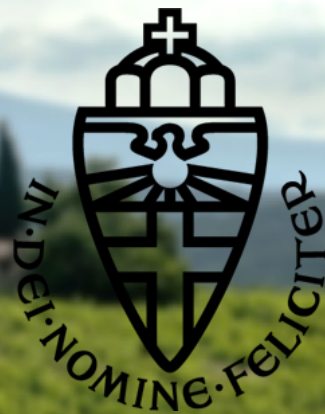


# VINEYARDS ON THE RISE

THE SHIFT OF VINEYARDS INTO HIGHER ALTITUDES, AND  
THE SYSTEM'S RESILIENCE



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DATE: 20-6-2024

WORD COUNT: 21674

## ABSTRACT/SUMMARY

This study explores the impact of shifting viticulture into higher altitudes on the resilience of the agro-ecosystem, by focusing on three chosen disturbances that come with mountainous viticulture; irrigation, clearance of nature, and land alteration through terracing. The effects (both positive and negative) that come with these human-induced disturbances are explored based on previous scientific literature findings. Ill-managed irrigation and the clearance of nature especially bring along more negative effects to the system. Consequences like biodiversity loss, erosion and landslides all have the potential to be just as harmful to vineyards as to the natural environment. Terracing however, if well-maintained, have the possibility to actually bring positive interactions with the surrounding environment, by creating space for nature where it is previously not found. These results lead to a case study in the Aosta Valley, where an interview with a viticulturist in challenging conditions is conducted to explore their opinions and insights about resilience in this specific environment. The Aosta Valley contains many vineyards, but lies at an altitude of around a 1000 m asl, thus is an interesting environment to conduct this detailed case study. The interview sheds light on both their methods in dealing with the explored risks and dangers of the chosen disturbances' effects, and the viticulturists' view on how to mitigate and further help this agricultural sector in the future. The viticulturist mentions strategies like drip irrigation (dealing with the high evaporation rates in the valley and efforts to save water) and the Pergola systems that helps them be productive in this climate. But while mountainous regions come with challenges, it's also found that there are opportunities for innovation and adaptation, with potential implications for agriculture in lower-altitude regions. The more social aspects mentioned, like cooperative farming practices, aids smaller farmers in gaining support with organizations like the CAP (Common Agricultural Policy). Even though they still face barriers to accessing support in becoming more sustainable, this is one of their solutions to the problem. It's highlighted how dialogue and increasing interaction between farmers and the organizations trying to support them is important to viticulturists.

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# 1. INTRODUCTION

## 1.1 PROBLEM STATEMENT

Global climate change is proceeding at a high rate, according to the Intergovernmental Panel on Climate Change (IPCC, 2014), and is therefore continuing to put pressure on agricultural practices. These pressures can range from changes in weather precipitation (such as extreme droughts; potentially causing a loss of crops, or extreme rainfall; potentially causing flooding and land erosion), higher temperatures (which could increase the number of pests), or shifts/decreased windows of optimal growing seasons (Zwane et al., 2016). This could all result in a risk/instability in our food security worldwide. These threats also extend to viticulture, the cultivation of grapevines, mostly due to extremer weather (e.g. droughts) and the overall increase in temperature (Vigl et al., 2018).

Grapevine cultivation is highly dependable on temperature, usually ranging in ideals from 12°C to 22°C (Arias et al., 2022). This means that, were temperatures to increase due to climate change, vineyards will need to adapt. One of these potential adaptations is their shift into different (cooler) locations. At the same time, this creates an opportunity to extend viticulture in the places where it was previously too cold.

The 'wine belt' (figure 1) (being the location with optimal conditions for vineyards) lies between 40° and 50° on the northern hemisphere, and 30° and 40° in the southern hemisphere. There are options to shift towards more northern (above the equator) or southern (below the equator) hemispheres, thus, a move towards the poles to acquire these cooler temperatures in a changing climate (Ashenfelter et al., 2014).

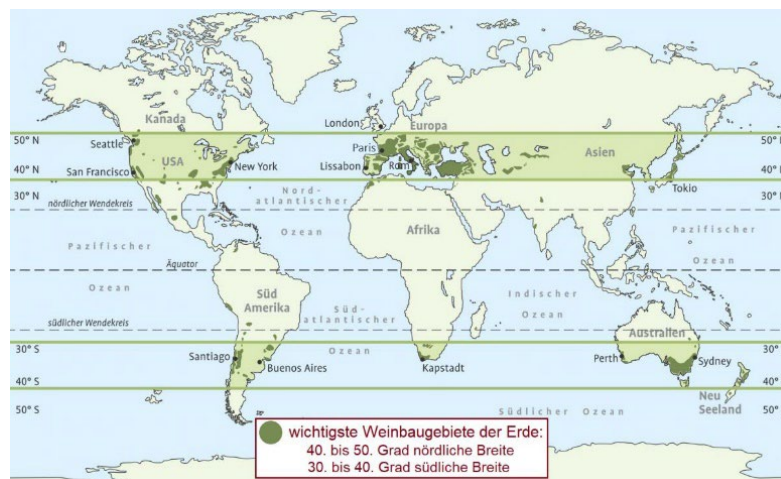


Figure 1, the wine belt (Müller et al., 2019)

However, both these belts also contain several mountainous areas, such as the Alps in Europe, or the Andes in South America. Mountainous areas are often seen as an environment with more agricultural challenges and handicaps than lowlands, and therefore unattractive to farmers (Delay et al., 2015). However, with the increasing temperatures because of climate change, this geographical diversity also creates options for viticulturists to explore higher altitude locations. And while not all farmers can extend at will, there is the possibility of an alternative against the pressures of climate change, or even just the possibility to expand. Within these mountainous areas, there is the potential of creating a refuge against the impacts of an increasing temperature. Van Leeuwen et al. (2019, p. 12) states

that “in mountainous areas, temperature decreases by 0.65 °C per 100 m of elevation”, concluding this increase in altitude can have definite effects on temperature. It is expected to get progressively warmer under future climate conditions, allowing for a wider selection of vineyard locations at these heights (Arias et al., 2022).

A good example of one of these Alpine regions heavy with viticulture is Switzerland. While Switzerland ranks only 132nd in terms of land area, its land area of vineyards ranks in 20th place worldwide. Comparing land area to vineyard area of a country, Switzerland ranks 10th. Especially places like Valais, lying in the heart of the Alps, contains about one third of Switzerland’s viticulture. Additionally, Europe’s highest vineyards are located in Valais, at 1150 m asl (Swiss Wine Promotion, n.d.). Italy also has one of these regions, such as Valle d’Aosta, with vineyards around 1200 m asl. Viticulture regions like these make for a good starting point in constructing ideas about the potential effects of viticulture shifting towards higher elevations in the Alps.

This upwards shift of viticulture into higher regions of mountainous areas could cause ecological consequences for those ecosystems (like the alteration of land, the loss of biodiversity, etc.), but these aspects remain relatively unexplored. It is also not widely researched how viticulturists in areas similar like the Alps deal with these disturbances, and what their opinions are on sustainable farming. This necessitates an examination of the potential disturbances that viticulture expansion could bring upon ecosystems. What is the viticulturists’ stance in terms of sustainability in this challenging environment? And does the system have the potential to be resilient? This will be done through literature reviews for the known disturbances vineyards could bring to an environment, and interviews with farmers to determine their view on mitigating these negative effects.

## 1.2 SOCIETAL RELEVANCE

This research can contribute to society by understanding the effect of ascending vineyards on the resilience of agro-ecosystems in these higher altitudes. The research will look for potential warning signs for viticulturists, since negative disturbances to the environment can harm agro-ecosystem in turn. The goal is to create a bridge to possible further research on how to manage these changes by listening to the opinion of farmers on this, and think of solutions for possible problems. It can influence policy development about how the response (resilience) to the three chosen disturbances used to measure the viticulture’s impact on upland ecosystems influences viticulture.

The research can bring in perspective how resilient the agro-ecosystem in mountainous areas will be in the event of vineyard production moving upwards in the Alps. This resilience can mean the environment changes, or is able to bounce back to a balanced system. A case study on the Aosta Valley can give more specific insights in this area, and for viticulturists that operate here. This information is important to the European agricultural economy, as nature directly and indirectly interacts with surrounding agriculture. This knowledge could possibly even be extended to other regions with similar environments.

Since the research gives insight to agricultural practices in mountainous regions, it can be important information for its stakeholders, including farmers and industry players, and influence future decisions regarding the shift in locations of viticulture. Especially, policy is explored. This is, for example, the case with the CAP program. A program launched by the European Union that aims to support farmers in many different categories, as well as (in the context of this study) being sustainable. Interaction with a viticulturist in the Aosta Valley leads to the belief that there are

certain changes that could be made in these programs to better aid farmers. Thus, policy makers could learn what improvements could be made in the results of this study.

### 1.3 SCIENTIFIC RELEVANCE

While much research focuses on the shift of vineyards into these northern or more southern poles in a latitudinal manner, there has been less focus on the shifts towards higher altitudes (e.g. the production of vineyards higher up in mountains) (Vigl et al., 2018). This research aims to contribute to this lack of scholarly attention, by providing insight into the shift of vineyards into higher altitudes and its effect on the resilience of agro-ecosystems. This study draws upon ample research (field research, case studies and longitudinal research) that focuses on ecosystems in mountainous areas in order to develop the connection between the upwards shift of agriculture, and its implications from a resilience perspective (Kanianska, 2016). The interaction between expanding viticulture and climate change raises important questions like how the conditions differ at these heights. Because when looking at high altitude vineyards, compared to lower altitude vineyards, there are notable differences in the methods that can be applied to harvest or fertilize, or even differences in diseases because of the difference in climate. These conditions will be explored, as well as what impact they have on the resilience of the agro-ecosystem. What strategies do viticulturists possess to be more resilient/sustainable in these circumstances? Here, this research builds a promising connection between the resilience theory and wine agro-ecosystems to understand viticulture in changing altitudinal conditions. The aim of this research is therefore to offer a new perspective and connection between these different phenomena, through a case study done on the Aosta Valley in Italy.

### 1.4 RESEARCH AIM

The aim of this study is to understand how the shift of vineyard locations into higher altitudes in the Alps influences the agroecosystem, and what viticulturists' view is on mitigating them and being resilient in the future. This study will look into this question by focusing on specific *man-made disturbances* related to wine production, where 3 main factors/disturbances are chosen to focus on. These disturbances are the need for water/irrigation in higher altitudes, the alteration of the land (like through terracing methods), and the clearance of nature needed for agricultural fields. Applying the DPSIR framework and surrounding theory, these disturbances will then create certain *natural responses* by the surrounding ecosystems which could potentially be negative for the viticulturists' vineyards as well. It will be researched what we know about these potential effects, and what farmers think about the sustainability of the agro-ecosystem, eventually trying to make a conclusion on how resilient the agro-ecosystem in higher altitudes can be based on a case study in the Aosta Valley. This study will act as the question on whether or not there are warning signs/risks accompanied with mountain viticulture, and how capable farmers are on mitigating the disturbances, drawing on existing literature and interviews.

Thus, the study has implications for the application of resilience theory to understanding altitudinal shifts in agriculture due to climate change. Can we, based on the theory of resilience, determine if sustainable/resilient vineyard methods are possible in mountainous areas? And how can we attend to this resilience? The main question to answer is; How does the shift of viticulture into higher altitudes in the Alps affect its surroundings, and how do viticulturists' in the Aosta Valley go about these disturbances? This main research question will be answered through the sub questions; How

do the chosen disturbances affect ecosystems in higher altitudes? And what do viticulturists in the Aosta Valley think about mitigating the problems? Answering these questions offers a conclusion regarding fostering resilience in mountainous agro-ecosystems.

## 2. THEORETICAL FRAMEWORK

### 2.1 KEY CONCEPTS

A key concept in this study is ecosystems, specifically upland ecosystems, but it is important to specify on what the study will focus when regarding to an (high altitude) ecosystem. Tsujimoto et al. (2018, p. 50) defines an ecosystem as “a biological system composed of all the organisms found in a particular physical environment, interacting with it and each other”. In this study, biodiversity will be considered as an important aspect of an ecosystem, and analysed in these mountainous regions. Thus the reason that the definition needs to be researched to understand its importance in relation to ecosystems and their resilience. The UNEP (United Nations Environment Programme) defines biodiversity as the variety of life of earth. It includes all organisms and species, and its genetic variation among these. The reason ecosystems and biodiversity are specifically important to mention as definitions is because these differ greatly from the most common types of vineyards on lower altitudes (such as Tuscany in Italy or the Champagne region in France). As this study (explained further in chapter 3.1) goes into heights of 900 m asl to 1300 m asl, the montane zone is the existing ecosystem of this area. This ecosystem is different from the temperate climates such as the maritime zone in France, or the mediterranean zone in Spain (European Environment Agency, 2022). Along with these differences, come different scientific articles in resilience. There are studies done of the ecosystem resilience such as mediterranean forests, atlantic Europe, tundra ecosystems or tropical rainforests. All these regions differ in biodiversity rates as well, hence the importance of the understanding of the concept, seeing as biodiversity is in connection with the level of resilience of an ecosystem (Willis et al., 2018).

Sustainability may also be mentioned throughout this research, seeing as the resilience of the viticulture system largely connects with its sustainability. The definition provided by the United Nations Brundtland Commission is that sustainability “meets the needs of the present generation without compromising the ability of future generations to meet their own needs” (United Nations, n.d., para. 2.). Next to this are the Sustainable Development Goals, to which this paper will focus on goal number 15 ‘Life on Land’. A study by Purvis et al. (2018) defines three pillars surrounding the concept sustainability. This includes a social, economic and environmental pillar that all encompass the concept of sustainability, often visualised in the three circles visible below in figure 2. It is important to explore how this definition is interpreted in the study as this research will focus primarily on the pillar ‘environment’, and will not take economic or social sustainability into account when analysing vineyards’ shift to higher altitude and whether or not they are resilient against ecosystem’s responses to disturbances. Sustainability will also be looked at in the context of an

ecosystem, thus, how an ecosystem will be affected and has the ability to survive a change in land use over the long term.

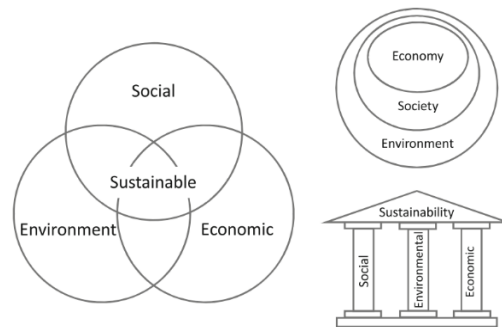


Figure 2, Typical representation of sustainability by three intersecting circles (Purvis et al. 2018)

To extend on this definition, it is useful to explore sustainable/resilient farming techniques in viticulture, as this is what the research eventually touches upon. One of the challenges in mountainous viticulture is the steepness of the landscape, and this factor has always been more burdensome than on flatter terrains. This challenge was not as significant when all viticulture existed of manual labour, but when mechanization truly overtook the agricultural process in production, mountain viticulture was not deemed as sustainable as on flat terrains (Strub & Loose, 2021). Ways to work around this are terraces, being a viable option in mountain regions because of their prevention in soil erosion (very present in steep slopes) and water retention. But even this method is not straightforward in its effectiveness, such as in a study done in the Priorat region in Spain. Here, newly made terraces divert from the traditional methods of building them. The modern terraces are made wider to allow mechanization, even though research suggests these terraces are less sustainable and should only hold one row of vines on the benches to achieve long-term sustainability. The modern terraces lack in resilience because they are not held up through stone walls or strengthened by natural vegetation. But these older, more narrow benches, while more sustainable, are reducing yield. The decreasing of mechanization options and increasing of costs make the old terraces not attractive to viticulturists. In the research area of the study, farmers also crush rocks found on the vineyards, believing it will increase water retention. But this has been found to not be the case, and the retention was actually lower. Additionally, this process increases infiltration of water, allowing more movement of water, and resulting in mass land movements. So, while these modern terraces are adapted to mechanization, their environmental impact and cost due to destruction caused by land movements should be considered (Ramos et al., 2007). When looking at sustainable ways of irrigation, a case study in Portugal found that the STICS method of irrigating is highly effective. In this technique, water is only applied when the system detects a certain level of water stress. The method has resulted in higher yields and effective water management (Fraga et al., 2018). Drip irrigation is another highly water efficient method of irrigation, compared to sprinkling or flooding. This is due to the precise amounts applied directly to the soil, leading to a decrease in evapotranspiration (Prichard, 2000). The last factor, clearance of nature, impacts the environment significantly. This is because vegetation on vineyard sites competes with the vines for water and nutrient availability, which usually leads to farmers tilling the vineyards. However, strategies advocating sustainability often recommend maintaining vegetation in inter-rows. This method has been found to increase biodiversity and ecosystem service by 20%, as well as the decrease in soil loss

coming with inter-row vegetation. However, without irrigation and careful managing of this technique, it can also decrease grape-yield (Winter et al., 2018).

One of the main concepts integrated in the study is resilience, but resilience has a very broad terminology ranging from social, technological and environmental definitions. This research will focus only on the agricultural and ecological meaning of the term. While there is also the term 'climate resilience', defined by the IPCC (2022) as the ability of systems to recover from climate change, this is not precisely what is being researched in this study, there will not be an analysis on what climate change does to a specific area, but rather how climate change drives the shift of vineyards and how this movement of agricultural land influences the resilience of an agro-ecosystem. Therefore the term 'agro-ecosystem resilience' is much more appropriate, this is the capacity of an agro-ecosystem to respond to a disturbance by resisting its damage and make a recovery (Folke et al., 2004). The theory accompanying this term is the Resilience Theory. The Resilience Theory provides a foundation for understanding how ecosystems respond to and recover from disturbances, this includes disturbances caused by climate change, but in this study the focus relies on man-made disturbances. This theory is useful to apply because it is a framework assessing the entire process of resilience. It determines disturbances, and then assess how the Alps could respond to these disturbances. This is important to understand if they are to be mitigated. It allows the researcher to assess if the ecosystem can absorb the changes, and its overall adaptive capacity. The Resilience Alliance (2014, para. 3) defines this term as "the ability to absorb disturbances, to be changed and then to re-organise and still have the same identity (retain the same basic structure and ways of functioning)". Within the context of vineyard relocation to higher altitudes, this theory creates the opportunity to explore the adaptive capacity of ecosystems in mountainous regions, especially when looking at the disturbances created in this (significantly) different environment than lower altitude vineyards, altering conditions such as temperature, vegetation types and water availability. But even though the environment might be altered, this doesn't necessarily mean it can't adapt. With re-organization and different strategies, there are perhaps opportunities here. This perspective is essential for identifying potential risks and challenges associated with the shift to higher altitudes.

Analysing the resilience of agro-ecosystems is not one-dimensional. Resilience of a system requires the examination of several environmental factors, this makes the framework complex, but also more precise. One of which is the scale and frequency of the disturbance. Studies have hypothesized that an ecosystem becomes less resilient the more disturbed it becomes, by looking at recovery rates after each disturbance. However, this does not always hold true over longer time intervals. Cole et al. (2014) found the opposite happening, where an ecosystem that was often disturbed recovered faster each time. This was assumed to be because the area became dominated with a species that had a very quick recovering ability.

Biodiversity is a factor that can greatly influence the resilience of an ecosystem. In one of the measures disturbances; 'clearance of nature', biodiversity is an important concept, since this might increase or decrease due to specific disturbances and responses within the ecosystem. Harper and Hawksworth (1994) argue that biodiversity does not necessarily increase with the number of species in an ecosystem, as species differentiate in their contribution to biodiversity. They put the example of an ecosystem with 10 different species, but all from the same genus or family. Therefore, it's important to view how different its inhabitants are from each other (like how Harper and Hawksworth (1994) mention an oak creates a lot more resources for other species than a herbaceous plant does). The widely cited 'insurance hypothesis' suggests that the more biodiverse an ecosystem

is, the more resilient it is, because a greater number of species will be available to replace functions that are lost. This holds for some ecosystems, but not on a continental scale. Most biodiverse ecosystems in Africa have the highest sensitivity to disturbances (Willis et al., 2018). These are all findings to be taken into consideration when analysing mountain regions in specific later on in the research.

When assessing the change in agricultural locations for viticulture, it's important to look into which regions will remain suitable for its production, which regions will be lost (due to climate change and increasing temperatures), and which regions will become suitable in the future. A map made by a study by Lee et al. (2013), visualizes these regions. The map below shows which areas will change over time (figure 3). The areas in red will decrease by 2050, the areas with current suitability are marked light and dark green, while areas not suitable currently but becoming suitable by mid-century are indicated in a light and dark blue.

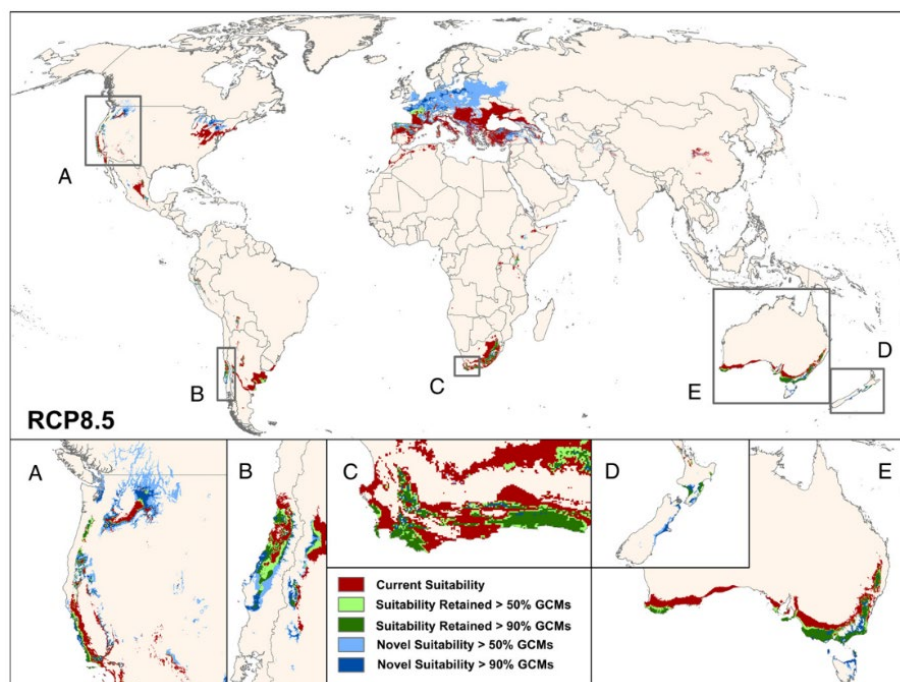


Figure 3, Global change in suitability for viticulture, showing Europe is in the fastest need scientific research on this topic, as the region for the decreasing, exploration and opportunity of vineyard locations is most extensive here. (Lee et al., 2013)

A model created by Chambers et al. (2019), defines several factors to resilience in ecosystems (figure 4). These are: environmental characteristics, which are stated in the research area chapter. As well as ecosystem attributes and processes that focus on risks/effects to biotic life forms. The kind of disturbance, which in this study are the three chosen disturbances: irrigation, clearance of nature and land transformation; all anthropogenic disturbances. Another factor is landscape composition, which is not detailedly investigated in this study, as there is a focus more on the potential risks disturbances can bring, instead of how the exact state of the ecosystem and what it undergoes. And finally, landscape configuration, which is dependent on viticulture characteristics, in the case of the Aosta Valley it is described in chapter 5.2. The personalized factors of each dimension of the model match the case study done in the Aosta Valley. Disturbances like irrigation are chosen because this method varies significantly from those in lower altitudes (relying on different water sources).

Terraces too come specifically with mountainous regions, as well as the different vegetation types present in the Alps resulting in different effects of clearing it.

Resilience theories offer lessons for agro-ecosystems, but must carefully engage with the way food production introduces a constant flow of disturbances. The agricultural resilience is therefore different in its approach. Meuwissen et al. (2019, p. 3) mention that; “Farming systems differ from

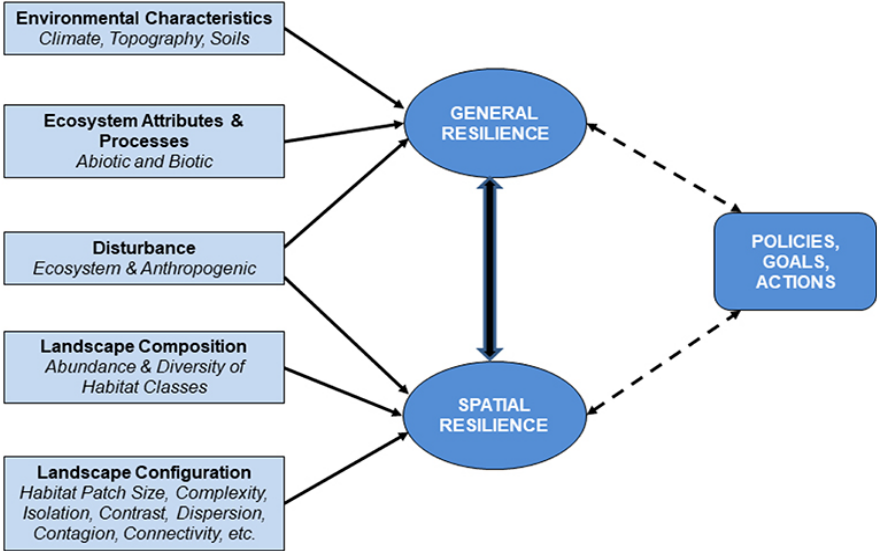


Figure 4, Resilience model ecosystems, used to assess the resilience of vineyard allocated mountain locations, and to draw from and combine with other models (Chambers et al., 2019)

ecological systems in their production purpose and their deliberate attempts to control their environment and to escape environmentally induced disruption.” The purpose of resilience is then to see if disruptive challenges (in this case 3 disturbances caused by viticulture itself) can be mitigated/adapted to through risk management. This management is done to ensure that the farming system returns to status quo and does not suffer from significant costs or losses due to a yield reduction. However, some disturbances may call for new strategies or techniques in farming. This is later studied to see how the chosen disturbances are handled. If the disturbances cannot be handled, the system may lead to a collapse, and be considered non-resilient (often leading to decreased yield, overall sustainability and weakness in the system). These implications provoke Meuwissen and colleagues to develop a framework for applying resilience theory to agriculture with a focus on the values embedded in human landscape management oriented around production (figure 5). This framework highlights three important dynamics of resilience: robustness, adaptability and transformability, which are actually based on previous research about ecosystem services.

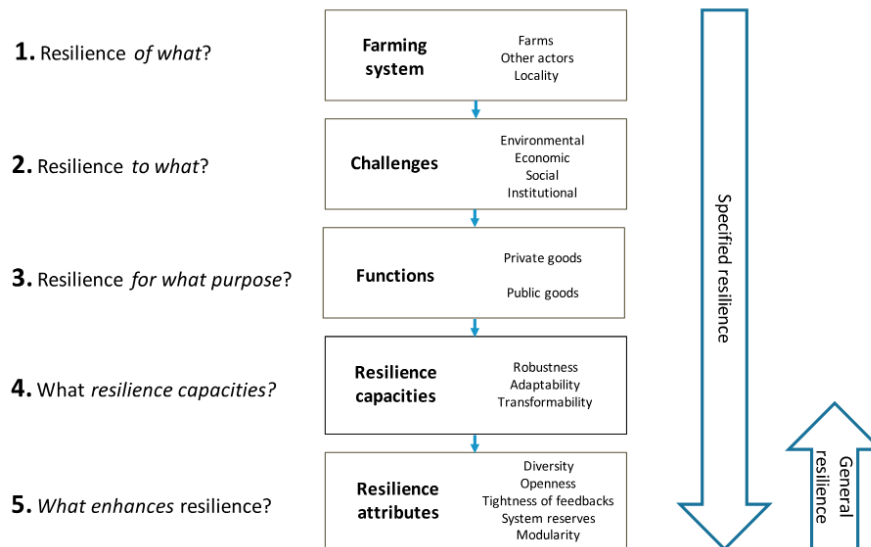


Figure 5, Framework to analyse resilience in farming systems, its differences from the ecosystem resilience model notable (Meuwissen et al., 2019)

The first step is ‘the resilience of what?’, which is in this case viticulture in high mountain altitudes in the Alps. There is a more detailed description and case study of the Aosta Valley in Italy in chapter 5. The second step ‘the resilience to what?’ concerns the chosen disturbances in this study, which, interestingly, are disturbances caused by viticulture itself. It could be categorized under ‘environmental’, following the framework provided by Meuwissen et al. (2019). Since the chosen disturbances affect the environment first and foremost, and is less about economy or institutional matters. Environmental disturbances lead to effects to the natural surrounding ecosystems, such as biotic life and abiotic elements in said environment. Disturbances that could have effect on institutional dimensions could be matters such as the changing of a policy or law concerning viticulture practices. Or in the case of effects on economy, it could be a new invention or improvement in mechanization that revolutionises the process of viticulture, creating lower costs of production and changing the market price. Whether the chosen disturbances only have temporary effects, or permanent damage, depends on the system’s resilience. Temporary effects usually imply a system can be resilient against the disturbance, because it is able to bounce back from it, making it only a temporary problem. Permanent damage, however, could refer to a system’s inability to be resilient against the disturbance, leaving a disturbance to actually change processes or characteristics of the system.

Step three is ‘the resilience to what purpose?’, this factor relies on more specific boundaries, since this choice is mostly up to the viticulturists themselves. The purpose of this study is also to listen to the farmer’s voices on their views on resilience, this means it could lead to trade-offs in a system. Meuwissen et al. (2019, p. 4) explain it as; “Private goods include the production of food and other bio-based resources but also ensuring a reasonable livelihood for people involved in farming. Public goods include maintaining natural resources in good condition, animal welfare and ensuring that rural areas are attractive places for residence and tourism.” In this study, it is both possible to mitigate the disturbances due to implications it could bring on production itself, or because the farmer finds it important to maintain surrounding ecosystems or tourism. The first purpose, private goods, is valid in viticulture (and the chosen disturbances of this study) because disturbances such as

clearance of nature, have been proven to result in soil erosion and even landslides. To protect the production of food and ensuring a good livelihood for farmers, it is in their interest to become resilient. A resilient irrigation system also falls into this category, where methods like drip-irrigation can aid in preserving scarce water resources. This caution in water availability makes the system resilient against droughts. Public goods are just as viable to aim to be resilient for as well. The ensuring of a region being attractive to tourism could generate income to viticulturists, just as making the place attractive to residences being build creates more opportunities for labour forces. Thus, the view on the exact purpose of the resilience depends on the farmer.

The fourth step ‘what resilience capacities?’, this is about the robustness (the system’s capacity to endure stresses and unexpected shocks), adaptability (the capacity to change without significant losses to the system), and transformability (a larger, more notable change of the entire farming structure, often after a collapse).

The last step ‘what enhances resilience’ is seeing what viticulture methods could decrease the negative effects of certain disturbances. This could be found out through previous scientific research, or conversations with viticulturists that deal with these specific sets of disturbances on their vineyards.

An existing model to understand the outline of this study and why preserving agro-ecosystem resilience is important is the DPSIR framework (figure 6). This framework exists of Driving forces (viticulture), Pressures (land alteration, clearance of nature, and irrigation needs for water) which can also be seen as the disturbances, State (the current state of the environment), Impacts, and Responses (what these impacts mean for viticulture) (Almusaed, 2016). The DPSIR framework suggests for the need to assess the disturbances, as they may have impacts and responses in a certain environment.

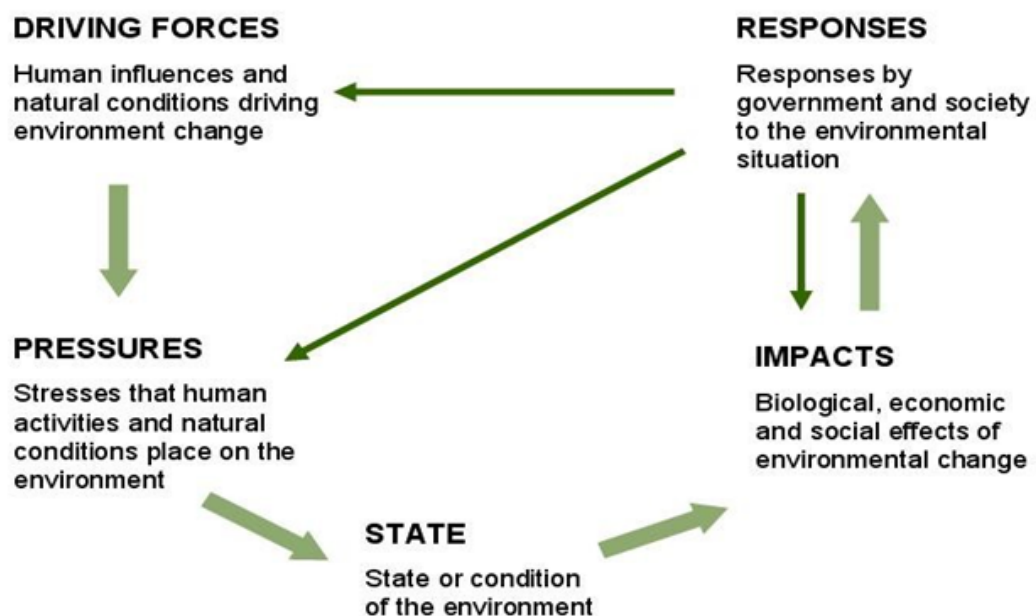


Figure 6, DPSIR framework (Darkoh & Mbaiwa, 2014)

## 2.2 RESEARCH MODEL

The first, more simple research model developed for this study is visible in figure 7. To assess the resilience of upland agro-ecosystems, there is a focus on three specific disturbances that could be caused by the upwards shift of viticulture. These disturbances are irrigation needs for water accessibility, clearance of nature to make space for the agricultural field, and the alteration of land/soil through for example terracing. This is done to make for a more qualitative focus, and narrow down the field of study. This part, chapter 4, will explore the effects of these disturbances on the environment. This is followed by an investigation on how farmers think to mitigate these disturbances in chapter 5, specifically in the Aosta Valley. In the end there is an assessment of the resilience of the system, and what conclusions could be drawn from the previous chapters' findings. This model provides an outline for how the study will be organized/put in order of its chapters, showing the basic goal of the research and what topics and factors will be considered to do the research.

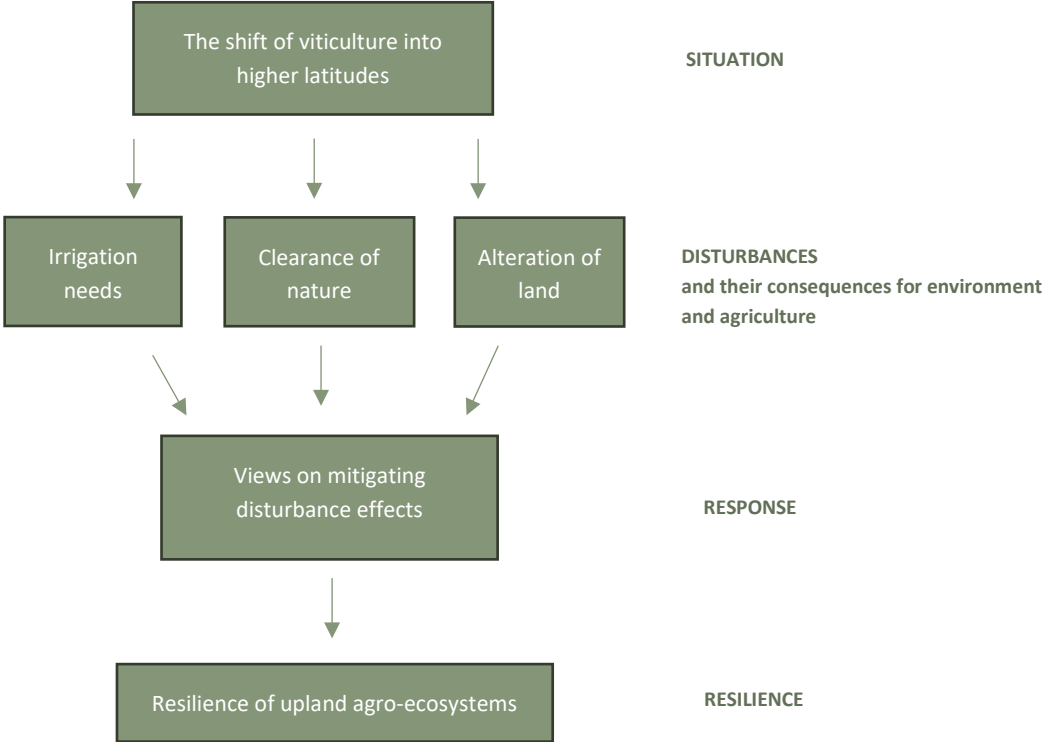


Figure 7, Research model, providing an overview of the build up of the study

These specific disturbances have been chosen because they each represent a unique set of challenges to mountain environments in viticulture that are important to the dynamics of agro-ecosystems, how will be explained further below. When we look at viticulture in a higher altitude, it forces us to look into these changes, such as how sustainability or resilience can work out in these more unique and challenging vineyard locations.

The disturbance 'alteration of the land', such as terracing, is known to happen in viticulture in higher altitudes. In Northern Italian Regions, slopes greater than 30% are altered to create terraces or embankments, to plant the vines (Corinto et al., 2019). This study states that viticulture landscapes designed around hilltops, are fragmented into small pieces of land. This imposes that using traditional techniques are often necessary, instead of motorization of farming. Only when terraces

are wide enough, is some mechanization possible. The method of terracing alters the land greatly, practically creating a new landscape. This feature is unique to high altitude viticulture, thus chosen as a significant disturbance that could have effects on the system's resilience.

For vines to be planted, removal of native vegetation is often necessary. Creating this space at the expense of nature can have consequences for its resilience. It is found that on steep hillslopes (24–32°, which converts to about 15%, even less steep than the minimum for terracing) there is already evidence of impacts on soil runoff and erosion (McDonald et al., 2002). These concerns are especially present in steep environments, such as the Alps. Not to mention that the flora and fauna of the Alps is quite different from those in valley regions. Where mountains are often seen as recreational opportunities, such as hiking, rock climbing or tourism, which all have to do with the natural look of the Alps, this shift in viticulture could create a new lens through which we see the Alps. This creates a need to look into this clearing of nature in a 'new' environment. Additionally, both the creation of terraces and clearance of nature, results in the fragmentation of ecosystems, which is the divide of large habitats into smaller and isolated patches. Studies prove the creation of agricultural lands and the extension of them causes habitat fragmentation. This process has the possibility to increase species extinction in an ecosystem (Grashof-Bokdam, 1997). Other impacts of clearance of nature can include a change in biodiversity. This is found by a study by Mattila et al. (2011), which also provides a model on land use change and its impact on the environment. In this model it is suggested agricultural processes cause land transformation, which in turn causes habitat loss and fragmentation, which then alters an environment's biodiversity. The study by Meuwissen et al. (2019) mention habitat loss as a significant disturbance that can have effect on the resilience of agriculture. Erosion is mentioned as well (which can be a consequence of the clearance of nature) as a 'long term-stress' on agricultural resilience. This disturbance of the clearing of natural vegetation is therefore considered important to viticulture and ecosystems alike, and reflected in the model developed for this study.

Irrigation is often necessary for agriculture; this can change the hydrological cycle of an ecosystem. This change can range from disturbances like water abstraction from the ground, or even total depletion of moist in certain areas of the land (Kanianska, 2016). This disturbance is included because irrigation in mountainous regions differs from irrigation in valleys. Not only in its need, but also in its technique and sustainability.

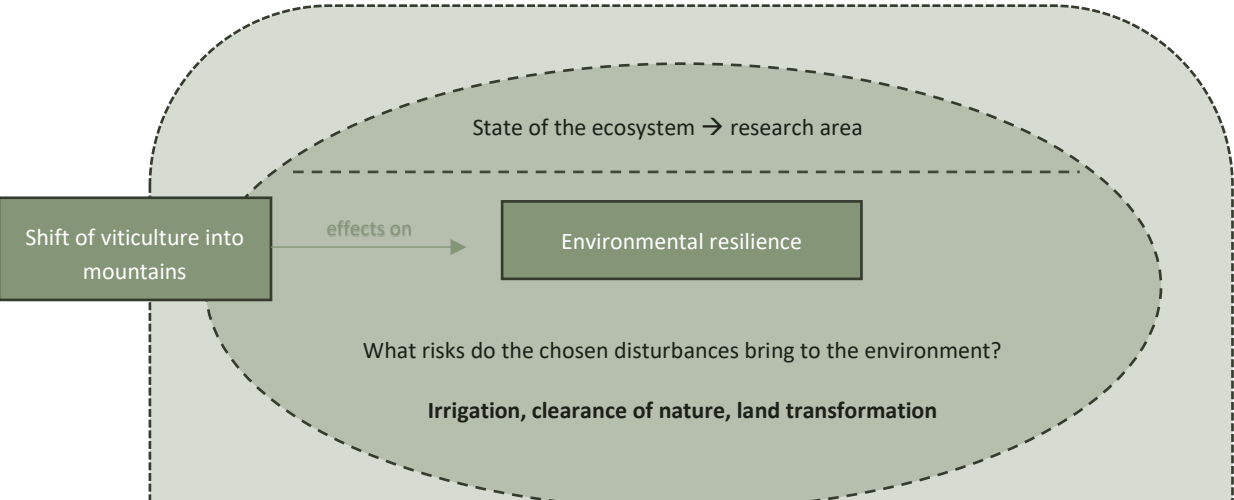
The third block is to see how farmers can mitigate these disturbances (either in the interest of protecting the environment, their own vineyard or both) and what their view is on sustainable methods of mountainous viticulture.

The fourth block in the research model is about the overall resilience of the agro-ecosystem, thus trying to draw a conclusion out of the effect and mitigation of disturbances, and the possibility to adapt to them. This is added because nature and agriculture often share close borders, and are let to intertwine and work together consciously or unconsciously by farmers. Meaning the connection between agriculture and nature is of importance when looking at viticulture systems in higher altitudes. Van Zanten et al. (2014, p. 309) state that: "In contrast to natural ecosystems, ecosystem service flows and values in agricultural landscapes are often a result of interactions between agricultural management and ecological structures." The concept ecosystem service refers to a service a healthy ecosystem (whether agricultural, natural or both) can provide for humans. When there is interaction between agriculture and nature (whether this is even the case, will be studied), it is desirable for humans to make sure this (mixed) ecosystem is a healthy one that can provide

services. Management of agriculture greatly influences its surroundings (the disturbances), such as the biodiversity of plants. The response this has can in turn affect agriculture and the ecosystem services, such as increased pest problems, due to the disappearance of certain predators when biodiversity is lost in an area (J. Megan Woltz, 2012).

An agro-ecosystem that has low resilience and is unable to bounce back from disturbances, might lower the biodiversity of agricultural surroundings, thus possibly attracting less helpful insects. While if an agro-ecosystem is resilient to disturbances, the implications of its response could be less devastating for viticulture systems in high altitudes. These disturbances have been chosen to see what a viticulturist think about making the disturbances, such as irrigation, resilient to the system.

Figure 8 represents a model created in combination of both earlier provided models (figure 4 and 5), in the totality of 'agro-ecosystem resilience' with the specific focuses of this study. The assumption/hypothesis is that the shift of viticulture in mountains has negative effects on the environmental resilience (or ecosystem resilience), which are specified in three disturbances; irrigation, clearance of nature and land transformation. The question the first chapter of this paper tries to answer is; do the chosen disturbances bring risks to ecosystems and agriculture? The above noted 'state of the ecosystem' is described in chapter 3.1, which helps understand the situation and environment that is being researched. The next section goes into how these risks are dealt with through the eyes of the viticulturist. And how capable farmers are of this mitigation, basically; how possible is it to make the agricultural environment resilient to these disturbances? The outcome of this then has effects on the resilience of agriculture itself. Because the capability of viticulturists to be resilient results in the system's overall resilience. Everything combined forms the agro-ecosystem resilience (the resilience of agriculture when looking at environmental-related disturbances). This is the more complex model for the study (while figure 6 provides merely an outline for the research setup).



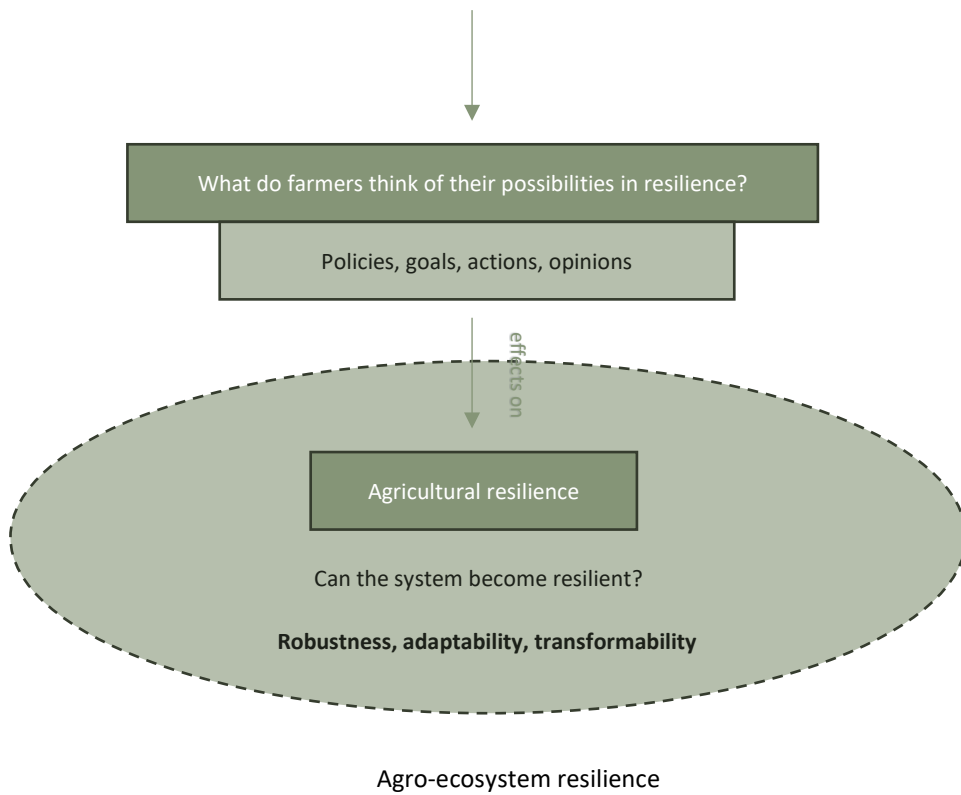


Figure 8, A model combining the most important factors (to this specific study) of ecosystem and agriculture resilience, to create a new agro-ecosystem resilience model that can be used to assess the overall resilience of the system, instead of only one of these dimensions of it

## 3. MATERIALS AND METHODS

### 3.1 RESEARCH AREA

The research area of this study are the European Alps. The choice to focus on this Alpine region is because different climates could have different forms of precipitation, ecosystems, environmental challenges, or biodiversity. Thus the specific disturbances chosen could have varied responses in different mountain regions. With this analysis, it will be assumed the higher regions were previously nature environments.

This research will mention 'higher altitudes'. The concept of what is considered 'high' due to climate change is context-specific and depends on the region, grape and local climate conditions. For this research, there will be a generalized area that is compared to the traditional vineyard locations. This would include areas that were previously deemed unfit for vine production. There have been several studies on these shifts, these will be analysed to conclude an average region for this study.

Data from Vigl et al. in 2018 states that the range for Alpan/Mediterranean climatic zone vineyards was between 200 and 1100 meters above sea level. And the current limit for wine production is often considered at this 1100 meters, but some extreme sites reach into 1300 meters. In this study, there is a figure provided that records the locations (in an altitudinal matter) for vineyards over several years. As visible in figure 9, while there have always been vineyards above 850 meters asl, there is a significant increase in the amount of these vineyards.

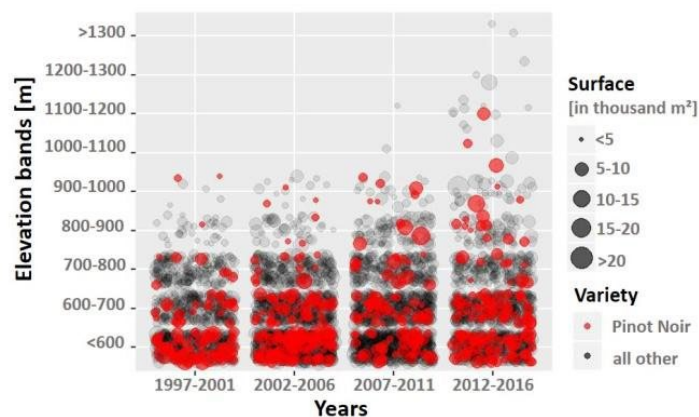


Figure 9, Altitudinal distribution and size of new vineyard plantings in the Alto Adige wine growing region (Vigl et al., 2018)

Another study by Ferretti (2020) over the region of South Tyrol, states that because of plateaus occurring in these mountain areas, even altitudes over 800 m asl are compatible with viticulture. It mentions historical vineyards in this region are located between 200 and 1300 m asl. Vineyards located at higher altitudes in Europe range around 1300 m asl, have been explored in 2013 and 2014 due to the possibility climate change and recent technology creates for exploration of these higher altitudes.

A study by Viana et al. (2017) states 'high altitude vineyards' are those considered 900 meters asl and above.

Van Leeuwen et al. (2019) writes that there need to be warm conditions to cultivate above 800 meters asl.

And a study by the project MOVING (MOUNTAIN Valorisation through INTERconnectedness and Green growth) in Italy reports “as a result of climate change, viticulture has begun to move to the highest slopes of the Trentino valleys, reaching 900 m” (Kleshcheva, 2020, p. 2).

To make an average of these several studies, this research will view vineyards at 800 meters asl and above as ‘high altitude vineyards’.

Agriculture in the Alps is (in our current climate) not possible above 1500-1600 m asl (Crook & Jones, 1999). Seeing as the highest vineyard in Europe currently is located around 1150 m asl, the maximum height of the research area will be around 1300 m asl (as it conducts a study on the increasing futuristic shift of vineyards). This altitudinal limit however is chosen because there should be a focus on one specific climatic life zone in the Alps, as to investigate the reaction of an ecosystem in that specific area. 900 m asl to 1300 m asl lies averagely in the montane zone of the European Alps.

When looking at the earlier determination of what ‘high altitude vineyards’ mean in this study, the range is considered from 900 m asl to 1300 m asl, which in the northern and central Alps averagely coincide with the ‘montane zone’, and the ‘super-mediterranean zone’ in the southern Alps (figure 10) (Mattavelli, 2016). According to a study done in the Rhone valley of the Valais in Switzerland, 900 m asl to 1300 m asl consists of the ‘lower montane zone’ more specifically (Moser et al., 2010). So to aim for more clear and precise answers on the research question, there will be a focus on this montane climatic zone of the Alps.

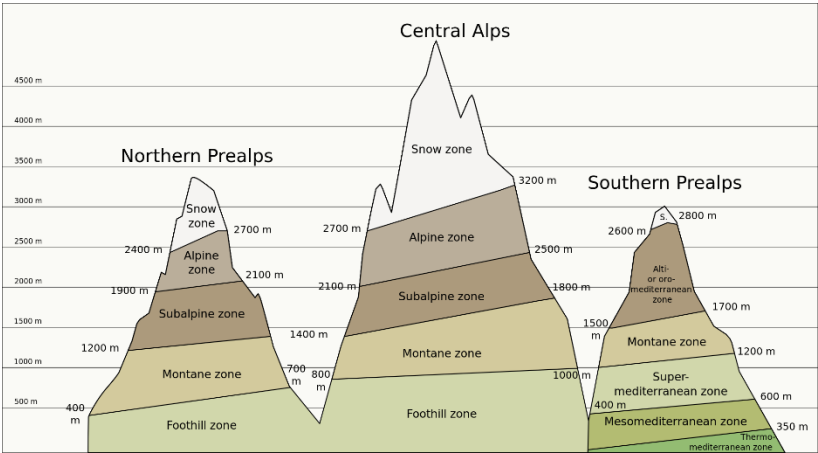


Figure 10, Climatic Zones per Altitude to assess climatic zone and its characteristics for the research area (Mattavelli, 2016)

To study the resilience of agro-ecosystems in this place, there needs to be an assessment of what kind of natural ecosystems reside in this climate.

The montane zone is both characterised by dense forests at the lower regions, and montane grass- and shrublands at higher ones. The forests in Europe’s montane zone are often identified as temperate coniferous forests mixed with temperate broadleaf forests. “Dominated by European beech, Norway spruce and silver fir” in elevations from 600 m asl to 1200 m asl (Sebald et al., 2019, p. 3). Colombaroli et al. (2012), that did a study on ecosystems in the Valais of Switzerland, also mention that regions between 500 m asl to 1000 m asl favour more drought-adapted broadleaved species, such as the downy oak, sessile oak, small-leaved linden, field maple and European red pine dominating the place. Between 800 m asl and 1400 m asl, being moister, contains mostly of the European spruce, along with the earlier mentioned European silver fir, European beech and Swiss pine, which become dominant up to the timberline. Furthermore, the Alps are home to a few wild

mammals, such as ibexes, foxes, marmots and several bird species that all contribute to the ecosystem's health. Pollinators and other insects are also found in abundance on biodiverse sites.

A more specific case study follows in chapter 5, which is the Aosta Valley in northern Italy, also located in the Alps. This location is chosen because of its height (vineyards ranging up to 1200 m asl), and interesting circumstances in terms of microclimates and challenges with viticulture. This region will be further described in chapter 5 with the help of a viticulturist that operates there.

The findings of this qualitative study may not be fully generalizable due to the focus on vineyards in the European Alps, not every vineyard over the globe. However, the insights will contribute to a deeper understanding of this specific context, especially the Aosta Valley.

If mitigations to disturbances are known in a specific region within the Alps (like a previous case study, or an in-depth interview with someone researching or managing a specific area in the European Alps) these do have the potential to be generalized to other areas in Europe mountainous areas, or areas with similar conditions like temperature and climate.

## 3.2 RESEARCH DESIGN

This study adopts a qualitative research approach to explore the shift of vineyard locations into higher altitudes in the Alps, the disturbances and farmers' possibilities to mitigate these effects. This will be done by choosing specific disturbances and assessing what we know about the responses, whereafter there is an assessment on the impact of said responses on viticulture in mountainous areas. The research model used for the study of the main research question is visible in figure 10. This model is drawn from previous research about both ecosystem resilience and agricultural resilience. The qualitative research approach is used because it is useful to describe disturbances and how they could influence the resilience of agro-ecosystems in words, instead of numbers and statistics. Corresponding, the second part of the study, which focuses more on opinions and experiences of the viticulturists in this situation, capturing the subtleties and depths of the human experiences and environmental interactions that quantitative methods might lack in. The farmers' strategies, adaptive capacities and insights are richer described in this method of data production. Qualitative data gives complex interactions present in this study the opportunity to actually be complex, while still understandable to the reader.

The primary methods used include in-depth interviews and extensive article research, which includes looking at data relevant to viticulture and reports on programs and other European Union institutions.

## 3.3 DATA COLLECTION

### 3.3.1 ARTICLE RESEARCH

Extensive article research will be the main method of collecting data for this study. There will be a review and analysis of existing literature on the topics of agro-ecosystem resilience, viticulture's shift into higher altitudes, the effects of disturbances, etc. There are multiple studies on these topics, but the purpose of this research is to connect these articles in a way that draws a result and conclusion to the main research question. There is also an opportunity to look at different regions or circumstances, and see if they could potentially be applied to this situation of the research area and topic.

The scope of the literature review includes academic journals, case studies, reports, policy documents and grey literature. The objective is to identify and explore what we know of the chosen disturbances and their effects, and connect these together. Another example of the literature review goal is to assess how the government or European Union provides support or measurements to agriculture in the Alps.

The search will primarily be done through Google Scholar, or other academic databases. Reports could be found through official governmental websites or similar. The use of a systematic review of data collection allows for a comprehensive literature review focused on topics specific to this study. This method includes clear criteria for selecting data.

Articles were selected to include the specific research area, such as the correct type of agriculture (viticulture), topics of resilience, and if possible the right climatic zone (montane zone) and altitude (800 m asl to 1300 m asl). Examples of search terms used for the broader explorations are: 'high altitude viticulture resilience', 'disturbances viticulture mountain zones', 'resilience montane zone alps'. And for more specific data: 'irrigation effects in high altitude', 'land clearance effects in the montane zone', 'policy on sustainability in mountainous viticulture'. Another factor to consider is the year of publication of scientific articles. While data such as definitions are more time-insensitive and can possibly be derived from older articles, data like climatic trends or sustainable inventions are definitely prone to being outdated. Therefore, the data that is eventually used is selected to be as recent as possible. With the limited options of doing field work however, sometimes it must be accepted data is from older years (considered to be before 2000). If this is the case, it must be mentioned in the discussion. From data such as policy reports, it is always aimed to find the latest and up to date publication. To decide whether an article is useful in the study, the abstract and introduction are first screened, whereafter (if approved) there is a full-text review for relevance and quality.

Furthermore, the findings from the literature review will be used to either confirm, deny or back up other findings from the interview results. Or to provide a comprehensive understanding of the situation when there is need of further investigation of a certain topic. Visual aids such as tables, charts and diagrams can be used to visualize information found on the study.

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### 3.3.2 IN-DEPTH INTERVIEW

To gather the opinion of farmers on the topics presented in this study, there will be qualitative in-depth interviews with viticulturists in the Aosta Valley that are knowledgeable in these topics, or experience them themselves. The purpose is to capture detailed perspectives from this viticulturist on how they deal with the chosen disturbances and their effects.

These interviews will be semi-structured, which allows for more flexibility to explore themes, and would allow the expert to potentially introduce themes that have not been previously thought of. Certain themes and questions will be prepared beforehand, about the three disturbances, and the viticulturists own opinions on the help they receive and their future vision on resilience/sustainability. The interview guide in the appendix is developed with key questions that cover the topic, and to be well prepared for the interview. The viticulturists will be contacted primarily through the email on their website, after which interviews could be conducted through online methods (given the distance of the interviewee and the interviewer) like Teams or Zoom. The interviews are expected to last around 45 minutes, but are free to end whenever both parties are done discussing the topic, or one party wants to end the interview. With given consent the interviews will be audio-recorded and transcribed for later analysis.

The criteria of participants mostly depends on location. The Aosta Valley has been chosen as the research area of the case study, which makes it the location for the viticulturists that are interviewed. The viticulturists have to be knowledgeable on the ways their vineyards are managed, and work in this high-altitude area with the additional challenges identified. If necessary, the transcripts can be coded using qualitative data analysis software like Atlas.ti.

The danger of these interviews is that the viticulturists on topics such as resilience and agro-ecosystems might have an opinion that reflects negatively towards the potential effect viticulture could have on mountainous ecosystem, or be defensive about the negative effects vineyards could have on the environment, and in turn viticulture itself. There will need to be a critical eye on whether or not the expert is biased. Alike, their declaration on sustainability, especially when not being anonymous, the viticulturists might aim to present themselves as sustainable as possible. Additionally, and as mentioned earlier, triangulation will be used to validate findings from the interview, by using articles to ensure the reliability of what the interviewee tells the interviewer.

The choice to use qualitative methods is useful when going into a specific context, environment or case. Also because the opinion of farmers about resilience, mitigation or affects of disturbances are not easily put into numbers, but better described through words. Qualitative research allows for in-depth and personal analysis, the cons are that it is more difficult to generalize.

This study is largely based off the view of viticulturists and previous theories and research, meaning the validity also needs to be based mostly on the materials and experts presented. But due to the many diverse sources used, mostly qualitative, there is less of a chance that there is invalidity, seeing as there are multiple insights given, multiple theories to check which works the best, and multiple experts to provide information.

The validity in interviews can be achieved by asking more open questions, as to not lead the interviewee towards a specific direction. As well, the right measurements need to be chosen to ensure validity. In this study the three chosen measurements for disturbance factors are based off previous scientific research, to ensure its validity.

The reliability of this study might depend on when it is repeated. If this topic is being researched again after a decade or even multiple, a lot of factors could have changed in the meantime. The research area and what is considered a 'high altitude' viticulture location might have significantly changed in the future, possibly due to climate change and its rising temperatures. What is possible, is to assess if the predictions and results of this study have come true, were this study to be repeated once more.

## 4. THE DISTURBANCES DUE TO VINEYARDS

The first sub question of this study will answer what we know about the chosen disturbances; irrigation needs, clearance of nature and the alteration of land through methods like terracing. Using the DPSIR framework, disturbances are indicated to introduce effects and responses by the surrounding factors. This chapter will analyse the potential scenarios and the effects these disturbances have on the environment, and acts as an investigation on whether it is necessary to create this hypothesised 'warning sign' that calls for sustainable viticulture in mountain areas.

### 4.1 IRRIGATION NEEDS

#### 4.1.1 WATER IN EUROPEAN MOUNTAINS

The European parliament has strict rules in terms of irrigation and water use in agricultural systems, a briefing report from the European Parliamentary Research Service (2019, p. 1) written by Rossi states that; "In today's economy, agriculture is one of the sectors that consumes the most water resources. Irrigation is the major cause of water consumption in agriculture." This makes it a threat to (non-replenishable) water resources. "Therefore, the issue of water scarcity requires careful reflection on the trade-off between higher agricultural productivity and the deterioration of water resources." The European Parliament strives towards more sustainable water management to decrease droughts both in reservoirs and agriculture via these laws on irrigation.

The Alps do not have an as dry climate as locations like South Africa or Chile do, and each climate calls for their own way of irrigation agricultural lands. Thus, there are many diverse types of irrigation, such as primary irrigation and supplemental irrigation. Primary irrigation is used in regions where there is a lack of rainfall to such a degree that viticulture could not even exist without irrigation (Robinson & Harding, 2015). While supplemental irrigation is used in places where there is usually a good amount of rainfall, but which can be supplemented to fill in the gaps of dry periods, so that the growth of vines is not slowed or harmed (Diatta et al., 2021). The Alps usually receive rainfall that is sufficient to take care of agricultural water needs for most of the year, meaning rain-fed and traditional irrigation often live hand in hand in these regions. However, rain patterns highly depend on the elevation. In most regions the presence of irrigation varies even in very small areas, such as in the Aosta Valley. Even though irrigation may be necessary in all vineyards, the environment or accessibility to water can prevent the ability to irrigate all fields.

Despite the fact that the Alps receive more rainfall than southern Europe and therefore needs less irrigation systems overall, irrigation has still been seen to increase throughout Europe due to climate change and its increasing unpredictability in weather forecasts such as extreme droughts (Rossi & European Parliamentary Research Service, 2019). Even in the mountainous areas of Europe, while usually experiencing more precipitation, irrigation zones are expanding. The Global Irrigation Map (2018) demonstrates a shift in irrigation into the Alps (figure 11).

Figure 11 also visualizes where irrigation is necessary, which is especially on the edges of the Alpine region. This corresponds with the presence of most agricultural land, since the centre of the Alps contain much higher peaks that are inhospitable to agriculture. Vineyards especially are the third highest irrigated type of agriculture in the Swiss Rhone catchment (figure 12) compared to different land uses. Places like the Swiss Rhone catchment, the Valle d'Aosta in Italy or the Austrian Tyrol, suffer from a rain-shadow effect in the summer (Fuhrer et al., 2014). This happens when moist air is

driven upwards along a mountain by wind directions, cools down due to a lowering temperature, and condenses into precipitation. This creates a dry climate on the leeward side as all rain has already been released before reaching the other side. These circumstances call for irrigation needs, and confirm the need to look into its consequences and effects (Whiteman, 2000). The driest part of Switzerland, The Valais, has vineyards on mountain slopes that need irrigation to not be dry and brown by August (Grove & Grove, 1990). In addition to this, rainfall is less predictable in high altitudes compared to valleys (Mitchell et al., 1994).

While in drier landscapes like Andalucia, water has to come from springs in limestone areas, in the mountainous areas of the Alps, irrigation possibilities are largely based on surface water resources, like snowmelt-fed rivers (Hublart et al., 2014). But while mountains can function as catchment areas

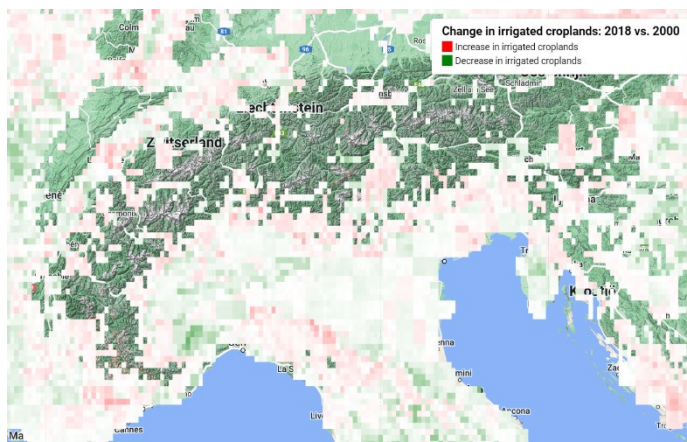


Figure 11, Irrigation increase Alps showing increase also in mountainous areas (Global Irrigation Map, 2018)

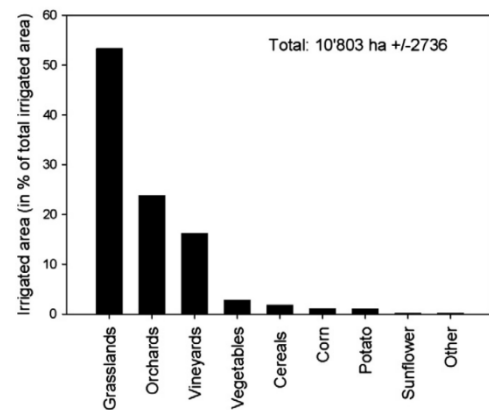


Figure 12, Distribution irrigated land between land use classes in Swiss Rhone, viticulture being significant here (Führer et al., 2014)

for precipitation, they usually lack the capacity to store it naturally. Valleys often have more storing capacity, and a more diverse set of water resources such as underground basins (Snyder, 1962). This means water depletion is more renounced in mountain areas, making good water management a crucial factor. This also highlights the special circumstances mountain irrigation often deals with, calling for case-specific regulation. Additionally, seeing as this study is based on the fact that climate change creates new possibilities for viticulture, it cannot be overlooked that climate change also has negative effects on irrigation possibilities. Changes in the numbers of snowfall days could lead to reduced runoff in summer periods (where irrigation is most needed). Not to mention the fact that higher temperatures often call for an increase in irrigation needs, both because of droughts and the expanded growing season possibilities (Führer et al., 2014). These events result in the demand for water exceeding the resources, and suggests climate change should be thought of when building current irrigation systems. Alike, irrigation should be made resilient and sustainable to survive in the case of climate change in mountain regions.

An example of water sources in Switzerland are the bisses of Valais. The earlier mentioned region in Switzerland, Valais, are home to the highest vineyards in Europe, reaching up to 1150 m asl (Tourismus, n.d.). This region holds traditional mountain irrigation systems that were constructed to water agriculture in the dry summer months of Valais. The course of streams was altered due to man-made redirections to lead into pastures, orchards and vineyards (Crook & Jones, 1999). These irrigation streams (the red lines) are also directed towards altitudes of above 900 m asl, thus, high altitude agriculture (figure 13). These constructions are still used for irrigation of agriculture today (figure 14). These figures display the evidence of irrigation needs at the altitudes of the research

area, meaning the assessment of its consequences in 4.1.2 is necessary. Additionally, historical knowledge in irrigating in challenging environments such as the Alps is valuable and worthy to be looked at when creating effective irrigation systems.

#### 4.1.2 IRRIGATION'S CONSEQUENCES

Irrigation can contribute to dramatically changed water cycles in the mountains. With the aim to increase agricultural production in mountainous areas in the Alps, irrigation is used. The inner-alpine dry regions such as the Valais in Switzerland are often irrigated via sprinklers. This method can

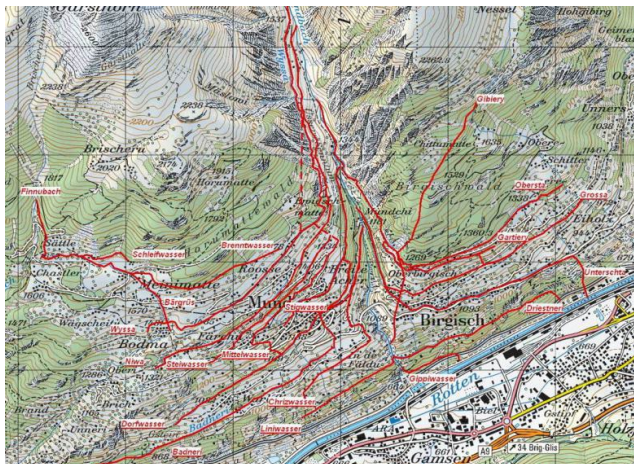


Figure 13, Irrigation system of the bisse of Valais above 900 m asl (The Bisses of Valais – Irrigation Channels a Tourist Hit, n.d.)



Figure 14, Visualisation aid of construction of bisse channel

drastically change the mini-climate in a specific zone. This method in irrigation has been known to create a loss of specialist species found in the Alps, especially in xeric vegetation types, which is found in the dry areas montane zones (thus, exactly the area that needs irrigation). This is because irrigation increases the growth of mesophilous plant species (which are fast-growing) that outcompete more drought adapted species. This means the climate is altered in this area of irrigation, making it 'wetter' and changing the biodiversity (Boch et al., 2021), sometimes leading to a 'simpler' ecosystem. These changes in biodiversity highlights the possible trade-offs between irrigation and ecosystems, emphasising the need for careful management.

Additionally, mountain streams, where most of the water in mountain irrigation is taken from, provide habitat conditions and promote biodiversity (Pompeu et al., 2024). In the Alps, dams are known to contribute to irrigation systems for agriculture (Marnezy, 2008). After a post hoc test done by Pompeu et al. (2024), it was revealed nitrate levels were influenced by dams, which presented a significant reduction downstream, independently of the mountain range where the tests were conducted. Furthermore, diatom communities were seen to be increasing in richness, possibly due to the stable flow of water being favourable to algae growth. The consequences of this algae growth could result to be similar to processes like eutrophication. This process of algae growth (which is blocking the sunlight from coming into rivers/streams) causes underwater flora to die due to a lack of photosynthesis opportunities. This in turn creates a lack of oxygen underwater, which can be detrimental to fauna species present in the body of water. According to (Gordon et al. (2010) eutrophication usually leads to a loss in ecosystem services, due to the biodiversity decreasing. While the study about dams was done in the central Pyrenees, this could still be taken into consideration when looking at the Alps. While the Alps have generally more lakes and water storage than the Pyrenees, the Pyrenees does have a similar richness in biodiversity compared to the Alps. While the

Alps is slightly richer in species, this could mean the problems of dams could be even more impactful to biodiversity (Nagy et al., 2003). This suggests the expansion of large irrigation systems need careful planning, to avoid significant environmental impacts. Overall, these changes in water regimes cause a disruption in an ecosystem's natural state. Whether or not the ecosystem can recover/bounce back from this, depends on the scale of the disturbance and the resilience of the existing system.

There is also a higher risk involved with water management in upstream environments, compared to downstream environments. Upstream use of water can impact the downstream ecosystems services, making the management of it even more important. This can be the effects of both the quantity of water used, meaning there must be enough water still flowing to downstream areas to maintain its nature and agriculture alike. As well as the quality of the water, as irrigation often goes paired with pesticide use or additional supplements to enhance growths, like fertilizers (Gordon et al., 2010).

However, there is also a region in the Spanish mountains that were studied for an apparent increase in precipitation if the mountain was located downwind from irrigated lands. These areas had been seen to become wetter. Despite this, the runoff is not increased enough to supply available water resources, since the rainfall was distributed over a too broad region. Still, the rainfall did increase summer precipitation weight, and may aid small plant species to survive summers (Jódar et al., 2010). To determine if this scenario is applicable to the Alps, there needs to be a comparison of evaporation rates between these places. Research by Henning and Henning (1981) especially show that the Pyrenees generally have higher evapotranspiration levels than any region in the Alps. But while evaporation is higher in places with higher temperatures and more sun, which would both be the Pyrenees, it is not exclusively so for every region in the Alps. A study in the central Valais (Switzerland) stated that "The combination of high summer temperatures, clear skies, and intense sunshine means that the central Valais and parts of the Haut-Valais have a high evapo-transpiration rate." (Crook & Jones, 1999, p. 82). Thus, the theory cannot be completely ignored. And while the higher evapotranspiration rate could cause a dryer landscape within the irrigated area, it could prove beneficial elsewhere.

A study in Yourjogh (Pakistan) concluded uncontrolled irrigation, and especially the overwatering of agricultural fields can lead to an increase in landslips. The expansion of irrigation saturated the soil further, which resulted in widespread subsidence (Ali et al., 2017). However, this scenario is not deemed likely to happen in the Alps because of the European Unions tight laws on irrigation and water use. The European Union's Water Framework Directive and the Common Agricultural Policy include strict guidelines to prevent over-irrigation. These regulations are designed to protect soil stability and prevent degradation, making the likelihood of landslips due to over-irrigation in the Alps much lower (Water Framework Directive, 2024). So, the resilience of the irrigation system itself does seem to depend largely on the maintenance and governance of it and its sources.

## 4.2 CLEARANCE OF NATURE

### 4.2.1 ROOM FOR VINEYARDS

Mountain environments are considered as a major source of ecosystems. Additionally, what happens at higher altitude (such as influences to the hydrological system) often influences regions in lower altitudes. The Alps, one example of a biodiverse mountain system, cover 61% of Switzerland. Switzerland also contains 146 km<sup>2</sup> of vines, some of which are located in the Alps; “Valais, Chablais vaudois, part of Ticino and Graubünden” (Swiss Wine Promotion, n.d., para. 6) are all major viticulture regions (figure 15/16). The expansion of farming land is one of the main causes of the clearance of nature, like in vineyards in north-west Italy where; “this implies a loss of natural areas bordering the vineyards, and loss of potential role of the woods in protecting both biodiversity and stability of the territory against geological hazards.” Which warns us of the consequences of the clearance of nature (Guidoni et al., 2012, p. 38). Implying natural areas surrounding vineyards provide protection against hazards, and are deemed beneficial to the resilience of viticulture. These findings imply a trend that encourage vineyards, but at the expense of natural habitats. If the ecosystem resilience is not ready to adapt to these changes, the effects could also have consequences for viticulture itself, as the natural surroundings around vineyards can contribute to vineyard health. The trend of prioritizing agricultural profitability over ecological preservation can pose a risk to the resilience of this system, making them more vulnerable to disturbances like landslides or soil erosion.

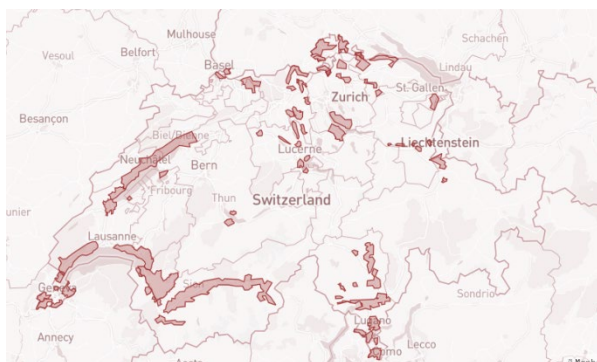


Figure 15, Vineyard locations in Switzerland, showcasing viticulture in the Alps (Swiss Wine Promotion, n.d.)

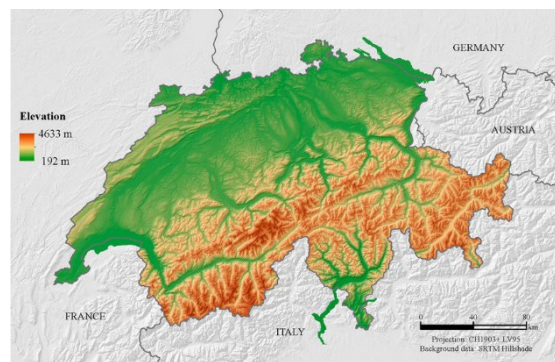


Figure 16, Terrain Switzerland, for comparison to vineyard locations (Schmidt et al., 2019)

#### 4.2.2 CONSEQUENCES OF A LOSS OF NATURE

Alpine ecosystems are major biodiversity hotspots, characterized by species that are highly specialized in their adaptation to specific climatic conditions (Monzani, 2021). Depending on the biodiversity loss, effects of large-scale changes in land coverage could cause abrupt, irreversible and harmful changes, which can decrease the level of resilience (Chakravarty et al., 2012). A study done by Bruggisser et al. (2010) investigated the biodiversity in several vineyards in northern Switzerland, which were typical (in size and management) for vineyards in the northern Alps. Their findings were that the type of vineyard (organic or conventional) did not differ much in biodiversity. What did influence the species richness by 13.9% were the site conditions, wherein slope, followed by altitude, explained most of the variation. To assess what altitude does to the response of ecosystems to disturbances in the following chapter, is more significant than to assess different types of vineyard management. Understanding how ecosystems work at different altitudes and how they respond to disturbances is the key to predicting the impact of viticulture shifting upwards in altitude. The explanation of why organic vineyards may not have such a noticeable effect on the biodiversity compared to conventional vineyards, can be explained by the differences between annual and

perennial cropping systems. Annual cropping systems experience a much higher level of disturbances (often due to the big differences in pre- and post-harvest characteristics), which makes the shift to organic farming a much more impactful change to the environment, and correlates positively to biodiversity. While in vineyards, it was stated that “in generally less disturbed perennial systems a decrease in disturbance reduces environmental heterogeneity and allows superior competitors to exclude the more stress-tolerant species” (Bruggisser et al., 2010, p. 1526). This could result in vineyards being ‘overall’ less harmful to the natural biotic life surrounding it than other types of agriculture are. This also means the shift to organic farming for vineyards is less pronounced and recognized because the system overall is already more stable. Without extensive research covering this, it could mean vineyards receive the same amount of laws and regulations, despite distinct levels of disturbances being inflicted on the natural environment compared to other types of agriculture.

Erosion is another problem that comes with the clearance of nature. Deforestation causes landscape opening, through which the soil is less protected against the effects of erosion. Nature clearance also disrupts water cycles, as the removal of roots from the soil has negative effects on the amount of water it can hold. Downstream flooding can be of effect, which in turn causes more soil erosion. This is then a positive feedback loop of reoccurring erosion that also harms viticulture itself (Chakravarty et al., 2012). As mentioned in the ‘research area’ chapter, the montane zone of the Alps is largely covered by coniferous trees, this type of vegetation is found to be very non-resilient to floods, their recovery time taking over 30 years (Swanson et al., 1998). This is just one example of a response to such a disturbance, since all vegetation reacts differently, but it is a clear sign that there could be long-lasting effects due to the risks in clearing of nature for viticulture. The clearing of woody vegetation (much more present in high altitudes, due to the adaptation to the harsh and cold climate) for viticulture can also lead to salinization. As these types of flora are good at keeping the groundwater low enough to prevent the mixing of salt (Gorden et al., 2010). This change has previously been observed in Alpine rivers at heights of 800 m asl (Niedrist et al., 2020), possibly leading to vegetation growth failure (as well as agricultural crops) and ecosystem simplification, like a more salt-resistant species outcompeting all others. Viticulture’s yield can be affected by these responses, suggesting viticulturists should not overlook these events.

A study by Sebald et al. (2019), conducted in the Alps of Austria, state that forests (that cover a significant amount of the montane zone) are proven to be effective in providing protection against natural hazards. In steeper slopes, the roots of trees provide stability to the soil, making landslides less likely to happen. Forests also function as a buffer for surface runoff during peak precipitation, both by improved soil infiltration and their canopy that intercepts water. And while forests can be managed to be regenerated after clearance, studies indicated that unmanaged forests provide a higher level of protection against natural hazards than managed forests do (Irauschek et al., 2017). And especially in the case of nature clearance of vineyards, forests are cleared without the intention to be regenerated as they are solely cleared for vineyards. This could introduce the need to surround vineyards with trees or other large types of vegetation, to make up for this problem. The only upside is that land clearances for the room of vineyards do not stay abandoned, and the roots of vines will take the place of earlier vegetation. Yet, there are significant findings that floristic biodiversity, and therefore root diversity and density, are far more effective in the prevention of landslides (Tasser et al., 2005). There has been a study done in the north-west of Italy by Bordoni et al. (2019), where they investigated different methods of viticulture on the root density. It was found that with combined methods, such as the combination of grass-mulching and tillage between rows, resulted in a higher root density and stronger root reinforcement. This implies monocultured vineyards can have more

negative effects than vineyards where other types of vegetation are allowed to survive between the rows of vines. Additionally, the diversity of roots protects against landslides. “Shallow landslides triggered by intense rainfall events frequently affect vineyards located in sloping terrains, causing the partial or complete destruction of the vineyards.” (p. 2) And while the results suggested vineyards can improve by themselves to prevent landslides, the study by Borndoni et al. (2019) was conducted in less steep slopes than those the research area of this study deals with. Their slopes were about 10° to 20°, and resided in a less high altitude region. Thus, it is not directly assumed the vineyards in the montane zone of the Alps will be as well off with certain combined methods of farming in their root density to significantly affect risks on landslides, meaning the clearance of nature remains a probable cause to landslide threats.

Another effect of vineyards moving upwards is the mosaic-like landscapes they create. These patches of different land-uses (if mixed with other kinds of agricultural lands) are often accompanied by strips of natural or semi-natural vegetation, such as small patches of woods or trees scattered among vineyards for either aesthetic or technical purposes. This can have several effects depending on the species studied. Generally, the creation of smaller fragments in an ecosystem causes those lands to be not large enough to support the populations of the original inhabitants (Heaton & Merenlender, 2000). While some species can be restricted by certain environmental elements, others may use agricultural fields as a habitat equally. But even for the species that do thrive more easily in these new land uses, the seasonality of agriculture influences the resources greatly (Bennett et al., 2006). While vineyards do not often lay barren during periods of the year (only in the case of destroying and replanting vines), they do undergo cycles of flowering and fruiting, which changes resources seasonally. The mosaic environments of agricultural lands risk the loss, fragmentation, simplification and degradation of habitats and the spread of plants and animals. Migration in between patches is important for the survival of species (where in extreme events they go to extinction). Important for the resilience of agro-ecosystem is that, while the natural surroundings will almost always undergo negative effects from the clearing of nature, these effects can be decreased when being mindful of the positive interactions vineyards can have with the natural surroundings (as mentioned in the theoretical framework, such as inter-row vegetation that works positively with vines). This, with well-managed methods, can increase the system’s resilience when working together.

## 4.3 ALTERATION OF LAND

### 4.3.1 SLOPES AND TERRACING IN THE MOUNTAINS

The availability of arable land in mountains had always been a challenge, due to its steepness and difficult terrain. However, historically, steep slope vineyards had the highest reputation, and produced the best quality wines. In autumn, during the late ripening phase, solar altitude is low, steep slopes have been found to receive 30-40% more sunlight than flat vineyards. Still, steep slope vineyards suffer from the competitive disadvantages to flatter regions. This includes higher evaporation rates (due to the increase in solar energy) which can lead to water deficits, a lower soil depth making vines more susceptible to stress, and higher production costs due to the lack in opportunity of mechanization. To keep mountainous viticulture economically viable, terraces have been developed in many regions (Strack et al., 2021), as well as in Switzerland (figure 17).

This way of transforming slopes into terraces provides a good depth of soil on slopes where the

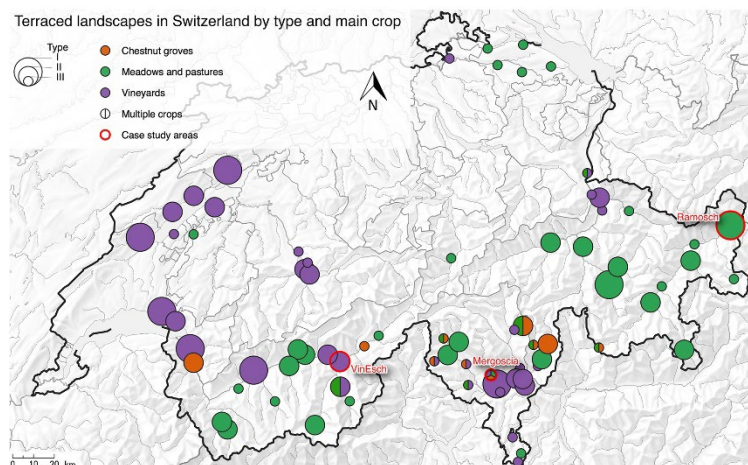


Figure 17, Vineyard terracing in Switzerland, showcasing the need for terraced land in order to sustain viticulture practices (Liechti & Rodewald, 2020)

earthy layer is generally thin, and creates a more stable environment for agricultural overall. Terraces also give a better ability to control water and irrigation, as terraces often come with internal drainage systems. Terraces for rainfed agriculture are often slightly outwardly sloped to help remove water from the fields. They usually begin with smaller walls in valleys, and are then build of further to level the increasing angle of slopes. Bench terraces can be found in rainfed agriculture on slopes of 60°, but most irrigation stays on the slopes of under 35° (Vincent, 1995).

#### 4.3.2 CONSEQUENCES OF TERRACING

Terraces are very labour intensive, both in their built (often done through handmade stone walls and alteration of soil) and their upkeep. Regions like Lavaux in Switzerland (figure 18) make skillful use of these terracing techniques. But when terraces are not well maintained, the increase in erosion can lead terraces to collapse (figure 19). It has been found terraces are more prone to superficial mass movements than woodland areas are (Tarolli et al., 2014). Crosta et al. (2003, p. 33) state that “The number of soil slips and slumps is ten time greater in terraced areas than in woodland. This is both due to the possible incompleteness of the inventory, because of thick vegetational cover and unfavorable slope exposure, and to the anthropogenic disturbance in terraced areas.” Alpine and pre-alpine terraces experience phenomena such as soil slips, soil slumps and soil slips-debris flows, which can cause a lot of damage to human or natural environments. In a study in the northern Italian Alps, about 75% of slope failures took place on terraced areas. However, for this study’s particular research area (900 m asl to 1300 m asl) there are significantly less terraces, meaning that woodland

areas still surpass the number of landslides compared to terraced slopes (unlike in valleys where terraces cover about the same amount of land as woodland and grassland does). In the case of this study (revolving around active vineyard terraces shifting upwards in mountains, these abandonment effects are unlikely. Such as there is also evidence of the Lavaux vineyards in Switzerland being well-maintained (Wei et al., 2016). Nevertheless, it should be noted that these studies imply an ill-managed terrace can create significant harm to both the agro- and ecosystem resilience.

When not looking at potential hazards the mismanagement of terraces can produce, there is scientific evidence for the decrease in soil



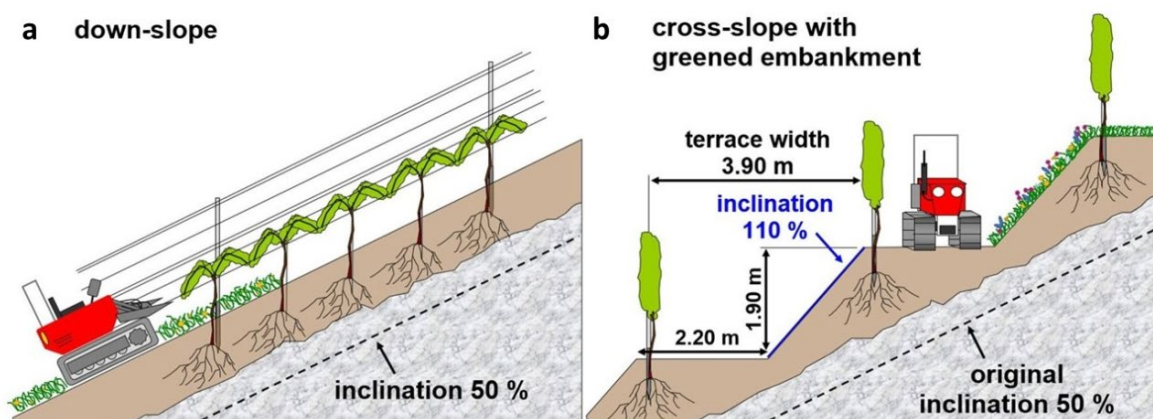
Figure 18, Lavaux vineyards (Communication, 2021)



Figure 19, Terrace collapsing (Tarolli et al., 2014)

erosion and water runoff. Terraces would ensure more infiltration of water into soils, and improving the control of runoff compared to slopes. This can be effective in soil protection and conservation, and relates positively to the yield of vineyards (Brandolini et al., 2017). Thus, while terracing does greatly affect a land's composition and natural elevation/sloping terrain, the method can aid in inhibiting erosion, as well as slow the flow of water.

A study done by Bohm et al. (2024) compares down-slope vineyards (no terracing) with cross-slope vineyards (terracing) (figure 20) in their biodiversity rates. They state that terraces allow the use of standard machinery, and that greened embankments are conducted with an extended flowering



period. While down-slope vineyards commonly result in sparser vegetation between the rows of vines because of tillage, soil condition and mulching management. It was found that the number of

Figure 20, Down-slope and Cross-slope viticulture (Bohm et al., 2024)

species and individuals of several counted insects and plants in cross-slope vineyards with greened embankments were significantly higher than those in down-slope vineyards (figure 21). While this study was conducted in south Germany, the researchers note that the selected study region is considered representative for other landscapes with steep-slope viticulture of other parts of central Europe. In Japan it was even found that the diversity of weed species was greater in terraces than in sloped nature. If interaction between native vegetation and vineyards is allowed, it could promote ecosystem restoration. Slopes have been found to become generally more stable after terracing, with the negative effects only occurring in poorly-designed/managed terraces (Wei et al., 2016). This could suggest the resilience of an agro-ecosystem actually increases with these human-introduced ‘disturbances’ of terraces, if they are well-maintained.

Wider terraces and levelling slopes could provide the possibility for mechanization on vineyards. In the Aosta Valley, Italy, vineyards on slopes over 100% have been made possible to mechanize

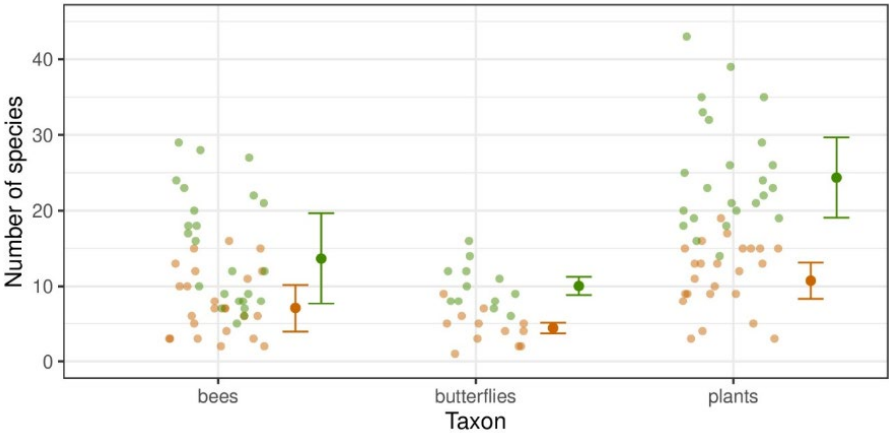


Figure 21, Number of species in cross-slope vineyards with green embankments (green) and without green embankments (orange) (Bohm et al., 2024)

through terracing. This development, while economically enhancing, can be more destructive to nature. ““industrial terracing” with heavy earthmoving machinery can affect both landscape and soil. It often alters the original proportion of terracing (longer terraces, higher walls, more regular design), breaking the original harmony of the landscape and resulting in a “quarry effect”.” (Stanchi et al., 2012, p. 94). This implies terracing, while (when looking at previous research) appears to bring along a couple of positive effects on the natural environment (especially compared to slopes), it should not be forgotten other negative disturbances are also enabled when terracing becomes part of the agricultural process. Terracing can introduce mechanization, which can erase all the positive effects that were determined previously.

#### 4.4 MODEL RESULTS

The model developed in figure 8 can now be expanded, due to research about the effects the disturbances can have on surrounding ecosystems (figure 22). The third row showcases the found effects on the natural environment, from which the more negative effects are coloured in dark green, while the more positive effects are coloured in a lighter green. It is clear that clearance of nature seems to be the disturbance with the most negative effects on the natural environment. However, it is also the disturbance that is most necessary when having vineyards in the mountains.

Vineyards cannot exist without (at least some of) the natural vegetation being removed to create space for the vines. While irrigation and terraces are still sometimes optional, depending on the location. It seems irrigation mostly bring along negative risks when the process is not well-maintained or overused. Terracing does bring forth more positive than negative consequences, judging on the article research.

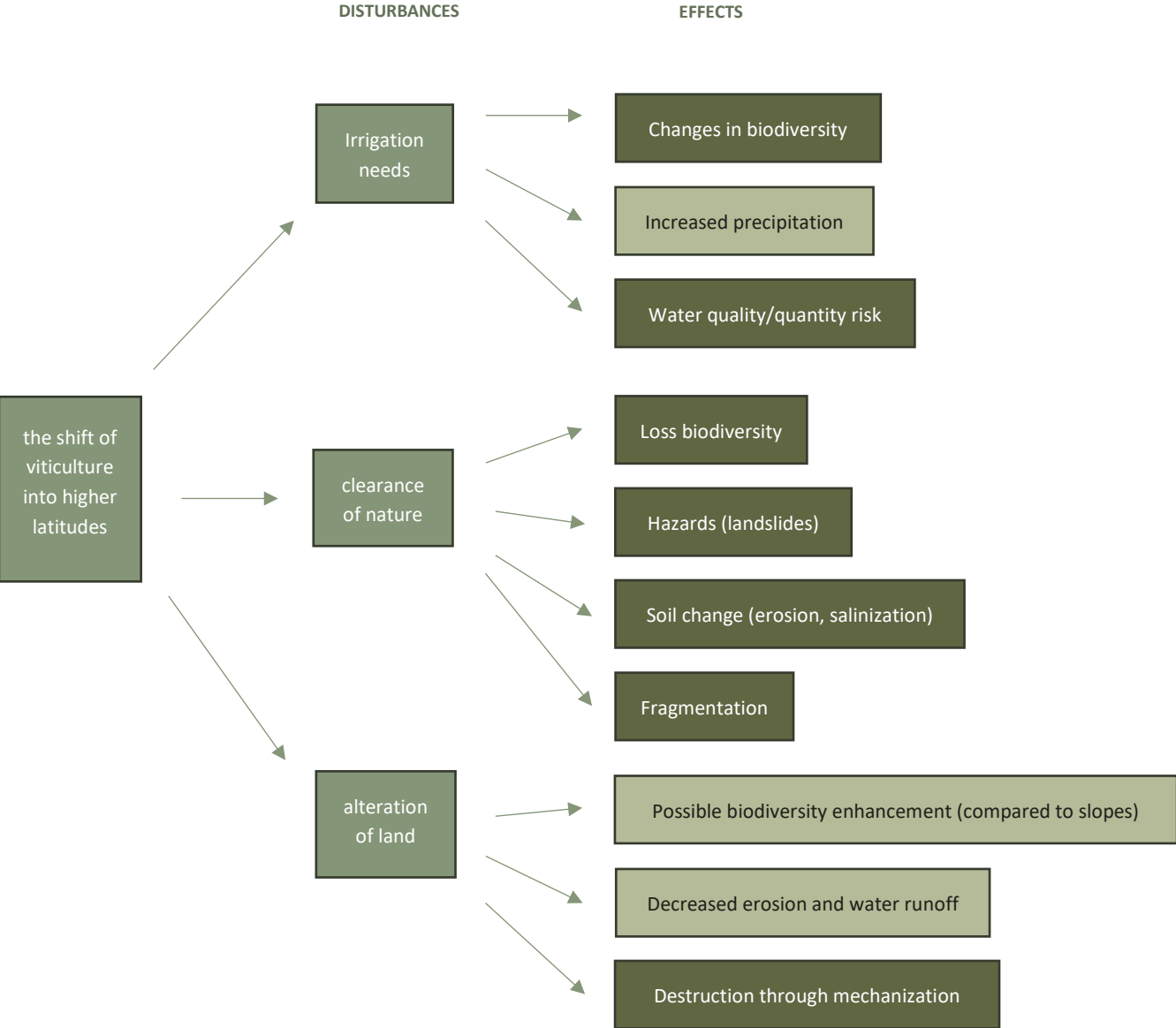


Figure 22, Expanded model of effects, showcasing positive effects (light green) and negative effects (dark green) of several disturbances

## 5. THE VIEWS ON MITIGATION IN THE AOSTA VALLEY

### 5.1 WHY SHOULD FARMERS MITIGATE THE DISTURBANCES?

While in the previous chapter, it has been explored what the chosen disturbances could do to the natural environment, this subchapter will go into how these natural effects could risk viticulture itself (creating a loop, as agricultural disturbances eventually come back to carry negative consequences for itself). It acts as an explanation on why we even should think of sustainability in mountainous viticulture, by going over the more negative effects (especially for viticulture itself) of figure 22.

Viticulture, just as any other form of agriculture, is intertwined with the surrounding ecosystems, relying on natural processes and interaction to thrive in the assigned environment. When the placement of viticulture in high altitude regions causes certain disturbances, the impact these disturbances have on the natural surroundings can in turn impact the vines themselves. The sustainability and resilience of this system relies on the balance between the ecosystem and agriculture being able to co-exist (J. Megan Woltz, 2012).

Barnes et al. (2009, p. 250) mention that; “Natural ecosystems provide a multitude of functions that benefit humankind. Valuable ES include pollination, soil formation, flood mitigation, carbon capture, biological control, tourism and aesthetics.” Implying viticulture could thrive from a healthy surrounding ecosystem. Consequences like a loss of biodiversity does not only bring harm to natural ecosystems, but also to vineyards. Biodiversity brings along insects that are also useful to agriculture, and while vines do not need external pollination, the presence of certain insects can enhance the resilience against pests and diseases through natural predators (Barnes et al., 2009). The problems irrigation can bring with the decrease in quantity and quality of water also relates back to a possible decrease in biodiversity (as mentioned in 4.1.2), resulting in the same problems noted above. Habitat fragmentation falls into the same category, thus all reasons to mitigate these disturbances to prevent the loss of biodiversity.

Alike, hazards like landslides have been known to destroy vines and cause significant economic loss due to a failed or decreased harvest. Not only the plants themselves can be destroyed by landslides, but also the nutrient rich top soil that the vines thrive on can be erased or displaced, creating long-term effects on the area of viticulture (Bordoni et al., 2017). Afterwards, there can be significant costs in the rebuilding of certain areas, terraces and vines. Even simple infrastructure related to the vineyards can be destroyed in the process, leading to economic loss or the viticulturists. These are reasons for the viticulturists to mitigate the presence of these disturbances.

Another mentioned negative effect in figure 22 is changes to the soil such as erosion and salinization. Soil erosion, similar to landslides, can cause the top layer of the soil to be removed, creating nutrient loss. Farmers and policy makers should understand the economic loss generated by soil erosion (aside from the broad research done towards environmental effects) so that they can recognize the need for conservation methods (Martínez-Casasnovas and Ramos, 2006). Because not only does soil erosion remove natural nutrients from the earth in which the vines grow, it also has the possibility to remove fertilizers and organic composts. Salinization can also lead to the loss of vines, due to the salt destroying/sickening the roots of the plants, which in turn decreases yield. As a result, the loss of income should be another motivator for viticulturists to mitigate harmful soil changes.

## 5.2 THE WORK AND OPTIONS, A CASE STUDY IN THE AOSTA VALLEY

The Aosta Valley is one of the highest European viticulture regions, located in north-west Italy, surrounded by the Alps, bordering Switzerland. This valley is renowned for its unique viticulture practices and the production of high-quality wines. This region is situated at altitudes ranging from 300 m asl to 1200 m asl. The topography, combined with a dry, continental climate, creates distinct challenges, but also opportunities for viticulture. The south facing slopes generally receive the most sun, and is the place where you will find the most pastures and grasslands (Monzani, 2021). The valley deals with harsh conditions, ranging from steep slopes, high evapotranspiration levels and varied microclimates that contribute to a diverse range of grape varieties. Species like Prié Blanc, Nebbiolo and Pinot Noir can all be found in this area (Bassi, 2023). Vineyards here lie within the research area and chosen altitudinal range (800 m asl to 1300 m asl), thus are typically terraced to manage the steep slope challenges. Irrigation is required in the driest months, often utilizing glacial meltwater of the Dora Baltea.

Despite agriculture being widespread, the main income is tourism (often because of the vineyard terraces and natural landscape), which brings yet another argument for the importance in being resilient against the effects of disturbances that could bring harm to this sector (Monzani, 2021).

The question that is now raised is; how do viticulturists in the Alps view their possibilities on being resilient against the chosen disturbances and their negative effects? By asking them about the challenges they face, their relation to the environment, their mitigation techniques and views on the future in being resilient and sustainable in this specific environment.

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### 5.2.1 CAVE MONT BLANC

Thus, for this study, the researcher has interviewed a viticulturist located in the Aosta Valley. A representative of the Cave Mont Blanc winehouse agreed to inform me about their practices and resilience in viticulture with an interview. To talk about the challenges they face in the unique environment (full interview transcript can be found in the appendix. Several quotes will be mentioned in this chapter). The upper valley, also called the Valdigne, is the base of the highest elevated vineyards in Europe at 1200 m asl. This is where the Prié Blanc is cultivated, and also the main grape of the Cave Mont Blanc vineyards. The cultivation area of Cave Mont Blanc is in and around the towns Morgex et de la Salle, which in the past used to consist of many small, individual winegrowers with no constant presence on the market, and no guarantee of the general quality and image of the Aosta Wines. In 1983, the development of the 'Association des Viticulteurs' was established which led to the creation of the company 'Cave Mont Blanc'. "We are between 900 and 1200 meters of altitude, so at the moment we are the highest appellation in Europe. Sicily on the Etna and also in Trentino they make vineyards up to 1300 meters, but when we talk about appellation of origin, the highest is ours." The interviewee mentions, meaning the Aosta Valley holds the record for the highest officially recognized wine designations under their specific appellation of origin. It is interesting to mention how at this point in the interview, height does not sound to be referred to as something 'challenging' or 'negative' yet. Instead, the viticulturist announces their height clearly, giving them a sense of uniqueness and pride. Alike, his words about the pre-filox grape, of which the name is the earlier mentioned Prié Blanc, where he also describes it as a type of grape that is only specifically found in their area. This type of wining is also often called 'heroic viticulture', implying the pride of the viticulturists at work.

The interviewee himself stated that their company consisted of 70 families, who work on 18 hectares of vineyards and that Cave Mont Blanc is a 'co-op winery'. This is an agricultural cooperative owned by its members. The advantage of this system is that they can pool their resources and costs for both marketing and the making of wine itself (Robinson, 2006). Later in the interview he also said that the system to obtain money like subsidies (from the European Union) is difficult for little wineries. And in that same way, it becomes difficult to be sustainable. "So we have help, but to have the help, for a little farmer that has 2000 square meters of soil, doesn't get it. Because the help is for bigger farmers." Meaning it is more economically viable for viticulturists to work together. In turn, saving more money means that there is more money to improve the resilience of their vineyards.

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#### 5.2.2 DEALING WITH IRRIGATION

The interviewee explained how the snowfall in winter helps their water resources in the summer. It makes for a strange sight, seeing the grapes and vineyards covered in a layer of snow (figure 23 and 24), but this cycle is quite important to the survival of the vines in the summer. However, the vines are normally supposed to be harvested before snowfall because of the grapes' short ripening period. Even though the blooming starts just after frost (meaning the flowers turn into grapes successfully), which is generally considered late in the year, the ripening cycle is so quick that it is ready to harvest earlier than other grape varieties. This is an example of a thoroughly adapted type of vine for this specific, rather harsh environment. Despite all of this there are still occasional years where the snowfall arrives early, which could delay ripening (lowering sugar concentrations, affecting wines) and bring damage to the grapes (Cave Mont Blanc, 2024).

However, the snow is still vital to this viticulture system. The representative of Cave Mon Blanc



Figure 23 & 24, Snowfall in the Aosta Valley on the Cave Mont Blanc vineyards (Cave Mont Blanc)

mentioned that there was not much snow last year, which made for water shortages in the summer. Because generally, the valley is very dry during summer. Their new vineyards therefore have been made with irrigation, but the old vineyards still rely on natural rainfall to survive, as there is not a good water source to make irrigation possible in these areas. He does mention that so far, every year they have managed around the dry summers, but that if climate were to further change, it could become a much bigger problem.

This leads into the first mentioned disturbance of 'irrigation'. The new vineyards, the interviewee describes, use the 'goccia goccia' method. This is translated to the drip irrigation system. This system is generally considered as one of the most efficient methods of irrigation, as explored in the theoretical framework. As Prichard (2000, p. 61) describes it; "This irrigation method relies on the frequent application of low volumes of water to a limited soil volume." Verifying this, the interviewee

mentions the method is particularly good for them because of the low water use it comes with. This is especially useful in a dry climate like the summers in the Aosta Valley, which are prone to high evaporation rates. Drip irrigation methods wet less surface area compared to flooding or sprinkling systems, which reduces the amount of water lost to evaporation from the surface of the soil (Prichard, 2000). He does highlight a problem with this method of irrigation; where the roots of the vine stay very close to the top of the soil, and do not grow as deep into the earth, because the water is always steadily available at the surface and the roots have no reason to search for water deeper within the soil. If irrigation cannot be used (like in especially dry conditions), the plant will go into stress and die, meaning it is a system they have to use carefully and frequently.

It should be mentioned that the environment of the Aosta Valley also does not allow for all types of irrigation. For example, furrow irrigation on vineyards is commonly only used on fields that are not steeper than 2%. If they are, and furrow irrigation is used, erosion becomes a significant problem, along with inefficient water and salt movement, and evaporation. This is the reason drip irrigation is now widely adopted in this region (Giordano et al., 2013), and so far, resilient to the challenges mountain agriculture faces.

A second method to deal with the specific climatic circumstances of the Aosta Valley (and aiding the irrigation methods) is the use of the Pergola system (figure 25 and 26). The Pergola system uses horizontal structures close to the soil, held up by stone pillars. While this method is no longer the dominant form of vine-growing in the whole valley, it is still the most used method in the upper valley. The ancient method is presumed to be lost because of the uncomfortable conditions in which the viticulturists must operate, both in terms of management and maintenance (Giancarlo et al., 2020). The upside of this method is that the soil retains heat from the sun during the day and releases it slowly at night. At Alpine vineyards such as the Aosta Valley at a 1000 m asl, temperatures can drop and potentially harm production. The interviewee mentions; by keeping the grapes close to



Figure 25 & 26, Pergola system in Cave Mont Blanc vineyards (Cave Mont Blanc, 2024)

the soil, this heat can help moderate the temperature around the grapes. The Pergola system also provides more shade cover over the soil, decreasing the earlier mentioned problem of evapotranspiration (Cave Mont Blanc, 2024).

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### 5.2.3 DEALING WITH TERRACING

The next discussed disturbance to the natural environment of the Alps, is the method of terracing. The interviewee states they have both terraced vineyards, and vineyards without terraces. “It is a system that man has built to work. So I think it has an impact on the mountains, but without the terraces we can’t plant, and the vineyards stop. But the terrace also has the system to cultivate in some place where, if we don’t have terrace, we just have rock. So actually we insert a place where the man has the possibility to cultivate the vineyards, but also plants have the possibility to grow, because without terraces you don’t find anything.” Thus announces the negative consequences mentioned in chapter 4.3.2, do depend on context-specific circumstances. As the representative says, there is the possibility to create terraces on rocky surfaces, that previously, had no native vegetation growing on it, and has the potential to offer more to the ecosystem. If biodiversity is enhanced, resilience could increase too. Figure 27 shows the terraces of Cave Mont Blanc, as well as the Pergola system integrated in them.



Figure 27, Terraced vineyards of Cave Mont Blanc (Cave Mont Blanc, 2024)

The more positive consequence of terracing mentioned in figure 22, decreased erosion, is confirmed by the representative later in the interview. He states that they deal with erosion every year, as “mountains are made to go down”, but that the terraces preserve this erosion, especially in the case of great rainfall. His views on even further increasing the resilience against this problem, are once more specific to the area. “In some areas it’s possible, in other areas it is not so simple to work and preserve the erosion.” He says the work in the vineyards there is difficult, and that if they have a lot of people that work there, they can make the terraces to preserve erosion. But if they do not have people, it is difficult in terms of accessibility and access to work. So while, according to a report from the European Network for Rural Development (2016) on the Aosta Valley specifically, 66% of the population there works in rural employment, it is sometimes not enough for sustainability improvement. The interviewee recognizes high altitude viticulture faces more challenges in terms of erosion than lower altitude vineyards, and that it is beneficial for both the environment and the vineyards themselves to preserve the maximum amount of soil.

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#### 5.2.4 DEALING WITH NATURE AND ITS INTERACTION

The interviewee explains the interaction with nature is 'perfect'. They cut the weeds that grow between the vineyards to be able to work, but do not insert other varieties of plants. They use small machineries to cut the weeds, but that is about the only machinery they can use of their vineyards. He highlights that they do not change the biodiversity they have in their vineyards that way. Agriculture often has a complex link with biodiversity, since cultivation of land could bring diversity of species to an environment (such as cattle), but at the same time it takes space away from natural wildlife habitats. The context of this relationship depends on what someone includes in biodiversity (Monzani, 2021).

Cave Mont Blanc's vineyards do not use any methods that kill insects anymore. The product that used to kill the pests they had (a pesticide) also killed all the bees, and he recognizes them as important to our biodiversity and environment. Since they eliminated this product because of its negative consequences, they started using a method called 'sexual confusion'. The European grapevine moth has been a persistent pest in vineyards in Europe, attacking the vine in various stages of the plant's growth cycle. Instead of using pesticides, there is a transmitter installed that disrupts the mating forms of the insect, as the dispenser releases female pheromones, which confuses the males trying to locate non-existent females, and so prevents the moth from mating and increasing in numbers (Duplo, 2024). This is a method that, while effecting a species, does not exterminate it completely, leaving the biodiversity largely in tact without a significant threat to the vineyards. This makes it more likely that the natural ecosystem surrounding the vineyards can adapt to the disturbances, as they are not as large as the extinction of a species would be.

When asked if the interviewee's vineyards are fenced in, he answers yes, but that one can move in between them. When looking on google maps (although the photos are from 2011) it seems most of the vineyards are completely open to the public, which means it is also open for organisms to travel through freely, decreasing the habitat fragmentation's negative effects. The only thing that might impede organisms from migrating through the fields, is the terraces, but this would depend on the species looked at. He also mentions that the Aosta Valley does not have monocultures, and that there are diverse types of agricultural fields (occasionally switched by a patch of nature) such as herbs, wheat and vineyards. A study by (Bennett et al., 2006) found that many species naturally move between different types of landscapes to obtain their resources. Meaning mosaic landscapes such as the Aosta Valley being composed of multiple different types of patches instead of being a monoculture gives species the opportunity to use the landscape simultaneously and enhance species richness. It must be mentioned the influence of mosaic diversity does depend on the composition of elements that contribute to the diversity, and its effectiveness differs per studied area and its elements. As well as that Alpine ecosystems are often highly specialized, making this 'advantage' of multiple resources being available probably less relevant to the area (Monzani, 2021). The same study mentions the risks of Alpine environments simplifying to less specialized species and generalist plant communities.

When further looking through the google maps street view in Cave Mont Blanc's vineyards, it seemed the fields had many diverse levels in the amount of 'weeds' or natural vegetation growing in between the vines (figure 28). A study by Wersebeckmann et al. (2023) did a similar comparison between different types of vineyard management and their biodiversity effects. The first type being similar to C in figure 28, with vineyards being regularly tilled and extensively managed, revealing bare soil. A second type being focused on terraced vineyards with moderate vegetation in between the embankments, similar to B). And an overgrown (in their study considered 'abandoned', thus most likely a slightly more extreme version of what can be seen in A) vineyard with lots of vegetation, similar to A. The study concluded that orthoptera species richness differed significantly between vineyard types, with terraced vineyards (B) having the highest species diversity. While type A actually had the least diverse amount of species. With 3 other orders of insect species, the abandoned vineyards similar to type A all contained the lowest density and diversity of species. Therefore, maintaining vineyards is of great importance to habitat enrichment and biodiversity. Terraced vineyards came on top on almost all biodiversity assessment, also due to the solution to maintaining



Figure 28, Different levels of vegetation in vineyards, top (A): highest level of vegetation, middle (B): medium level of vegetation, bottom (C): bare soil with occasional vegetation (Google, 2011)

the vineyard (compared to slopes) and creating an economically stable land (Wersebeckmann et al., 2023).

The interviewee mentions, while the environment is harsh, it comes with certain benefits, such as the absence of the Phylloxera; the insect that has destroyed a wide range of European vineyards. “The height helps us with the sickness of the vineyards because we have a fresh climate, and so we don’t have many problems of sickness.” But as he mentions this, he does explain the work itself is much more difficult than in lower altitudes. The work is not simple because they do not have much machinery, and that it might be easier to work in regions like Tuscany (although he still thinks the natural interaction is better at this altitude). The harvest and pruning are all done by hand, and requires a lot of labour.

Still, research done by MOVING (MOUNTAIN Valorisation through INTERconnectedness and Green growth) that research mountain agriculture environments in Europe, found that Alpine vineyards usually benefit from the colder/harsher temperatures. If temperatures in these regions were to increase, it could affect the amount of pests and diseases (in a negative way for viticulture) and influence the growth cycle. While mountain vineyards usually rely on a late harvest (benefiting from late fall sun that shines directly on the angled slopes), an increase in temperature could cause the flowering to be ready earlier in spring, which results in a much greater risks of frost damage, especially because mountainous environments deal with such extreme conditions in snowfall and the cold (González-Moreno et al., 2022).

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#### 5.2.5 VIEWS ON THE ABILITY TO BE RESILIENT

The next topic to explore is how possible it is for viticulturists to be resilient against these disturbances and their consequences in this specific environment, judging by the winemaker’s opinions on the matter.

When asked about the possibility of being sustainable in Cave Mont Blanc’s region, he explains farmers in the European Union have the possibility to receive support from certain organizations. One of these organizations is the CAP (Common Agricultural Policy). The CAP provides funding and support to farmers across the European Union, including support for promoting sustainability and environmentally conscious practices. They also aim for a stable and affordable supply of food, reasonable living for farmers, maintaining rural areas across the European Union, and promoting jobs in agri-food sectors. The CAP provides income support through direct payments, ensuring income stability and remunerates farmers for sustainable farming methods, as well as rural development measures with programmes to address specific challenges and needs that rural areas face (Agriculture and Rural Development, 2024).

Despite the support they provide, the interviewee mentions the program is difficult for little farmers to get into, especially non-enterprise viticulturists. “So the system to obtain the money, to obtain the helps of being sustainable is difficult for little winery and little farmers. So the problem is that. So we have help but to have the help, for a little farmer that has 2000 square meters of soil, does not get the help. Because the help is for bigger farmers.” He states, whereafter he explains the Aosta Valley consists mostly of little farmers, and that is why the earlier mentioned co-op system exists. When looking at an analytical factsheet on the CAP website, it can be confirmed that 20% of farmers receive the highest level of direct payments (receiving 80% of the funds), compared to the other 80% of (smaller) farmers. This co-op system permits farmers to work, because for single people it is very difficult to get the money with the system that exists now. The study by Aleffi et al. (2020) confirms

this, having done interviews with viticulturists in several locations in Europe about their sustainability. While the viticulturists in regions like Tuscany and Marche state they have no cooperation among companies (but do acknowledge it is the key to success; less effort, lower costs, greater efficiencies), an interview with another winemaker in the Aosta Valley does mention they make use of networking. This is stated to give more strength in both production and political level. On the fact sheet on the CAP website is written that Member States will define who qualifies to receive direct payments in their CAP Strategic Plans. 'Active farmers' is the name for the farmers that qualify, and is determined according to a minimum level of agricultural economic activity (that Member States have to determine with non-discriminatory and objective criteria). For the farmer to qualify, they must also respect the basic social labour rights of farm workers, such as transparent employment conditions and on-farm safety and health (European Commission, 2022). This all has raised questions over the fairness of the distribution system.

Interestingly, wine has (over the last few years) become the highest valued player in agricultural sectors in Italy. The wine sector has the highest farm net value of all of these (figure 31). This could suggest winery faces less challenges in terms of money (perhaps needing less support) than other sectors. However, when including the specific environments this study deals with (mountainous areas) the statistics paint a very different picture. Statistics from the analytical factsheet of Italy on the CAP website (2024) shows the agricultural factor income per worker (Farm Net Value Added per Annual Work Unit) is much lower in areas with natural constraints (ANCs) and especially mountain regions. These are the areas that face difficulties to effectively farm due to specific problems caused by natural conditions. This also includes mountain areas (usually characterized by their altitude, slope, or latitude) (Analytical Factsheet - Italy, 2024, para. 2). The Aosta Valley is considered to belong to this 'area with complex development problems' for 99.3% of the region (The European Network for Rural Development, 2016). Meaning mountainous agriculture does indeed face more economic challenges than low altitude agriculture does.

On the CAP factsheet for Italy it is also visible mountain agriculture has the lowest farm net value in all years except 2014. While other types of natural constrained agriculture and non-natural constrained agriculture surpasses them almost at every year. This is reason for specific attention to these ANCs, and to not give them the same treatments as other regions. In this context, the CAP website does state 54% of the budget of the CAP program that the Aosta Valley receives goes to 'Areas with natural constraints', with the rest going for a large part to 'Agri-environment-climate' (The European Network for Rural Development, 2016). Another detail to mention is that the Aosta Valley's cost of investments in agriculture surpasses Italy's national budget by more than twice the amount. This is due to the difficulty of the terrain they operate in, such as poor access to machinery and lower productivity because of steeper slopes. The same study notes small scale farms do not often benefit from the savings offered by an economic scale (Monzani, 2021).

The Aosta Valley is not only dependent on the CAP program, however. There are several more organizations dedicated to the protection of the territory. The ones in relation to agro-ecosystems are; the Alpine Convention (an international treaty created for protecting sustainable development of the Alps), the Green New Deal (decarbonization of the economy and recognizing the environment as a driver of the economy), Land improvement consortia (maintaining matters such as infrastructure and irrigation), and the Rural Development Program for Aosta Valley; a pillar of the CAP, specified towards the Aosta Valley, such as safeguarding ecosystems linked to agriculture (Monzani, 2021).

The interviewee states that, even outside the co-op organization, people in the Aosta Valley commonly work together to strengthen all vineyards. When asked for an example, the president of Cave Mont Blanc said; "So after winter (because of snowfall) we have to restore some streets or something like that, all the people work to restore this place. Or like in the harvest all the people try to help the others, so it's a system that helps people." Making the winery culture in this region seem quite collective, opposed to a more individualist community.

When the interviewee was asked about his views on the improvement of the help he receives to be resilient, he voiced that he would like to see more informative programs covered by the European Union. Thus, to explain farmers or viticulturists how to be more sustainable in agriculture. The website of the European Commission contains a graph about the amount of training young farmers (under the age of 35) receive over the years. They state improving the educational status of farmers and providing access to professional training remains a priority for policies of sustainable use of natural resources. However, the graph shows there is barely any improvement in the percentage of people receiving training over the years 2010-2020, with basic training decreasing drastically (from 86% in 2010 to 62% in 2020), along with several other forms of training (yet with a less dramatic decrease). Additionally, only 0.1% of the budget the Aosta Valley receives from the CAP program goes towards 'knowledge' (The European Network for Rural Development, 2016).

According to him, there must be much more dialogue between governmental agencies and the farmers. This is because, right now; "It could be difficult to make a system that works with what the European Union wants and what we do here to be sustainable." When asked if the European Union's goals for sustainability are too high to achieve, he states it is not necessarily the height of the goal, but more the ability to demonstrate that he is a viticulturist achieved this goal. He repeats creating more dialogue could help with this problem. The website of the CAP program states that the European Commission does regularly consult civil dialogue groups and agricultural committees so that they can best shape the law and policies that govern agriculture. Expert groups provide their input to the European Commission, like the agricultural market task force on unfair trading practices. But apparently, this is not to the satisfaction of all farmers. The interview done with another viticulturist in the Aosta Valley by Aleffi et al. (2020) mentions that university and business cooperation would also help improve the situation, so that students can bring new techniques to the company, and gain general knowledge from it.

However, money seemed to not be the main challenging factor of Cave Mont Blanc's ability to be resilient. The interviewee mentions the main challenges are the environment, the time to imply sustainable methods of farming, and the access to workforces. Labour is difficult to come by. An interview done with another viticulturist in the Aosta Valley about sustainability possibilities mentioned that one of the major disadvantages for small wineries is the recruitment of staff. Because it is seasonal work, there is a lot of bureaucracy making the system complicated, resulting in the inability for them to hire anyone in that situation (Aleffi et al., 2020). The report from the European Network for Rural Development (2016, p. 1) confirms this, stating; "Valle d'Aosta's main challenges derive from its geographical situation. With the whole territory classified as mountainous, farming takes place under very difficult conditions, mainly in areas with natural constraints. Moreover, the competitiveness of agricultural holdings is affected by an ageing farmer population and the small size of farms." Additionally, the earlier mentioned MOVING project also notes this as one of the main risks in Alpine viticulture. They mention the demographic change is very present in rural areas in mountainous regions. This includes depopulation, abandonment of villages and

facilities and difficulty in generational change in agricultural areas. Nowadays, the combination of farming and tourism plays the biggest role in attracting youth (González-Moreno et al., 2022).

## 6. DISCUSSION

The results gained from the literature review and interview have the potential to provide new insights towards resilient and sustainable vineyard agro-ecosystems in high altitude regions in the Alps. The findings on the effects of disturbances mostly correlate with expectations, being that vineyard/human-introduced disturbances bring along mostly negative effects to the natural environment. However, it was not expected terracing methods could have more positive effects on the environment than negative, and are not deemed as much as a 'disturbance' compared to irrigation and clearance of nature. Therefore it should be considered not all mountainous vineyard practices necessarily have to bring along 'disturbances', but (if managed correctly) can actually find ways to contribute to the surrounding ecosystem. Another unexpected finding was that the difficulty in high altitude farming relied not as much on the environment in the natural sense, but more the availability of workforces and social/economic problems. This means resilience, in the larger implication of the whole combined model of agro-ecosystem resilience, has to be balanced with the social aspects of it when it comes to agriculture in ANCs. It is not just the environmental factor that is important to the resilience system, while that is what this study mainly focused on. Instead, the agro-ecosystem model needs to be considering more factors/dimensions to fully grasp the concept of resilience.

While the European Union works to contribute to the resilience of these viticulturists, it is difficult to gain support from the organizations when owning a smaller business or vineyard. When looking back at the problems illustrated in the introduction, it appears high altitude viticulture is not that much more of a concern than low altitude viticulture in its resilience. While resilience does require more work and more adaptations compared to other more 'standard' places of viticulture, these adaptations viticulturists have taken to be successful in mountainous areas actually seem to be ahead of the rest of the viticulture sector in terms of resilience against (for example) climate change. The conditions of the environment creates challenges, but when achieved it can serve as an example on how we can deal with certain difficulties in these circumstances. The results showed that the natural ecosystem will often suffer in its stability due to disturbances brought by viticulture, but that (if viticulturists take care of the environment) it is possible to co-exist in a possibly resilient agro-ecosystem. This can be done by methods such as terracing, if well-maintained and not leading to abandonment, can even create more places for vegetation to grow, compared to the ecosystem's previous state (such as there being a rock surface present previously). Other techniques like drip-irrigation are sustainable options for water management in these altitudes, with their low levels of water-waste. Even biotic life can be spared due to the use of natural predators or sexual confusion methods, instead of pesticides.

Theories of resilience makes it possible to get a look into how the system interacts and works together with natural and agro-ecosystems. However, it is difficult to exactly determine the level of its resilience without more specific data, field research in a specific area, or more time to study the phenomena. The theories provide a framework that, for this type of research, give a basis/set up to what can be achieved with more tools to analyse it. While the researcher had no budget to physically travel to regions like the Aosta Valley to explore it more detailedly, this provides a good set up for further research in these areas. Like to do experiments and field research that can provide more precise insights into the workings of the system. Still, the findings intersect with the theoretical framework by illustrating how dynamic the connection between disturbances, adaptation and resilience is in agro-ecosystems. The case study in the Aosta Valley shows how it is possible to

introduce sustainable methods against a harsh environment, in the need for the circumstances-specific resilience that the theory calls for. By putting these theoretical concepts into a real-world setting, the research can provide an understanding of the agro-ecosystem dynamics, adding a social dimension of how farmers can deal with this problem.

But, for the studying of more social problems (such as the opinion of viticulturists on their resilience), interviews are still a good option to gain such insights and learn from viticulturists and their experiences first hand. Unfortunately, the researcher has not succeeded in attaining more than one interview. While contacting over 40 viticulturists, there was a lack of response, even when trying other methods to get results and information from them besides interviews. An attempt has been made to turn the second chapter in a more detailed, qualitative case study that studies the specific viticulturist and their methods in depth. This has been done to try and sketch a specific image of a viticulturists, and is therefore not aimed to generalize anything about all viticulturists in a region. To give the case study a bit more depth and quality, existing interviews and data with viticulturists from scientific articles have been added. This can serve to make the case study more reliable than if it were only based on the one interview conducted. The website of Cave Mont Blanc also provided additional information even beside the interview. It must be mentioned however, that there could be potential bias when it comes to the results of the interview. Since a viticulturists doing an interview about sustainability and its interaction with the natural environment will generally want to come off as green and innovative in these topics, as to not spoil the image of their brand. To counter this, the things the interviewee mentions were often checked for its reliability on sites with statistics, or even confirmed with additional interviews found online.

Reasons why the research cannot be 100% reliable, can be because of several factors. For one, the literature review on disturbances and their effects is not absolutely complete. It has been attempted to find as much insights as possible, to determine what we know of the existing disturbances and their consequences, but inevitably, most likely not everything has been taken into account here. Expectedly, there are more different consequences (especially relating to micro-levels, and more biological areas) to the three chosen disturbances than shown here in this study. It has been tried to see if articles not exactly fitting the research area of this study could be applied to this research area, but these are not confirmable, and mostly act as warning signs of what could potentially take place here, if the system was non-resilient. It may also be important to mention the trend of writing research articles that focus mostly on being sustainable and green, which can lead to biases in the articles that appear after a search on certain effects of disturbances. With research often revolving around how agriculture can have negative consequences on the environment, it is likely more of those 'negative' focusing articles appear on top, compared to articles that do not focus solely on sustainability. The researcher did try to look for both negative and positive findings on the three disturbances, but the negatives still outnumbered the positives. This could simply be because those are the facts, but it is difficult to fully check that for its truth without seeing the consequences first hand. Methods to avoid unreliabilities like these, may once again be to physically travel to a research area, to see the effects for oneself, instead of having to rely on previous findings.

This research proves there are both positive and negative consequences to the disturbances high altitude vineyards bring, but that the negative ones are possible to overcome or have to be completely destructive to the natural ecosystem and its resilience. A well-maintained terrace with a considering stance towards biodiversity, can contribute to both agro- and ecosystem resilience. Alike, sustainable methods for irrigation and pesticide treatment can actually be in a healthy dynamic

relationship with the surrounding ecosystems. The consequences of this research may extend beyond the focus on viticulture, with implications about resilience of agro-ecosystems, policy in the agricultural sector, sustainability and regional development. Through the shedding of light on the challenges, opportunities and opinions on the chosen topic, it informs efforts to promote resilience in agricultural systems facing similar conditions. The research highlights it is not only important to look at natural sustainability, but also the engagement of stakeholders in forming policies, and the access to support smaller farmers in this sector need. If the situation is not oversaw correctly or resiliently, there could be self-induced harm to vineyards. Such as when their own clearance of nature causes erosion, which in turn harms the soil on which vines grow. Environmental degradation is therefore important to mitigate, both for the nature itself and agriculture. Furthermore, without helpful and accessible support to farmers by larger organizations, there is a risk of economic hardships, especially in these (often closed-off and remote) high altitude locations. And with economic hardships, it becomes harder to focus on secondary 'luxuries' when it comes to sustainability like towards the protection for bees in using different (non-harmful to biodiversity) pesticides.

Future research could include more specific, on-site investigations in high altitudes, to determine more precisely the damages or positive consequences these (or other) disturbances due to viticulture can bring. It could also go into more long-term effects of viticulture practices, or look into the future in bringing climate change into the topic. Because this research did not go into detail about how the rising of temperatures could change the high altitude environment (and agro-ecosystem), but only used it as a cause/event leading up to the study. As climate change is a continuing trend, this might be useful to investigate further. Exploring alternatives to support small-scale farmers, and looking even more into the social aspect of this topic could also be a helpful future study. Especially when the findings of this study suggest that the problems may not lie as much in the adaptation of viticulture to the natural environment, but more towards the social one in finding labour, money and support. It could also be interesting to do comparative studies across different mountain ranges, to provide insights into the generalizability of the findings here, or find certain differences. Context-specific differences could be helpful to those dealing with more specific problems, which in this case study and general research is more difficult to assess. Even just the fact that, for example; Switzerland is not part of the European Union. This makes the policy in this country (also located in the Alps, and home to many high altitude vineyards) for resilient agriculture very different, and can hardly be included when looking at the findings in the case study on the support farmers receive. Instances like these could invite for more different types of research in both the social and natural aspects of high altitude viticulture.

## 7. CONCLUSION

In this study, it has been explored how the shift of viticulture into higher altitudes affects the natural environment. The chosen disturbances; irrigation, clearance of nature and land alteration through terracing all bring several consequences for the surrounding ecosystem, some more negative than

others. The research question of how the vineyard disturbances effect the natural environment can be answered by analysing what we know of these disturbances. The analysis reveals that irrigation, while often essential to vineyards, can create risks to water resources and local biodiversity. Even in rainier areas like the Alps, viticulturists mention climate change increases the need for irrigation due to droughts. Clearance of nature for the creation of vineyards can disrupt montane ecosystems, creating a loss of habitats due to fragmentation and decreases in biodiversity, risks to soil erosion and potentially hazards like landslides. Although depending strongly on the location and context, terracing presented several more positive changes to the surrounding ecosystems. Like providing more surface and earth depth to create space for vegetation, decrease soil erosion and water retention. However, this is only the case if the terraces are well-maintained, otherwise the very positive consequences can revert back into negatives such as landslides.

All these findings conclude that attention should be given to the consequences of this viticulture shift, and the risk these disturbances bring to the resilience of ecosystems. This calls for sustainable agricultural practices that can reduce or mitigate the negative effects that vineyards bring to mountainous environments, especially because several of the consequences are also harmful to vineyards themselves. Ecosystem services provide support to vineyards, as the natural environment and agricultural works together in interrelated ways. Thus, the next topic explored was how viticulturists view their possibilities in becoming sustainable in the context of agro-ecosystem resilience.

With a case study in the Aosta Valley, interviewing a viticulturists in this region, it became clear the area faces several challenges, and answered the research question of what viticulturists' views are on resilience in this environment. Steep slopes, high altitudes creating demanding work environments and a harsh climate all call for different methods to achieve resilient viticulture. To work in the mountains of the Aosta Valley, viticulturists use practices like drip irrigation (preventing water loss), Pergola systems (preventing water loss) and terraces to create a workable environment in the steep slopes. However, mountains also seem to come with several advantages, such as the decrease in pests and diseases because of the altitude, or how low autumn suns allow for direct sunlight on slope mountain vineyards (extending the growing period). Additionally, several of the techniques mentioned by the interviewee seem to mitigate the negative consequences of their own created disturbances, which could favour the surrounding ecosystem's ability to bounce back after negative changes to its environment, and become resilient. What is a specifically interesting finding, is that it seems the sustainable techniques practiced by Cave Mont Blanc are not made mandatory through the European Union or society, but more so forced exactly by the high altitude environment and the risks the disturbances brings if they do not pay attention to the resilience of the natural environment. Every reason the representative of Cave Mont Blanc mentions for the choice of their system and methods derives from the harsh mountainous environment, instead of being done because of money or time. The surroundings force viticulturists to take care of things such as water resources, soil erosion (being more prone in steep sloping regions) and the maintaining of biodiversity. Alike with the Pergola system. While this method is considered more difficult for workers, the environment pushes for resilience because the colder mountain climate needs the soil to give off heat to the overhanging vines. The pergola system therefore has a lower environmental impact compared to methods that require extensive irrigation. Here, the altitude simply does not allow for a lot of different techniques. A thought deriving from this information could be; are these regions actually ahead of climate change? Do they provide a model for future changes in the environment for lower

altitude regions? Like how the viticulturists are very aware of the risks and methods to mitigate drought and evapotranspiration rates, like using the drip irrigation system.

Still, the case study of the Cave Mont Blanc winery illustrates the strategies and opinions of the local farmers in this region about outside help. Their co-operative strategy allows the multiple small-scaled farmers to access support from larger organizations such as the European Union CAP. However, the interviewee still mentions the difficulties and favouritism towards larger farmers in the system of distribution of subsidies. Technically, the Aosta Valley has a diverse range of earlier mentioned programs, but this does not equal to the farmers being satisfied with the working of the systems.

In conclusion, the agro-ecosystem resilience of the viticulture practices in the Aosta Valley rely on the ability to preserve the positive interaction between the natural ecosystem and vineyards, using traditional and sustainable practices. While it is difficult to compete with non-mountainous regions in this practice, vineyards here can rely more heavily on tourism because of its unique environment. Which could prove to be another motivation to preserve natural ecosystems. The resilience of the agro-ecosystem can however be better achieved if there is more dialogue between the farmers and the European Union's agricultural organizations. As well as more knowledge generated about how farmers can actually build this resilient system, and that they know how to use the tools available to them in this specific environment.

Because of limited labour opportunities and the conditions of the environment being unfavourable to intensification, it is important for subsidies to keep supporting these agricultural practices, as to decrease the land abandonment problems in these areas. Because as mentioned before, land abandonment in the case of terraces can have significant negative impacts on the environment, including nature. Furthermore, tourism seems to be one of the solutions for this abandonment, attracting youth and decreasing depopulation.

The resilience theory framework can in fact help to understand the context of the upwards shift in viticulture; by exploring the disturbances and their consequences, evaluating the farmer's ability to be resilient against the explored risks, and assess if the system can manage in this region.

## 8. APPENDIX

### 8.1 INTERVIEW GUIDE

Hello, thank you for agreeing to do this interview with me, I very much appreciate it. Would you mind if I record the interview, just so I can take the time to listen to the audio again later to make sure I catch all of your thoughts in the right way, and for transcribing purposes? It would not be shared anywhere except for the transcribed texts in my study, read by my thesis supervisors and me. So before we start let me quickly run through some details about the interview, to have you well informed about what you and I will be talking about today. So I'm currently researching how, due to climate change, it's becoming increasingly popular to have vineyards shift up in terms of elevation in mountainous areas. I am researching how this shift could create challenges for both viticulture and the surrounding natural environment, and what viticulturists think about their opportunities in the future of being sustainable in mountainous farming, so how capable or possible it is for viticulturists in this altitude to be sustainable. For this interview to you, I would mostly like to know more about how viticulture operates in the Alps.

The interview should take about 45 minutes, if that's okay with you? Since the interview is purely voluntary you can stop at any moment if you want to. Are there any questions on your mind before we begin?

I'll shortly introduce myself; my name is Fenne Hulshof. I'm a bachelor student at Radboud University, I currently study geography, planning and environment with a specialisation in environment.

First introductory question, could you introduce yourself and what you do in relation to viticulture?

1. Could you tell me about the ways you water your vineyards, do you make use of irrigation, and maybe what types?
  - What makes you choose this type of irrigation/watering over another?
2. What do you think of the technique in relation to sustainability? Like, do you have aspirations on making the technique more sustainable in the future?
  - If not; what keeps you from making it more sustainable? (Is it possible to make it more sustainable?)
3. How much is the natural environment able to interact with your vineyards? (Such as; can native plants or cover crops grow between the vines? Or does that harm the yield?)
  - Do you know if viticulture at this altitude makes biodiversity more or less difficult than at lower heights?
4. What can you tell me about erosion in your vineyards? Especially relating to mountain environments?
5. Do you have opportunities to decrease erosion? (Can it be prevented in mountainous vineyards?)
6. Are vineyards often fenced? Is there free movement in between different vineyards or agricultural fields? And why?
7. What can you tell me about the terracing of your vineyards? (Does it come with challenges in its sustainability? Is it more or less difficult than sloping vineyards?)

- Do you experience advantages or disadvantages about either of these methods?
8. Can your vineyards be mechanized? Do you think this is more or less sustainable?
  9. How well do you think vineyards in mountains can be sustainable, compared to lower altitude vineyards? Are there more challenges, and more difficult to overcome?
  10. Do you experience outside help in this topic? Does the government provide support to encourage viticulturists to be sustainable, and if so in which way?
  11. What do you think would help sustainability in viticulture in your region? (Government support, working together with other viticulturists, etc.)
  12. How would you like to improve the sustainability of your vineyard? And what is potentially keeping you from it? (Money, time, the environment)
  13. Do you have anything to add?

## 8.2 INTERVIEW 1: TRANSCRIPTION

*(F: Fenne (Interviewer), R: Representative of Cave Mont Blanc (interviewee))*

Interview with representative of Cave Mont Blanc

*President of Cave Mont Blanc, Valle d'Aosta*

**Introduction;** Fenne greeting \*anonymous name\* (interview held online through Teams) and explaining the reason for the interview, along with its topics and what I would like to learn from the representative. Asking for permission to record audio, and if he has any questions before we begin. He is fine with the recording, and has no questions, so we begin the interview.

F: Then the first question is just, could you introduce yourself and what you do in relation to viticulture?

R: Okay, so nice to meet you,

F: Thank you

R: So I'm \*anonymous\*, and I'm the \*anonymous\* of Cave Mont Blanc. Cave Mont Blanc is uh a little winery in the Aosta Valley. It is a co-op winery, so we are 70 families that work on 18 hectares of vineyards. We are between 900 and 1200 meters of altitude, so at the moment we are the highest appellation in Europe. We are into the highest ... vineyards, because in the last year in Sicily on the Etna and also in Trentino they make vineyards up to 1300 meters but when we talk about appellation of origin, the highest is ours, it is called Blanc de Morgex et la Salle. Morgex and la Salle are the two little cities where you find the vineyards. And we cultivated just one typology of grape, that is pre-filox grape, the name is Prié Blanc. And you find it just in our area, the total surface is 30 hectares and we work 18 hectares. We produce just white wine, because the Prié is a white grape. Both sparkling and still wine. We produce in the sparkling wine the Metodo Classico, the Champagne method, and the Metodo Charmat which is the Prosecco method. But the grape is only Prié Blanc. And so the cooperative is born in 1983 and so we have 40 years of work in this sector. The system of cultivation is an ancient system, we call it pergola bas, is like uh.. I don't know if you know what is pergola?

F: No I'm not sure.

R: If you want I share the screen and I show you.

F: Oh yeah thank you.

R: \*starts sharing screen and directs to homepage of Cave Mont Blanc website, opens the gallery and shows the following photos:\*



R: So the pergola is this system.

F: Ah okay.

R: So the vine here \*point to the horizontal wooden frames that are held upwards by the stone pillars\*, and that is this system of cultivation. And this is made to keep the grape near to the soil, because we are at 1000 meters so it's not simple to have water in summer. The last year we have a lot of hot summers, but it's not so good for our water.

F: Yeah, and can I ask how do you.. Or do you make use of irrigation? Or is it just the rainfall that you depend on?

R: Uh so the Aosta Valley in general, there is snow in winter that help the plants in summer, because usually in our summer we don't have many rain. The last year the snow reduced in winter so it's a problem. So for the new vineyards we have irrigation, but for the old vineyards we don't have irrigation because the water doesn't exist, so it's not possible to irrigate. The irrigation we use in the new vineyards, because if we don't irrigate it's impossible to work. And this is a problem, so in the Aosta valley we don't have a problem now of water because we have the mountain very near, we have the glacier, but if the climate changing goes in this direction I don't know in ten years what happens.

F: Okay yeah, so when you do use irrigation, is it like sprinklers? Or how should I envision how it works?

R: Uh I don't understand sorry.

F: You said for the new vineyards you do use irrigation right?

R: Yes.

F: And how do you irrigate it? Like what is the system or method?

R: Ah the system is uh 'goccia goccia' that I don't know in English.

F: Oh that's okay, I will look it up later.

R: It is uh.. Just one moment, I search the term of goccia goccia. \*interviewee googles translation\* 'drop by drop system'.

F: Oh yeah I know it. I believe that's a quite sustainable technique, did you aim for a sustainable technique or what is the reason you chose that method?

R: No that method is good because we use low water, and so it is a good system. The problem is that with this system we don't have to exaggerate the water because if you use a drop by drop system the foot of the plant stays up in the soil, they don't go down. So if for a reason we aren't able to use drop by drop, the plant goes in stress and they die. So it's a system that we have to use frequently. And so the problem is that.

F: Okay thank you, so just to move on to the next topic; I would like to know how much your vineyards are able to interact with the natural environment, because of course you deal with very different types of ecosystems around you than like lower valleys. So just, how much interaction is there, can native plants grow in between the vines or do you use cover crops, anything you can tell me about that?

R: Yeah so with biodiversity there is a perfect interaction. Our wine you find it here and in other places you don't find it. The herbs (interviewer assumes he means 'weeds') that grow in the vineyards we just cut, and we don't insert other varieties of herbs to work in the vineyards so. We don't change the biodiversity that we have in our vineyards. I think we have a good interaction between the biodiversity and our vineyards. Another thing, we have eliminated all systems that kill insects. So we use just for our problem uh.. we have a sickness of the vineyards that we call falena (interviewer is unsure about translation or spelling), for English I don't know the name..

F: That's okay.

R: Just one second. \*starts googling term\* So I give you the correct name. The 'moth' (interviewer is unsure about translation), I think, is good.

F: Thank you.

R: Okay and for this insect we used uh.. sexual confusion. Because the product (meaning; the pesticide that they would have used otherwise) that kills the insect also kills the bees, and they are very very important to our biodiversity and environment. So I think at the moment we have a good interaction with our biodiversity and our vineyards. The other thing is that in our region we don't have monocultures, we have different cultures. We have the vineyards, we have the herbs, we have the.. uh.. 'grain'.. \*googles term in English\*. The 'wet', you know what I mean?

F: Sorry no?

F: Oh wheat! Yeah I know.

R: Yes sorry wheat!

F: So does this all belong to you as well? Those other types of agriculture?

R: No,

F: Those are just from other farmers?

R: Yes, but still we have a different cultivation in our area. I don't know if you know like Tuscany or Piëmont, we have vineyards vineyards vineyards,

F: Yeah.

R: Here we have different cultivations.

F: Okay. And do you know if the altitude, this specific height you cultivate in, makes it more difficult to have a biodiverse vineyard? Or does that make it perhaps easier compared to valley vineyards, or like vineyards in Tuscany?

R: The height helps us with the sickness of the vineyards because we have a fresh climate, and so we don't have many problems of sickness. The other thing is that to work in altitude is difficult for the

people. So we have mountains, the vineyards are not in the low valley, so the work is not so simple. All the work is by hand, so we don't have many machinery. I think its better to work in Tuscany, but for the biodiversity it is better to work here.

F: Okay, because I was going to ask about machinery, can you.. uh do you have machines or is it impossible where you are?

R: No so to cut the herb we use little little machinery. But for the harvest, the pruning and the operation on the plants is all by hand.

F: Okay, so do you have terracing vineyards?

R: Yes, also. And we have both terracing and the vineyards without terrace.

F: Yeah, and do you know if there is a lot of difference in sustainability between the terracing and the slopes?

R: Yeah, I don't think.. The terracing, of course we have modified the mountains. So the mountains don't have natural terraces. It is a system that man has built to work. So I think it is an impact on the mountains, but without the terraces we can't plant and the vineyards stop. But the terrace also has the system to cultivate in some place where, if we don't have terrace, we just have rock. So actually we insert a place where the man has the possibility to cultivate the vineyards, but also plants have the possibility to grow, because without terraces you don't find anything.

F: Yeah okay. So I read a lot about erosion and even landslides in terracing compared to slope regions. Do you experience a lot of erosion or landslides with terracing?

R: In mountains the erosion we have every year, so the mountains are made to go down.

F: Hmhm, yeah. And how do you deal with that in your vineyards?

R: Well the terraces is also a system to preserve erosion, because if we don't have terraces all the rocks go down and into the valley. So I think it also helps the erosion. Without terraces, if we have great rainfall we have a problem of erosion, yes.

F: Do you think you can improve the resilience against erosion in the future? Or do you think it's a lasting problem the erosion?

R: No I think.. Hm, I don't know, we can make a system to preserve the mountains and to protect the erosion. But I don't know.. In some areas it's possible, in other areas it is not so simple to work and preserve the erosion.

F: And could I ask what the differences are? Like what makes it more difficult or less difficult to mitigate erosion?

R: It depends. So work in the vineyards here is difficult work, so if we have a lot of people that work we can make he terraces, we can cultivate and so preserve the erosion. If we don't have people it is difficult to work and in some area it is very difficult in terms of accessibility, there I think it's probably difficult to preserve it but the aim is to preserve the maximum soil.

F: Yeah of course. And do you think viticulture in mountainous regions experience a lot more challenges in being sustainable or preventing erosion compared to valleys?

R: Yes! I think yes because, here in the mountains if we don't have active cultivation like vineyards or like other things, the erosion is more frequently.

F: Okay, and do you experience outside help in sustainability, like does the government provide support or encourage viticulturists to be sustainable? And if so in which way?

R: Yes, there is the program of the European Union CAPS. The difficulty of our farmers is that we have low low, little little... uh.. not enterprise. So they are one people that have the enterprise. So the system to obtain the money, to obtain the helps of being sustainable is difficult for little winery and little farmers. So the problem is that. So we have help but to have the help, for a little farmer that has 2000 square meters of soil, doesn't have the help. Because the help is for bigger farmers. So the only problem is that. But the system exists yes.

F: Yeah okay, and in the Aosta valley where you work, are there a lot of little farmers or are there more big companies?

R: Yes, no we have little little farmers. And that is the reason that the co-op system exists. Because the co-op system groups little farmers and they permit them to work. Because for the single people it is very difficult with the system that exists now, it is a bit complex to work if we have just one people.

F: Okay. And is there a lot of interaction between different viticulture companies or little farmers that they help each other out? Or is it really individual people managing their businesses?

R: No they help because they have also.. uhm.. it's better, it works better if we help each other.

F: Yeah okay, and could you maybe tell me in which way you help each other?

R: An example is when we, after the winter, when the snow goes.. when the snow doesn't.. So after winter we have to restore some streets or something like that. And all the people work to restore this place. Or like in the harvest all the people try to help the others, so it's a system that helps people and other people yes, I think.

F: Ah okay, and what do you think would help you being more sustainable the most? Like think of the more government support or more interaction between the different viticulturists, etc..

R: I think yes the interaction, the support yes, the support of the government is important. But I think what is better is to explain what is the sustainability to agriculture.

F: Okay thank you. And how would you in the future like to improve the sustainability of your vineyard? And what is potentially keeping you from it? Like money or time, or just the harsh environment of the mountains?

R: No I think it is the environment. Because money yes, but it is not the.. our image is to preserve the territory, so the aim is that I think. And yes being sustainable is.. the difficulty is the time, because some practice not sustainable they help the work. So the problem is to have time, and people, that are able to work in a sustainable direction I think.

F: Okay thank you. Just something popped into my head, just a general question for me, are your vineyards fenced? Like you said that there was a lot of vineyards and then there is wheat and herbs. Is it all closed off from each other or can you move in between them freely?

R: No you are able to move in between them, but yes they are closed, but you are able to move inside the places

F: Okay like there is a little interaction between those fields?

R: Yeah, a little interaction it has yes.

F: Okay, I think those were my main questions, just going to check. Yeah. I don't know if you maybe want to add something yourself?

R: Uhm.. No I think that.. Just the thing that I can add is yes, being sustainable is the direction to help the world and the environment. But in mountains some practices are now sustainable, and if the system that the European Union imposes in a certain way, it could be difficult to make a system that

works with what the European Union wants and what we do here to be sustainable. So I think we have to create more dialogue between the government/the European Union and the farmers.

F: Yeah okay. So do you think that the European Union is like unachievable, the levels that they want you to be sustainable?

R: Uhm.. Some achievements yes. Some requirements of the European Union are not difficult to do but it is difficult to demonstrate that you have made their goal. So I think if we have more, in the future, more dialogue between the parties is better.

F: Okay, and just wondering if, because you said there were other agricultural practices in the Aosta valley, do you think vineyards have more difficulty or maybe less in being sustainable compared to wheat or herbs?

R: Hmm.. No we don't have much difference in being sustainable from vineyards. Maybe herbs is simple, vineyards are a bit complex, but not so much, so we don't have a very good difference between the two.

F: Okay, well thank you so much. I think I've got most covered, so thank you for doing this interview with me.

R: Thank you too, sorry for my English it's not the best.

F: Oh no actually it's pretty great, I didn't know what to expect but no you were fine!

R: Okay, so uhm thank you and if you come to Aosta valley come visit us!

F: Yes I will! Well thank you very much and have a nice day!

R: Yes you too, bye!

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