

Preliminary GIS Multi-Criteria Suitability Assessment for Small Modular Reactor Siting in Thailand

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1. Introduction

The global shift toward low-carbon energy has renewed interest in small modular reactors (SMRs), whose lower capital cost, modular fabrication, and smaller emergency planning zones broaden the range of feasible deployment sites. Thailand's draft Power Development Plan has identified SMRs as a candidate low-carbon technology toward its 2050 net-zero target [1], making early identification of suitable sites timely. Site selection is typically a staged process, screening candidate areas against exclusionary attributes, then evaluating favorability factors [2, 3] and Geographic Information System (GIS) combined with multi-criteria methods are widely used to translate these principles into suitability maps at the national scale [4].

This study develops a preliminary suitability assessment for SMR siting across Thailand, integrating five exclusionary constraints (seismic, environmental, terrain, and population) with three graded suitability factors (water availability, flood safety, and proximity to existing power plants). The last represents the brownfield concept reusing existing grid, cooling water, and infrastructure to reduce cost [5] which is rarely applied as an explicit spatial criterion in national siting studies. The factors are combined through weighted linear combination to produce a national screening intended to identify candidate regions for subsequent site-specific investigation, rather than to replace detailed site evaluation.

2. Methodology

2.1. Methodological overview

This study assesses SMR site suitability across the entire territory of Thailand following a two-stage framework consistent. Exclusionary constraints first remove areas unsuitable or prohibited for development, producing a binary candidate-area mask; the remaining areas are then evaluated using graded suitability factors, standardized to a common scale and combined through weighted linear combination (WLC). The final suitability score is obtained by multiplying the combined suitability surface by the constraint mask, so that excluded areas are removed regardless of their favorability on other factors.

All datasets used in this study, together with their sources and roles, are summarized in Table 1.

Table 1 Datasets used in the analysis

Dataset	Role in analysis	Source
Active faults	Exclusion (8 km buffer)	GitHub, 2021
Reserved areas	Exclusion	OpenStreetMap, 2026
Wildlife non-hunting areas	Exclusion	Overpass-turbo, 2026
Digital elevation model (DEM)	Exclusion (Slope derivation)	USGS Data Source, 2017
Population density	Exclusion	WorldPop Data, 2020
Coastline	Suitability	OpenStreetMap, 2026
Main rivers	Suitability	OpenStreetMap, 2026
Reservoirs and lakes	Suitability	Overpass-turbo, 2026
Existing power plants	Suitability	Electricity Generating Authority of Thailand (EGAT), 2026
Flood risk	Suitability	Joint Research Centre (JRC), 2026

All data layers projected to EPSG:32647 and resampled to 90 m resolution.

2.2. Exclusionary constraints

Five exclusionary constraints were applied to remove areas unsuitable or prohibited for SMR development. Each was represented as a binary raster (suitable = 1, excluded = 0), and the layers were combined multiplicatively so that any area failing one or more constraints was excluded. A buffer of 8 km was applied around active faults, following the fault-distance criterion adopted in a comparable GIS-based nuclear siting study [4].

The slope threshold of 25° slope limit reflects constructability considerations, and the population cut-off of approximately 120 persons/km² corresponds to the highest-density classes of the WorldPop distribution. The criteria, thresholds, and rationale are summarized in Table 2.

Table 2. Exclusionary constraints and rationale.

Constraint	Exclusion criterion	Rational
Active faults	Within 8 km of an active fault [4]	Avoid seismotectonic hazard and surface-rupture risk [3]
Reserved areas	Within boundary	Development legally restricted in reserved land
Wildlife non-hunting areas	Within boundary	Conservation constraint not captured by protected-area layer
Slope	> 25 degrees	Construction feasibility and ground stability; steep terrain raises site-preparation cost and risk
Population density	>120 person/km ²	Maintain separation from densely populated centers [3]

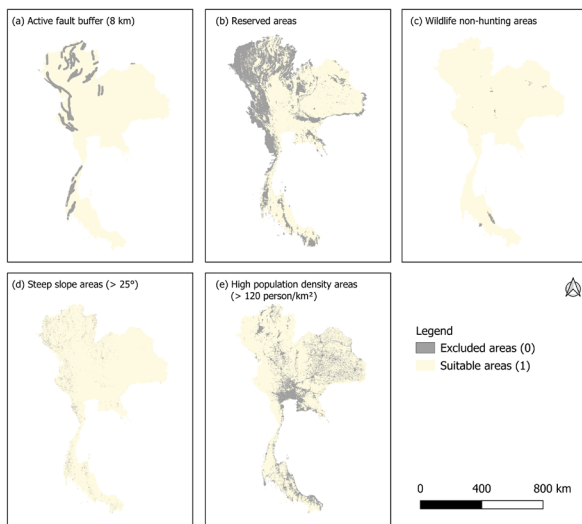


Fig. 1. Exclusionary constraint layers

2.3 Suitability factors

Three suitability factors were evaluated, each standardized to an ordinal score from 1 (least suitable) to 5 (most suitable) so that higher scores consistently indicate greater favorability.

Distance to water sources (coastline, main rivers, reservoirs and lakes) and distance to existing power plants were derived from the range of distances observed within the study area rather than from fixed external values, ensuring that all five suitability levels were represented across the country, while flood suitability was derived directly from the JRC flood hazard classification with 100-years return period.

The rationale and scoring schemes are summarized in Table 3.

Table 3. Suitability factors, rationale and scoring

Constraint	Rational	Classification	Score
Water proximity	Near cooling-water access provided lowers pumping and conveyance cost.	0–5 km	5
		5–15 km	4
		15–30 km	3
		30–50 km	2
		> 50 km	1
Flood hazard	Lower inundation depth reduces flood risk to the site [3]	No hazard	5
		<1 m	4
		1–3 m	3
		3–10 m	2
		> 10 m	1
Power-plant proximity	Brownfield advantage: nearer sites reuse existing grids, cooling water, transport, and workforce, reducing cost [5]	0–15 km	5
		15–30 km	4
		30–50 km	3
		50–100 km	2
		> 100 km	1

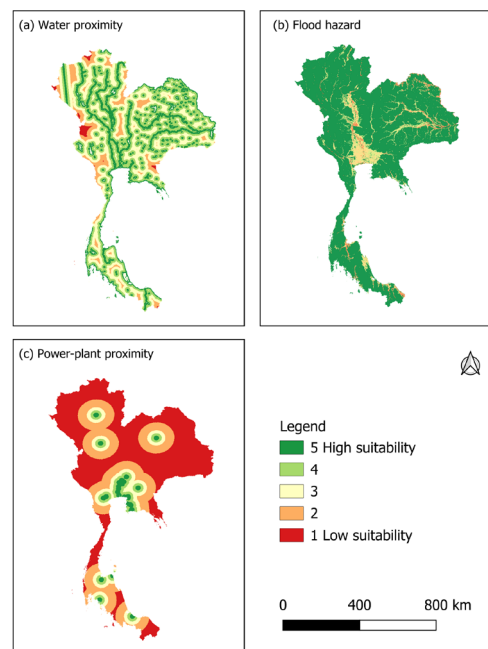


Fig. 2. Suitability score maps for (a) water proximity, (b) flood hazard, and (c) proximity to existing power plants. Scores range from 1 (least suitable) to 5 (most suitable); classification details are given in Table 3.

2.4 Spatial integration

The three suitability factors were combined using weighted linear combination (WLC) with equal weights,

reflecting the assumption that the factors contribute comparably to overall favorability at this preliminary stage and avoiding subjective weight elicitation prior to a full multi-criteria analysis. The combined suitability score was computed as

$$S = \frac{S_w + S_f + S_p}{3} \quad (1)$$

yielding a continuous index between 1 and 5. The final suitability score was then obtained by applying the exclusionary constraint mask,

$$S_{final} = S \times M \quad (2)$$

where S_w , S_f , and S_p are the suitability scores for water proximity, flood hazard, and power-plant proximity, respectively; S is the combined suitability score; M is the product of the five binary constraint layers (1 for suitable and 0 for excluded); and S_{final} is the final suitability score. Areas failing any single constraint therefore received a final score of 0 and were removed from the candidate set, while areas satisfying all constraints retained their continuous suitability score.

3. Results

The final suitability map is shown in Fig. 3, and the distribution of suitability classes is summarized in Table 4. Of the total national area assessed, roughly half was removed by the exclusionary constraints, reflecting the combined effect of mountainous terrain, protected and non-hunting areas, and separation from densely populated areas. This large excluded fraction is consistent with the conservative, screening-level nature of the assessment, in which an area was removed whenever any single constraint was violated.

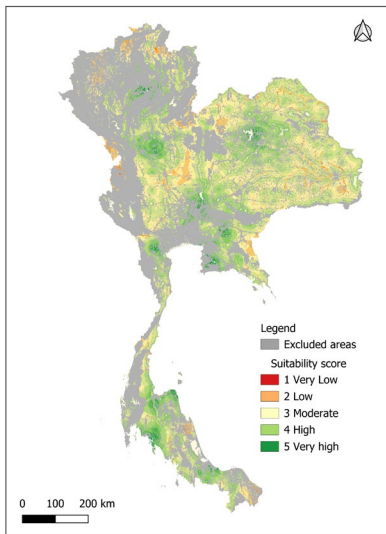


Fig. 3. Final suitability map

Among the areas passing all constraints, the majority fall into the moderate suitability class (about 30% of the

assessed area), while high and very-high suitability areas together account for roughly 2%. Although this highest-suitability fraction is small in relative terms, at the national scale it still corresponds to an area well beyond the footprint required for SMR deployment, indicating that suitable candidate zones, while spatially limited, are not scarce.

Table 4. Distribution of final suitability classes

Suitability class	Share of assessed area (%)
Excluded	53.4
1 Very low	0.1
2 Low	13.9
3 Moderate	30.4
4 High	1.5
5 Very high	0.7
Total	100

4. Discussion

This study presented a preliminary, national-scale GIS multi-criteria assessment of SMR site suitability for Thailand, integrating exclusionary constraints with graded suitability factors. The results show that many of the most suitable areas coincide with the surroundings of existing plants, suggesting that the reuse of established grid connections, cooling-water access, and supporting infrastructure could provide meaningful siting advantages worth considering at an early planning stage.

The assessment excluded slightly more than half of the national area. This relatively large excluded fraction reflects the conservative, screening-level intent of the analysis, an area was removed whenever any single constraint was violated, and the population constraint was applied at a level that also removes semi-urban surroundings rather than dense urban cores alone. The remaining candidate areas should therefore be interpreted as broadly permissive zones that warrant further evaluation, rather than as confirmed suitable sites.

Several limitations should be acknowledged. First, a number of thresholds including the slope limit and the class breaks for the distance-based suitability factors were established through engineering judgment appropriate to a screening-level study and informed by the observed data distributions, rather than by fixed regulatory limits; their influence on the results has not yet been tested systematically. Second, the three suitability factors were combined with equal weights, which assumes comparable importance among them and avoids subjective weighting, but may not reflect their true relative significance. Third, the analysis relied on openly available datasets at a fixed spatial resolution, so the accuracy of the results is bounded by the resolution and currency of the input data. Finally, the suitability classification is relative to the national distribution and does not by itself guarantee compliance with site-specific regulatory requirements.

These limitations point to clear directions for further work. A formal sensitivity analysis of the thresholds and a structured weighting approach, such as the analytic hierarchy process (AHP), would allow the relative importance of the criteria to be represented more rigorously. The candidate areas identified here would also require detailed site-specific investigation including geotechnical, hydrological, and environmental assessment consistent with a staged site evaluation process, before any location could be considered for development.

5. Conclusion

This study developed a preliminary GIS-based multi-criteria assessment of SMR site suitability across Thailand, combining five exclusionary constraints with three graded suitability factors, including proximity to existing power plants as a representation of the brownfield concept. The analysis identified candidate areas concentrated in the central and northeastern lowlands and along accessible coastal margins, frequently clustering near existing power plants where infrastructure and water access coincide. Although roughly half of the national area was excluded under the conservative screening criteria, the remaining suitable areas still represent a substantial resource relative to the footprint required for SMR deployment. The results provide a reproducible, national-scale screening intended to support, rather than replace, the detailed site-specific investigations required at later stages of nuclear siting. As such, this assessment can serve as a starting point for more detailed SMR siting studies in Thailand.

ACKNOWLEDGEMENT

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