ΠΑΝΕΠΙΣΤΗΜΙΟ ΠΕΙΡΑΙΩΣ

ΣΧΟΛΗ ΝΑΥΤΙΛΙΑΣ ΚΑΙ ΒΙΟΜΗΧΑΝΙΑΣ

ΤΜΗΜΑ ΒΙΟΜΗΧΑΝΙΚΗΣ ΔΙΟΙΚΗΣΗΣ ΚΑΙ ΤΕΧΝΟΛΟΓΙΑΣ

UNIVERSITY OF PIRAEUS

SCHOOL OF MARITIME AND INDUSTRIAL STUDIES

DEPARTMENT OF INDUSTRIAL MANAGEMENT AND TECHNOLOGY

Siting refugee camps in mainland Greece using geographic information systems-based multi-criteria decision-making

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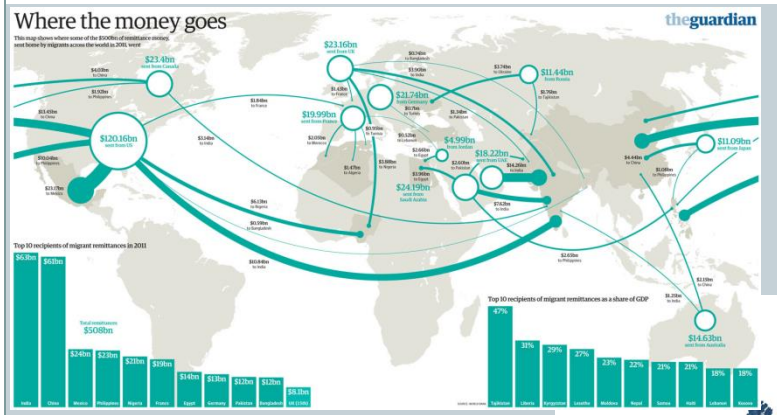
Migration


Where the money goes
theguardian
$120.16bn
$23.16bn
$23.4bn
$21.74bn
$19.99bn
$11.44bn
$11.09bn
$4.99bn
$18.22bn
$24.19bn
$14.63bn
Top 10 recipients of migrant remittances in 2011
Top 10 recipients of migrant remittances as a share of GDP


MARINA MILITARE

Migration

- **Refugees**, including asylum seekers and beneficiaries of international protection, are persons mainly fleeing armed conflict or persecution.

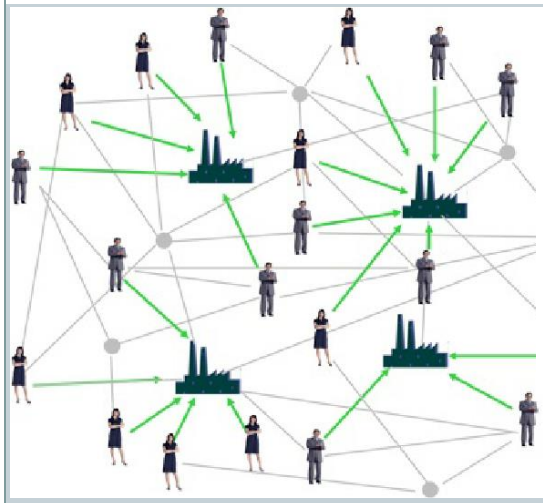
- **Migrants** choose to move out not because of a direct threat of persecution or death but mainly to improve their living conditions.

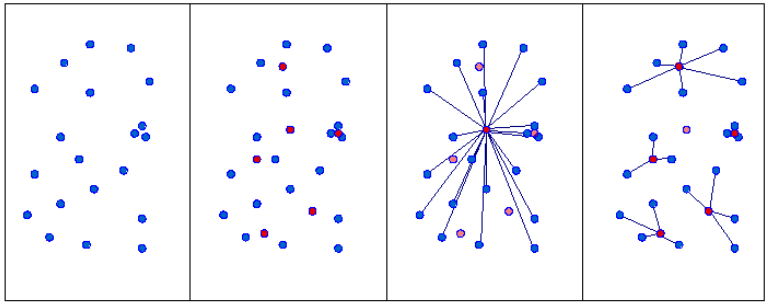
- These two groups are often treated in unison when provided with settlements.

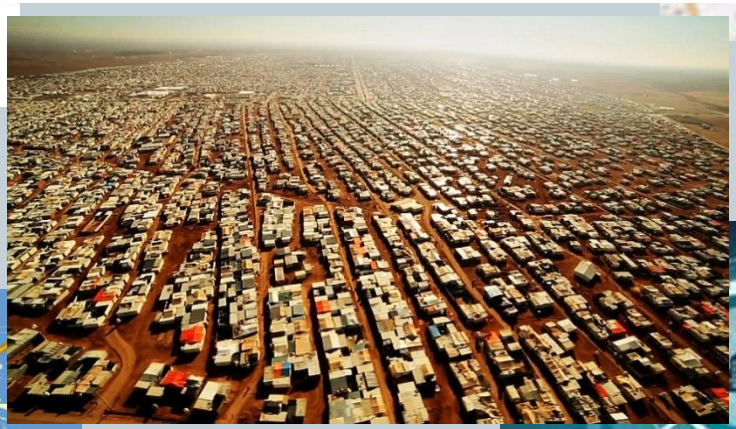
Migration

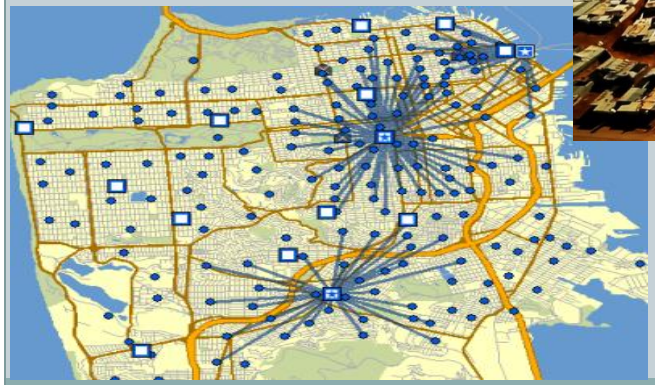
- From 2015 onwards, Europe is facing massive refugee and migrant flows from its southeastern borders, mainly due to the Syrian crisis.
- The eastern Aegean Sea islands are burdened with the task of receiving refugees and migrant flows, as they are the main entry points for Europe due to their proximity to the Turkish coasts.
- Deploying an extended range of sustainable refugees and migrants hosting facilities is a major challenge for Greece.
- Depend on the policy implemented, the magnitude of the flows to be accommodated and the existing hosting infrastructure.

Facility Location/Allocation









Facility siting using MCDM and GIS

- Geographic Information Systems (GIS)
  - ✓ Analyze geospatial data
  - ✓ They perform different management and analysis tasks

- Multiple Criteria Decision-Making (MCDM)
  - ✓ the structure to fill the gap in the decision-making process
  - ✓ the tools to evaluate and prioritize a large number of conflicting decision criteria
  - ✓ the tools to evaluate and classify the alternatives

- Suitability Analysis
  - ✓ Systematically identifies and ranks possible sites for a particular use and is divided into two types: “Absolute Suitability” and “Relative Suitability”.

Facility siting using MCDM and GIS

- In order to identify the most suitable areas for siting a facility, researchers use operations management including MCDM methods.

- MCDM :“The study of methods and procedures by which multiple and conflicting criteria can be incorporated into the decision process” (Zardari et al., 2015).

Facility siting using MCDM and GIS

- For siting facilities, the decision-making process is divided into two stages in order to better understand the complexity of the problem (Erkut and Neuman, 1989):
  - ✓ the problem is classified as a *site search* or *site generation problem* or *suitability analysis*
  - ✓ the second stage of the final decision to site a facility is *site selection*

- If there are no a priori candidate sites, the facility siting problem is split into two individual problems that are tackled separately and by different methods.

Facility siting using MCDM and GIS

- Suitability analysis determines both the suitability of the sites for a given purpose and their characteristics.

- Two categories, depending on the goal set:
  - ✓ "*explicit site*" goal targets analytical and detailed determination of the suitable areas boundaries for siting, using mathematical programming models.
  - ✓ "*good area for site*" goal targets suitable areas where candidate sites are likely to be found, using MCDM techniques.

Facility siting using MCDM and GIS

- In MCDM, the basic principle for the evaluation is the construction of an evaluation matrix to prioritize criteria.
- In suitability analysis, criteria are usually weighted using the analytical hierarchy process (AHP) - its classification scheme makes it easier to compare criteria pairwise in cases where weighting is not performed by experts.
- All criteria are aggregated to obtain a score value. The process of aggregating the criteria is known as a "*decision rule*" and "*assessment*" is the process of implementing a decision rule.
- The most commonly used multi-criteria aggregation process is the weighted linear combination (WLC) or simple additive weighting method (SAW).

Facility siting using MCDM and GIS

- WLC method:

  The value of the area is multiplied with the weight coefficient of the criterion. This is repeated for all the areas, for each criterion. Then the weighted values for all criteria are added to each corresponding area and the sum for all criteria is

$$S = \sum w_i x_i$$

where **S** is the suitability, w_i is the weight coefficient for criterion **i** and x_i is the score that the base unit (area) has for criterion **i**

Facility siting using MCDM and GIS

- Suitability analysis is often implemented using analytics (GIS) combined with MCDM techniques.
- In a GIS environment, the suitability analysis problem is translated to spotting areas on a map, such as cells or polygons and each area represents an alternative.
- The combination of GIS with MCDM methods is increasingly used for resolving a wide range of decision and management problems.
- Multiple domains: environmental, transportation, urban planning, waste management, agriculture, forestry and natural hazard studies to tackle decision/evaluation problems such as land suitability, site search, scenario evaluation and resource allocation among others.

Refugees' camps - the N.I.M.B.Y. phenomenon

- The decision-maker should take into account all factors that contribute to the construction of a sustainable facility, including social ones.
- The social response for a facility to be built near an urban area depends on the type of the facility.
- The phenomenon of the local community opposing facilities is called N.I.M.B.Y. (Not-In-My-Backyard) phenomenon or syndrome.
- Such facilities are characterized as semi-obnoxious, semi-desirable or pull-push.
- One universal factor in all NIMBY conflicts: geographical proximity

Refugees' camps siting problem MCDM & GIS

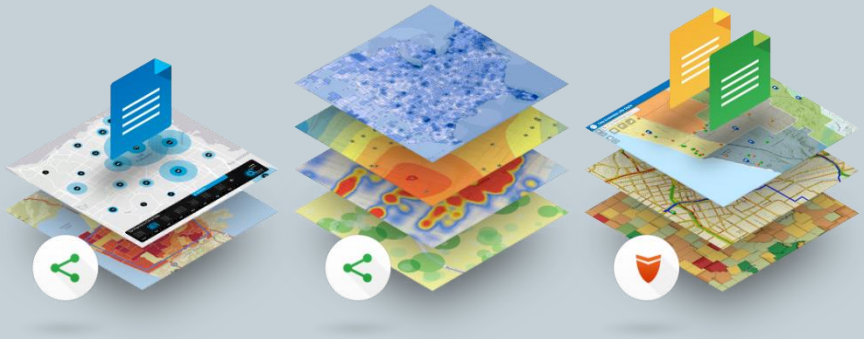
- Siting refugees' camps in Greece:

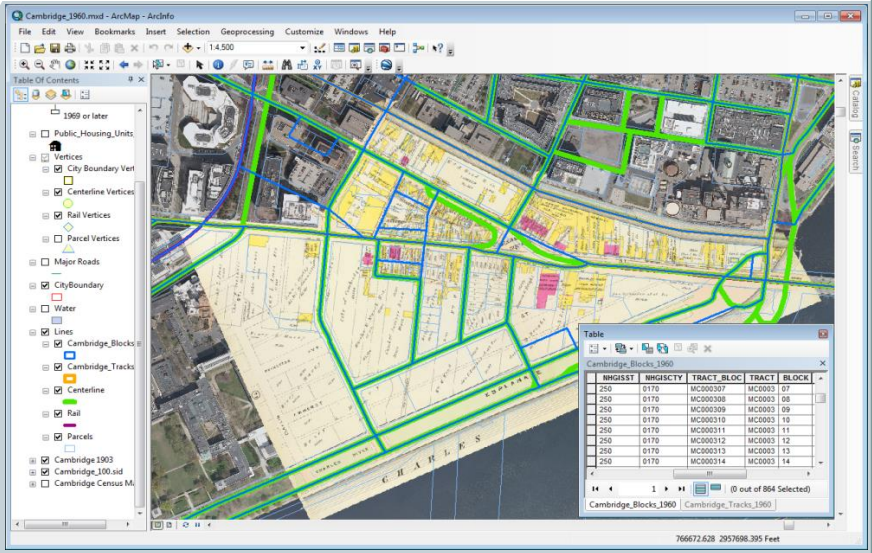
  - ✓ Long-term refugees' camps
  - ✓ Refugees' camps are identified as semi-desirable facilities, taking into account the N.I.M.B.Y. phenomenon by considering the local opposition.
  - ✓ Synergy of GIS and MCDM
  - ✓ Suitability Analysis

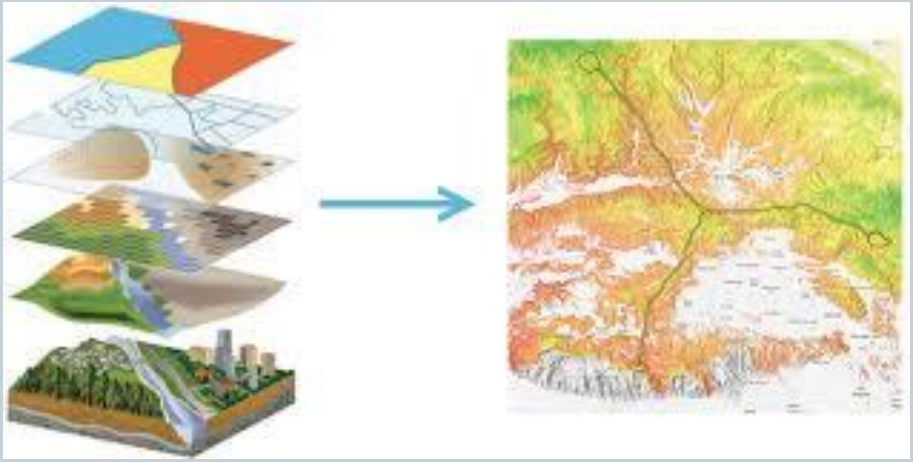
Refugees' camps siting problem MCDM & GIS

- Geographic Information Systems (GIS)
  - ✓ Arcgis 10.1
- Multiple Criteria Decision-Making (MCDM)
  - ✓ WLC method
  - ✓ $S = \sum w_i x_i$
- Suitability analysis
  - ✓ Implemented in GIS environment

Methodology







Methodology

- **Step 1** – Standardization and criteria scoring
  - ✓ The objective to be achieved is identified
  - ✓ Identification of decision rules, criteria, subcriteria and restricted areas
  - ✓ Decision rules are divided to classification and selection rules
  - ✓ Determine which areas are appropriate and which are not for further analysis
  - ✓ Criteria attributes are grouped into five classes
  - ✓ Collection, processing and creation of geospatial data using GIS (Arcgis 10.1)
  - ✓ Criteria standardization

Methodology

Level 1 Main criteria	Level 2 Subcriteria	Value ranges of each class	Score (xi)
1. Topographic	1.1 Slope	<2 %	3
		2–4%	5
		4–10%	4
		10–20%	2
		>20%	1
	1.2 Elevation	<400 m	5
		400–600 m	4
		600–800 m	3
		800–1,000 m	2
		>1,000 m	1
2. Operational	2.1. Distance from the nearest hospitals or health centers	<1,000 m	5
		1,000–2000 m	4
		2,000–3,000 m	3
		3,000–4,000 m	2
		4,000–5,000 m	1
	2.2. Distance from the nearest police station	<2,000 m	5
		2,000–4,000 m	4
		4,000–6,000 m	3
		6,000–8,000 m	2
		8,000–10,000 m	1
	2.3. Distance from the nearest airport	<13,000 m	1
		13,000–30,000 m	5
		30,000–50,000 m	4
		50,000–80,000 m	3
		800,000–110,000 m	2
	2.4. Distance from the major road network	<200 m	5
		300–400 m	4
		400–600 m	3
		600–800 m	2
		800–1,000 m	1
3. Social	3.1. Distance from the center of the city with population over 2,000 inhabitants	<3,000 m	2
		3,000–6,000 m	5
		6,000–9,000 m	4
		9,000–12,000 m	3
		12,000–15,000 m	1
4. Spatial	4.1. Distance from protected areas	<400 m	1
		400–600 m	2
		600–800 m	3
		600–1,000 m	4
		>1000 m	5

Methodology

Score	Suitability description
1	Minimum suitability
2	Low suitability
3	Moderate suitability
4	High suitability
5	Excellent suitability

Methodology

- **Step 2** – Criteria weighting

  - ✓ Criteria weighting
  - ✓ Analytical Hierarchy Process (AHP)
  - ✓ Application of Super Decisions tool

Methodology

Level 1 Main criteria	Weight coefficient (w_1)	Level 2 Subcriteria	Weight coefficient (w_2)	Weight coefficient w ($w = w_1 * w_2$)
1. Topographic	0.29679	1.1 Slope	0.875	0.260
		1.2 Elevation	0.125	0.037
2. Operational	0.16641	2.1. Distance from the nearest hospitals or health centers	0.45668	0.076
		2.2. Distance from the nearest police station	0.06289	0.010
		2.3. Distance from the nearest airport	0.33496	0.056
		2.4. Distance from the major road network	0.14547	0.024
3. Social	0.46862	3.1. Distance from the center of the city with population over 2000 inhabitants	1	0.469
4. Spatial	0.06817	4.1. Distance from protected areas	1	0.068

Methodology

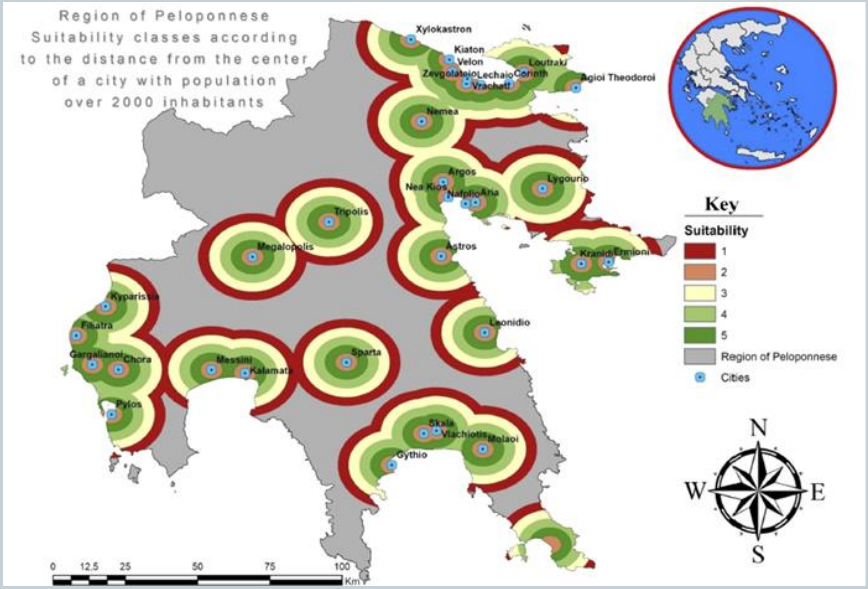
- **Step 3** – Aggregation of weighted criteria
  - ✓ Criteria aggregation using the WLC method
  - ✓ Corresponding GIS tool (raster calculator)
- **Step 4** – Results

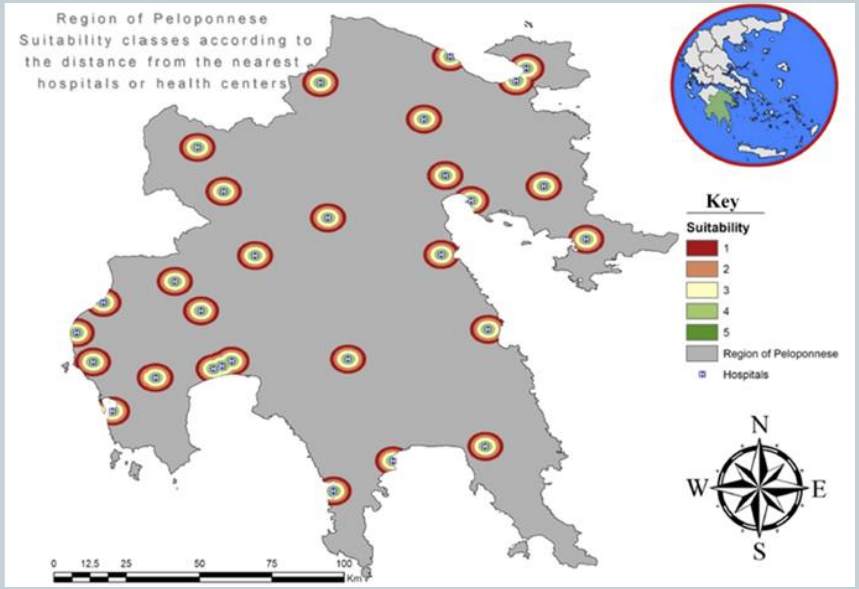
Methodology

- Primary criteria data

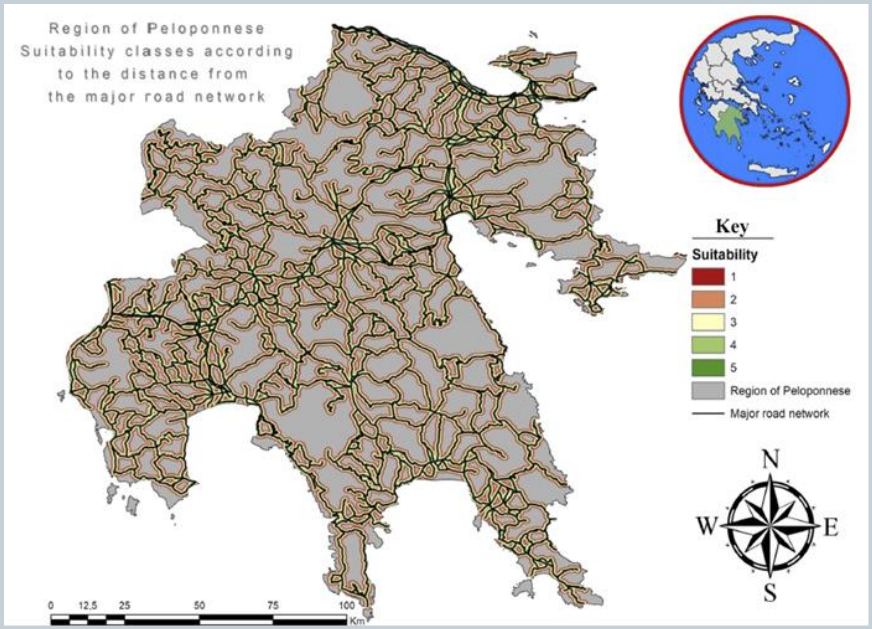
Data description	Data type	Data source
Digital elevation model	Raster	https://www.eea.europa.eu/data-and-maps/data/eu-dem
Callicrates regions	Vector	http://www.statistics.gr/documents/20181/1194366/perifereies.rar/39886ba8-6335-4199-b651-92fac372386b
Callicrates local units	Vector	http://www.statistics.gr/documents/20181/1194366/oikismoi_2011.rar/05cc0b6c-5b70-418b-b9fd-33cfe72f5d19
Natura 2000 sites	Vector	http://land.copernicus.eu/local/natura/natura-2000-2012/view
Common Database on Designated Areas (CDDAs)	Vector	https://www.eea.europa.eu/data-and-maps/data/nationally-designated-areas-national-cdda-12/gis-data/cdda-shape-file
Points of interest (Police stations, Hospitals, Airports)	Vector	http://geodata.gov.gr/dataset/demosia-kteria
Major road network	Vector	http://www.esri.com/software/arcgis/arcgisonline (using tool of Arcg is 10.1)
Rivers	Vector	http://geodata.gov.gr/dataset/potamoi-hydroscope-gr/resource/36e66076-5836-42ab-a090-01d346f7bc5f

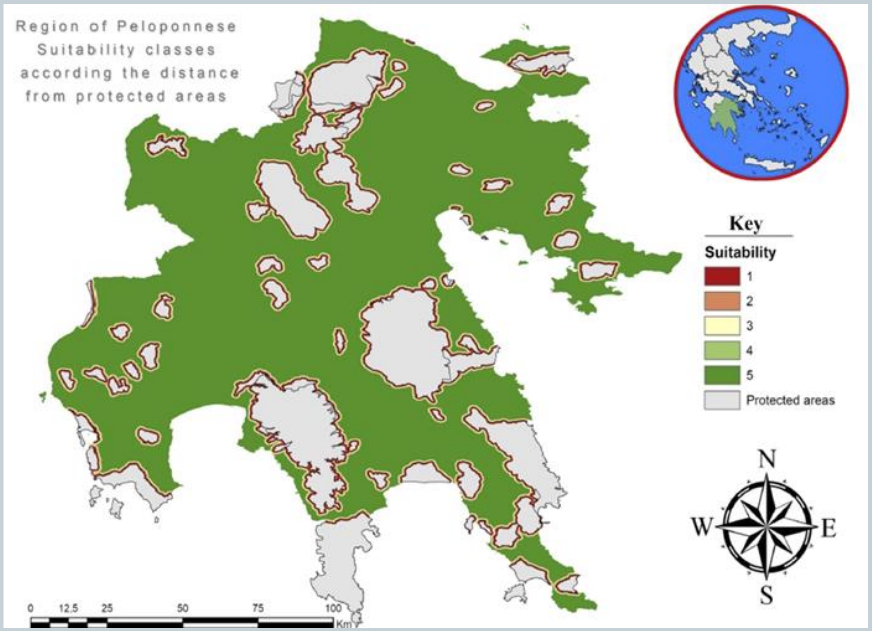
Thematic layers – Region of Peloponnese





Thematic layers – Region of Peloponnese





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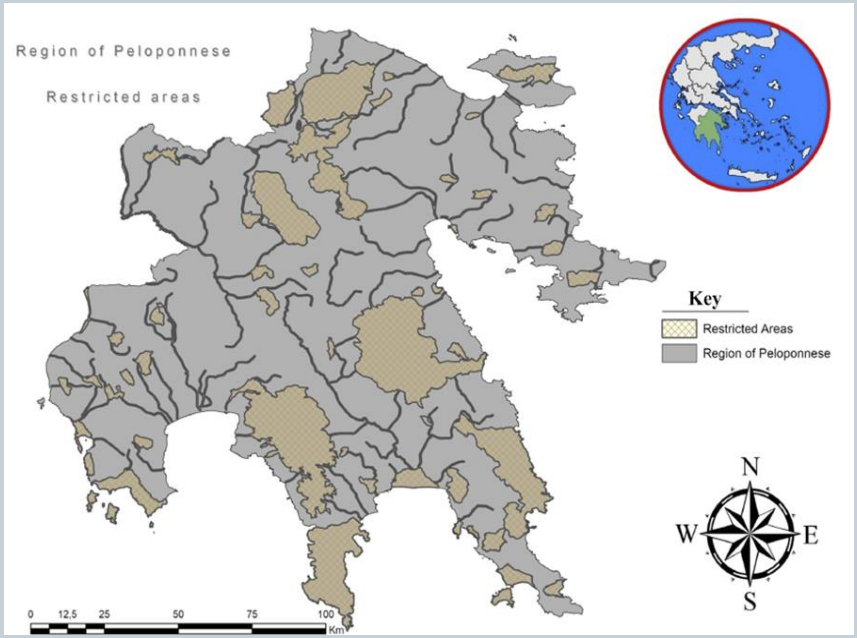

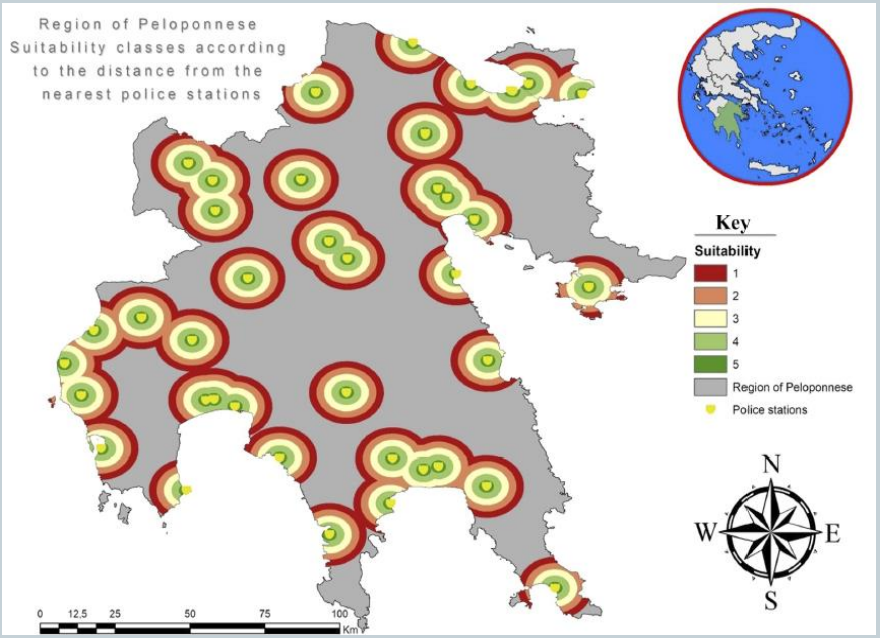

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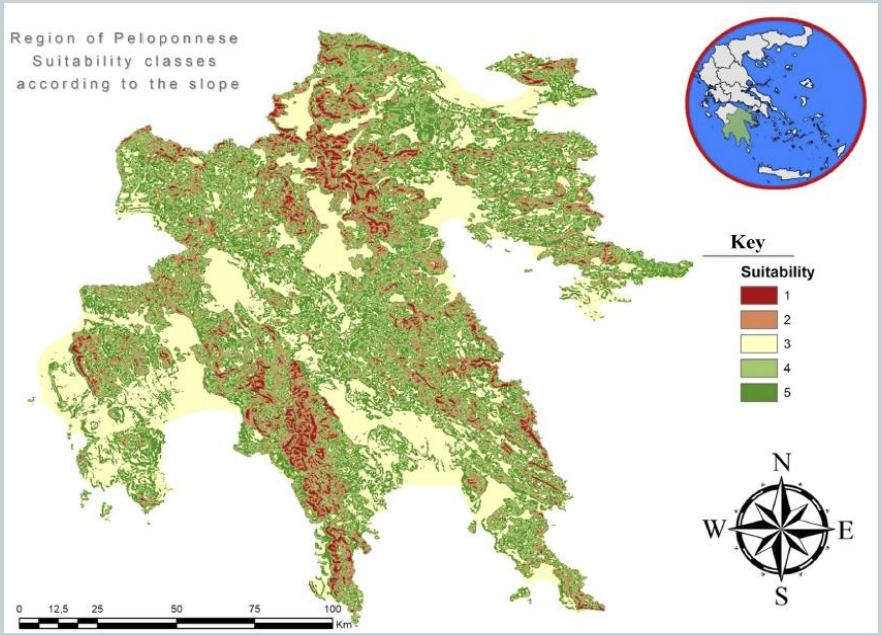
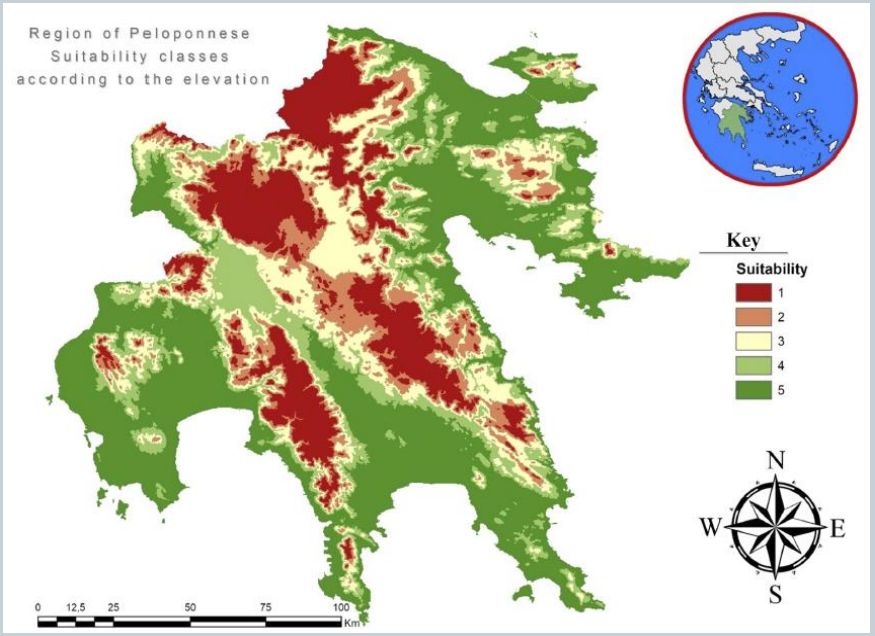




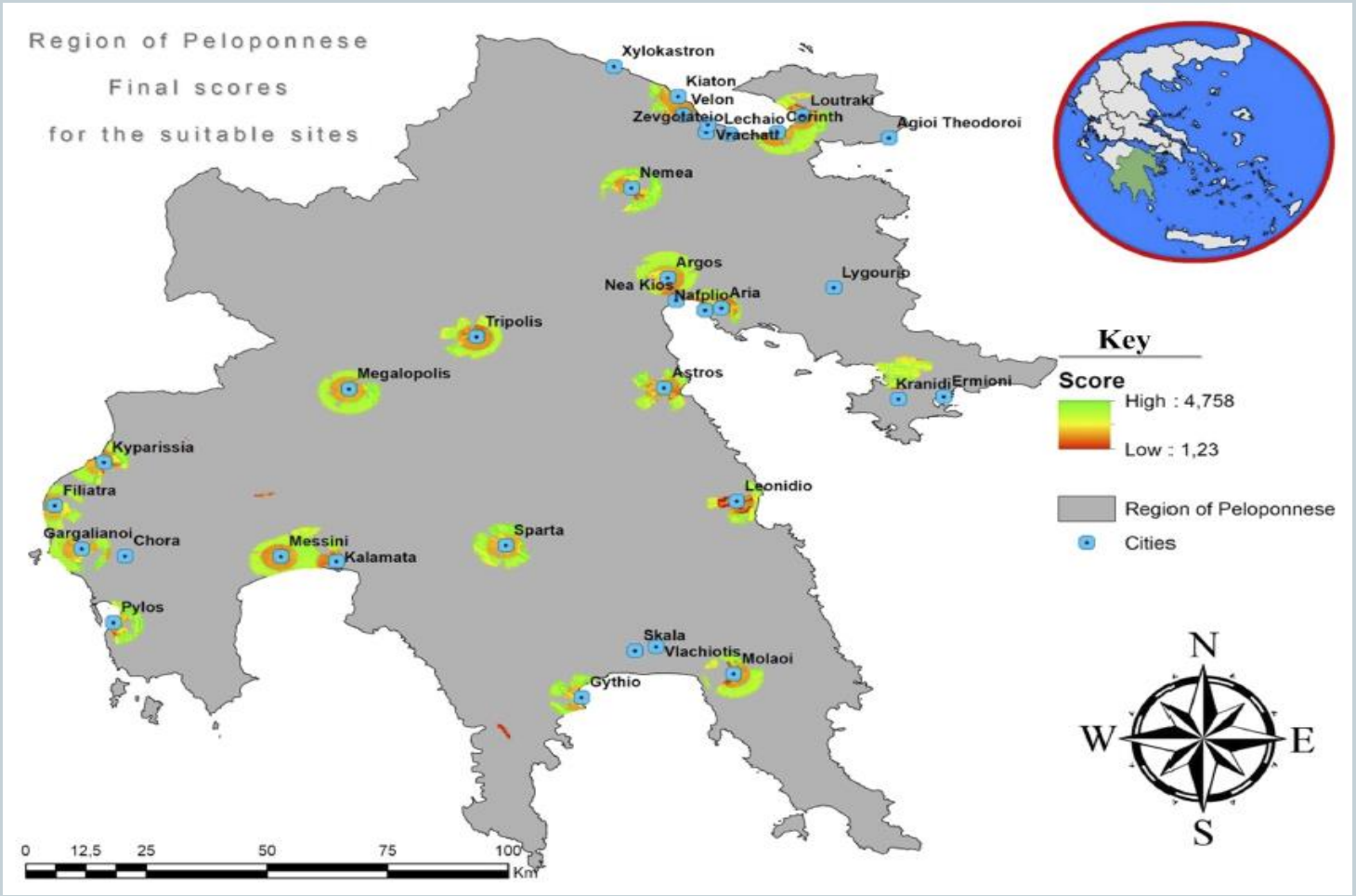
Results

- The result from the summation is a new thematic layer of the raster model with cell scores from 1.23 to 4.758
- Thematic layer rendered by the WLC is used with a score threshold of 4.7/5
- 36 cells with a score of 4.7 and above were finally identified
- 15 polygons match the scores of the original cells

Results

	Candidate sites	Score	Size (sq. m.)	LNG	LAT
1	Filiatra	4.758	29.316	21.57762	37.12897
2	Messini 1	4.718	29.325	22.06104	37.07263
3	Messini 2	4.718	29.325	22.05887	37.0748
4	Gargalianoi	4.71	29.349	21.63179	37.0373
5	Pylos 1	4.706	29.406	21.71721	36.88313
6	Pylos 2	4.706	29.404	21.71512	36.8873
7	Pylos 3	4.706	29.389	21.72346	36.92688
8	Pylos 4	4.706	57.939	21.7309	36.92904
9	Sparta 1	4.706	281.037	22.4531	37.0532
10	Sparta 2	4.706	29.307	22.41729	37.1018
11	Sparta 3	4.706	208.382	22.41215	37.10485
12	Sparta 4	4.706	187.664	22.43718	37.10438
13	Kyparissia 1	4.706	29.267	21.71096	37.24772
14	Kyparissia 2	4.706	29.259	21.70262	37.26855
15	Gythio	4.702	58.013	22.57479	36.78323

Results


Region of Peloponnese
Final scores
for the suitable sites
Xylokastron
Kiaton
Velon
Zevgolateio
Lechaio
Loutraki
Corinth
Vrachati
Agioi Theodoroi
Nemea
Argos
Nea Kios
Nafplio
Aria
Lygouriο
Tripolis
Megalopolis
Astros
Kranidi
Ermioni
Kyparissia
Filiatra
Leonidio
Gargalianoi
Chora
Messini
Kalamata
Sparta
Pylos
Skala
Vlachiotis
Molaoi
Gythio
Key
Score
High : 4,758
Low : 1,23
Region of Peloponnese
Cities
N
W
E
S
0
12,5
25
50
75
100
Km

Limitations

- Limitations:
  - ✓ Lack of studies on measuring the level of desirability for refugee camps.
  - ✓ The main criteria and subcriteria, their attributes and pairwise comparisons were determined according to existing literature and authors' informed judgment.
  - ✓ This process involves the participation and cooperation of multiple experts on issues related to all criteria, such as civil engineers, topographers as well as local authorities, along with the policy decision-makers.
  - ✓ This process includes an on-the-spot study of the candidate sites by experts, which would take into account criteria such as availability and ownership status.

Conclusions

- Proposed methodology and its uses:

  - ✓ Identify suitable candidate areas for new sites.
  - ✓ Applicable to re-assess existing refugee camps' locations.
  - ✓ Can be applied to create a "pool" of candidate sites for different types of facilities.
  - ✓ Flexibility of software tools, it is much easier to perform a "what if analysis".

References

Denekos, S.N., Koutsoukis, N.-S., Fakiolas, E.T., Konstantopoulos, I. and Rachaniotis, N.P. (2021), "Siting refugee camps in mainland Greece using geographic information systems-based multi-criteria decision-making", Journal of Humanitarian Logistics and Supply Chain Management, Vol. 11 No. 3, pp. 457-480.

https://doi.org/10.1108/JHLSCM-02-2020-0009

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