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Assessment of Environmental Management Performance in Wineries: A Survey-Based Analysis to Create Key Performance Indicators

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Abstract: This study assesses the adoption and operational effectiveness of Environmental Management Systems (EMSs) in Italian wineries, focusing on ISO 14001:2015. It evaluates commitment, planning, communication strategies, emergency preparedness, and employee training practices. Using a comprehensive survey-based methodology, the research elucidates the dynamics of EMS implementation across various scales of winery operations. The research reveals a strong commitment among wineries to environmental objectives such as waste reduction and efficient electricity and water use. However, significant deficiencies were identified in EMS policy implementation, emergency preparedness, and the uptake of ISO 14001:2015 certification, with larger wineries showing more robust engagement in environmental training than smaller ones. The study incorporates five key performance indicators (KPIs) and a predictive model using logistic regression and Random Forest to analyze the likelihood of ISO 14001 certification based on the analyzed variables. The model highlights established processes, environmental policies, and frequent reviews as significant predictors of certification. These findings contribute original value by identifying critical leverage points and barriers affecting EMS effectiveness within the wine sector. The research uncovers nuanced interactions between the scale of operations and management engagement influencing EMSs' success. It proposes novel, survey-based KPIs essential for assessing EMS performance in wineries, demonstrating their practical utility in pinpointing areas for improvement. The research limitations include potential biases from varying participation rates among surveyed wineries, affecting extrapolation to the broader Italian wine industry. Despite these limitations, the study provides substantive practical implications, suggesting that wineries can enhance both environmental sustainability and a competitive edge by addressing gaps in EMS implementation.

Keywords: environmental management; environmental methodologies; key performance indicators; sustainable wineries; clean production

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1. Introduction

The journey towards environmental sustainability in the European Union (EU) has been gaining momentum over the last two decades, particularly within key agricultural sectors such as the wine production [1–3]. The primary sector focus on sustainability can be traced back to the Lisbon Strategy in 2001 and it has been continuously reinforced through significant policy initiatives, including the United Nations Sustainable Development Goals, which are a part of the Agenda 2030 strategy [4]. In 2016, the initiative "Next steps for a sustainable European future—European action for sustainability" marked a pivotal commitment to these goals [5]. The 8th Multiannual Environment Action Programme introduced in 2020 aimed to secure well-being within the ecological limits of the planet by 2030 [6], and it was supported by the European Green Deal (EGD) which aims to transform Europe into the world's first climate-neutral continent by 2050 [7,8]. The ambitious goals of the EU Biodiversity Strategy for 2030 [9,10] include transitioning toward organic farming and are aligned with the broader objectives of the EGD and the Farm to Fork (F2F) strategy [11].

Wine production is profoundly impacted by these regulations because of its extensive use of natural resources and significant environmental footprint [12,13]. Vineyards and wineries are not merely agricultural spaces but integral components of broader ecological systems that have the potential to enhance biodiversity, soil health, and water quality [14]. Conversely, this sector can also be a source of considerable environmental degradation, with issues such as pesticide runoff, habitat destruction, and water overuse being prevalent [15]. In response to these challenges, the EU has intensified its efforts to integrate sustainable practices within viticulture that mitigate environmental impacts while preserving the sector economic viability and cultural heritage [16,17]. The narrative around sustainable wine production techniques such as organic viticulture and agroecological practices highlights these methods as essential in addressing environmental challenges.

Central to these efforts are Environmental Management Systems (EMSs), and particularly EMSs based in ISO 14001:2015 [18,19]. An EMS is a group of procedures, rules, and sets of evidence that an organization establishes to minimize the environmental impacts produced in the development of its activity [20]. This EMS ISO standard has emerged as an essential tool for aligning the operations of vineyards and wineries with broader EU sustainability goals [21–23]. Adoption of the ISO 14001:2015 standard enables these businesses to demonstrate their commitment to environmental improvement and positions them to gain a competitive edge in sustainability [24].

Diving specifically into Italian wineries, we find a rich history of wine production [25–27]. However, they face the crucial challenge of finding a balance between the use of common production practices and the urgent need for environmental sustainability. The implementation of EMS in Italian wineries offers an insightful case study into the effectiveness of these balanced within a context marked by diverse operational scales and varying degrees of resource availability [28,29]. The Italian wine production sector had 37,298 wine farms in 2021 [30]. Italian wine production amounted to 54,005 million hectoliters as of April 2023, mainly in the Veneto region (11,870) and the Puglia region (10,846), Emilia-Romagna region (6139), and Sicilia (5881) [31]. The sector's main characteristics regarding to farm size are high segmentation and deep duality. Four percent of all wineries have a vineyard production area of more than 30 hectares, and together account for more than twenty-four percent of the total wine-growing area. On the contrary, fifty-five percent of wine farms have an area of less than 3 hectares, and these constitute seventeen percent of the total wine area [32]. Thus, there is a co-existence between firms that have a big wine production amount, and, on the other hand, thousands of small wine farms that have a small grape production, usually for self-consumption. Several studies highlights that wine cooperatives play a critical role in the Italian wine sector, particularly for those small-scale producers [33–36]. Cooperatives provide a platform through which small vineyards can achieve a more significant market presence, leveraging collective resources to enhance their bargaining power and market penetration [37–39].

In this context, the following research questions are proposed: What is the current state of environmental management performance in Italian wineries? Which key indicators determine their environmental performance through this management? Arising from these questions are two primary research objectives. The first objective is to evaluate the effectiveness of environmental management practices within wineries. The second objective is to identify and analyze the key components of environmental management and propose a tool for measure them.

2. Materials and Methods

2.1. Study Design

The research design was proposed by conducting a questionnaire and its subsequent analysis using appropriate statistical methods. The survey-based method is widely used in this type of research [40–42]. The sample was selected among Italian wineries from different wine regions. From June to November of 2022, the survey was conducted, and then, SPSS Windows software SPSS (IBM Corp. 2020. IBM SPSS Statistics v 27.0. Armonk, NY, USA) and Excel (Microsoft Corp. 2021. MS Excel v 18.0. Redmond, Washington, DC, USA) were used to analyze the data. Logistic regression analysis and a Random Forest model were used utilizing machine learning through Python software (Python Software Foundation, Python Language Reference, version 3.8, http://www.python.org (accessed on 10 June 2024)). Logistic regression is a statistical method used for binary classification problems, where the outcome or dependent variable can take only two possible types, such as 0 and 1, true and false, or yes and no [43–45]. It is a type of regression analysis used when the dependent variable is categorical. Random Forest model is an ensemble learning method that constructs multiple decision trees during the training phase and outputs the class that is the mode of the classes (for classification) or the mean prediction (for regression) of the individual trees [46].

2.2. Sample Selection

A sample of one hundred and twenty wineries were selected from several Italian WPDOs. The sampling method of selection was the non-probabilistic method [47,48]. Researchers used earlier information to make the sample selection, instead of random selection. Wineries were asked about their EMS performance. The questionnaire was made with Google forms software [49]. Each winery received the questionnaire by email twice from May to November 2022. Survey was fulfilled by fifty-four wineries. This permitted the application of the Central Limit Theorem (CLT) [50,51] as we obtained more than thirty wineries' answers. The CLT is a cornerstone principle in statistics that supports the use of samples of thirty or more to make inferences about a broader population. This includes the context of categorical variables, particularly when evaluating proportions or percentages.

2.3. Survey Preparation

The design of the survey was carried out through a questionnaire with a total of thirty-two questions divided into twelve sections. Questions (Qs) were made based on the ISO 14001:2015 content and research studies about EMS implementation and environmental impacts in Italian wine production [15,28,29,52–57]. Twenty-nine Qs were closed, that is, the answer alternatives were limited, and three questions were opened, which allowed a long explanation or description by the respondent. Research studies that are causal, descriptive, and conclusive use this kind of questionnaire [58]. In addition, a Likert scale [59] was utilized, incorporating both a qualitative scale and a V_Q to measure and assess the performance of wineries. Figure 1 provides an overview of the questionnaire structure, including questions and variables. The questionnaire is included in Appendix A.

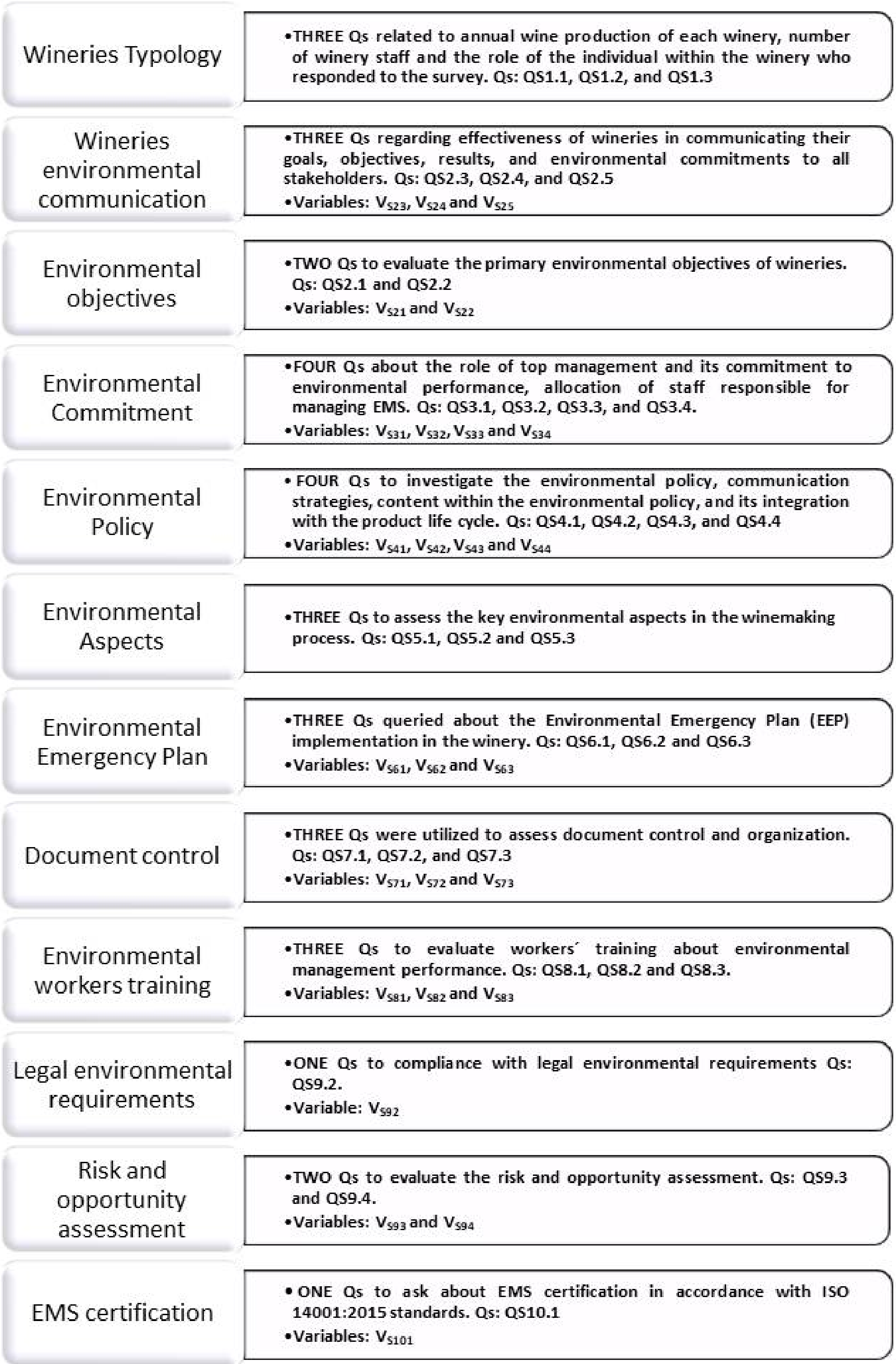

Figure 1. Questionnaire structure, including questions and variables.

3. Results

The distribution of wineries in descending frequency is depicted through the Pareto chart in Figure 2. A significant majority of wineries (75.0%) produce less than 100,000 L/year, while 12.5% exceed 1,000,000 L/year. The distribution of the sample wineries exemplifies the duality within the Italian wine sector. This sector is characterized by many small wineries with low annual production volumes and a smaller number of large wineries with high annual production volumes. However, it is crucial to acknowledge the role of Italian wine cooperatives in the annual production distribution. Notably, 43% of the production in the category 'more than 1,000,000 L/year' and 58% of the production in the category '250,000–1,000,000 L/year' are attributed to wine cooperatives. Regarding number of winery workers, 80.8% of wineries has less than 10 workers, and 19.2% have between 10 and 49 workers.

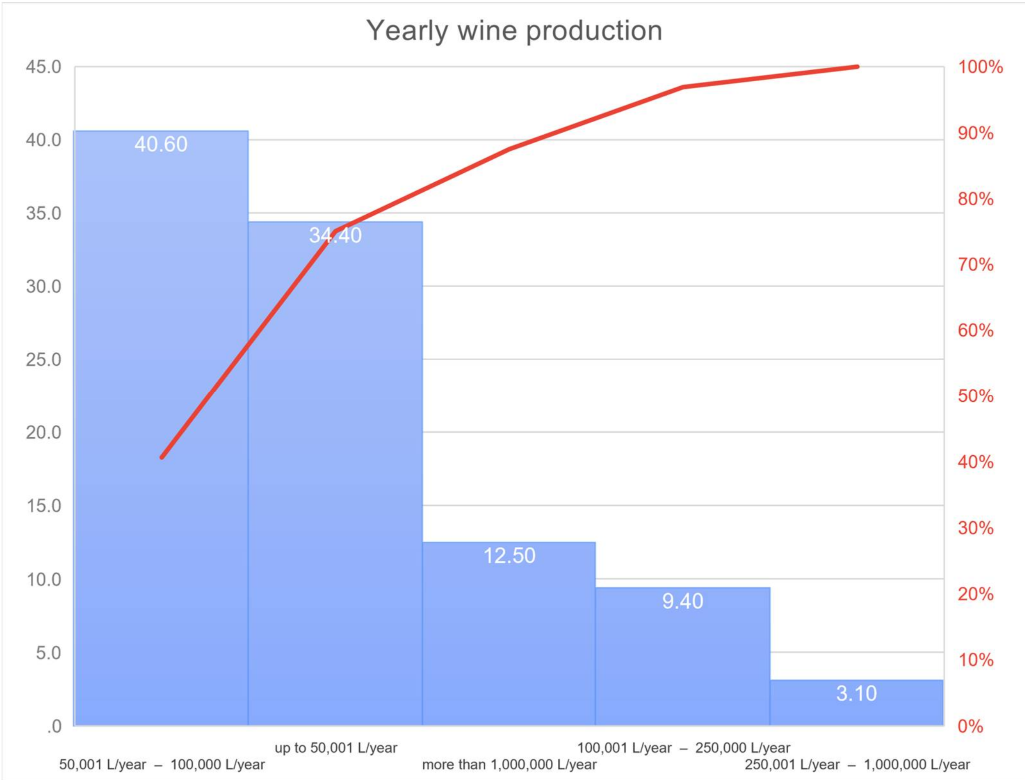

Figure 2. Wineries' Pareto chart regarding their yearly wine production.

The areas related to environmental management of which the wineries claim to consider are as follows: environmental management (48.0%), leadership (12.0%), planning of environmental objectives (40.0%), environmental risk and opportunities (10.5%), resources and environmental support (20.0%), communication (52.0%), operation and environmental control (40.0%), emergency response (12.0%), and monitoring, analysis, and evaluation of EMS performance (52.0%). The results show a lack of clearly defined EM areas in the Italian wineries. Only large wineries (80%) have a defined and implemented structural focus on EMS.

3.1. Environmental Communication

Internal communication is the way in which senior management communicates environmental issues with its staff. Email is used by 74.2% of wineries, being the most widespread regardless of the size of the winery. Websites (45.2%) and social media (35.5%) were the next most used media. Newsletters (22.6%) and internal staff sites (12.9%) were basically used by large wineries. Finally, other methods such as WhatsApp (3.2%), direct communication (6.4%), and informative talks (3.2%) were very rare systems.

External communication is harnessed by wineries to explain their environmental awareness and environmental performance to external stakeholders. In total, 84.4% of wineries used social media such as Facebook and Instagram, and websites were used by 81.3% of wineries. Newsletters (31.3%), advertisements (6.3%), and marketing campaigns (25.6%) were other minor communication methods.

Figure 3 shows the different stakeholders that wineries use to inform about their environmental performance and environmental awareness. Clients (88.9%) and shops (74.1%)

were the most popular stakeholders that received environmental information from wineries, then public administrations (48.19%) and suppliers (37%). Ecology associations (3.7%) or wine club members (3.7%) were rarely represented.

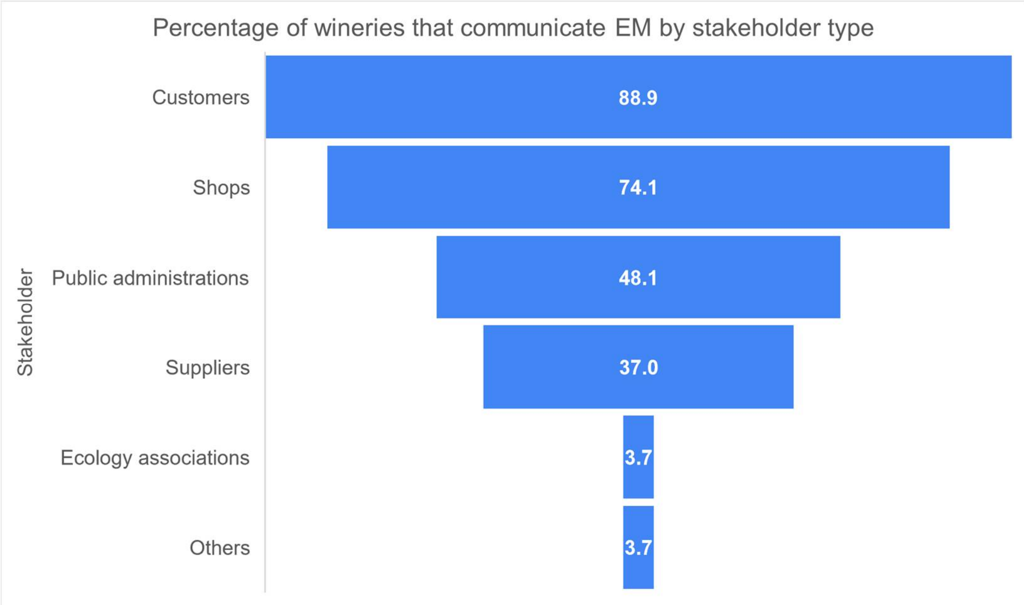

Figure 3. Percentage of wineries that communicate environmental management performance by stakeholder type.

The results show that Information and Communication Technologies (ICT) [60] are clearly most often used by wineries to inform about their environmental management performance to all stakeholders, and environmental communication is focused on selling wine as customers (88.9%) and shops (74.1%) are the main target for wineries.

The wineries add value to their wines by informing about adequate environmental management, and for this they use social media marketing. Social media marketing (SMM) is being used to promote businesses and brands interacting with current and prospective customers through social networks. Instagram or Facebook are popular social networks that companies use to promote their products [61,62]. One in three wineries communicate to suppliers and one in two inform public administrations; in both cases, this is accomplished with the EMS communication requisites.

Finally, ecology associations or others, related to wine club members, appear as other minor stakeholders that are related to the specific contexts where wineries develop their activity.

3.2. *Environmental Commitment: Policy, Leadership, and Roles Management*

Environmental policy represents the organization's intentions and its leadership in relation to its environmental performance. These intentions expressed and formally communicated by senior management constitute this policy [24]. A total of 71.9% of wineries have set up an environmental policy and have an environmental senior management. However, 28.1% do not have it, and this represents that one in three wineries has a big failure in its EMS. Environmental policy and senior management leadership are essential to commit the wineries with environmental protection and awareness.

The distribution of who assumes the main responsibilities for EM in the wineries is represented in Table 1. The results highlight the significant role of owners in environmental management, with 50% of the responsibilities allocated to them. This suggests that ownership plays a crucial role in shaping the environmental policies and practices within a vineyard. Executive managers and vineyard managers follow closely, contributing 14% and 12%, respectively, showcasing their integral role in implementing and overseeing EMS.

The presence of a "No answer" category at 6% suggests a potential gap in awareness or acknowledgment of environmental responsibilities among certain personnel.

Table 1. Distribution of position roles that assume EMS high responsibility in the wineries.

Position	Percentage (%)
Owner	50
Executive Manager	14
Vineyards Manager	12
General Manager	9
No Answer	6
Administration Officer	3
Environmental Officer	3
Quality Advisor	3

Administration officers, environmental officers, and quality advisors collectively contribute 9%, indicating that specialized roles also play a significant part in ensuring EM. The distribution emphasizes the need for a holistic approach, incorporating both general management and specialized roles to address environmental challenges effectively.

Regarding EMS reviewing by senior management, 26.9% review it at least every six months, 15.4% more than once a year, 53.8% review it annually, and 3.8% never review it. Finally, 56.3% of wineries have established procedures to achieve annual environmental results, compared to 43.8% that have not.

3.3. Environmental Planning: Objectives, Environmental Aspects, Risk and Opportunities, and Legal Requisites

Environmental planning encompasses environmental objectives, environmental aspects, legal requirements related to the environment, and risk and opportunity assessment. These components together form the basis for effective environmental planning, ensuring compliance and the ongoing improvement of environmental performance.

The main winery environmental objectives are waste production reduction (75.0%), electricity consumption reduction (75.0%), water consumption reduction (71.9%), substances releasing into the soil reduction (68.8%), greenhouse gas emissions reduction (53.1%), other gases emissions reduction (28.1%), use of raw materials reduction (21.9%), land-use reduction (15.6%), and others as agricultural land recovery (3.1%).

The alignment between the long-term environmental policy commitments made by wineries and their annual environmental objectives is illustrated in the cross-table (Figure A1) which is provided in Appendix C for reference. In general, the greatest consistency occurs in electricity consumption (84.6%) and water consumption (83.3%), and the lowest coherence occurs in fossil fuel consumption (57.9%).

The environmental aspects of the winemaking process consulted were electricity consumption (V_{S51}), solid waste production (V_{S52}), and gases production hazardous to workers' health (V_{S53}). The measures used to reduce electricity consumption were the installation of solar panels (50%), use of electrical energy produced by renewable sources (15%), use of buried structures to keep heat produced with electrical energy (10%), and active management of electricity consumption reduction in luminaires and equipment (10%). In total, 10% of wineries do not have measures to reduce electricity consumption. The measures used to reduce waste production are waste classification and separated disposal (71.4%), recycling and reuse of packaging (23.8%), use of biodegradable ecological packaging (4.72%), and agronomic use of organic waste (4.7%). In total, 4.7% of wineries do not have measures to reduce waste production. In total, 61.3% of wineries adhere to the stipulated legal requirements set forth by relevant authorities regarding environmental impact. Prioritizing compliance with environmental regulations is pivotal for wineries. By systematically identifying and assessing applicable legal requirements, over half of the wineries showcase a dedicated commitment to environmental responsibility.

A total of 68.8% of wineries have certified their EMS according to the ISO 14001:2015 standard. This certification guarantees legal compliance, resource efficiency, and waste reduction. Demonstrating a commitment to environmental responsibility, more than half of the wineries aim to build trust and capitalize on business opportunities in environmentally conscious markets.

3.4. Other Environmental Management Requirements: Environmental Emergency Plan, Document Control and Organization, and Certification

Other environmental requirements are based on the development of an EEP, the implementation of a documented management system, and certification. This framework provides a solid foundation for environmental management and continuous improvement of environmental performance. EEP in wineries is crucial for safeguarding human and environmental resources. Wineries face various potential emergencies, such as fires and chemical spills, which can impact their operations and the environment. In total, 38.7% of wineries have not formulated an EEP to prevent or mitigate adverse environmental impacts arising from emergency situations, leaving the remaining 61.3% with an EEP in place. When it comes to the periodic assessment of an EEP, over half of the wineries conduct these assessments annually. Table 2 provides insight into the frequency with which wineries verify their EEPs, categorized by winery size groups.

Table 2. Percentage of wineries by size groups according with the frequency that they verify their EEP.

	Periodicity Verified EEP (%)				
Winery Size	**At Least Very Six Months**	**More Than Once a Year**	**Annually**	**Less Than Once a Year**	**Never**
Up to 50,000 L/y	8	8	58	0	25
50,001–100,000 L/y	0	0	62	16	31
100,001–250,000 L/y	0	25	75	0	0
250,001–1,000,000 L/y	0	0	100	0	0
More than 1,000,000 L/y	25	0	50	0	25

Regarding the inclusion of environmental emergencies in EEPs, data reveal that fire is a component in 86.4% of winery EEPs. An uneven discharge of water is incorporated into 45.5% of EEPs, while an unusual presence of stains or foams of unknown origin from nearby water channels is considered in 18.2% of these plans. The presence of waste and/or abandoned waste is addressed in 54% of EEPs, and the spillage of hazardous substances is a part of 22.7% of these plans. Additionally, other types of environmental emergencies are accounted for in 4.5% of winery EEPs.

A total of 94.12% of wineries implement an organized and controlled documentation system, and 53% annually update information in line with ISO 14001 standard. Yet, 30% of wineries do not engage in the annual updating process.

With respect to ISO 14001:2005 certification, 31.3% of wineries have obtained certification for their Environmental Management Systems (EMSs) according to this standard.

3.5. Environmental Training for Workers

Employee training in environmental management is pivotal in raising awareness about environmental aspects within their roles and responsibilities. This training encompasses understanding sustainable objectives and activities, thereby contributing to the continuous improvement of environmental performance.

In total, 71% percent of wineries provide training to their employees in connection with their environmental management system, whereas the remaining 29% do not offer such training. Table 3 illustrates the distribution of training offerings based on winery size.

Table 3. Percentage of wineries that offer training to their workers categorized by their annual wine production size.

	% of Wineries That Offer Environmental Training to Their Workers				
Winery Size	Up to 50,000 L/year	50,001–100,000 L/year	100,001–250,000 L/year	250,001–1,000,000 L/year	More than 1,000,000 L/year
Percentage	42	69	75	100	100

The frequency of worker participation in environmental training courses and the percentage of total workers participating in such courses annually, categorized by winery size, is shown in Table 4.

Table 4. Percentage data regarding the frequency of worker participation in environmental training and the percentage of total workers participating in such training annually categorized by winery size.

	% of Wineries Categorized According to the Frequency at Which Their Workers Participate in Environmental Training				
Winery Size	**At Least Every Six Months**	**Annual**	**More Than Once a Year**	**Never**	
Up to 50,000 L/year	0	67	33	0	100
50,001–100,000 L/year	11	78	11	0	100
100,001–250,000 L/year	0	100	0	0	100
250,001–1,000,000 L/year	0	100	0	0	100
More than 1,000,000 L/year	25	75	0	0	100
	% of wineries categorized based on the proportion of their total workforce participating in annual environmental training				
Winery size	**more than 75%**	**between 50–75%**	**between 25–50%**	**less than 25%**	
Up to 50,000 L/year	17	0	67	16	100
50,001–100,000 L/year	56	0	11	33	100
100,001–250,000 L/year	34	33	33	0	100
250,001–1,000,000 L/year	100	0	0	0	100
More than 1,000,000 L/year	75	0	25	0	100

3.6. Integrated Table and Graph of the Grade of Progress in Wineries Generated by Environmental Performance Indicators (KPIs)

Effectiveness in EM is achieved through the integration of five key components: communication, commitment, planning, compliance with other requirements, and worker training. Five KPIs have been developed based on the quantitative variables associated with the questions in the questionnaire to quantitatively measure the progress in the performance in each component. Appendix B contains the calculations of the KPIs. These KPIs enable the determination of the extent of progress each group of wineries has achieved in relation to EM performance. Table 5 shows KPIs values by winery sizes groups and grade of progress. Each KPI represents the level of progress in a specific component. I_{ecm} stands as the performance metric reflecting advancements in the communication component. I_{ecx} serves as the indicator representing progress in the commitment component, I_{epx} denotes the metric showing progress in the environmental planning component, I_{erx} serves as a metric indicating progress in the implementation of other EM requirements, and I_{ewt} signifies the indicator reflecting progress in the training component. The components' performance levels by each winery size group in EM are illustrated in Figure 4.

Table 5. KPIs values by winery size groups and their corresponding grade of progress in their performance.

Winery Size	I_{ecm}	Grade of Progress	I_{ecx}	Grade of Progress	I_{epx}	Grade of Progress	I_{erx}	Grade of Progress	I_{ewt}	Grade of Progress
Up to 50,000 L/year	0.29	Star	0.55	In progress	0.40	In progress	0.44	In progress	0.38	In progress
50,001–100,000 L/year	0.33	Star	0.65	In progress	0.53	In progress	0.45	In progress	0.83	Maturity
100,001–250,000 L/year	0.36	In progress	0.66	In progress	0.56	In progress	0.67	In progress	0.63	In progress
250,001–1,000,000 L/year	0.35	In progress	0.90	Maturity	0.77	Maturity	0.77	Maturity	0.92	Maturity
More than 1,000,000 L/year	0.46	In progress	0.83	Maturity	0.98	Maturity	0.66	In progress	0.90	Maturity

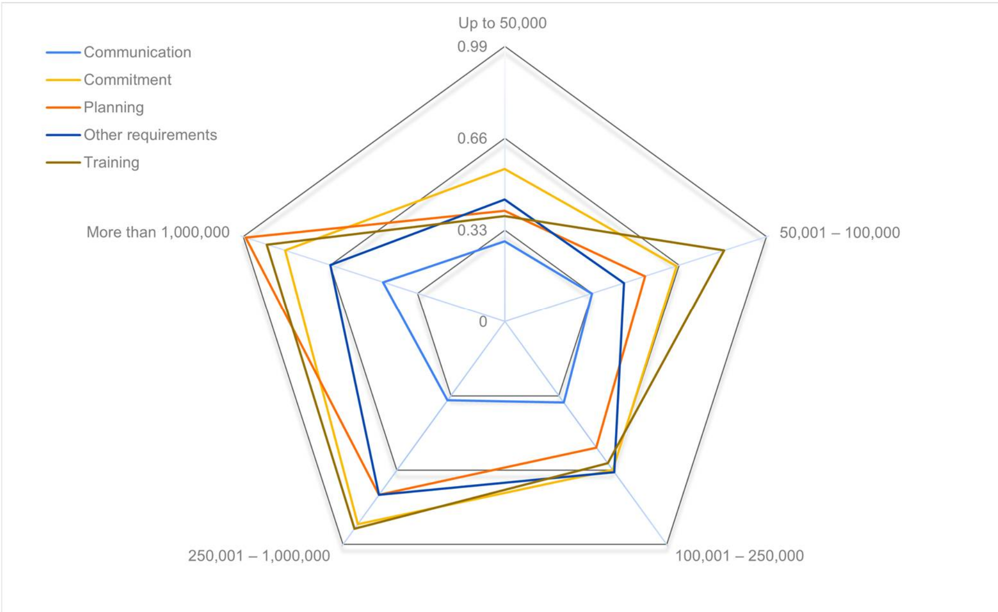

Figure 4. Radial diagram with each EM component's performance by each winery size group.

3.7. Predictive Analysis for ISO 14001 Certification

The dataset obtained from the questionnaire included various variables that were used to create a predictive model to analyze the likelihood of ISO 14001 certification in wineries. The target variable was ISO 14001 certification (Yes/No). The predictor variables were:

- *X1*: Job Position: Position held in the winery (e.g., manager, technician);
- *X2*: Annual Production Capacity: The scale of production capacity (e.g., high, medium, low);
- *X3*: Number of Employees: The size of the workforce (e.g., 50–100, 10–50);
- *X4*: Main Environmental Objectives: Environmental goals (e.g., reduce energy consumption, reduce waste production);
- *X5*: Company Areas The areas present in the winery (e.g., R&D, production; sales, production);
- *X6*: Review Frequency: How often the environmental management system (EMS) is reviewed (e.g., monthly, quarterly);
- *X7*: Established Processes: Whether the winery has established processes for achieving environmental results (Yes/No);
- *X8*: Environmental Policy: Whether the winery has an environmental policy (Yes/No);

- $X9$: Internal Communication Strategy: Strategies for internal communication (e.g., meetings, emails);
- $X10$: External Communication Strategy: Strategies for external communication (e.g., website, reports);
- $X11$: Environmental Info Stakeholders: Stakeholders to whom environmental information is communicated;
- $X12$: Risk Analysis Method: The method used for risk analysis (e.g., qualitative, quantitative);
- $X13$: Opportunity Analysis Method: The method used for opportunity analysis (e.g., qualitative, quantitative);
- Y: ISO 14001 Certification: The certification status of the winery (Yes/No).

The logistic regression model was applied for predicting the probability P of a winery being ISO 14001 certified. The logistic regression was defined by Equation (1):

$$P(Y = 1 \mid X) = \frac{1}{1 + e^{-(\beta 0 + \beta 1 \cdot X1 + \beta 2 \cdot X2 + \beta 3 \cdot X3 + \beta 4 \cdot X4 + \beta 5 \cdot X5 + \beta 6 \cdot X6 + \beta 7 \cdot X7 + \beta 8 \cdot X8 + \beta 9 \cdot X9 + \beta 10 \cdot X10 + \beta 11 \cdot X11 + \beta 12 \cdot X12 + \beta 13 \cdot X13)}} \quad (1)$$

where

- P(Y=1|X) is the probability that the winery is ISO 14001 certified given the predictor variables X.
- $\beta 0$ represents the log-odds of the winery being ISO 14001 certified when all predictor variables are zero. Since predictor variables in this context are categorical and typically encoded, the intercept is the baseline log-odds when all predictors are at their reference category levels.
- $\beta 1$, $\beta 2 \ldots$, $\beta 13$ are the coefficients for the respective predictor variables. This logistic regression model calculates the log-odds of a winery being certified based on the given variables. The logistic function then maps these log-odds to a probability value between 0 and 1, indicating the likelihood of certification.

The logistic regression model was evaluated using the following metrics:

- Accuracy: The proportion of correctly predicted instances;
- Confusion Matrix: A matrix showing the true positives, false positives, true negatives, and false negatives.

Logistic regression analysis was performed using Python applied to machine learning [63,64]. Specifically, the pandas library was used for data cleaning, transformation, and exploration [65], and scikit-learn was used which is a machine learning library in Python that provides simple and efficient tools for data mining and data analysis [64,66,67]. It includes algorithms for classification, regression, clustering, and model selection, among others. The Random Forest prediction model was used to improve and train the model [68–70]. Appendix C shows the calculation and analysis of the prediction model.

The results of the logistic regression analysis showed an accuracy of 0.714 and a confusion matrix of $\begin{bmatrix} 5 & 2 \\ 0 & 0 \end{bmatrix}$. This indicates that the accuracy of the model is moderately high at 71.4%, which is a positive outcome considering the sample size. The confusion matrix reveals that the model correctly identified five of the non-certified wineries but struggled to classify certified wineries, with none correctly identified in this case. The classification report highlights that there are no certified wineries in the test set, which affects metrics such as precision and recall for Class "1".

The cross-validation results were as follows. Cross-validation scores: [0.714, 0.714, 0.714, 0.667, 0.833], mean accuracy: 0.729, and standard deviation: 0.056. The scores are quite consistent across the different folds, with a low standard deviation. The Random Forest model shows a stable performance with an average accuracy around 72.9%. Both models, logistic regression and Random Forest, exhibited a similar performance with an average accuracy over 70%. The consistency of the cross-validation scores suggests that both models have a stable performance.

Influence of Variables and Beta Coefficients on ISO 14001 Certification

Beta coefficients provide insight into the influence of each predictor variable on the probability of achieving ISO 14001 certification. A positive coefficient indicates that an increase in the predictor variable is associated with an increase in the probability of certification, while a negative coefficient indicates a decrease in probability.

The job position within the winery significantly impacts the likelihood of ISO 14001 certification. Managers typically have more influence over environmental policies and processes, which can drive the adoption of certification standards. The annual production capacity indicates the scale of operations and resource availability for implementing comprehensive EMS. The coefficients for high and medium production capacities reveal how scale impacts the likelihood of certification. For instance, a positive beta for high capacity might suggest that larger operations are more likely to pursue certification due to greater resources.

The number of employees reflects the complexity and resource allocation within the winery. Larger teams facilitate better management and adherence to ISO standards. Positive coefficients indicate that a higher number of employees is associated with a greater probability of certification, likely due to better organizational capabilities.

The specific environmental objectives of a winery directly influence its commitment to sustainable practices, which are central to ISO 14001 certification. Objectives focused on reducing energy consumption and waste production typically align well with the ISO 14001 requirements, enhancing the likelihood of certification.

The presence of specific areas such as R&D shows a focus on innovation and continuous improvement, which are important for maintaining certification standards. Positive coefficients for areas like R&D and production suggest that these areas contribute positively towards certification efforts.

The frequency with which the management reviews the EMS is crucial for ongoing compliance and improvement. More frequent reviews, such as monthly, are positively associated with certification, reflecting a proactive approach to environmental management.

Having established processes for achieving environmental results is fundamental for systematic and consistent compliance with the ISO 14001 standards. A strong positive coefficient for "Yes" indicates that established processes are a significant factor in achieving certification. A formal environmental policy demonstrates a commitment to environmental management and sustainability. A positive coefficient signifies that having an environmental policy is a critical driver for certification.

Effective communication strategies are essential for disseminating information and ensuring that all stakeholders are aware of the environmental policies and procedures. Positive coefficients for robust internal and external communication strategies show their importance in achieving certification.

Communicating environmental information to stakeholders ensures transparency and accountability, which are key principles of ISO 14001. Positive coefficients demonstrate that broader stakeholder communication is beneficial for certification.

The method used for risk analysis reflects the winery approach to identifying and managing environmental risks. Positive coefficients for either qualitative or quantitative methods highlight the importance of systematic risk analysis in the certification process.

Identifying and leveraging opportunities for improvement is vital for continuous enhancement of the EMS. Like risk analysis, positive coefficients demonstrate that structured opportunity analysis contributes positively to achieving certification.

4. Discussion

Our investigation has unearthed essential insights into the EM practices within Italian wineries, delving into their environmental objectives, communication tactics, and adherence to environmental policies and leadership frameworks. Mirroring the findings of Nishitani K., our research underscores the profound influence that EMSs exert on a firm's environmental performance [71].

Regarding the scale of winery operations, a significant majority, 80.8%, employ less than ten individuals. This distribution by workforce size is crucial, potentially impacting their approach to environmental management.

Environmental objectives are a focal point for wineries, aiming for reductions in waste, electricity, and water use, and emissions. However, there is variability in how these long-term commitments align with annual goals, particularly concerning fossil fuel usage. Rahman's research [72] provides insights into the challenges and opportunities within the wine industry, noting the positive correlation between electricity consumption, economic growth, and CO_2 emissions, and the negative impact of globalization on emissions. In regions like California, the adoption of renewable energy sources by wineries, exemplified by the Napa Green program, marks a significant step towards reducing non-renewable electricity dependence [73].

The domain of environmental communication is pivotal, utilizing both internal and external channels. Internal communication heavily relies on email, used by 74.2% of wineries, underscoring the digital platform's ubiquity. Externally, social media, especially Facebook and Instagram, play a significant role, with 84.4% of wineries using them to share their environmental initiatives with stakeholders. This proactive use of ICT for environmental management communication was supported by Galati [74] in 2019, in a study which found that the wineries most active in social responsibility and engagement on social media platforms have a marked impact on information dissemination. Clients (88.9%) and shops (74.1%) are the most popular stakeholders that receive environmental information from wineries. These data underscore wineries' commitment to reaching their customers and shops, which constitute the main target audience for their environmental communication efforts. This result corresponds with the growing interest of wine consumers in environmental issues, as demonstrated in various studies [75,76], and the different stakeholders that wineries inform about their environmental performance and environmental awareness. However, there is room for growth in connecting with specific stakeholder groups such as ecology associations and wine club members. These segments are relatively underrepresented in wineries' environmental communication strategies, presenting an opportunity for further engagement.

Environmental commitment is a foundational aspect in environmental awareness. Approximately 71.9% of wineries have established environmental policies, indicating a solid commitment to environmental stewardship. However, the existence of wineries without such policies, about 28.1%, reveals gaps in EMS adoption. The role of senior management in fostering environmental responsibility is critical, with more than half of the wineries undertaking annual EMS reviews, although a small percentage, 3.8%, never review their EMS, highlighting varied commitment levels across the industry. These findings align with research by Burawat [77], underscoring the impact of leadership on sustainable practices. The responsibility for environmental management is distributed between viticulture places' owners, executive managers, and vineyard managers at the forefront of implementing sustainability measures. The presence of a "No answer" category emphasizes the need for awareness and accountability across management levels. Our environmental commitment indicator offers a metric for assessing progress in EM among wineries, reflecting their dedication to environmental responsibility based on annual wine production.

This commitment is manifested in various environmental goals, such as waste reduction and lower electricity and water usage, and aligned with Fragoso's research [78] on primary environmental objectives in Portuguese wineries. However, the alignment between long-term commitments and annual targets, especially regarding fossil fuel consumption, needs improvement. The winemaking process involves strategies to reduce electricity usage and waste production, with a notable interest in sustainable practices highlighted by similar research from Iannone [79] in 2021, and Zhang [80] in 2019. Measures primarily include waste classification and disposal (71.4%) and the recycling and reuse of packaging materials (23.8%). A notable 4.7% of wineries utilize agronomic practices for organic waste, indicating an increasing interest in sustainable methods.

Emergency preparedness remains vital, with 38.7% of wineries lacking comprehensive plans, though the majority conduct periodic assessments. Preparedness for fire emergencies is robust in our findings. Our results align with the requirements related to emergency preparedness in food businesses as identified by Song [81]. Song indicated that improving technology, employee skills, and process monitoring enhances effective emergency preparedness in food businesses.

Nearly all wineries prioritize organizing and controlling documentation, essential for aligning with ISO 14001 standards and demonstrating commitment through the documentation system. However, a third of wineries do not update their documentation annually, indicating an area for improvement.

The level of EMS certification to the ISO 14001:2015 standard is relatively low, consistent with findings in the Italian wine sector [82,83].

Our data emphasize the significance of environmental training in wineries supporting research that shows workers environmental responsibility and personal values drive sustainable behavior and innovation [84,85]. It also sheds light on trends based on winery size and annual wine production. Notable findings include information about winery size and training provision revealing a relation between winery size and the provision of environmental training. The findings demonstrate that the frequency of worker participation in environmental training varies among wineries of different sizes. This divergence underscores the diversity of training approaches based on winery size. The results are consistent with the findings about winery workers' training conducted by Lopez-Santiago [86].

The environmental performance indicators developed in our study provide a benchmark for evaluating EM progress across different winery sizes, offering insights into the industry's commitment to improving its environmental footprint. These findings highlight the wine industry's diverse efforts towards sustainability, emphasizing the critical role of communication, training, and leadership in advancing environmental management practices aligned with the findings of Lopez-Santiago [87].

The logistic regression model provides a clear and quantifiable way to assess the impact of various predictors on the likelihood of ISO 14001 certification. The model coefficients, which can be interpreted as log-odds, offer insights into how changes in predictor variables influence the probability of certification. For instance, the positive coefficient for "Job_Position_Manager" suggests that having managerial involvement increases the odds of certification. This aligns with existing literature that emphasizes the role of leadership in driving sustainability initiatives [88,89]. Similarly, the positive influence of frequent EMS reviews and established processes underscores the importance of systematic and continuous improvement practices, which are fundamental to the ISO 14001 standards [90]. These findings are consistent with studies by Zutshi and Sohal (2004), who highlighted the critical role of structured processes and regular reviews in maintaining ISO 14001 certification [91,92]. Overall, the implement predictive model serves as a valuable tool for wineries to assess their readiness for ISO 14001 certification and identify key areas for improvement. Wineries can strategically focus their efforts and resources to enhance their EMSs and achieve sustainable operations understanding the factors that significantly influence certification.

Limitation and Strength of the Study

One of the key drawbacks of this research resides in the diminished rate of participation received from the wineries under examination, which could potentially influence the inclusiveness and applicability of the data to the broader Italian wine industry. Additionally, this research has not considered the destination of wine production, given that significant or predominant export rates could influence the propensity to adopt EMSs. Nonetheless, a fundamental merit of this study is grounded in the formulation of performance metrics utilizing the questionnaire approach. This instrument establishes a sturdy groundwork for scrutinizing data and facilitates the assessment of wineries' performance in EMSs.

5. Conclusions

Our study has successfully met its two research objectives by providing a detailed overview of how Italian wineries manage their environmental practices, communicate their strategies, and commit to environmental management. Additionally, it analyzed the key components of environmental management and proposed a quantitative measure through the development of the five KPIs. The research identified both strong points and potential areas for enhancement in their efforts towards environmental sustainability, offering a clear view of the varied strategies and dedication levels across the industry. Furthermore, it developed a collection of indicators, based on survey responses, that allows us to measure the advancement of EMS adoption within wineries.

In addition to reducing environmental impacts, EMS implementation helped wineries to improve their reputation and gain a competitive advantage in the global market. Wineries that have a certified EMS could differentiate their products from other conventional wines. Despite the benefits of EMS implementation, there are also challenges and limitations to their effectiveness. One of the main challenges is the cost and complexity of implementing EMSs, which can be a barrier for small and medium-sized wineries. Additionally, EMS implementation requires ongoing monitoring and evaluation to ensure that environmental goals are being met.

While existing research underscores the importance of environmental practices and workforce engagement in the wine industry, there is a noticeable gap in the literature specifically addressing how the size of wineries influences engagement levels in environmental training. This gap presents an opportunity to explore the relationship between winery size and workforce engagement, particularly how small and large wineries differ in their approaches and challenges to engaging their workforce in environmental initiatives. The capacity of larger firms in the food industry to leverage economies of scale for environmental sustainability is evident across various sectors and countries. These firms play a pivotal role in advancing sustainable practices, from agriculture to manufacturing and retail. However, realizing the full potential of these initiatives requires addressing challenges related to transparency and supply chain complexity and ensuring that sustainability efforts benefit all stakeholders within the food system.

The policy implications emphasizing the importance of technological investment, education, and global cooperation are directly applicable to the wine industry. Collaborative efforts, possibly in the form of international partnerships or certifications, could promote the sharing of sustainable practices and technologies across borders, enhancing the industry's overall sustainability. Globalization's role in environmental degradation is complex; however, it is implied that increased globalization can lead to improved environmental quality. In the context of wineries, globalization has facilitated the exchange of sustainable technologies and practices. New World wine-producing countries, such as New Zealand and Chile, have rapidly adopted sustainable viticulture and winemaking practices, partly due to their integration into the global wine market.

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Appendix A. EMS Questionnaire

Environmental management system questionnaire (Italy). * Obligatory

1. Company name *
2. Email address *
3. S1.1 Annual production capacity

Mark only one oval.

- ○ Less than 50,001 L/year.
- ○ 50,001 L/year–100,000 L/year.
- ○ 100,001 L/year–250,000 L/year.
- ○ 250,001 L/year–1,000,000 L/year.
- ○ More than 1,000,000 L/year.

4. S1.2 Number of employees

Mark only one oval.

- ○ <10.
- ○ 10 to 49.
- ○ 50 to 249.
- ○ 250.

5. S1.3 Job position in the company

Mark only one oval.

- ○ General Manager.
- ○ Owner Manager.
- ○ Ecological Manager.
- ○ Administration Officer.
- ○ Vineyard Manager Executive Director.
- ○ Other.

6. S2.1 What are the company's main environmental objectives?

Select all that apply.

- ○ Electricity consumption reduction.
- ○ Water consumption reduction.
- ○ Land-use reduction.
- ○ Greenhouse gas emissions reduction.
- ○ Other gases emissions reduction.
- ○ Waste production reduction.
- ○ Use of raw materials reduction.
- ○ Substances released into the soil reduction.
- ○ Other.

7. S2.2 Does the company have any of the following areas/departments?

Select all that apply.

- ○ Environmental management.
- ○ Leadership.
- ○ Planning of environmental objectives.
- ○ Environmental risk and opportunities.
- ○ Resources and environmental support.
- ○ Communication.
- ○ Operation and environmental control.
- ○ Emergency response.
- ○ Monitoring, analysis, and evaluation of EMS performance.

8. S2.3 What is the company's internal communication strategy?

   Select all that apply.

- ○ Website.
- ○ Email.
- ○ Social media (Facebook, Instagram, etc.).
- ○ Newsletters.
- ○ Internal staff site.
- ○ Other.

9. S2.4 What is the company's external communication strategy?

   Select all that apply.

- ○ Website.
- ○ Social media (Facebook, Instagram, etc).
- ○ Newsletters.
- ○ Advertisement.
- ○ Marketing campaigns.
- ○ Other.

10. S2.5 Does the company disclose environmental information to any stakeholders?

    Select all that apply.

- ○ Clients.
- ○ Ecology associations.
- ○ Public administrations.
- ○ Suppliers.
- ○ Shops.
- ○ Other.

11. S3.1 Has the organization clearly identified the Environmental Director in the company?

    Mark only one oval.

- ○ Yes.
- ○ No.

12. S3.2 How often does the senior management review the organization's environmental management system?

    Mark only one oval.

- ○ At least every six months.
- ○ Annually.
- ○ Over a year.
- ○ Never.

13. S3.3 Has the company established processes to achieve annual environmental results?

    Mark only one oval.

- ○ Yes.
- ○ No.

14. S4.1 Has the company established an environmental policy?

    Mark only one oval.

- ○ Yes.
- ○ No.

15. S4.2 How does the company communicate and/or promote its environmental policy?

    Select all that apply.

- ○ Website.

- ○ Newsletter.
- ○ Social media.
- ○ Advertisement.
- ○ Email promotion.
- ○ Marketing campaigns.
- ○ Courses.
- ○ None of these.
- ○ Other.

16. S4.3 Does the company's environmental policy include any of these commitments?

    Select all that apply.

- ○ Reduce use of water.
- ○ Reduce use of fossil combustible.
- ○ Control of electricity use.
- ○ Reduce of fertilizers and pesticides use.
- ○ Reduce of gas emissions.
- ○ Increasing land use efficiency.
- ○ Improvement in packaging (glass bottles).
- ○ Improvement in wines distribution.

17. S4.4 What aspects of the life cycle are included in environmental policy?

    Select all that apply.

- ○ Environmental impacts of the supply chain.
- ○ Environmental impacts of product use.
- ○ Environmental impacts of waste generation.

18. S3.4 Who is responsible for environmental management?

    Mark only one oval.

- ○ Owner.
- ○ General Manager.
- ○ Environmental Manager.
- ○ Administrative Manager.
- ○ Vineyard Director.
- ○ Executive Director.
- ○ Other.

19. S5.1 Considering that wineries have a high energy consumption, what actions or measures does the company take to reduce the environmental impact?
20. S5.2 Wineries generate a lot of solid waste which, once disposed of, has a high environmental impact. How is this high amount of waste managed?
21. S5.3 Wineries generate gases that are usually impregnated with fruit or machinery. What processes should be in place to reduce these emissions and therefore generate less impact?
22. S6.1 Has the company prepared plans to prevent or mitigate negative environmental impacts resulting from emergency situations?

    Mark only one oval.

- ○ Yes.
- ○ No.

23. S6.2 If so, which environmental emergency is the company prepared for? (Select one or more)

    Select all that apply.

- ○ Fire
- ○ Water uncontrolled discharge with cleaning product or organic matter residues.

- ○ Water drains with chemical contaminants.
- ○ Landfilling of waste and/or abandoned waste.
- ○ Leakage of dangerous substances.
- ○ Other.

24. S6.3 Does the company periodically review planned response actions for emergency situations?

    Mark only one oval.

- ○ At least every six months.
- ○ Annually.
- ○ Over a year.
- ○ Never.

25. S7.1 Does the organization have documented information to demonstrate that monitor, measure, and evaluate its environ-mental performance?

    Mark only one oval.

- ○ Yes.
- ○ No.

26. S7.2 How does the organization record information to demonstrate that it evaluates the effectiveness of its environmental management system?

    Select all that apply.

- ○ Data records.
- ○ Reports.
- ○ Technical instructions.
- ○ Procedures.
- ○ None of these.
- ○ Other.

27. S7.3 How often does the company create and update documented information consistent with its environmental management system?

- ○ Mark only one oval.
- ○ At least every six months.
- ○ Annually.
- ○ Over a year.
- ○ Never.

28. S9.2 Does the company have legal requirements from government bodies or other relevant authorities in relation to environmental impacts?

    Mark only one oval.

- ○ Yes.
- ○ No.

29. S8.1 Is training offered to staff on environmental management systems?

    Mark only one oval.

- ○ Yes.
- ○ No.

30. S8.2 If so, how often do staff take these environmental trainings?

    Mark only one oval.

- ○ At least every six months.
- ○ Annually.
- ○ Over a year.
- ○ Never.

31. S8.3 How many workers have already undergone environmental management training?

Mark only one oval.

- ○ Less than 25%.
- ○ Between 25 and 50%.
- ○ Between 50 and 75%.
- ○ More than 75%.

32. S9.3 What method does the organization use to carry out risk analysis?

Mark only one oval.

- ○ Quantitative method.
- ○ Qualitative method.
- ○ None.

33. S9.4 What method does the organization use to perform the opportunity analysis?

Mark only one oval.

- ○ Quantitative method
- ○ Qualitative method
- ○ None

34. S10.1 Has the company certified its EMS with ISO 14001:2015?

Mark only one oval.

- ○ Yes.
- ○ No.

Appendix B. Calculation of the Key Environmental Performance Indicators

1. **Environmental Communication Key Indicator ($\mathbf{I_{ecm}}$)**

The Environmental Communication Key Indicator $(\mathbf{I_{ecm}})$ for each group of wineries according to their yearly wine production size is calculated by Equation (A1):

$$\mathbf{I_{ecm}} = \frac{\sum_{i=1}^{m} \mathbf{W_{ecm}}}{\mathbf{m}} \tag{A1}$$

- $\mathbf{I_{ecm}}$ is the Environmental Communication Key Indicator for each group of wineries according to yearly wine production;
- **m** is the number of wineries of the related group;
- $\mathbf{W_{ecm}}$ is the aggregated communication variable for each winery, defined by the Equation (A2) [93–95]:

$$\mathbf{W_{ecm}} = \frac{\mathbf{V_{S23}+V_{S24}+V_{S25}+V_{S42}}}{n} \tag{A2}$$

- $\mathbf{W_{ecm}}$ is the aggregated communication variable for each winery;
- $\mathbf{V_{S23}}$ is the internal communication strategy variable of the winery, $\mathbf{V_{S23}} = \sum_{j=1}^{6} a_j$, a_j is each item of this multiple-choice question (yes = 0.167, no = 0);
- $\mathbf{V_{S24}}$ is the external communication strategy variable of the winery, $\mathbf{V_{S24}} = \sum_{j=1}^{6} \mathbf{b_j}$, $\mathbf{b_j}$ is each item of this multiple-choice question (yes = 0.167, no = 0);
- $\mathbf{V_{S25}}$ is the stakeholder's variable to whom the winery communicates its environmental information of the winery, $\mathbf{V_{S25}} = \sum_{j=1}^{6} \mathbf{c_j}$, $\mathbf{c_j}$ is each item of this multiple-choice question (yes = 0.167, no = 0);
- $\mathbf{V_{S42}}$ is the environmental policy communication variable of the winery, $\mathbf{V_{S42}} = \sum_{j=1}^{9} \mathbf{d_j}$, $\mathbf{d_j}$ is each item of this multiple-choice question (yes = 0.125, no = 0);
- **n** is the number of variables that have been aggregated, and its value is 4.

2. **Environmental Commitment Key Indicator (I_{ecx})**

The Environmental Commitment Key Indicator ($\mathbf{I_{ecx}}$) for each group of wineries according to their yearly wine production size is calculated by Equation (A3):

$$\mathbf{I_{ecx}} = \frac{\sum_{i=1}^{m} \mathbf{W_{ecx}}}{\mathbf{m}} \quad \text{(A3)}$$

- $\mathbf{I_{ecx}}$ is the environmental commitment key indicator for each group of wineries according to yearly wine production;
- **m** is the number of wineries of the related group;
- $\mathbf{W_{ecx}}$ is the aggregated commitment variable for each winery, defined by Equation (A4):

$$\mathbf{W_{ecx}} = \frac{\mathbf{V_{S41}+V_{S31}+V_{S32}+V_{S33}}}{n} \quad \text{(A4)}$$

- $\mathbf{W_{ecx}}$ is the aggregated commitment variable for each winery;
- $\mathbf{V_{S41}}$ is the winery environmental policy variable of the winery, (yes = 1, no = 0);
- $\mathbf{V_{S31}}$ is the environmental director variable of the winery (yes = 1, no = 0);
- $\mathbf{V_{S32}}$ measures the senior management environmental system evaluation frequency. It could take one of next four values, 1 if (at least every six months), 0.75 (more than once a year), 0.50 (annually), and 0 (never reviewed).;
- $\mathbf{V_{S33}}$ is the environmental evaluation procedure variable of the winery, (yes = 1, no = 0);
- **n** is the number of variables that have been aggregated, and its value is 4.

3. **Environmental Planning Key Indicator (I_{epx})**

The Environmental Planning Key Indicator ($\mathbf{I_{epx}}$) for each group of wineries according to their yearly wine production size is calculated by Expression (A5):

$$\mathbf{I_{epx}} = \frac{\sum_{i=1}^{m} \mathbf{W_{epx}}}{\mathbf{m}} \quad \text{(A5)}$$

- $\mathbf{I_{epx}}$ is the environmental planning key indicator for each group of wineries according to yearly wine production;
- **m** is the number of wineries of the related group;
- $\mathbf{W_{epx}}$ is the environmental management framework variable for each winery, defined by Equation (A6):

$$\mathbf{W_{epx}} = \frac{\mathbf{V_{S21}+V_{S22}+V_{S43}+V_{S44}+V_{S51}+V_{S52}+V_{S53}+V_{S92+}V_{S93}+V_{S94}}}{n} \quad \text{(A6)}$$

- $\mathbf{W_{epx}}$ is the aggregated environmental management planning variable for each winery;
- $\mathbf{V_{S21}}$ measures the wineries' primary environmental objectives of the winery, $\mathbf{V_{S21}} = \sum_{j=1}^{9} \mathbf{e_j}$, $\mathbf{e_j}$ is each item of this multiple-choice question (yes = 0.112, no = 0);
- $\mathbf{V_{S22}}$ is the EM specific areas variable of the winery, $\mathbf{V_{S22}} = \sum_{j=1}^{9} \mathbf{f_j}$, $\mathbf{f_j}$ is each item of this multiple-choice question (yes = 0.112, no = 0);
- $\mathbf{V_{S43}}$ is the environmental commitments variable of the winery, $\mathbf{V_{S43}} = \sum_{j=1}^{8} \mathbf{g_j}$, $\mathbf{g_j}$ is each item of this multiple-choice question (yes = 0.125, no = 0);
- $\mathbf{V_{S44}}$ is the life cycle aspects variable, $\mathbf{V_{S44}} = \sum_{j=1}^{3} \mathbf{h_j}$, $\mathbf{h_j}$ is each item of this multiple-choice question (yes = 0.334, no = 0);
- $\mathbf{V_{S51}}$ is the winery energy consumption environmental aspect variable of the winery, (yes = 1, no = 0);
- $\mathbf{V_{S92}}$ is the legal environmental requirements variable of the winery (yes = 1, no = 0);
- $\mathbf{V_{S93}}$ is the risk assessment variable. It could take one of next three values, 1 if (quantitative method), 0.50 (qualitative method), and 0 (none);

- $\mathbf{V_{S94}}$ is the opportunity assessment variable. It could take one of next three values, 1 if (quantitative method), 0.50 (qualitative method), and 0 (none);
- **n** is number of variables that has been aggregated, and its value is 10.

4. **Other Environmental Management Requirements Key Indicator ($\mathbf{I_{erx}}$)**

The Other Environmental Management Requirements Key Indicator ($\mathbf{I_{erx}}$) for each group of wineries according to their yearly wine production size is calculated by the following Expression (A7):

$$\mathbf{I_{erx}} = \frac{\sum_{i=1}^{m} \mathbf{W_{erx}}}{\mathbf{m}} \tag{A7}$$

- $\mathbf{I_{erx}}$ is the other environmental management requirements key indicator for each group of wineries according to yearly wine production;
- **m** is the number of wineries of the related group;
- $\mathbf{W_{erx}}$ represents the other environmental management requirements variable for each winery, defined by Equation (A8):

$$\mathbf{W_{erx}} = \frac{\mathbf{V_{S61}+V_{S62}+V_{S63}+V_{S71}+V_{S72}+V_{S73}+V_{101}}}{n} \tag{A8}$$

- $\mathbf{W_{erx}}$ is the aggregated other environmental requirements variable for each winery,
- $\mathbf{V_{S61}}$ is the EEP availability variable of the winery (yes = 1, no = 0);
- $\mathbf{V_{S62}}$ measures the kind of emergencies in the EEP of the winery, $\mathbf{V_{S62}} = \sum_{j=1}^{6} \mathbf{k_j}, \mathbf{k_j}$ is each item of this multiple-choice question (yes = 0.167, no = 0);
- $\mathbf{V_{S63}}$ measures the EEP evaluation frequency. It could take one of next four values, 1 if (at least every six months), 0.75 (more than once a year), 0.50 (annually), and 0 (never reviewed);
- $\mathbf{V_{S71}}$ is the EMS document availability variable of the winery, (yes = 1, no = 0);
- $\mathbf{V_{S72}}$ measures how the EMS information is recorded in the winery, $\mathbf{V_{S72}} = \sum_{j=1}^{5} \mathbf{o_j}, \mathbf{o_j}$ is each item of this multiple-choice question (yes = 0.2, no = 0);
- $\mathbf{V_{S73}}$ measures the document control frequency. It could take one of next four values, 1 if (at least every six months), 0.75 (annually), 0.50 (more than once a year), and 0 (never reviewed);
- $\mathbf{V_{S101}}$ is the legal environmental requirements variable of the winery (yes = 1, no = 0);
- **n** is the number of variables that have been aggregated, and its value is 7.

5. **Environmental Workers Training Key Indicator ($\mathbf{I_{ewt}}$)**

The Environmental Workers Training Key Indicator ($\mathbf{I_{ewt}}$) for each group of wineries according to their yearly wine production size is calculated by Equation (A9):

$$\mathbf{I_{ewt}} = \frac{\sum_{i=1}^{m} \mathbf{W_{ewt}}}{\mathbf{m}} \tag{A9}$$

- $\mathbf{I_{ewt}}$ is the Environmental Workers Training Key Indicator for each group of wineries according to yearly wine production;
- **m** is the number of wineries of the related group;
- $\mathbf{W_{ewt}}$ is the aggregated environmental workers training variable for each winery, defined by Equation (A10):

$$\mathbf{W_{ewt}} = \frac{\mathbf{V_{S81}+V_{S82}+V_{S83}}}{n} \tag{A10}$$

- $\mathbf{W_{ewt}}$ is the aggregated environmental worker training variable for each winery;
- $\mathbf{V_{S81}}$ is the EMS workers training availability variable of the winery (yes = 1, no = 0);
- $\mathbf{V_{S82}}$ measures the workers training frequency. It could take one of the next four values, 1 (if at least every six months), 0.75 (annually), 0.50 (more than once a year), and 0 (never);

- **V_{S83}** measures the number of employees who participate in environmental training courses annually. It could take one of the next four values of 1 (more than 75%), 0.75 (between 50 and 75%), 0.50 (between 25 and 50%), and 0.25 (less than 25%);
- **n** is number of variables that have been aggregated, and its value is 3.

Appendix C

Cross-Table QS4.3 - QS2.1

			Q S2.1[a]									
			Electricity consumption reduction	Water consumption reduction	Land use reduction	Greenhouse gas emissions reduction	Other gas emissions reduction	Waste production reduction	Use of raw materials reduction	Substances releasing into the soil reduction	Others: Agricultural land recovery	Total
QS4.3[a]	Reduce use of water	Count	20	20	4	12	7	18	6	15	0	22
		% inside QS4.3	90.9	90.9	18.2	54.5	31.8	81.8	27.3	68.2	0.0	
		% inside QS2.1	76.9	83.3	66.7	63.2	77.8	69.2	75.0	65.2	0.0	
		% total	58.8	58.8	11.8	35.3	20.6	52.9	17.6	44.1	0.0	64.7
	Reduce use of fosil combustibles	Count	16.0	16.0	5.0	11.0	8.0	17.0	6.0	14.0	1.0	20.0
		% inside QS4.3	80.0	80.0	25.0	55.0	40.0	85.0	30.0	70.0	5.0	
		% inside QS2.1	61.5	66.7	83.3	57.9	88.9	65.4	75.0	60.9	100.0	
		% total	47.1	47.1	14.7	32.4	23.5	50.0	17.6	41.2	2.9	58.8
	Control of electricity use	Count	22.0	19.0	3.0	14.0	8.0	19.0	6.0	14.0	0.0	23.0
		% inside QS4.3	95.7	82.6	13.0	60.9	34.8	82.6	26.1	60.9	0.0	
		% inside QS2.1	84.6	79.2	50.0	73.7	88.9	73.1	75.0	60.9	0.0	
		% total	64.7	55.9	8.8	41.2	23.5	55.9	17.6	41.2	0.0	67.6
	Reduce of ferlizers and pesticides use	Count	22.0	21.0	5.0	18.0	8.0	24.0	7.0	20.0	0.0	29.0
		% inside QS4.3	75.9	72.4	17.2	62.1	27.6	82.8	24.1	69.0	0.0	
		% inside QS2.1	84.6	87.5	83.3	94.7	88.9	92.3	87.5	87.0	0.0	
		% total	64.7	61.8	14.7	52.9	23.5	70.6	20.6	58.8	0.0	85.3
	Reduce of gas emissions	Count	9.0	9.0	3.0	11.0	7.0	11.0	7.0	8.0	1.0	12.0
		% inside QS4.3	75.0	75.0	25.0	91.7	58.3	91.7	58.3	66.7	8.3	
		% inside QS2.1	34.6	37.5	50.0	57.9	77.8	42.3	87.5	34.8	100.0	
		% total	26.5	26.5	8.8	32.4	20.6	32.4	20.6	23.5	2.9	35.3
	Increase land use efficiency	Count	11.0	12.0	6.0	9.0	5.0	15.0	4.0	12.0	1.0	16.0
		% inside QS4.3	68.8	75.0	37.5	56.3	31.3	93.8	25.0	75.0	6.3	
		% inside QS2.1	42.3	50.0	100.0	47.4	55.6	57.7	50.0	52.2	100.0	
		% total	32.4	35.3	17.6	26.5	14.7	44.1	11.8	35.3	2.9	47.1
	Improvement in packaging (glass bottles)	Count	13.0	14.0	5.0	10.0	6.0	18.0	6.0	13.0	1.0	20.0
		% inside QS4.3	65.0	70.0	25.0	50.0	30.0	90.0	30.0	65.0	5.0	
		% inside QS2.1	50.0	58.3	83.3	52.6	66.7	69.2	75.0	56.5	100.0	
		% total	38.2	41.2	14.7	29.4	17.6	52.9	17.6	38.2	2.9	58.8
	Improvement in wines distribution	Count	6.0	4.0	1.0	6.0	3.0	7.0	2.0	5.0	0.0	9.0
		% inside QS4.3	66.7	44.4	11.1	66.7	33.3	77.8	22.2	55.6	0.0	
		% inside QS2.1	23.1	16.7	16.7	31.6	33.3	26.9	25.0	21.7	0.0	
		% total	17.6	11.8	2.9	17.6	8.8	20.6	5.9	14.7	0.0	26.5
Total		Count	26.0	24.0	6.0	19.0	9.0	26.0	8.0	23.0	1.0	34.0
		% total	76.5	70.6	17.6	55.9	26.5	76.5	23.5	67.6	2.9	100.0

Figure A1. Cross-table between Question S2.1 and Question S4.2 showing coherence between environmental policy and annual environmental objectives by wineries.

Appendix D. Calculation and Analysis of Prediction Model

1. Data Preprocessing

The dataset was loaded utilizing the pandas library in Python, facilitating an initial examination to ascertain the structure and content of the data. Figure A2 presents the code utilized for this process, illustrating the importation of essential libraries and predictive models, alongside the loading procedure of the dataset.

```python
import pandas as pd
from sklearn.model_selection import train_test_split, cross_val_score
from sklearn.preprocessing import StandardScaler, OneHotEncoder
from sklearn.compose import ColumnTransformer
from sklearn.pipeline import Pipeline
from sklearn.linear_model import LogisticRegression
from sklearn.ensemble import RandomForestClassifier
from sklearn.metrics import accuracy_score, confusion_matrix, classification_report

# Load the dataset
file_path = '/mnt/data/ISO 14001_2015 ITA CSV (Responses).csv'
data = pd.read_csv(file_path, delimiter=';', encoding='latin1')
```

Figure A2. Illustration of a scikit-learn pipeline. (a) The code example demonstrates the importation of libraries and predictive models, as well as the procedure for loading the dataset.

2. Data Cleaning

To maintain the robustness and accuracy of the predictive model, rows with missing values in the target variable were meticulously removed. This step ensures that the dataset is complete, and the model training process is not adversely affected by incomplete data.

3. Categorical Variable Encoding

The transformation of categorical variables into a machine learning-compatible format was performed using the "OneHotEncoder" from the scikit-learn library. This encoding method converts categorical features into a series of binary variables, enabling the model to interpret categorical data effectively. Figure A3 provides a comprehensive view of the following processes:

- Selection of Relevant Columns: Identification of features relevant to the predictive analysis, including job position, annual production capacity, number of employees, and various internal and external communication strategies.
- Handling Missing Values: Implementation of a strategy to drop rows containing missing values in the target variable (ISO 14001 Certification), thereby ensuring a clean dataset.
- Data Splitting: Division of the dataset into training and testing subsets using the train_test_split function, with an 80–20 split to facilitate model evaluation.
- Target Variable Mapping: Conversion of the target variable's categorical values ('Yes' and 'No') into binary numerical values (1 and 0) for compatibility with machine learning algorithms.
- Categorical Features' Preprocessing: Utilization of the ColumnTransformer to apply the OneHotEncoder to all categorical features, converting them into a format suitable for the machine learning model.

These steps collectively form a robust preprocessing pipeline that ensures the dataset is well-prepared for subsequent modelling and analysis.

```
# Select relevant columns
features = ['Job_Position', 'Annual_Production_Capacity', 'Number_of_Employees', 'Main_Env
            'Company_Departments', 'Review_Frequency', 'Established_Processes', 'Environme
            'Internal_Communication_Strategy', 'External_Communication_Strategy', 'Environ
            'Risk_Analysis_Method', 'Opportunity_Analysis_Method']
target = 'ISO_14001_Certification'

# Drop rows with NaN values in the target variable
data_cleaned = data.dropna(subset=[target])

# Split the data into training and testing sets
X = data_cleaned[features]
y = data_cleaned[target].map({'Si': 1, 'No': 0})  # Map target values to 1 and 0

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42)

# Preprocess features (One-Hot Encoding for categorical variables)
categorical_features = features  # All features are categorical in this case
preprocessor = ColumnTransformer(
    transformers=[
        ('cat', OneHotEncoder(), categorical_features)])
```

Figure A3. Code illustration of the data cleaning and preprocessing steps.

4. **Predictive Model**

- Logistic Regression

This model is particularly advantageous in classification problems where the objective is to determine class membership, such as predicting whether an entity is ISO 14001 certified (Yes/No). Figure A4 outlines the following key steps:

- Pipeline Construction: Integration of preprocessing and classification steps into a cohesive pipeline using scikit-learn's pipeline class.
- Preprocessing: Application of the previously defined preprocessor to handle categorical feature encoding and any other necessary data transformations.
- Model Specification: Inclusion of the logistic regression classifier with the max_iter parameter set to 1000 to ensure convergence of the algorithm.

```
# Logistic Regression Model
model_logistic = Pipeline(steps=[('preprocessor', preprocessor),
                                 ('classifier', LogisticRegression(max_iter=1000))])
```

Figure A4. Illustration of the implementation of a logistic regression model using a scikit-learn pipeline.

This structured approach encapsulates both data preprocessing and model fitting within a single pipeline, thereby streamlining the workflow and enhancing reproducibility. The logistic regression model serves as a foundational classification tool, providing a probabilistic framework for predicting the likelihood of ISO 14001 certification based on the provided features.

- Random Forest

Random Forest was applied to enhance and train the classification model. Its performance was systematically evaluated, and the hyperparameters were meticulously adjusted. This ensemble technique significantly improves predictive accuracy and provides robust control over overfitting. Random Forest operates by creating each decision tree using a random subset of the data and a random subset of the features. This randomness ensures that the model is more robust and less likely to overfit to any subset of the data, thereby enhancing generalization to unseen data. Figure A5 shows the following key steps:

- Pipeline Construction: Similar to the logistic regression model, a pipeline is constructed to encapsulate both the preprocessing and the classification steps using Scikit-learn Pipeline class.
- Preprocessing: The previously defined preprocessor is applied to handle categorical feature encoding and other necessary data transformations.
- Model Specification: Incorporation of the RandomForestClassifier with a specified random state of 42 to ensure the reproducibility of the results.

```
# Random Forest Model
model_rf = Pipeline(steps=[('preprocessor', preprocessor),
                           ('classifier', RandomForestClassifier(random_state=42))])
```

Figure A5. Illustration of the implementation of a Random Forest model using a scikit-learn pipeline.

This structured approach encapsulates the preprocessing and model fitting steps within a single pipeline, thereby streamlining the workflow and enhancing the reproducibility of the results. The Random Forest model is particularly advantageous due to its ensemble nature, which leads to improved accuracy and robustness by aggregating the predictions of multiple decision trees. The classification task benefits from reduced variance and improved generalization by leveraging the Random Forest model.

- Cross-Validation

Cross-validation with five folds was conducted to rigorously assess the consistency and performance of the Random Forest model. Cross-validation is a robust model evaluation technique that mitigates overfitting and provides a comprehensive understanding of model performance. In this method, the dataset is divided into "folds" (subsets), and the model is iteratively trained on a combination of folds while being tested on the remaining folds. This process is repeated several times to ensure that every data point has been used for both training and testing, thereby yielding a more reliable and unbiased measure of model performance. Figure A6 outlines the following key steps:

- Cross-Validation Execution: Implementation of five-fold cross-validation using the cross_val_score function, where the model is evaluated on different subsets of the data. The scoring parameter is set to 'accuracy' to measure the proportion of correctly classified instances.
- Performance Metrics Calculation: Computation of the mean and standard deviation of the cross-validation scores to quantify the average model performance and the variability across the folds, respectively.

The cross-validation process provides essential insights into the model's ability to generalize to unseen data by evaluating its performance across multiple iterations and different data partitions. This technique ensures that the model's performance metrics, such as accuracy, are not overly optimistic and are reflective of its true predictive capability. The mean accuracy score provides an overall indication of model performance, while the standard deviation reveals the stability and consistency of the model across different subsets of the data.

```
# Perform cross-validation with 5 folds for the Random Forest model
cv_scores_rf = cross_val_score(model_rf, X, y, cv=5, scoring='accuracy')
cv_scores_rf_mean = cv_scores_rf.mean()
cv_scores_rf_std = cv_scores_rf.std()
```

Figure A6. Illustration of the cross-validation process for the Random Forest model using scikit-learn.

5. <u>Model Evaluation and Results</u>

The performance of the logistic regression model was evaluated, yielding an accuracy of 0.714 and a confusion matrix of $\begin{bmatrix} 5 & 2 \\ 0 & 0 \end{bmatrix}$. The model's accuracy is moderately high at 71.4%, which is a positive outcome given the sample size. The confusion matrix reveals that the model accurately identified five out of seven non-certified wineries but struggled with the classification of certified wineries, as there were none in the test set. Figure A7 shows detailed metrics, including the precision, recall, F1-score, and support for each class.

```
              precision    recall  f1-score   support

           0       1.00      0.71      0.83         7
           1       0.00      0.00      0.00         0

    accuracy                           0.71         7
   macro avg       0.50      0.36      0.42         7
weighted avg       1.00      0.71      0.83         7
```

Figure A7. Illustration of the precision, recall, F1-score, and support for each class.

Table A1 summarizes the precision, recall, F1-score, and support for each class, along with the overall accuracy and average metrics:

Table A1. Precision, recall, F1-score, and support for each class.

Metric	Class 0 (Non-Certified Wineries)	Class 1 (Certified Wineries)	Overall Metrics
Precision	1.00	0.00	
Recall	0.71	0.00	
F1-score	0.83	0.00	
Support	7	0	
Accuracy			0.71
Macro Average			0.50, 0.36, 0.42
Weighted Average			1.00, 0.71, 0.83

The classification report highlights the absence of certified wineries in the test set, which adversely affects the metrics such as precision and recall for Class "1". This imbalance in the dataset is a critical factor to consider when interpreting the model's performance. Table A2 summarizes the cross-validation results with a clear summary of the cross-validation scores, mean accuracy, and standard deviation.

Table A2. Cross-validation results.

Cross-Validation Scores	Mean Accuracy	Standard Deviation
[0.714, 0.714, 0.714, 0.667, 0.833]	0.729	0.056

These cross-validation results indicate that the model's performance is consistent across different subsets of the data, with a mean accuracy of 72.9% and a relatively low standard deviation, reflecting stability and reliability in its predictive capability.

6. Beta Coefficients of the Model

The beta coefficients' values from the logistic regression calculations are shown in Table A3.

Table A3. Beta coefficients' values.

Variable: Value	Beta
Intercept	−0.1
Job_Position: Manager	0.15
Job_Position: Technician	0.20
Annual_Production_Capacity: High	0.05
Annual_Production_Capacity: Medium	−0.10
Number_of_Employees: 50–100	0.12
Number_of_Employees: 10–50	−0.15
Main_Environmental_Objectives: Reduce_energy_consumption	0.08
Main_Environmental_Objectives: Reduce_waste_production	−0.05
Company_Departments: R&D_Production	0.10
Company_Departments: Sales_Production	−0.12
Review_Frequency: Monthly	0.18
Review_Frequency: Quarterly	−0.08
Established_Processes: Yes	0.22
Established_Processes: No	−0.20
Environmental_Policy: Yes	0.25
Internal_Communication_Strategy: Meetings_Emails	0.10
Internal_Communication_Strategy: Emails	−0.10
External_Communication_Strategy: Website_Reports	0.05
External_Communication_Strategy: Reports	−0.05
Environmental_Info_Stakeholders: Public_Employees	0.12
Environmental_Info_Stakeholders: Employees	−0.12
Risk_Analysis_Method: Qualitative	0.15
Risk_Analysis_Method: Quantitative	−0.15
Opportunity_Analysis: Method_Qualitative	0.18
Opportunity_Analysis: Method_Quantitative	−0.18

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