COMBATING DROUGHT, LAND DEGRADATION AND DESERTIFICATION FOR POVERTY REDUCTION AND SUSTAINABLE DEVELOPMENT

The contribution of science, technology, traditional knowledge and practices

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MONITORING LAND DEGRADATION & DESERTIFICATION in LESVOS ISLAND with the ESAI & MULTIWAY DATA ANALYSIS

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BACKGROUND: According to the UNCCD, **Greece has a marked problem of desertification** over large areas. Unfortunately, the breadth, complexity and dynamism of the desertification process has so far precluded the development of a comprehensive model and methods of assessment and monitoring have involved the **use of indicators**.

The most frequently applied indicator-based system for assessing LDD in the Mediterranean is the **Environmentally Sensitive Area Index (ESAI)** framework (Kosmas et al. 1999), mainly due to its simplicity in model building as well as its flexibility in the use of relevant variables as indicators.

AIM: To modify and improve the standard ESAI method that can be used to monitor the dynamic nature of environmental sensitivity of Mediterranean environments to land degradation and desertification.

AREA OF STUDY: the 73 sub-municipalities of the Island of Lesvos (Greece)

Lesvos is an island of Greece in the Aegean Sea, in the eastern Mediterranean. It covers an area of 1,633 km^2. Maximum altitude of 947 m. Climate is characterised by strong seasonal and spatial variations of rainfall and high oscillations between minimum and maximum daily temperatures.

Olive groves, Mediterranean shrubs (Maquis, phrygana), pine and deciduous oak forests as well as various types of agricultural uses dominate the landscape.

DATASETS & METHODS

Estimation of 21 indicators belonging to 5 main environmental **Quality Indices** related with: **Climate**, **Vegetation**, **Soil**, **Groundwater**, **Socio-economic** characteristics

Indicators were standardized from 1 (=least sensitive) to 2 (=most sensitive) according to the ESAI scheme (Tables 1-5).

According to the ESAI, the Quality Indices are estimated as follows:

*CQI = (rainfall * aridity * aspect)*$^{1/3}$, *VQI = (drought res. * erosion prot. * fire risk * plant cover)*$^{1/4}$, etc…

final Environmental Sensitive Area Index is then estimated as (Figure 1):

$$ESAI = (CQI * VQI * SQI * GQI * SEQI)^{1/5}$$

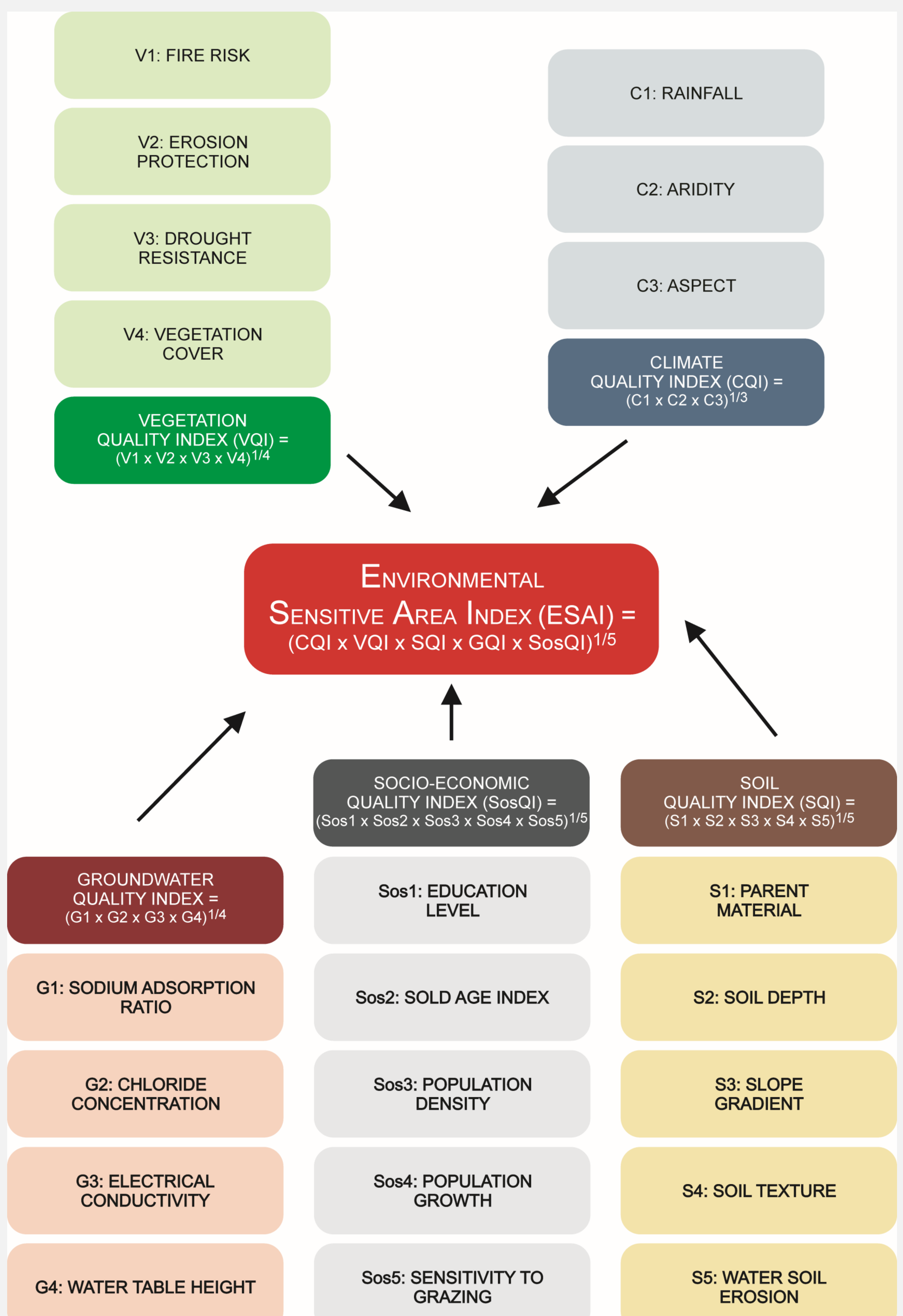

Figure 1. Flowchart of the methodological framework for the estimation of the modified Environmentally Sensitive Area Index (ESAI) (Symeonakis et al., 2014)

ESAI widely used, BUT:

- The ESAI assumes that **all indicators** used in the system **are equally important** and hence, assigns an **equal weight (=1.0)** to them all
- This issue has been identified as **a potential flaw of the ESAI** approach and was addressed initially by Salvati & Zitti (2009)
- **We employ a modification of the ESAI** that combines the multivariate analytical framework suggested by Salvati and Zitti (2009; **Multiway Data Analysis, MDA)** and the work of Leibovici (2010) on **Principal Tensor Analysis**
- We **compare the results** from both approaches

Multiway Data Analysis (MDA)

The freely available **R-package *P-tak*** (Leibovici, 2010) was used to implement the multivariate, multitemporal analysis. The weights were computed for each indicator *i* by multiplying the contribution of each indicator to the *m* most important (i.e. explaining>10% of total variance) factorial axes by their proportion of explained variance (for further details see Salvati and Zitti, 2009).

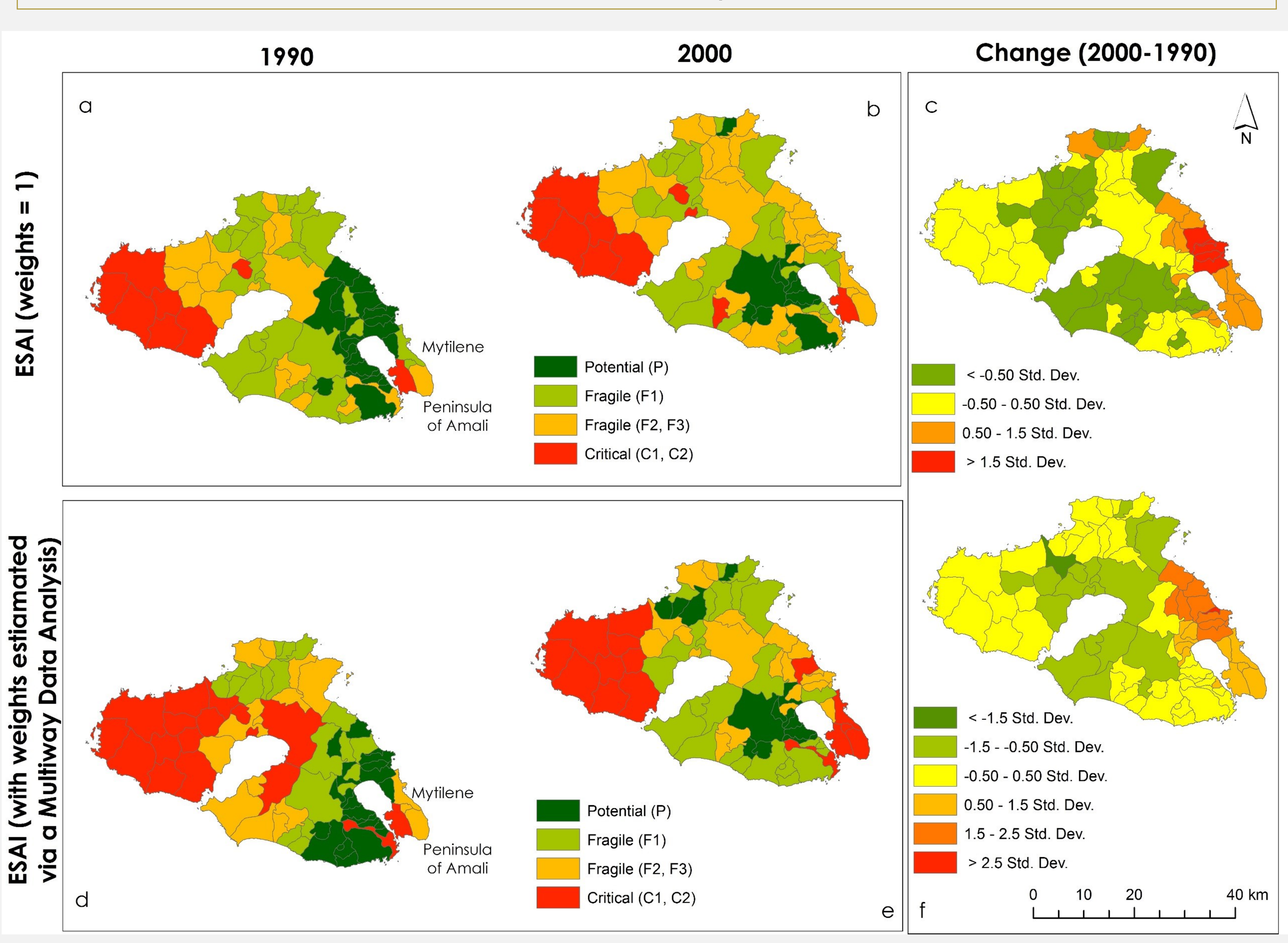

Figure 2. Environmental sensitivity in 1990 and 2000 according to: (a, b) the original Environmentally Sensitive Area Index (ESAI); (c, d) the modified version with weights estimated with a Multiway Data Analysis. (e): Change in sensitivity between 1990 and 2000 according to the original ESAI; (f) change in sensitivity according to the modified method.

Results (Figure 2), Discussion

Agreements

Both methods of estimating the indicator weights agree in that:

- Vast **majority of island**: **fragile** or **critically sensitive**
- **Most critical areas** are in the **western part**. In agreement with Kosmas et al. (1999), Symeonakis et al. 2014)
- The **eastern part** of the island is **degrading fast**

Disagreements

When the MDA weighing scheme is applied:

- In 1990 (Figure 2d), a large number of municipalities in the western and central part of the island appear as Critical rather than Fragile, as in the case of the equal weights (Figure 2a)
- In 2000 (Figure 2e), a number of municipalities in the eastern part of the island appear to be in a Critical rather than a Fragile state, as in the case of the equal weights (Figure 2b)
- In 2000, the entire **Peninsula of Amali**, south of the capital of the island (**Mytilene**, Figure 2e), appears to degrading to a Critical state, due to vegetation and climatic factors as well as the growth in human population.

Validation

Field validation is currently carried out to identify which method produces more reliable results

	Indicator	Classes	Score
Climate Quality	Rainfall (mm)	>650	1
		280-650	1.5
		<280	2
	Aridity = Precipitation / Potential Evapotransp. (P/PET)	>0.65	1
		0.5-0.65	1.5
		<0.5	2
	Aspect	N,NE,NW, plain (<5%)	1

Vegetation Quality	**Drought resistance**	Evergreen forests (exc. coniferous); mixed Med. Maquis-evergreen forest (with Q. ilex); bedrock; bare soil	1
		Conifer forests; Deciduous forests; Olives	1.2
		Almonds; Orchards; Vines	1.4
		Perennial grasslands; Pastures; Shrublands	1.7
		Annual crops (annual grassland; cereals; maize; sunflower); Horticulture; Very low vegetated	2
	Erosion protection	Evergreen forest (except conifers); mixed Med. Maquis-evergreen forest (with Q. ilex); Bedrock	1
		Med. Macquis; Conifer forests; Perennial grasslands; Pastures; Olives; Shrubs	1.3
		Deciduous forests (oak, mixed).	1.6
		Almonds; Orchards	1.8
		Vines; Horticulture; Annual crops (cereals, maize, annual grasslands, etc.); Very low vegetated; Bare soils	2
	Fire risk	Bare soils; Bedrock; Almonds; Orchards; Vines; Olives; Irrigated annual crops (maize, sunflower, etc.); Horticulture	1
		Perennial grasslands; Pastures; Cereals; Annual grasslands; Deciduous forests (oak, mixed); Mixed Mediterranean Maquis-Evergreen forests (with Q. ilex); Very low vegetated; Shrublands	1.3
		Mediterranean Maquis	1.6
		Pines and other conifer forests	2
	Plant cover (%)	>40	1
		10-40	1.8

Soil Quality	**Parent material**	Shale; schist; basic; ultra basic; conglomerates; unconsolidated; clays; marl (with natural veg.)	1
		Limestone; marble; granite; rhyolite; ignibrite; gneiss; siltstone; sandstone; dolomyte	1.7
		Marl; Pyroclastics	2
	Texture	L,SCL,SL,LS,CL	1
		SC,SiL,SiCL	1.2
		Si,C,SiC	1.6
		S	2
	Soil depth (cm)	>75	1
		30-75	1.2
		15-30	1.6
		<15	2
	Water erosion (mm/year)	<0.0001	1.0
		0.0001-0.0087	1.2
		0.0087-0.026	1.5
		0.026-0.07	1.7
		>0.07	2.0
	Slope gradient	<6	1
		6-18	1.2
		18-35	1.5
		>35	2

Groundwater Quality	Water table depth(m)	>3.15	1
		2.85-3.15	1.5
		<2.85	2
	Sodium Adsorption Ratio (SAR; meq/l$^{0.5}$)	<10	1
		10-18	1.3
		18-26	1.6
		>26	2
	Chloride concentration (mg/l)	<250	1
		250-500	1.2
		500-1500	1.5
		1500-3000	1.7
		>3000	2
	Electrical conductivity (μmohs/cm)	<250	1
		250-750	1.2
		750-2250	1.5
		2250-5000	1.7
		5000	2

Socio-economic Quality	**Population density (people per km^2)**	**<25**	**1**
		25-50	1.2
		50-100	1.4
		100-200	1.6
		200-400	1.8
		>400	2
	Population growth rate (%)	<2	1
		2-4	1.2
		4-6	1.4
		6-8	1.6
		8-10	1.8
		>10	2
	Old age	<200	1
		200-400	1.3
		400-500	1.6
		>500	2
	Education level (%)	>40	1
		30-40	1.2
		25-30	1.4
		20-25	1.6
		15-20	1.8
		<15	2
	Sensitivity to grazing (sheep and goats per km^2)	<0.0066	1
		0.0066-0.13	1.3
		0.013-0.019	1.6
		>0.019	2

Tables 1-5. Main indicators & adopted scores used in the GIS to assess environmental sensitivity to degradation & desertification

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