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Cubist and TRIX models used in combination to assess and diagnose the trophic status of Coastal Ecosystems: Ichkeul Lake

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1. Introduction

Wetlands have undergone several disruptions, which have been threatening their ecological status , their biodiversity, and their socio-economic services.

Necessity to assess their sensitivity to anthropogenic pressures and climate change.

2. Objectives

- Characterize the trophic status of the water body and,
- Provide a predictive model of chlorophyll a based on environmental parameters.

Mediterranean Wetlands

3. Study Site

Situation

North of Tunisia

Morphological Characteristics

An area of 133 km² with three units: Lake, marshes, and wooded massive (Djebel Ichkeul).

Continental Hydrology

The catchment (2100 km²) drains a developed network of six rivers.

Connection with the Bizerte Lagoon

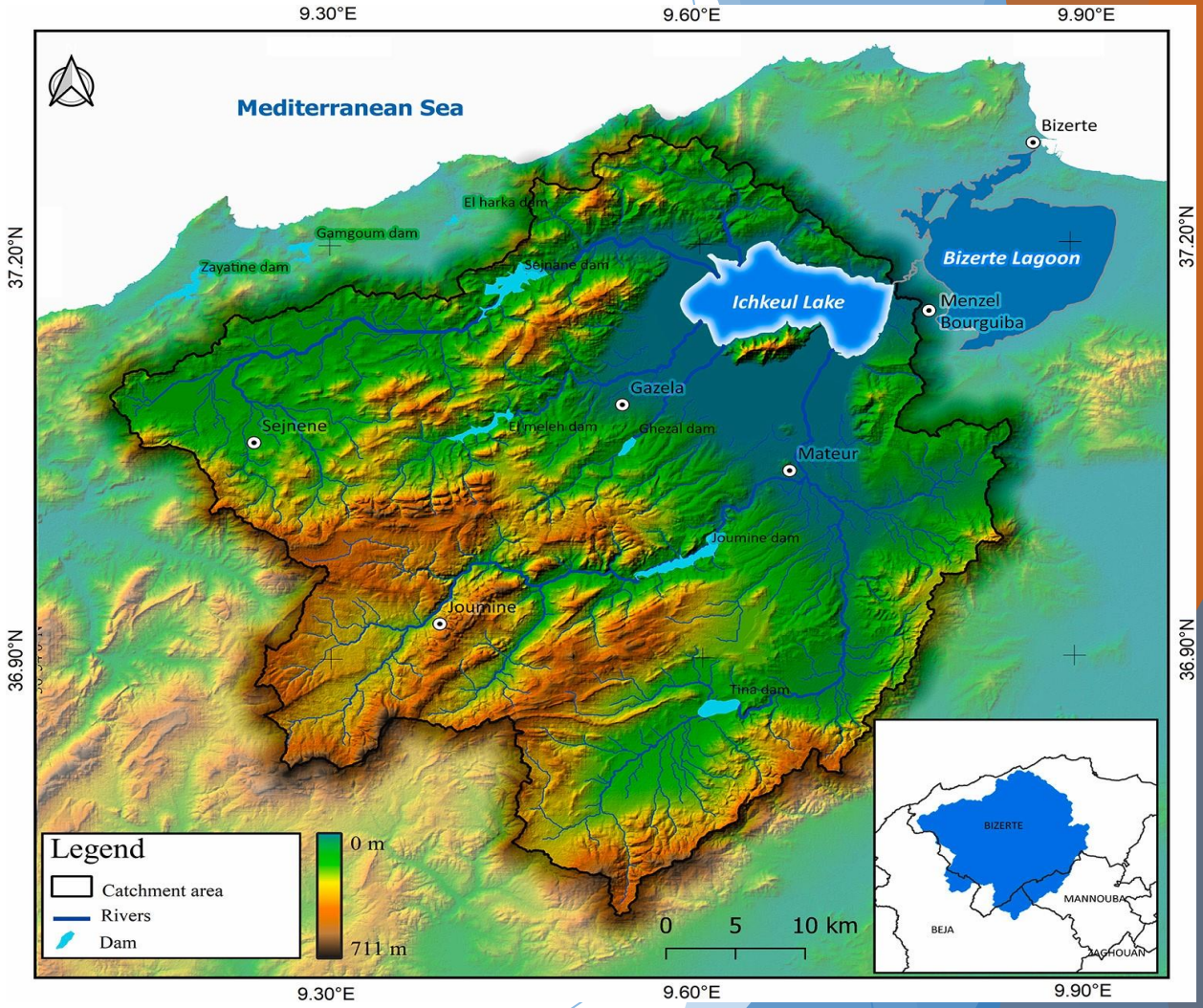
The Lake communicate with the Bizerte Lagoon.

Ecological value

- The most productive environment in Tunisia.
- Its registration in three international conventions.

Ecological fragility

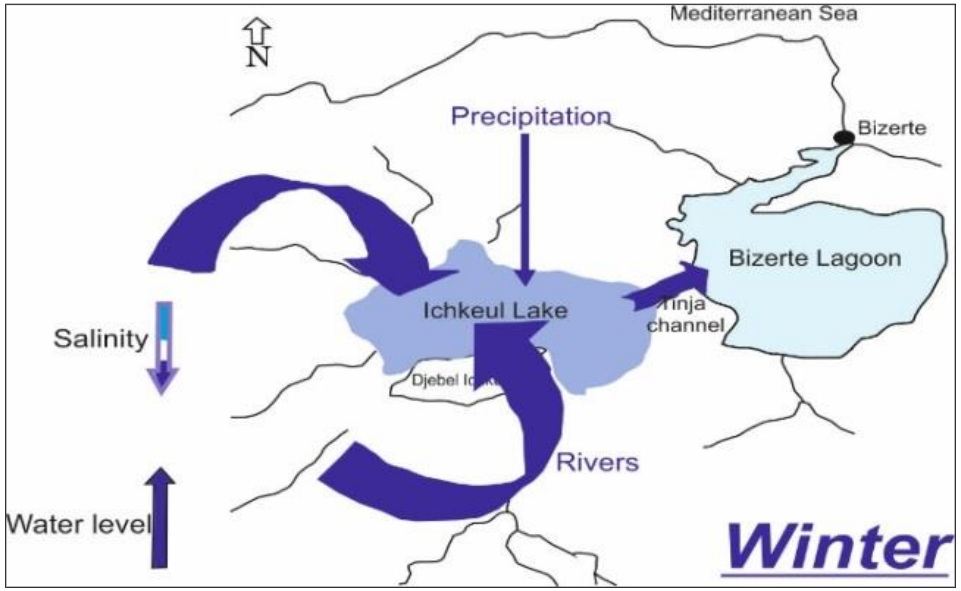
- Climate change: increase in T and decrease in P.
- Anthropogenic pressures: construction of dams and locks, over-exploitation of resources, pollution...



Localisation of Ichkeul Lake

3. Study Site

- The water budget in the Ichkeul Lake is characterized by seasonal variation:

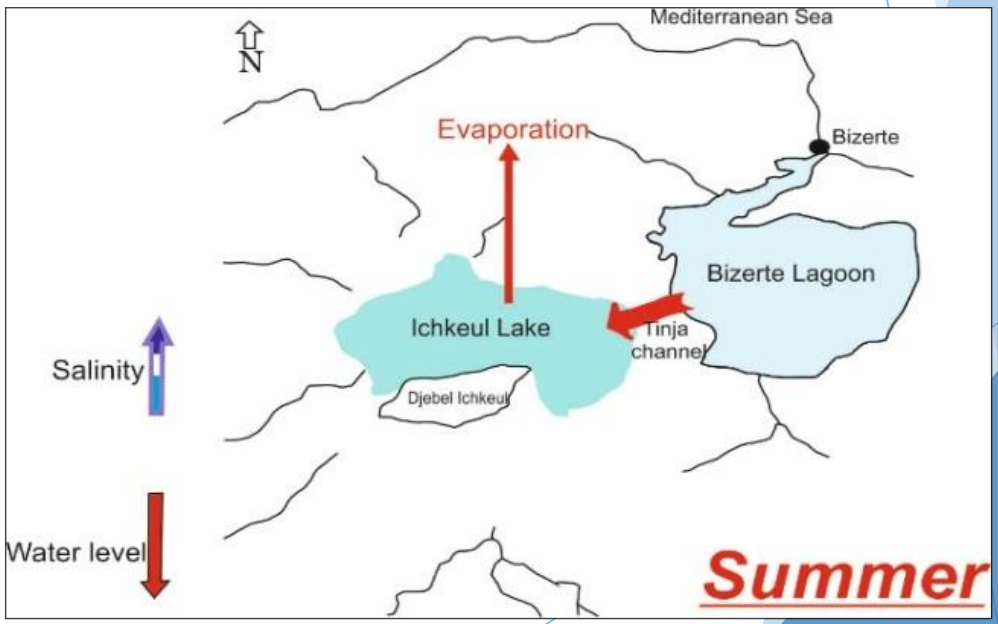


In winter:

- Water leaves Ichkeul Lake,
- High rainfall,
- High water level / low salinity.

In summer

- Water spills off to the Bizerte Lagoon,
- High evaporation,
- High salinity/low water level.



4. Data collection

- **Dataset = 142 samples of 12 variables (from 2010 to 2022)**
- **Data sources:** From BASSIANA database, and field monitoring.
- **Abiotic parameters**:

  Meteorological parameters: P, and W.

  Physico-chemical parameters: T, WL, S and DO.

  Chemical parameters: DIN,DIP, TP and TN
- **Biotic parameter**: Chl.a

5. Experimental and numerical approach

- **Box-Cox transformation:** to conform to the requirement for normality (assessed using Shapiro–Wilk test),
- **Pearson correlation and Principal Component Analysis :** to assess the correlation between parameters,
- **Trophic index TRIX and,**
- **Cubist model.**

Table1: Summary of environmental parameters in Ichkeul Lake for the period 2010-2022

Parameter	Abbreviation and Unit	Mean	
Period	Pr	Dry	Wet
Precipitation	P (mm)	26.76	69.34
Wind Intensity	W (m/s)	5.71	4.60
Temperature	T (°C)	18.30	17.55
Water Level	WL (m)	0.57	0.64
Salinity	S (psu)	37.06	28.48
Dissolved Oxygen	DO (mg/l)	9.42	7.97
Turbidity	Tur (NTU)	31.56	27.91
Dissolved Inorganic Nitrogen	DIN (µM)	17.43	20.15
Total Nitrogen	TN (µM)	20.92	16.30
Dissolved Inorganic Phosphorus	DIP (µM)	1.34	1.04
Total Phosphorus	TP (µM)	10.83	7.71
Chlorophyll a	Chl.a (µg/l)	5.90	4.35

5. Experimental and numerical approach

5.1. TRIX index:

- Provide the degree of trophic status of coastal ecosystem, based on nutrient concentrations and productivity,
- Analytical expression:

$$TRIX=[log10(DIN*DIP*|D\%O2|*chla) + a] /b$$

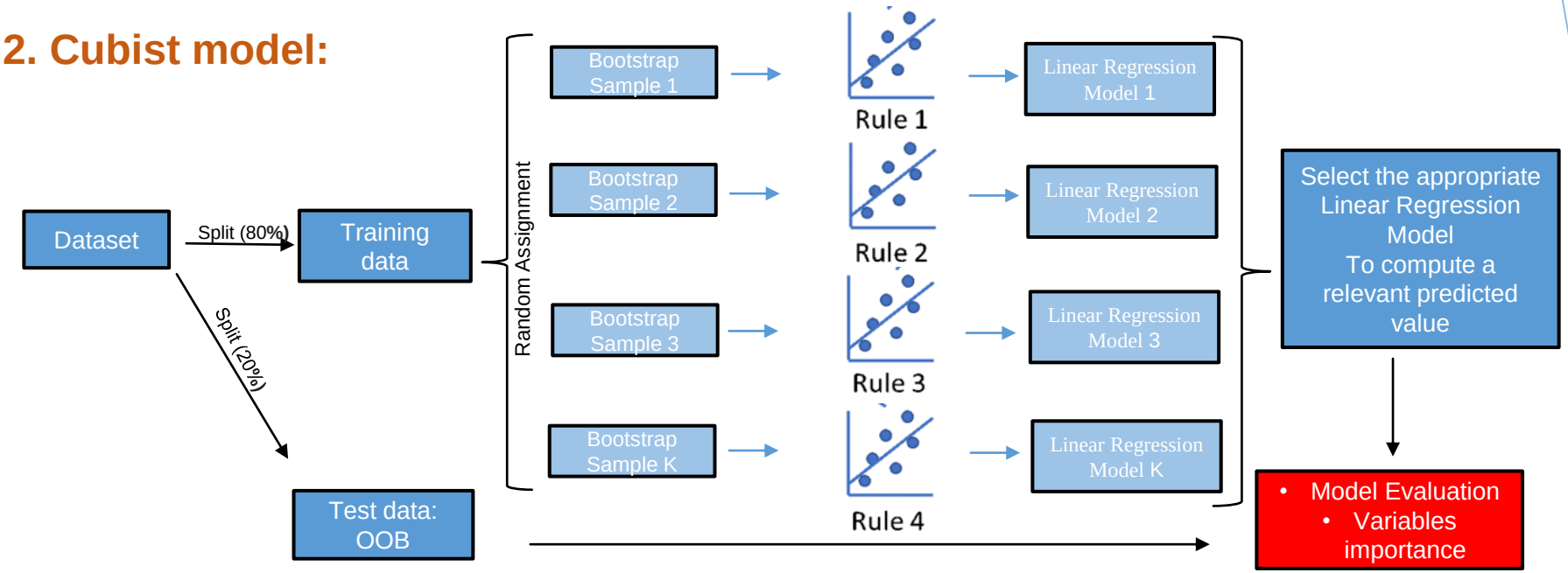
a and b are scale coefficients, with a=1.5 and b=1.2

- Applied to several coastal areas and seas, such as the Caspian Seas, Bizerte,Ghar El Melh and Tunis Lagoons, and the Greek Coastal Lagoon.

Table 1: Reference TRIX values and corresponding eutrophication level, water quality state and trophic conditions (Vollenweider et al., 1998).

TRIX units	Eutrophication level	Water quality state	Water conditions
< 4	Low	High	Oligotrophic
4-5	Medium	Good	Mesotrophic
5-6	High	Poor	Mesotrophic
> 6	Very high	Bad	Eutrophic

5.2. Cubist model:



❑ Models Optimizing

a) Hyperparameters selected for tuning: neighbors (Number of instances) and committees (Number of rules set),

b) Five-folds Cross-Validation Method: used to determine the final optimum hyperparameters of the model.

❑ Models Validation

- Coefficient of Determination R^2 ➡ A good model prediction was expected to have an R^2 value close to 1.

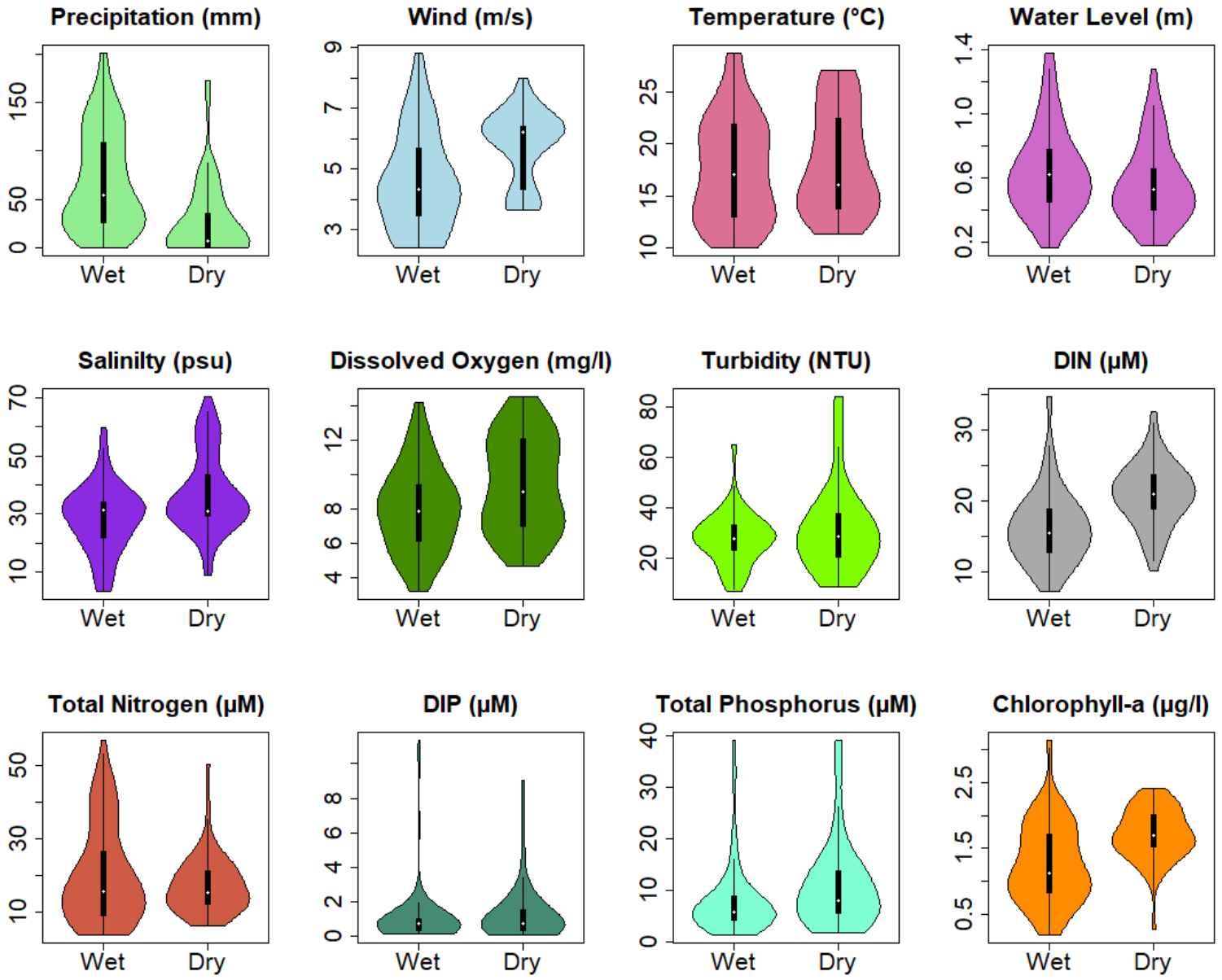
$$R^2 = \frac{\sum_{i=1}^{n} (y_i^{obs} - \overline{y}^{obs})^2 - \sum_{i=1}^{n} (y_i^{obs} - y_i^{pred})^2}{\sum_{i=1}^{n} (y_i^{obs} - \overline{y}^{obs})^2}$$

6. Results & Discussions

6.1. Parameter's properties

➢ Ichkeul Lake is characterized by :

- Seasonal variability of environmental parameters.
- The waters turbidity was high throughout the year due to the effect of meteorological and morphological characterisrics.
- High levels of TP, DIP,TN and DIN during the period of study and,
- A clear variations between the seasons for the Chl.a concentration.



Data visualization with box and violin plots (VIP)

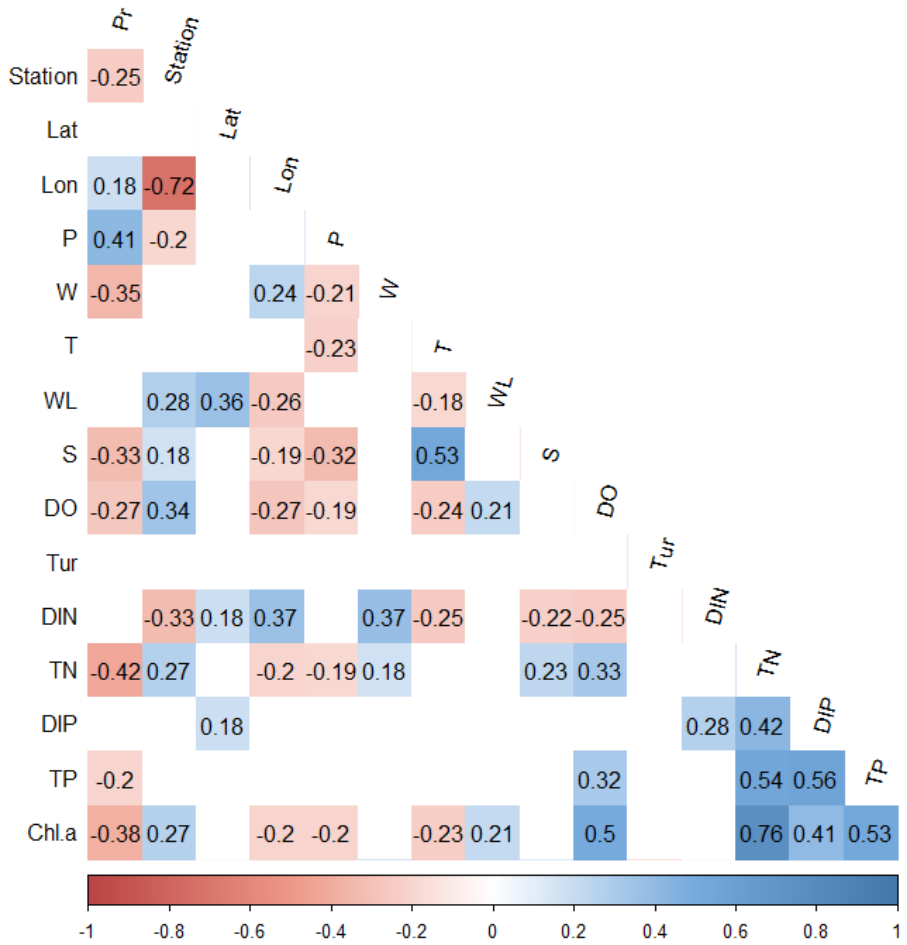
6. Results & Discussions

6.2. Pearson correlation

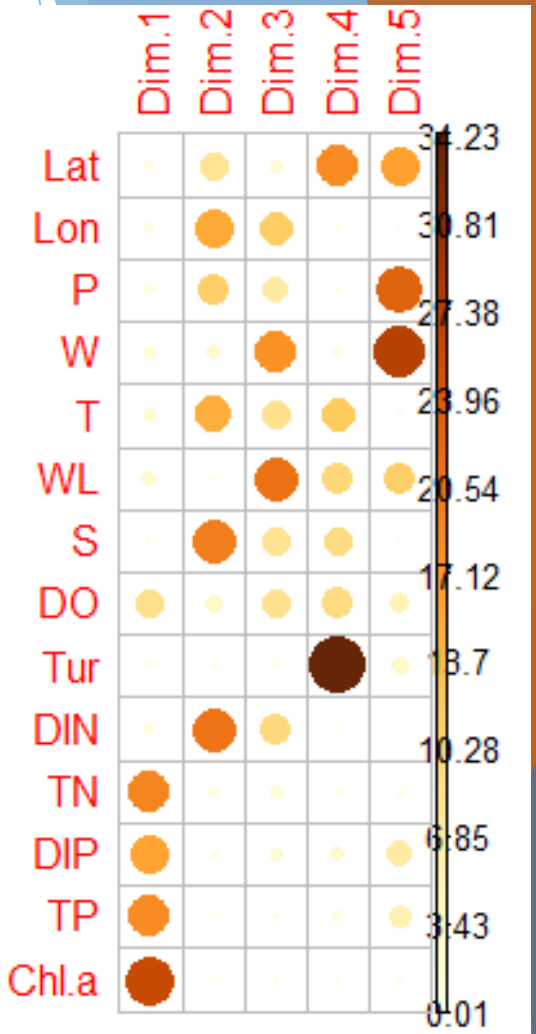
- The Pearson correlation shows that the highest correlation coefficients were found among nutrients parameters.
- Chlorophyll a concentration shows a strong correlation with TN, TP, DO, and DIP.

6.3. PCA analysis

- The first factor is supported by Chl.a, TP, DIP, TN, and DO in descending order of importance. While the second factor is supported mainly by DIN, S, and T.



Lower triangular correlation matrix of the environmental variables.

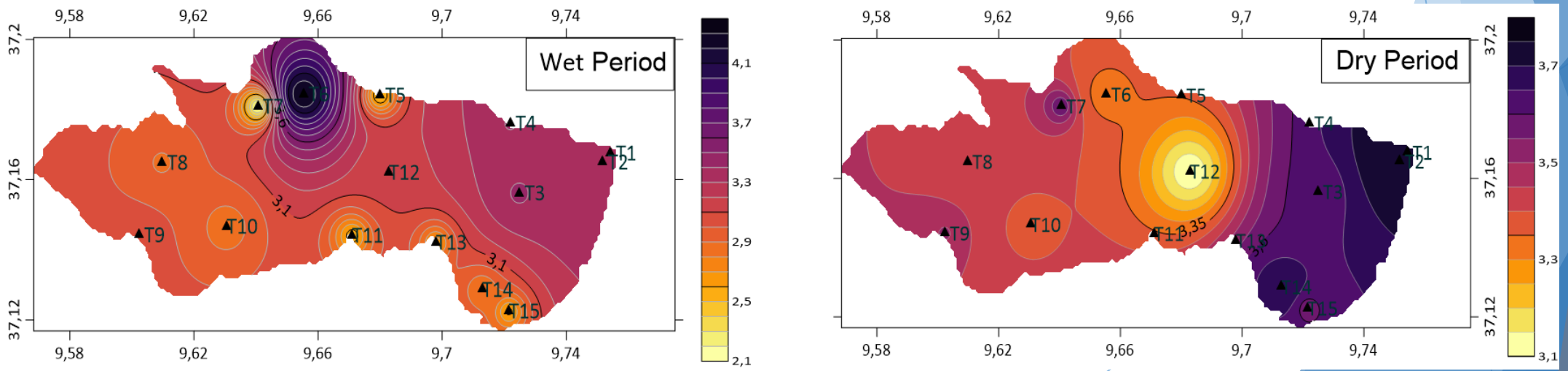


Projection of chlorophyll a and environmental variables on the factors (Dim.1 to Dim.5).

6. Results & Discussions

6.4. TRIX derivation

- Sharp contrast between the occidental, the central, and the oriental sectors of the lake, and a variation between seasons.
- In wet period: the north and east side recorded the highest values.
- In dry period: The lowest values were observed in the central sector compared to the east and the west.
- The waters quality in wet period were poorer than in dry period.
- Ichkeul Lake is a mesotrophic ecosystem with water quality varying from good to poor especially in wet period, and the eutrophication is mainly caused by the important input of nutrients.



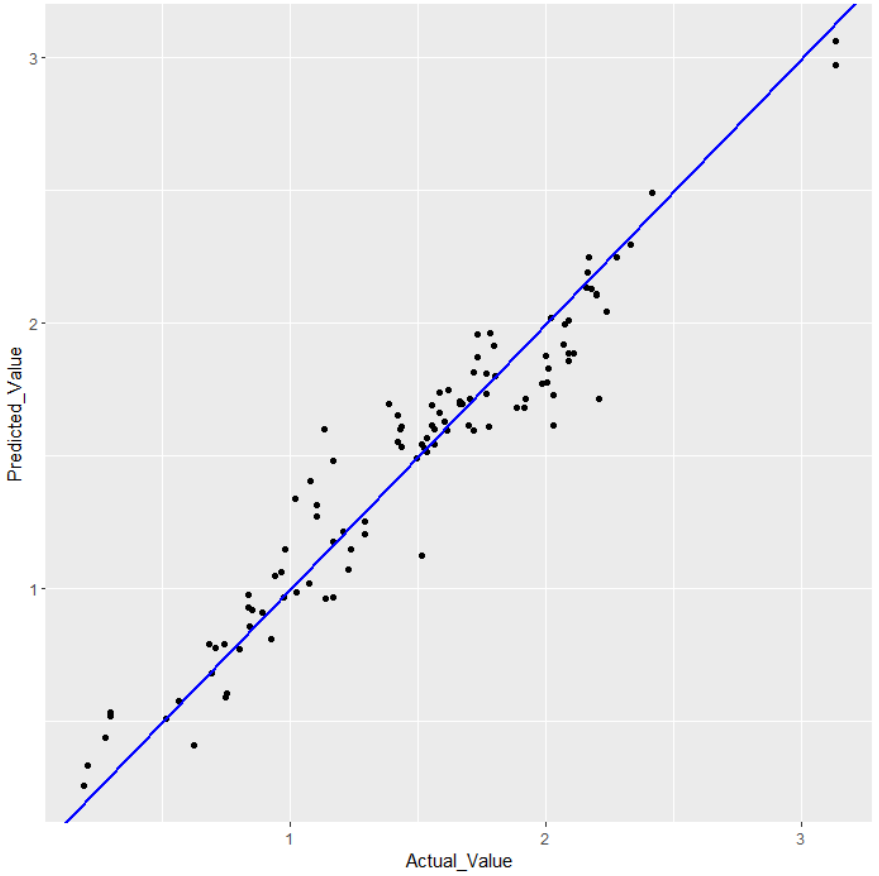
Spatial distribution of TRIX values during the wet and dry period

6. Results & Discussions

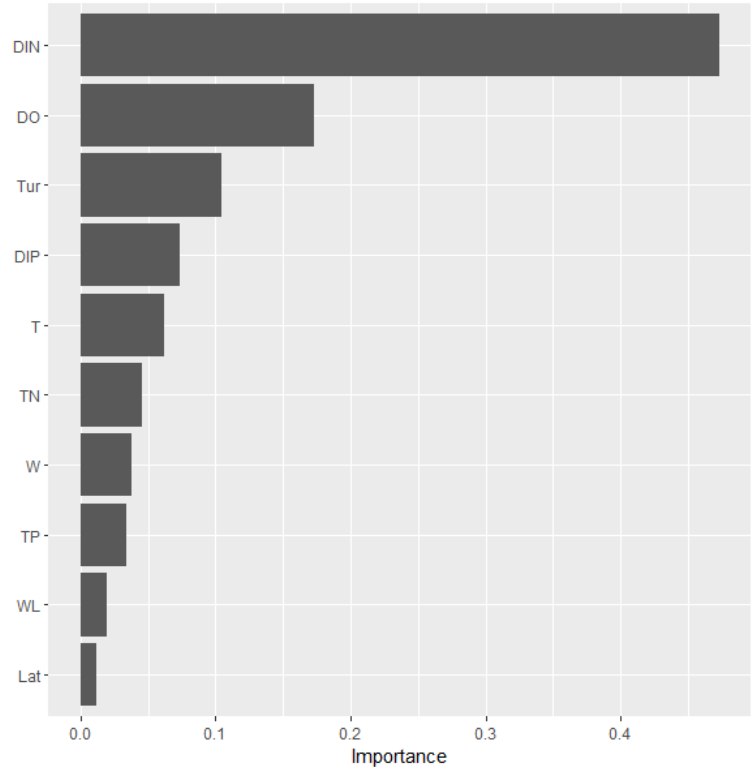
6.5. Cubist model derivation

- The final values used for model were committees= 10 and neighbors=9.
- Model gaves R^2 =57.4%.
- For comparison, we performed a multivariate linear regression on the same data, obtaining an R^2 of about 35 %.

➢ The Cubist model captures the dependency of Chl.a on other variables in a significantly better way than multivariate linear regression.



Scatter plot of the observed and the predicted eels landing using the Cubist model



Predictors importance ranking for Cubist model.

- In Ichkeul Lake, the most important predictors affected the Chl.a concentration appear to be DIN followed by DO, Tur, DIP and T.

➢ The model result between Chla and the predictors is consistent with the relationships found with Pearson correlation and PCA.

8. Conclusion

Based on the numerical approach:

- Climate change and anthropogenic pressures have affected the hydrological, the biogeochemical and the metabolic functioning of the Lake.

➔ Increase of the nutrients loading, the risk of episodic eutrophication, and thus the decrease of Palearctic bird population and of biotic resources.

Actions required

- For the management of the Ichkeul Lake wetland, the key to success resides in improved water management and depollution.

Thanks for your attention

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