APPENDIX B. SUITABILITY ANALYSIS

Suitability Analysis

Introduction

Suitability analysis is a method used to determine the most suitable location for a specific use. This project utilizes GIS-based suitability analysis to screen the most suitable locations for community resilience hubs. It also describes the methods and techniques that are used to carry out the suitability analysis, including the identification of criteria, subcriteria, and their suitability rating standardization. Subsequently, it provides preliminary suitability maps for community resilience hubs based on the information collected from the islandwide survey as well as other spatial data from publicly available online sources. The findings from the preliminary suitability analysis will be used to facilitate community workshops in phase II to screen locations for site selection and accordingly rank the candidate sites.

Literature review

As per Steiner et al. (2000), suitability analysis is the process of determining the fitness of a given tract of land for a defined use. The GIS-based suitability analysis has been used in a wide range of disciplines including suitability of land for agricultural purposes (Akıncı et al., 2013; Yalew et al., 2016; Zolekar & Bhagat, 2015), habitat suitability for animal and plant species (Buruso, 2017), landscape planning and evaluation (Uy & Nakagoshi, 2008) and environmental planning (Dai et al., 2001). While it is increasingly used for general site selection for public and private sector facilities (Chandio et al., 2011; Parry et al., 2018), there are very limited records of GIS based suitability analysis being used for the identification of sites for community resilience hubs.

The origin of GIS-based approaches to suitability analysis has their roots in the use of hand-drawn overlay techniques used in the late nineteenth century (Malczewski, 2004). With the advancement of computer and information technology, overlay procedures have become an integral part of many GIS applications (O'Sullivan and Unwin, 2003). The analysis of land-use suitability using overlays has become increasingly complex due to consideration of a variety of criteria, including natural and physical features as well as socio-economic and environmental impact implications (Polat, 2021). The selection of suitability criteria and method of suitability value standardization is the most important part in this process of analysis. One of the major criticisms of this approach is the irrelevant identification of suitability criteria and unverified underlying assumptions about criteria standardization (Malczewski, 2004). This limitation can be significantly removed by integrating GIS and multicriteria decision making (MCDM) methods (Feizizadeh & Blaschke, 2013; Malczewski, 2004; Polat, 2021) .

Polat (2012) outlines an approach of land use suitability assessment using a Multi-Criteria Decision Making process and GIS. The first step in the analysis process is to develop a model by building a hierarchy for analyzing the decision (Mu & Pereyra-Rojas, 2018). The first level of the hierarchy is the goal; for our project, selecting a site for a resilience hub. The second level of the hierarchy constitutes a set of criteria to be used for selecting the site. *USDN Guide to Developing Resilience Hubs* (2019) has provided a list of criteria for assessing possible resilience hub sites ranging from community support to the infrastructure requirements such as building conditions, access to resources, energy systems, etc. The criteria list often varies from project to project and will need to be identified based on the stakeholder inputs and ground situations. The process of identifying criteria is a crucial part of model building and should engage experts to ensure that all possible criteria and alternatives are considered (Mu & Pereyra-Rojas, 2018). Additional levels in the hierarchy may also be necessary in the form of sub-criteria based on expert and stakeholder consultation. The site selection criteria that are developed should align with project goals and should reflect the community for which the hub is planned for (Sandoval, n.d.). As per the guidelines from *USDN Guide to Developing Resilience Hubs* (2019), the services offered by the resilience hub may include following but not limited to:

- Food Preparation
- Food Storage
- Water & Ice
- Cooling/Heating
- Child Care
- Restrooms
- Showers
- Briefings & Meeting Space
- Response Coordination
- News & Information
- WiFi Access
- Basic Medical Care
- Medical Support
- Accessibility
- Logistical Support (first responders) - support for communications, mustering, etc.
- Transportation
- Counseling Support
- Logistical Support (community members) -communication with local, state and federal recovery agencies
- Sheltering
- Local Food Access
- Air Filtration

The next step in the model is to derive relative priorities (weights) for each of the identified criteria, measured with respect to each other. The identification of criteria will be discussed more in detail in the subsequent methodology section.

Simultaneously, the tentative list of candidate sites has to be identified based on the given set of site potential and threats. The suitability analysis allows the identified sites to be ranked according to their degree of suitability for a specific purpose (Polat, 2021). Identifying lists of prospective resilience hub sites should utilize community input and expertise in addition to the information from the suitability assessments (*USDN Guide to Developing Resilience Hubs*, 2019). The candidate sites for this study will be determined through an island-wide survey and community collaboration.

Methodology

Criteria for suitability Evaluation

Various factors are important for determining the suitability of land for community resilience hubs. It should be noted that the list of criteria can get exceedingly exhaustive, but for the purpose of this study, only those salient factors for which information is of great significance and those whose data are publicly available are considered. A total of six broad criteria were identified for carrying out the suitability analysis for community resilience hub. Each criteria is further divided into sub-criteria as deemed necessary. Community support plays an important role in site selection as community resilience hubs will be based on community led initiatives . Similarly, proximity to critical infrastructure is considered because the hub is expected to function as a support system with access to medical services, evacuation shelters, childcare services, and so forth, which requires community resilience hubs to be conveniently located within close proximity of the critical infrastructure. The other criteria being considered is hazard vulnerability, since a community resilience hub should be located on a site that is relatively less vulnerable to hazards. Next, transportation accessibility is considered to maximize the ease of access and to facilitate effective disaster response and recovery effort during emergencies. Finally, social vulnerability is considered to prioritize the ones that are most vulnerable to disasters. Fig. 1 shows the suitability analysis model for Community Resilience Hub along with the hierarchy of all the criteria and sub-criteria.

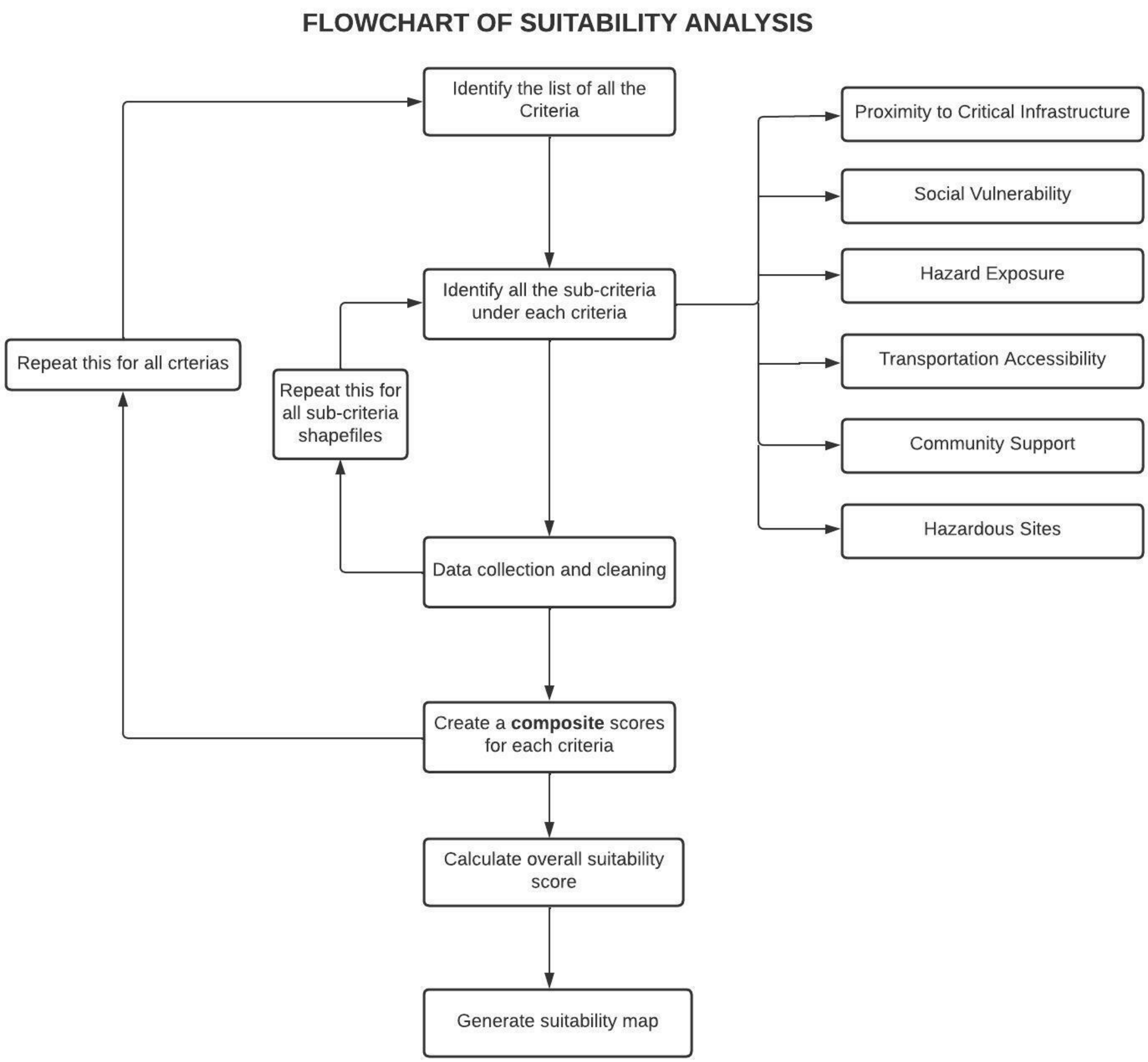


Figure 1: Suitability analysis model for Community Resilience Hub along with the hierarchy of all the criteria and sub-criteria.

Standardization of factor measurements

A primary step in a geo-spatial suitability analysis is to ensure standardized measurement values across all criteria and subcriteria (Dai et al., 2001). Since every criteria set used for the analysis holds a different unit system, these values have to be standardized to a uniform suitability rating. This study adopts the rating scale used by Dai et al. (2001) on a scale of 0 to 4. Table 1 shows the corresponding suitability interpretation for each standardized suitability rating.

Table 1: Suitability interpretation of standardized suitability rating

Standardized Value	0	1	2	3	4
Suitability Score	Very low	Low	Medium	High	Very high

The standardized rating and the suitability score are positively correlated. For example, the higher the rating for community support, the more suitable the site is for the resilience hub. Table 2 shows standardization of suitability ratings for all criteria and sub-criteria for identification of sites for community resilience hub in Oahu.

Table 2: Standardization of suitability ratings for all criteria and sub-criteria for identification of sites for community resilience hub.

Criteria	**Factors (Sub-Criteria)**	**Unit**	**4**	**3**	**2**	**1**	**0**	**Data Source**
Community	Community Support/Interest	%	90-100	80-90	70-80	60-70	<60%	Islandwide Survey
Proximity to Critical Infrastructure	Emergency medical facilities	Mile	<1	1-2	2-3	3-4	>4	Honolulu Open Geospatial Data
	Emergency Evacuation Shelter	Mile	<1	1-2	2-3	3-4	>4	Honolulu Open Geospatial Data
	Disaster response facilities	Mile	<1	1-2	2-3	3-4	>4	Honolulu Open Geospatial Data
	Food production Centers	Mile	<1	1-2	2-3	3-4	>4	Honolulu Open Geospatial Data
Hazard Vulnerability	Flood	Zone	X,	XS	D	A, AE, AH, AO	V, VE	Hawaii Statewide GIS Program
	Sea level rise exposure area (SLR-XA)	Exposure Category	Outside	Area 0	Area 1	Area 2	Area 3	PacIOOS (Pacific Islands Ocean Observing System)
	Tsunami Evacuation	Zone	3	-	2	-	1	Honolulu Open Geospatial Data
	Hurricane Storm Surge Inundation	Inundation Height	Outside	<2ft	2ft-4ft	4ft-6ft	>6ft	NOAA (National Oceanic and Atmospheric Administration)
Transportation Accessibility	Intersection density	Intersection/sq.mile	400-500	300-400	200-300	100-200	<100	The Housing and Transportation Affordability Index
	Bus stops (0.25 miles buffer)	%	>80	60-80	40-60	20-40	<20	Honolulu Open Geospatial Data

	Compact neighborhood score	HTA Score	8-10	6-8	4-6	2-4	<2	The Housing and Transportation Affordability Index
	Population density	Person/Mile	>7600	2800-7600	1700-2800	900-1700	<900	State of Hawaii Data Book
Social Vulnerability	Social Vulnerability Index	CDC SVI	0.8-1	0.6-0.8	0.4-0.6	0.2-0.4	0-0.2	CDC Social Vulnerability Index
Hazardous Sites	Brownfields	Mile	>2	1-2	0.5-1	0.12-0.5	<0.12	iHEER System
	Superfund	Mile	>7	5-7	3-5	1.8-3	<1.8	EPA Superfund search
	Resource Conservation and Recovery Act (RCRA sites)	Mile	>2	1-2	0.5-1	0.12-0.5	<0.12	EPA RCRA

Results – Suitability Maps

Community Support

Community support is an important factor to maintain the functionalities of resilience hubs. As such, an islandwide survey was carried out to understand the overall support level for the community resilience hub. The support levels are calculated based on the overall support percentage from an islandwide survey and spatially mapped based on neighborhood boards boundaries (Fig. 2).

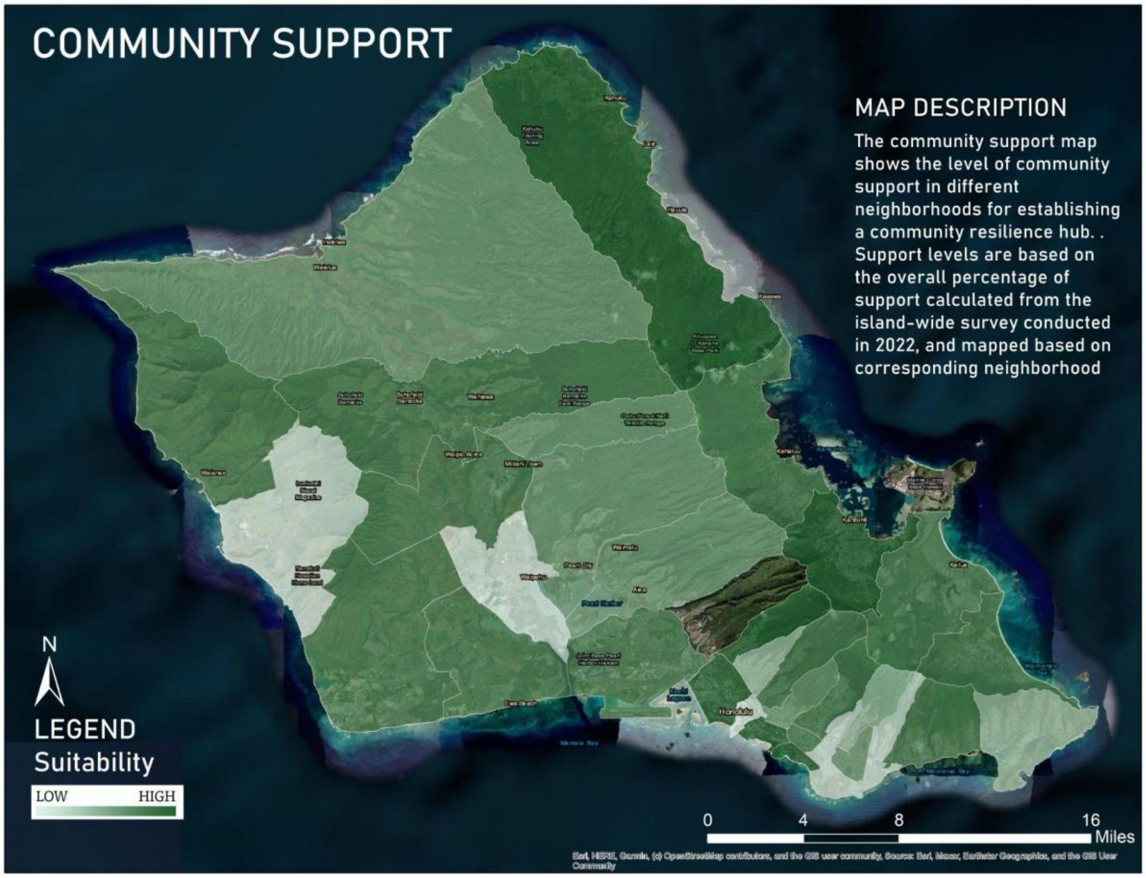


Figure 2: Community support suitability map for establishment of Community Resilience Hub by Neighborhood Boards

Proximity to critical infrastructure

Critical infrastructure forms a lifeline during the disaster response and recovery efforts. Four critical infrastructure types were identified as the crucial components for the functioning community resilience hub.

1. Emergency medical facilities
2. Emergency Evacuation Shelter
3. Disaster response facilities
4. Food production center

The geo-location for each of the facilities is spatially mapped in GIS across the island. Subsequently, multiple rings of buffer at 1, 2, 3, and 4 miles are created around each of the facilities. The closer the area is to the facility, the higher the suitability rating; the farther the area is from the facility, the lower the suitability rating. For the details of criteria standardization, refer to Table 2. Once all the individual maps with multi-ring buffers are completed, a composite map is created from the union of all the critical infrastructure facility maps. Fig. 3 shows how individual maps are overlaid to create the composite map.

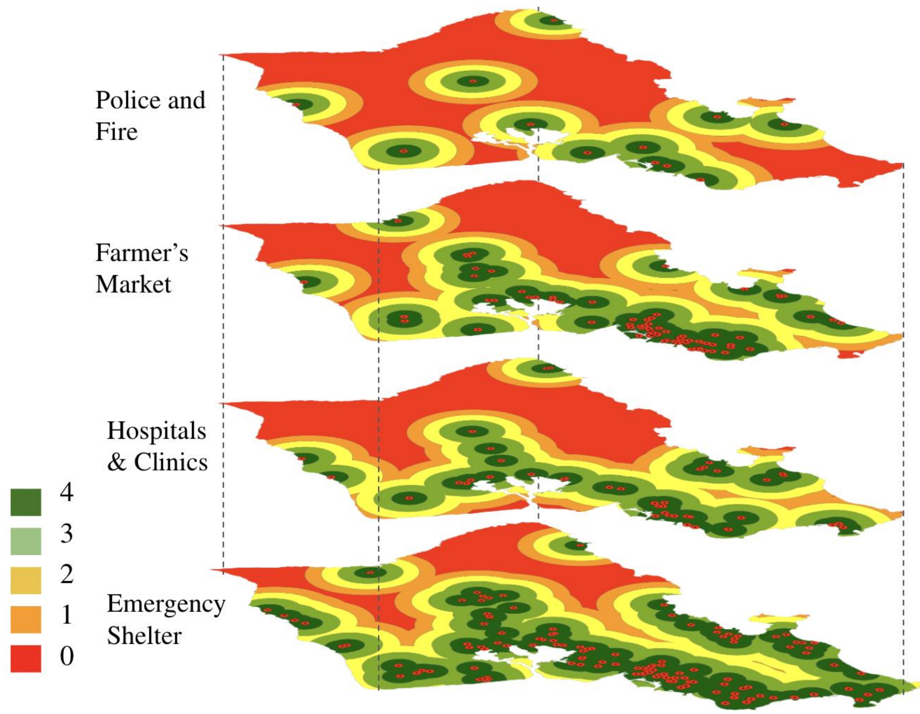


Figure 3: Overlay of individual sub-criteria maps to create the composite map for proximity to critical infrastructure

Fig. 4 shows the final suitability analysis map of Oahu for proximity to critical infrastructure criteria.

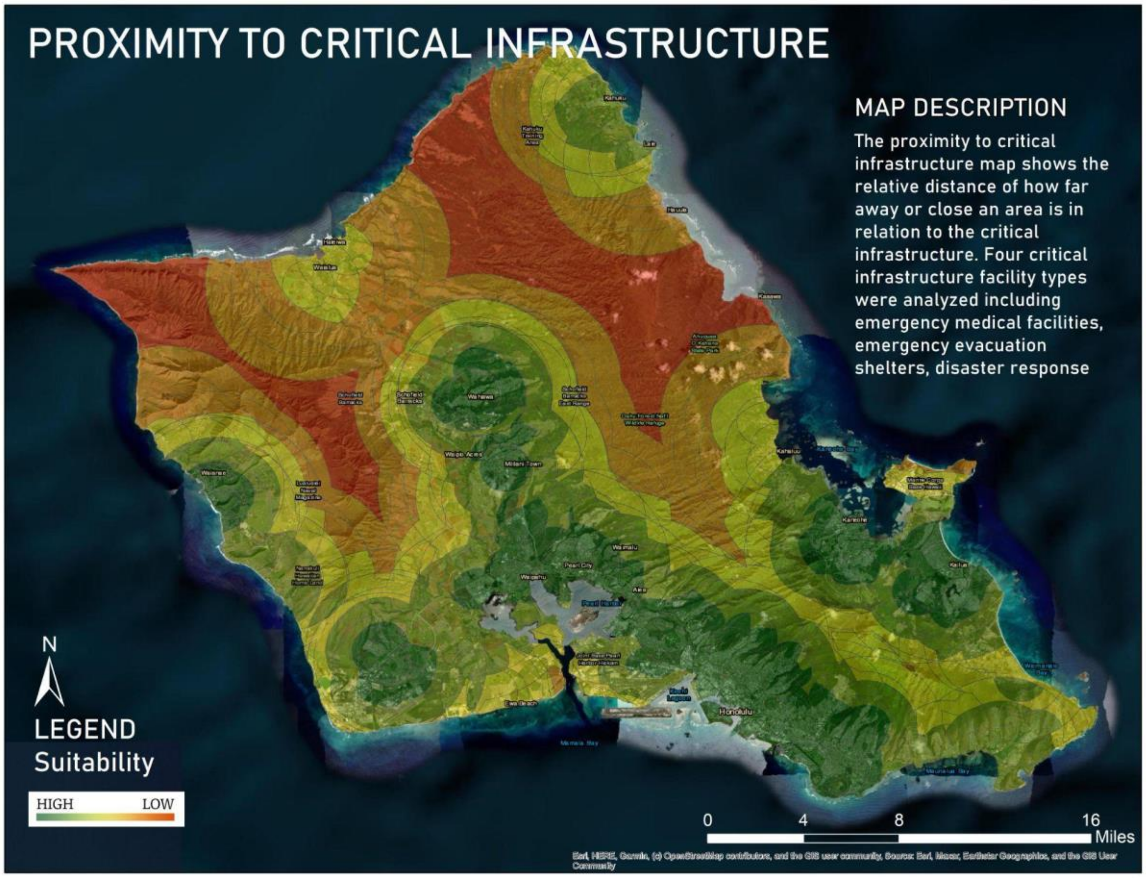


Figure 4: Proximity to critical infrastructure suitability map of Oahu.

Hazard Vulnerability

The third criteria that we considered for site suitability analysis for the community resilience hub is hazard vulnerability. A community resilience hub should be strategically located in areas that have minimum hazard exposure. The following hazard categories are considered under this category:

1. Flood
2. Sea level rise
3. Tsunami
4. Hurricane

Ola Oahu Resilience Strategy (2019) ranks these hazard categories as some of the top shocks that O'ahu is currently facing. The geo-spatial data for these hazard categories are obtained from various publicly available data sources. Subsequently, the hazard vulnerability scores are standardized to a uniform suitability rating (Table 2). Generally, the higher the hazard exposure, the lower the suitability rating and vice versa. Once hazard maps with standardized suitability ratings are completed, the individual maps are overlaid and a composite map is created using the union tool in ArcGIS. The Fig. 5 shows the maps overlays to create the composite map

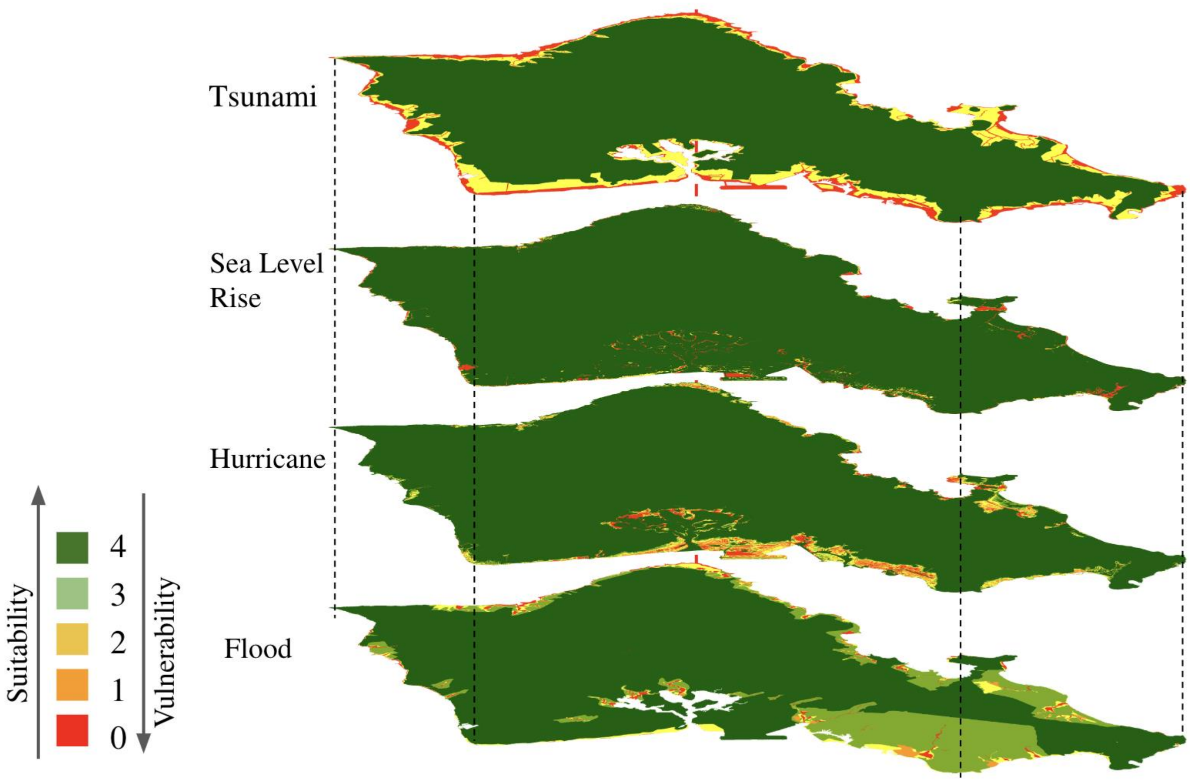


Figure 5: Overlay of individual sub-criteria maps to create the composite map for hazard vulnerability

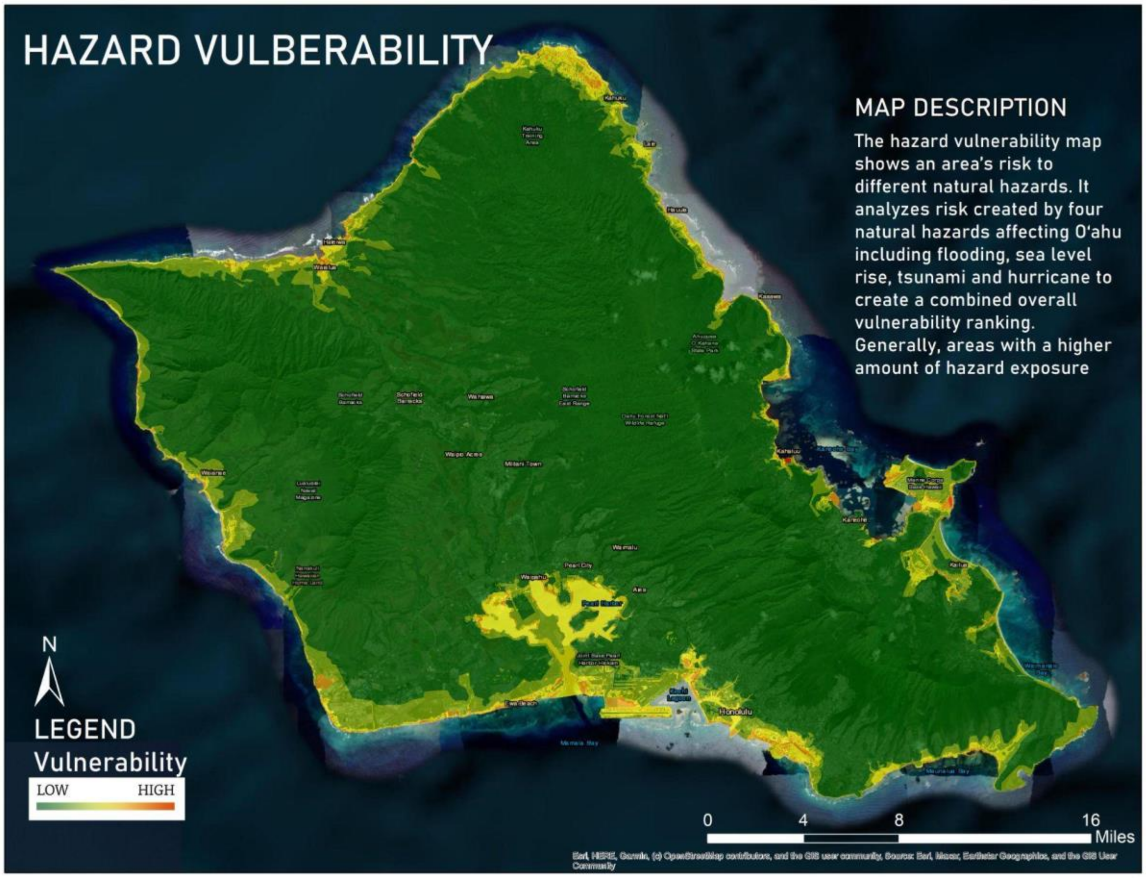


Figure 6: Hazard vulnerability suitability map of Oahu.

Transportation Accessibility

The transportation system is one of the most vital services to cities during disasters. The speed and success of response and recovery efforts are often determined by transportation accessibility (*Transportation Planning for Disasters*, n.d.). Therefore, it is of paramount importance that the location of the community resilience hub be situated in areas that are easily accessible. In analyzing the suitability in terms of transportation accessibility, we used intersection density, bus stop density, compact neighborhood rating, and population density. For standardization of suitability ratings, refer to Table 2. Generally, the higher the density of bus stops and compact neighborhood scores, the higher the suitability rating and vice versa. The Fig. 7 shows a composite map for transportation accessibility.

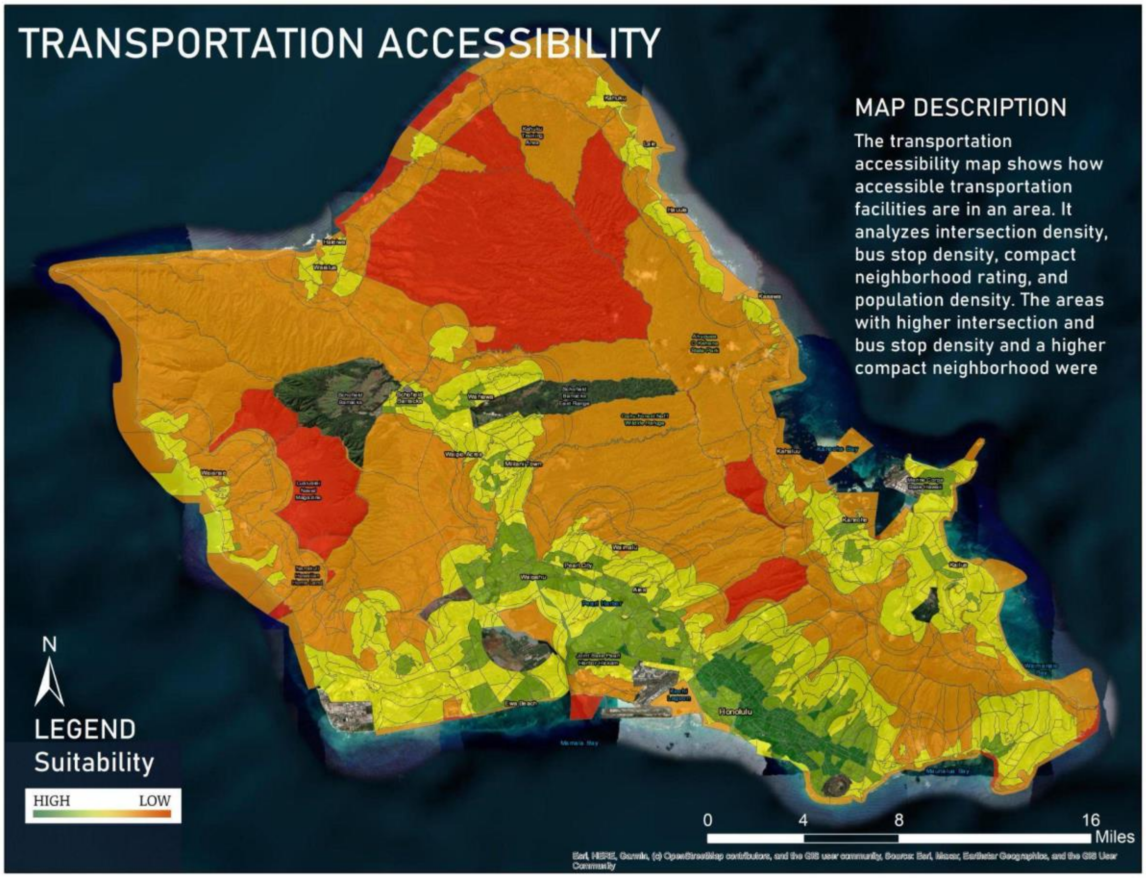


Figure 7: Transportation accessibility suitability map of Oahu.

Social Vulnerability

Social vulnerability refers to the socioeconomic and demographic factors that could potentially affect the resilience of communities against the external stresses. Studies have shown that socially vulnerable groups are more likely to be adversely affected and less likely to recover (Flanagan et al., 2011). We considered social vulnerability as the fifth criteria for assessing site suitability for community resilience hub. It adopts the social vulnerability index (SVI) prepared by the Center of Disease Control (CDC) against the U.S census tracts. SVI ranks the tracts on 15 social factors, including unemployment, minority status, and disability, and further groups them into four related themes (Fig. 8).

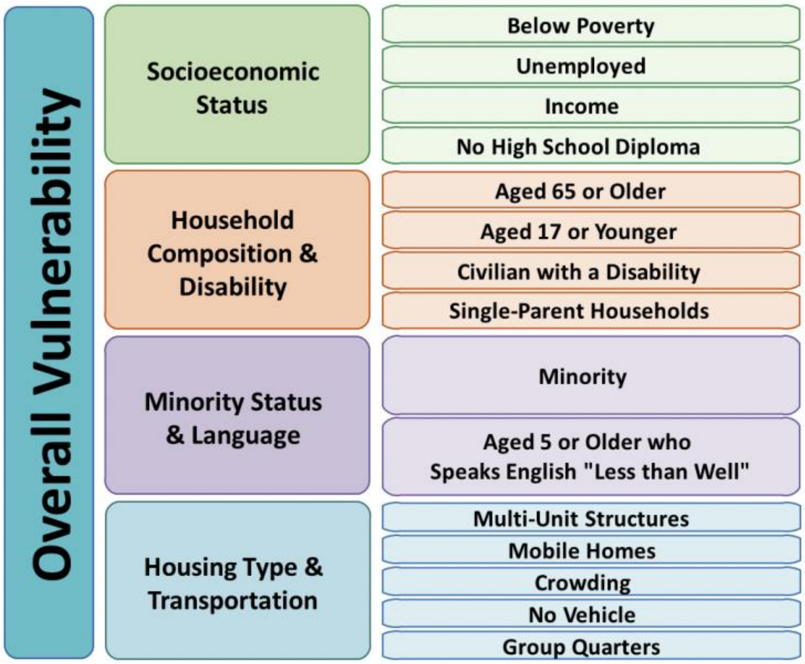


Figure 8: Variables used by CDC for calculation of social vulnerability (Source CDC/ATSDR Social Vulnerability Index (SVI), 2022)

For the suitability analysis, we used the calculated overall percentile rankings from the sum of each theme and map against the census tract of Honolulu county. Similar to other criteria, the rankings are then standardized to a standard suitability ranking. The Fig. 9 shows the suitability map of Oahu based on social vulnerability. The higher the social vulnerability index score, the higher the suitability ranking of a location.

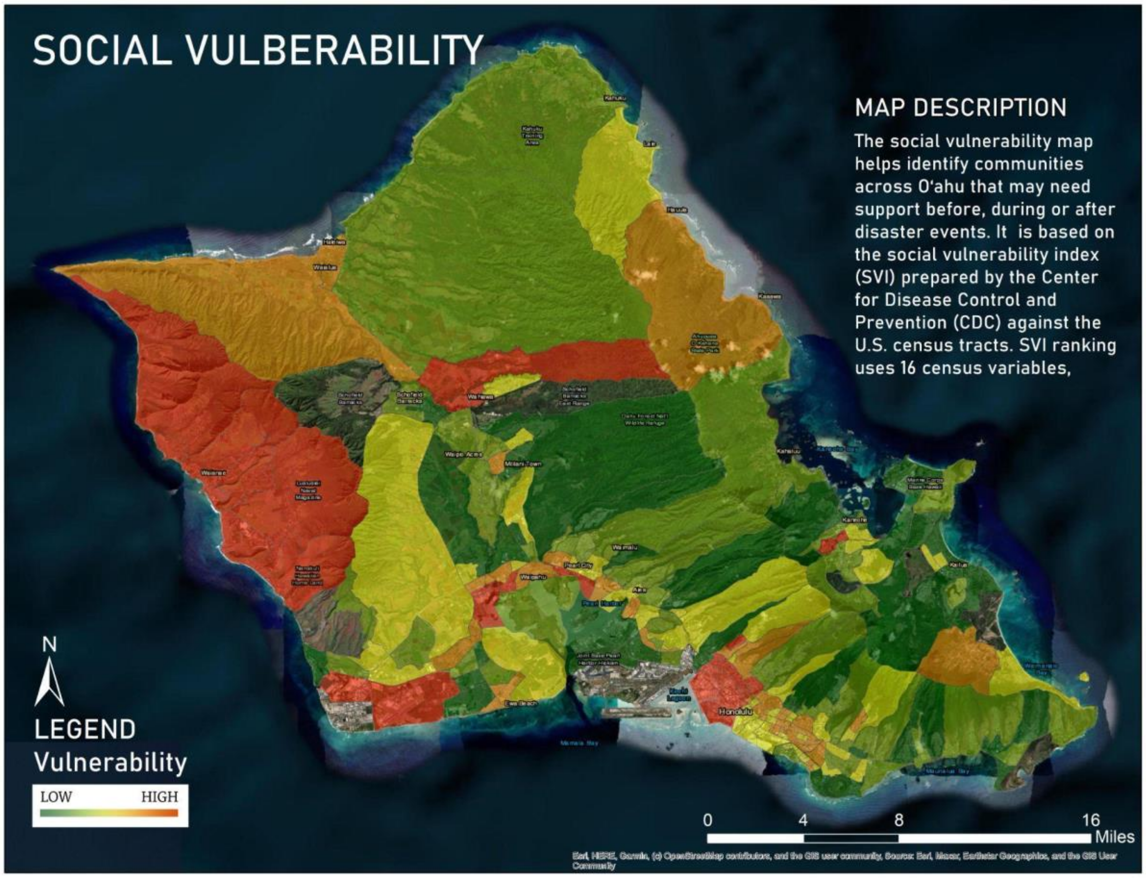


Figure 9: Social Vulnerability suitability map of Oahu

Hazardous Site Vulnerability

A place can be considered as a "hazardous site" due to different kinds of contamination. We considered superfund sites, brownfield, and Resource Conservation and Recovery Act Information (RCRAInfo) sites as hazardous sites and have potential harms to proximity facilities. Superfund sites are contaminated sites due to hazardous waste improperly dumped (EPA, 2022a). Empirical studies have noted residents living within the 1.8 miles boundary of a superfund have adverse health, property value, and quality-of-life impacts compared with residents living beyond 1.8 miles to a superfund (Mascarenhas, 2021). Therefore, we classified the areas in a scale of 0-4 based on their distances to superfunds (Table 3).

A brownfield is land that has previously been developed but currently abandoned due to contamination (Alker, 2000). A public law known as the Resource Conservation and Recovery Act (RCRA) establishes the foundation for the responsible management of both hazardous and non-hazardous solid waste. RCRAInfo, a nationwide program management and inventory system for hazardous waste handlers, contains information about hazardous waste. (EPA, 2022b). Since empirical studies show people live within 200 meters from brownfields or highways have significantly lower naïve T-cell production (Lodge et al, 2020), we set a scale of 0-4 based on this 200 meters threshold for brownfields and RCRAInfo sites (Table 3).

Factors (Sub-Criteria)	**Unit**	**4**	**3**	**2**	**1**	**0**
Brownfields	Mile	>2	1-2	0.5-1	0.12-0.5	<0.12
Superfund	Mile	>7	5-7	3-5	1.8-3	<1.8
Resource Conservation and Recovery Act Information (RCRAInfo sites)	Mile	>2	1-2	0.5-1	0.12-0.5	<0.12

Table 3: Hazardous sites sub-criterias and their scales classifications

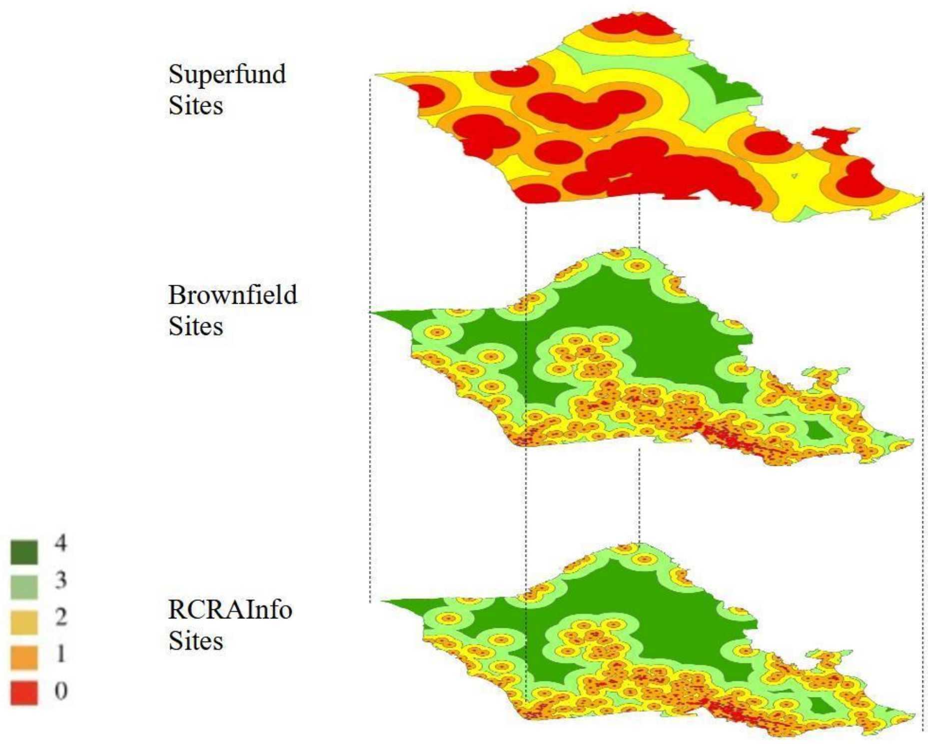


Figure 10. Overlay of individual sub-criteria maps to create the composite map for hazard sites

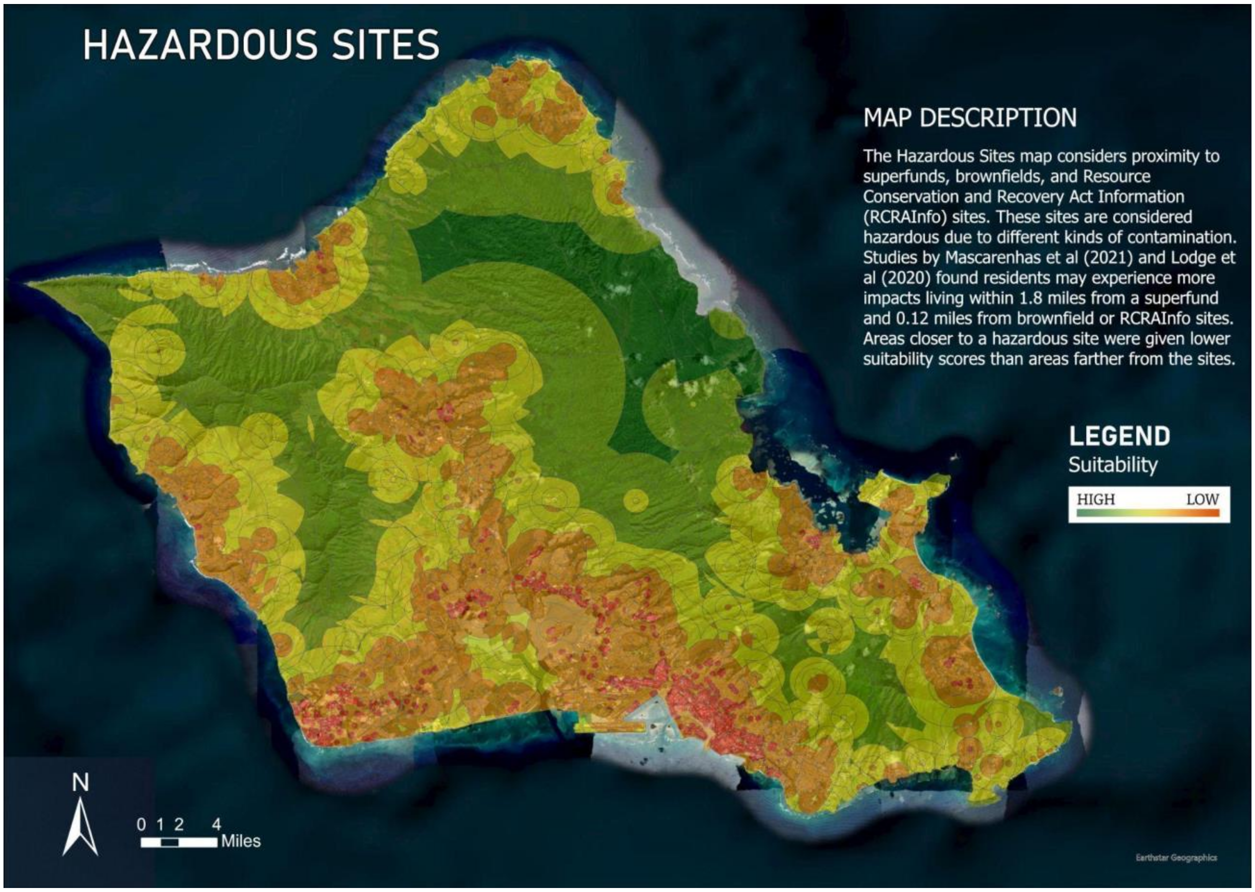


Figure 11: Hazardous sites suitability map of Oahu

Way forward

For the next step, these suitability maps along with zoom-in maps for each development plan areas, as well as rankings of potential community resilience hub locations identified by respondents in the islandwide survey will be made available to the public as a starting point of discussion in community workshops. The next step community engagement workshop will ask people to evaluate potential candidate sites and select their most preferred choices based on community knowledge of site conditions. People could also review the suitability maps and suggest additional locations if their preferred sites are not listed in the site ranking from survey results. In addition, the suitability maps will also be made available through online maps for people to find out the suitability ranking of their preferred sites and also give feedback on other candidate sites.

Reference

Alker, S., Joy, V., Roberts, P., & Smith, N. (2000). The Definition of Brownfield. Journal of Environmental Planning and Management, 43(1), 49–69. doi:10.1080/09640560010766

Akıncı, H., Özalp, A. Y., & Turgut, B. (2013). Agricultural land use suitability analysis using GIS and AHP technique. *Computers and Electronics in Agriculture*, *97*, 71–82. https://doi.org/10.1016/j.compag.2013.07.006

Buruso, F. H. (2017). Habitat suitability analysis for hippopotamus (H. amphibious) using GIS and remote sensing in Lake Tana and its environs, Ethiopia. *Environmental Systems Research*, *6*(1), 6. https://doi.org/10.1186/s40068-017-0083-8

CDC/ATSDR Social Vulnerability Index (SVI). (2022, June 13). https://www.atsdr.cdc.gov/placeandhealth/svi/index.html

Chandio, I. A., Matori, A.-N., Lawal, D. U., & Sabri, S. (2011). GIS- based Land Suitability Analysis Using AHP for Public Parks Planning in Larkana City. *Modern Applied Science*, *5*(4), p177. https://doi.org/10.5539/mas.v5n4p177

Dai, F. C., Lee, C. F., & Zhang, X. H. (2001). GIS-based geo-environmental evaluation for urban land-use planning: A case study. *Engineering Geology*, *61*(4), 257–271. https://doi.org/10.1016/S0013-7952(01)00028-X

EPA. (2022)a. What is Superfund? *United States Environmental Protection Agency.* https://www.epa.gov/superfund/what-superfund

EPA. (2022)b. RCRAInfo Overview. *United States Environmental Protection Agency.* https://www.epa.gov/enviro/rcrainfo-overview

Feizizadeh, B., & Blaschke, T. (2013). Land suitability analysis for Tabriz County, Iran: A multi-criteria evaluation approach using GIS. *Journal of Environmental Planning and*

Management, *56*(1), 1–23. https://doi.org/10.1080/09640568.2011.646964

Flanagan, B. E., Gregory, E. W., Hallisey, E. J., Heitgerd, J. L., & Lewis, B. (2011). A Social Vulnerability Index for Disaster Management. *Journal of Homeland Security and Emergency Management*, *8*(1). https://doi.org/10.2202/1547-7355.1792

Lodge, E. K., Engel, L. S., Ferrando-Martínez, S., Wildman, D., Uddin, M., Galea, S., & Aiello, A. E. (2020). The association between residential proximity to brownfield sites and high-traffic areas and measures of immunity. Journal of exposure science & environmental epidemiology, 30(5), 824-834.

Malczewski, J. (2004). GIS-based land-use suitability analysis: A critical overviewq. *Progress in Planning*, 63.

Mascarenhas, M., Grattet, R., & Mege, K. (2021). Toxic waste and race in twenty-first century America: Neighborhood poverty and racial composition in the siting of hazardous waste facilities. Environment and Society, 12(1), 108-126.

Mu, E., & Pereyra-Rojas, M. (2018). Understanding the Analytic Hierarchy Process. In E. Mu & M. Pereyra-Rojas, *Practical Decision Making using Super Decisions v3* (pp. 7–22). Springer International Publishing. https://doi.org/10.1007/978-3-319-68369-0_2

Ola Oahu Resilience Strategy. (2019). *Ola Oahu Resilience Strategy*. CIty and County of Honlulu.

Parry, J. A., Ganaie, S. A., & Sultan Bhat, M. (2018). GIS based land suitability analysis using AHP model for urban services planning in Srinagar and Jammu urban centers of J&K, India. *Journal of Urban Management*, *7*(2), 46–56. https://doi.org/10.1016/j.jum.2018.05.002

Polat, E. (2021). *An Approach for Land- Use Suitability Assessment Using Decision Support*

Systems, AHP and GIS An Approach for Land-Use Suitability Assessment Using Decision Support Systems, AHP and GIS.

Transportation Planning for Disasters: An Accessibility Approach. (n.d.). https://doi.org/10.1068/a35195

USDN Guide to Developing Resilience Hubs. (2019). Urban Sustainability Directors Network.

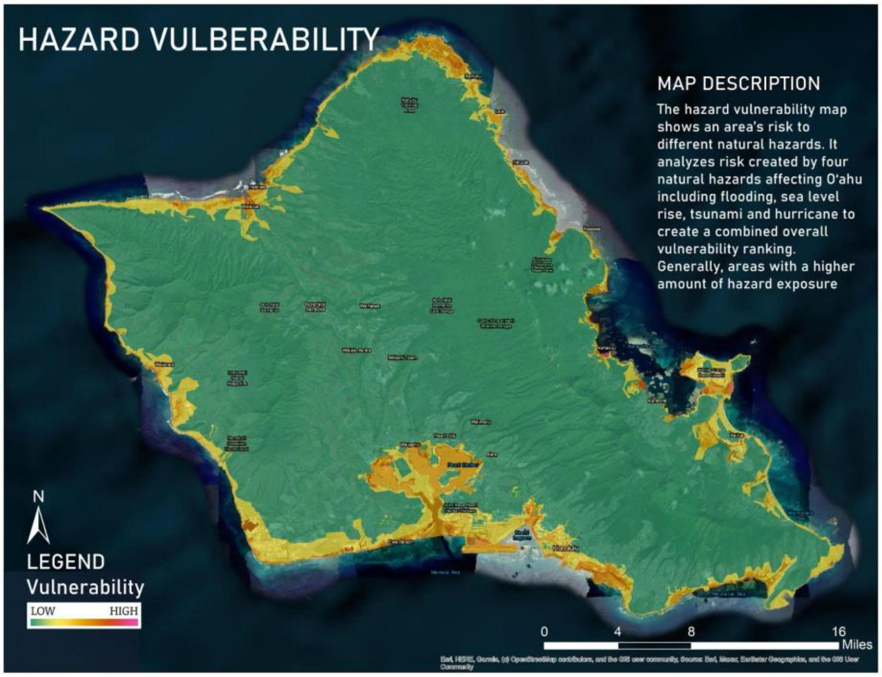
Uy, P. D., & Nakagoshi, N. (2008). Application of land suitability analysis and landscape ecology to urban greenspace planning in Hanoi, Vietnam. *Urban Forestry & Urban Greening*, *7*(1), 25–40. https://doi.org/10.1016/j.ufug.2007.09.002

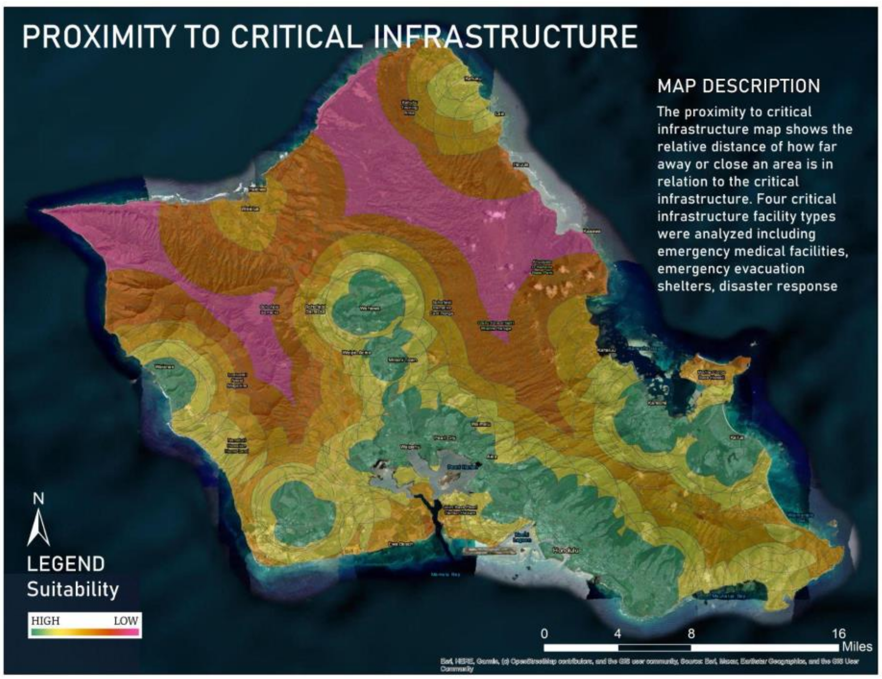
Yalew, S. G., van Griensven, A., Mul, M. L., & van der Zaag, P. (2016). Land suitability analysis for agriculture in the Abbay basin using remote sensing, GIS and AHP techniques. *Modeling Earth Systems and Environment*, *2*(2), 101. https://doi.org/10.1007/s40808-016-0167-x

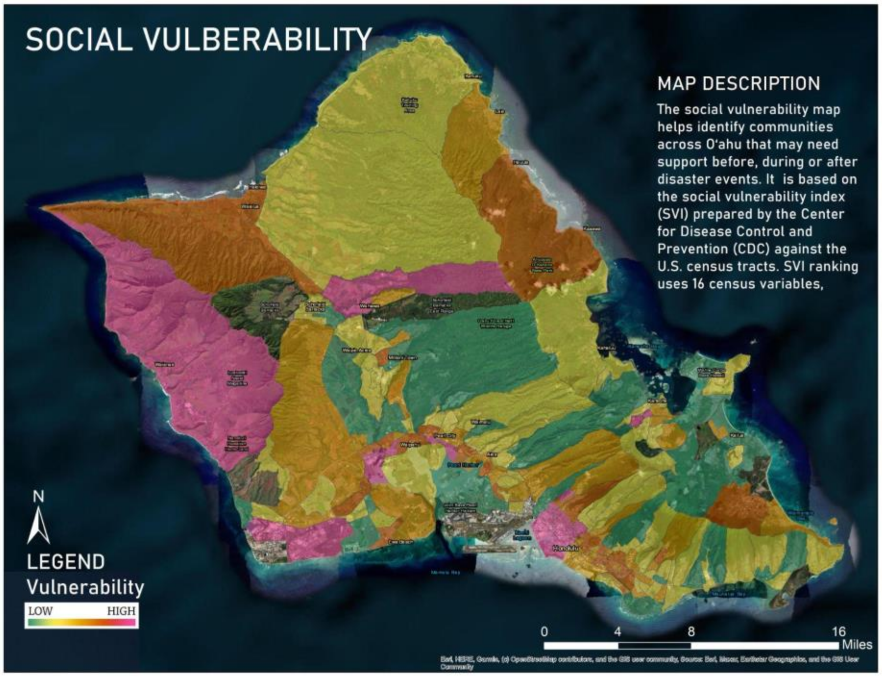
Zolekar, R. B., & Bhagat, V. S. (2015). Multi-criteria land suitability analysis for agriculture in hilly zone: Remote sensing and GIS approach. *Computers and Electronics in Agriculture*, *118*, 300–321. https://doi.org/10.1016/j.compag.2015.09.016

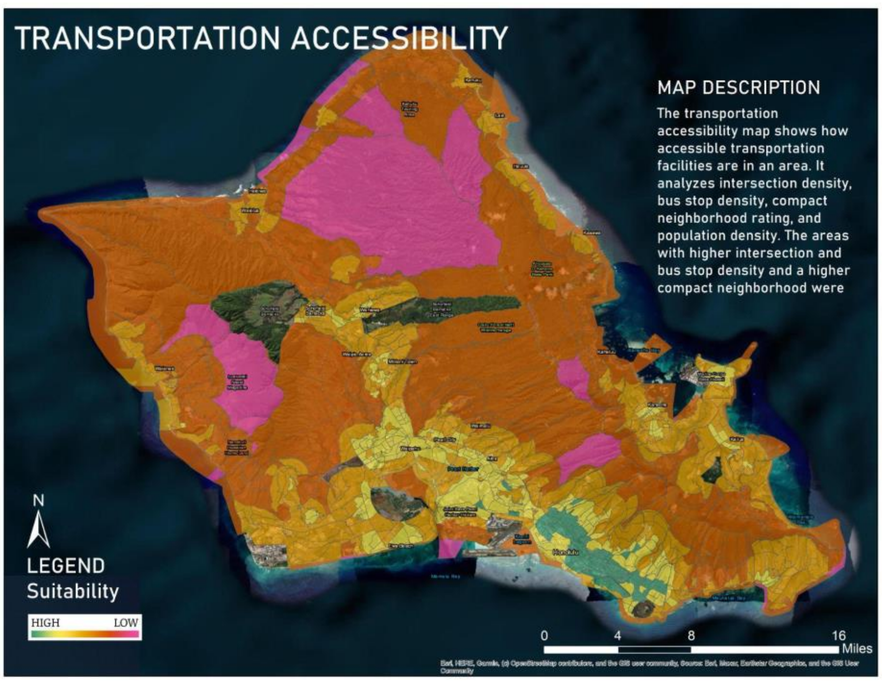
Appendix A

The appendix A contains the same suitability analysis maps included above in the color blind version.

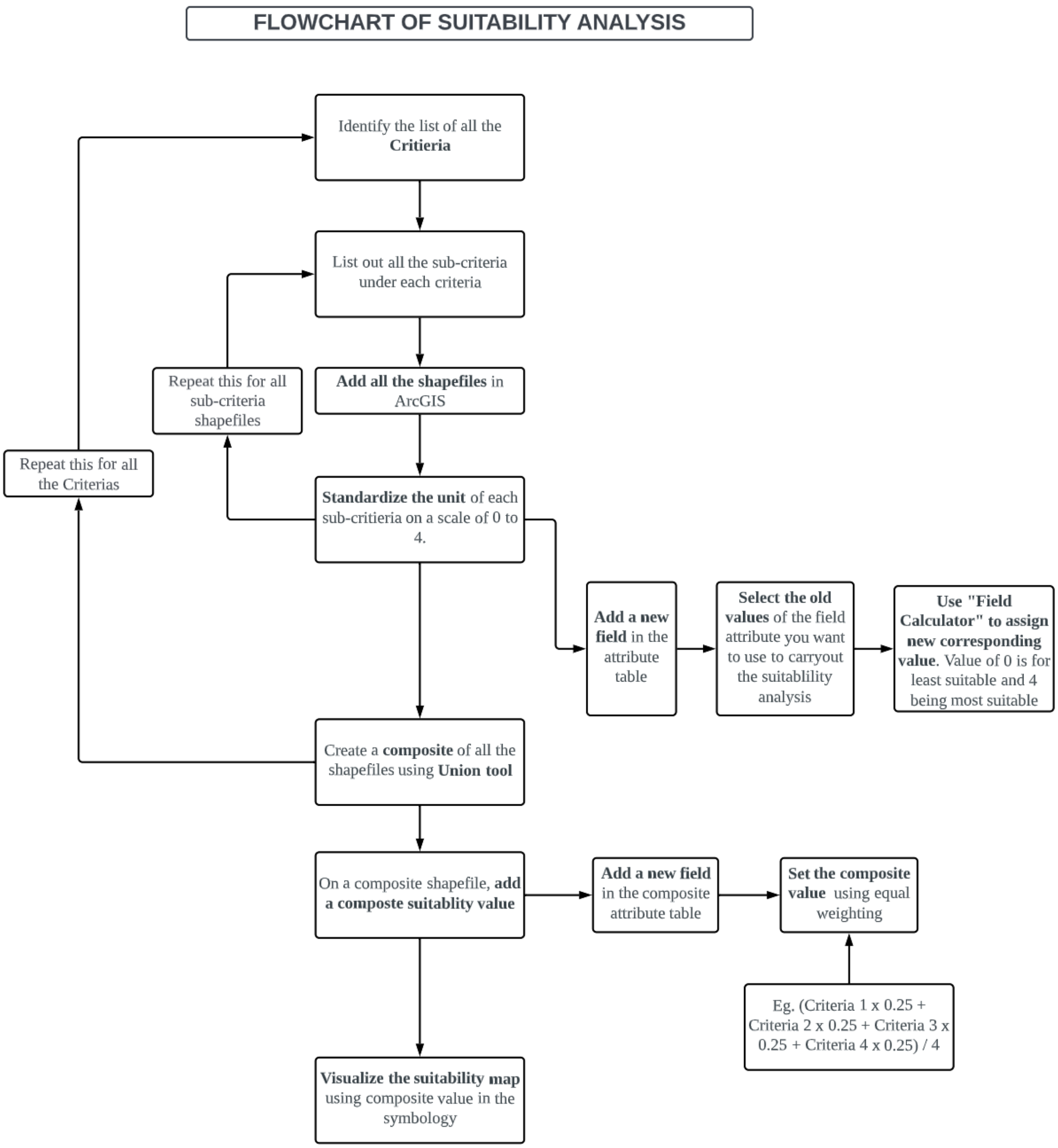





SOCIAL VULBERABILITY
MAP DESCRIPTION
The social vulnerability map helps identify communities across O'ahu that may need support before, during or after disaster events. It is based on the social vulnerability index (SVI) prepared by the Center for Disease Control and Prevention (CDC) against the U.S. census tracts. SVI ranking uses 16 census variables,
N
LEGEND
Vulnerability
LOW
HIGH
0
4
8
16
Miles


TRANSPORTATION ACCESSIBILITY
MAP DESCRIPTION
The transportation accessibility map shows how accessible transportation facilities are in an area. It analyzes intersection density, bus stop density, compact neighborhood rating, and population density. The areas with higher intersection and bus stop density and a higher compact neighborhood were
N
LEGEND
Suitability
HIGH
LOW
0
4
8
16
Miles

Appendix B


FLOWCHART OF SUITABILITY ANALYSIS
Identify the list of all the Critieria
List out all the sub-criteria under each criteria
Add all the shapefiles in ArcGIS
Repeat this for all sub-criteria shapefiles
Repeat this for all the Criterias
Standardize the unit of each sub-critieria on a scale of 0 to 4.
Add a new field in the attribute table
Select the old values of the field attribute you want to use to carryout the suitablility analysis
Use "Field Calculator" to assign new corresponding value. Value of 0 is for least suitable and 4 being most suitable
Create a composite of all the shapefiles using Union tool
On a composite shapefile, add a composte suitablity value
Add a new field in the composite attribute table
Set the composite value using equal weighting
Eg. (Criteria 1 x 0.25 + Criteria 2 x 0.25 + Criteria 3 x 0.25 + Criteria 4 x 0.25) / 4
Visualize the suitability map using composite value in the symbology