Applying the Fuzzy ARTMAP neural network for mapping erosive status in the Ria Formosa catchment (Portugal)

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Introduction

The study of soil degradation is the starting point for development and sustainable land management. The most important type of soil degradation in the Mediterranean area is soil erosion, due to land use, soil management practices and climate (Fig. 1).

The objective of this work is to map soil erosion risk in the Ria Formosa catchment (Algarve, Portugal), using the "Fuzzy ARTMAP" technology, a class of neural network architectures that perform incremental supervised learning of recognition categories and multidimensional maps in response to vectors presented in arbitrary order.

Five classes of soil erosion risk were obtained and compared with the map of erosive status erosive proposed by the Priority Action Plan/Regional Activity Centre methodology (PAP/RAC, 1997).

Figure 1. Effects of soil erosion processes in Gambelas (Faro, Ria Formosa catchment).

Study Area

The catchment includes Ria Formosa which is a shallow coastal lagoon with an area of about 16.000 ha located in the Algarve, S Portugal (Fig. 2).

The area is currently protected by EU and national laws, and is classified as a wetland of international importance under the RAMSAR convention (PORTUGAL Ramsar Site 212).

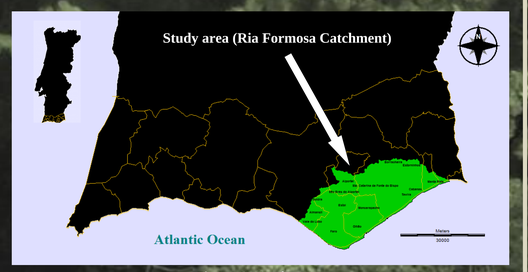

Figure 2. Study area.

Methods

Erosive status map

The erosive status map was designed according to the methodology proposed by PAP/RAC (1997), which was modified and adapted to the study area. Slope classes wer derived from the digital elevation model (100 × 100 m²); litofacies were obtained from the geologic map of Portugal (1:50,000); the land use map was obtained from the CORINE Land Cover data; and soil cover was calculated from the PVI1 index, extracted from Landsat 7 images (Fig. 3).

Fuzzy ARTMAP (supervised classification)

Training areas (< 1% of the study area) including the five classes of erosive status established according to PAP/RAC (1997) were selected.

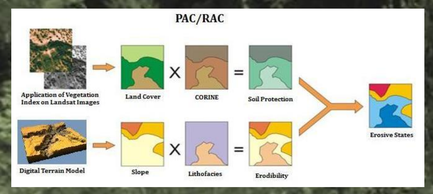

Figure 3. Scheme of the modified PAP/RAC methodology.

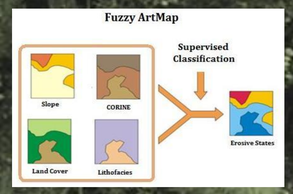

Figure 4. Methodology Fuzzy ARTMAP.

Slope class, litofacies, land use and soil cover were used as inputs for supervised classification (Fig. 4). The characteristic of the network (Fig. 5) were the following:

- 8 input neurons
- 5 output neurons (5 classes).
- Parameter of choice α = 0001
- Learning rate module ARTa, $\beta 1$ = 1.0
- Learning rate module ARTb, $\beta 2$ = 1.0
- Monitoring parameter, $\rho 1$ = 0.98
- Monitoring parameter, $\rho 2$ = 1.0

The learning process finished after 6977671 iteractions. The number of neurons in categorization layer was 414.

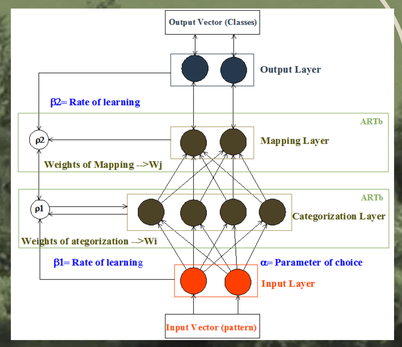

Figure 5. ARTMAP architecture.

Results

Soil erodibility (Fig. 6) and soil protection maps (Fig. 7) were obtained using the modified PAP/RAC method. Detailed information is shown in Table 1 and 2. Figure 7 shows the erosive status maps modeled by the Fuzzy ARTMap neural network and by the PAP/RAC methodology. Table 4 shows the charactersitics of areas with homogeneous erosive status.

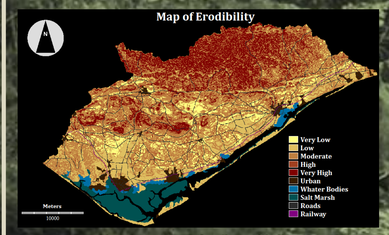

Figure 6. Map of soil erodibility.

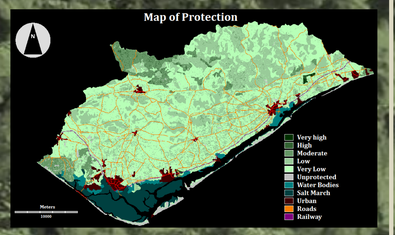

Figure 7. Map of soil protection.

Table 1. Soil erodibility results.

Erodibility	Area	Slope	Soil	Zone	Flow velocity
Very low	11%	0-3 %	Limestone	Barrocal	Very slow/Slow
Low	15%	0-3 %	Slightly cohesive	Littoral	Very slow/Slow
		3-16 %	Volcanic-sedimentary	Foothills/Barrocal	Moderate/Rapid
Moderate	47%	3-16 %	Limestone and clay	Barrocal and Mountains	Moderate/Rapid
High	8%	8-21%	Schist (formation of Mira)	Mountains	Rapid/Very rapid
			Limestone	Barrocal (lowlands)	Rapid/Very rapid
		21-31%	Volcanic-sedimentary	Foothills/Barrocal	Very high
Very high	19%	>21%	Schist (formation of Mira)	Mountains	Very high
			Limestone	Barrocal (high lands)	Very high

Table 2. Soil protection results.

Protection	Area	Land cover	Zone
Very Low	53.1%	Agriculture with natural spaces	Mountains
		Annual crops associated with permanent crops	Barrocal
Low	34.6%	Sclerophyllous vegetation	All areas
Moderate	8.3%	Forests and other areas	Alportel/Vale Lobo
High / Very high	0.7%	Forests and irrigated agriculture	Alportel /Tavira
Unprotected	3.3%	Beach, sand dunes, sand plains and bare soils	Coastline/Barrocal

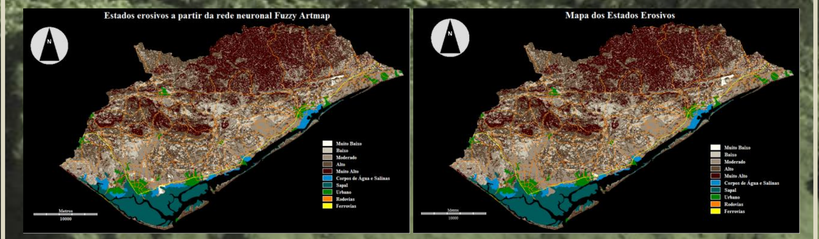

Figure 7. Erosive status mapped by the Fuzzy ARTMap model (left) and by the PAP/RAC methodology (right).

Table 3. Erosive status results.

Erosive State	Area	Slope	Soil	Land Cover	Zone
Very Low	0.4%	0-3%	Limestone	Permanent annual crops irrigated	Tavira
Low	11.6%	0-3%	Limestone /Dolomite	Permanent annual crops/Agriculture with natural spaces /Orchards	Barrocal
Moderate	30.3 %	0-3%	Sands/Gravels/ Conglomerates	Cultures and systems parcelares complex / Orchards	Barrocal
High	33.2%.	3%-16%	Limestone/Dolomite/Formation of Mira	Permanent annual crops/ Agricultural areas with natural areas	Barrocal / Saw
Very High	24.5 %	>16%	Formation of Mira/ Limestone	Sclerophyllous vegetation /Agriculture with natural spaces	Saw/ Barrocal

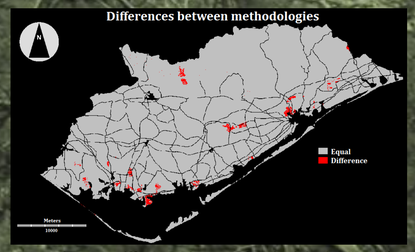

Figure 8 Differences between methodologies (in red).

The differences between the two methods were only around 1% of the total area (779 ha).

Fuzzy ARTMap neural network can be used as a helpful tool for qualitative soil erosion risk assessment, alternatively to classic methodologies.