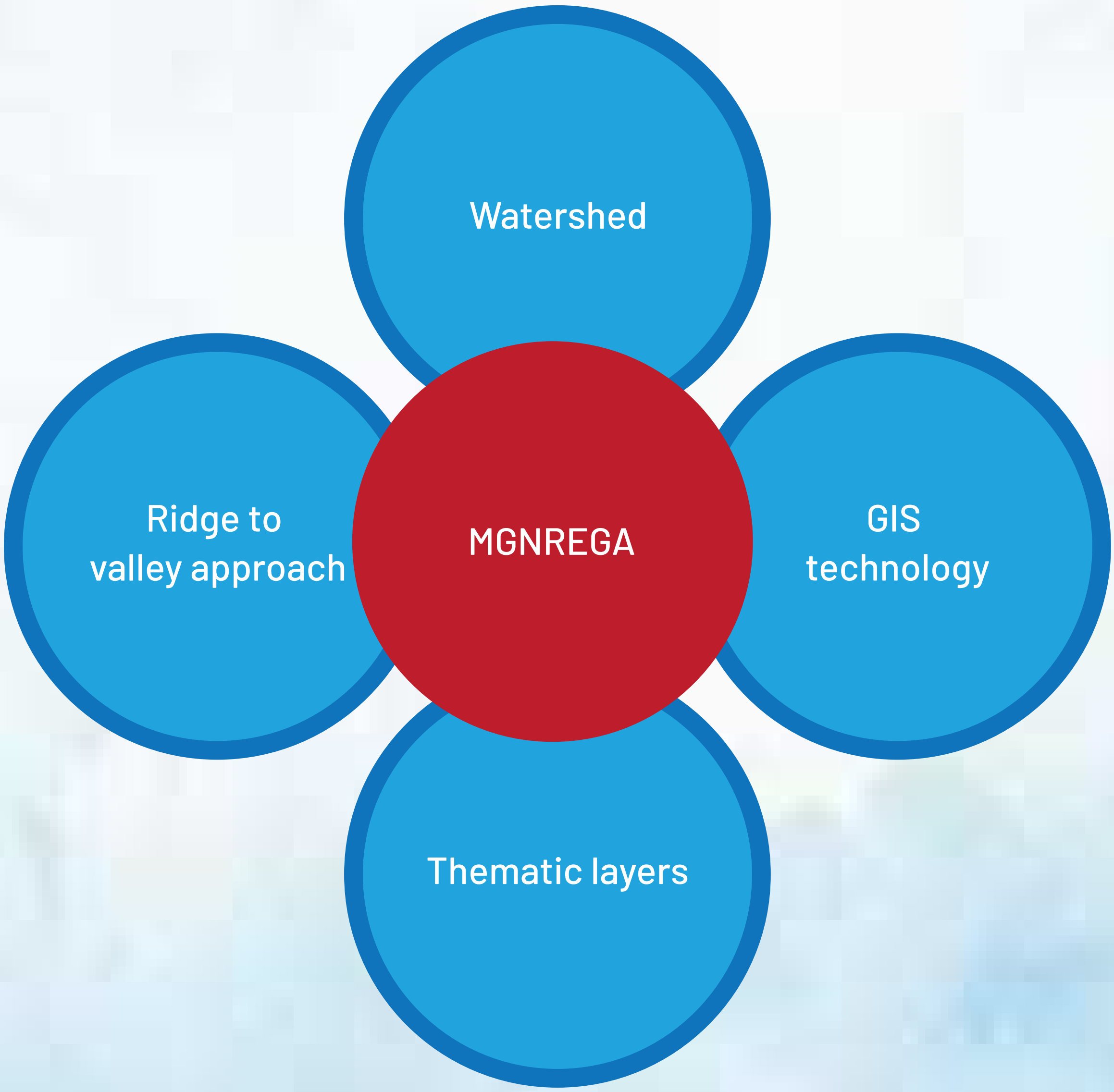
- If there are already water bodies or plantations, GIS helps ensure that resources are directed towards improving or expanding these features instead of duplicating efforts.
- GIS also prioritizes projects based on community needs, ensuring that the resources are used effectively and for projects that will benefit the community.

This leads to better financial management, improved asset quality, and enhanced rural livelihoods.

Integrated planning

Integrated planning involves combining various techniques such as watershed management, the ridge-to-valley approach, and GIS. This holistic approach ensures that natural resources are used efficiently, leading to long-term environmental and economic benefits. The ridge-to-valley approach focuses on treating higher elevation areas first to control soil erosion and increase water retention, gradually moving to lower regions. GIS tools help to map the terrain and water systems, allowing planners to implement this strategy effectively. Thematic layers (such as land use, soil types, and water resources) play a crucial role in decision-making. By analysing these layers, planners can determine the most suitable locations for MGNREGA works like check dams and percolation ponds. This ensures that projects align with the natural environment, maximizing their impact.

By combining these approaches, MGNREGA enhances water conservation, prevents land degradation, supports agriculture, and improves rural livelihoods, making development more sustainable and impactful. The map matrix further strengthens this integration by linking thematic maps with specific works, ensuring that the right projects are implemented in suitable locations for maximum impact.



Thematic map matrix

The Thematic Map Matrix is a structured framework used in MGNREGA to assist in scientific planning and decision-making. It helps in selecting the most suitable locations for rural development projects by analysing different thematic layers such as drainage patterns, land use, erosion risk, wasteland areas, slope, geological features (lineament), groundwater potential, and geomorphology (Table 5.1), the Map Matrix ensures that each project is strategically implemented in the right location to maximize environmental and social benefits.

Table: 5.1 Thematic Map Matrix for MGNREGA Project Planning

Serial	MGNREGA Works	Drainage	LULC	Erosion	Wasteland	Slope	Lineament	Groundwater prospect	Geomorphology
1	Block Plantation		✓	✓	✓				
2	Continuous Contour Trench		✓	✓	✓	✓			
3	Staggered Trench		✓	✓	✓	✓			
4	Earthen Gully Plugs	✓	✓	✓	✓	✓			
5	Stone Boulder Gully Plugs	✓	✓	✓	✓	✓			
6	Boulder Check Dam	✓	✓	✓	✓	✓			
7	Brushwood Check Dam	✓	✓	✓	✓	✓			
8	Drainage of chaur or waterlogged area		✓		✓				
9	Water Harvesting Ponds	✓	✓		✓	✓			
10	Distributary Canal	✓	✓			✓			
11	Storm Water Drain	✓	✓			✓			
12	Earthen Anicut Check Dam	✓	✓	✓		✓			
13	Earthen Spur	✓	✓	✓					
14	Farm Ponds	✓	✓		✓	✓			
15	Feeder Canal	✓	✓		✓	✓			
16	Fisheries Ponds	✓	✓						
17	Flood/ Diversion Channel	✓	✓						
18	Gabion Check Dam	✓	✓	✓	✓	✓			
19	Irrigation Open Well		✓						✓
20	Masonry/CC Check Dam	✓	✓	✓	✓	✓			
21	Mini Percolation Tank	✓	✓		✓		✓	✓	
22	Minor Canal	✓	✓		✓	✓			
23	Recharge Pits	✓	✓		✓		✓	✓	
24	Sand filter for Borewell recharge								
25	Sand filter for Open well recharge								
26	Stone Spur	✓	✓	✓					
27	Sub-minor Canal	✓	✓		✓	✓			✓
28	Underground Dykes	✓	✓					✓	✓
29	Water Absorption Trench	✓	✓		✓	✓			
30	Wire crate (gabion) Spur	✓	✓	✓			✓		

Understanding the table structure

- Rows (MGNREGA Works) – Each row represents a type of MGNREGA work, such as "Block Plantation," "Check Dams," "Farm Ponds," etc.
- Columns (Thematic Maps) – The different thematic map types (Drainage, LULC, etc.) are listed as columns.
- Check mark (✓) – If a check mark appears in a column, it means that the corresponding thematic map is relevant for that particular MGNREGA work.

For example:

✓ Block Plantation: Use the LULC and wasteland map to find barren land and the Erosion map to target soil loss areas. Planting trees in these locations helps restore vegetation and prevent erosion.

✓ Continuous Contour Trench: Refer to the Drainage map for high water runoff areas and the LULC, Erosion, Wasteland, and Slope maps for degraded lands. These trenches slow water, reduce erosion, and improve soil moisture.

✓ Gabion Check Dam: Use the Drainage map to locate streams or gullies and the LULC, Erosion, Wasteland, and Slope maps to find erosion-prone areas. Check dams control water flow, prevent soil loss, and improve groundwater recharge.

✓ Irrigation Open Well: Check the Groundwater Prospect map to find areas with good water availability. Proper placement ensures a steady irrigation supply without overusing groundwater.

Similarly, other MGNREGA activities can be planned using the relevant thematic maps from the Thematic Map Matrix. A tick mark (⊠) indicates which map should be used for planning a specific activity. GIS-based planning helps implement projects in the most suitable locations, improving effectiveness and sustainability.

Here's the GIS-based criteria for suggesting MGNREGA works by using thematic layers

Table 5.2: Suggesting MGNEGA works by using GIS planning

MGNREGA Work	GIS-Based Criteria for Selection
Block Plantation	Suggested in degraded forests, barren lands, and erosion-prone areas using LULC and Erosion maps. Preferable on gentle to moderate slopes.
Continuous Contour Trench	Recommended in sloping lands with high runoff using Slope and Drainage maps. Must follow contour lines to control erosion.
Staggered Trench	Suitable for moderate to steep slopes in degraded lands using LULC and Erosion maps. Best for seasonal rainfall regions to improve water infiltration.
Staggered Trench	Suitable for moderate to steep slopes in degraded lands using LULC and Erosion maps. Best for seasonal rainfall regions to improve water infiltration.

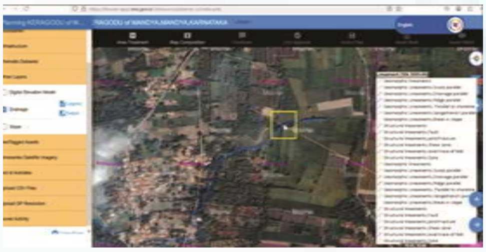
MGNREGA Work	GIS-Based Criteria for Selection
Earthen Gully Plugs	Suggested where two first-order streams meet, based on Drainage maps. Effective in active gully erosion zones from Erosion and Slope maps.
Stone Boulder Gully Plugs	Recommended where second-order streams join in rocky terrain. Suitable for flash flood-prone areas to control erosion.
Boulder Check Dam	Identified in seasonal streams with moderate slopes from Drainage and Slope maps. Ideal for semi-arid and hilly areas to slow water flow.
Brushwood Check Dam	Best for small seasonal streams with low water velocity, as per Drainage maps. Effective in sandy or loose soils for sediment trapping.
Drainage of Chaur or Waterlogged Area	Suggested in low-lying, waterlogged regions from LULC and Wasteland maps. Needed where natural drainage is poor.
Water Harvesting Ponds	Identified in natural depressions or gentle slopes from Drainage, Wasteland, and Slope maps. Ideal for moderate rainfall zones with low groundwater recharge.
Distributary Canal	Planned along existing water flow paths using Drainage and LULC maps. Suitable for agricultural water distribution.
Storm Water Drain	Suggested in urban/rural areas prone to waterlogging, identified using Drainage and LULC maps. Helps prevent flooding and erosion.
Earthen Anicut Check Dam	Suitable for seasonal streams in moderate slope areas, based on Drainage and Erosion maps. Helps in groundwater recharge.
Earthen Spur	Suggested for streambank stabilization in erosion-prone areas, identified using LULC and Erosion maps. Prevents riverbank collapse.
Farm Ponds	Recommended for agricultural water storage in areas with seasonal rainfall, identified from Drainage and Wasteland maps.
Feeder Canal	Located in farmland irrigation zones, based on Drainage, LULC, and Slope maps. Helps in connecting main canals to fields.
Fisheries Ponds	Suitable in flood-prone and waterlogged areas, identified using LULC maps. Ensures sustainable fish farming.
Flood/Diversion Channel	Suggested in flood-prone regions identified from Drainage and LULC maps. Used to redirect excess water.
Gabion Check Dam	Planned for stream stabilization in areas with high erosion risk, identified using Erosion and Slope maps. Helps store water and prevent landslides.

MGNREGA Work	GIS-Based Criteria for Selection
Irrigation Open Well	Recommended in groundwater-rich zones, identified from Groundwater Prospect maps. Best for agricultural irrigation.
Masonry/CC Check Dam	Suitable for semi-permanent water storage in areas with moderate slopes, identified using Drainage and Erosion maps.
Mini Percolation Tank	Planned in water-scarce regions based on Drainage, Wasteland, and Groundwater Prospect maps. Aims to increase groundwater recharge.
Minor Canal	Designed for small-scale irrigation in agricultural areas, identified using Drainage, LULC, and Slope maps.
Recharge Pits	Recommended in groundwater deficit zones, identified using Groundwater Prospect and Drainage maps. Improves rainwater percolation.
Sand Filter for Borewell Recharge	Suggested in borewell recharge zones based on Groundwater Prospect maps. Helps in improving water quality.
Sand Filter for Open Well Recharge	Recommended in open well recharge locations based on Groundwater Prospect maps. Helps maintain clean water supply.
Stone Spur	Suggested for riverbank stabilization in erosion-prone areas, identified using Erosion and LULC maps.
Sub-Minor Canal	Designed to distribute water from minor canals to fields, based on Drainage, Geomorphology, and LULC maps.
Underground Dykes	Recommended to prevent groundwater depletion, identified using Lineament and Groundwater Prospect maps. Helps retain subsurface water flow.
Water Absorption Trench	Suggested in high runoff areas using Drainage and Slope maps. Aims to reduce surface runoff and increase groundwater recharge.
Wire Crate (Gabion) Spur	Installed in streambank erosion zones, identified from Erosion and Lineament maps. Helps in riverbank protection.

In the following sections, will explain a few selected MGNREGA works—such as recharge pits, block plantations, and gully plugs—and how they can be effectively implemented using GIS technology and the ridge-to-valley approach.

MGNREG works by GIS planning

Recharge pit



Recharge pits play a crucial role in improving groundwater levels by allowing rainwater to percolate into the ground. They support drought proofing, improve irrigation and reduce water scarcity in rural areas. The flowchart outlines the GIS based planning process for recharge pits under MGNREGA ensures that they are strategically placed in areas where they will be most effective.

RECHARGE PIT

THERMATIC DATA COLLECTION & MAPPING

Drainage map
Identifies areas with natural water flow, such as streams and seasonal rivers. helping identify areas where surface runoff is available.

LULC & Wasteland map
Helps identify suitable land types, such as agricultural fields and barren lands, while avoiding urban and industrial areas

Lineament Map
It represent geological features such as fractures, faults, and cracks in the Earth's surface that influence groundwater movement. These natural structures

Groundwater Prospect Map
Highlights areas with low groundwater levels that require recharge.

Slope Map
Highlights areas with Determines land gradients to ensure that recharge pits are placed in areas where water can collect without quickly running off.

Identifying suitable locations using GIS

Criteria

Groundwater Deficit Areas
Recharge pits are placed in locations with declining groundwater levels to improve water availability.

Gentle Slopes 1-5% Gradient
Ensures water accumulates rather than flows away rapidly.

Available Land
Agricultural fields and wastelands are chosen, while urban and developed areas are avoided

Proximity to Drainage Paths
Areas near natural drainage lines are prioritized to maximize rainwater collection. Recharge pits are best placed where natural drainage lines intersect with lineaments, as these spots allow better water collection and faster groundwater percolation.

Overlay and spatial analysis
Multiple GIS layers (such as groundwater prospect, drainage, slope, and land use) are overlaid to identify intersecting zones that meet all criteria

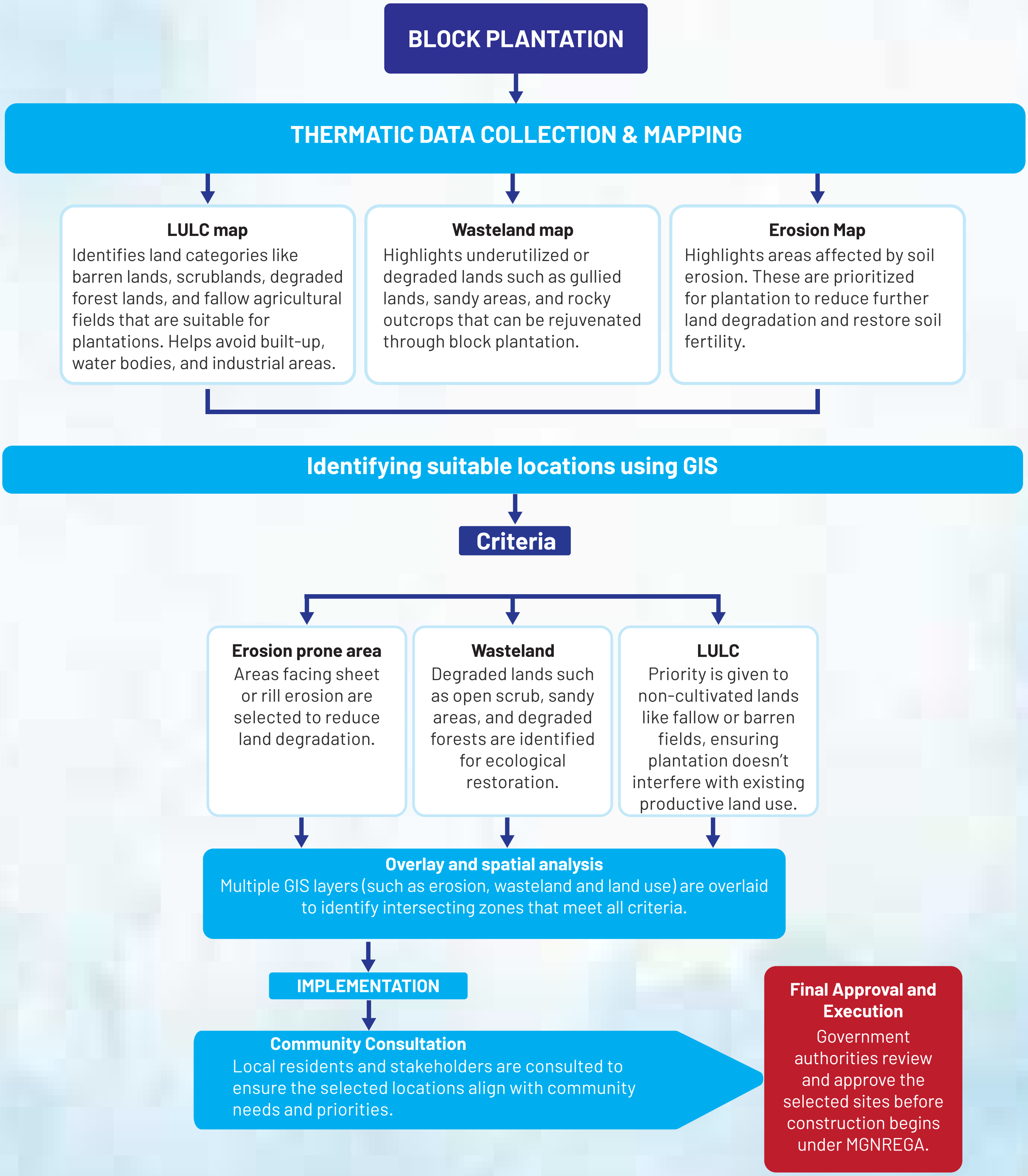
IMPLEMENTATION

Community Consultation
Local residents and stakeholders are consulted to ensure the selected locations align with community needs and priorities

Final Approval and Execution
Government authorities review and approve the selected sites before construction begins under MGNREGA

Block plantation

Block plantation under MGNREGA helps restore degraded lands, control soil erosion, and improve green cover. It supports environmental conservation while enhancing livelihoods through job creation. These plantations also improve soil fertility and promote sustainable agriculture. The attached flowchart illustrate the GIS based planning process for block plantation under MGNREGA.



Gully plug

Gully plugs under MGNREGA are small structures built across erosion-prone gullies to check soil erosion and improve moisture retention. They help stabilize gullies, reduce land degradation, and promote groundwater recharge. Constructing gully plugs also creates rural employment while supporting sustainable land and water management. The flowchart illustrates the GIS based planning under MGNREGA to identify effective sites for gully plug

GULLY PLUG

THERMATIC DATA COLLECTION & MAPPING

Drainage map
Identifies natural water flow paths such as small streams, rivulets, and gully channels. Helps locate active gullies and assess water movement patterns critical for placing gully plugs.

LULC & Wasteland map
Highlights land types like open scrub, agricultural boundaries, degraded forests, and fallow lands where gully formation is common. Avoids settlements, irrigated zones, and protected areas.

Erosion map
Pinpoints zones with severe to moderate soil erosion where gullies are likely to form or already exist. Helps prioritize areas needing immediate intervention.

Slope Map
Shows terrain steepness. Gully plugs are most effective in areas with moderate slopes (5–15%), where water runoff speed is high enough to cause gully erosion.

Identifying suitable locations using GIS

Criteria

Existing Gullies or Drainage Lines
Areas with visible gullies or ephemeral streams are targeted to intercept runoff and reduce erosion velocity.

LULC & available waste land
Ensures water land categorized as open scrub, fallow, or degraded forest is preferred for treatment.

High Erosion Zones
Sites with evident soil loss due to water flow are prioritized for erosion control through gully plugs.

Moderate Slope Zones
These slopes facilitate enough runoff to form gullies but are manageable for constructing low-cost plug.

Overlay and spatial analysis
Multiple GIS layers (such as groundwater prospect, drainage, slope, and land use) are overlaid to identify intersecting zones that meet all criteria.

IMPLEMENTATION

Community Consultation
Local residents and stakeholders are consulted to ensure the selected locations align with community needs and priorities.

Final Approval and Execution
Government authorities review and approve the selected sites before construction begins under MGNREGA.

Note: Multiple thematic layer data sets are collected from the Bhuvan portal (ISRO). These datasets are then overlaid and analysed using GIS platforms such as Google Earth, QGIS, or ArcGIS to identify suitable locations for groundwater recharge. Once the selection criteria are met through GIS analysis, potential sites for recharge pits, block plantation, gully plugs.etc are marked using point features or place marks, line and polygon feature within the GIS environment for further evaluation and planning

Conclusion

The integration of GIS technology has revolutionized MGNREGA planning by enabling data-driven, location-specific, and environmentally sustainable decision-making. Through thematic maps, remote sensing, and spatial analysis, planners can now identify the most suitable sites for interventions like recharge pits, block plantations, and gully plugs—ensuring efficient resource utilization, climate resilience, and transparency.

To further enhance these capabilities and overcome limitations of traditional planning methods, Yukthadara was launched in 2022. This advanced GIS-based platform significantly increases the efficiency of rural development initiatives by enabling real-time project monitoring, scientific asset planning, and seamless integration of geospatial data. Yukthadara marks a transformative step in strengthening grassroots governance and accelerating sustainable development under MGNREGA.

6. Yukthadara

Part-1

Introduction

Rural development in India has evolved significantly over the years, with technology playing a crucial role in shaping its progress. This journey began with the launch of Mahatma Gandhi NREGA in 2006, a revolutionary initiative aimed at enhancing livelihood security through employment generation.

Genesis of Yukthadara

In 2006, the Mahatma Gandhi National Rural Employment Guarantee Act, or MGNREGA, was introduced, transforming rural development by ensuring employment and creating durable assets such as water conservation structures, roads, and irrigation channels. By 2016, the integration of Remote Sensing (RS) and Geographic Information System (GIS) technology revolutionized MGNREGA's asset management. GIS provided a single, unified view of asset information across rural India, allowing planners to collect, store, and analyze data efficiently. Now, assets such as watershed locations, farm ponds, percolation tanks, and irrigation channels could be **mapped, visualized, and optimized** for better decision-making, improving the efficiency and transparency of asset management at the grassroots level.

In 2021, pilot projects introduced GIS-based planning at the Gram Panchayat level, where four GIS-based plans per block were developed. This initiative laid the foundation for data-driven, geospatially informed decision-making in rural development. Following the success of the pilot phase, by 2022, GIS-based planning had expanded to **2.56 lakh Gram Panchayats across India**, demonstrating the potential of technology to drive large-scale rural transformation. In 2024, Yuktdhara was launched in collaboration with ISRO-NRSC, bringing geospatial planning onto a single, unified platform. Previously, Gram Panchayats had to use multiple tools and platforms for GIS-based planning. Now, with Yuktdhara, everything is available in one place—making planning easier, faster, and more efficient.

By integrating multiple layers of geospatial data, Yuktdhara simplifies decision-making and ensures better utilization of resources for sustainable rural development. From its inception in 2006 to the launch of Yuktdhara in 2024, the journey of **MGNREGA and GIS-based** planning has transformed rural asset creation in India. Yuktdhara is not just a portal; it is a vision for the future—a step towards **scientific, transparent, and efficient rural planning.**

Purpose

Rural planning faced several challenges that made the process inefficient and time-consuming. Manual processes slowed down planning efforts, making it difficult to ensure accuracy and efficiency. With Yuktdhara, planning is now automated and conducted online, bringing a scientific approach that enhances precision and saves time. Previously, there was no integration between geospatial data and NREGAsoft, leading to fragmented workflows. Yuktdhara seamlessly connects with NREGAsoft, ensuring that all planning activities are unified within a single platform.

Another major hurdle was the lack of centralized spatial and non-spatial data, making it difficult for officials to access and analyze critical information. Yuktdhara addresses this by offering a centralized geospatial data system, improving accessibility and informed decision-making. Project approvals were often delayed due to the absence of an online approval mechanism. Now, with Yuktdhara, approvals are streamlined through a transparent online system, making evaluations and decision-making faster and more efficient.

Finally, GIS data and tools were scattered across multiple software, requiring planners to navigate different platforms for different tasks. Yuktdhara simplifies this by serving as a single storage and reserve of datasets, equipped with built-in GIS tools to support effective planning. With these enhancements, Yuktdhara has transformed rural planning—making it faster, smarter, and more integrated than ever before.

Understanding about Yuktdhara

Yuktdhara is a geospatial planning platform developed to support better decision-making under the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA). It helps streamline the planning and execution of rural development works by integrating spatial data and simplifying the planning workflow into four major stages

Major stages of Yukthadara

Familiarization – Understanding the Landscape

In the Familiarization stage, where planners get acquainted with the area using various maps and spatial data. Key tools include:

- ✓ **Thematic layers:** Base maps, administrative and watershed boundaries.
- ✓ **Geographical features:** Drainage networks, road connectivity, and settlement patterns.
- ✓ **Topographic data:** Digital Elevation Models (DEMs) and slope maps.
- ✓ **Historical data:** Satellite imagery and geotagged assets that show previous work.

Planners can analyse drainage networks, roads, and settlements, along with digital elevation models and slope data. Satellite imagery and geotagged assets provide historical data for planning."

Planning – Identifying Activities and area treatment & map composition

This stage combines three core tasks:

- ✓ **Identification of Activities:** Selecting the types of work (e.g., water conservation, land
- ✓ **Identification of Area Treatment:** Using drainage lines, micro-basins, pour points, and DEM analysis to locate where interventions are needed.
- ✓ **Map Composition:** Combining all spatial layers to prepare detailed maps. These maps include overlays of selected activities on satellite imagery, showing roads, drainage lines, and settlements.

This process ensures each activity is placed accurately based on scientific and spatial analysis.

Approval – Quality Checks and Official Reviews

This stage also has three sub-processes:

- ✓ **Porting for Quality Check (QC):** The draft maps are submitted to higher officials for review.
- ✓ **Feedback and Printing:** Maps are printed and presented to the Village Panchayat and Gram Sabha, who review and provide feedback.
- ✓ **Second Round of Approval:** After incorporating feedback, maps are reviewed again and officially approved.

This ensures transparency and community participation in the planning process

Finalization – Saving the Annual Action Plan (AAP) and asset bank

This final stage includes:

- ✓ **Saving the Annual Action Plan (AAP):** Once approved, the plan is digitally saved for download or online reference.
- ✓ **Final Asset Bank:** A comprehensive list of all planned works is compiled for implementation and monitoring.

This stage ensures that the approved plans are documented and ready for execution.

Salient Features of Yuktdhara

- **Gram Panchayat**-Level Planning: Yuktdhara enables local-level planning specifically for MGNREGS(Mahatma Gandhi National Rural Employment Guarantee Scheme) activities. It empowers Gram Panchayats to design development plans using geospatial data, ensuring that planning is grounded in accurate, location-based information.

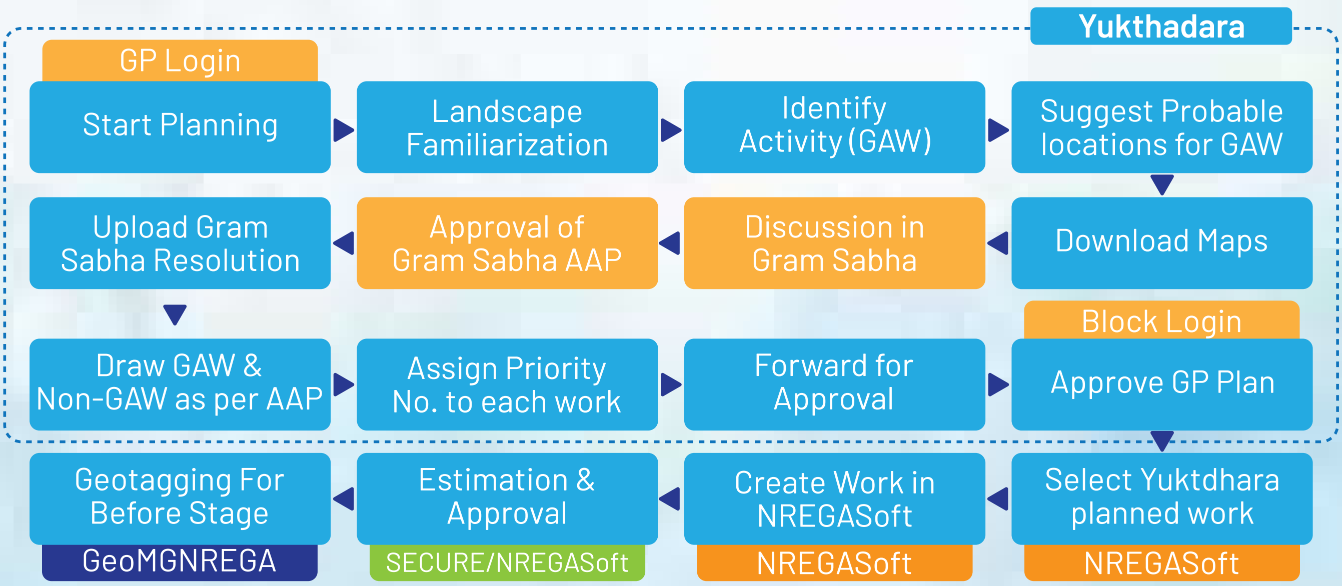
- **Categorization of Works:** GAW and Non-GAW: All permissible MGNREGS works are categorized into two types:
  - Geospatially Analysed Works (GAW): Identified using GIS and remote-sensing data.
  - Non-GAW: Works that are not dependent on spatial analysis.

This classification helps in focused and efficient planning.

- **Alignment with NREGASoft Database:** The list of permissible works in Yuktdhara is fully aligned with the official NREGASoft database. This ensures consistency between what is planned using GIS tools and what is approved or recorded in the national MIS (Management Information System).
- **Automated Suggestions Using Geospatial Analysis:** Yuktdhara uses advanced remote-sensing and geospatial analysis to suggest suitable locations for development works. These suggestions are based on terrain, land use, water flow, and other spatial factors, helping planners make data-informed decisions.
- **Integration with Annual Action Plans (AAP):** There is a direct connection between the GIS-generated work plans and the Gram Sabha-approved Annual Action Plans. This ensures that community-approved activities are accurately represented in spatial planning, enhancing transparency and accountability.
- **Online Approval Mechanisms:** The portal includes built-in systems for digital approvals. Officials can review, comment on, and approve proposed works directly within the platform, streamlining the approval process and reducing delays in implementation.

Yukthadara activity flow

The flowchart illustrates the complete workflow of planning, approval, and integration of GAW and Non-GAW activities in Yuktdhara for MGNREGA (Figure 6,1). It outlines the steps from Gram Panchayat login and activity identification to final work creation in NREGASoft, with geotagging and estimation approvals.



1. GP User can login using MSE credentials, in the familiarization can get familiar with the GP where he can use various boundaries (admin boundary, watershed boundary, roads etc), thematic maps (LULC, GWP, erosion, wasteland etc), get the geotagged info, satellite images etc.,

2. under the initial phase of planning stage the user can identify the activities & get the automated probable locations from the system based on rule set.

3. This map is submitted to gram sabha to get approvals on the location for the GAW plans. Also Non GAW plans are also approved at this point. Final GP Resolution is collected at the end of Gram Sabha.

4. under the second phase of planning stage the user uploads The CSV file + GP resolution is approved by Gram sabha & proceeds to the "Identification of area treatment" phase where he can draw various activities using the categories inbuild for 265 MNREGA activities.

5. Later can compose the map with various proposed activities & assign priority & submit for block level approval.

6. BLO login using GAS credentials and gets the activities showcased he can download them, review them & then approve or reject the activities.

7. the rejected activities are sent back to GP user for correction once corrected the BLO can sent to NREGASOFT.

8. works are created in NREGAsoft & the work details are entered and estimates calculated for the financial year.

9. Financial year wise Works taken up under NREGAsoft are displayed in BLO login.

GAW and Non GAW work

GAW work

GAW refers to activities that require geospatial analysis and mapping tools for effective planning and execution. These activities depend heavily on physical location, terrain, and environmental data, making the use of GIS technology essential.

Examples of GAW work

- Construction of water harvesting structures (e.g., check dams, farm ponds)
- Road construction
- Afforestation and plantation projects
- Construction of stormwater drains for coastal protection

Non-GAW work

Non-GAW activities do not rely primarily on spatial or geographic data. These are generally more generic in nature and can be implemented without detailed GIS-based planning.

Examples of Non GAW work

- Maintenance or repair of existing structures
- Plantation in school or community premises
- Renovation of public facilities
- Construction of link/intermediate stormwater drains for communities

NRM and Non NRM works

NRM work

NRM activities focus on the conservation, management, and sustainable use of natural resources such as land, water, and vegetation. These works play a crucial role in improving the productivity and ecological balance of rural landscapes.

Examples:

- Construction of graded bunds
- Water conservation structures
- Agroforestry
- Soil erosion control measures

Relationship Between GAW/Non-GAW and NRM/Non-NRM

It's important to note that GAW and Non-GAW activities can belong to either NRM or Non-NRM categories (Table 6.1). The classification is not mutually exclusive.

Table 6.1: relationship between GAW/Non GAW and NRM and Non NRM

Activity Type	Category	Example
GAW & NRM	Location-based natural resource work	Construction of Pebble Graded Bund
GAW & Non-NRM	Location-sensitive infrastructure	Construction of Storm Water Drain for Coastal Protection
Non-GAW & Non-NRM	Non-GAW & Non-NRM	Construction of Intermediate and Link Storm Water Drain for Community

Note

GAW and Non-GAW activities are not restricted to a specific category. Both types of activities can fall under either Natural Resource Management (NRM) or Non-NRM.

There is no fixed rule that a GAW activity must be NRM-related, or that a Non-GAW activity cannot be part of NRM. The classification depends on the nature and purpose of the work, not just its spatial requirements.

7. SECTIONS OF YUKTDHARA

Under the *Yuktdhara* framework, the planning process is systematically organized into four key sections, each comprising nine distinct stages. These sections are: **Familiarization, Planning, Approvals, and Finalization.** Each section represents a critical phase in the holistic planning and implementation of development activities.

The **Familiarization** section involves understanding the local context, resources, and community needs. The **Planning** section focuses on formulating detailed action plans based on the gathered data. In the **Approvals** section, proposed plans undergo scrutiny and sanctioning by the relevant authorities. Finally, the **Finalization** section ensures the integration of all components into a comprehensive, approved development plan ready for execution. This structured, stage-wise approach ensures transparency, consistency, and alignment with local priorities.

Each stage within these sections are explained in detail below to guide users through the complete Yuktdhara planning workflow.

Landscape Familiarization

It refers to the initial orientation process where users learn to navigate the platform, understand its features, and utilize its tools for spatial planning. It includes getting acquainted with GIS-based mapping layers, thematic datasets, and geotagged assets. The goal is to help the planners and officials to use Yuktdhara effectively for preparing the gram panchayat development plan. Different layers help to get familiarized with the landscape, layers include the following:

Boundary Layers

Boundary layers display the administrative outlines for Districts, Blocks, and Villages within the Gram Panchayat. These layers allow users to zoom in and out to focus on details at different scales—from the broad district level down to individual villages. The boundaries are essential for understanding jurisdictional extents and are foundational for any planning activity, ensuring that interventions are correctly located within the administrative units.

Road, Settlements, and Watershed Layers

The road and settlement layers' act like a roadmap of the Gram Panchayat. They show major transportation routes such as national and state highways, which are vital for planning activities like roadside tree plantations or road maintenance. When zoomed in, smaller village settlements appear, each clearly labelled, aiding precise local planning. The watershed layer is particularly important as it depicts the natural water flow patterns by highlighting ridges and valleys. This information helps in managing water resources efficiently by understanding how water moves through the landscape.

Thematic Data Sets

The Thematic Data Sets/ Thematic Layers in Yuktdhara provides extensive information about land characteristics and natural resources, crucial for making informed decisions. Unlike traditional GIS methods that require users to separately collect and overlay thematic layers, Yuktdhara integrates these data sets directly with vector boundaries, simplifying analysis. Thematic layers include Erosion, Geomorphology, Groundwater, Land Degradation, Land Use/Land Cover (LULC), Lineaments, Wasteland, and Groundwater Prospects (GWP).

Other Layers

Gram Panchayat can be better understood by using different map layers. These maps show details about land height, water bodies, and terrain slopes.

The DEM layer shows the height of the land. Different colors represent different heights. This layer also shows where the land is flat or hilly. The Drainage layer shows all the water bodies like rivers, canals, and streams. The Slope layer shows how steep or flat the land is. All these layers together help us make better decisions. They are useful for planning roads, farming, water use, and protecting land from erosion or floods.

Geotagged assets

The Geotagged Assets tab marks important locations on the map where projects or resources exist, helping avoid duplication and improving coordination. This layer allows filtering by financial year and project type, showing details like project scope and beneficiaries, which is vital for efficient resource allocation. Users can also upload their own data in CSV or point layer formats, allowing customization and inclusion of additional information on the map.

Time series satellite imagery

This tab offers historical satellite images, enabling users to analyze land use changes over time. Using tools we can compare past and present imagery to detect changes such as water body shrinkage, urban expansion etc., This temporal analysis supports environmental monitoring and planning.

Activity List, Uploading Data, and GP Resolution

Yuktdhara provides a comprehensive list of permissible activities that can be proposed for your Gram Panchayat's development. Clicking here downloads a PDF document containing the complete list of activities, categorized as Non-GAW and GAW. Each activity is assigned a category ID and a symbol for easy identification. For example, block plantation is represented by a green leaf symbol. The document also provides details about the work type, beneficiary type, activity type, and permissible works under each category.

Data can be uploaded into Yuktdhara by using CSV or Excel files. This feature allows you to integrate information that may have been collected separately, such as field data, survey points, or other geospatial attributes relevant to planning. Once uploaded, the data can be visualized directly on the map, helping to enrich the planning context with localized inputs. Alternatively, you can mark specific points manually if you need to highlight a location or propose a new activity on the map.

Note: For a detailed explanation of thematic layers, please refer to Chapter 4

PLANNING

The planning platform enables users to effectively plan development activities for Gram Panchayats using insights gained during landscape familiarization.

Before proceeding to the next stage, it's crucial to upload the Gram Panchayat Resolution. This document signifies the approval of the proposed activities by the Gram Sabha, ensuring that the planning process is participatory and democratic. Once the GP Resolution is uploaded, the activities planned for the next stage will be displayed in the Saved Activity Plan section.

Identification of Activities & Area Treatment

Identification of activity

At this stage, we define the specific development works to be carried out in the Gram Panchayat. As explained earlier, these activities are generally classified into two broad categories: GAW and Non-GAW.

Let's focus on the GAW category first, as these activities are geographically analysable and planned using the platform's spatial data. Under the GAW category, we have several options to refine our selection. The categorization is done broadly following the below selections:

Master Work Category (4) -> Major Scheduled Category (23) -> Beneficiary type (3) -> Activity Type (3) -> Work Type (39) -> Permissible Work (266)

Lets understand the categories with one example - Public Works -> Land Development -> Community -> Construction/Plantation/Development/Reclamation -> Bunds ->

Master Work Category:

This is the broadest classification, and we have four options here.

1. **Public Works:** These are primarily related to Natural Resource Management (NRM).
2. Individual Assets for Vulnerable Sections: This category focuses on creating assets for individuals who are vulnerable.

3. Rural Infrastructure: This category deals with infrastructure development in the village.

4. Common Infrastructure for NRLM Complaint Self Help Groups

For this example: let's select Public Works which, as mentioned, is related to NRM. Once we select the master category, the next options become available.

Major Scheduled Category:

There are in total 23 Major Scheduled Categories. Under Public Works, we have four major categories.

1. Land Development
2. Water Conservation
3. Afforestation
4. Watershed Management

Let's select Land Development as our Major Category. After selecting the major category, we need to define the beneficiary type.

Beneficiary Type: Here, we specify whether the work will benefit the community as a whole or individual beneficiary.

1. Community
2. Individual
3. Groups

We'll select Community Work for this example. Once we select the beneficiary type, we define the activity type.

Activity Type: This defines the nature of the work.

1. Construction/Plantation/Development/Reclamation
2. Renovation
3. Repair & maintenance

Let's choose Construction/Plantation/Development/Reclamation as the Activity Type. Now we move on to selecting the work type.

Work Type: This specifies the specific type of work to be carried out. There are in total 39 work types. In our example of Land Development for Community work, under construction, we can select "Bunds" or "Land Related Works." We'll select Bunds as the Work Type. After selecting the work type, we select the permissible work.

Permissible Work: This is the most specific level of detail, defining the exact work to be done.

If we select "Bunds" as the work type, we can select from options such as: Construction of Stone Peripheral or Field Bund/Farm Bund for the community. This construction can be of stone type, pebble type, or earthen type. It's important to note that the numbers associated with these permissible works (e.g., 266) refer to entries in the Activity List, which we explored earlier. You can refer to that list to get more details about these specific works. This detailed process allows you to carefully define the activities you wish to undertake, ensuring that they align with the needs and priorities of your Gram Panchayat.

Identification of Area Treatment

After successfully identifying the activity, the platform guides us to the next stage. It involves analyzing the area where we plan to implement the selected activity to ensure its suitability and effectiveness. This stage has few important parts. The first part is Analyze. When we click on the construction of a stone peripheral bund tab, the platform provides us with tabs to determine the probable locations for that activity, draw and also check if the previous geotag data is available.

Rule Set

When we click on probable locations, the platform gives us Rule Sets. These are pre-defined criteria that help us identify suitable locations based on various factors. For example, for bund construction, the rule sets might specify that bunds can be constructed in Agricultural land and cropland, Slope and soil type to be mentioned that helps in displaying the probable location based on the filters using the land use, slope, soil type information.

The platform also provides the possibility to Reset the Rules, allowing users to adjust the criteria based on their specific needs and local conditions. For certain activities, such as construction, there might be Additional Criteria. In our example, the platform specifies that for construction activities, the rainfall has to be greater than 600 mm. Then the graded bunds are used to secure this.

With all this information, we can now check the probable locations for our chosen activity. The platform will highlight these probable locations on the map based on the applied rule sets. Below, explaining a scenario to analyze a specific area for suitability of bund construction.

"Analyze" tool

To analyze this area, we use the Analyze tool. First, we select the area we want to analyze. Once the area is selected, we click to finish the selection. Then, we initiate the analysis. The Analyze tool provides various operations to gather information about the selected area. These operations allow us to overlay different layers and obtain relevant data."

For example, we can use the Buffer operation to check the proximity of the selected area to drainage lines. We can select the Drainage layer as the output layer to see if there are any drainage lines within a specified distance of our area. The platform then displays the drainage map, showing the location of drainage lines. In this case, we can observe that the drainage is relatively far away from our selected area. Similarly, we can use another operation, such as the Buffer of LULC (Land Use Land Cover) layer. For instance, we can check the LULC within a 500-meter buffer of our selected area. The platform then provides the LULC information for that buffer area. We can also access the legend to understand the different land use categories. In our example, we can see that the land use in the area is primarily agriculture plantation.

The Analyze tool allows us to gather crucial information about the area where we plan to implement our activity. This information helps us make informed decisions about the suitability of the location

Add Non-GAW Activities

and potential impacts of our interventions. After analyzing the area, we can delete the AOI (Area of Interest) and close the legend. In our example, we learned that the area has an agriculture plantation, which might be a suitable context for bund construction."

This detailed analysis empowers us to select appropriate locations for our activities, ensuring that they are aligned with the local context and contribute to the sustainable development of our Gram Panchayat.

After adding Geographically Analyzable Works (GAW) activities, you can proceed to add Non-GAW activities. However, before adding a Non-GAW activity, there are a few prerequisites:

1. **Upload a CSV file containing the necessary activity data.**
2. **Provide the Gram Panchayat (GP) resolution link.**

Non-GAW activities fall under various categories. For example, if you want to add canal renovation, you would select the relevant categorieS that include the below broader categories:

- Master Work: Public Works related to natural resource management.
- Major Scheduled Category: Irrigation.
- Activity Type: Renovation.
- Work Type: Canals.

After uploading the required files and obtaining the Gram Panchayat approval, the system will allow you to add Non-GAW activities. If you try to add a Non-GAW activity before these steps, the platform will display an error message.

Once the required steps are complete, you can add activities. For instance, under the Public Works category, you might select an activity such as Construction of Plantation Work. Upon finalizing your selection, click Add Activity, and the system will display the activity. You can add multiple activities as needed.

Probable Location Map

After analyzing the area and confirming the suitability of the location, the next step is to draw the activity on the map. Before drawing, you can print the map by selecting the Print Option. This allows you to generate a high-resolution map that can be used for community meetings such as Gram Sabha. The printout will include relevant activity details and the selection criteria used to identify the locations.

Gram Sabha Approval

The printed map can be taken to the Gram Sabha for community review and approval. Once the locations are finalized, you can proceed to draw the activity on the platform.

Draw the Activity on the Map

The Draw/Edit Line Tool represents activities such as bunds on a map using line features. It displays the length of each segment to indicate the size of the activity. Once the drawing is completed, the activity is labeled for identification. The named activity is then saved as part of the sub-plan in the system.

Use Geotagged Information

To avoid duplication, you can check if there is any existing geotagged data by selecting the Previous Geo-tagged Data option. This feature ensures that no previously marked data overlaps with the newly planned activity.

Refer Landscape Familiarization Layers

For some activities, such as wasteland management, you can refer to the Landscape Familiarization Layers which are already available in the previous stage that helps to correlate and get detailed information that helps to plan the activities.

Map Composition

After the identification of activities and specifying their locations, the next step is Map Composition. In this stage, you will configure the map to display relevant layers and information.

Steps for Map Composition:

1. Select the layers to display on the map. Common layers include:

- Satellite Image (for a visual backdrop).
- Settlements (to show village and habitation locations).
- The names of the added locations (e.g., "Keragodu Block", "Bunds", and "Self-Help Groups").
- Additional activity layers like Rooftop Harvesting Structures.

2. Ensure that the Gram Panchayat Boundary Layer is clearly visible on the map to define the geographical area of the plan.

3. After selecting the desired layers and adjusting the map view, generate the final output by clicking Download PDF. The system will create a PDF map showing the identified activities and other relevant features.

Assigning Priority

Once the map composition is complete, you can move on to the Assign Priority. This step is crucial for ensuring the proper order of activities.

Steps for Assigning Priorities:

- Go to the Saved Activities tab to review all activities that have been identified and drawn on the map.
- Ensure the GP resolution has been added to authorize the planned activities.
- Review each activity to verify details such as location and type.
- If any duplicates exist, remove them to avoid errors.

Rank each activity in the order of importance by assigning a priority number (e.g., First, Second, Third, etc.). The priorities can be adjusted based on community input and the Gram Panchayat's decisions. Once all activities have been prioritized, you can submit the plan to the block-level authorities for further review and approval. By following these steps, you will have a comprehensive, geospatially informed plan ready for implementation.

Approval

In this section, we will outline the process from the perspective of the Block Level Officer (BLO). The Block Level Officer can access the Yuktdhara portal using their credentials. Upon successful login, the BLO will be presented with a dashboard showing the Panchayat-wise count of plans that are marked as "Yet to moderate."

Approve/Reject

To review a specific Panchayat's plan, the Block Level Officer can click on the 'Click here to approve' option. This will open a detailed visualization of the Geospatial Plan for that Panchayat, allowing the officer to examine the planned activities in their geographical context. The Block Level Officer can then select the activities for review and download them for further evaluation.

Additionally, the Block Level Officer has the option to download the Gram Panchayat (GP) Resolution, which contains the official approval from the Gram Panchayat. This ensures that all plans are backed by the necessary community resolutions.

Statistics

The platform provides detailed statistics on the **rejected** or **accepted** activities, categorized for easy analysis. This enables the Block Level Officer to identify trends and patterns in the proposed plans. After reviewing each plan, the Block Level Officer can enter any necessary **remarks** and **'SAVE DATA'** to ensure that the moderation status and comments are saved.

The Block Level Officer has two options for each plan:

1. 'Accept': Approves the proposed activity.
2. 'Reject': Disapproves the proposed activity.

Once all the plans have been moderated, the Block Level Officer can either: 'Accept' to approve all the planned activities or 'Send for correction' if any plans need further revisions.

Edit/Correct Plans and Resubmit

If any plans are rejected by the Block Level Officer, the Gram Panchayat (GP) user will have to edit the rejected plans. Once the corrections are made, the GP user can use the 'Submit all plans' option to resubmit all plans to the Block Level Officer for further approval. The resubmission process ensures that any necessary revisions are made before the plans are finalized.

Send to NREGAsoft

Once the plans have been **approved** by the Block Level Officer, they can be sent to **NREGAsoft** by selecting the 'Send to **NREGAsoft'** option. The platform will display a success message confirming the successful transfer of the approved plans to **NREGAsoft.**

Key Points

01

Once all plans are moderated, the Block Level Officer can submit the report by clicking '**Accept**' if all activities are approved or **'Send for correction'** if any plans need further revisions.

02

If the Block Level Officer does not wish to submit the data at that moment, they can save the progress by clicking **'Save Data'.**

03

Plans can only be sent to **NREGAsoft** after all the activities have been approved

04

Rejected plans are available for review by the GP user. These plans will display an '**Edit**' option, allowing the GP user to make the necessary changes.

05

After editing the rejected plans, the GP user can resubmit all plans to the Block Level Officer by using the **'Submit all plans'** option.

CONCLUSION

The Yuktdhara portal offers a structured and participatory approach to planning and implementing rural development works under MGNREGS. The process begins with the Gram Panchayat (GP) planner logging into the system and undertaking landscape familiarization—an essential step involving the exploration of the village's geographical and thematic characteristics through multiple GIS-based map layers. These include administrative boundaries, land use patterns, soil erosion zones, groundwater availability, and satellite imagery, which collectively support informed decision-making.

Following this, users identify activities under the categories of GAW (GIS-based Asset Works) and non-GAW. For GAW activities, the system suggests probable locations based on predefined rule sets. These proposed plans are then presented before the Gram Sabha for approval. Once a GP resolution is uploaded, the user can delineate approved GAW activities on the portal.

For non-GAW activities, a CSV file upload enables the visualization of point layers, allowing users to map and prioritize these works. A composite map is then prepared, and activities are assigned priorities before submission to the block level.

At the block level, designated officers review the proposed plans. Based on their assessment, activities may be approved or returned to the GP user for revisions. Approved activities are transmitted to the NREGASoft platform, where work records are created and cost estimates are generated. NREGASoft subsequently maintains a year-wise list of sanctioned activities, thereby completing the cycle of participatory, data-driven planning and implementation.

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Ministry of Rural Development
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