

User guide of Google Earth Engine based Analytical Hierarchy Process (AHP) Tool

(focusing on landfill site suitability analysis of Dhapa landfill site, Kolkata)

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This user guide is designed for GEE-based AHP tool developed by Bhattacharya et al. (2022).

1. Background

Kolkata is one of the largest metropolitan cities in India. The amount of Municipal Solid Waste (MSW) generation in the city is about 3500-4500 MT/Day (KMC, 2019). Dhapa being the main dumping ground for Kolkata Municipal Corporation (KMC) accepting waste from the aforementioned organization and private haulers, have been in use since 1881 as an open dumping ground when India was still under British rule. Continuous waste disposal has been going on due to which steep, unstable slopes, uncontrolled leachate accumulation and runoff into nearby water bodies and groundwater, and uncontrolled release of biogas have become a common occurrence. When this Biogas comes in contact with oxygen, it ignites spontaneously and causes fires (Chattopadhyay et al., 2018). Proper guidelines for setting up a landfill is to be established by the Central Pollution Control Board (CPCB) and West Bengal Pollution Control Board (WBPCB). In the absence of any such guidelines, alternative guidelines were recommended by Central Public Health and Environmental Engineering Organisation (CPHEEO). Going through the criteria from the CPHEEO report (CPHEEO, 2016) and correlating them, one can easily understand how Dhapa landfill site is violating many of the criteria set by CPHEEO and is still under use. The quality of normal leachates from the solid waste disposal site at Dhapa was found to have concentrations of solids, biochemical oxygen demand (BOD), chemical oxygen demand (COD), and chloride much higher than those permissible for discharge onto inland surface water (Mandal, 2007). The uncontrolled leakage of landfill leachate is continuously contaminating many groundwater reserves and surface water bodies around the Dhapa landfill site. Groundwater and surface water of this area are used as irrigation water for the nearby agricultural fields. Due to which diseases such as hepatitis, diarrhoea, vomiting, abdominal pain, dysentery, etc. have frequently occurred in most people living in Durgapur, Makaltala, Khanaberia areas around the Dhapa landfill site (De et al., 2016). In groundwater samples, heavy metal concentration was found in and around the Dhapa landfill site (Ali and Ahmad, 2019), confirming the leachate seepage from the openly dumped wastes. Fe, As, Cd, Cr, Hg, Pb all had concentrations above the desirable limit set by CPCB (Kumar and Puri, 2012). According to the CPCB criteria, finding alternative sites is a credible option that will provide a clean slate for most cities, on top of which engineered landfills can be built after scientific design. As for the case of Dhapa landfill site, its location alone dictates the necessity to relocate the landfill site to a new site. It is right in the vicinity of East Kolkata Wetlands, which was designated as a Ramsar site in early 2000.

Analytical hierarchy process (AHP) is one of the widely used techniques for various multi-criteria decision-making problems (Saaty 1980, Alanbari et al., 2014, Acharya et al., 2019) like landfill site suitability integrated with geospatial datasets. The incorporation of Big Data analytics, Cloud Computing and Earth Observation datasets to facilitate large-scale scientific applications in the field of Geosciences and Environmental sciences has revealed an easy-to-use approach to the extreme computational and storage challenges. This is hugely beneficial because now anyone can view and process those data without owning costly and powerful hardware as well as software. One such example is Google Earth Engine (GEE). GEE is a cloud-based service that is free for research purposes (Gorelick et al., 2017). Google's cloud-computing infrastructure is the backbone of the platform, and Google itself handles computations. All are automatically performed on the Central Processing Units (CPUs) and Graphics Processing Units (GPUs) of Google

(Gorelick et al., 2017). Since GEE was mainly developed and optimized for analysis on geospatial data, it can process large amounts of RS data in large geographical scales and long temporal coverage (Ravanelli et al., 2018). Thus, it is a great tool for analyzing regional or global-scale applications. Various datasets are already available within GEE, and users can also easily upload and use their datasets and scripts to generate the products on the fly (Kumar and Mutanga., 2018). GEE is a prime example of cloud computing with many inbuilt and native functions and commands that make it very simple to code. GEE has a lot of worked-out examples and an active community. It uses JavaScript (JS) and Python script which are very established and mature disciplines. GEE has many inbuilt functions and datasets, but the AHP has not been implemented as a native algorithm or developed by any researcher. In the paper (Bhattacharya et al., 2022), the AHP method has been developed in GEE environment using JS. Landfill suitability analysis as a case study has been taken up in the present study to highlight the technological prowess of GEE which may further help other environmental applications based on AHP.

A brief description about the functional connectivity is presented below (**Figure 1**). A detailed description can be found here (Bhattacharya et al., 2022).

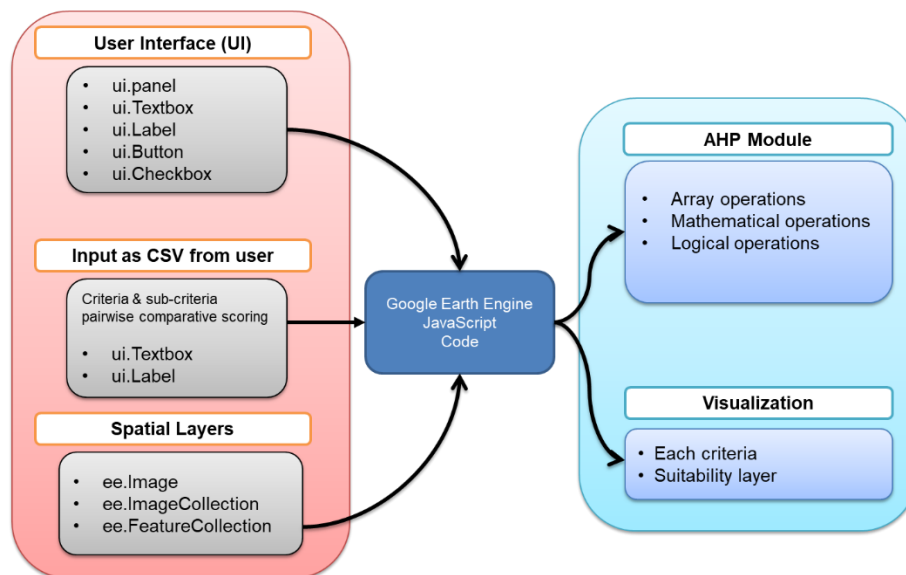


Figure 1 Connectivity between different sections of AHP tool

2. Step by step instructions

The code has been set for Kolkata Municipal Area. If the user wants to use this for other areas, corresponding criteria layers and boundary layers need to upload. Step by step instructions to use the UI (**Figure 2**) are demonstrated below to use the tool.

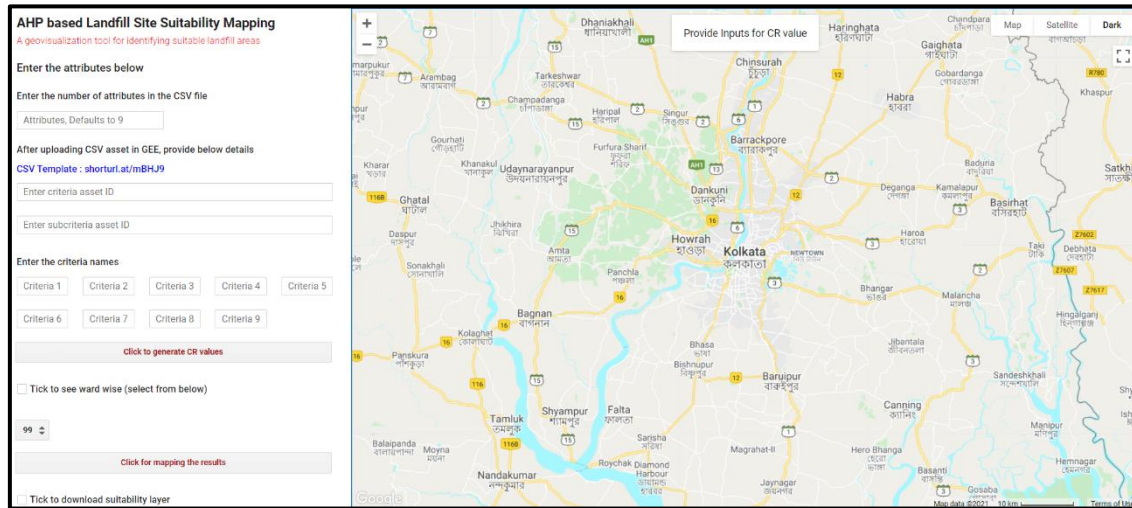


Figure 2 User interface of GEE based AHP tool

a) **File preparation and upload**

- 1) The user will have to assess the comparative importance of the criteria (Slope, Population, Precipitation, Temperature, distance to Road and Water bodies, etc.) taking all possible combination of two criteria at a time (e.g., Slope and Population, Slope and Precipitation, etc.). Accordingly score of 1-9 can be assigned to the criteria while comparing. 1 being of equal importance and 9 being of extreme importance with respect to the other criteria being used for the comparison (Table 1). For the Sub-criteria the pairwise comparison needs to be done on the basis of user-defined reclassification or ranges. For example, the population layer can be reclassified as 1-10, 10-50, 50-100 (say), these ranges will have different importance like a higher population near a landfill site is very unsuitable than a lesser population range thus given a score of 1.

Table 1 Pair wise comparison value and its significant

Intensity of importance	Definition	Explanation
1	Equal importance	Two criteria contribute equally to the alternative
3	Moderate importance	Experience and judgement slightly favour one over another criteria
5	Strong importance	Experience and judgement strongly favour one over another criteria
7	Very strong importance	One criteria dominates strongly over another
9	Extreme importance	One criteria dominates over another at the highest possible order
2,4,6,8	Intermediate importance	Represents compromise between the importance listed above

- 2) The matrix format for the pairwise comparison has been provided as a CSV file template with instructions (Figure 3 and 4). This has to be applied for both the main criteria and sub-criteria.
- 3) These CSV files will need to be uploaded to the GEE asset library by clicking on 'NEW' asset (Figure 5), selecting .CSV, providing the proper name to the asset, clicking on upload, after the ingesting part is completed in a few minutes, the asset will be ready to be called with a unique asset ID.

	SLOPE	POP	PRECIP	TEMP	WATER	POI	ROADS	Geomorphology	Soil			
SLOPE	1	2	2	2	2	2	2	2	2		C11	1
POPULATION	0.5	1	9	9	5	5	6	7	5		C12	2
PRECIP	0.5	0.11	1	5	3	3	3	5	3		C13	2
TEMP	0.5	0.11	0.2	1	3	3	3	3	3		C14	2
WATER	0.5	0.2	0.33	0.33	1	7	7	3	5		C15	2
POI	0.5	0.2	0.33	0.33	0.14	1	7	5	5		C16	2
ROADS	0.5	0.167	0.33	0.33	0.14	0.14	1	4	5		C17	2
Geomorphology	0.5	0.14	0.2	0.33	0.33	0.2	0.25	1	7		C18	2
Soil	0.5	0.2	0.33	0.33	0.2	0.2	0.2	0.14	1		C19	2
											C21	0.5
											C22	1
											C23	9
											C24	9
											C25	5
											C26	5
											C27	6
											C28	7
											C29	5
											C31	0.5
											C32	0.11

Figure 3 CSV Template for Main Criteria

Cell Loc	Slope	Pop	Precip	Temp	Water	POI	Road	Geomorph	Soil
C11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
C12	3.00	4.00	2.00	4.00	2.00	4.00	3.00	2.00	2.00
C13	7.00	8.00	6.00	6.00	6.00	8.00	7.00	8.00	7.00
C14	8.00	7.00	9.00	9.00	7.00	9.00	8.00	7.00	8.00
C15	9.00	8.00	8.00	8.00	8.00	8.00	9.00	9.00	9.00
C21	0.33	0.25	0.50	0.25	0.50	0.25	0.33	0.50	0.50
C22	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
C23	5.00	6.00	6.00	6.00	4.00	6.00	5.00	4.00	6.00
C24	6.00	7.00	5.00	7.00	5.00	7.00	7.00	6.00	5.00
C25	7.00	8.00	6.00	8.00	6.00	8.00	6.00	7.00	6.00
C31	0.14	0.13	0.17	0.17	0.17	0.13	0.14	0.13	0.14
C32	0.20	0.17	0.17	0.17	0.25	0.17	0.20	0.25	0.17
C33	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
C34	2.00	3.00	3.00	3.00	1.00	2.00	3.00	2.00	3.00
C35	3.00	2.00	2.00	4.00	2.00	3.00	5.00	3.00	3.00
C41	0.13	0.14	0.11	0.11	0.14	0.11	0.13	0.14	0.13
C42	0.17	0.14	0.20	0.14	0.20	0.14	0.14	0.17	0.20
C43	0.50	0.33	0.33	0.33	1.00	0.50	0.33	0.50	0.33
C44	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Figure 4 CSV Template for Submit-Criteria

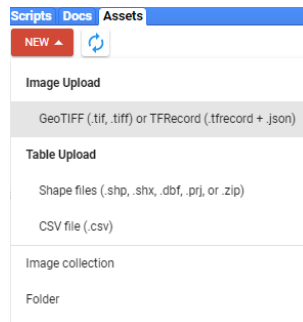


Figure 5 GEE asset upload window

b) **Criteria and Sub-criteria in the UI**

- 1) The user has the choice to run the Main AHP function using 3 to 9 Criteria. But by default 9 has been set for the present study. However, there is a scope to change the number of criteria or layers by altering the code for other AHP applications.
- 2) In the UI of the code, the first box asks the Number of Criteria the User is using (9 by default), next a download link is provided for a handy template to prepare the required CSV files as explained above (1b).
- 3) These CSV files then need to be uploaded as assets to the GEE Asset library, which will generate unique Asset IDs for each of the CSV files. These Asset IDs will need to be provided in the boxes 'Enter Main asset ID' and 'Enter subcriteria asset ID' for the Main AHP and sub-criteria AHP functions respectively (1c).
- 4) In the next step, the layer names (criteria) need to be input as per the CSV header names provided by the user. The boxes under the heading "Enter the criteria names" will need the criteria names (Slope, Population, etc.).

c) **Consistency ratio (CR) Check**

- 1) Next, the user can check if the CR value is less than 0.10 or greater than, by clicking on the button "Click AHP for Main Criteria", a dialogue box in the Map UI will tell if the CR value is less than or greater than 0.10.
- 2) If the user is satisfied and wants to proceed they can. For the time being, 0.10 has been set in the code as it is widely used but can be easily changed by editing the code.

d) **Area Selection**

- 1) Next, the user is given an option which when ticked will generate layers of the selected region (ward). If kept unticked (by default) layers for the whole area will be generated. If the box is ticked then the user has the option to select the regions from a dropdown list or they can also draw a rectangular boundary with Latitude, Longitude and buffer values for which Individual *Input Boxes* are also provided, note that to activate the rectangular boundary function, the below checkbox must be ticked.

e) **Layer Generation and Download**

- 1) The button "Click for mapping the results" is to be clicked to generate and visualise the suitability layer. The backend code will run the AHP based on the given criteria and sub-criteria. The AHP framework has been applied to input layers. In addition to the suitability layers, the input layers can also be visualized.
- 2) The "Tick to Download Suitability layer" button helps to download the suitability layer in Google drive in .tiff format.

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