Are Nuclear Power Plants in Japan Built in Optimal Locations?

Introduction

The 2011 East Japan Earthquake caused widespread seismic and tsunami damage to the Pacific coast of Japan. The earthquake sequence and tsunamis were responsible for 15,000+ deaths and the destruction of many seaside towns. Moreover, several coastal nuclear power plants in the Tohoku region sustained damage from tsunamis. Three reactors at the Fukushima Daiichi Nuclear Power Plant suffered level 7 meltdowns, resulting in a mass evacuation that is still in effect today.

In the aftermath of the nuclear disaster, many questions were posed about the locations of the reactors. Pundits questioned whether natural disasters were taken into account during the planning stage, and whether the nuclear reactors could have been placed in better locations. This GIS project will analyze the criteria used in selecting nuclear power plant sites, and determine the most suitable locations for nuclear reactors in Japan.

This project will determine areas in Japan that are best suited to house a nuclear power plant site. The analysis will be based on 4 criteria: population density, land use, feasibility of emergency evacuation and frequency of nearby earthquakes.

Methodology

In order to determine the suitability of a nuclear power plant in a given area, a "suitability grade map" was generated. The suitability grade is represented by a single raster map. The pixel values are calculated with raster addition based on 4 raster maps. The Frequency of Nearby Earthquakes map is doubly weighted because much of the risk of nuclear disasters emerges from earthquakes and secondary disasters.

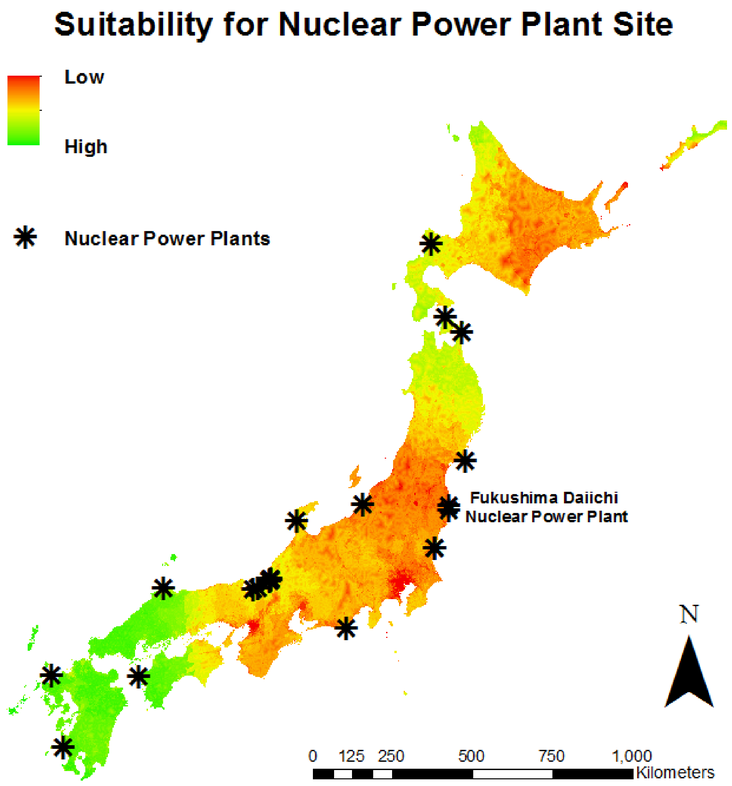
Frequency of Nearby Earthquakes * 2 + Suitability of Land Use * 1 +
Feasibility of Emergency Evacuation * 1 + Population Density * 1 = Suitability Grade

The Frequency of Nearby Earthquakes map was generated using point vectors of major earthquake epicenters since 1970. Each point was given a buffer with a 500-kilometer radius. A spatial join was used to count how many buffers in which each city/town/village in the Boundary Map is included.

The Suitability of Land Use map was generated using a raster map of land uses. Land uses with high population density and irrigation are undesirable, while low density and limited irrigation are desirable. Irrigated lands such as rice fields are undesirable because accelerated drainage could lead to extended damage during a nuclear disaster. Radioactive waste can spread quickly through sewage and water routes.

The Population Density map was generated using the population for each Japanese city/town/village. The Calculate Geometry tool was used to generate the area in square kilometers for each polygon. The population density was found by dividing the population by area.

The Feasibility of Evacuation map was generated by determining the distance from the closest major road. The Euclidean Distance tool was used to generate a raster map showing distances from the closest major road.



Conclusions

This study yielded clear-cut results. Some areas of Japan are much better suited to be nuclear power plant sites than others. The most ill-suited areas were urban areas such as Tokyo, Yokohama, Kyoto and Aichi. They were unsuitable from most aspects: high population density, unsuitable land use and average-to-frequent exposure to earthquakes. This result matched expectations. However, it was surprising to see rural areas such as the lower Tohoku region and eastern Hokkaido classified as unsuitable locations as well. Since these regions are sparsely populated and consist mostly of forest, it was expected that these regions would be at least moderately suitable. However, frequent earthquakes originating in both the Sea of Japan and the Pacific Ocean render these locations risk-prone. On the other hand, the northern Tohoku region, the Chugoku region and the Kyushu region are classified as suitable locations for nuclear power plants. These regions are moderately populated, consist of mainly farmland and forest, and have less frequent exposures to earthquakes.

It is particularly striking that the lower Tohoku region is classified as unsuitable. The Tohoku region is home to the Fukushima Daiichi Nuclear Power Plant that suffered a nuclear meltdown during the 2011 East Japan Earthquake.

Out of the 21 nuclear power plants in Japan, 8 are located in regions that are moderately or highly unsuitable. The lower Tohoku region, which houses 5 of those plants, is particularly risk-prone. On the other hand, nuclear power plants in the northern Tohoku region, the Chugoku region and the Kyushu region are in suitable locations. These regions can be recommended as suitable nuclear power plant sites in the future.

This project can be improved by incorporating more factors into the analysis such as the potential spread of effluents in the atmosphere and hydrosphere. In addition, while this is an inevitable limitation, it is difficult to predict future seismic activity based on past activity. Further work can be devoted to producing more precise conclusions on seismic activity.

Data and Sources

Data from the Geospatial Information Authority of Japan (GSI): Global Map Japan Boundary, Global Map Japan Land Use, Global Map Japan Transportation.

Data from Esri Online: Earthquakes since 1970, Nuclear Power Plant Reactors.

1:15,000,000

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Scale: 1:15,000,000
Projection: WGS 1984 Web Mercator