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Contribution the Failure Mode Analysis and Criticality Evaluation Method to the Rehabilitation of Cork Oak (*Quercus suber*) Forests in Forest Massif of Tlemcen (Algeria)

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Abstract

The controling of forest sustainability and preforest ecosystems in achieving stability of forest ecosystem require the identification of biophysical indicators, anthropological, and technological. The significant degradation of Quercus suber formations in forest massif of Tlemcen (Algeria) are imposed by both climatic factors, the fires, the overgrazing land, anthropogenic aggression as well as by ineffective management. The making of a reference matrix would make possibility the identification of probable hazards and risks. This study aimed to identify the understanding how the mode of operation of a system to identify failures and treat, and the create the intention of eliminating or minimizing the associated risks. This matrix will consist of relevant indicators which easy guide to estimate and following the understanding of the forest degradation process in Algeria. The FMECA method allowed identification of 20 main defective targets which be grouped into 3 categories namely: technical, ecological, organizational, and facilitate of remediation. Each error can be scored and action plans can be prioritized, allowing different with all forest sector players to better understand the degradation of this natural space in order to implement efficient and appropriate remediation plans.

Keywords: *Quercus suber regression, matrix risks management, sustainability forest, Tlemcen*

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Introduction

Preserving forest ecosystems is an obligation for an arid country like Algeria in view of the ecological and economic role they play. Global warming was a reality to which we must adapt. However, it is necessary to adapt the strategies to the local environmental conditions. We must have effort to mitigate the damage with adapting system to the realities of global warming. This means that humanity has to solve the issue of environmental constraints before it can consider the issue of resource depletion (Yoshida, 2012).

The forest ecosystem is highly threatened cause atmospheric pollution, desertization, water and wind erosion and the management of precipitation. Water stress positively enhances catastrophic fires and forest dieback, and promotes proliferation of existing pests and diseases. According to Lindner et al. (2010), the important impact of climate change is observed in Mediterranean region, with major damages for the functioning and sustainability of Mediterranean forest ecosystems.

Mediterranean countries have around 85 million ha of forests, representing 2% of the world's forest area (FAO, 2013). According to the national forest inventory of 2003 (FAO, 2010), the current situation of forest in Algeria is dramatic. The forest ecosystem covers a total of 4 million ha where the degraded formations represent more than 3 million ha that must be managed to initially preserve their sustainability.

In Algeria, forests occupy an area of around 4 million ha, i.e. less than 2% of the country's area. It is mainly composed of forest species such as the Aleppo pines, oak cork, holm oak, Junipers, and others (Thuja, eucalyptus, and various) (ONS, 2015).

Algeria area of Mediterranean rim countries are experiencing an intense degradation of their forest heritage. All the forest and pre-forest structures are related to their vulnerability, instability and vulnerability imposed by bioclimatic, ecological, floristic and socio-economic conditions. More than 80% of this situation is caused by lack of control over the forest space is believed to be a major cause of the through thoughtless and inappropriate human intervention commonly observed. The operating conditions and especially the safeguarding conditions present many problems. Forest management has a dynamic problem; actions taken today have important consequences for the backup. The manager must be have an ability to resolve or take-charge forest harvesting operations technical efficiency (Mhamdia, 2019).

The original vegetation has been altered significantly and strongly transformed by the action of man. The original forests were in many cases replaced by secondary formations

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of matorral and shrub scrub (Pedrotti, 2021).

The forest heritage is often considered to be deeply degraded in Algeria. The forest ecosystems are strongly threatened by anthropogenic pressures characterized by overexploitation and pastoral overloading, frequent fires, and inadequate management. This situation is also confronted to a decrease precipitation. The situation of Algerian forests in general and those of *Quercus suber* is a particularly serious situation. *Quercetum suberis* is an overexploited ecosystem, weakened by natural (climate and soil) and anthropogenic (overgrazing, overexploitation, fires) pressures. The majority of cork oak forests in Algeria are more than 100 years old and their reconstitution through a strategy of adaptation of sylvicultural techniques and assistance becomes more than imperative (Mostefai & Robert, 2010).

The current situation is described as dramatic, only ambitious integrated ecological management programs will make it possible to save the fragments of forests that remain, or to preserve some areas that have still remained miraculously safe from this destruction (Quézel & Médail, 2003). All the forest formations are characterized by their heterogeneity, their instability and their vulnerability imposed by bioclimatic, ecological, floral and socioeconomic conditions. This has led to particularly by the lack of control over forest space and by interventions that are most often unsuited to the characteristics of these forest formations.

Problematic Since the 1970s all forest ecosystems have been strongly threatened, first is in fact the result of a combination of edapho-climatic and anthropogenic factors, in particular: clearing, overgrazing, cutting, frequent and repeated fires as well as inadequate management.

Algeria does not benefit from the subhumid Mediterranean climate only on a narrow coastal strip, about two-thirds of their territories are exposed to semi-arid and arid climates. Strong spatio-temporal variability of precipitation has a major influence on forest ecosystems. However larger precipitation values were recorded, mostly during winter time, the mean temperature is 7.2 °C, yearly average temperature is around 17.8 °C. The mean driest month is July, rainfall becomes scarce, the average temperature exceeds above 29.4 °C (Babaousmail et al., 2019).

This worrying situation needs appropriate imperative strategy avoiding forest management actions mistakes undertaken since 1962. Forests and scrub cover 4.3 million ha (in 1830 the area was of the order of 5 million ha), equivalent to an afforestation rate of 16.4% in the north of Algeria. Strictly-speaking, the forest covers only 1,249 million ha, including 424,000 ha of planted forests (Meddour-Sahar & Derridj, 2012). The vulnerability of forest ecosystems in Algeria is linked to natural and anthropogenic factors which can both be amplified under the effect of climate change. Accidental and man-made forest fires, for example, have been an integral part of the life cycle of Mediterranean ecosystems for thousands of years and will remain so in the future. However, "knowledge about the vulnerability and expected impacts of climate change on the main ecosystems, as well as their biological diversity, remains limited (Meddour-Sahar & Bouisset, 2013; Bouhabila, 2019).

During the last years, oak forests Tlemcen Mountains suffered strong degradations caused by repeated the clearing, fires and human activity pressure, notably overgrazing. In the context of risk, adequate management is required to make these training courses profitable and ensure the sustainability of these resources. Urgent efforts are required to preserve the cork oak as well as endemic species confined to it. Only the identification of the hazards that are the source of risk is possible. In this paper, we used the failure mode, effects, and criticality analysis (FMECA) approach, a fairly easy-to-use tool ensuring reliable results in terms of risk management to assess the risks hampering the development of forest ecosystems in the Tlemcen Mountains and allowing proposition of solutions for sustainable forest development.

Major element constraints analysis In Algeria, in addition to fires and human pressures (overgrazing, exploitation of wood and various products), forest formations are in continuous struggle against drought (> 6 dry months).

By consideration to historical elements, pressures exerted unceasingly, and people and their livestocks, Algerian forest seems to slide quickly on a progressive degradation of the main species and its replacement by secondary species forming, consequently, matorrals (shrubland), maquis and mainly a scrub.

In all Mediterranean countries, the cork oak forest preservation is compromised by several factors especially the negative bioclimatic conditions and the unbalanced management of forest ecosystem. Cork oak ecosystems, which are biodiversity hotspots and have great socio-economic importance in the western Mediterranean basin, have been experiencing serious decline in the last decades attributed to different causes (Gauquelin et al., 2018).

The decline of Algerian *Q. suber* forests is very worrying. Several authors have drawn attention to the main constraints hindering both the preservation and rehabilitation of the *Q. suber* formations (Djaoud, 2003; Belghazi et al., 2003; Messaoudene, 2008; Bouhraoua et al., 2014; Navarro-Cerrillo et al., 2019; Mahamedi et al., 2020; Younsi et al., 2021). Like all forest formations in Algeria, *Q. suberis* is an overexploited ecosystem and weakened by both natural and anthropogenic pressures. However, it's important to adopte a strategy for the rehabilitation of forest in cork oak (*Q. suber*) stands.

To ensure the sustainability of these forest formations, the identification allows to target the main constraints hindering both the preservation and rehabilitation must be a priority, making it possible to assess the sources the danger-threatening. The main constraints can be summarized as follows: a) irregularity of formations and physiognomy imposed by fires and grazing; b) presence of all degradation stages and lack of rejection by sowing; c) dominance of maquis at very clear tree strata and dense maquis; d) clear maquis with dense undergrowth; e) old fossil forest tree without future; f) strong anthropogenic pressure: cuts, fires, overgrazing; g) lack of cork-cultural traditions and/or appropriate sylviculture; h) strong natural installation of conifers and competition by other species; and i) high failure rate in reforestation.

It would be necessary to recognize the forest heritage is threatened, during in recent years, due to climate change and the spread of the desert, there has been a decline in natural capital, a limited forest, which is experiencing unreasonable exploitation in the face of a lack of public authority, with a consequent loss of forest reserves. Cork production in Algeria dropped sharply from 35,000 tonnes in 1965 to less than 8,000 tonnes in 2010 (Figure 1). According to Mezali (2003), taking into account the installed processing capacity, the cork demand to meet local demand and generate an export surplus would be 30,000 t year^{-1}. Softwood production is currently at 12,000 tonnes year^{-1} and will have to increase significantly in the coming years due to simple management measures, refilling and improved access to certain plots. Over 20 years of cork oak renovation and expansion plans since 1980 have not allowed for an increase in cork production. Restoration of Algerian cork oak forests has not yet adopted any strategy.

The lack of sylvicultural interventions for a rejuvenation of the cork oak forests and the lack of their own management justifies the decline of the national production. A forest inventory compiled in 1984 by the National Service for Rural Development (NSORD) in 1984 shows that of the 230,000 ha of cork oak, 61% are old, 37% by young forests tree, 1% by perch and 1% by copses. 24 years later, and following reforestation and repopulation works, the NSORD reveals in 2008 a subericole heritage of 357,231 ha (Figure 2). The surface area of *Q. suber* increased, but also the proportion of old forests tree from 61% to 68%. The proportion of perch, on the other hand, improved from 1 to 4.7%. The most common are those over 100 years old, which explains the difficulty of natural regeneration (Bouchaour-Djabeur, 2016).

Stress evaluation with the FMECA method AFNOR (2016), French standardization association defines FMECA as an inductive method that allows a quantitative and qualitative analysis of the reliability or security of a system. The method consists in methodically evaluating the potential failures of the systems (failure mode analysis) their causes and their consequences on the operation of the whole (the effects). After prioritizing the potential of failures based on estimate of the level of failure risk, which is none other than the criticality of priority actions is triggered and followed up. The FMECA is a tool used in the quality and safety approach to the operation of systems. This is the acronym for Failure Mode Analysis and Criticality Evaluation. The method always involves a qualitative identification of the causes, modes and failures effects. A quantitative assessment follows of the frequency of occurrence of these failures, their severity and their probabilities. Applied to fairly complex situations, this method made it possible to identify sources of danger with fairly good precision.

In order to achieve these purposes, a four-step methodology was employed:

Preliminary analysis Forest ecosystems in the region of Tlemcen can be diagnosed with this method which is based on the concept of indicators by prioritizing namely: a) compositional indicators covering landscape types, their structures, habitat types, communities and species; b) management indicators describing the studies, techniques and strategies of development and sustainability; c) operating indicators describing the processes and their impact on sustainability.

Other additional indicators should also be used since they complement the previous ones such as: a) pressure indicators reflecting the pressure exerted by human activities and/or natural processes that cause changes. State indicators providing a description of the environmental situation of an environment at a given time as well as changes of state over time; b) response indicators making it possible assessing the resilience of forest ecosystems according to the strategy adopted.

Qualitative analysis The failure modes were identified by qualitative data analysis. The term of failure modes was defined as symptom reveals failure. This analysis allows failure modes detection which could affect forest ecosystems.

Quantitative analysis Once actual and potential risks identified, quantitative risk assessment will be conducted. This analysis consists of estimating associated risk with the potential failure. The purpose of this assessment is to identify

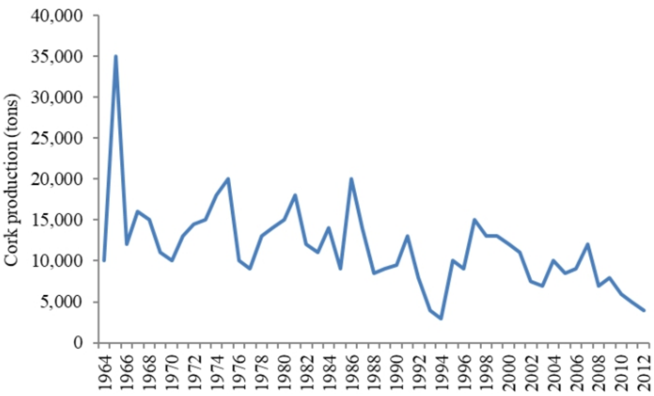

Figure 1 Annual fluctuation (1963–2012) of cork production in Algeria (in tons) (DGF, 2013).

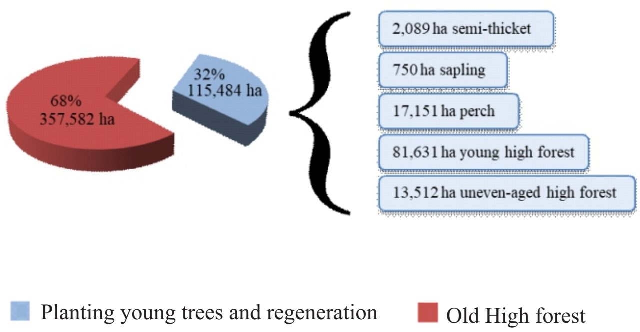

Figure 2 Composition of the Algerian cork oak forest (NSORD [2008], *in* DGF [2013]).

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and to prioritize potential failures. This step classifies failures according to the probability or frequency of cause occurrence that leads to the failure (F), the risk of failure non-detection (D) and the failure seriousness effect (G). For each risk, three evaluations are attributed on a scale ranging from 1 to 5. A global value, resulting from the 3 previous notes G × F × D, allows to evaluate and to classify the criticality level.

Failure modes hierarchization The main difficulty of a study anticipating problems and looking for preventive solutions comes from the wide diversity of potential problems to be considered. So, the hierarchization classifies the failure modes and organizes their treatment in importance order. According to quantitative analysis table, 20 failure modes were identified.

Corrective and preventive actions and follow-ups After classifying the different failure modes according to critical indicators, corrective or preventive actions were established to minimize risks.

The choice of this evaluation method is necessary in view of the difficulties in identifying the causes at the origin of the situation of cork forests in Algeria. Applied to fairly complex situations, this method used to identify the sources of danger with fairly good precision. Method is necessarily conducted by multidisciplinary group, whose members are competent in their profession, trained to assess of the situation in different spaces (ISO 37101-2016).

Quantifying the degree of alteration and identifying constraints The alteration degree can be a useful approach is primarily based on knowing the attributes of the natural forest as a reference state for setting management targets. It is the basis for ecosystem-based management. The degree of alteration approach alone cannot provide all the guarantees that biodiversity will be effectively conserved. It is important to use additional knowledge and information on the habitat requirements of species to strengthen it (Drapeau et al., 2008; Gauthier et al., 2008; Drapeau et al., 2009). By verifying whether different species find the conditions conducive to their maintenance within the targets established using the degree of alteration approach, it is possible to assess and correct any gaps observed or to choose to pay particular attention to the problem species. In addition, some attributes of the natural forest are sometimes difficult to quantify (e.g. size of clumps, quantity and desired characteristics of dead wood, etc.). Knowledge of species' habitat requirements becomes very also useful for determining quantitative targets and thresholds for certain forest attributes. the maintenance of key attributes natural ecological and processes is the surest way to promote the ability of forests to resist change, to be resilient to disturbance. The response of species to disturbances in an area is not directly proportional to habitat loss. A decrease in amount of habitat does not automatically affect the ability of species to occupy a territory. However, when a certain threshold is exceeded, the drop can become significant, with the numbers of a population, or the number of species in the case of communities, even going as far as the local scale extinction. It is therefore necessary to establish safe thresholds and define degrees of alteration that make it possible to control the risks to biodiversity in an economically viable context (Rompré et al., 2010) (Table 1).

There can be no preservation and rehabilitation of forest formations subject to almost permanent pressure without a diagnosis focused primarily on the identification of the sources of danger that have generated risks. Various specialist approaches in the field remain imprecise and difficult to achieve, such as typology, management studies, phytoecological diagnosis and risk mapping. Face therefore this dilemma, recourse to the tool used in management of risk method of analysis of failure modes, their effects and their criticality (FMECA).

Advantage of the FMECA method The method FMECA always involves a qualitative identification of the causes, modes and failures effects. There follows a quantitative evaluation of the occurrence frequency of these failures, their severity and probabilities. Applied to fairly complex situations, this method made it possible to identify sources of danger with fairly good precision. Hence his choice with regard to the difficulties to identify the causes at the origin of the cork oak forest situation in Algeria. FMECA is a more precise and modern means than the classic diagnostic made by foresters; it should make it possible to increase the Mean Time Before Failure (MTBF). Its use allows to target the failures of the management system, both technical and

Table 1 Three degrees of weathering

Degree of alteration	
Low	Deviations from the average historical are small and ecosystems are probably within the limits of natural variability. The risks of biodiversity loss are very low.
Moderate	Deviations from the historical average are greater, but are above an alert thres hold. The alert threshold is defined as the proportion minimum of habitat to conserve in a landscape, a proportion below which not be able to maintain viable populations for sensitive species (Rompré et al., 2010). Regarding this degree of alteration, conditions are close to the natural state and the risks for biodiversity are considered moderate.
High	The deviations from the historical average are large, they are below the alert threshold and are probably outside the limits of natural variability. The risks of biodiversity loss are high. Old forests represent only 30% of the average historical.

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organizational of *Q. suberis* ecosystem, then to modify the classic approach to management formations. All formations in the *Q. suber*, regardless of their composition, location, potential, and degree of degradation, can be initially identified using the main disturbance indices. These are the causes of ecosystem failures and help to understand failure modes that shed light on the impact of failures. Any anomalies found can then be corrected to determine a remediation strategy. Failure modes can be easily identified when there are enough elements about ecosystem functioning and its characteristics.

The method always involves a qualitative type analysis (analysis of the causes of failure, analysis of failure modes and analysis effects of these failures). Then, a quantitative evaluation (evaluation of the frequency of occurrence of these failures, evaluation of the severity of these failures and evaluation of the probability that these failures go unnoticed.

The purpose of this study was to understand the system operates, identify failures and treat them before they occur, with intention to elimination or minimizing associated risks. These failures arise, for example, from any object, machine, service or process. A forest management intervention study without detailed analysis, as a consequent, leads to a strong possibility of poor technical performance results. Followed by disturbance series, at this stage, the hazard turns into a risk of ecosystem disruption (Benabdeli, 2016).

The identification of risk source hazards is possible using FMECA method, with easy-to-use tools and technique ensuring reliable risk management results.

Methods

FMECA method is a more precise and modern means than the classic diagnostic made by foresters. It should make it possible to increase the MTBF.

The forest ecosystems that we are currently managed work differently all escape and the classic approach we use. The manager's objective is to contribute to increasing the operating life of a system. Therefore, the method boils down to: a) the initiative aims to facilitate through formalization, and a systematic approach, a critical examination of a means of production; b) requirements of definition of the specifications to monitor and improve quality and actions to be taken; c) in order to enable and maintain the guidelines for sustainable management; d) study guide for technical choices analysis; and e) to integrate prevention arises as an essential way to ensure ecosystem resilience.

Identification of main development axes The major constraints hampering any sustainable governance of forest formations require a new management approach induced by a sustainable management strategy that remains to be developed. The latter must revolve around the following elements: a) to characterize the forest area ecologically and map it on a medium scale; b) to evaluate the different weight pressures and the ecosystems response; c) to identify the iso-potential areas allowing a stands typology; d) to initiate a pre-management adapted to each typology; e) to control the formations fonctionning dynamics (structure and potential); f) to opt for educational sylviculture to prepare management formations; and g) to develop a sustainable management plan for the different forest formations.

The possibility of application to forest formations: An overview of data sources The FMECA is a safety and reliability analysis tool and risk management to assess risks hindering the development of forest ecosystems in the Tlemcen Mountains and to propose solutions for sustainable forest development. Methodological approach to allowing application of the FMECA method is based on the following points: The monitoring of operations forest ecosystems of the Tlemcen Mountains occurred between 2014 and 2020. For this study, a mixed research design that incorporated qualitative data and quantitative data was used. Data are essentially technical reports, scientific papers and the results of interviews. A method of data collection which includes the identification of technical and scientific papers reports, magister thesis and PhD carried out on territory, background information the official database from the Algerian Forest Direction.

Ecological characterization of the Tlemcen Mountains The Mountains of Tlemcen constitute most extensive mountains range in the northwest of western Algeria, mainly dominated by evergreen oak matorral and juniper matorral, and conifer plantations. The vegetation is composed of shrublands, holm-oak forests and green oak matorral and Juniper matorral, and conifer plantations (*Q. ilex*, *Q. suber*? *Ceratonia siliqua, Pinus halepensis*). Low shrubs cover formation encompass the groups (*Ulex boivini, Chamaerops humilis subsp. argentea, Asparagus acutifolius, Ziziphus lotus, Rosmarinus officinalis, Genista*). The forest of the Tlemcen Mountains are continually deteriorated overgrazing, the clearing and high frequency of fires endommaged the dynamic of the natural vegetation (Letreuch-Belarouci et al., 2009).

To the south-west of the city of Tlemcen appear the cork oak forests of Zarifette (962 ha) and Hafir (9,872 ha), Ain Souk (1,307 ha), and Zerdeb (2,381 ha). The Yfri forest located lower, in city of northeast Tlemcen covering of 1,080 ha (Figure 3). In a general way, the climate is typically Mediterranean, and is characterized by two main seasons, a hot-dry and a cold-humid season (Medjahdi et al., 2018).

The gradual deterioration of the forest cover of the Tlemcen mountains is considered a major environmental problem in Algeria. Forest management must be based on the ecological restoration of degraded forest lands is a difficult undertaking that requires a global and long-term vision of the structure, diversity, functioning and dynamics of forest ecosystems.

One method often used on risk assessment, the FMECA method can easily be applied to identify and assess the risk sources of degradation of forest formations.

The latter, whatever their composition, potential and stage of deterioration, may be initially identified by the main signs of disturbance which It may lead to failure of ecosystem function.

This identification makes it possible to understand the malfunctioning of ecosystems modes which provide information on the effects of failure. It is possible, however, to correct all the anomalies observed in order choosing

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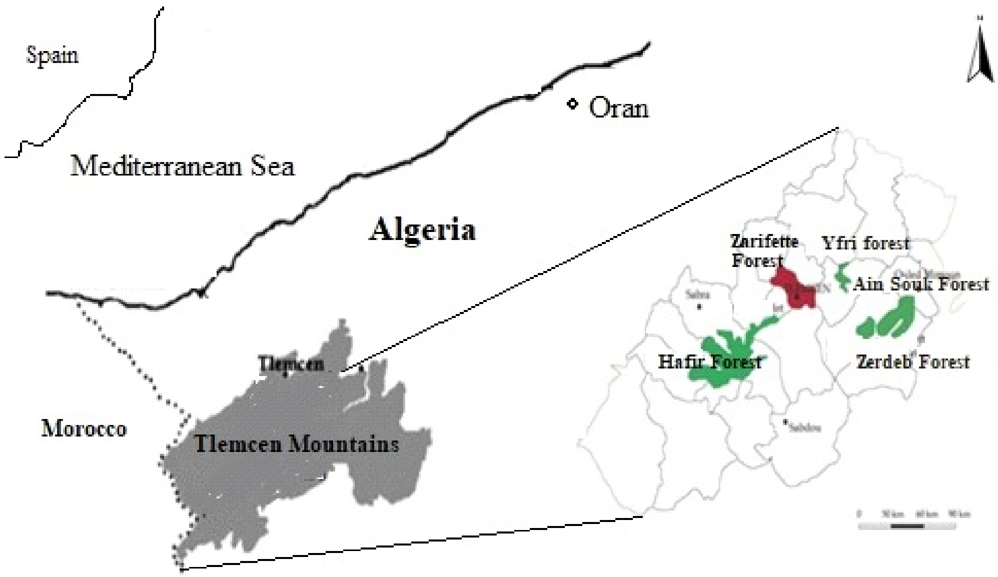

Figure 3 Forest geographic location of cork oak forests in the mountains of Tlemcen.

rehabilitation strategy. The approach will be structured around 4 points: 1) complete failure (ecosystem is no functioning); 2) partial failure (anomalies on ecosystem functioning); 3) intermittent failure (the ecosystem depends periodically events); and 4) failure over time (the ecosystem is showing signs of exhaustion).

The strategy employed to identify the failure mode, primarily; we need to acquire sufficient information about the functioning of the ecosystem and its characteristics. Above all, this phase makes it possible to identify the main causes associated ecosystem. As a matter of fact, a quantitative measure of the criticality where it is recommended to note: (G) the gravity of the effects associated with each failure mode; (F) the frequency of occurrence of each failure mode; (D) the probability of not detecting the failure mode; and (C) the criticality is then defined as the product of the three factors: $C = G \times F \times D$.

The methodology adapted to failures identification in systems for safeguarding cork wood: FMECA. The results obtained are then enregistred into the evaluation matrix according to the following points: a) identification of hazards sources and risks; b) segmentation of hazard source factors; and c) risk evaluation (severity, frequency, non-detection). Various factors for assessing degradation cork were based the scale in 5 levels: 1) very weak; 2) weak; 3) medium; 4) strong; and 5) destructive.

Failure mode, effects, and criticality analysis (FMECA)

In order to examine the main constraints, the potential failure modes within a system in which the various formations at *Q. suber* find themselves. Both matrices are focused on the FMECA method.

A matrix for identifying failures and their cause and their effects, then a second matrix evaluating the criticality through gravity, frequency and non-detection. The development of a failure matrix first allows you to target the constraints and classify them according to their source. The latter depends on three causes: organizational, technical or natural; each of them, and there are many, generate effects generating a criticality that must be assessed in order to prioritize the actions to be taken.

The assessment focuses and mostly pertains to the impact of failures on the rehabilitation of cork oak formations revolves around three matrices: a) organizational failures; b) technical failures; and c) failures of ecological.

This approach is based on the concept of indicators. It permits us to see how indicators can be prioritized based upon their perceived namely: a) composition indicators indicating landscape types, habitat types, communities, species, intra-specific elements; b) structural indicators describing the physical assembly of the elements of the system: landscape model, structure and heterogeneity of habitats; c) performance indicators describing ecosystem processes such as hydrological regime, land use trends, species interactions, etc.; d) other additional indicators should also be used since they complement the previous ones such as: 1) pressures exerted by human activities and/or natural processes that cause changes in the environment; 2) state indicators provide information about of the environmental situation. They specify the ecological, physical, socioeconomic situation of an environment at a given time as well as changes in condition over time; and 3) response indicators are used to assess the efforts or means must be found of resolving by society to resolve an environmental problem.

Bennet and Tkacz (2008) point out that sustainable forest management can be seen as a comprehensive monitoring system that provides statistically precise and accurate baseline and forest health trend information to determine detrimental changes or improvements that occur in our forests over time. Thus, forest health and sustainability, consists of separate, interrelated activities, including

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detection monitoring, evaluation monitoring, research on monitoring techniques, and intensive site monitoring. Descriptions and examples are provided for each activity.

Furthermore, an annual report focuses on maintenance of forest ecosystem health and vitality. The report is composed of main data sections which indicator section contains analyses of abiotic, biotic, and anthropogenic disturbances including drought, hurricanes, tornadoes, fire, insects and diseases, introduced species and indicator section contains analyses of tree health data including tree mortality, crown condition, and damage (Coulston et al., 2005).

Failure assessment The identification and assessment of risks threatening forest ecosystems using the modified and adapted FMECA method allows the development of an interesting synthetic matrix.

Primary matrix The identification and assessment of risks threatening forest ecosystems using the modified and adapted FMECA method made possible developing an interesting primary matrix. The configuration of this matrix is based on a multitude of indicators that can be classified into three classes: a first focused on the concept of State-Diagnosis, the second on potentialities and resilience and the third on the causes of alteration, the source of this situation (Table 2).

Then it is possible to produce a synthetic matrix listing all the hazards, the risks that result from them with an assessment of their effects through a 5-level scoring grid focused on severity, frequency, detectability and criticality.

Example of a risk matrix in a *Quercus suber* stand The methodology adopted to assess cork forests vulnerability is based on Statistical processing of data information was obtained from the General Directorate of Forests (DGF, 2016) which is in charge of preserving, conserving and sustainably managing forest and woodlands for the present and future generations research activities are coordinated by the National Institute of Forestry Research (INRF) respectively, for forest management and exploitation in the country.

First, a global test using all the *Q. suber* forests in the western region and made it possible to produce a risk identification and assessment matrix (Table 3). Using the scores achieved by the 20risks, it is possible to rank according to severity, frequency and detectability. All formations in the *Q. suber*, regardless of their composition, location, potential, and degree of degradation, can be initially identified using the major causes of disruption. These are the causes of ecosystem failures and help to understand failure modes that how it may shed light on corporate success and failure. Any anomalies found can then be corrected to determine a remediation strategy. Failure modes (if any) can be easily identified sufficient elements about ecosystem functioning and its properties. But most importantly, this stage makes it possible identify relevant root causes based on our experience. In terms of criticality, this is the quantitative part of the study where it is recommended to note.

This classification makes it possible to better understand the strategy for preserving forest formations. It is because of this that it is possible to combine the various risks that can be taken care of simultaneously.

Risk identification and grouping main weakness and predisposing factors associated with the decline of cork oak populations This situation could generate, in the future, disturbances in forest ecosystem dynamic balance, leading to risk situations emergence.

Cork oak forests are threatened by several factors such as management practices are inappropriate and inconsistent and do not provide an enabling environment for the development conditions of the forest ecosystem. Main risk factors associated with the decline of cork oak populations are then defined by the Criticality as the product of three principal components: $C = G \times F \times D$. (Figure 4). These predisposing factors are acting constantly, mainly leading to an overexploited ecosystem and weakened by both natural (climate and soil) and anthropogenic (overgrazing, overexploitation, fires) pressures which lead to the gradual weakening of the cork oak, related to habitat characteristics and management strategies. In order to allow the

Table 2 Primary matrix

Categories	Content	Objective sought	Categories
Status and diagnosis	Phytoecological and silvicultural description of stands.	Control the forest area in its ecological, economic and social aspects.	Status and diagnosis.
Potentialities and resilience	Forest stand resistance and ecological and plant resources.	Evaluate the potential of the environment and compare them with forest formations.	Potentialities and resilience.
Causes of deterioration	Overexploitation, overgrazing, mismanagement, fires.	Identify the main causes and classify them according to their aggressiveness.	Causes of deterioration.
Hazards and risks	Disturbances, changes in composition and structure.	Characterizing, hazards, identifying, assessing the risks involved.	Hazards and risks.

Table 3 Failure matrix

	Factor-source	Gravity	Frequency	Detection	Score
Technical failures	Cork oak ecosystems functioning	4	5	4	80
	Planting techniques	3	5	4	60
	Seedlings quality	5	5	3	75
	Pest attacks (Xylophagous and xylomycetophagous species, pathogenic fungi) Insect defoliators	4	3	1	12
	Formations typology	5	5	3	75
	Physiological and genetic aspects of cork oak ecosystems adaptation	4	3	5	60
	Rehabilitation techniques of cork oak forests	5	4	4	80
	Cork exploitation	3	3	2	18
	Average	4.12	4.12	3.25	57.5
Ecological failures	Incidence of droughts, descreased rainfall	4	5	2	40
	Global warming temperature increase	4	3	4	48
	Development of secondary woodland in oak wood	3	4	2	24
	Regressive dynamics of the forest ecosystem	4	5	3	60
	Average	3.75	4.25	2.75	43
Organizational failures	Biological program to the long-term ecological research	4	5	2	40
	Sustainable management strategy	5	3	3	45
	Financing schemes of plots that can be developed	3	5	4	60
	Verification and validation of research results and development	5	4	3	60
	Implementing an appropriate financing method for responsibilities from the design to operation related to the project	5	4	2	40
	Land clearance by saving endangered spaces	5	3	4	60
	The valorization of the resources rural areas closest subject to strong pressures towards urbanization	3	4	1	12
	Development of coaching and mentoring strategies on the human resources sustainable development	4	5	4	80
	Average	4.25	4.12	2.87	49.62

Source: General Directorate of Forests (2016)

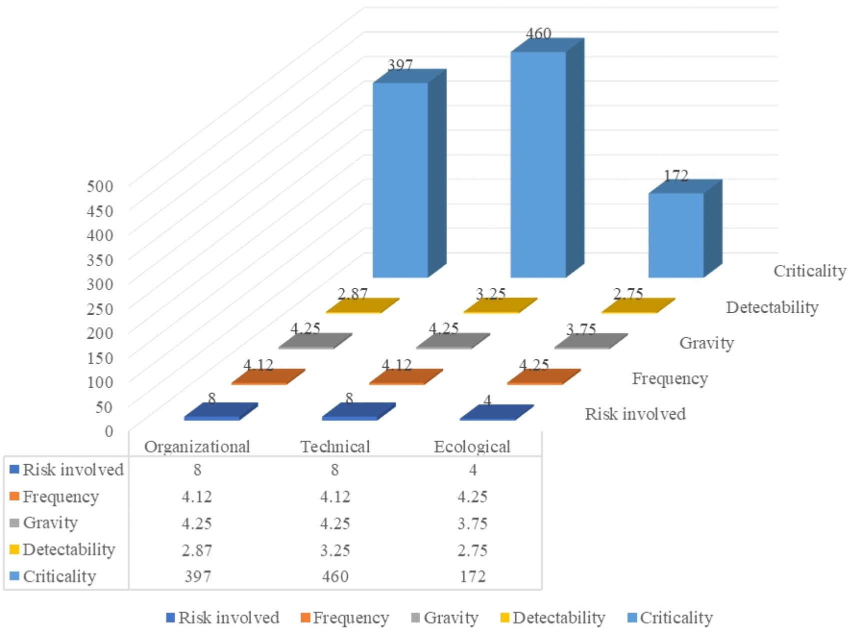

Figure 4 Risk typology

implementation of a policy, evaluation is carried out on the same scale.

The use of matrix makes it possible to target 20 risks induced by different hazards can be classified into 3 types.

The prerequisites raised for the rehabilitation of forestry formations The prerequisites for the successful identification of the risks threatening the sustainability of forestry formations in Algeria are of several types, first of all political since there is no long-term strategy for this sector that can play an ecological and socio-economic role determinant.

The use of the FMECA method combined with the causes and consequences diagram have made it possible to identify ten supposedly important and whose management is urgent.

By grouping together content of 20 failures, it is possible to have only 5 determining axes that should be addressed as follows: 1) study of different ecosystems functioning of and development of a typology, 2) training and research program for the mastery of modern techniques, 3) silvicultural, production and planting techniques in semi-arid and arid zones, 4) development of surrounding areas to reduce anthropogenic pressure, and 5) integration of small and medium-sized enterprises in the promotion of products.

Conclusion

In light of the foregoing, it will be delusive to want to preserve and rehabilitate cork oak forests in Algeria without putting in place a strategy stemming from a precise diagnosis, focused on a methodological approach which must be based on the determination of the points identified above, making it possible to deal with all the technical, organizational, and natural failures. After the conservation of cork oak forests and the understanding of their function by the typology, their development can only be initiated by a real risk management of the factors inducing potential and permanent risks. The proposed strategy is based on the following points: 1) to understand the cork oak forests functioning through a typology, 2) identify failures and classify them in impact order, 3) professionalize stakeholders, and 4) classify failures starting with that of organizational and then technical order. In order to identify the sources of danger inducing risks hindering the sustainable management of cork forests, a synthesis matrix gives a global overview which makes it possible to classify the cindynic causes in order to develop a rehabilitation strategy for Algerian cork stands.

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