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Soil Structure as a Key Factor in the Vine Growing Improvement

Liubov Shkarupilo, José Luis Aleixandre-Tudó, José Luis Aleixandre

Instituto de Ingeniería de Alimentos para el Desarrollo. Universitat Politècnica de València (Spain)

***Corresponding Author:** José Luis Aleixandre, Instituto de Ingeniería de Alimentos para el Desarrollo. Universitat Politècnica de València, Spain*

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ABSTRACT

The aim of the study was to make a bibliographic review on the improvement soil structure and enhance soil micro porosity in a Mediterranean region of Spain. Activate soil fauna, which will create aggregate structure, thus increase aeration, facilitate roots penetration and rise water-holding capacity of the soil. Introduce no-tillage techniques in order to decrease the effect of soil erosion and degradation of organic matter, caused by cultivation. The methods and techniques analysed were: ramial chipped wood (RCW), combination of the RCW and beans as a cover crop, control plot, cultivated and without cover crop. Following water state of the plant by analyses of predawn leaf water potential and stem leaf water potential. The conclusions of the study stated that techniques as RCW and cover cropping are able to activate soil fauna, which improves soil structure and contributes into increase of the soil organic matter. Comparing to the cultivated soil, enhanced soils where techniques were applied, positively affect the water state of the vine plant and decreases its stress under the hot Mediterranean climate.

Keywords: *RCW, cover cropping, soil fauna, organic matter.*

INTRODUCTION

Evidence of Climate Change and its Influence on Vine Growing and Quality of Wine Consequently

According to updated World Map of Köppen-Geiger Climate Classification (Figure1), territory of mainland Spain consists of five classification zones: Cfb and Cfa on the North-East, Csb on the North-West and Csa on the South, with some incorporations of BSk on South-East, Centre and North-East. The main climates are: arid (B) and warm temperate (C); concerning precipitation: fully humid (f), summer dry (s), and steppe (S), about temperature: hot summer (a), warm summer (b), cold arid (k).

From the map (Figure 1), it is evident that most territory of Spain considered being in the warm temperate climate zone, with fully humid warm, somewhere hot summers on the North-East, dry warm summers on the North-West and dry and hot summers on the South of the country. There are, however, zones on South-East, Centre and North-East where climate is cold arid steppe.

This updated world map of Köppen-Geiger climate classification was based on temperature and precipitation observations for the period 1951-2000. Authors also developed a series of digital world maps for the extended period 1901-2100 to depict global trends in observed climate and projected climate change scenarios. World maps for the observational period 1901-2002 are based on recent data sets from the Climatic Research Unit (CRU) of the University of East Anglia and the Global Precipitation Climatology Centre (GPCC) at the German Weather Service. World maps for the period 2003-2100 are based on ensemble projections of global climate models provided by the Tyndall Centre for Climate Change Research. The main results comprise an estimation of the shifts of climate zones within the 21st century by considering different IPCC scenarios. The largest shifts between the main classes of equatorial climate (A), arid climate (B), warm temperate climate (C), snow climate (D) and polar climate (E) on global land areas are estimated as 2.6-3.4% (E to D), 2.2-4.7% (D to C), 1.3-2.0% (C to B) and 2.1-3.2% (C to A)(Kottek, 2006).

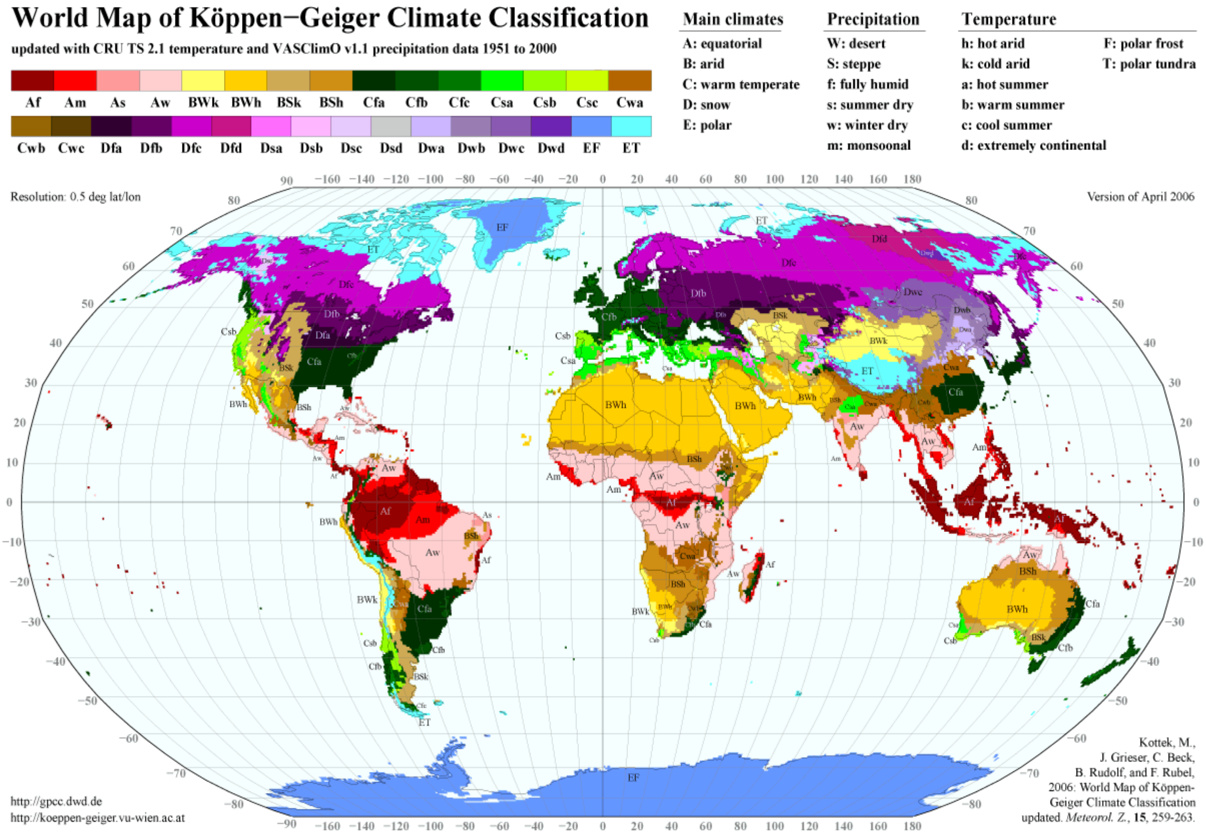

Figure1. *World Map of Köppen-Geiger climate classification updated (Kottek, 2006)*

These evidences in climate change are real threats to European viticulture and production of good quality wine, as climate strongly influences the development of the crop, by requiring suitable temperatures, radiation intensities/duration, and water availability during vine growth cycle, which ultimately influence yield and wine quality (Jones, 2007; Fraga et al., 2013; Fraga, 2014; Lorenzo, 2015).

Effect of climate was greatest on most parameters, followed by soil and cultivar. It was shown that climatic conditions of the vintage can influence grape quality through the amount of insolation, temperature, or water balance. The effects of climate and soil on vine development and grape composition can be explained in large part by their influence on vine water status (van Leeuwen et al., 2004; Schultz and Jones, 2010).

The impact of climate on grapevine phonology, composition, production, and quality is commonly described in terms of air temperature and precipitation. The mean temperature of the growing season ranges between 12 and 22°C with an optimal vegetative response to daily average values of between 20 and 35°C. When the 35°C threshold is exceeded, vegetation activity is reduced and vineyards may suffer serious and permanent damage. Water resources and availability are key factors affecting vineyard productivity (Fraga et al., 2013).

The sequence of the vine development phases is perceived by observing the major phonological stages: budburst, flowering, veraison, maturation or harvest (Charbonneau, 2007).

Air temperature is considered the most important factor in the overall growth and productivity of wine grapes. In effect, grapevine physiology and fruit metabolism/composition are highly influenced by the mean temperature along the growing season (Fraga et al., 2013). According to Charbonneau (2007) temperature has a direct action to most of the mechanisms or cell metabolism in the vine plant. The consequence is that whole plant responds in a global way and it is coordinated to temperature variations, especially in terms of development. Extreme heat or heat weaves, that occur during Mediterranean summers (Geeson et al., 2002), may permanently affect vine physiology and yield attributes, although some varieties may be more tolerant than others. Grapevines growing under severe heat stress experience a significant decline in productivity, due to stomatal and mesophyll limitations in photosynthesis as well as injures under other physiological processes (Fraga et al., 2013).

Berry weight, berry sugar concentration, berry anthocyanin concentration, and must total acidity, that were measured in the research, are the variables that have a direct influence on wine quality. According to the authors, berry weight is mainly influenced by the soil type, followed by the cultivar; berry sugar concentration depends mainly on the cultivar and the soil type, but also on the vintage. Total acidity and pH of the grape juice depend on the vintage and, to a less significant extent, on the cultivar and the soil type. Total acidity is mainly determined by malate, which is highly variable among vintages and cultivars, and less so by tart rate (van Leeuwen et al., 2004).

About the influence of temperature on fruit development (Figure 2), increasing temperatures generally has a beneficial influence on sugar accumulation, except above 32–35ºC. The upper limit may result from disruption of photosynthesis at these temperatures. Warm conditions can increase the amino acid content of developing fruit. Most of the change is expressed in the accumulation of proline, argentine, or other amino acid amides. Potassium accumulation usually increases with warmer temperatures (Jackson, 2008). Has also stated that high temperatures that can develop in sun-exposed fruit can lead to color loss in some varieties.

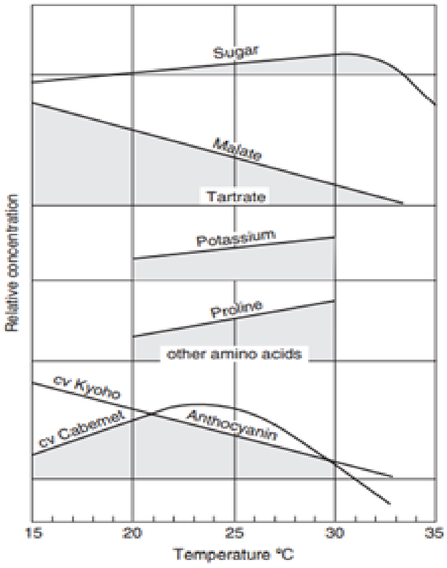

Figure2. *Summary of some of the temperature effects on the concentration of chemical compounds in grapes.*

Study of van Leeuwen et al. (2004) demonstrated a significant effect of vintage and soil type on berry anthocyanin concentration. This statement was also proved in the experiment carried out by Spayed et al. (2002), when a lower anthocyanin concentrations was found in the clusters exposed to elevated temperature either through degradation, inhibition of synthesis, or, more likely, both.

Annual precipitation and its seasonality are also critical factors influencing viticulture, as water stress can lead to a wide range of effects, yet largely dependent on the stage of development (Fraga et al., 2013).

The intensity of vine water deficit stress depends not only on climatic parameters but also on the water-holding capacity of the soil. In the study of van Leeuwen et al. (2004), the sandy soil parcel included a water table within reach of the roots, thereby even in a dry vintage, vines did not face water stress on this soil type. In contrast, the gravelly soil had a low water-holding capacity: water stress can be severe on this soil. Finally, the clayey soil was subject to early but moderate water deficits (Simonneau, 2014).

Authors claim the existence of strong relationship between improved grape quality and water deficit before veraison, when water deficit probably affects grape quality indirectly. It was observed, that early water deficit provokes early shoot growth cessation and reduces berry size. Under these conditions, berry sugar and anthocyanin concentrations are increased because of greater ripening speed. Total acidity is reduced, as berries contain less malic acid. Grape quality was high on the soils that induce water deficit, especially on clayey soils where water deficits occur early in the season but are moderate. Good vintages was demonstrated when vine water uptake became limiting early in the season. Soil influences vine development and fruit ripening through mineral supply. However, in their study, mineral nutrient uptake by the vine or the ability of the soil to provide those nutrients did not appear to have a significant impact on fruit quality (van Leeuwen et al., 2004).

Likewise, "mean daily minimum" (solid blue line) shows the average minimum temperature. Hot days and cold nights (dashed red and blue lines) show the average of the hottest day and coldest night of each month of the last 30 years (Meteoblue, 2016).

From the graph (Figure3) we can observe, that in the end of March-beginning of April that corresponds to the budburst, the first stage of vine growing season, the mean of daily temperature is in the rate of the optimum (≥10°C according to Carbonneau, 2007) for succesful beginning of the cycle. At the flowering phase, which corresponds to end of May-beginning of June, optimal temperature is 25°C. Graph shows us that temperature at this period corresponds to the optimum. It is also known that low rainfall is favourable at this stage and this accordance is observable from the graph. However, last stage of the flowering that is relative to the end of June, may be decelerated by early water stress. From the graph we can also observe that the hottest months are also the driest. The interaction of temperature with water stress is very strong in the sense that drought increases the depressive effect of the temperatures higher than optimum (Charbonneau, 2007).

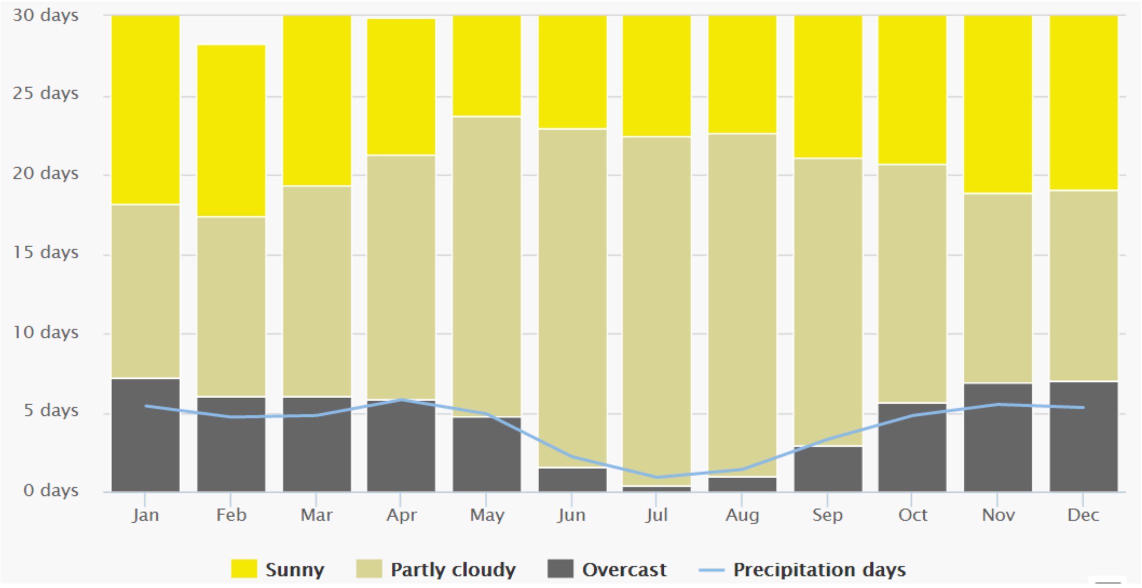

Figure3. *Cloudy, sunny and precipitation days (Meteoblue, 2016)*

The graph (Figure4) shows the monthly number of sunny, partly cloudy, overcast and precipitation days. Days with less than 20% cloud cover are considered as sunny, with 20-80% cloud cover as partly cloudy and with more than 80% as overcast (Meteoblue, 2016). As demonstrated, that there are more partly cloudy days during growing season.

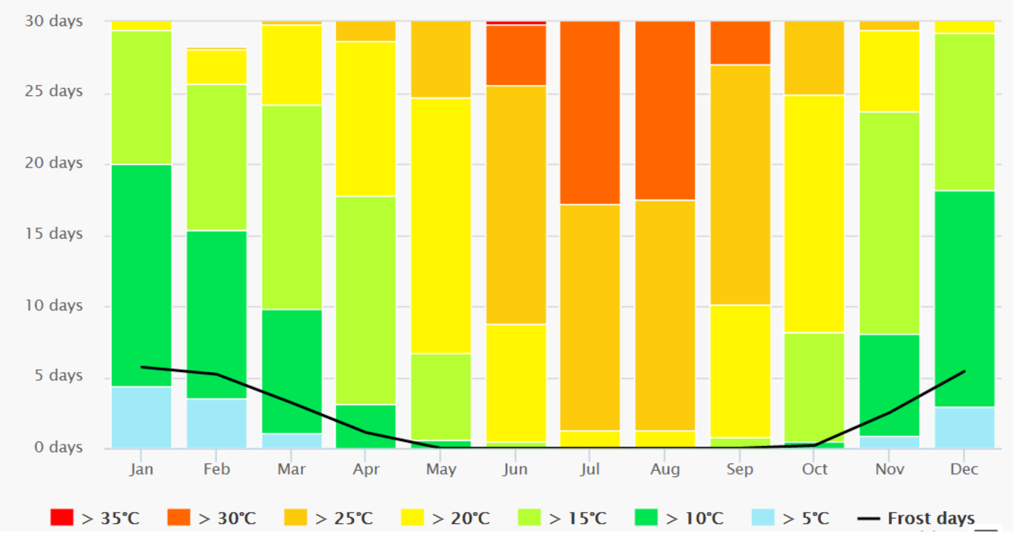

Figure4. *Maximum temperatures (Meteoblue, 2016)*

The graph (Figure 4) demonstrates temperature rates. It is evident, that already in June there are seventeen days with a temperature above 25°C. In July quantity of these days is not changed, but there are around two weeks when temperature is above 30°C, possibly reaching 35°C. The same situation is observable in August. These values are above optimal 25°C for this period. As it was previously noticed, temperature 35°C significantly reduces or completely inhibits formation of anthocyanins.

The precipitation diagram (Figure5) for Mediterranean region of Castellón (Spain) shows on how many days per month, certain precipitation amounts are reached (Meteoblue, 2016). According to this precipitation diagram, there averagely 316 dry days per year. It also never snows (black line on the bottom of the graph indicates this), so there are not too much water inputs in the vineyard. The “driest” months are June, July and August with 28, 30 and 29 dry days respectively.

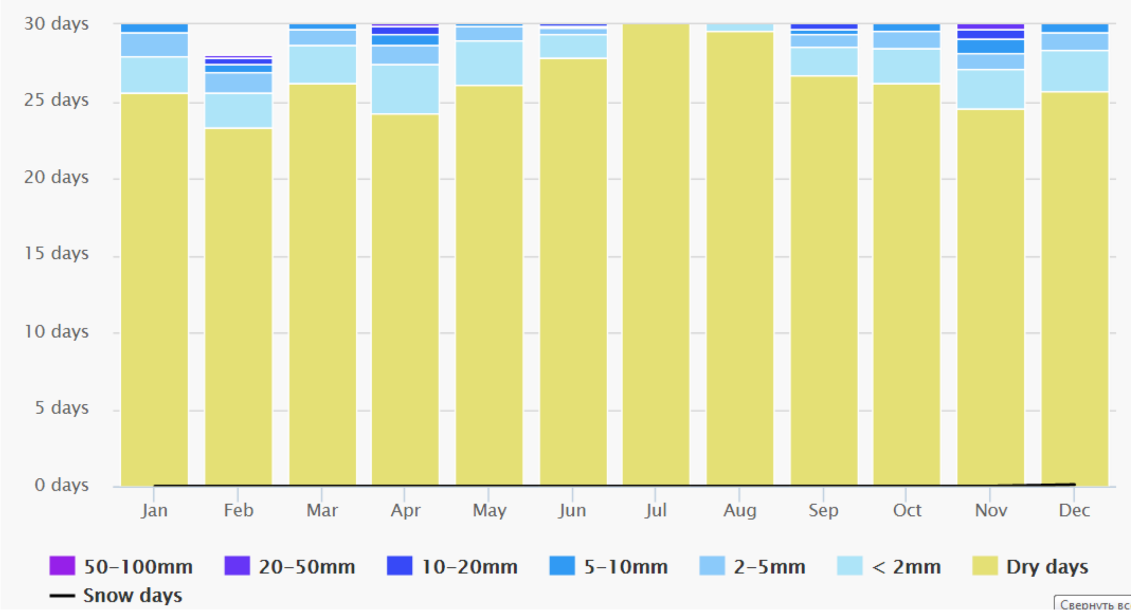

Figure5. *Precipitation amountsin Les Useres (Castellón, Spain) (Meteoblue, 2016)*

Adaptation and Mitigation Measures

In frames of The European Commission (2016), Climate Adaptation Platform (CLIMATE-ADAPT) the Spanish National Climate Change Adaptation Plan, was established(European Commission, 2016). This programme was adopted in October 2006 after endorsement by the Cabinet of Ministers. The text has been discussed within the main national coordination and participation bodies dealing with climate change issues: the Commission of Climate Change Policy Coordination, the National Climate Council and the Environment Sectoral Conference (Spanish Nation Climate Change Adaptation Plan, 2006)

From the Plan we know that global warming and the decrease of water resources (decrease of precipitation) will lead to the “mediterranization” of the northern regions and the “desertification” of the southern regions. Severe impacts are expected in arid and semi-arid areas (approximately 30% of the national territory), where water yields may decrease by 50%. Desertification is already a real problem and a threat for a great part of the Spanish territory. To traditional factors –fires, erosion and Stalinization- now should be added the effects of climate change. The main related effect will be the reduction of organic carbon content of Spanish soils, with negative consequences for their physical, chemical and biological properties (FAO Soils Portal, 2016).

Numerous studies have found that native soil organic matter (SOM) levels rapidly decline by up to 60% within a few years of clearing and cultivation. By (Lines-Kelly, 2004), this decline occurs because: Erosion removes SOM-rich topsoil, cultivation aerates and breaks down aggregates exposing previously protected SOM to microbial activity, cultivation dilutes SOM-rich topsoil with SOM-poor subsoil

Among the first actions mentioned in the Spanish National Climate Change Adaptation Plant here are: Identifying long term and minimal cost climate change adaptation strategies, specifically for fruit trees, olive trees and vineyards, soil-conservation farming practices.(Spanish Nation Climate Change Adaptation Plan, 2006), Fraga et al. (2013) gives examples of possible long- and short- terms adaptation to climate change measures in viticulture. These measures mostly imply changes in management practices. The spectrum of vineyard sites, climatic conditions, soil types and varieties across the world's grape growing areas is so large, that a general type of adaptive strategy is not possible (Schultz et al., 2010)

Awareness of harmful effect on the vine plant caused by hot and dry weather conditions, considering temperature-increasing projections, arise the questions: How to face climate change in vine growing and maintaining wines at high quality level.

The Most Important Factors to Take into Account

Problems of Desertification and Soil Impoverishment

Desertification has been recognized as one of the biggest problems facing the European Mediterranean countries (Geeson et al., 2002).

The United Nations Convention to Combat Desertification (UNCCD), the only internationally legally binding framework set up to address the problem of desertification, was signed in Paris in 1994 and entered into force in 1996. According to its glossary, "desertification" is a land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities.

By the same glossary, "land degradation" is a reduction or loss, in arid, semi-arid and dry sub-humid areas, of the biological or economic productivity and complexity of not- irrigated cropland, irrigated cropland, or range, pasture, forest and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns, such as: soil erosion caused by wind and/or water, deterioration of the physical, chemical and biological or economic properties of soil, long-term loss of natural vegetation(United Nations Convention to Combat Desertification, 2016).

UNCCD developed a Map of Deserts and Desertification Prone Areas in the World (Figure6). At this map, the entire south-eastern Spain (Almeria, Granada, Malaga, Murcia, Alicante, Valencia and Castellon) was ranked at a very high risk of desertification (Ministry of Agriculture, 2016).

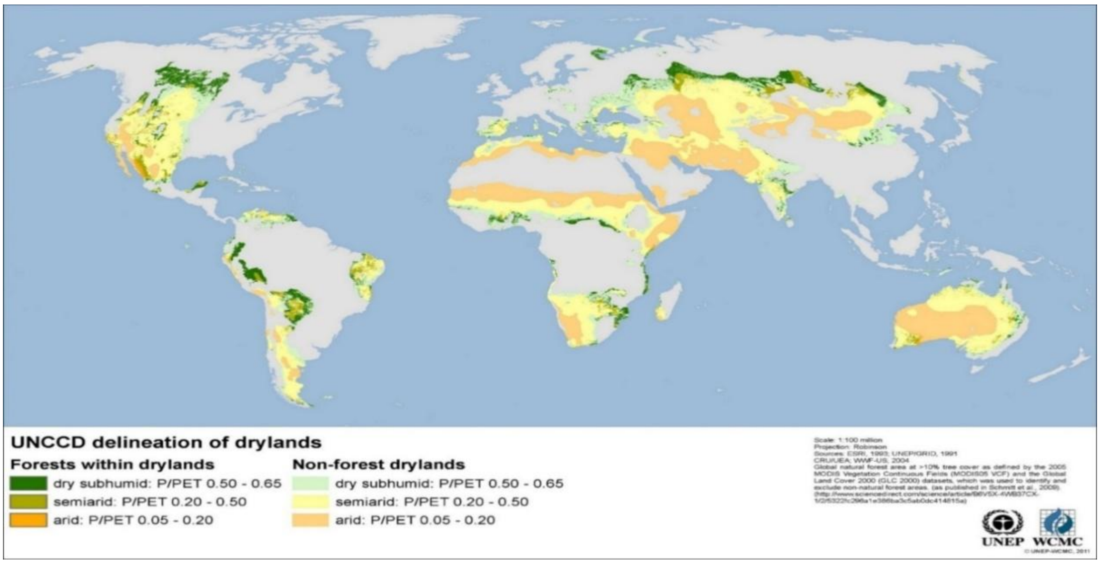

Figure6. *Map of deserts and desertification prone areas in the world (United Nations Convention to Combat Desertification, 2011)*

By the author of the "Mediterranean desertification" (Geeson et al., 2002) among the causes of desertification there are:

- Soil erosion, which is the most serious land degradation hazard in the Mediterranean uplands. It drastically reduces soil productivity, due to soil structural deterioration, nutrient wash out, and reduction of the water-holding capacity, limits vegetation growth and eventually leads to extensive desertification;
- Salinity and the effects of intensive cultivation have left the soils impoverished, and this is a first step towards desertification.

Author also states that in the semi-arid regions of the Mediterranean the conservation of the soil and water resource is of particular importance; soils are often poor and soil and water are both in short supply.

Soil impoverishment and desertification are on the highlight importance, both, ecologically and economically:

a) From the climate change prospection, stopping land degradation is a major step toward mitigating climate change, as soil is the second largest carbon storage after the ocean due to the carbon sequestration.

b) From the economical point of view, unemployment, rural impoverishment and land abandonment can be linked to land degradation.

(United Nations Convention to Combat Desertification, 201 and 2016; Geeson et al., 2002; Lines Kelly, 2004)

Soil in Viticulture

As it was mentioned in the foregoing statements (van Leeuwen et al., 2004) soil has less significant effect on grape and wine quality comparing to climate. However, it is crucial to understand soil indirect influences.

For this purpose, data from the book “Wine science. Principles and application” by (Jackson, 2008) was taken as a reference, since it consists precise and comprehensible statements concerning this subject.

Author reports that when discussing soil and its effects on grapevine growth, it is important to distinguish among the various physicochemical properties of soil (texture, aggregate structure, nutrient availability, organic content, effective depth, pH, drainage, and water availability).

The geologic origin of the parental material of the soil has little direct influence on grape quality. Fine wines are produced from grapes grown on soils derived from all three basic rock types–igneous (derived from molten magma, e.g., granite), sedimentary (originating from consolidated sediments, e.g., shale, chalk, and limestone), or metamorphic (arising from transformed sedimentary rock, e.g., slate, quartzite, and schist).

Soil texture refers to the size and proportion of its mineral component. Most agricultural soils are classified only by their relative contents of sand, silt, and clay. Heavy soils have a high proportion of clay, whereas light soils have a high proportion of sand. Because important features such as aeration, water availability and nutrient availability are markedly influenced by soil texture, this property significantly affects grapevine growth and fruit maturation (Profit, 2012 and 2014).

Structure often refers to the association of soil particles into complex aggregates. Aggregate formation starts with the binding of mineral (clay) and organic (humus) colloids by bivalent ions, water, microbial filamentous growths, and plant, microbial, and invertebrate mucilage´s. These agglomerates bind with particles of sand and silt, as well as organic residues, to form a variety of aggregates of differing size and stability. These are subsequently rearranged or modified by the burrowing action of the soil fauna, root growth, and frost action.

Soils high in aggregate structure are friable, well aerated, and easily penetrated by roots; have high water holding capacities; and are considered to be agriculturally superior.

Humus modulates pore size, facilitating the upward and lateral movement of water, increases water absorbency, and retains water at tensions that permit roots ready access to the water.

Water availability is affected by both, soil texture and structure. In arid regions, poor drainage significantly enhances salt build up in the root zone. This results from insufficient leaching of salts precipitated by the evaporation of water drawn up by capillary action.

Effective *soil depth* may decrease as a consequence of various viticulture techniques (Institute François de la Vigne et du vin, 2016). For example, cultivation promotes microbial metabolism and degradation of organic material. This weakens the crumb structure of the soil, leading to the release and downward movement of clay particles. In addition, Stalinization as a result of improper irrigation can disrupt aggregate structure, releasing clay particles. If clay particles flow downward, they tend to plug soil capillaries. Over time, this can result in the formation of a clay pan.

Soils vary in the accumulation of nutrients through their soil horizons. Soil depth can also influence water availability (Wolf, 2003).

Soil pH is one of the most well-known factors affecting mineral solubility and thereby availability. However, except where deficiency or toxicity is involved, there seems little justification for assuming that wine quality is dependent on either a specific soil pH or mineral composition.

Microporosity of the soil. Under zero tillage, the number of pores and pore area are significantly higher than under cultivation. Conventional tillage results in greater total porosity, but this consists primarily of a few, large, irregularly shaped cavities. Generally, root development is better under zero tillage. Under no-till conditions, most root development occurs in the upper portion of the soil, whereas conventional cultivation limits root growth to deeper portions of the soil. Under grass cover, root distribution is relatively uniform in the top one meter of the soil. Cultivated vineyards show lower levels of organic material. This may result from enhanced aeration and solar heating. Both stimulate the microbial mineralization of the soil's organic content.(Jackson, 2008)

Major Role of the Minimal Creatures

Soil is one of our most precious non-renewable resources and the soil biota represents a large portion of the earth's biodiversity. Soil accommodates innumerable species of bacteria, fungi, algae, protozoans, nematodes, spring tales, and other insect larvae, mites, and earthworms. Soil organisms (biota) carry out a wide range of ecosystem processes that are essential for crop production, soil resource quality and environmental health in both natural and managed agricultural soils (Lines-Kelly, 2004; Rochette and Hutchinson, 2005; Jackson, 2008).

Among the major beneficial effects of the soil fauna and flora is the generation of the aggregate structure of the soil. This is the intermediate end-result of their metabolic activities. Bacteria are especially active in releasing polysaccharides that bind the cells to soil particles and, consequently, soil particles to each other. Additional polysaccharides are secreted during the feeding activities of earthworms and other organisms. Fungi help to hold soil particles together with their long filamentous growths (Jackson, 2008).

Although algae and a few bacteria are net producers of organic material in soil, most of the nutrients on which the soil biota survives come from green plants. These are derived primarily from leaves and from the death of feeder roots. The initial decomposers are bacteria and fungi. These are, in turn, grazed by the fauna, notably protozoa, nematodes, and mites, or consumed along with soil during the feeding of earthworms or various insect larvae (Monroy, 2010). Their feeding releases inorganic nutrients bound in the microbial flora, which promotes an additional round of microbial decomposition on material defecated by the fauna. The grinding action of most of the fauna destroys the morphological and cellular structure of the plant remains. This especially helps to expose plant cell-wall constituents to further decomposition (Winchester, 1999).

If conditions are favourable (warm and moist), most organic material (with the exception of woody tissues) are rapidly mineralized. However, in cooler or drier conditions, mineralization is only partial. What remains tends to be a collection of highly complex, oxidized phenolic material. It forms the bulk of what is called humus. Humus, along with polysaccharides released by the soil fauna and flora, constitutes the organic component of the aggregate structure of the best agricultural soils. Another significant contribution of the soil micro biota, notably several genera of bacteria, is in the inter conversion of various forms of nitrogen. Ammonia, released during decomposition or added as fertilizer, is converted to nitrate by nitrifying bacteria (Delas, 2000). Other bacteria, under anaerobic conditions (in an oxygenic centres of soil aggregates), perform the reverse reaction (ammonification). In addition, anaerobic bacteria can release nitrogen gas from nitrate in a process termed denitrification. Under low-nitrogen conditions, other groups of bacteria fix nitrogen gas, releasing nitrates to the soil. Nitrogen fixation is particularly well known, relative to the action of rhizobia bacteria in the root nodules of legumes. It also occurs in free-living nitrogen fixing soil bacteria and cyano bacteria (Jackson, 2008).

Soil organisms can be grouped according to their size, morphological characteristics, function and tropic (food) preference (Table1). Soil microorganisms are also combined into groups based on their role in specific soil functions (functional groups), irrespective of their taxonomic classification, in order to relate their activities to soil processes (Lines-Kelly, 2004).

Table1. *Major groups of soil biota and their influence on soil processes in ecosystems, based on (Coleman, 2004)*

	Nutrient cycling	**Soil structure**
Microflora (bacteria, fungi, algae and actinomycetes)	Catabolise organic matter Mineralize and immobilize nutrients	Produce organic compounds that bind aggregates Hyphen entangle particles onto aggregates
Microfauna (protozoa, nematodes)	Regulate bacterial and fungal populations Alter nutrient turnover	May affect aggregate structure through interactions with microflora
Mesofauna (collembolan, mites)	Regulate fungal and micro-faunal populations Alter nutrient turnover Fragment plant residues	Produce fecal pellets Create biopores Promote humification
Macrofauna (earthworms, beetles, termites)	Fragment plant residues Stimulate microbial activity	Mix organic and mineral particles Redistribute organic matter and microorganisms Create biopores Promote humification Produce fecal pellets

Large numbers of the micro arthropod group (mainly mites and collembolans) are found in most types of soils. The soil mites, Acari, chelicerae arthropods related to the spiders, are the most abundant micro arthropods in many types of soils. Oribatidas are the most numerous of the micro arthropods (Larochelle, 1993).

Techniques Able to Increase Organic Matter Content Improve Water State and Stimulate Soil Life.

As stated by (Charbonneau, 2007), organic matter plays an important role in the soil functioning by improving its structure, increasing cation exchange capacity and biological activity and releasing nitrogen and phosphor throughout its mineralisation. Generally, input of organic matter improves soil fertility. In the viticulture soil, however, organic matter input should be moderate. For this reason, it is possible “to play” on the quality of organic matter. Organic matter poor in nitrogen (C/N elevated, more than 20), for example pruning waste, shredded branches, stalks, wood chips; will be slowly mineralised by lack of nitrogen. This organic matter will improve soil structure without additional inputs of nitrogen.

Among the benefits that mulches can contribute, there are:

- Improvement of vine establishment by promoting root development
- Enhancement of the yield (especially in low-rainfall regions)
- Reduction of irrigation water use in dry climates (Jackson, 2008)

Another positive input of organic matter can be cover cropping (Charbonneau, 2007).

In the next section we will take a closer look on these two techniques: mulching by Ramial Chipped Wood (RCW) and cover cropping.

Ramial Chipped Wood

The applications of the Ramial Chipped Wood (RCW) are advised in the soils, where water resources are limited, soil is compacted and poor in organic matter content. Shredded wood is richer in lignin and hemi cellulose than “classical” amendment and its potential in stable humus is very high.

Generally, RCW has a proportion Carbone/ Nitrogen (C/N) always higher (30 to 170) and low concentration in fertilizing elements. In short term, shredded wood does not contribute to available azote for the cultures, but contrary, mobilize mineral azote of the soil. Agronomical advantages essentially base on the biodegradation of the wood and augmentation of humus rates. (Nouet, 2009)

Effects of RCW utilization, more or less important according to the case, are next: improvement of soil structure, improvement of the water retention capacity, potential improvement in retention of fertilizing elements, decrease of nitrates leaching, especially in case of autumn delivery, limitation of soil erosion and compaction by agricultural tools, improvement of the soil porosity and infiltration capacity, stimulation of soil life: presence of fungi, bacteria, insects, earthworms, enrichment in fertilizing elements (phosphor, potassium, calcium, magnesium in particular), decrease of damages linked to pathogenic soil fungi, and risks of loss of yield by nitrogen deficiency (Ministry of Agriculture, 2012).

Microorganisms that play role in the degradation of the wood, consume azote contained in the soil in order to assure their metabolism. This utilization of azote can compete with the cultures. This phenomenon can be seen particularly after the first input and can take several weeks to months depending on the amount applied. Afterwards, the progressive degradation of fungi releases mineral azote that becomes available (Sanches, 2003).

One of the practices, suggested to avoid risks of decrease in production, is planting legumes (Ministry of Agriculture, Food and Forestry, France 2012).

Beans as a Cover Cropping

Generally, groundcovers can promote the development of a desirable microbial and invertebrate population in the soil and limit soil erosion.

Vegetation breaks the force of water droplets that can destroy soil-aggregate structure. Cover crop roots and their associated my corrhizal fungi improve soil structure by binding soil particles, thus limiting sheet erosion. Furthermore, as roots decay, water infiltration is improved and organic material is added to the soil. This is especially so for legumes which can incorporate organic nitrogen into the soil. Poorly mobile nutrients, such as potassium, are trans located down into the soil by the roots, as well as by the burrowing action of soil invertebrates. In addition to limiting soil erosion, cover crops can improve water conservation by reducing water runoff. Finally, cover crops facilitate machinery access to vineyards when the soil is wet, as well as reducing the incidence of some pests. In arid regions, the ground vegetation may restrict dust production, and thus assist minimizing mite damage.

Nonetheless, cover crops may equally be potential carriers of grapevine pest and disease-causing agents: legumes can be hosts of light brown apple moths.

Because cover crops usually suppress root growth near the soil surface (Figure 6), the applicability of cover crop use often depends on soil depth, water availability, and desired vine vigour(Jackson, 2008).

The use of cover cropping is currently increasing in vineyards but its development remains hampered in Mediterranean regions because of the possibility of severe competition for resources. However, recent studies (Celetteet al., 2008) on intercropping in vineyards have shown that in some situations, water stress may not be greater than that prevailing in bare soil vineyards.

The grapevine root system is plastic and highly sensitive to the soil water content and temperature conditions. Its distribution in different soil compartments changes with the introduction of cover cropping. Because of the time shift between the two crop cycles, the cover crop takes precedence in terms of water uptake from the surface soil compartment beneath the inter-row. As a result, the grapevine root system tends to be concentrated under the row where cover crop root density is low (compensatory growth). The grapevine can take up water from all soil compartments and at deeper soil layers than a cover crop. Cover crop improves winter replenishment of the water profile. This is related to a reduction in runoff and the resulting improvement in water infiltration. However, it cannot totally replenish the soil profile during winter (Celette et al., 2008).

Beans as cover cropping. Nitrogen fixation is the process that changes nitrogen gas (N_2) to the useful ammonia (NH_3). This process is produced in nature only by bacteria. Legume nitrogen fixation starts with the formation of a nodule that the plants naturally does. At that point, a common soil bacterium, *Rhizobium*, invades the root and multiplies within it, hence fixing nitrogen and turning it into the useful form. A soil could be rich in N_2 but it is unfortunately not directly accessible by plants (Figure7).

There are many legumes that can be used, some are good fixers, others not as good. Commonly used legumes are: alfalfa, clover, beans, peanuts, soybeans, cowpeas, soybeans, and fava beans. An important factor should be taken into consideration - any stress that reduces plant activity will reduce nitrogen fixation. Factors like temperature and water may not be under the direct control of the farmer or maybe too costly to maneuver, but nutrition stress can be corrected with fertilizers, which are easily accessible.

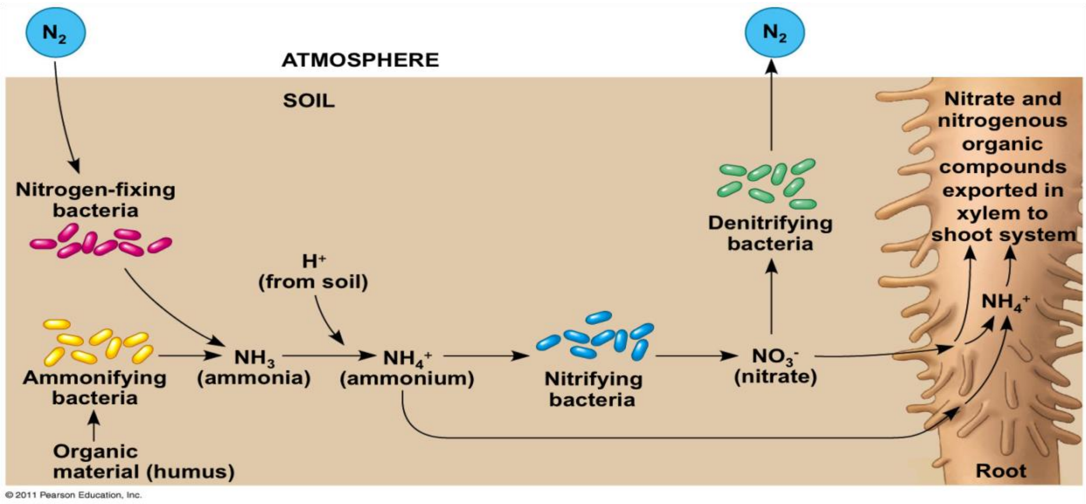

Figure7. *The process of nitrogen fixation in the soil (Google images)*

However, almost all of the nitrogen fixed goes directly into the plant and not the soil. Little amounts could leak their way into the soil for a neighboring non-legume plant, such as a vine. Nonetheless, nitrogen eventually returns to the soil when parts or the entire legume die and decompose. It is hence important to consider human intervention if needed to increase the amounts of nitrogen in the soil when in the most necessary moment (Lindemann and Glover, 2003 and 2008).

CONCLUSIONS

The conclusions of the study stated that techniques as RCW and cover cropping are able to activate soil fauna, which improves soil structure and contributes into increase of the soil organic matter. Comparing to the cultivated soil, enhanced soils where techniques were applied, positively affect the water state of the vine plant and decreases its stress under the hot Mediterranean climate.

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