

# Review of Input Selection Criteria; Comparison of Popular Methods Used In Water Stress Analysis

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## Abstract

*This paper examines input variables and their respective selection criteria intended for application in methodologies addressing water scarcity. It presents a comparative analysis of prominent approaches utilized in assessing water stress within urban contexts, such as the Analytic Hierarchy Process (AHP), Multiple Criteria Decision Making (MCDM), Geographic Overlay Decision (GOD), and System for Integrated Assessment of City Transformation towards Sustainability (SINTACTS). The principal aim is to scrutinize prevailing input parameters employed in water stress analyses, ensuring standardized accuracy and comprehensive coverage, particularly at the national level. The effectiveness of these methods is acknowledged at broader scales, suggesting finer-level applicability through careful consideration of data suitability, especially in diverse hilly terrains. Additionally, the paper discusses strategies to enhance the quality and precision of analyses to accommodate city and district-level assessments by harnessing highly precise spatial and non-spatial data. By offering a methodological framework that enhances the precision and dependability of water stress evaluations within urban landscapes, this review contributes pertinent insights to urban planning and water resource management*

**Keywords:** Water stress, AHP, MCDM, urban planning, water resource management.

## INTRODUCTION

Hydrologists have applied several methods such as GOD, Sintacts, Fuzzy logic, System dynamic modelling, AHP, and MCDM to water vulnerability assessments especially those related to micro-level urban environments [1]. In the present study assignment of weights and input selection criteria used in the previous studies for AHP related to MCDM has been discussed.

In this study, we initiate a rigorous investigation into the fundamental significance of input selection and weighting within the frameworks of AHP [2] (Analytic Hierarchy Process) and MCDM (Multi-Criteria decision-making) [3]. methodologies for evaluating urban water stress. Our attention is directed towards the process of input selection, which constitutes a pivotal yet frequently underappreciated phase in this analytical context.

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This review investigates the deliberate selection of input criteria that impact water stress within urban environments. Departing from generalized compilations, we meticulously scrutinize the pertinence, dependability, and responsiveness of each criterion to the distinct milieu of urban settings [4,5]. Our objective is to discern the most advantageous set of criteria, ensuring a thorough and precise depiction of water stress while mitigating the risk of information saturation.

It is evident from the literature review almost all the studies have used spatial data such as satellite images from USGS [6], sentinel [7], modis [8] sources. These open-source data are usually at a small scale i.e. 30m and below spatial resolution which is suitable for country-level analysis.

Further review was conducted and compared the methods such as AHP, MCDM, GOD [9] and SINTACTS used for water sustainability and water scarcity analysis.

Conclusively, an examination of prior research has been conducted concerning the selection of thematic dataset layers for input, encompassing both primary and secondary data. Emphasis has been placed on delineating criteria influencing the accuracy of the analytical process.

### REVIEW OF POPULAR METHODS RELATED TO WATER STRESS ANALYSIS

Hydrologists have employed various methodologies for assessing water vulnerability, particularly within micro-level urban settings. In this study, we compare input selection criteria among the three predominant methods: Geographical Overlay Decision (GOD), System for Integrated Assessment of City Transformation towards Sustainability (SINTACTS), and Multi-Criteria Decision Making (MCDM), as presented in Table 1 within the current discourse.

The comparison of input selection criteria in these methods is crucial for understanding their applicability and effectiveness in assessing water vulnerability in urban environments. By analyzing and contrasting the criteria utilized in GOD, SINTACTS, and MCDM, we can gain insights into the strengths and limitations of each approach, facilitating informed decision-making in water resource management and urban planning contexts. This comparative analysis contributes to advancing our understanding of water vulnerability assessment methodologies and enhances their utility in addressing the complex challenges of sustainable urban development.

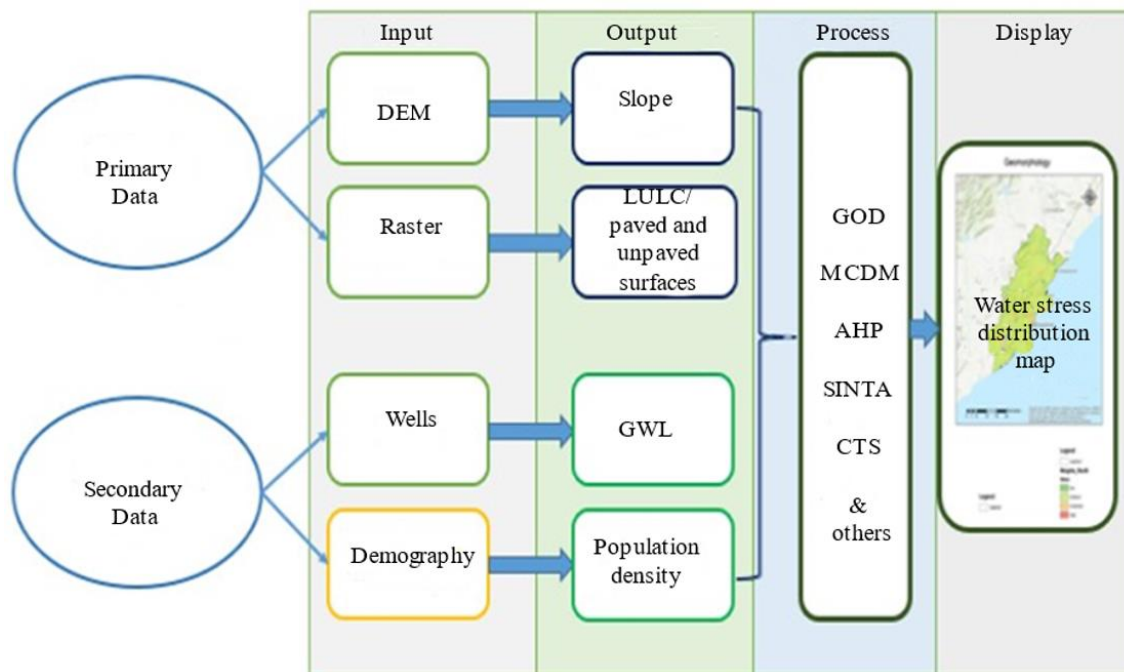
**Table 1.** Comparison of GOD, SINTACTS, MCDM and AHP Methods

Aspect	GOD	SINTACTS	MCDM	AHP
Methodology	Utilizes geographical overlay and mapping	Integrates various dimensions of city planning	Applies a systematic approach to evaluate options	Hierarchical structure to analyze complex decisions
Focus	Geospatial analysis at the local level	Comprehensive urban transformation assessment	Decision-making across multiple criteria	Prioritization and pairwise comparison of criteria
Data Integration	Incorporates diverse geospatial data sources	Integrates data on social, economic, and environmental aspects	Weighs and combines data from various criteria	Integrates subjective judgments into decision-making
Spatial Analysis	Emphasizes spatial relationships and patterns	Examines spatial impacts of urban development	Considers spatial implications in decision-making	Limited focus on spatial aspects, more on priorities
Sustainability Consideration	Addresses environmental sustainability issues	Evaluates sustainability across various dimensions	Considers sustainability in the decision process	Emphasizes on incorporating sustainability criteria
Decision Support	Supports decision-making based on spatial analysis	Aids in planning decisions for city transformation	Facilitates decision-making with multiple criteria	Provides a structured framework for decision support
Applicability	Suitable for localized geospatial analysis	Focused on assessing and guiding city transformations	Widely applicable to decision-making in various contexts	Applicable to diverse decision-making scenarios
User Involvement	Requires expertise in geospatial analysis	Involves stakeholders in city planning and decision-making	Requires user input in defining criteria and weights	Involves expert judgments in pairwise comparisons

Flexibility	Flexible in handling diverse spatial datasets	Adaptable to different urban contexts and objectives	Flexible in accommodating various decision scenarios	Versatile for handling different decision contexts
Limitations	Limited in assessing non-spatial factors	May face challenges in data availability and accuracy	Dependence on the accuracy of criteria and weights	Sensitive to subjective judgments and pairwise comparisons

### Methodology

Many scholarly inquiries concerning water sustainability and related analyses adhere to a straightforward methodology, as illustrated in *Figure 1*. Primary data sourced from entities such as USGS [6], Sentinel, MODIS, or analogous online repositories are collated and standardized to a uniform coordinate system [10]. Subsequently, these data are utilized to generate spatial grids with consistent extents, facilitating overlay analysis procedures.



**Figure 1.** Methodology of water stress analysis.

The primary datasets employed in Multi-criteria Decision-Making (MCDM) and other research endeavours encompass the following *Table 2*. These datasets are tailored for applications at small scales with relatively lower accuracy, rendering them suitable for country and state-level analyses [11] However, for assessments involving smaller areas, the acquisition of data from aerial platforms, high-resolution spaceborne platforms, or even low-flying Unmanned Aerial Vehicles (UAVs) [12,13] such as drones is imperative to attain heightened accuracy in surveys.

**Table.2.** Generic data sets used in water sustainability analysis

Dataset	Available Year	Dataset year	Resolution	Dataset catalogue name	Satellite Name
LULC	2021-2022	2022	10m	Copernicus global landcover layers: CGLS-LC100 Collection 3	Sentinel - 2
NDVI	1999-2021	2021 -04-01 to 2021-05-01		Landsat 7 collections 1 Tier 1 32 Day NDVI Composite	Sentinel -2
Global Surface	1984 - 2022	2022	30m	JRC Global Surface Water	JRC

water				Metadata v1.4	(Copernicus)
Population	2000-2020	2020	1km(30 arc sec)	GPWv411:UN Adjusted Population Density (Gridded Population of the World Ver 411)	NASA
Ground Water	2012-2022			CGWB	
Impervious Surface	1985 - 2018	2018	30m	Tsinghua From GLC year of change to Impervious Surface	NASA
Precipitation	2000 -2021	2020 -05-01 to 2020-06-05	11132 m	GPM: Monthly Global Precipitation Measurement	NASA
Geology	2018				GSI
Geo-morphology					
Soil	2018 -2023	2019-06-21 to 2019-06-28	55660 mtrs	NOAA NWS National Centers for Environmental Prediction(NCEP)	
Digital Elevation Model	2014		30m	SRTM	NASA
Evapotranspiration	2000-2020	2020	500m	("CAS?IGSNRR/PM L/V2_v017")	

Satellite data [6] selection for Multi-Factors Decision Making (MCDM) in water stress analysis involves evaluating criteria like spatial and temporal resolution, spectral bands, data accuracy, historical accessibility, mission characteristics, model compatibility, and open data policies. Similarly, Land Use Land Cover [14] (LULC) data selection focuses on resolution, classification accuracy, model compatibility, historical availability, and open accessibility. Normalized Difference Vegetation Index [15] (NDVI) data choice emphasizes temporal updates, spatial resolution, spectral bands, accuracy, model compatibility, historical data, and open access. Population data selection prioritizes temporal and spatial resolution, demographic details, accuracy, integration capabilities [16] and information. Precipitation [8] data should have high resolution, long-term availability, model interoperability, openness, consistency with environmental data, and accurate representation of local conditions [5]. These considerations enable precise analysis, supporting informed decision-making for water resource management and sustainability initiatives.

### REVIEW OF INDICATORS INFLUENCING WATER STRESS

It is recognized that the complete removal of water from watersheds, amounting to 100%, does not singularly signify water stress. The water resource vulnerability index emerges as an effective tool in highlighting water stress within watersheds, especially in cases of significant water utilization, as it heavily relies on withdrawal data.

**Table 3.** Criteria for water stress adaptation

Water stress	Indicator
Low or no water stress	: Less than 0.2% ( withdrawals from the available supply)
Medium water stress	: 0.2 to 0.4%
High water stress	: 0.4% and above

Anticipated future scenarios are contingent upon withdrawals, influenced by factors such as demographic shifts, drought occurrences, and the demands of domestic, industrial, and agricultural sectors. Standard water stress adaptation can be found in the table:3. The acceptance of using recycled wastewater for both drinking and other uses shows a positive attitude towards sustainable water management practices [17].

### Review of Factors Influencing The Criteria

Water stress, a condition characterized by a disconcerting incongruity between water demand and supply, is subject to multifaceted influences emanating from diverse environmental and anthropogenic

factors. In scholarly discourse, elucidating the nuanced impacts of these factors is pivotal for a comprehensive comprehension of the intricate dynamics governing water resource management. The following elucidates the influence of specific factors, namely:

*Groundwater recharge:* About the rate at which aquifers are replenished, groundwater recharge exerts a profound influence on the overall availability of subterranean water resources. Regions characterized by high recharge rates typically manifest heightened resilience to water stress, while those with diminished rates are predisposed to depletion and concomitant stress.

*Geomorphology:* The geological and topographical attributes of a given terrain exert discernible ramifications on water dynamics, significantly shaping the distribution and accessibility of water resources. Complex geomorphological features may engender spatial heterogeneity in water availability, precipitating localized instances of water stress.

*Slope:* The gradient of terrain imparts considerable influence on the dynamics of water runoff and infiltration, thereby modulating both surface water availability and groundwater recharge. Steep slopes often engender accelerated runoff, curtailing water retention and exacerbating downstream water stress dynamics.

*Groundwater level (Pre and Post):* Variations in groundwater levels, observed both antecedent and after specific events or interventions, serve as salient indicators of prevailing water stress dynamics. The pre-event groundwater levels furnish insights into extant stress conditions, while post-event fluctuations serve as proxies for the efficacy of mitigation measures or exacerbation of stress levels.

*Land Use land cover (LULC):* The configuration and utilization patterns of terrestrial landscapes exert pronounced influences on water availability and quality. Urbanization, agricultural practices, and deforestation can perturb hydrological regimes, amplifying water demand, and compromising the integrity of aquatic ecosystems, thus exacerbating water stress.

*Evapotranspiration:* A composite process encompassing surface evaporation and plant transpiration, evapotranspiration profoundly influences the net flux of water within ecosystems. Elevated rates of evapotranspiration in arid environs accentuate water stress by depleting available moisture, thereby constraining water availability for other consumptive uses.

*Impervious surface:* The extent of impermeable surfaces within a given landscape modulates the capacity for water infiltration and amplifies surface runoff. The predominance of impervious surfaces, particularly within urbanized settings, attenuates groundwater recharge rates and augments water stress through diminished aquifer replenishment.

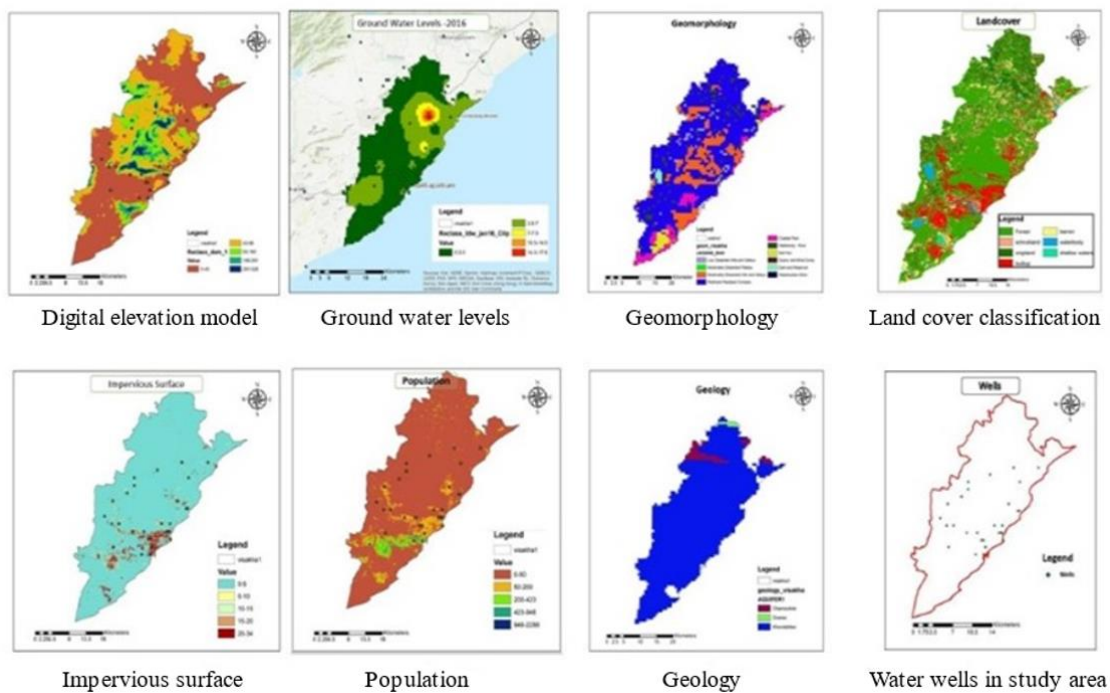
*Population:* Human demographic density engenders concomitant escalations in water demand, thereby exerting palpable pressure on water resources. Accelerated population growth rates precipitate heightened competition for finite water supplies, accentuating the prevalence and severity of water stress, particularly within densely inhabited locales.

*Elevation:* Altitudinal gradients exert discernible ramifications on precipitation patterns and water resource distribution. Higher elevations typically exhibit augmented precipitation regimes, while lower-lying regions are predisposed to water stress owing to diminished rainfall and heightened evapotranspiration rates.

*Stream order:* The hierarchical classification of riverine networks based on size and connectivity influences the magnitude and spatial distribution of water fluxes. Higher-order streams play pivotal roles in augmenting downstream water availability, thereby shaping the spatial manifestation of water stress dynamics within watershed contexts.

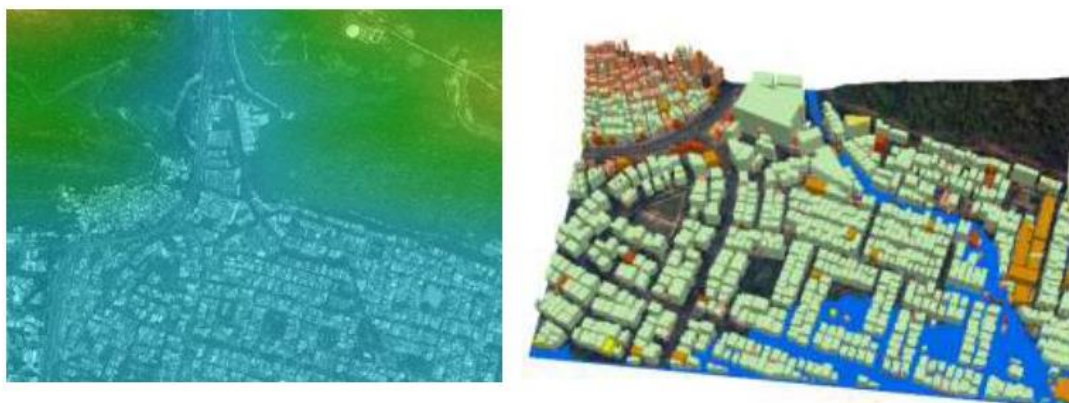
Scholarly dialogue emphasizes the necessity of thoroughly understanding the interaction among these factors to guide prudent water resource management approaches, thus alleviating the widespread threat of water stress in susceptible areas.

Graphical representation of some of the processed key factors are shown in Figure 2



**Figure 2.** Processed key inputs for water stress analysis.

The scale and resolution of the data are also an important factor for micro-level water stress analysis. An illustration of the distinction between small-scale and large-scale topography is depicted in Figure 3.



**Figure 3.** Contrast between small and large-scale topography.

In Multi-Criteria Decision Making (MCDM) for water stress analysis, selecting groundwater data involves assessing various factors such as spatial and temporal resolutions, aquifer characteristics, monitoring network density, data quality, historical availability, model compatibility, open accessibility, and inclusion of groundwater management information. Through meticulous evaluation

of these criteria, researchers ensure the chosen groundwater data effectively contributes to MCDM analyses, providing precise insights into water stress dynamics and facilitating informed decision-making in water resource management and sustainability endeavours.

Febres G explained a clear way to understand and measure how we observe and interpret different kinds of information, focusing on the detail level, overall view, and clarity of the information we see [18].

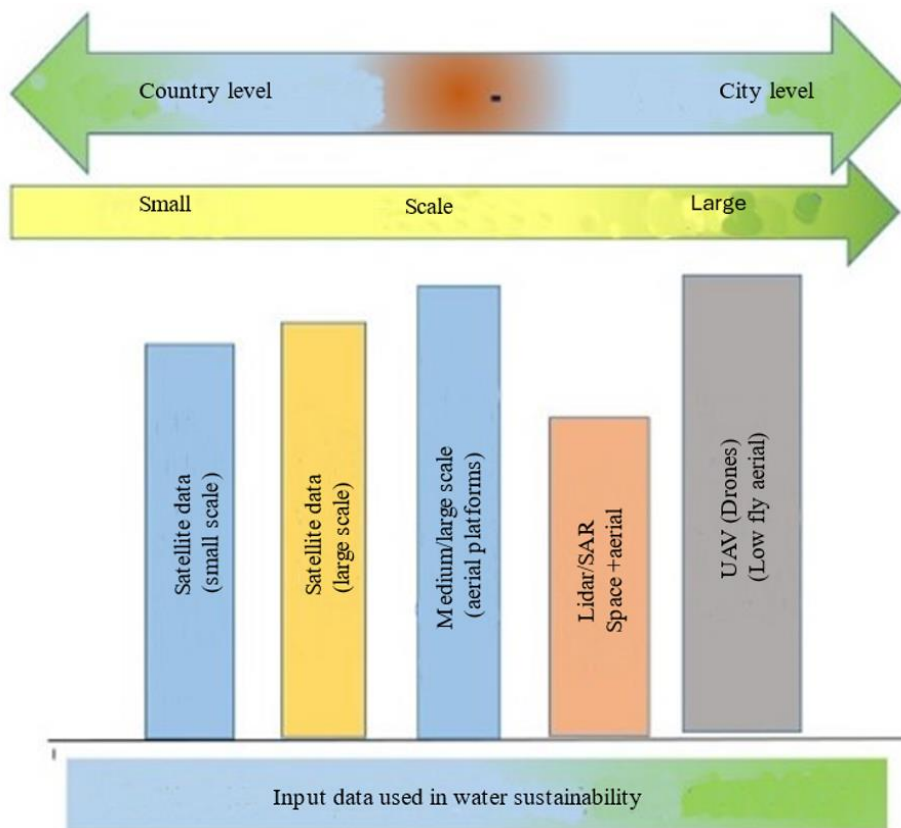
Siu-Ngan has discussed how the size and detail (scale and resolution) of maps and images from space affect our understanding of the Earth's surface, especially in geography and climate studies [19].

## **DISCUSSION AND CONCLUSION**

The scholarly community engaged in water stress and sustainability research utilizes data inputs from various sources such as USGS, Sentinel, MODIS (Remote et al., 2010), research institutions, and governmental organizations. However, it is noted that the data inputs for multi-criteria decision-making tend to be at a small scale, suitable only for broader geographic analyses such as country-level assessments *Figure 4*. To enhance the accuracy and quality of studies, there is a need for large-scale data obtained through aerial and terrestrial surveys.

Smith A studies how different uses of land and the size of the area we look at in models affect water distribution and the age of water using special models that track water movement and quality [20].

Yousefi P introduced a novel approach to converting low-detail information on water consumption into high-detail daily data for urban planners, employing specialized mathematical techniques. This methodology resulted in a remarkable accuracy rate exceeding 90% in forecasting water requirements, all without the necessity of utilizing costly equipment. This accomplishment represents a notable advancement in the realm of urban water resource management and city planning [21].



**Figure 4.** Data type and its level of utilization for water sustainability.

In summary, this review identified a significant advancement in urban water stress assessment through meticulous input selection and weighting. The refined framework ensures the incorporation of pertinent and dependable criteria, capturing the intricacies and nuances of individual urban contexts. Furthermore, it underscores the importance of precise weight allocation, accurately reflecting the influence of each factor within its specific context. Ultimately, this approach facilitates more precise, nuanced, and actionable assessments, empowering researchers and decision-makers to devise targeted interventions and implement sustainable water management strategies essential for addressing the escalating water stress crisis in urban areas. Moreover, it underscores the importance of considering the topography [22]. and demographics of the study area to ensure a comprehensive understanding of the real-world scenario translated into data for multiple criteria. It is imperative to reassess whether the data accurately represents the real-world scenario before presenting the outputs for analysis and decision-making.

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