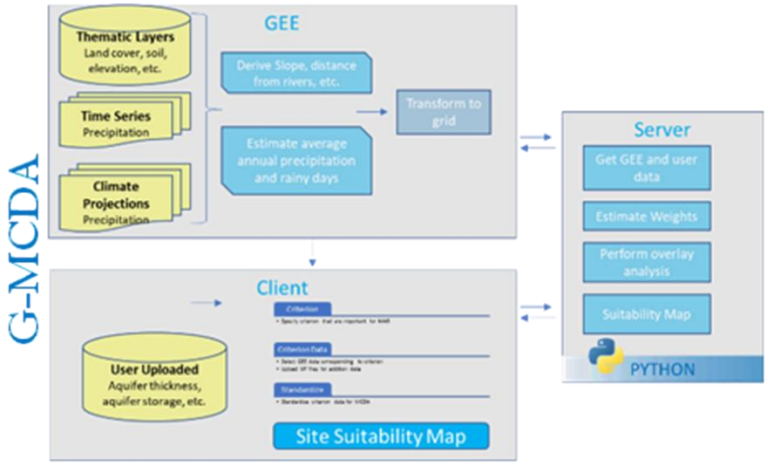
G-MCDA

Google Earth Engine based Multi-Criteria Decision Analysis



A web-based tool that integrates Google Earth Engine and geospatial analysis with multi-criteria decision analysis for the site suitability mapping for MAR

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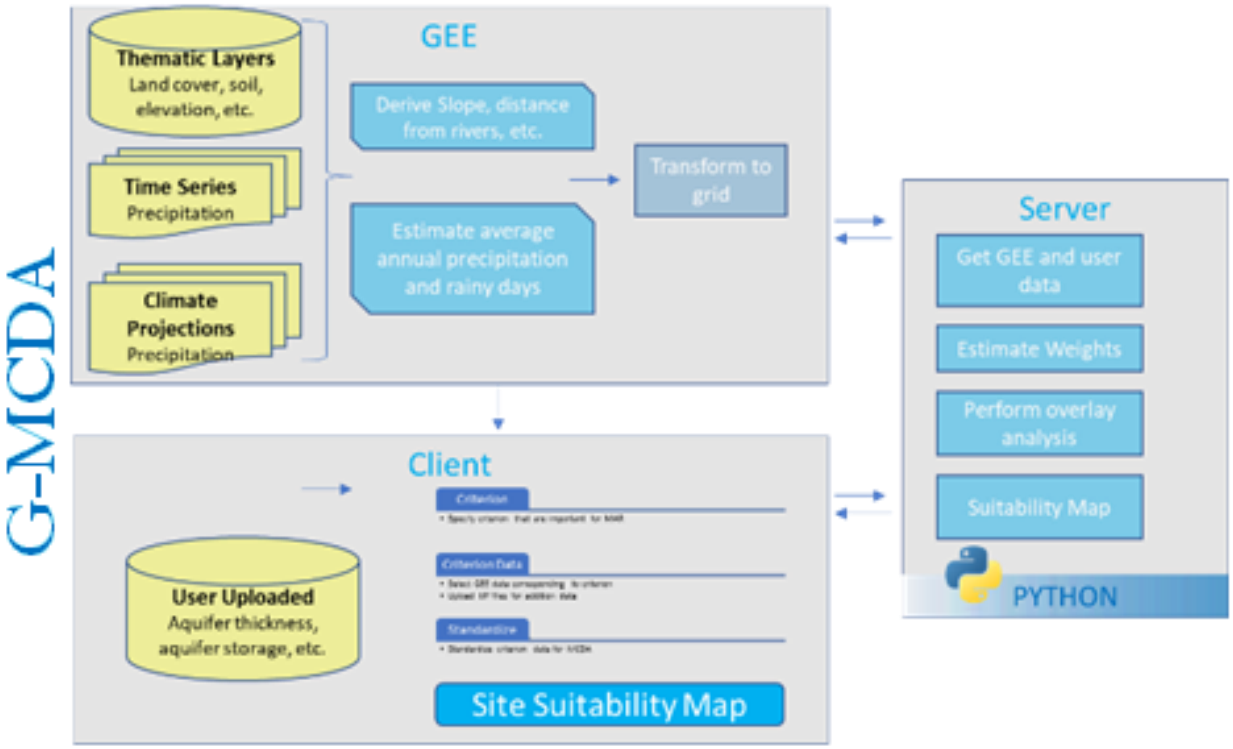
The G-MCDA is a powerful tool for site suitability mapping that encompasses Google Earth Engine (GEE) based cloud computing, remote sensing data, and various python-based GIS libraries for quick site suitability mapping. The web-based user interface of G-MCDA also supports user-based inputs, graphical and map visualizations and data download. Running G-MCDA is a few hours job if the input steps are properly followed. For site suitability mapping, there are mainly four major steps, namely criteria, data, standardization and suitability. User can register and create/delete multiple projects from the dashboard page. It also allows direct navigation from one step to the other, however it is advised to use next button during the first run so that all steps are completed to produce suitability map.



1. Criteria

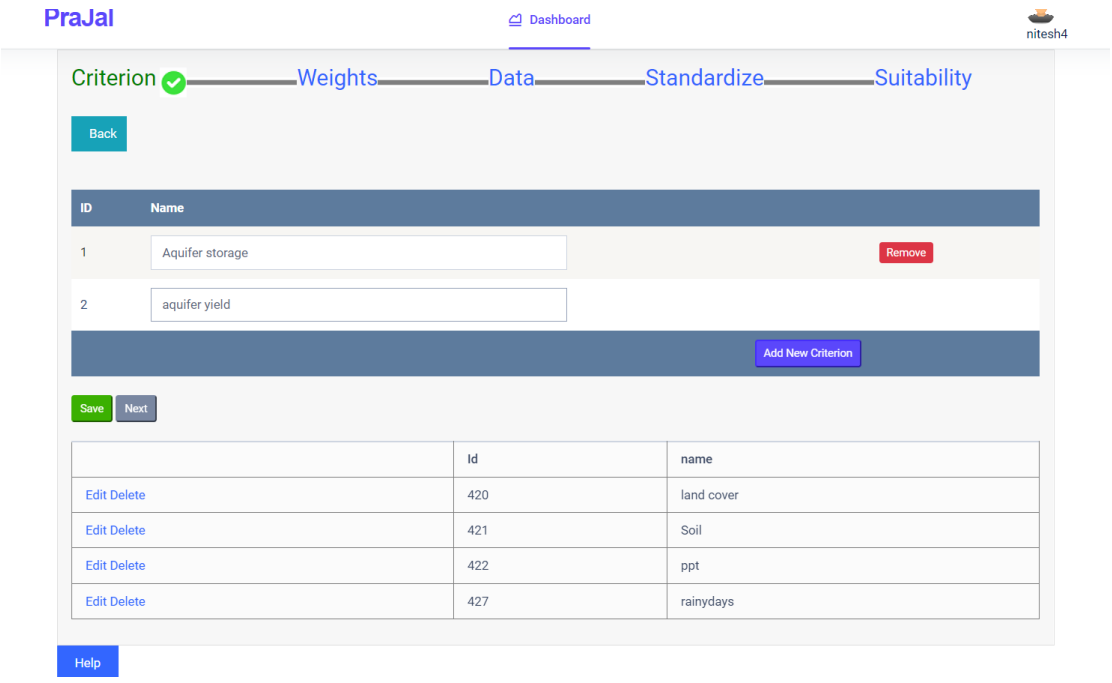
Number and type of criteria depend upon method of MAR, objective of MAR project and data availability. Generally, the factors that govern recharge and help improving groundwater quality are considered for site suitability mapping. For surface spreading methods, the surface characteristics, such as land cover, soil, slope, etc., are important, while in case of injection methods, subsurface characteristics, such as aquifer storage and yield, become important. MAR has a variety of applications, ranging from aquifer replenishment to improving groundwater quality. Selection of criteria thus also depends on the main objective of MAR projects, for instance, if MAR is to be implemented for improving groundwater quality the source water quality and factors that govern the dilution of contaminants in groundwater should be considered. The important criterion may be identified based on their importance and data availability. Multiple criteria that provide similar thematic information are

unnecessary and therefore the appropriate criteria should be selected considering the data availability, for example the infiltration rate and soil type both provide same information and inclusion of both at the same time is not required and the one which is available with required accuracy and scale may be used.

Considering the wide applicability of MAR, the G-MCDA provides option to add a maximum of 11 criteria. The commonly used criteria in surface spreading and injection methods are given in Table.

Sr. No.	Criteria
1	Infiltration rate/soil texture
2	Slope
3	Land cover
4	Aquifer storage/thickness
5	Aquifer yield
6	Distance from river
7	Water quality
8	Climate change indicator

New criterion can be added using + button. The existing criterion will be shown in the table and any criterion may be deleted at any stage using delete button.



2. Weights

G-MCDA allows estimation of weights using three different methods, namely ranking, rating and Analytic Hierarchy Process (AHP). The interface allows the user to define the importance

of criterions in a simple and logical way and displays the estimated weights. Since, it allows a quick estimation of weights, the results of different methods can easily be compared.

2.1 Rating

Rating is a simple method in which rates are assigned to criterions as per their importance. The weights are estimated based on the ratings using the following equation.

$$w_i = \frac{r_i}{\sum_{i=1}^{n} r_i}$$

Where, w_i is weight of criteria i, r_i is the ranking assigned to criterion i, and n is the number of criterions.

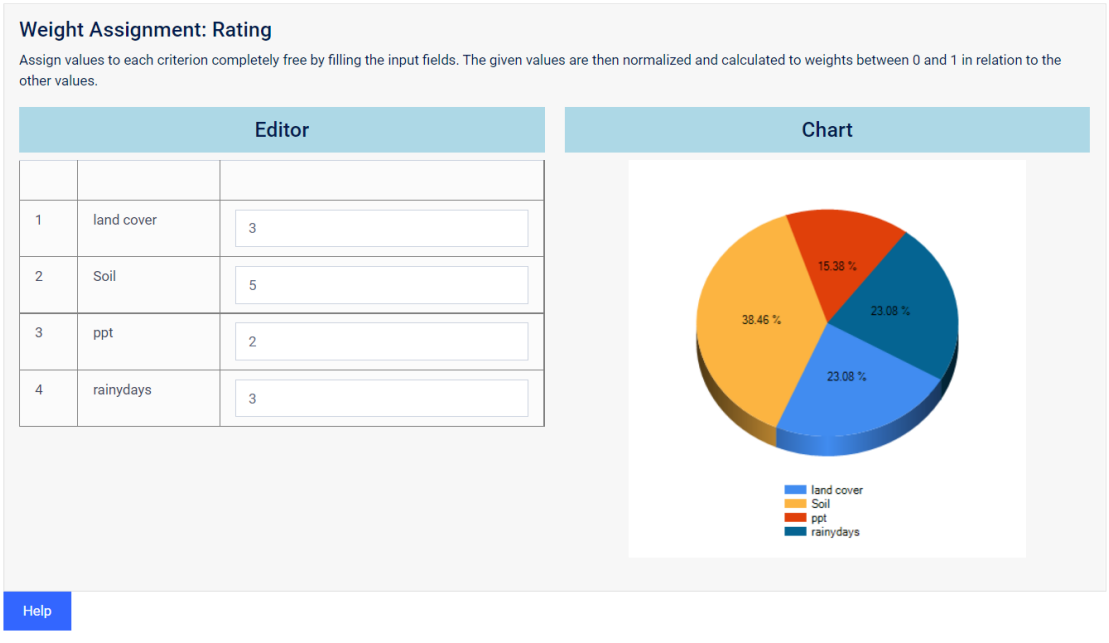
Ratings

	Criteria-1	Criteria-2	Criteria-3	Total
Alternative-1	3	4	2	9
Alternative-2	2	3	4	9
Alternative-3	5	3	2	10

Weights

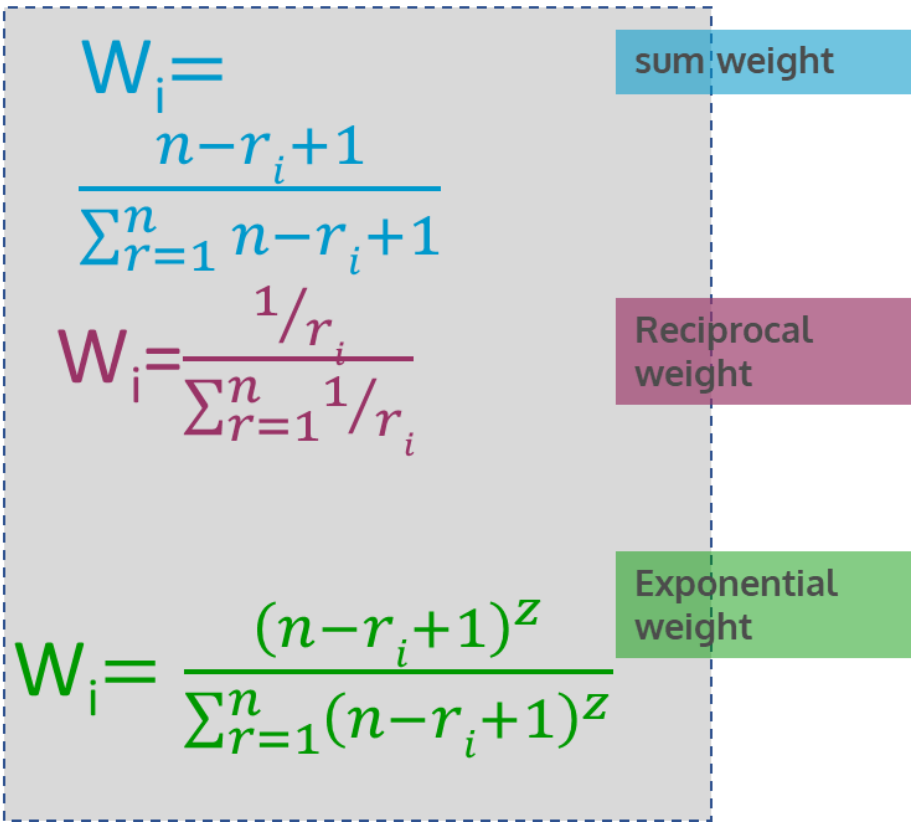
	Criteria-1	Criteria-2	Criteria-3
Alternative-1	3/9 = 0.33	4/9 = 0.44	2/9 = 0.22
Alternative-2	2/9 = 0.22	3/9 = 0.33	4/9 = 0.44
Alternative-3	5/9 = 0.55	3/9 = 0.33	2/9 = 0.22

Using the G-MCDA, rating of each criterion can be assigned by typing a numeric value against each criterion. Estimated weight will be displayed in the pia chart as shown below.

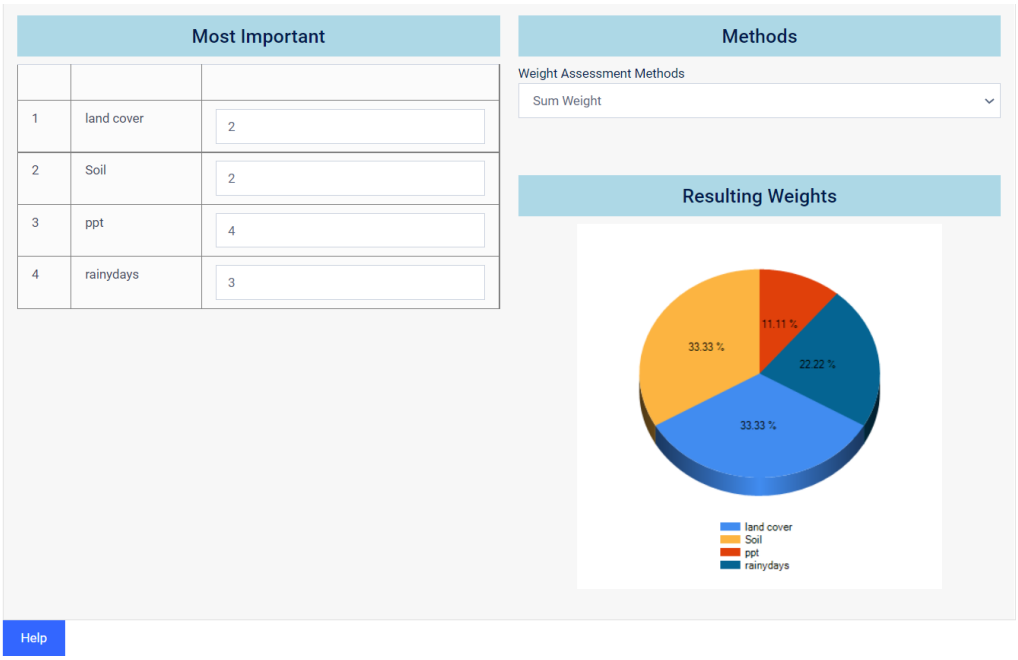


2.2 Ranking

In ranking method, the rank of criterions is assigned as per their importance. The criterions with higher importance are ranked higher. G-MCDA allows estimation of weight using three ranking-based methods, i.e., sum, reciprocal and exponent based methods. The weight using these methods are estimated using the following formulae.

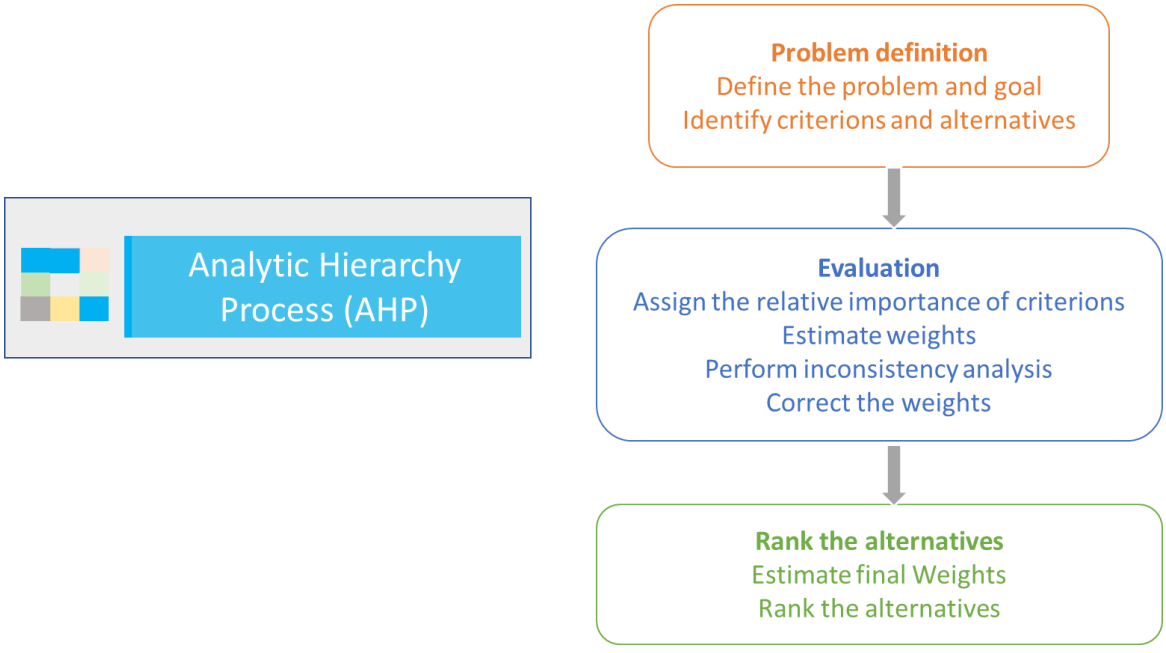


Where, r_i is rank assigned to criterion *i*, *n* is the number of criterions and *Z* is the exponent. User can select the ranking method from the dropdown, and accordingly the weights will be displayed in the pie chart.



2.3 Analytic Hierarchy Process (AHP)

AHP is a widely used method for estimating weights for complex problems. With its logical framework, AHP allows to estimate weight of multiple conflicting criterions with consistency check. AHP organizes complex priorities and analyze them for decision making using hierarchy-based approach. AHP utilizes Pair-wise Comparison Matrix (PCM) for estimating weights.



G-MCDA allows easy implementation of AHP through web-based interface. The importance of criterions is assigned through a comparison matrix. The relative importance of criterions is to be assigned by assigning a numerical value (between 1 and 9, 9 indicates the highest importance) to the top right of the matrix, the lower half is estimated automatically. The Consistency Ratio (CR) can be checked by clicking on the button 'Calculate'. It should be ensured that CR is less than 0.1 for consistent weight estimation.

3. Data

G-MCDA provides two options, i.e., GEE-based and user-based, to define data for criterions. The GEE plug-in of the tool allows to use 10 kinds of data that are partially processed on GEEs cloud. In most of the cases, these data are enough to produce site suitability map with reasonable accuracy for spreading MAR methods. However, in case the site suitability mapping is done for subsurface MAR methods, such well injection, few data of aquifer storage and yield may be required. Such data can be easily uploaded.

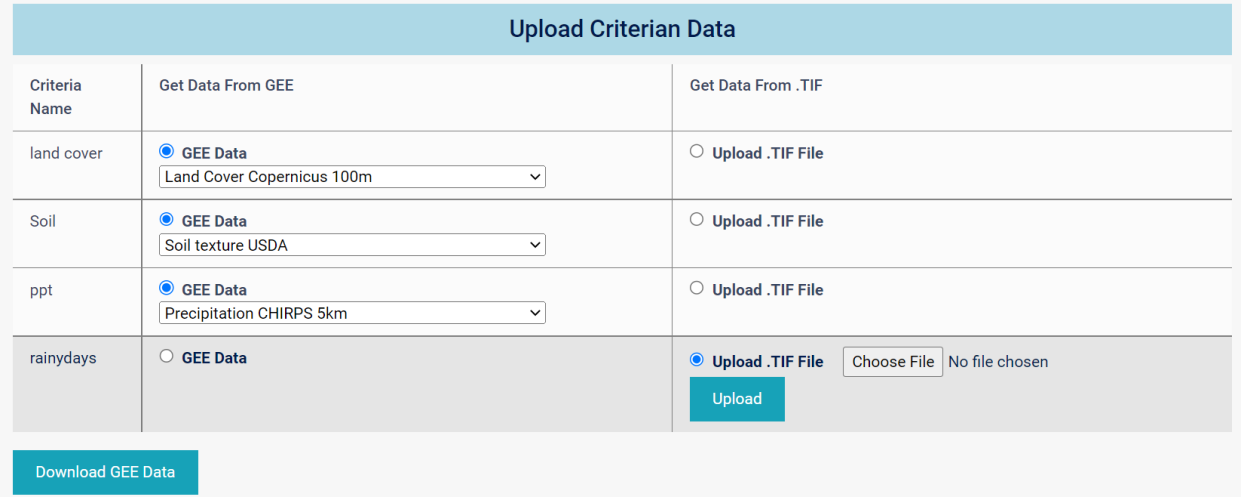
The data that are available from GEE are listed in the table with the links to get more details about their specifications and accuracy.

Sr. No.	Data ID	Description	Link to get more information
1	Land Cover Copernicus 100 m	Land cover map of 100 m resolution	https://developers.google.com/earth-engine/datasets/catalog/COPERNICUS_Landcover_100m_Proba-V-C3_Global

2	Precipitation CHIRPS 5 km	Annual precipitation at 5 km resolution derived from daily precipitation data of Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) from 2011 to 2020	https://developers.google.com/earth-engine/datasets/catalog/UCSB-CHG_CHIRPS_DAILY
3	Rainydays CHIRPS 5 km	Average number of rainy days at 5 km resolution counted from daily precipitation data of CHIRPS from 2011 to 2020	https://developers.google.com/earth-engine/datasets/catalog/UCSB-CHG_CHIRPS_DAILY
4	Slope srtm 90 m	Slope derived from SRTM 90 m data set	https://developers.google.com/earth-engine/datasets/catalog/CGIAR_SRTM90_V4
5	Population GPWv411	Gridded Population Version 4 (GPWv4), Revision 11	https://developers.google.com/earth-engine/datasets/catalog/CIESIN_GPWv411_GPW_National_Identifier_Grid
6	TWS GRACE Monthly Mass Grids - Land	GRACE-based monthly anomaly of TWS for the year 2016.	https://developers.google.com/earth-engine/datasets/catalog/NASA_GRACE_MASS_GRIDS_LAND
7	Soil texture USDA	Soil texture data (USDA system) developed by EnvirometriX Ltd.	https://developers.google.com/earth-engine/datasets/catalog/OpenLandMap_SOL_SOL_TEXTURE-CLASS_USDA-TT_M_v02
8	Significant Sens slope of ppt - CMIP5 RCP4.5	Significant Sen's slope of precipitation during 2021 to 2040 derived from NASA Earth Exchange Global Daily Downscaled Climate Projections.	https://developers.google.com/earth-engine/datasets/catalog/NASA_NEX-GDDP
9	Significant Sens slope of rainydays - CMIP5 RCP4.5	Significant Sen's slope of number of rainydays during 2021 to 2040 derived from NASA Earth Exchange Global Daily Downscaled Climate Projections.	https://developers.google.com/earth-engine/datasets/catalog/NASA_NEX-GDDP
10	Distance from river - Hydroshed River-based	Distance from pixel to river cell derived from river network data of HydroSHEDs.	https://developers.google.com/earth-engine/datasets/catalog/WWF_HydroSHEDS_v1_FreeFlowingRivers

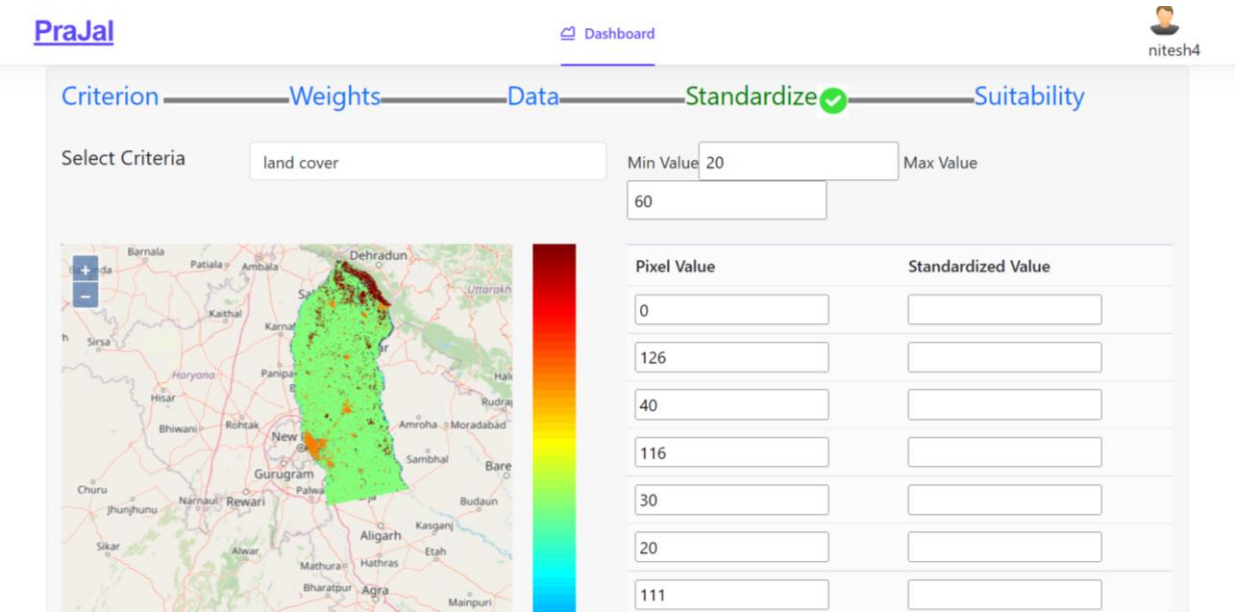
To use GEE data, select GEE option and select the data to be used against the criteria from the dropdown. Similarly, to upload thematic later, use upload .TIF File option and choose tif file from your computer and upload.

Click on Download GEE data to start downloading. Once the process is finished, list of all downloaded files can be seen. Click on Refresh List to see recently downloaded files.



4. Standardize

Standardization is an important step in MCDA. Since each criterion data is at different scale and reparents different numeric ranges, standardization of these data is required for overlay analysis. To make the criteria layer uniform, these data sets are reclassified to standard values. In G-MCDA, the values are reclassified to values between 0 and 1, wherein the importance increases from 0 to 1. The data are classified into two categories, discrete and continuous. Data with few classes, such as land cover and soil, are classified as discrete data. While, data that can have any value between some given ranges are classified as continuous data. Standardization of both kinds of data are delt differently. In case of discrete data, each value is to be assigned with a standard value (between 0 and 1), while ranges of standard values can be assigned to continuous data. A linear function is applied to continuous data based on the user specified standard value ranges.



5. Suitability

Suitability is calculated using weighted overlay analysis. The estimated weights are applied to the standardized data in a GIS framework and final suitability map is derived. The suitability map indicates values between 0 and 100 where 100 is being the most suitable pixel for MAR implementation.