Predictive Modelling of Vulnerability Level of French Irrigated Farms

Ferdaous Ben Brahim[1]
Islem Kedidi[1]
Marie-Rose Randiamarolo[1]
Hanitra Randrianasolo[1,2]

(1) UniLaSalle, InTerACT, 60000 Beauvais

(2) Université Paris - Saclay, IDEST, 92330 Sceaux

Chaire Management des Risques en Agriculture
AVEC ET POUR LES AGRICULTEURS

Contents

Introduction

Introduction

Types of risk in agriculture

Farms are subject to the following risks **(Komarek et al., 2020)**:

Production risk: climate factors, pests, diseases ...

Market risk: market and input prices ...

Institutional risk: public regulations and policies ...

Financial risk: variations in the farmers' income, non-payment and liquidity risks …

Human risk: equipment degradation, employee illnesses or deaths and theft ….

Climate-related risks are closely linked with other risks

Introduction

Water-related risk: a focus imposed by current events

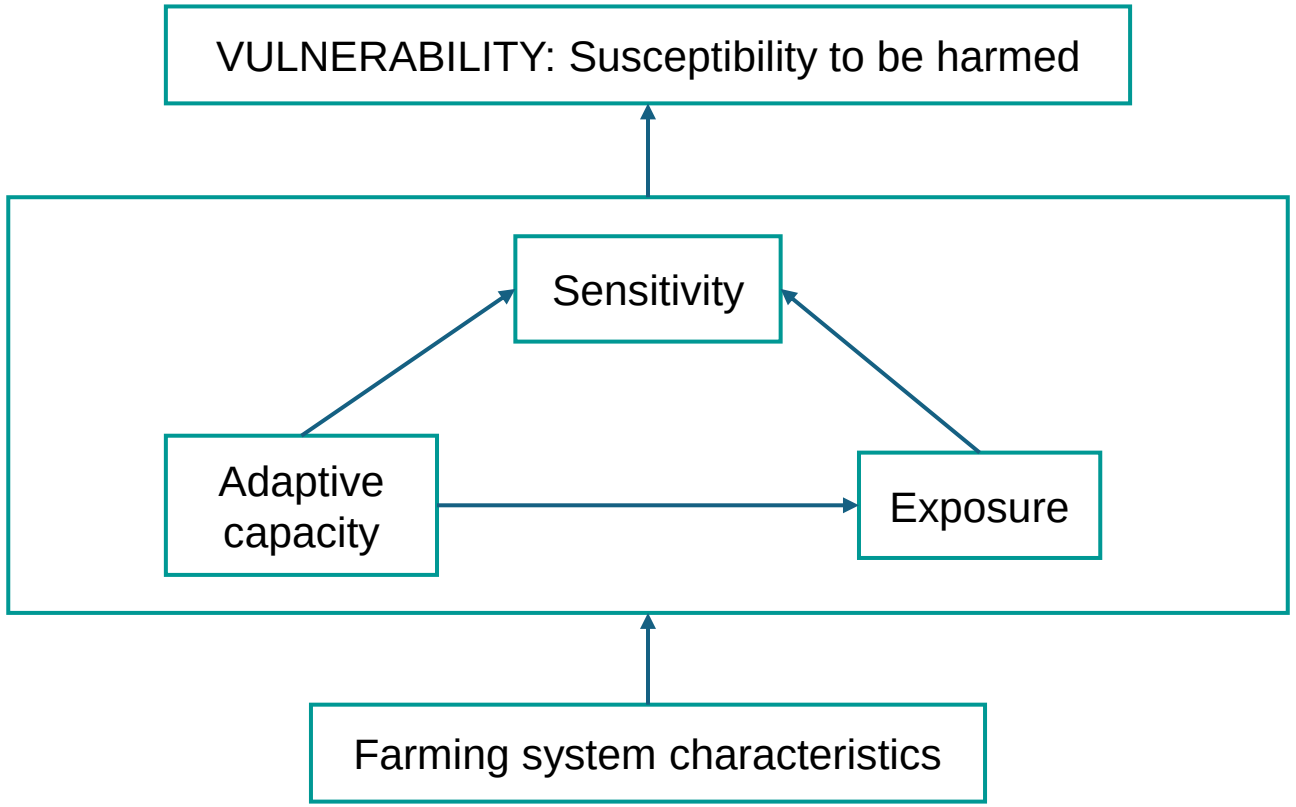
IPCC Sixth Report (2023): "(...) the evidence of observed changes in extremes, such as water-related risks (heavy rainfall, droughts, heatwaves...) has strengthened between 2014 and 2023."

There is a long list of adapting production systems and preventive measures in response to new challenges, especially those imposed by climate change among which irrigation that acts as insurance against the risk of drought (Amigues et al., 2006).

Introduction

Vulnerability Level: a key indicator in farms' risk management

IPCC Third Report (2001): "The degree to which a farming system is susceptible, or unable to cope with all types of risks is its vulnerability."



Introduction

Factors influencing farms' vulnerability level to climate change

An increasing number of publications have studied vulnerability to climate change, and the agricultural sector is often described as one of the most vulnerable ones **(Neset et al., 2019)**.

Mirza (2003): farms' size, geographical location and altitude.

M. G. Debesai (2020): socio-economic, biophysical and environmental factors.

P. Marie Chimi et al. (2023): climate related factors, crop types and infrastructure conditions.

Introduction

Research questions

Do irrigation-related parameters contribute to determining the farms' vulnerability level ?

What are the predictions for the farm's vulnerability level if such a parameter is chosen ?

1- Data & Methods

Data & Methods

Farm Accountancy Data Network (FADN): National dataset based on an annual survey conducted in all Member States of the European Union according to common rules. Information on the status of the farm, economic data, and cultivated crops is provided for each farm. The data is anonymized to prevent the identification of any specific farm within the network. Therefore, in terms of the farm's location, the finest scale provided is the administrative region.

In our study, we examined 631 irrigated farms in metropolitan France during a three-year period from 2020 to 2022.

Data & Methods

Study features:

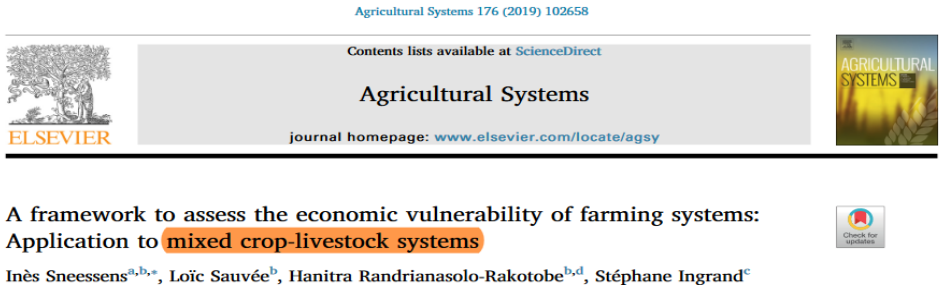
- Farms' ID : Identifies each farm (not a feature but included).
- Year of the observation : Categorical — Year of data collection (2020, 2021, 2022).
- Region Code : Categorical — Geographical region (Bretagne, Occitanie, Normandy …).
- Disadvantaged zone code : Categorical — Geographical and environmental constraints (Non-disadvantaged zones, Natural constraints, Specific constraints, Mountainous areas).
- Technical-economic orientation : Categorical — Type of production system (Cattle or Pig farming, Field crops …).
- Code for main source for irrigation water : Categorical — Individual network (hill reservoirs, ponds, water reservoirs, not connected to a watercourse), Individual network (groundwater: wells, boreholes), Individual network (surface water: streams, canals, lakes), Collective Networks, Individual network (other sources).
- Code for main irrigation method : Categorical — Surface irrigation, Sprinkler irrigation, Micro-irrigation.
- Irrigation water costs per irrigated area : Continuous — measured in €/ha.
- Vulnerability Level : Categorical — Slightly vulnerable, Moderately vulnerable, Highly vulnerable.

Data & Methods

Measuring Vulnerability Level

A framework for measuring farms' vulnerability level

Using FADN


Agricultural Systems 176 (2019) 102658

Contents lists available at ScienceDirect

Agricultural Systems

journal homepage: www.elsevier.com/locate/agsy

A framework to assess the economic vulnerability of farming systems: Application to mixed crop-livestock systems

Inès Sneessens[a,b,*], Loïc Sauvée[b], Hanitra Randrianasolo-Rakotobe[b,d], Stéphane Ingrand[c]

Four indicators

The Relative standard deviation (RSD) of the annual consolidated current result before tax per worker (CR.LU). It measures the variability of the annual farming income :

$$RSD^{CR.LU}\ (\%) = \left| \frac{SD^{CR.LU}}{\mu^{CR.LU}} \right| * 100$$

The mean relative distance (RD) of the annual consolidated current result before tax per worker to minimum wage (SMIC). It compares the farming system's income to the national minimum wage :

$$RD^{CR.LU}\ (\%) = \text{mean}\ \left(\frac{CR.LU - SMIC}{SMIC}\right) * 100$$

The number of economic disruptions (ED) which corresponds to the number of times the annual income per worker drops by more than 25% from one year to the next.

The number of years for economic recuperation after disruption which corresponds to the number of years it takes for the system to recover to the pre-disruption level of income after a significant drop.

Data & Methods

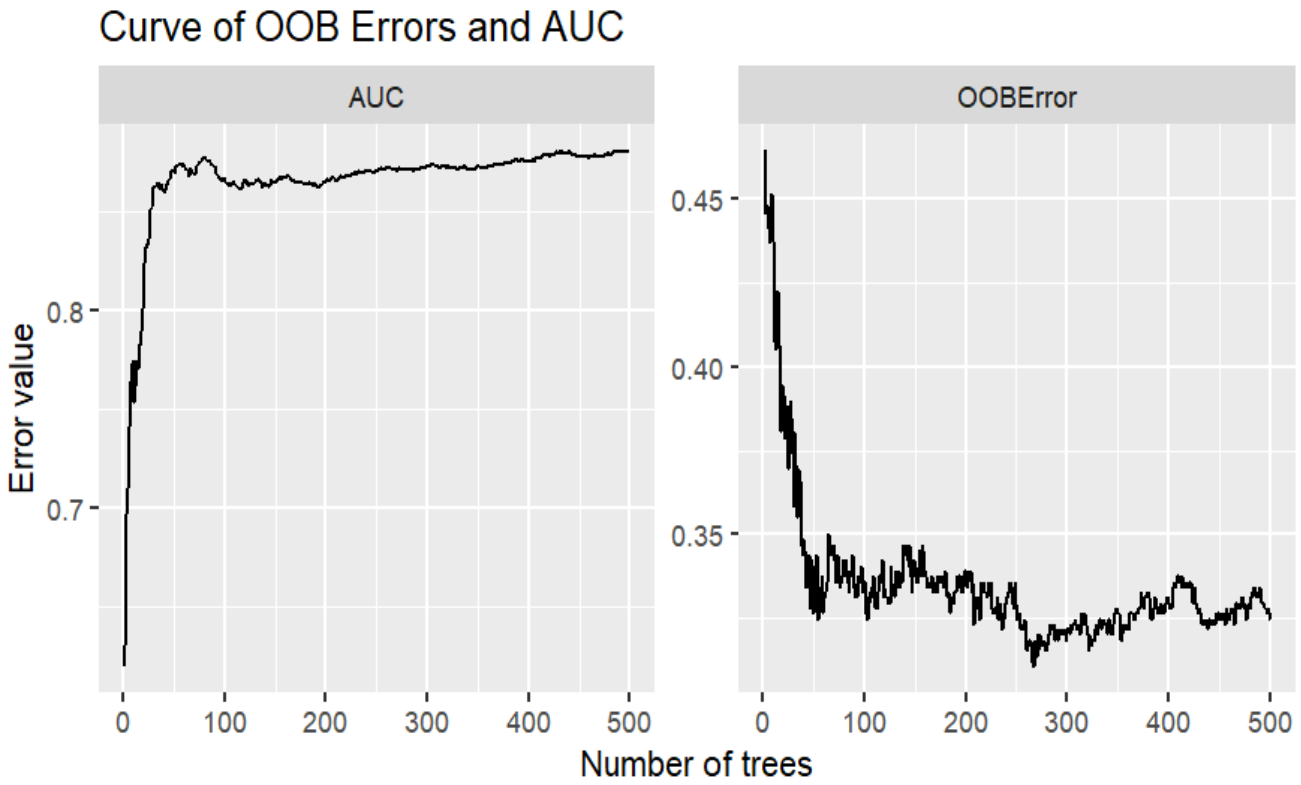
Measuring Vulnerability Level

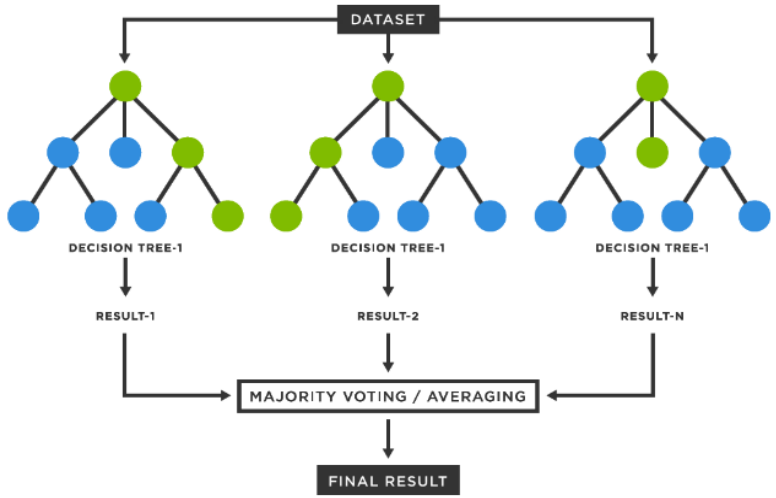
The combination of results obtained for the four indicators of vulnerability through an Ascending Hierarchical Classification permits identifying three clusters of farming systems.

The statistical analysis of these three clusters permits then to define the vulnerability levels of each cluster identified.

Data & Methods

Predictive Modelling « Random Forests »





500 decision trees

Achieving the highest accuracy of 92.86%

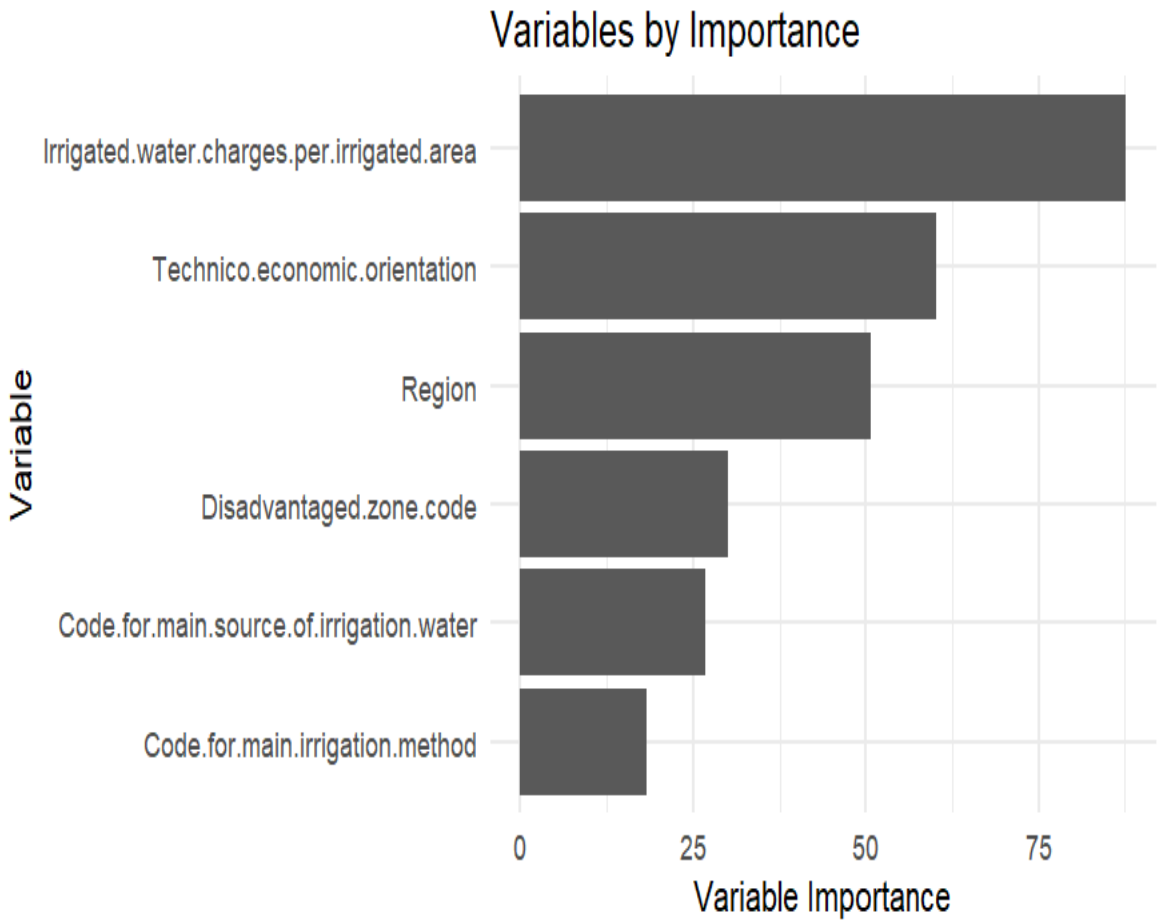
2- Results

Results

Variable importance is calculated through a Mean Decrease Impurity :

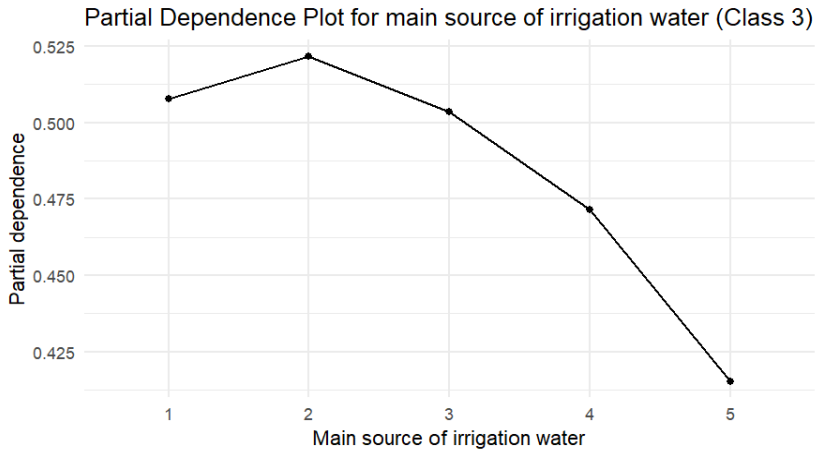
$$V_{imp}(x_i) = \frac{1}{n_{trees}}\left[1 - \sum_{j=1}^{n_{trees}} GI\,(i)^{(j)}\right]$$

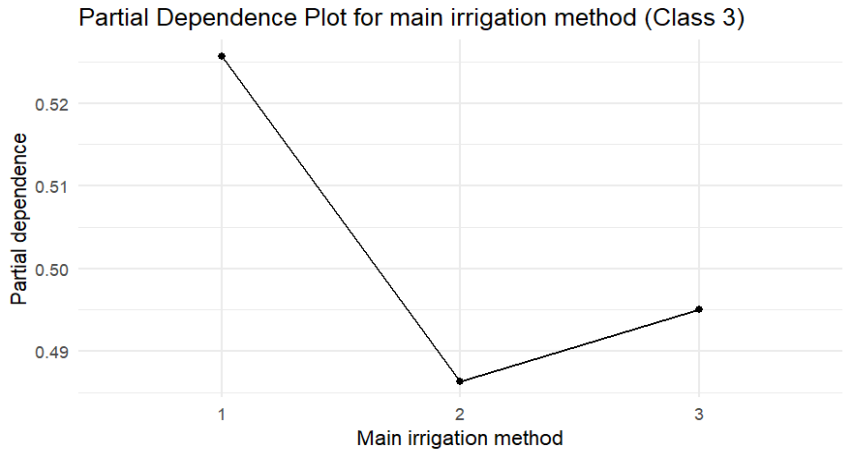
- A higher mean decrease in Gini imply a higher importance of each feature in predicting the outcome feature.



Results

Partial Dependence Plots for Features Influencing Predicted Probability of Class 3 (Highly Vulnerable) : a focus on irrigation water source and method





Source 2 (Groundwater: wells, boreholes) exhibits a strong positive effect (~0.525), making it the most favorable for classifying farms as highly vulnerable. Meanwhile, source 5 (Other individual water sources) shows the lowest effect (~0.425), indicating it is the least favorable for classifying farms as highly vulnerable.

Surface Irrigation (Method 1) exhibits the highest positive marginal effect (~0.56), making it the most favorable method for classifying farms as highly vulnerable. Meanwhile, sprinkler Irrigation (Method 2) shows a negative marginal effect (~0.44), indicating that it is less favorable for classifying farms as highly vulnerable.

3- Discussion

Discussion

- The study aim was to utilize random forests to predict farm's vulnerability level using the Farm Accountancy Data Network 2020-2022.
- Random Forests was also used to determine the important features that help in telling the level a farm belongs to in terms of vulnerability and predictions on how it varies based on two irrigation-related parameters.
- Irrigation water costs per irrigated area, followed by the technical-economic orientation and the region were more important in predicting a farms' vulnerability level.
- Partial Dependence Plots highlighted the empirical differences between modalities of two irrigation-related parameters. The predicted gradient between highly vulnerable and irrigation methods defines a difference between surface irrigation and sprinkler irrigation. Similarly, for the class highly vulnerable and the source of irrigation water. Individual networks from groundwater and those from less common sources show a difference in predicting the highly vulnerable outcome.

Conclusion

Conclusion

This study brings out the application of random forests to predict the vulnerability level of a farm in France. The random forests are a significant improvement from classical regression techniques when dealing with unbalanced data panel with a temporal dimension.

Irrigation water costs per irrigated area, farms' technical-economic orientation and regions' characteristics should be taken into consideration when interventions are being considered for improvement of farms' vulnerability level in the country.

In the future, we aim to consider a longer study period using the detailed Farm Accountancy Data Network, which contains non-anonymous individual farm data, and which is only accessible in specific cases, upon request to the Data Access Security Center and after review by the Data Secrecy Committee. This database contains all the values for the studied features, unlike the publicly available one used in our study, where for some features, the data is only available starting from the year 2020.

Thank you for your attention !