Reconfigurable Tool for Feasibility Assessment of NRM Works

B.Tech Project I & II - Om Krishna & Harshita

Abstract

The aim of the project is to use GIS based methods for the site suitability analysis of feasibility of NRM works in India. Groundwater recharge potential is used as a metric to divide the area under study into various classes. The type of NRM for a location is based on said classification.

Introduction

The Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA), promises unskilled manual work to every adult for at least 100 days in rural parts of the country. Huge funds (Rs. 73,000 crore in the last budget) are allocated for this, making it the government's one of the top rural focused schemes. Roughly 60-70% of these resources are spent on Natural Resource Management (NRM) works like check dams, percolation tanks, and irrigation channels. The overall focus of the scheme is on ensuring higher incomes for farmers by increasing the water availability and productivity of land. The traditional way of suitable site identification for these structures has been based on local people's opinion, and taking into consideration factors such as geomorphology, climate, annual rainfall, vegetation cover, distances from farms and so on.

However, misidentification of suitable locations for NRM works has resulted in non-operation, non-utilization and inefficient investment. On a state or national level, Geographic Information System (GIS) based methods for site suitability analysis are much more time saving and cost effective than field studies. Recommended sites can be cross verified by field workers resulting in a smoother workflow.

Research Methodology

Weighted multi-criteria overlay analysis is a methodology useful for identifying the relationship between multiple feature layers. This is done by superimposing multiple layers of datasets that represent different themes/criteria.

Depending on how the different layers impact the classification under consideration (groundwater recharge potential in this case), these layers can be assigned different weights to result in a composite map combining different attributes and dataset geometries.

For GWRP, the following input layers are considered - lithology, drainage density and lineaments. This recharge potentiality in weighted combination with slope percentage results in a feasibility score layer which can be used to determine the type of NRM work most suitable for the area in consideration.

The analysis was initially done on QGIS Desktop manually for the district of Jamui, Bihar, and then automated using Python. The automation allowed easy extension of the process for the whole of India. The most recent work involves transferring the preprocessed layers to Google Earth Engine to create a reconfigurable assessment tool with dynamic scoring to allow flexibility based on requirement.

Lineaments

Lineaments are linear features in a landscape which represents cracks or faults in the surface of the earth. Since the depression allows water to get collected around the lineament, they form good regions for groundwater to be recharged.

Source: The state-wise lineaments data has been taken from Bhuvan at a resolution of 1:50k (25m by 25m) by sending out a WMS request and generating .tif files from the packets.

Pre-Processing: The lineament layers are processed to generate a proximity mask. The Proximity (Raster Distance) algorithm computes the distance from the center of each pixel to the center of the nearest pixel on a target pixel (a lineament in this case). The generated raster proximity map is now scanned for pixels with a distance of less than a buffer value (currently 2m) and selected pixels are exported to form a Lineaments Buffer Mask. This mask is now georeferenced to the respective state for ease of visualization.

Scoring: Since the lineaments facilitate groundwater recharge, the areas/pixels within the said lineament buffer (2m) are assigned a score of 10, and remaining pixels are assigned a score of 1.

Lithology

Lithology is a representation of the underlying rock structure of the area under consideration. Infiltration is the process of seepage of water into the groundwater table. Lithologic structure of a place determines the infiltration factor of the area and hence is an important feature in the assessment.

Source: The state-wise lithology data has been downloaded as shapefiles manually from Bhukosh at a resolution of 1:50k (25m by 25m).

Pre-Processing: The downloaded shapefiles are analyzed to understand the different lithology types in the area. These types can be combined into broader classes depending on the requirement of the study. Individual classes are extracted and rasterized. These rasters can be combined to generate a state lithology mask which is georeferenced to the respective state for ease of visualization.

Scoring: The rainfall infiltration factor from the GEC 1977 report is used as a measure of recharge potential. Among the current classes, alluvium has the highest infiltration and is assigned a score of 1, quartz has the lowest and is assigned 3, while the remaining classes (Granite, Gneiss, Phyllite and Schist) are assigned 2.

Drainage Density

Drainage network of the watershed helps in visualizing which areas have a high groundwater recharge. Drainage density is directly related to slope and inversely proportional to permeability. The steeper the slope with low permeability, the higher the drainage density, thus less infiltration and more surface runoff.

Source: SRTM Digital Elevation Model (DEM) data at a resolution of about 1:60k (30m by 30m) is used to find for each pixel the number of its neighbors which drain into it. The D8 algorithm is used for flow directions and thresholding is done to get drainage lines for India.

Pre-Processing: Drainage density is a measurement of the sum of the channel lengths per unit area. The drainage lines are processed to measure the sum of line lengths per unit area using the QGIS Line Density tool, which calculates for each pixel the line density as the sum of lengths of the vectors in the surrounding unit area weighted by their thickness and returns a raster mask with each pixel having the value of the corresponding line density. This drainage density mask is now georeferenced to the respective state for ease of visualization.

Scoring: Low drainage density is more likely to dominate in highly permeable, dense vegetation, and low relief areas. Therefore, points with a drainage density (< 0.5) are assigned high infiltration and a score of 1, those with density over 1.5 are assigned low (3) and the others moderate (2).

Slope Percentage

Slope represents the rate of change of elevation for each DEM cell. Steep slopes generally reduce recharge as runoff flows very rapidly and would not permit infiltration. Plains, however, enhance groundwater recharge because higher retention time is provided for rainwater to infiltrate the soils.

Source: SRTM Digital Elevation Model (DEM) data at a resolution of about 1:60k (30m by 30m) is used to get elevation data which can be processed to obtain pixel-wise slope.

Pre-Processing: Slope percentage is defined as the ratio of the amount of elevation change by the amount of horizontal distance covered. It is computed from the DEM data using Horn's algorithm.

Scoring: Since slope percentage is the tan of the slope angle, the values range from 0 to infinity (a maximum value varying with the area under consideration).

Recharge Potentiality

Natural groundwater recharge occurs as precipitation falls on the land surface, infiltrates into soils, and moves through pore spaces down to the water table. Natural recharge also can occur as surface-water leakage from rivers, streams, lakes, and wetlands. Recharge Potentiality is a measure of the ability of an area to recharge the groundwater.

Source: The pre-processed lineament, lithology and drainage density masks.

WMCA: For each pixel, its score for lineaments (10,1), lithology (1,2,3) and drainage density (1,2,3) are multiplied. Since the scores represent the weights of the features in each layer, further weighting of the layers is not required.

Scoring: The pixel values are studied and categorized into High RP with an assigned score of 1 (pixel values 1,2,10,20,30), Moderate RP scored 2 (pixel values 3,4) and Low RP scored 3 (pixel values 6,9). Rest of the pixel values currently correspond to holes (unclassified) in the final result.

Feasibility Score

Slope percentage can be used as a measure of surface runoff and recharge potentiality that of groundwater recharge. Recharge potentiality can be combined with different slope categories to help analyze the feasibility for the creation of different water harvesting structures in the area under consideration.

Source: The pre-processed slope percentage and recharge potentiality.

WMCA and Scoring: The table shows the feasibility score for different slope categories and recharge potentialities.

Slope %	RP	Feasibility
Less than 5% of maximum slope %	3	1
	2	2
	1	3
Between 5-25% of maximum slope %	2 or 3	4
Over 25% of maximum slope %	1, 2 or 3	5

A feasibility score of 1 represents a high recharge area suitable for recharge structures like percolation dams and contour trenches. The score of 2 represents a moderate recharge area suitable for recharge structures like check dams and 3 represents low recharge area suitable for farm ponds and bunds. Areas with a score of 4 are suitable for regeneration via plantations, vegetation and trenching etc. and areas with a score of 5 are high surface runoff zones where stone bunding and trenching may help.

Reconfigurable Model

All steps beyond preprocessing - the combination of lithology, lineaments and drainage density to give recharge potentiality and the combination of RP and slope percentage to give the feasibility score have been hosted as a project on Google Earth Engine. All weights and scores are variable and can be changed as required to generate different results depending on the requirement. The flexible nature of this project allows for analyzing sensitivity of constituent layers.

The final feasibility score layer can be masked with different layers to understand different scopes of the model. For instance, the FS layer can be masked with Land Use Land Cover to display where NRM assets can actually be made - showing where no built-up/forests/waterbodies are present etc.

Github Repository : link

GEE Project : link and manual

Datasets : link