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Literature review

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Introduction

The following research will examine how the composition of the soil, the species, and functional traits in abandoned vineyards compare at multiple stages of abandonment. This research will give a better understanding of the ecological and pedological processes involved after the abandonment of vineyards. For this study, there is more consideration of the processes underlying salinization and the network of interactions it has with the plant communities that colonize the fields and less about a series of soil biophysical and chemical properties. In this review, we propose justifications for scientific sources that will be vital in the establishment of our research. We present four main thematics in order to conceptualize the project: the definition, processes, and consequences of soil salinity, the impacts of soil salinity on plants, an original view on the impacts of *plants* on soil salinity, and the management and abandonment of fields affected by high salinity.

1. Soil salinity

As a result of the accumulation of water-soluble salts in soil, a phenomenon called salinization occurs affecting environmental health and agricultural productivity[1]. Presently, soil salinisation is one of the most serious problems associated with soil degradation, threatening around 932.2 Mha worldwide[2]. Soils in this condition can be classified as saline, sodic and alkaline soils. The composition of saline soils varies greatly, but sodic soils are particularly rich in sodium cations (Na^+) concentrations, whereas alkaline soils have high pH levels and usually high CO^{2-} [3].

There are two main processes leading to salinization: primary salinization and secondary salinization. Primary salization depends on natural processes such as transport from the parent material, geological deposits or groundwater. Rich parent rocks in salt constituents or geological events promoting the rise of the salt concentration in groundwater are examples of mechanisms giving rise to soils which have a higher salt concentration in the future[4]. Other short-term possibilities include seawater flooding either for long or brief periods of time, and the current rising of the sea level causing seawater intrusion into coastal areas that already have a conexion with the sea[5]. When the salinization comes from human intervention, it is called secondary salinization of which the major causes are irrigation with saline waterfan[6], use of fertilizers[7], compacted and limited leaching soils[8], wastewater treatments[9], and salt based de-icing techniques[2].

Saline soils give measurements of an electrical conductivity above 4 dS m^{-1} [1], but the consequences of this phenomenon extend to other ecological and non-ecological characteristics of the soil. Some indicators of soil salinity in the field could be a poor response of the vegetation to soil minerals or even the total absence of vegetation and bioindicators; crusts and strains of some unnatural color could also represent an indicator of the phenomenon[10–12]. Often, high salt concentrations cause loss of fertility and microbial and enzyme activities[13], affect the stability of the soil aggregates[14], increase water and erosion rates through the augmentation of the clay particles dispersion[15], perturbate the water supply infrastructure[16], and lead to a negative feedback of the Soil Organic Carbon (SOC) situation[13].

Also, another important consequence of soil salinization refers to its economical losses. Once the land depreciates to a value less than 50% of its original value, the supply of raw materials is limited[17] and crop production and land development is restricted[18,19]. A major example is the desertification of certain regions along the Mediterranean coast that affects around 25% of the irrigated agricultural lands and it is caused predominantly by human activities[20].

2. Impacts of soil salinity on plants

As this research is predominantly focused on the interrelationship between plants and soil composition, it is necessary to show an understanding of the main effects a higher salinity soil has on plants including the consequences on plant growth and mechanisms of salt tolerance. There are many well developed studies identifying the responses of plants to saline stresses with a focus on physiological processes which will be the most illuminating for our project.

Usually, and what we imagine to be the case for our study, the most abundant dissolved salt in the soil strata is sodium chloride (NaCl) which explains why most plants have developed the most robust response to this type of salinity[21]. There are two main stresses that impact plant metabolism, ion toxicity and osmotic stress, which both activate secondary signals that immediately prompt physiological changes: “stromal closing, osmolyte accumulation, and increased Na^+/H^+ antiporter or activity” [22]. Osmotic stress, which induces a more rapid response, has a greater effect on growth rates than ionic stress which has later onsets affecting development[21]. At high levels of salt at the root layer, water will flow osmotically out of the cells towards the higher concentration of solutes which decreases the rate of shoot growth[21] .

These stresses have major consequences on plant growth and development by inhibiting seed germination, root length, plant height, fruitification, and photosynthesis which limits carbon uptake [22,23].

The ability to tolerate salty soils can greatly vary from one plant to another which is reflected by their physiological responses.[21] The mechanisms developed to surmount this problem can be classified into three groups: tolerance to osmotic stress, Na^+ exclusion from leaf blades and tissue tolerance. As osmotic stress reduces CO_2 fluxes, water vapor reduction, and inhibition of cell growth in young leaves, the best response to osmotic stress would be the improvement of stomatal conductance and growth. However, it would be desirable only in situations where the plant has enough soil water[21]. Na^+ exclusion by roots means that the plant will not accumulate toxic concentrations of this ion in its leaves, a failure in this mechanism can cause the death of older leaves though[21]. A high plant tolerance to accumulated ions in their tissue, like Na^+ or Cl^-, helps plants to avoid toxicity that occurs with time once the Na^+ concentrations increase in older leaves. For this mechanism, the ions' compartmentalization is needed at the cellular and intracellular level[21]. It is important to point out that plant tolerance to salt will vary according to the species as well its environmental condition, like the concentration of salt, length of exposure, air humidity and water supply.[21]

3. Impacts of Plants on Soil Salinity

There is unequivocal evidence that the effects of soil salinity can have major and sometimes detrimental consequences for plants and their productivity, on the other hand however, the inverse lacks rigorous study. Furthermore, where studies are present, most focus on the effects of halophytes and salt tolerant species on soil composition in an agronomic setting whereas research lacks for plant effects on soil salinity in abandoned plots. Salt tolerant species are plants that have a combination of expressed genes which allow the plant to withstand salt stress, and halophytes are plants which tolerate and grow on highly saline conditions; all halophytes are salt tolerant, but the inverse is not always true [24].

For this research, considering the effects of plant species on soil properties, and specifically soil salinity, is an important and original way to understand the web of plant and soil interactions in abandoned vineyards.

The application of cover crops, barley (*Hordeum vulgare* L.) and vetch (*Vicia villosa* L.), compared to fallow during an intercropping period has been studied by J. L. Gabriel *et al*. and shows that with cover crops salt leaching is more reduced than when left with fallow. But after several years of study, the authors concluded that cover crops may be beneficial to reducing salt concentration in the upper soil layers compared to fallow because when soil is left relatively bare there is higher soil water content and thus higher salt dissolution which will contribute to salt accumulation. Overall, however, salt loss was mainly attributed to high periods of rainfall which increased drainage and salt leaching [25]. This study may be beneficial when considering plots only a couple years after abandonment which may appear like fallow conditions, and thus some comparisons could be made with the results of this study and the effects spontaneous, random vegetation has on soil salinity.

Halophyte remediation of saline soils is studied more in the scientific community and may be helpful when considering our study of abandoned vineyards and the species and soil composition. If there are salt tolerant species present on the abandoned plots, which is safe to assume, it will be important to understand their interactions with saline soils and the mechanisms behind in order to draw conclusions for this study. Phytoremediation is the biological process of using plants to chemically remove salts from the soil in order to create a more suitable soil environment [24]. The processes involved take place at the root layer of salt tolerant plants and promote higher calcium levels in the soil solution which cause lower salinity levels due to a suite of pedochemical processes. In short, the roots of phytoremediation agents induce increased dissolution rates of calcite which result in more calcium ions which replace sodium and other salt ions from the soil exchange complex. When supplied with non-saline water, the salt ions will be carried away and leached out of the soil [26].

To cross reference any plants found on our plots, a list of species and their phytoremediation capacities are presented in the book *Plant Adaptation and Phytoremediation* [26] pages 335-355 by Ashraf et al., and in the journal *BioMed Research International*, “”, by Hasanuzzaman et al. [27].

While most research in this field focuses on how *agricultural* soils may be restituted by plants adapted to phytoremediation, the mechanisms and degree of soil salt remediation could be useful when examining the soils in our study while still giving an original view of the problem.

4. Management and abandonment of fields affected by high salinity

The increase of salinity in the soil of cultivated lands implies adaptations of the management of these lands in order to maintain a certain productivity.

“In order to preserve land resources and crop production potential, a possible solution to salinization is the promotion of sustainable land management practices that sustainably reduce salinity”[28]. Among practices, the most common for irrigated cropping systems is the leaching of saline soils with large amount of ‘clean’ and non-saline water; the adaptation of the drainage[29] (through various techniques to purify and desalinate the drainage waters); the adoption of drip irrigation; and the selection of crops tolerant to saline soil conditions.[30] When it is not possible to reduce the salinity, for economical or ecological reasons, this latest technique - named *biosaline agriculture* - is the most efficient and sustainable way to be able to continue cultivation of the lands and maintain productivity in the long term.

When the salinization increases to a point where it is no longer sustainable to use and manage the damaged lands, they usually fall into abandonment. This phenomenon increases with time, and the fields follow different trajectories depending on their cultivation legacies. The different stages of abandonment can be characterized through the evaluation of various functional traits[31] on plants. Those stages ultimately lead to the creation of new “ponds”, consequently to a marsh migration.

Focusing on former vineyards, which are the main targets of our study, we can describe more specifically some stages and phenomenons of abandonment. The main way to evaluate a stage of abandonment is to go in a field and observe specific parameters. Otherwise, to have a global overview and a history of the field, it is interesting to use remote sensing data obtained over the last decades[29] then identify and characterize different stages of abandonment.

In some cases, it is possible to rehabilitate the lands after years of abandonment, mostly by the use of halophytic plants [32]. The implementation of those plants on damaged territories can contribute to the improvement of the landscape and soil functions and characteristics (by increasing the availability and quality of land resources), and can serve several purposes (the recycling of hyper-saline drainage water for posterior use in agriculture, the revegetation of salt-affected tidal flats, serve as fodder crops, …). In coastal regions affected by strong abandonment because of the rise of the water level and the increasing infiltration of salt in the lands, as is particularly the case in the region around Narbonne[33] , the rehabilitation of former agricultural lands could be especially interesting to maintain agricultural activities in the area. It seems therefore interesting to investigate the agricultural management techniques in this zone, current and former management, and about the plant biodiversity[34] to better understand what happened to the fields that led to their abandonment.

Conclusion

This literature review gives an understanding of the context and tries to highlight the relationships between soil salinity, field abandonment and the effects on plants. Depending on the plant species, high levels of salt has a considerable impact on their development and can ultimately lead to land abandonment when agricultural practices cannot be adapted enough to continue the cultivation of plants in the stressful conditions induced by high salinity. Vineyards in coastal regions are specifically affected by this phenomenon of land abandonment. Among the several studies concerning the link between salinization processes and plant development and adaptation plants, we noticed a gap in the research in plant ecology about the effect of plant communities on soil salinity. *We hypothesize that plants' tolerance to salinity will persist in the areas falling into abandonment, and this evolution in biodiversity may influence the soil properties.* By studying these plant communities and furthermore their mechanisms, this study could give insight into how to rehabilitate abandoned agricultural land. This situation comforts us in our objectives to study how the composition of the soil, the species, and functional traits in abandoned vineyards compare at multiple stages of abandonment, with a particular focus on the effects on soil properties and specifically soil salinity.

The methodology used to study salinity or plant communities structuration, and functional traits impacted, will be inspired from the several articles referenced is this review.

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