XIII WORLD CONGRESS

of the European Water Resources Association

New challenges in understanding and managing
water-related risks in a changing environment

Understanding the Relationship between Ecosystem Services and Pressures of Islands: Fuzzy-cognitive Modelling Approach

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Key points:

• **Island vulnerability:** European islands face growing pressures threatening vital ecosystem services (ESs), essential for local livelihoods and regional economies.

• **Heightened exposure:** Isolation increases dependency on ESs and amplifies ecosystem vulnerability.

• **Pressure dynamics**: Pressures are interconnected; changes in one area can trigger cascading effects.

• **Research trends:**
Research growth from 2000 in three phases:

• **Key gap:** Limited studies on ES trade-offs in terrestrial island ecosystems.

SMILES COST Action (CA21158):

Title: **Enhancing Small-Medium IsLands resilience by securing the sustainability of Ecosystem Services**

The Aim: To provide a platform for coordinated interdisciplinary research on mapping and assessing ecosystem services in small and medium-sized European islands, with the goal of synthesizing and strengthening the knowledge base for island conservation and supporting their sustainable development.

214 SCIENTIST, RESEARCHERS AND ACADEMICS

42 COUNTRIES

6 WORKING GROUPS

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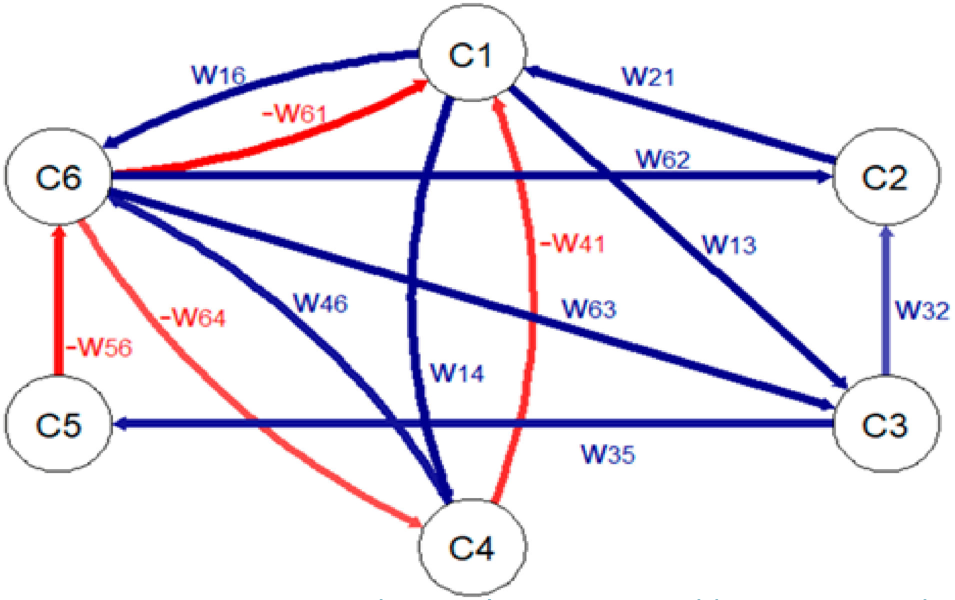
FUZZY COGNITIVE MODELING: An Introduction

Fuzzy Cognitive Mapping (FCM) is a qualitative or rather semi-quantitative and dynamic method to structure expert/stakeholder knowledge that aims to capture a person's perception of a particular issue in a diagrammatic format. (Kokkinos et al., 2018).

FCM is a graphical representation of a system used to illustrate the cause and effect relations between nodes, thus giving us the opportunity to describe its behavior in a simple and symbolic way. In FCM graphs, nodes represent concepts, and arcs represent the perceived relationships between these concepts (Axelrod, 1976).

Fuzzy cognitive map (left) and the correspondent weight adjacency matrix (right), showing the positive and negative causal influences.



$$W = \begin{bmatrix} 0 & 0 & w_{13} & w_{14} & 0 & w_{16} \\ w_{21} & 0 & 0 & 0 & 0 & 0 \\ 0 & w_{32} & 0 & 0 & w_{35} & 0 \\ -w_{41} & 0 & 0 & 0 & 0 & w_{46} \\ 0 & 0 & 0 & 0 & 0 & -w_{56} \\ -w_{61} & w_{62} & w_{63} & -w_{64} & 0 & 0 \end{bmatrix}$$

Papageorgiou et al.: Fuzzy Cognitive Map-Based Sustainable Socio-Economic Development Planning for Rural Communities. Sustainability 12(1), 2020.

FCM Development Using Expert/Stakeholder Knowledge

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1. Experts select the concepts C_i that constitute the FCM graph.

2. Each expert defines the causal relationship between any two concepts, if there exists one (positive/negative)

3. Experts carefully determine the value of the relationship between two concepts

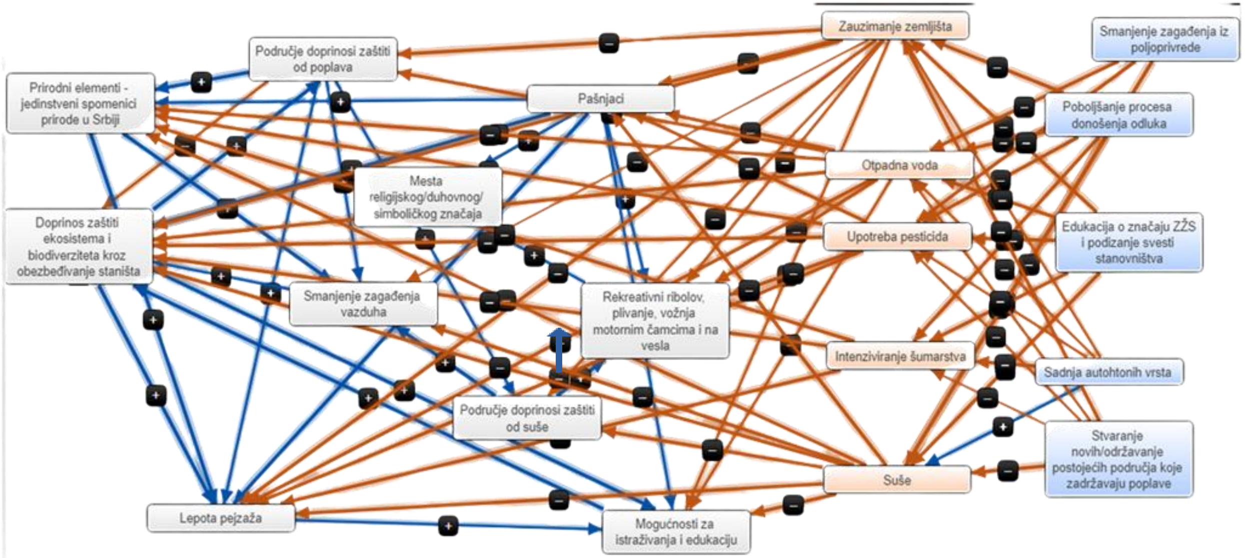
4. Experts describe initially the causal influence using linguistic variables, such as “low”, “medium”, “high”, etc. The sign of each weight (+ or -) represents the type of the influence between concepts. There are three types of interconnection between two concepts C_i and C_j:

- $w_{ij} \geq 0$ means that an increase or decrease in concept C_i causes the same result in concept C_j.
- $w_{ij} \leq 0$ means that an increase or decrease in concept C_i causes the opposite result in concept C_j.
- $w_{ij} = 0$ means that there is no relation between concepts C_i and C_j.

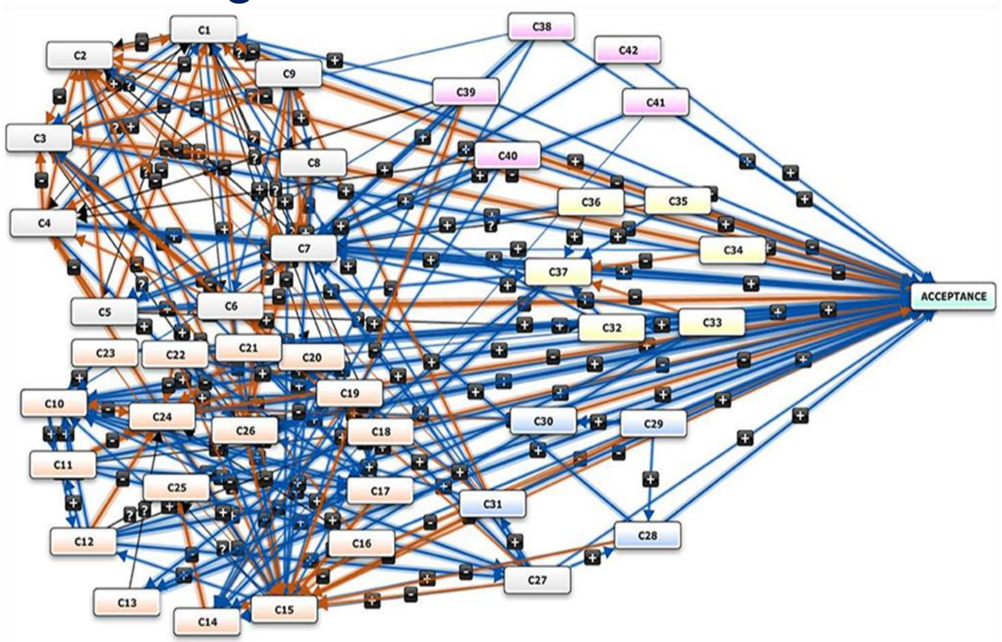
The degree of influence between the two concepts is indicated by the absolute value of wij.

MENTAL MODELER

- User friendly online system modeling software; helps individuals and communities capture their knowledge.
- Developing qualitative static model software translate to semi-quantitative dynamic model that is used for running “what-if scenarios”, thus it is possible to determine possible outcomes of decisions, policies or to predict system-level changes.

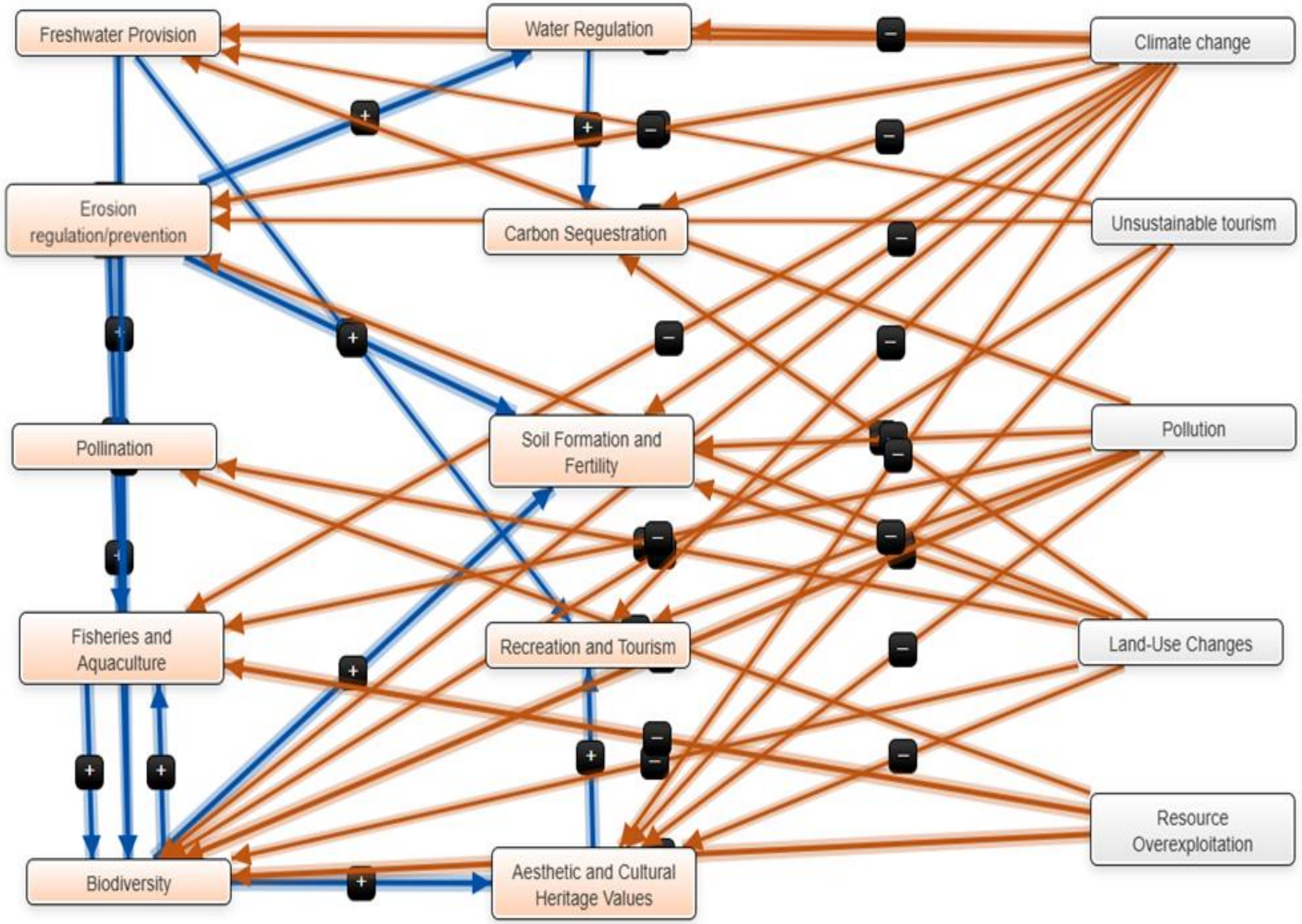


Giuca, R.C., Adamescu, C.M., Cazacu, C., Gheorghiu, C., Varga, M., Suhadolnik, P., Srdevic, Z., Benka, P., Srdevic, B., Ilic, M., Grabic, J., Tschikof, M., Vizi, D.B. (2022). Implementation of the IDES tool in five pilot areas. In J. Stäps, A. Gericke, A. Lungu & B. Stammel (Eds), Ecosystem services in floodplains and their potential to improve water quality – a manual for the IDES Tool, 112-136. DOI: 10.17904/ku.edoc.30670



Kokkinos et al. Fuzzy Cognitive Map-Based Modeling of Social Acceptance to Overcome Uncertainties in Establishing Waste Biorefinery Facilities. Front. Energy Res. 6, 2018.

Results:



- Literature-based and expert-informed assessment;
- FCM used – Mental Modeler;
- 10 ecosystem services (orange boxes) and 5 pressures (white)

The resulting network consists of 15 components connected through a total of 41 links.

There are: five drivers of changes - not affected by the others (the strongest one is pollution); four receivers (components influenced by the others, but has no influence on others) – pollination, carbon sequestration, soil formation and fertility, recreation and tourism. The rest are ordinary components, meaning that have an influence and are influenced by others. The highest relative importance has the ES “Biodiversity”, meaning that it is the most influential in the system. It is highly affected by all pressures, but it also affects other components. The lowest relative importance has the ES “Pollination”.

Model | Matrix | Preferred State & Metrics | Scenario | Info

Total Components	15
Total Connections	41
Density	0.1952380952
Connections per Component	2.7333333333
Number of Driver Components	5
Number of Receiver Components	4
Number of Ordinary Components	6
Complexity Score	0.8

Component	Indegree	Outdegree	Centrality	Preferred State	Type
Erosion regulation/prevention	1.8000000000000003	3.3	5.1	-	ordinary
Carbon Sequestration	2.3	0	2.3	-	receiver
Soil Formation and Fertility	3.9	0	3.9	-	receiver
Freshwater Provision	1.9	2.0999999999999996	3.9999999999999996	-	ordinary
Fisheries and Aquaculture	4.8	0.9	5.7	-	ordinary
Biodiversity	6.3	2.7	9	-	ordinary
Recreation and Tourism	2.9	0	2.9	-	receiver
Pollination	1.2999999999999998	0	1.2999999999999998	-	receiver
Aesthetic and Cultural Heritage Values	3.3999999999999995	1	4.3999999999999995	-	ordinary
Water Regulation	1.7000000000000002	0.8	2.5	-	ordinary
Land-Use Changes	0	4.2	4.2	-	driver
Resource Overexploitation	0	2.5	2.5	-	driver
Unsustainable tourism	0	2	2	-	driver
Pollution	0	4.5	4.5	-	driver
Climate change	0	6.299999999999999	6.299999999999999	-	driver

Conclusion:

This methodology highlights the most influential ESs and pressures, providing valuable insights for decision-making and conservation efforts.

By integrating participatory modeling with scientific data, it supports more effective policies and adaptive management strategies.

Engaging stakeholders from the outset not only streamlines the process but also enhances public acceptance and ensures access to critical firsthand knowledge that would otherwise remain unavailable.

Finally, scenario analysis allows for testing changes in individual elements or combined effects, providing a comprehensive view of ecosystem dynamics and informing strategic interventions.

THANK YOU FOR YOUR ATTENTION!

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