DEPARTAMENTO DE CIÊNCIAS E ENGENHARIA DO AMBIENTE

DEPARTAMENTO DE GEOGRAFIA E PLANEAMENTO REGIONAL

CORNELIS VAN VARIK

Licenciado em Geografia, Planeamento Urbano e Ambiente

ASSESSING THE DIFFERENT RISKS IMPOSED BY CLIMATE CHANGE UPON VITICULTURE IN CONTINENTAL PORTUGAL

EEN SLAK OP DE GOEDE WEG, WINT HET VAN EEN HAAS OP DE VERKEERDE WEG

MESTRADO EM URBANISMO SUSTENTÁVEL E ORDENAMENTO DO

Universidade NOVA de Lisboa
Novembro, 2021

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MESTRADO EM URBANISMO SUSTENTÁVEL E ORDENAMENTO DO TERRITÓRIO

Universidade NOVA de Lisboa
Novembro, 2021

Assessing the different risks imposed by climate change upon viticulture in continental Portugal

Dedicated to my friends and family

ACKNOWLEDGEMENTS

I would like to thank anyone who had a direct or indirect influence on my personal and professional development over the course of these 6 months, which not only included professional guidance, but also support from friends and family.

First of all, I would like to thank in particular Professor José Carlos Ferreira, not only for the support and orientation given to me during the creation of this internship report, but for the support given to me throughout the entire duration of the Master's.

This internship would also never have been possible without the help of Filipa Carlos, who not only provided me with the opportunity to follow this internship, but was also there to provide support and guidance, both as a orientator and a friend.

On a personal level, I would like to thank both Nuno Ferreira and his entire family. Your support throughout this year has been really valuable to me. Thank you so much for everything.

And of course my dear family, who I have only been able to see once in these last 2 years because of the Covid-19 pandemic. Thank you so much for all the endless videocalls, I can't wait to see you again.

At last, I also want to thank all my friends that have been part of this chapter of my life in Portugal. Wherever we will go after this Master's, I am sure we will always stay in touch.

I wish you all the best.

Um abraço!

“Een slak op de goede weg, wint het van een haas op de verkeerde weg”
"The snail on the right road will win it from the hare on the wrong road"
(Traditional Dutch saying)

ABSTRACT

The following internship report has the objective of presenting the work that has been done during 5 months within the scope of the non-teaching component of the master's course in Sustainable Urbanism and Spatial Planning, taught at the Faculty of Science and Technology (FCT) at NOVA University in Lisbon.

Over the course of the entire master’s from September 2019 until September 2021, I have developed a special interest in climate change adaptation. The objective of the internship consisted out of assisting and co-constructing the development of a project related to climate adaptation and to learn how to work in a team both on the national and international level.

During the time of the internship, I participated in the EIT Climate-KIC funded project 'MEDCLIV', which envisages to apply experimental and participatory approaches to develop and share solutions and co-built ways of climate adaptation and mitigation within the vine and wine value chain. Most of the activities realized are connected to the development of the platform called Vineas, a co-constructed platform for climate adaptation in the vine and wine sector made by all the participating countries in the Mediterranean.

As the platform Vineas is focussed on identifying possible climate adaptation and mitigation options, the question became pertinent to what extent different wine regions of Portugal (IGP’s) were actually affected by different climate risks. Therefore, a research was set up as part of this internship report to identify the potential climate risk for different parts of Continental Portugal for 5 different hazards. The methodology of this research follows the conceptual framework of the Fifth Assessment Report (AR5) of the IPCC, which states that the total climate risk is constituted through the interplay of the hazards, and the potential exposure and vulnerability. The internship report is ended by a short reflection on the research and the internship followed, which will result in some recommendations for further development strategies for the vine and wine sector and the platform Vineas.

Keywords: Climate risk, climate exposure, climate sensitivity, climate impact, capacity to adapt, climate adaptation, vulnerability, viticulture, collaboration, co-construction.

RESUMO

O seguinte relatório de estágio tem como objetivo apresentar o trabalho desenvolvido durante 5 meses, no âmbito da componente não letiva do curso de mestrado em Urbanismo Sustentável e Ordenamento do Território, ministrado na Faculdade de Ciências e Tecnologia (FCT) da Universidade NOVA em Lisboa. Ao longo do mestrado, de setembro de 2019 até setembro de 2021, desenvolvi um interesse especial na adaptação às alterações climáticas. O objetivo do estágio consistiu em auxiliar e co-construir o desenvolvimento de um projeto relacionado com a adaptação climática e aprender a trabalhar em equipa a nível nacional e internacional.

Durante o período do estágio, participei no projeto financiado pelo EIT Climate-KIC de nominado MEDCLIV, que visa aplicar abordagens experimentais e participativas para desen volver e compartilhar soluções e formas co-construídas de adaptação e mitigação do clima na cadeia de valor da videira.

Uma vez que a plataforma Vineas está focada na identificação de possíveis opções de adaptação e mitigação do clima, a questão tornou-se pertinente em que medida as diferentes regiões vitivinícolas de Portugal (IGP’s) foram efetivamente afetadas por diferentes riscos climáticos. Assim, foi realizada uma pesquisa no âmbito deste relatório de estágio para identificar estes riscos climáticos para diferentes regiões de Portugal Continental. A metodologia desta pesquisa segue o arcabouço conceitual do Quinto Relatório de Avaliação (AR5) do IPCC, que afirma que o risco climático total é constituído pela interação dos perigos, a exposição potencial e vulnerabilidade. O relatório de estágio é finalizado com uma breve reflexão sobre a pesquisa e o estágio realizado, que resultará em algumas recomendações para o futuro.

Palavras-chave: Risco climático, exposição climática, sensibilidade climática, impacto climático, adaptação climática, vulnerabilidade, viticultura

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ACRONYMS

AR4 – Fourth Assessment Report (AR4) of the United Nations Intergovernmental Panel on Climate Change (IPCC).

AR5 – Fifth Assessment Report (AR4) of the United Nations Intergovernmental Panel on Climate Change (IPCC) CMD – Climatic Moisture Deficit

DOP - Denomination of Origin

EIT – European Institute of Innovation and Technology

FCT – Faculdade de Ciência e Tecnologia

GHG – Greenhouse Gases

GIS – Geographical Information System

IG – Indicaçao Geográfica

IGP - Indicação Geográfica Típica

IPCC - Intergovernmental Panel on Climate Change

MAP – Mean Annual Precipitation

MEDCLIV - Mediterranean Climate Vine & Wine Ecosystem.

MAT – Mean Annual Temperature

MSP – Mean Summer Precipitation

MST – Mean Summer Temperature

NUTS - The Nomenclature of territorial units for statistics

RCP – Representative Concentration Pathway

SDG’s – Sustainable Development Goals

1. INTRODUCTION

1.1 Background of the internship

The internship report is one of the official ways to finish the Master's in Sustainable Urbanism and Spatial Planning (MUSOT), just like writing a dissertation or developing a project related to the field of urbanism. As a foreigner who started to learn Portuguese a year and a half ago and the global Covid-19 pandemic happening, it was not easy to find an internship. As my main area of interest is climate change, I sent an email to EIT Climate KIC Portugal to see if there were any projects in development or if there would be the possibility to develop a project together. On the 18th of November an interview took place with Diana Rodrigues from EIT Climate-KIC and Filipa Carlos from FCT-NOVA, which introduced the MEDCLIV project as a possible way to get some valuable working experience.

MEDCLIV stands for Mediterranean Climate Vine & Wine Ecosystem, and was erected in light of changing circumstances in the Mediterranean due to climate change for the cultivation of grapevines (viticulture). As the MEDCLIV project is focused on promoting climate adaptation and mitigation in the vine and wine sector, it touches directly upon spatial planning through the organization of future vineyards and the integration of adaptation/mitigation measures. The project is completely funded by EIT Climate-KIC, a Knowledge and Innovation Community (KIC) working to accelerate the transition to a zero-carbon, climate-resilient society (Climate-KIC, 2020). The project involves 6 countries in the Mediterranean, which are France, Spain, Portugal, Cyprus, Italy, and Slovenia. The following partners are involved in the project:

Italy:

Fondazione Edmund Mach (FEM) (lead partner)
Cons. Nazionale delle Ricerche – Ist. di Bioeconomia (CNR – IBE)

Cyprus:

Cyprus University of Technology (CUT)

France:

l'Institut national de la recherché agronomique (INRA)

Centre International de Recherche Agronomique pour le Développement (CIRAD)

Portugal

Universidade NOVA de Lisboa, Faculty of Science and Technology (FCT NOVA)

Slovenia

National Institute of Chemistry (NIC)

Spain

Universitat Politècnica de València (UPV)

1.2 Positioning of the internship

The MEDCLIV project aims and outcomes are the following: 1) To create a knowledge database, 2) Co-construction of the V&W stakeholders' priorities and viable solutions in «Living Labs» experiences, 3) Converting stakeholders engagement into action by «Learning events» , and 4) Tracking and dissemination of solutions through the MEDCLIV Agrisource platform, and 5) Ensuring the future sustainability of MEDCLIV's activities and stakeholders' involvement. the capacity building and development of the a virtual knowledge platform should contribute to the adaptive capacity of individual farmers, which in turn decreases the vulnerability of the vineyards and the farmers.

According to these objectives, the project MEDCLIV is trying to give 'tools' to farmers (and more broadly to society) to come up with innovative solutions through knowledge sharing and meetings. These solutions could subsequently contribute to new ideas, sharing of best-practices and innovation in the area of climate change adaptation and mitigation, which could subsequently improve the resilience of the viticulture sector to the adverse effects of climate change.

1.3 Objectives of the internship

- Contribute for the definition of an operational platform for knowledge dissemination on climate change and related solutions along the vine and wine value chain;

- Desk research on the current developments (scientific achievements, technical solutions, projects, news, events and other relevant documents) for vine and wine adaptation and mitigation to climate change;

- Attend consortium meetings;

- Prepare, together with the Portuguese national team, the launching of the platform Vineas, including the engagement of new users and contributors;
- Translations between English-Portuguese;
- Learn how to work and analyse geographical datasets.

1.4 Summary of the internship and activities done

- **Host institution: NOVA University**

  - **Department:** Faculty of Science and Technology (FCT)

- **Place:** Due to the Covid-19 pandemic, this internship had to be done partially re motely.

- **Beginning of the internship:** 12th of December, 2020

- **End of the internship:** 12-06-2021

- **Total duration of the internship:** 6 months

- **Total number of hours:** 770 hours

- **Work schedule:** From 8:00 to 16:00

- **Number of hours worked a day:** 7

1.5 Activities undertaken during the internship:

- Analysis of national and international documents and publications about viticulture/vini-culture

- Comprehensive bibliographic research on:

  - Value chain of the viticulture/viniculture sector

  - Adaptation and mitigation in viticulture/viniculture

  - Reviewing legislations, both on the national and European level

- Adding content to the platform:

  - Analysing literature and publications to put on the platform, creating summaries, connecting the documents with relevant actors, projects, solutions, news and events.

  - Creating profiles for all actors related to viticulture and viniculture on the European level and connect them with publications, projects, solutions, news and events.

  - Creating news articles for the platform and connect them with publications, actors, solutions, projects and events

  - Adding relevant projects and connect them with publications, actors, solutions, news and events.

  - Adding new events related to viticulture/viniculture, and connect them with publications, actors, projects, solutions and news.

  - Developing new adaptation and mitigation solution cards

- Desk research on geographical data

- Interview with potential key contributors for the platform

- Research data on the adverse effects of climate change on viticulture, so infographics could be made and generalized for all the participating countries.

- Translation of the entire platform to Portuguese. The entire platform had to be available in all native languages of the participating countries, so all words had to be translated individually in Excel.

- Assisting meetings

  - During the weekly team meetings, we would discuss the progress made and the further improvements for the platform Vineas

  - Private meetings with coordinator, where individual progress and future tasks would be determined.

- The official launch of the platform

  - Pre-preparation of the presentation and the event

  - Giving a virtual journey through the platform, where users could learn how to use the platform, how to create a profile and how to add content.

1.6 Structure of this internship report

This internship report contains 5 different chapters, which are ordered in a linear way. The report begins (chapter 2) by explaining the key concepts related to climate risks, such as vulnerability, exposure, and hazards. These concepts will form the methodology (chapter 3) for determining the final risk for viticulture related to different kind of climate hazards impacting Continental Portugal. After all the different climate risks for the different NUTSIII regions of Portugal have been identified, the report will link this information to the internship followed (chapter 4) with the eventual goal of making conclusions and recommendations which will reflect back on both the research and the internship followed (chapter 5).

2

KEY CONCEPTS AND DEFINITIONS

This chapter is going to introduce the reader to the key concepts and definitions that will be used throughout this research, such as climate risks, hazards, exposure and vulnerability. It is highly recommendable to read this chapter before embarking on chapter 3 (application of these concepts) to thoroughly understand each of the components.

2.1 Climate change

The vast majority of the scientific community agrees that climate change is happening (IPCC, 2014). Even if the entire world would become climate neutral this year, the climate would continue to change over time because of the delayed Earth's respond of greenhouse gases already present in the atmosphere (European Commission, 2021). Nowadays, there is a better understanding of climate trends, which show a growing evidence of the intensity and frequency of extreme weather events. To cite Working Group 1 of the IPCC (2013, p.7): "*Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased*". The authors Denton et al. (2018) state that climate change is currently only a moderate threat to current sustainable development, but will become severe threat to future sustainable development. This is also confirmed by the IPCC (2014), it is likely that the impacts of climate change over the next decades will become more severe because of the ongoing warming of the earth's atmosphere. Even though it is essential to know the expected climate trends for the future, it is only one part of the final equation to determine the final adverse risks posed upon our society by these climatic impacts.

2.2 Climate risks

According to the European Commission (2014), there is an increasing demand policy makers and the business sector on both the global, regional, and local level to understand the determinants of climate risks, just as viable metrics and policy options to mitigate these risks. But what is exactly meant with 'risk'?

The official Cambridge Dictionary (2021) defines risk as: "*The possibility of something bad happening*", which closely resembles the definition of a climate risk. Alternative definitions used are "*danger, or the possibility of danger, defeat, or loss*" and "*A risk is also someone or something that could cause a problem or loss*" (Cambridge Dictionary, 2021). When it comes to the technical literature, risk is often seen as a quantitative combination of the likelihood and consequences associated with the hazard. According to Pidgeon and Butler (2009, p. 9), approaches to risk often consist out of 4 elements: Problem framing (the problem is structured), risk assessment (quantitative evaluation), risk management (policy options) and risk communication (communication with stakeholders for various different purposes). To continue, social theorist have examined risk in terms of its wider implications for society, like a new way of thinking or a rationality that shows itself in several different forms (Pidgeon and Butler, 2009). The same authors state (2009, p. 9) that new regimes for risk management is capable of transforming social lives, such as through governance, social integration, self-identity, morality and value-based reasoning. The AR5 (2014, p.1772) of the IPCC defines risk as:

> "*The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability, exposure, and hazard. In this report, the term risk is used primarily to refer to the risks of climate-change impacts*".

Examples of these risks include severe weather impacts, such as heavy precipitation, cyclones, large storms, and heat and cold waves. The final risk for human and economic assets could be substantial diminished through the integration of prevention measures, preparedness, and early warning systems (European Commission, 2014). Different models are used to assess risk and vulnerability related to the changing climate, such as the model from the AR5 from the IPCC (figure 1). The model of the IPCC shows that the total risk is defined through the interplay of hazards, vulnerability and exposure, together with changes in the climate and socioeconomic processes. These 3 components will also be subsequently used for the methodology of this research (see chapter 3). The upcoming chapters are going to give a detailed explanation of each of these concepts.

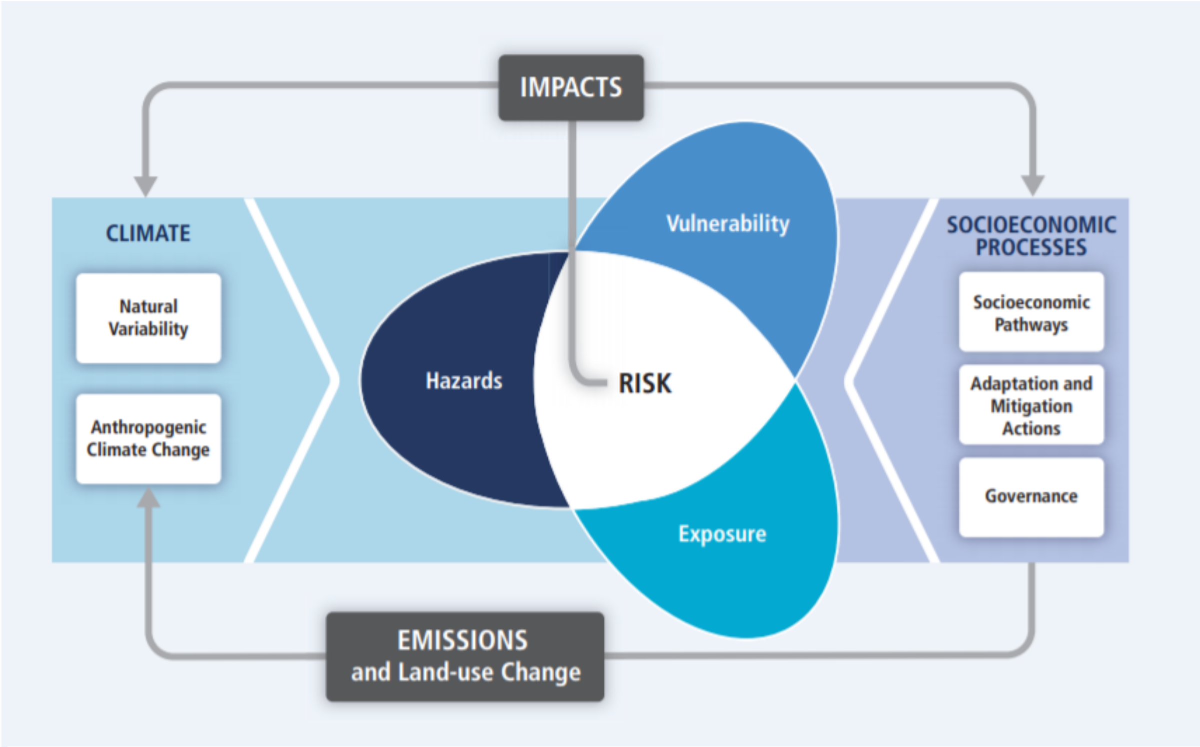

Figure 1: The conceptual framework of climate risks. The total climate risk is constituted by the hazards, vulnerability and exposure. The hazards are influenced by the natural variability of the climate, just as the anthropogenic CO_2 emissions. The vulnerability and exposure are in turn influenced by the socioeconomic pathways, adaptation and mitigation actions and governance. Source: IPCC (2014, p. 37).

2.3. The three components of climate risks

2.3.1 Vulnerability

Vulnerability is a key concept in the climate change context. A large research field has been created around the meaning of vulnerability since article 4 of the United Nations Framework Convention on Climate Change (UNFCCC) stated that country Parties should commit to "assist the developing country Parties that are particularly vulnerable to the adverse effects of climate change in meeting costs of adaptation" (United Nations, 1992).

However, even after decades of research, scholars have not yet been able to agree on the meaning of the term vulnerability (Hinkel et al., 2012). This is partly due to the many different disciplines (e.g poverty, ecology, and development studies) using it, which led to a myriad of different definitions and methodologies (Cutter, 1996). Whereas the scientific use of the word vulnerability originated in geography and natural hazards research, it is now widely used in other disciplines as well, such as disaster management, poverty, development studies, public health and climate change adaptation and mitigation (Füssel, 2010). According to the same author, the term vulnerability has been used by that many academic communities in that many different ways and definitions, that the term has become useless in an interdisciplinary context without any further specification.

So how could vulnerability best be defined? Vulnerability is the property of being vulnerable. The ordinary use of the word vulnerability could best be understood by the definition of the Oxford Dictionary of English, which describes vulnerability as '"*exposed to the possibility of being attacked or harmed, either physically or emotionally*' (Soanes and Stevenson, 2005). These chains are officially grounded in the AR4 (Fourth Assessment Report) of the IPCC to define climate vulnerability, which is seen as a factor of the exposure, sensitivity and adaptive capacity. The official definition of the IPCC for vulnerability is (2001, p. 995):

> "*The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity*".

This official definition has changed in the AR5 (IPCC, 2014, p.5) into:

> *"the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts including sensitivity or susceptibility to harm and lack of capacity to cope and adapt"*

Two different conceptualizations of the term vulnerability can be highlighted from the climate change literature: Outcome vulnerability and contextual/social vulnerability (Füssel, 2009). Whereas the first interpretation considers vulnerability as the outcome exposure to a specific hazard, the second interpretation is more focused on the internal characteristics of the system of community (Füssel, 2008).

Just like the exposure, the vulnerability is highly dynamic, and varies between different temporal spatial scales, and is influenced by the demographic, cultural, governance, institutional, economic, social, environmental, and geographic characteristics (Cardona et al., 2018). It is important to point out that some societal development paths not only have the capacity to potentially reduce the vulnerability of a system or element in the future, but also to increase it (Smith et al., 1999). Examples where systems could become more vulnerable in the future, include urbanizing coastal flood plains, deforestation of hill slopes, or building in risk-prone areas. In contrast, the vulnerability could also be decreased through building institutional and technical capacity to address climatic hazards. The most vulnerable are systems that are highly exposed to the hazards of climate change, with only a limited capacity to adapt, such as through low economic resources, poor infrastructure, or low levels to information and technology (Smit & Pilifosova, 2018).

The vulnerability used to be calculated by the Fourth Assessment Report (AR4) of the IPCC (2007) through the interplay of both the potential impacts (which is constituted out of the interplay of the hazards and sensitivity) and the adaptive capacity (see figure 2).

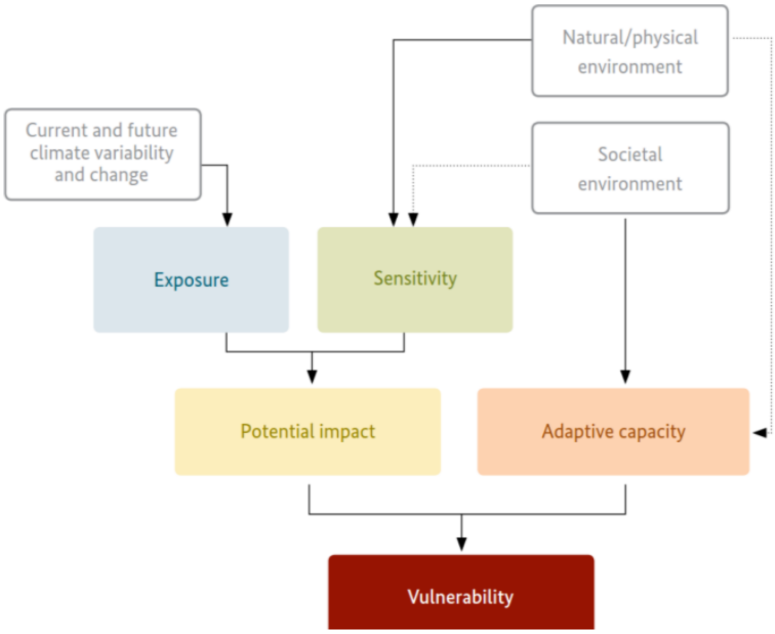

Figure 2: Conceptual framework for climate vulnerability as part of the AR4 of the IPCC. Source: Zebisch et al. (2017).

The fifth assessment report (AR5) of the IPCC (2014) shows a new operationalization of the term vulnerability, which replaces the vulnerability framework of the AR4 mentioned before. The AR5 introduced a new concept of climate risk, which is closer to the disaster risk community than the AR4. The exact difference could be seen in figure 3, which shows the difference between the AR4 and AR5. As could be seen below, the AR4 describes vulnerability as the final result of the exposure, sensitivity, potential impacts and adaptive capacity, whereas the AR5 describes vulnerability as only one of the 3 components (together with 'hazards' and 'exposure') of calculating the final risk. Important in this regard is that the concepts of sensitivity and adaptive capacity are now part of the vulnerability, which used to be separate variables. Risk in this sense could best be understood as the risks to the impacts of climate change, which results from the overlap of potential hazards from the physical climate and the exposure and vulnerability of people, ecosystems and assets.

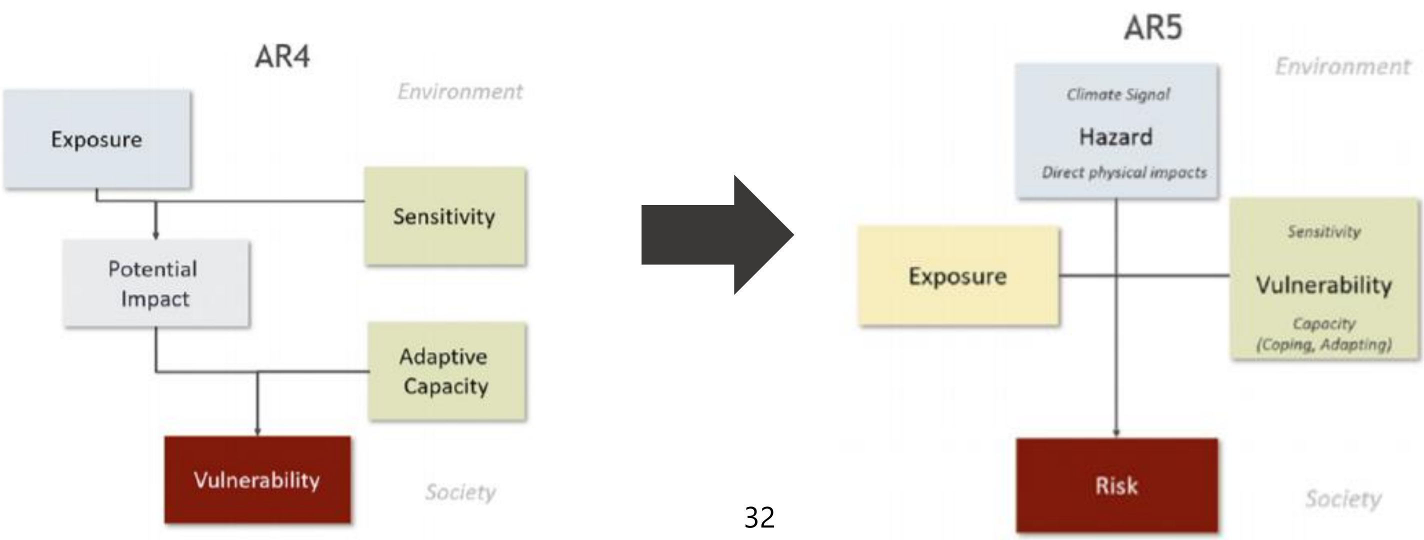

Figure 3: The difference between the conceptual frameworks of the AR4 and AR5. Source: Zebisch et al.(2017).

Adaptive capacity

As became visible in figure 3, the adaptive capacity has become an integrated part of the vulnerability in the AR5.

Adaptive capacity is officially defined as (IPCC, 2014, p. 1758):

> *"The ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences".*

The authors Brooks & Adger (2004, p. 168) describe adaptative capacity as:

> *"The property of a system to adjust its characteristics or behaviour, in order to expand its coping range under existing climate variability, or future climate conditions"*

Put in different words, the adaptative capacity could best be described as the ability to design and implement adaptation strategies to reduce the magnitude of the climate hazards. The authors Akku and Lynam (2010) state that the adaptive capacity could best be described as 'latent' or 'potential' adaptation.

Important in this regard is to point out that the adaptive capacity varies strongly between different regions, communities, systems, and changes over time (Smit & Pilifosova, 2018). This is also confirmed by Akku and Lynam (2010), who state that the adaptive capacity is dynamic and context-specific, just as stating that the adaptive capacity is fundamentally dependent on access to resources. Therefore, Improving the adaptive capacity could often be jointly implemented with equity goals, such as the Sustainable Development Goals from the Agenda 2030.

Potential indicators mentioned by Climate-ADAPT (2021) are statistics about income, education, availability of climate data, appropriate emergency response, business continuity schemes, and overall adaptation plans and strategies. Other factors that could also make an important influence is experience in leadership and administration. Important in this regard is the scale: Local and regional adaptive capacity may be significantly different from the national adaptive capacity (Climate-ADAPT, 2021). While the adaptive capacity of a specific region or city plays an important role in the mitigation of the damage or loss caused by the exposure, recent sources also note the implication of adaptive capacity in attracting business and finance, as adaptive capacity is more and more integrated in credit ratings and screening processes (Preudhomme, 2019).

The literature about adaptive capacity makes a clear difference between the adaptive capacity of natural systems and the adaptive capacity of social systems. Ecological adaptive capacity is the latent potential of an ecosystem to alter resilience in response to change (Angeler et al., 2019), which is more related to the ecological adaptive capacity of an ecosystem.

In contrast, the social adaptive capacity is more related to the ability of humans and communities to respond to (future) change and maintain well-being (Smit and Wandel, 2006). Improving the adaptive capacity of systems could directly and indirectly improve the vulnerability of systems, regions and communities (Smit & Pilifosova, 2018). It is important to note that many activities that could improve the adaptive capacity, could also contribute to the sustainable development goals (SDG's).

<u>Sensitivity</u>

Just as the adaptive capacity, also the component of sensitivity is now an integrated component in the vulnerability of the AR5. The sensitivity is officially defined as (IPCC, 2014, p. 1772):

> "*Degree to which a system or species is affected, either adversely or beneficially by climate variability or change. The effect may be direct (e.g., change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea level rise)*".

If the asset is not able to sustain and resist the negative impact of a specific climate hazard, it is generally thought to be sensitive to this type of hazard. In the example of the IPCC about coastal flooding, a furniture store may be vulnerable to flooding, whereas a parking lot may experience minimal/no negative impact from the same flooding (U.S. Climate Resilience Toolkit, 2021).

This is also confirmed by Yu et al. (2021), who state that the pre-existing sensitivity consists out of the intrinsic characteristics or conditions, with the specific example of people that are more likely to be affected by a higher exposure to climate change such as age or people having pre-existing health conditions.

2.3.2. Exposure

The second component of the total climate risk is exposure, which is defined as (IPCC, 2014, p. 1765):

> "*The nature and degree to which a system is exposed to significant climatic variations*".

This definition is complemented by the definition of the AR5 (IPCC, 2014, p. 39), which defines exposure as:

> *"The presence of people, livelihoods, species or ecosystems, environmental services and resources, infrastructure, or economic, social, or cultural assets in places that could be adversely affected by a hazard".*

Put in different words, exposure refers to the presence of specific elements in an area where specific hazard may occur. In this sense, if no systems or elements (e.g. population or economic resources) are present in the area, the exposure to climate hazards will also be low/non-existent. By contrast, if many systems or elements are present in an area highly affected by climate change, the subsequent exposure will be high.

The exposure is highly dynamic, varies between different temporal spatial scales and is influenced by demographic, cultural, governance, institutional, economic, social, environmental, and geographic characteristics (Cardona et al., 2018). According to the same author, one of the biggest issues in literature is the common conflation of the terms exposure and vulnerability, even though these terms have a clear difference. To be vulnerable to a certain hazard, one needs to be exposed, but it is also possible to be exposed to a climate hazard, but not be vulnerable.

2.3.3. Hazards

The word hazard is commonly used to describe something dangerous and like to cause damage (Cambridge Dictionary, 2021), which closely resembles the definition of the term in climate literature as well. The hazards are officially defined by the IPCC (2014, p. 1766):

> "*The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources. In this report, the term hazard usually refers to climate-related physical events or trends or their physical impacts*".

The U.S. Climate Resilience Toolkit (2021) defines hazards as:

> "*An event or condition that may cause injury, illness, or death to people or damage to assets*".

Examples of these climate-related physical events, trends and impacts include storms, droughts, floods and heavy rainfall. Whereas these events occur mostly once as an extreme event, the hazards also include the more slowly and gradually developing climatic variations, such as potential shifts in climatic regimes or future changes in the mean values of specific climate variables.

3.
CLIMATE RISKS

This chapter is going to apply the key concepts and definitions discussed in chapter 2 to the sector denominated as ' viticulture' (cultivation of grapes) in Continental Portugal. This chapter contains the research part of this internship report, which has the objective of providing a detailed contextualization of different climate risks associated with different hazards threatening Portuguese viticulture. Reading this chapter before embarking on chapter 4 about the internship is essential to understand the relevance and objectives of the internship followed. This chapter will begin with a short introduction and characterization of the vine and wine sector in Continental Portugal, followed by the exact methodology of the research, which is based on the conceptual framework of the AR5 of the IPCC. Each and one of the components (exposure, hazards and vulnerability) of the AR5 will be operationalized (chapter 3.2) and subsequently applied to the vine and wine sector in Continental Portugal (chapter 3.3, 3.4 & 3.5). The chapter is ended with the final results (chapter 3.6 and 3.7), which are the maps that show the final risk for different kinds of hazards for different NUTSIII regions and Portuguese wine regions. It is highly recommendable to read chapter 2 before embarking on this chapter, as all the concepts are explained and discussed here.

3.1 Global characterization of the vine and wine sector

3.1.1. Introduction

Perhaps one of the most iconic part of viticulture are the vineyards planted on deep slopes, a practice which dates back until the Roman Times (Strub & Loose, 2021). The grapevine belongs to one of the traditional Mediterranean crops with an immense cultural, economic and ecologic importance, together with wheat and olives (Ponti, Boggia, Neteler & Gutierrez, 2018). The cultivation of grapevines, or viticulture, is socially, culturally and economically important for the stability of the Mediterranean. According to Santillán, Sotés, Iglesias and Garrote (2019), the Mediterranean vineyards represent a livelihood for millions of farmers and wine industry workers. The preservation of the grape is therefore fundamental for the social, cultural and economic stability of the Mediterranean.

3.1.2. Viticulture around the world

Most of the vineyards are located between the 35th and 50th parallels in Northern Hemisphere and between the 30th and 45th parallels in the Southern Hemisphere (Van Leeuwen & Darriet, 2016). Especially the South of Europe, denominated as the Mediterranean, seems to be characterized by a high number of vineyards. According to the Statistical Report of the OIV (2019), the countries with the highest areas 'under vines' destined for the production of wine grapes in 2018 are Spain (969 thousand ha or 13%), China (875 thousand ha or 12%), France (793 thousand ha or 11%), Italy (705 thousand ha or 9%), and Turkey (448 thousand ha or 6%). These 5 countries make up 51% of the world's total wine production. Europe currently has the largest vineyard area in the world, even though vineyards in other parts of the world are quickly growing, for example in the USA, China and the Southern Hemisphere (e.g. Argentina, Australia, Chile & South Africa) (Fraga, 2019). Portugal accounts to 2,58% (969 ha) of the total vineyards of the world (7449 ha) in the year 2018. Interestingly enough, the total area of vineyards in the world is slowly diminishing (±1%), with Portugal ranking the highest (-14%) after Iran (-29%) for the year 2018 (OIV, 2019). Of the total wine production, 57% is classified as wine grape, 36% as table grape, and 7% as dried grape, with the production in Europe (and Portugal) mainly focused on producing grapes for wine production.

3.1.3 Viticulture in Continental Portugal

The wine sector is historically one of the most relevant socioeconomic activities in Portugal (Fraga et al., 2016). The country offers diversity and singularity of grapes and terroirs, with a very consistent quality and excellent value for money. As a result, there is a high international demand for the Portuguese wines. According to the statistics of ViniPortugal (2021), the total wine export had a value of 820 million in 2019, representing 45% of the total national wine production.

The grapes can be produced in the most varied climatic conditions in Portugal, the local situation (climate, soil, topography, etc.) determines which type of vine is possible to be cultivated and which types of vineyards are not possible to be cultivated. The climatic conditions of the vineyard are the main driver of the *typicity* of a specific type of wine, a term used to indicate the degree to which a wine reflects the signature characteristics of the grapes. In theory, as each vineyard is characterized by unique characteristics and circumstances, it is not possible to replicate the same typicity in another region or territory (Gonzaga et al., 2020). According to Fraga et al. (2016), there are currently have 300 authorized varieties of wine in Portugal. The most common is the Aragonez / Tinta Roriz variety (also known under the name 'tempranillo'), followed by Touriga-Franca, Castelão, Fernão-Pires and Touriga-Nacional.

The total agricultural area used for viticulture in the South (the provinces of Alentejo and the Algarve) is around 1%, the Centre more than 8% and the North around 2-4% (Eurostat, 2017). This means that most vineyards are located in the Centre and in the North of the country, the Douro region is by far the region with the highest production of grapes and wine (IVV, 2021). According to the official data of the International Organisation of Vine and Wine (OIV), the total wine production between 2009/2010 and 2019/2020 has grown by 10,74% (from 5,893,513 to 6,526,562), but there are substantial differences in growth between the difference wine regions. Whereas most wine regions saw an increase in wine production, the regions of Minho (-5,83%), Beira Atlântico (-35,53%), Terras de Dão (-13,45%), Algarve (-41,12%), Madeira (-15,16%) & the Azores (-3,69%) saw a decrease in wine production (see chapter 3.3). Whereas the total export of wine showed an increase of 41,95% between the year 2007 (595,987) and 2020 (846,016), the total of wine imports between 2007 (63,257) and 2020 (162,766) showed an increase of almost 157,31%!! Interestingly enough, the rise for both the export and import is substantially higher for countries outside of the European Union: The total export within the European Union has decreased by -0,93% (against an increase of +124,54% for outside the EU), and total import increased with 156,66% (against +228,13% for outside the EU). When it comes to the wine consumption, Portugal has seen a steady growth of 2% (1.8-2.2%) between the year 2000 and 2018, which seems to be quite low compared to other countries in the Mediterranean like Spain (4,92%), Italy (10,45%), and France (12,69%) (see Annex 3).

As the production of grapes is strongly dependent on climatic conditions, climate change could potentially have a significant impact on the grape quality and quantity. Both opportunities and challenges could be identified, such as regions in the North of the European Union (e.g. Alsace, Champagne, Bordeaux, Bourgogne and Loire Valley), who are able to produce higher quality wines due to the rise in temperature. This is also confirmed by the National Confederation of Agricultural Cooperatives and Agricultural Credit of Portugal (2019), who state that countries like Belgium and Germany are continuing to plant more vineyards. Within a range of 10-20 years, there will even be countries producing grapes that are currently characterized by climates not suitable for vineyards, such as England or Scotland!

According to Fraga et al. (2013), regions in the South of the European Union will be less suitable for wine production, which can be explained by the increase in extreme events (e.g. droughts) and the increase in the water deficit. As the vines are sensitive to changes in climatic conditions, a minimal change in one of the climatic factors could already have direct consequences for the quality and number of grapes (Silvestre, 2016; Pinto et al. 2013), which in turn could have severe economic consequences, given that the wine sector is one of the most important agricultural sectors in Portugal. Because of this, climate change has become one of the most important topics of viticulture and oenology literature over the first 2 decades (Van Leeuwen et al., 2019).

In order to learn more about the possible effects of climate change on viticulture in Continental Portugal, a research was set up based on the AR5 of the IPCC (2014). The next section (3.2) contains the methodology of this research.

3.2 Methodology

3.2.1 The conceptual model

As mentioned before, the conceptual framework of the AR5 of the IPCC (see figure 1 and 2) is used as a backbone to operationalize the concept of risk for this research. A total of 10 hazards were identified for the viticulture sector: Maximum annual temperatures (MAT), High rise in temperatures (MAT), maximum summer temperatures (MST), high rise in summer temperatures (MST), minimum annual precipitation (MAP), High annual decrease in precipitation (MAP), minimum total summer precipitation (MSP), High annual decrease in summer precipitation (MSP), High total annual moisture deficit (CMD) and High annual increase in moisture deficit (CMD). The exposure is determined through determining the location of the Portuguese wine regions (IGP's, DOP's and subregions) and calculating the current production for all the NUTSIII regions. The last component, vulnerability, is determined through data made available by ESPON (2012). To calculate the final risk, the following formula is applied:

Climate risk = Hazard x Exposure x Vulnerability

The exact data sources and methodology for each variable can be found in the respective chapter dedicated.

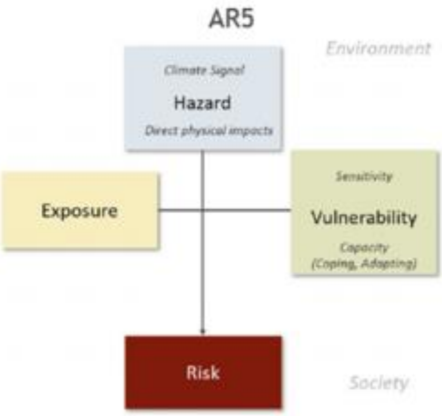

Figure 3: Methodology Is based on the AR5 of the IPCC. Source: Zebisch et al.(2017).

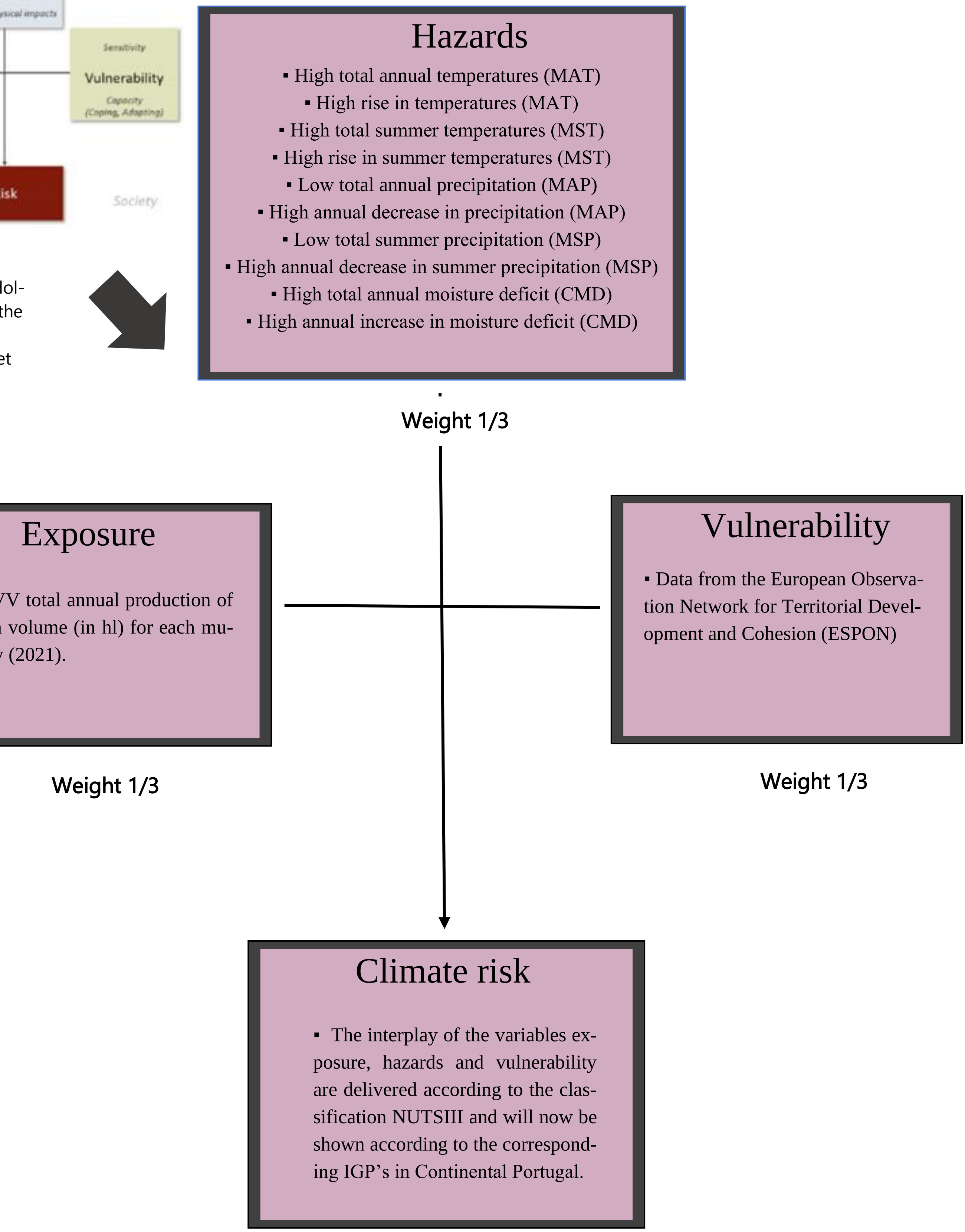

Figure 4: Methodology to calculate the climate risks to the correspondent hazards. Source: Own figure.

3.2.2 Visualization of the results

The following pages will show a variety of different choropleth maps to assess the hazards, exposure, vulnerability and final risk, which will be the main visualization method of this internship report. All these maps are made in the software QGIS, an open source Geographical Information System (GIS)[1]. Throughout the internship report, the steps that are used to undertake a specific technical visualization or data analyzation method are stated between brackets. All of the data used in this research is freely available online, with the reference link provided to the specific dataset.

All data is visualized through the Nomenclature of Territorial Units for Statistics III (NUTSIII), a hierarchical system for dividing up the economic territory of the European Union. Part of the objectives of this classification system is not only the collection, development and harmonization of European regional statistics, but also to perform socio-economic analysis of the different regions (European Commission, 2021). The NUTS classification consists out of three different levels: NUTSI (major socio-economic regions), NUTSII (regions for the application of regional policies) and NUTSIII (small regions for specific diagnoses). For this specific research, it was chosen to work with the classification of NUTSIII, because this classification system delivers more detailed results than working on the level NUTSI, NUTSII, or the official wine regions (called IGP's) of Continental Portugal. This is due to the fact that the NUTSIII regions are smaller in size, which allows the reader to see the spatial variety and difference of the hazards, exposure, vulnerability and total risk within the respective IGP's.

A map (figure 5 - Left) was made in QGIS to show the difference between the NUTSIII regions and IGP's for Continental Portugal. The dataset for the NUTSIII regions comes from Eurostat (2021) and is freely accessible here[2] as a shapefile (.shp). This shapefile was subsequently added to GIS (Data Source Manager > Vector > Add Vector dataset), followed by the exclusion of all the NUTSIII regions that were located outside Continental Portugal (Show attribute table > Toggle Editing Mode > Delete Selected Features). Subsequently, the colours were added (Symbology > Categorized > Classify > Random Colours > Reduce brightness of the colours manually) and the labels (Symbology > Labels > Single Labels > Value: 'Name' > Buffer: Draw Text Buffer > Mask: Enable Mask > Placement: Add X and Y coordinates > Apply). The X and Y coordinates had to be added to move around the labels that got misplaced automatically by the algorithms, the easiest way to solve this is to put the X and Y values manually in the attribute table (Toggle Editing Mode > New Field > Repeat this for both X, Y and R). After this is done, and the X, Y and R coordinates have been added (Symbology > Labels > Single Labels > Placement: Add X and Y coordinates > Select the columns X, Y and R from the

1 https://qgis.org/en/site/forusers/download.html
2 https://ec.europa.eu/eurostat/web/gisco/geodata/reference-data/administrative-units-statistical-units/nuts

attribute table), now it is possible to move the labels around (Label Toolbar > Move a Label or a Diagram).

The second map (figure 5 - Right) shows Continental Portugal according to the official Portuguese wine regions. The data is both freely available on both the website of the IVV and in Portuguese law. In order to select and group all relevant administrative units into the correct formation of the Portuguese IGP's, a dataset needs to obtained with all the administrative units of Continental Portugal. This data ('Unidades administrativas de Portugal') comes from the website ForestGIS, which can be accessed here[3]. The data is delivered in shapefile (.sph) format, which can be uploaded into QGIS (Data Source Manager > Vector > Add Vector dataset). Through a process of selecting all the districts, counties and municipalities (Attribute table > Show All Features > Advanced Filter > Fields And Values > Select the right districts, counties and municipalities) and subsequently create a separate layer out of the selection (Export > Save Selected Features As), the IGP's for Continental Portugal could be created. After having saved the files, the clip function was used to 'clip out' (Vector > Geoprocessing Tools > Clip > Input: Map Continental Portugal without administrative units > Overlay layer: Newly created IGP) all the unnecessary counties (concelhos) through using a map of Continental Portugal (without any identification of counties or districts) as a base layer. This map can also be found on the website ForestGIS under the name Gadm36_PRT_3.

3 https://forest-gis.com/2012/01/portugal-shapefiles-gerais-do-pais.html/

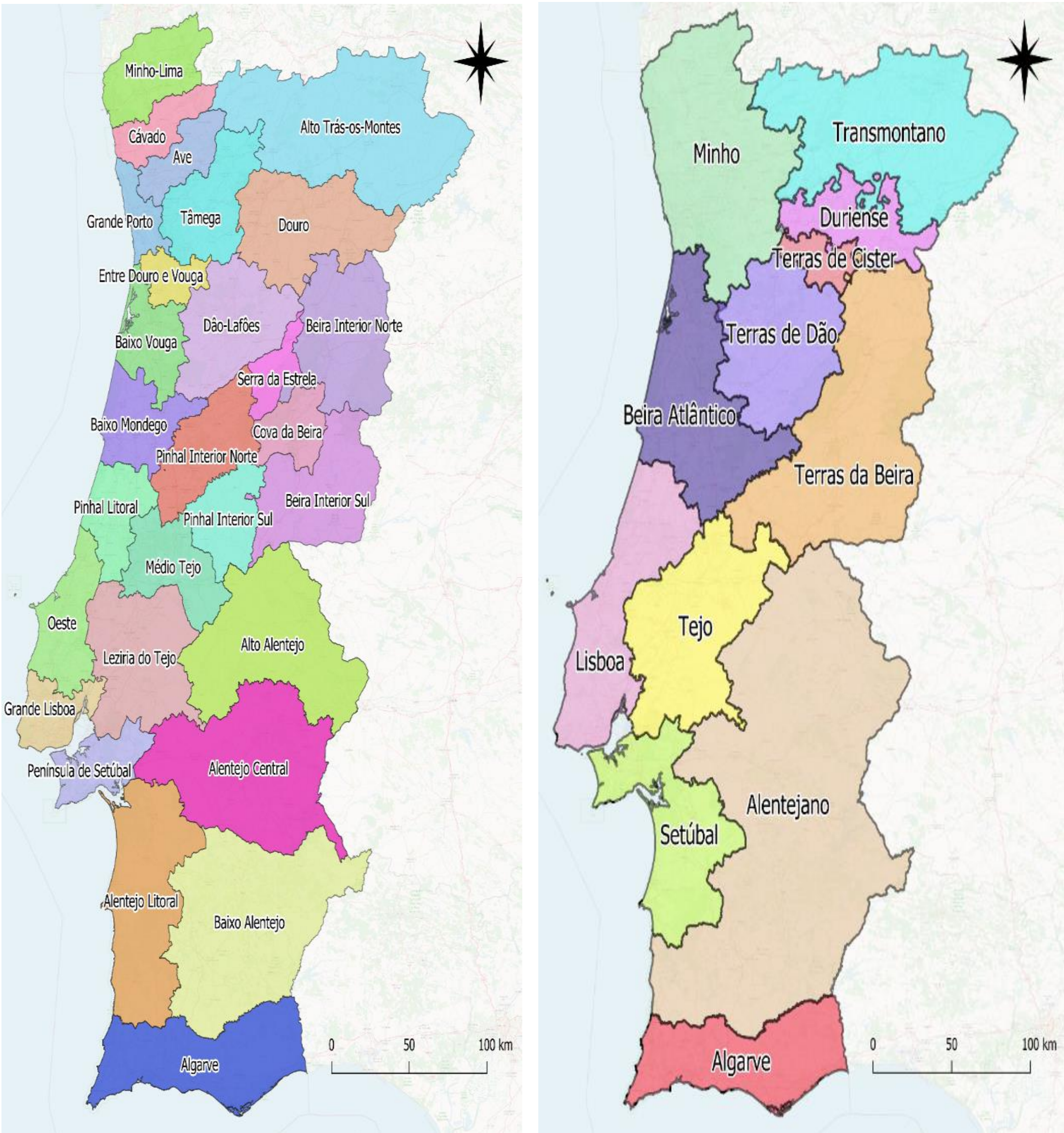

Figure 5: Continental Portugal according to the classification NUTSIII (left) and the IGP's (right). Source: own creation, data sources from Eurostat (2021) and IVV (2021).

The last map (figure 6) shows the combination of the two different classification methods (NUTSIII and the IGP's), to clearly see the difference between both. The same map for the NUTSIII regions is used, but this time without labels (Properties > No Labels) and with a transparency of 50% (Properties > Symbology > Opacity). On top if this layer, the boundaries of the IGP's are placed (Properties > Symbology > Simple Fill > 'Symbol Layer Type' = Outline: Simple Line > Change Stroke Width: 0.7), so now the difference between the NUTSIII classification and Portuguese IGP's can be clearly seen. It is clearly visible that the IGP's are generally larger in size, often making up several different NUTSIII regions, even though also larger NUTSIII regions exist (Douro & Península de Setúbal). Most of the IGP's follow the same boundaries (e.g. *IGP Algarve*, *IGP Alentejano* and *IGP Península de Setúbal*), but this is not always the case. Examples include Pinhal Interior Norte (*IGP Terras de Beira* and *IGP Beira*

Atlântico), Entre Douro e Vouga (*IGP Vinho Verde* and *IGP Beira Atlântico*) and Médio Tejo (*IGP Lisboa* and *IGP Tejo*).

Both of these classification systems will be used throughout this internship report. The data is gathered on the NUTSIII level and subsequently visualized with the boundaries of the Portuguese IGP's. One region requires special attention, which is the NUTSIII region of Douro, which includes both the *IGP Terras de Cister and IGP Douro*. Together with Alto Trás-os-Montes and Península de Setúbal, these are the only NUTSIII regions smaller than the IGP's for Continental Portugal. This should be duly taken into account, since the *IGP Terras de Cister* and *IGP Douro* will always seem to have the same value in the maps because these are joined together as one region in the NUTSIII classification (see figure 5 and 6). To clearly distinguish between NUTSIII regions and IGP's throughout the text, any spatial reference will always clearly state if the respective sentence is about the NUTSIII regions or IGP's. To facilitate the legibility for the reader, the IGP's are always put in *italics* throughout the entire internship report.

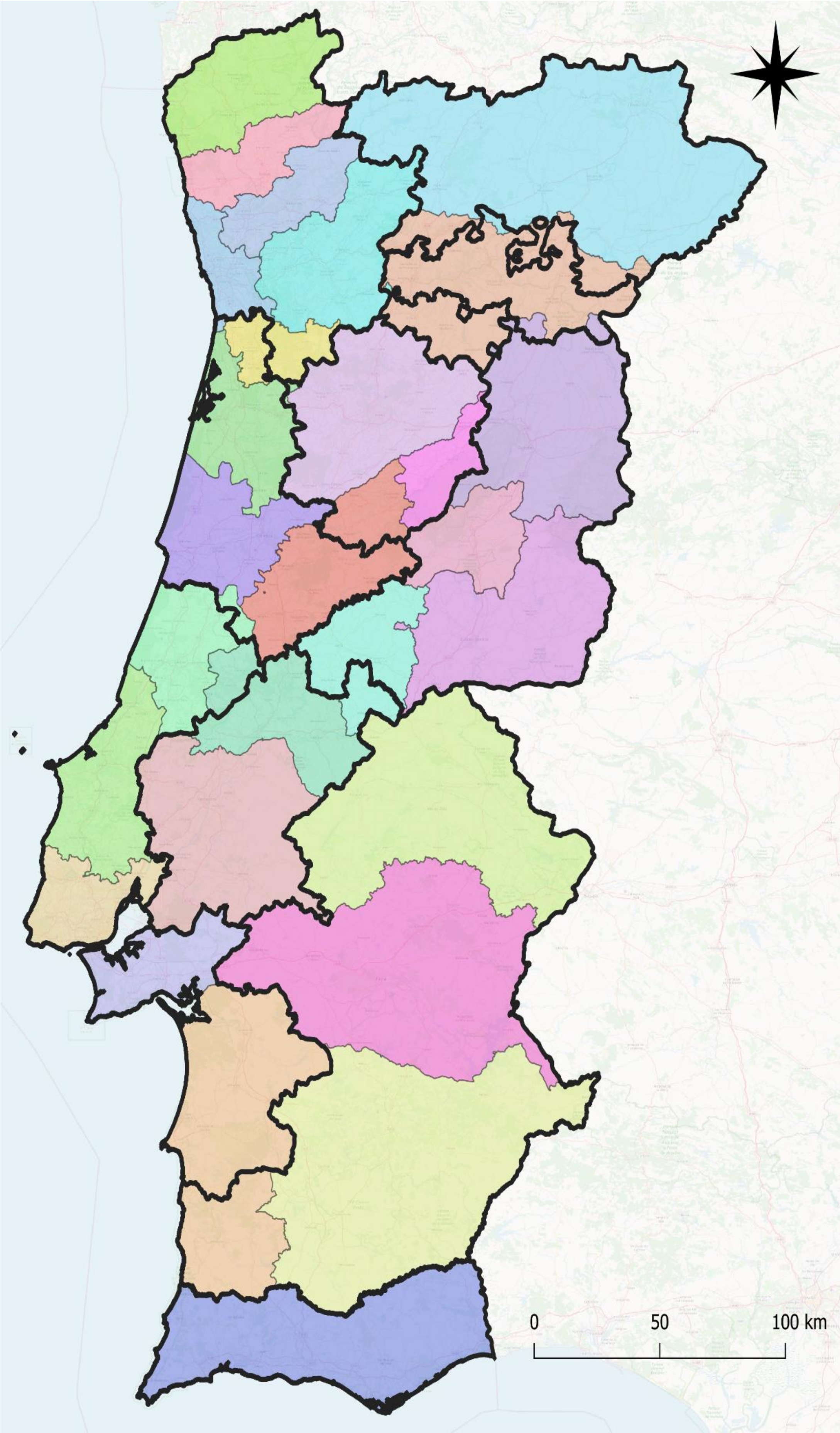

Figure 6: The different IGP's with the NUTSIII regions visualized. This will be the main format of map used throughout the entire internship report. Source: Own creation.

3.3 Exposure

As also mentioned in chapter 2, the exposure refers to the presence of specific elements in an area where specific hazard may occur. Therefore, the research will continue by identifying the most important regions of Continental Portugal regarding viticulture, which could best be described by the different IGP's, DOP's and subregions. Please note that this part serves the solely role of pointing out the areas of special interest for the reader and will NOT be part of the official methodology to calculate the exposure. This could be explained by the fact that the entire methodology uses the classification NUTSIII (and not the smaller DOP's), which was the only classification system possible to use the data from the hazards (chapter 3.4) and vulnerability (chapter 3.5). Notwithstanding, the identification of all the DOP's and subregions (these terms will be explained in chapter 3.3.1) is still deemed relevant for the readers understanding of areas of special importance for the exposure.

3.3.1 Wine regions of Portugal

Until now, the reader has had an introduction to the vine and wine sector, and a geographical identification of all the different wine regions (figure 5 – Right and figure 6). But, in order to create a clear picture of the consequences of these hazards, it is necessary to not only know the location of the IGP's, but also the location of the different DOP's exposed to the potential hazards. But what do these terms mean?

These 2 terms, 'IGP' and 'DOP' are probably one of the most important terms in viticulture and oenology literature. These abbreviations are used to divide Portugal into different wine regions, most commonly into IG's, IGP's and DOP's. The IG (indicação geográfica) indicates a wine that contains at least 85% of grapes that come from that region with typical grape varieties. These wines are also tested and controlled by a certifying entity to check if the right ratio is used. The IGP (Indicação Geográfica Típica) is essentially a protected IG, this register is used to commonly integrate all the IG's into a single community register and protects them according to the legislations in force, both from the European Union and from Portugal. In total, Portugal has 11 official IGP's, which are: Minho, Transmontano, Terras de Cister, Terras do Dão, Beira Atlântico, Terras de Beira, Lisboa, Tejo, Península de Setúbal, Alentejano and Algarve (see figure 5 – Right and figure 7). Within these wine regions, it is possible to distinguish wines that, due to the quality or inherent characteristics, are closely associated with a specific region. These regions are called the Denomination of Origin (DOP), which amount to 26 different regions spread around the IGP's. The DOP is also based on European and Portuguese laws and differ widely in size and location. To illustrate, whereas the DOP Vinho Verde is almost the entire *IGP Minho*, the DOP Budelas is only a small part of the *IGP Lisboa* (see figure 7). In turn, the DOP can be further subdivided into so-called 'subregions' spread around the IGP.

Figure 7 shows all the IGP's and DOP's and subregions for Continental Portugal, which are made according to the regions mentioned in the Portuguese law. To give an example of the amount of legislation and geographical areas involved, the example of the *IGP Minho* with the corresponding DOP and subregions is given in Annex 1. According to these laws and geographical indications, the laborious work was done to create a map with all the IGP's, DOP's and subregions. It has to be said that the final objective of this internship report was not to recreate the wine regions in detail, but to give an indication of the geographical location of the different wine regions, which could later on be compared with the different climate hazards. It has to be said that the law is not always clear about the exact geographical location of some of the DOP's, which could explain some minor flaws or errors present in figure 7. One difficulty found when making figure 7 with all the different DOP's and subregions is this ambiguity of the law, since it often not includes entire parishes ('freguesias') and counties ('concelhos'), but only a part of them. Subsequently, it is not completely clear how much of the parish or county is officially part of the DOP or subregion, the law often just states 'part of the parish of …', which could theoretically mean both 0.01% and 99.9% of the respective area. In addition to this, the laws sometimes refers to information that is not available online, such as the delimitation of the subregion 'Valpaços' in the DOP Trás-os-Montes which mentions the properties of the Clement Meneres Society, of which no information about the exact location could be found. Subsequently, the parishes were cut according to what seemed correct with all the existing maps and literature available. If the reader would like to know more about the different IGP's, DOP's or subregions, more information could be consulted here[4] by clicking either on 'vinhos IGP' or 'vinhos DOP'.

4 https://www.ivv.gov.pt/np4/77/

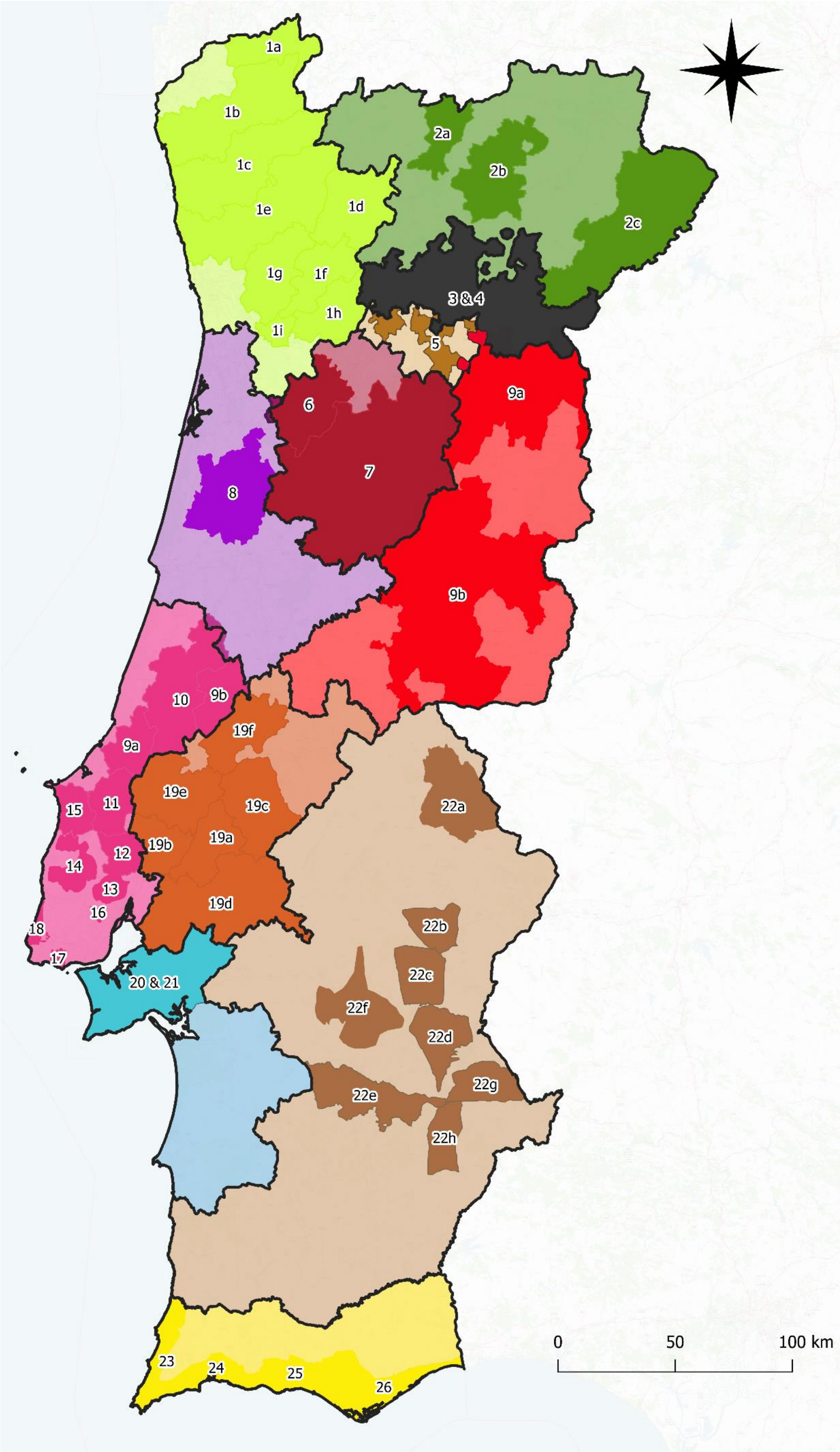

Figure 7: All the IGP's, DOP's and subregions of Continental Portugal visualized. Source: Own map, data from IVV (2021).

IGP's, DOP's and subregions of Continental Portugal

- IGP Minho
- 1a. Subregion Monção e Melgaço
- 1b. Subregion Lima
- 1c. Subregion Cávado
- 1d. Subregion Basto
- 1e. Subregion Ave
- 1f. Subregion Amarante
- 1g. Subregion Sousa
- 1h. Subregion Baião
- 1i. Subregion Paiva
- IGP Transmontano
- 2a. Subregion Chaves
- 2b. Subregion Valpaços
- 2c. Subregion Plantalto Mirandês
- IGP Duriense
- 3. DOP Douro
- 4. DOP Porto
- IGP Terras de Cister
- 5. DOP Távora-Varosa
- IGP Terras do Dão
- 6. DOP Lafões
- 7. DOP Dão
- IGP Beira Atlântico
- 8. DOP Bairrada
- IGP Terras da Beira
- 9a. Subregion Cova da Beira
- 9b. Subregion Pinhel
- IGP Lisboa
- 10. DOP Encostas de Aire
- 10a. Subregion Alcobaça
- 10b. Subregion Ourém
- 11. DOP Óbidos
- 12. DOP Alenquer
- 13. DOP Arruda
- 14. DOP Torres Vedras
- 15. DOP Lourinhã
- 16. DOP Bucelas
- 17. DOP Carcavelos
- 18. DOP Colares
- 19. IGP Tejo
- 19a. Subregion Almeirim
- 19b. Subregion Cartaxo
- 19c. Subregion Chamusca
- 19d. Subregion Coruche
- 19e. Subregion Santarém
- 19f. Subregion Tomar
- IGP Península de Setúbal
- 20. DOP Setúbal
- 21. DOP Palmela
- IGP Alentejano
- 22a. Subregion Portalegre
- 22b. Subregion Borba
- 22c. Subregion Redondo
- 22d. Subregion Resguengos
- 22e. Subregion Vidigueira
- 22f. Subregion Évora
- 22g. Subregion Granja-Amareleja
- 22h. DOP Moura
- IGP Algarve
- 23. DOP Lagos
- 24. DOP Portimão
- 25. DOP Lagoa
- 26. DOP Távira

3.3.2 Production per wine region

By now, the reader should have a clear image of the relevant regions in Continental Portugal for viticulture. Now it is time to see the difference in exposure between all these regions. As also mentioned in chapter 2, the exposure refers to the presence of specific elements in an area where a specific hazard may occur. The hazards researched in this report (see chapter 3.4) are the mean annual temperature (MAT), mean summer temperature (MST), mean average precipitation (MAP), mean summer precipitation (MSP) and the moisture deficit (CMD). In order to measure the exposure, it is important to think about what could be potentially be impacted (or 'exposed') by these hazards. The most reliable indicator for this was thought to be the grape production, because of the adverse effect of climate change on the quality and quantity of the grapes. Even more important, there are clear numbers available about the grape production for the last 10 years for each NUTSIII region and every IGP for Continental Portugal.

The data comes from the Instituto da Vinha e do Vinho (IVV), which is the national commission of the International Organisation of Vine and Wine (OIV). This organization has the mission to coordinate and control the institutional organization of the wine sector, audit the quality certification system, monitor community policy and prepare the rules for its enforcement, just as to participate in the coordination and supervision of the promotion of wine products (IVV, 2021). The data about the grape production is freely available here[5] for all the IGP's, and here[6] for all the counties (concelhos) and districts (distritos). As the data was not directly available at the NUTSIII level, each of the respective values of all the corresponding counties were added up to get the total value of each NUTSIII regions through the use of Excel.

The newly datasheets created with the grape production on the NUTSIII level were subsequently saved as a .csv file (File > Save as > .csv file) and subsequently joined in QGIS to the layer with all the NUTSIII regions of Continental Portugal (Properties > Symbology > Graduated > Choose the right column of joined variables > Classify > Choose colour ramp: Palette PiYG > Adjust legenda > Classify > OK). These maps are made with a different color palette to make a clear distinguishment between the following maps about the hazards (chapter 3.4), vulnerability (chapter 3.5) and final risks (chapter 3.6 and chapter 3.7).

Figure 8 (see also annex 3) shows the grape production for the year 2009/2010 (left) and the year 2020/2021 (right). Compared to datasheets from the year 2009/2010, the total output of grapes has increased from 5,834.310 to 6,372.416 (+ 9,22%) between 2009/2010 and 2020/2021. The regions that gained a higher production are IGP Península de Setúbal (+25%), IGP Lisboa (+29%), IGP Tejo (+18%), IGP Terras da Beira (14%) and IGP Alentejano (+43%). The regions that have lost wine production over the last 10 years are IGP Algarve (-45%), IGP Beira

5 https://www.ivv.gov.pt/np4/163.html
6 https://www.ivv.gov.pt/np4/2336.html

Atlântico (-29%), IGP Terras do Dão (-36%), IGP Terras de Cister (-21%), IGP Duriense (-6%), IGP Transmontano (-15%) and IGP Minho (-2%). A map can be consulted with the exact percentual difference between the grape production in 2009/2010 and the year 2020/2021 in annex 2. Especially striking seems to be IGP Alentejano (+43% production), since this IGP represents high values for both the MAT, MST, MAP, MSP and CMD (see chapter 3.4), which might have significant consequences for the grape production in the future. As a matter of fact, IGP Alentejano is currently one of the IGP's with the highest production (Figure 8 - Right), together with IGP Duriense and IGP Lisboa, followed by IGP Tejo and IGP Minho. The regions that are characterized by the lowest output of grapes consist out of IGP Terras de Cister, IGP Algarve and IGP Transmontano.

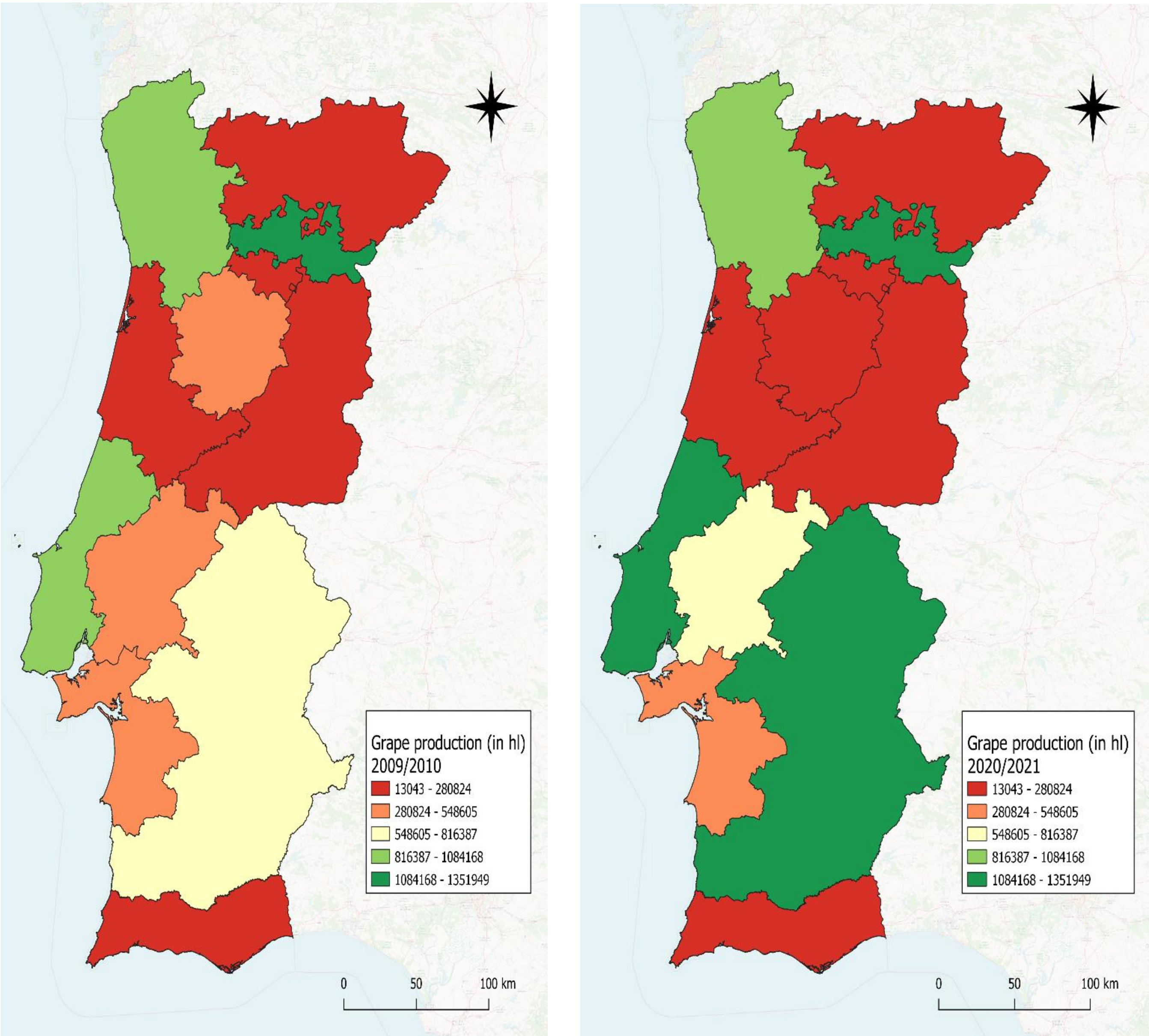

Figure 8: Grape production (in hl) in the year 2009/2010 and in the year 2020/2021. Source: Own maps. Data from IVV (2021).

To further detail the information provided of the current grape production (2020/2021) by the IVV for the different IGP's, the data was also gathered for all the smaller NUTSIII regions. After the data was joined from Excel (Open Data Source Manager > add .csv document > Attribute table layer NUTSIII region > Properties > Joins > Add New Join > Choose the Excel file), the boundaries of all the IGP's were imported again (Properties > Symbology > Simple Fill > 'Symbol Layer Type' = Outline: Simple Line > Change Stroke Width: 0.7). To clearly visualize these IGP's and improve the legibility and cleanness of the maps, the boundaries of the original NUTSIII regions were taken out (Properties > Symbology > Simple Fill > Match Fill Colour with Stroke Colour > OK).

In order to highlight the importance of relatively small regions for the national grape production, figure 9 (left) was created. This map is made according to the equal interval mode (Properties > Symbology > Mode: 'Equal Interval Mode'), which divided the IGP's in 5 classes according to the respective grape production. As the difference between each value is the same, the exceptionally high values (or 'outliers') can be clearly visualized. As could be seen below, the highest grape production takes place in two different NUTSIII regions: Douro (*IGP Duriense*) and Oeste (*IGP Lisboa*). As already stated in chapter 3.2.2., the *IGP Terras de Cister* should be interpretated with care. As could be visible in figure 9, the *IGP Terras de Cister* seems to be one of the main grape producers in Continental Portugal, but if the same IGP is studied in map 8 (right), it becomes clear that the production of Terras de Cister is one the lowest. This is due to the fact that the NUTSIII region has joined *IGP Terras de Cister* and *IGP Duriense*, which gives *IGP Terras de Cister* automatically the same value as *IGP Duriense*.

Even though figure 9 (left) is useful to show the difference in values (especially outliers), the reader might actually be more interested in seeing the relative difference between all the NUTSIII regions without the distortions of the outliers. Therefore, the same map of the current production 2020/2021 was made through the use of quantiles (Properties > Symbology > Mode = 'Equal Count: Quantile'). As each class is now represented by a more even distribution, it becomes visible which IGP's and NUTSIII regions earlier attributed the lowest value are actually characterized by quite some significant grape production, such as Baixo Alentejo (*IGP*

Alentejo), Minho-Lima (*IGP Minho*), Dão-Lafões (*IGP Terras do Dão*), and Beira Interior Norte (*IGP Terras da Beira*).

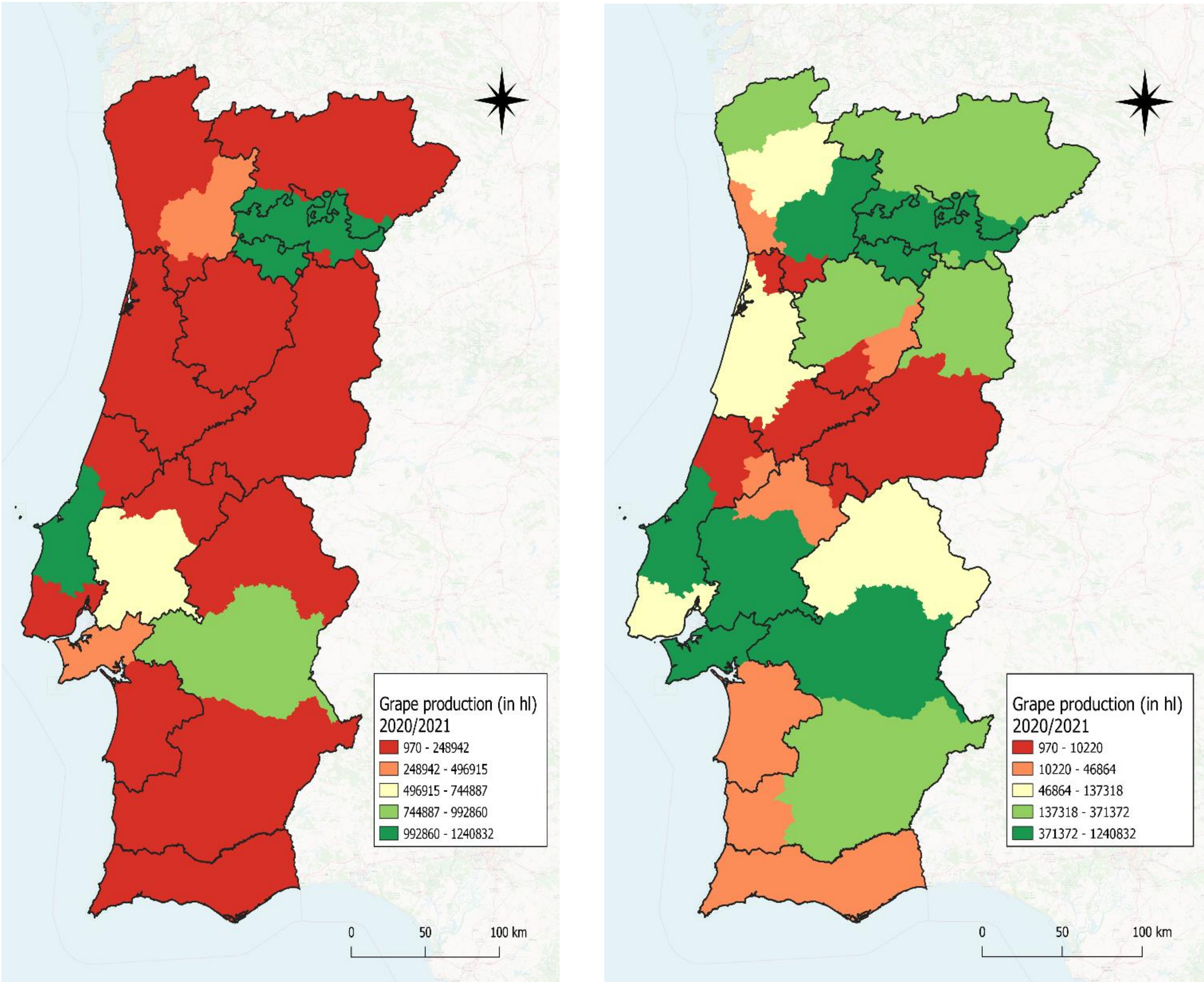

Figure 9: Current grape production (2020/2021) according to the equal interval method (left) and quantiles (right). Source: Own maps. Data from IVV (2021).

3.4 Climate Hazards

The production and quality of the grapes is directly linked to climatic variables, which is often most profoundly studied through a rising air temperature (Conceição, Tonietto & Souza, 2018). According to the environmental organization ZERO, Portugal will be one of the countries most affected by the effects of climate change with diverse effects such as coastal erosion, desertification, droughts, and forest fires (TPN/Lusa, 2021). This is also confirmed by The Lisbon Metropolitan Area (2018) and Santos (2015), who state that the main effects of climate change for Portugal are a higher average temperature, more frequent and intense heat waves, alteration of the precipitation regime and extreme precipitation events, more intense and frequent droughts, prolongation of summer period and sea level rise.

The main variables used in this research are Mean Average Temperature (MAT), Mean Summer Temperature (MST), Mean Average Precipitation (MAP), Mean Summer Precipitation (MSP) and the Climatic Moisture Deficit (CMD). The data used in the research comes from the CMIP5-based climate data (2.5km resolution), this dataset was originally created with the ClimateEU software package by Maurizio Marchi from the CRA-SEL (Council for Agricultural Research and Economics - Forestry Research Centre) of Arezza (Italy) for the project Trees4Future. The dataset can be found here[7] (Average Ensembles: RCP4.5 Emission scenario > 27 bioclimatic variables: 2020, 2050 and 2080), and should be officially referenced as Marchi, Castellanos-Acuña, Hamann, Wang, Ray & Menzel (2020). It was chosen to use the data from RCP 4.5, based on current projections and policies for the years 2030 and 2050. The European Union has the ambitious Green Deal to foster climate change mitigation and adaptation in the future, which should lead to a reduction of 55% of greenhouse gases by the year 2030 and climate neutrality by the 2050. Even though it is true that the total amount of greenhouse gases (and therefore temperature rise) will not only depend on Europe, the RCP 4.5 was considered the most likely scenario for the Portuguese context up until the year 2080. As the ensemble projections are averages across 15 CMIP5 models (CanESM2, ACCESS1.0, IPSL-CM5A-MR, MIROC5, MPI-ESM-LR, CCSM4, HadGEM2-ES, CNRM-CM5, CSIRO Mk 3.6, GFDL-CM3, INM-CM4, MRI-CGCM3, MIROC-ESM, CESM1-CAM5, GISS-E2R) and represented high validation statistics to the CMIP3 equivalents, it was not deemed necessary to provide any additional data checks.

The datasets are made available in .asc format, which can be subsequently loaded and processed in QGIS through creating new raster layers (Data Source Manager > Raster > Add Raster dataset). The data is delivered for the entire European Union, but as the research is only focused on Continental Portugal, it was decided to cut out all the other countries. In order to do this, the raster files had to be georeferenced (Raster > Georeference > Load Raster > Start Georeferencing > Add reference points > Run algorithm) first to get the right coordinate system. These points were attached to the OSM Standard basemap through the QuickMapServices plugin (Web > QuickMapServices > OSM > OSM Standard) to be able to provide a background to all the created maps. After the raster files of the variables were georeferenced, the clip function (Raster > Extraction > Clip Raster by Mask Layer > Input Layer: The different variables > Mask Layer: NutsIII Continental Portugal) was used to cut out Continental Portugal from the European Union. This process was repeated for each of the 5 variables (MAT/MST/MAP/MSP & CMD) and for each of the projections (2020, 2050 & 2080), which results in a total of 15 different maps with raw data.

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7 https://sites.ualberta.ca/~ahamann/data/climateeu.html

Every variable got 3 different sets of maps:

- The maps with the current (2020) and future projections (2050 & 2080) which show the exact value found for Continental Portugal. These maps were created through adjusting the symbology of the clipped layers (Properties > Symbology > Render Type: Singleband Pseudocolour > Create New Colour Ramp > Palette: RdYlBu > OK > Mode: Continuous > OK).

- The maps with the average value for each of the NUTSIII regions (28 in total) and variables for different years (5 variables x 3 different projections = 15 in total). A total of 420 layers were clipped and used to extract the layer statistics to create these maps. These maps were made to clearly see the difference between each of the NUTSIII regions, as it can be difficult to extract the average value with the human eye. The average values were obtained through the use of the clip function of QGIS (Raster > Extraction > Clip Raster by Mask Layer) and were subsequently calculated through the raster statistics function (Processing Toolbox > Raster Analysis > Raster Layer Statistics > Run the algorithm). The resulting average values for each of the variables was subsequently put in an Excel file, joined (Open Data Source Manager > add .csv document > Attribute table layer NUTSIII region > Properties > Joins > Add New Join > Choose the Excel file) to the layer of the NUTSIII regions and categorized (Properties > Symbology > Graduated > Choose the right column of joined variables > Classify > Choose colour ramp: Palette RdBu > Adjust legenda > Classify > OK) according to the values present from low to high. Especially important to note is the adjustment of the classes in the legenda, this was done to be able to compare all the different years (2020, 2050 and 2080) with each other. If the choice would have been made to choose the different minimum and maximum values for each year, the colors would represent different values for each of the three years. As a consequence, it would be impossible to make any comparison between these maps. To continue, the boundaries of each of the NUTSIII regions are made into the same color (Properties > Symbology > Simple Fill > Match Fill Colour with Stroke Colour > OK), and subsequently covered by only the boundaries of the IGP's for Continental Portugal (Properties > Symbology > Simple Fill > 'Symbol Layer Type' = Outline: Simple Line > Change Stroke Width: 0.7). The number of classes was deliberately chosen to improve the legibility of the maps and to show a clear patterns. The maps were finished through creating PDF's and PNG files from each of the maps (Project > New Print Layout > Choose Portrait Layout > Add Map/legenda/north arrow/scale bar > Save).

- The maps with the difference between the values for the years 2020-2050 and 2020-2080. These maps were created through the use of the field calculator in the attribute table (Open Attribute Table > Open Field Calculator > Subtract the value for each variable for the year 2020 from the years 2050 and 2080 > OK). Each increase or decrease got calculated for all the 28 NUTSIII Regions and 15 climate projections. The maps were finished the same as the second set of maps with the average values (Project > New Print Layout > Choose Portrait Layout > Add Map/legenda/north arrow/scale bar > Save).

3.4.1. Mean Annual Temperature

3.4.1.1. Characterization

This part begins with the climate projections for Portugal for the variable MAT (Mean Average Temperature), which is one of the most common variables for climate change. As could be visible in the first image of figure 10, the mean annual temperature of Continental Portugal is widely different between the South and the North. Whereas the North tends to be dominated by a temperature between 10.6 C°-15.9 C°, the South of the country ranges between 15.9 C° and 19.8 C°. The 'Centre', the transition zone between the North and the South, is mostly centred around 15.9 C°, with some out layers to higher and lower temperatures. The

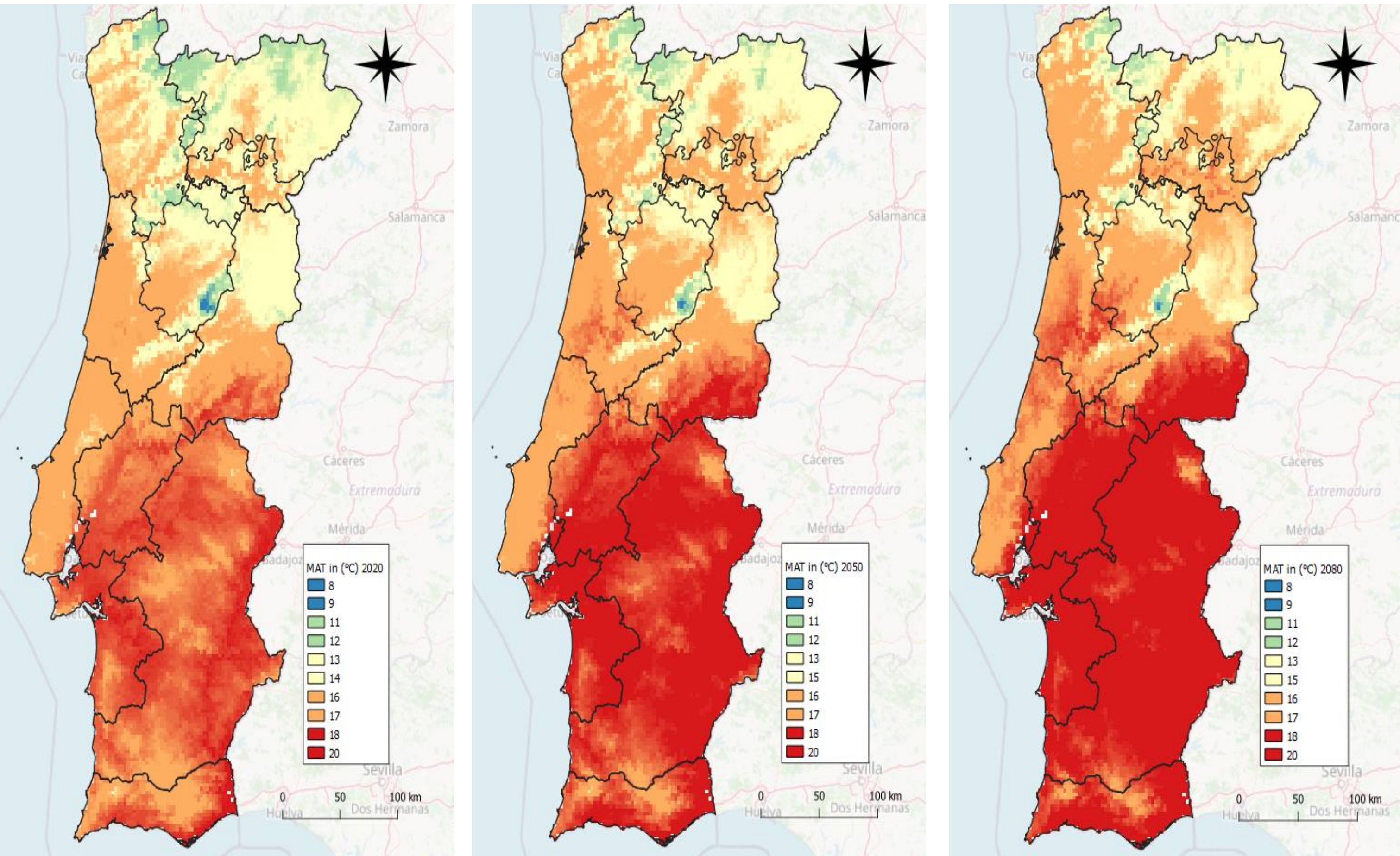


Figure 10: Mean Average Temperature (2020) in C° for all the IGP's in Continental Portugal for the years 2020, 2050 and 2080, compared to the year 2020. Source: Own maps, data based on CMIP5-based climate data (2.5km resolution)

coldest part of Continental Portugal can be found in IGP Terras de Dão, which represents the mountain range 'Serra de Estrela'.

3.4.1.2 Maximum values

As it can be tricky to distinguish the different colors (and therefore values) for each region, a second set of maps was made, visible in figure 11. This set of maps shows the average value of the MAT for each NUTSIII Region for Continental Portugal, with the boundaries of the IGP's visible. The tendency visible in figure 10 is confirmed, with only Baixo Alentejo (*IGP Alentejano*) and IGP Península de Setúbal representing currently high temperatures. When it comes to the projections for the projections for the year 2050 and 2080, the eye is immediately drawn to the South of Portugal, which almost completely turned red (equivalent to a temperature between 17.6 C° and 18.9 C°) in the year 2050 and 2080. By the year 2050, also the regions Alentejo Central and Alto Alentejo (*IGP Alentejano*), Lezíria do Tejo and Médio Tejo (IGP Tejo) and Beira Interior Sul (IGP Terras da Beira) show maximum temperatures, which is followed by the addition of Pinhal Interior Sul and Pinhal Litoral by the years 2080. The highest values found for the year 2050 in Península de Setúbal (18.47 C°) (IGP Península de Setúbal), followed by Alto Alentejo (18.42 C°) and Baixo Alentejo (also 18.42 C°) (*IGP Alentejano*). The year 2080 gives the highest value for Alto Alentejo (18.88 C°), followed by followed by Península de Setúbal (IGP Península de Setúbal) and Baixo Alentejo (*IGP Alentejano*).

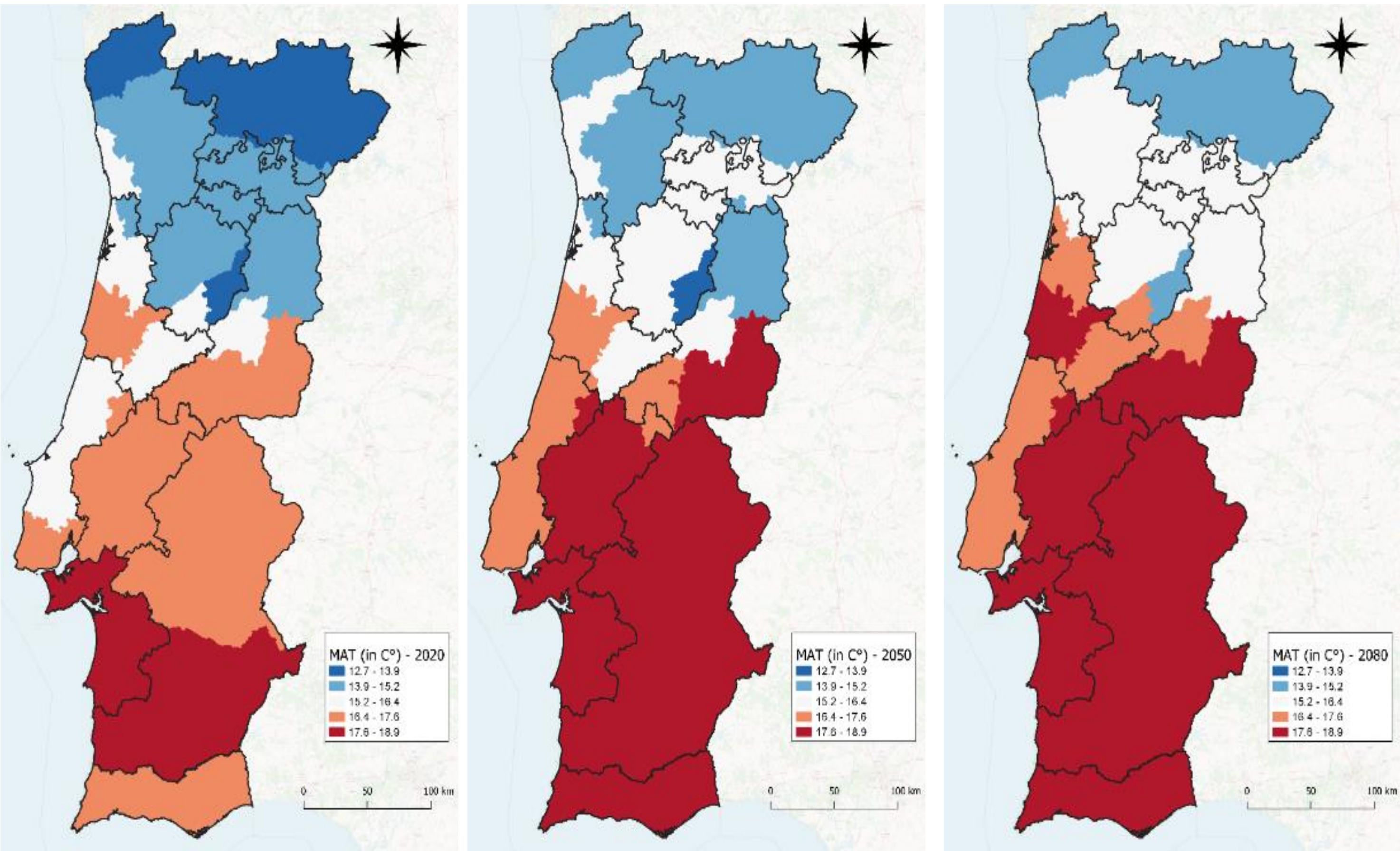


Figure 11: Average Mean Temperature (MAT) in C° for all the NUTSIII regions with the borders of the IGP's visualized for Continental Portugal – 2020 (left), 2050 (middle), and 2080 (right). Source: Own maps, data based on CMIP5-based climate data (2.5km resolution)

3.4.1.3. Increase

Whereas the maximum annual temperature (MAT) is clearly attained in the South, the highest rise in temperature does not necessarily have to follow this pattern. To illustrate, a third set of maps (Figure 12), which shows the increase in MAT (in C°) between the years 2020-2050 (left) and 2020-2080 (right). As could be clearly visible, a different pattern arises now, where the East will see the highest rise in temperature for the upcoming decades. The NUTSIII regions with the highest rise in MAT for both the year 2050 and 2080 are Beira Interior Norte (0.83 C°) and Beira Interior Sul (1.32 C°) (*IGP Terras da Beira*).

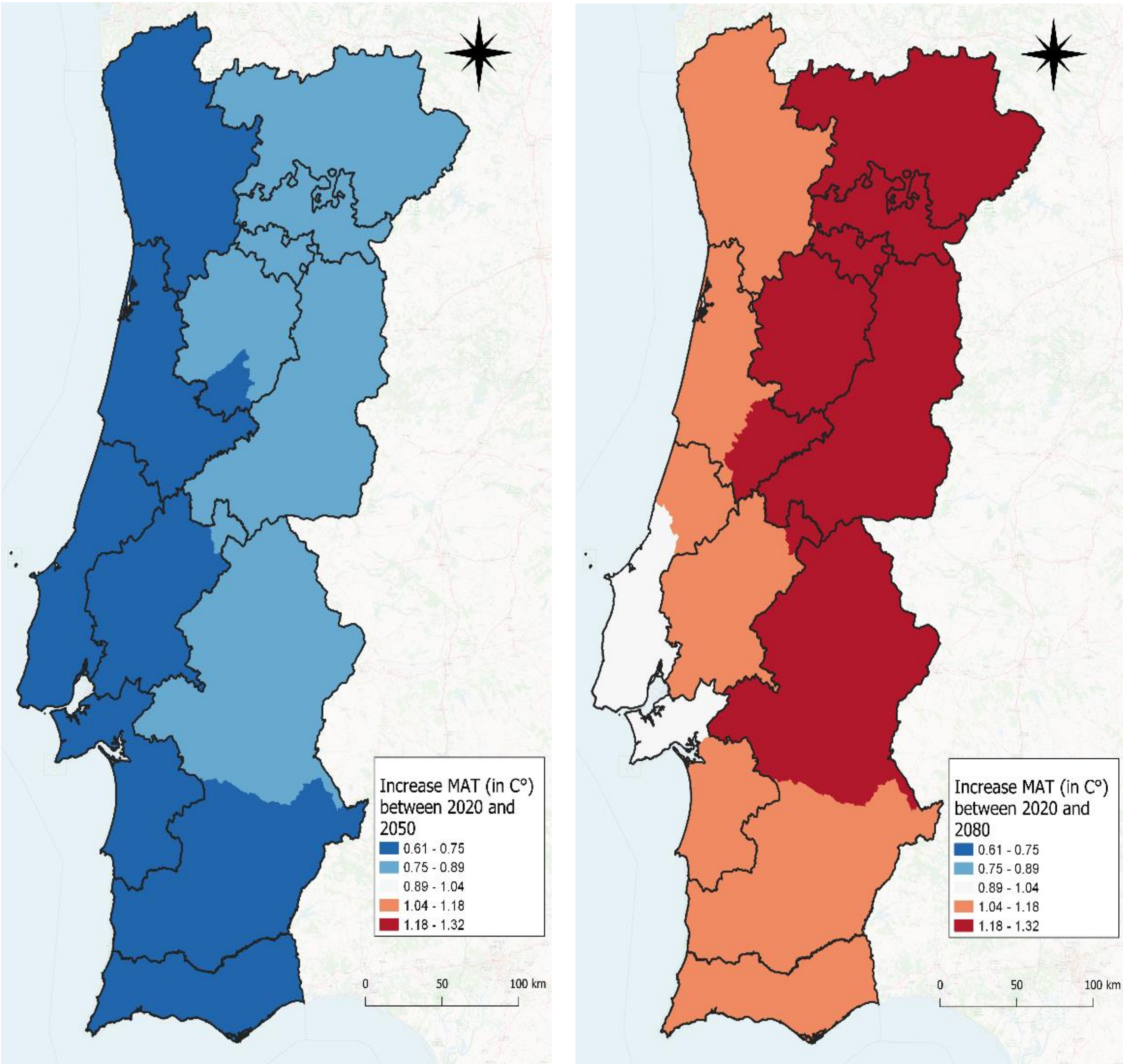


Figure 12: Rise in annual temperature (in C°) for all the NUTSIII regions with the borders of the IGP's visualized for Continental Portugal for the years 2020-2050 and 2020-2080. Source: Own maps, data based on CMIP5-based climate data (2.5km resolution).

3.4.2 Mean Summer Temperature

3.4.2.1 Characterization

As viticulture is strongly dependent on favourable growing temperatures during the summer (and both hot days, heat waves and droughts are more common during the summer months), it was chosen to include the summer temperatures (July-August) in the research as well. As clearly visible in figure 13, the higher temperatures seem to be 'creeping' from Spain into Portugal through the *IGP Alentejano* and *IGP Terras da Beira*. The regions more closely located to the Atlantic Ocean (e.g. *IGP Lisboa* or *IGP Beira Atlântico*) and to the North (e.g. *IGP Minho*) seem to be less affected by a high temperatures during the summer. Also note the *IGP Duriense*, which in both the projections for the year 2050 and 2080 showed a significant rise in temperature.

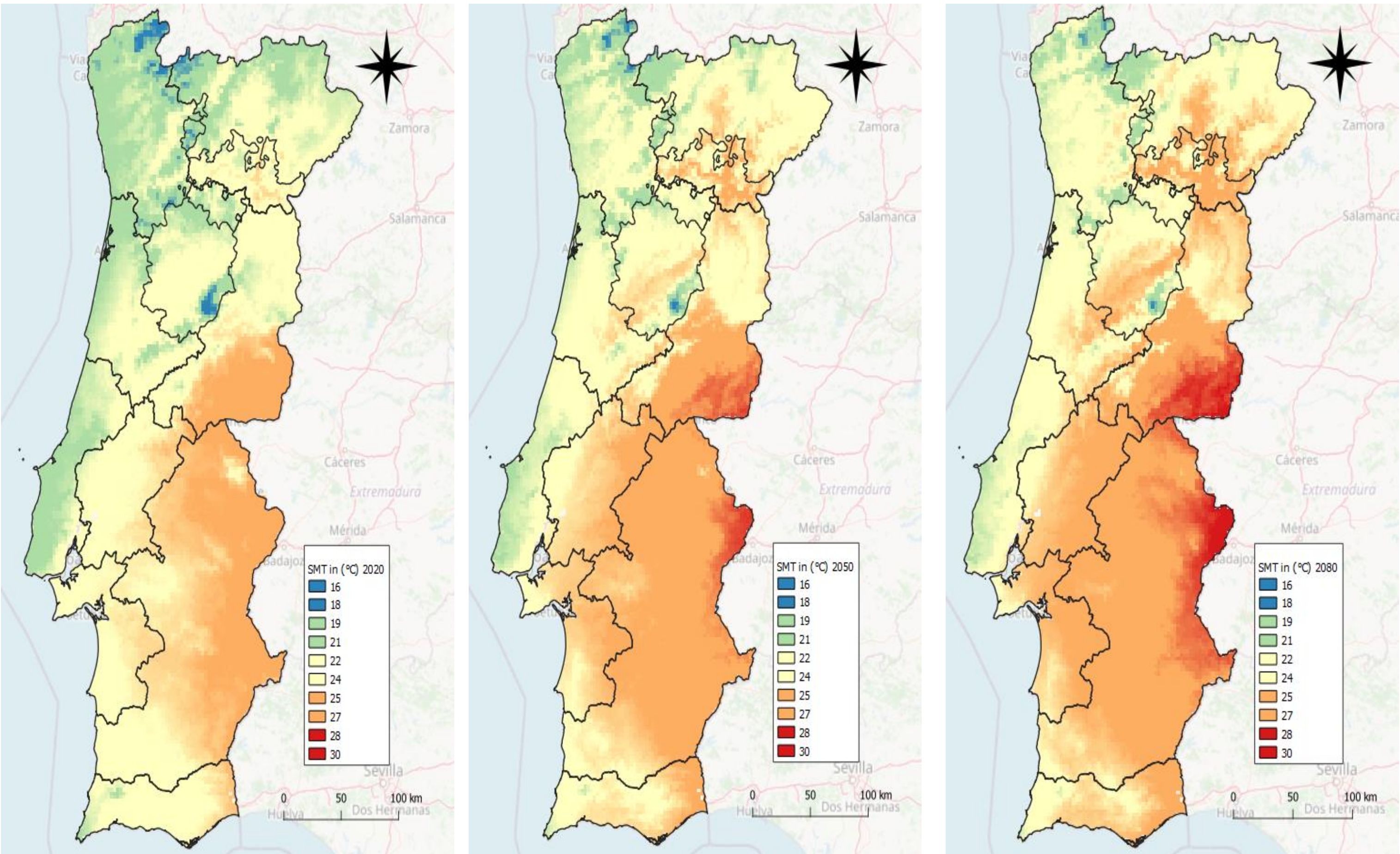


Figure 13: Average Mean Summer Temperature (MAT) in C° with the borders of the IGP's visualized for Continental Portugal – 2020 (left) (middle), and 2080 (right). Source: Own maps, data based on CMIP5-based climate data (2.5km resolution)

3.4.2.2 Maximum values

A second set of maps again was made to see the average temperature for every single IGP, which is visible in figure 14. The map with the current summer temperatures (left) shows that the highest summer temperatures could currently be found in Beira Interior Sul (25.27 C°) (IGP Terras da Beira), followed by Alto Alentejo (C° 25.05) and Alentejo Central (24.53 C°) (*IGP Alentejano*). Interesting in this regard is especially Beira Interior Sul, which now reaches the highest temperatures during the summer, but represented only the 8th highest value for the annual temperatures (MAT). When it comes to the year 2050, the highest values were found in Beira Interior Sul (26.48 C°) (*Terras da Beira*), Alto Alentejo (26.18 C°) and Alentejo Central (25.58 C°) (*IGP Alentejano*). The year 2080 shows a similar pattern, with maximum values being attained in Beira Interior Sul (27.1 C°) (*Terras da Beira*), Alto Alentejo (26.74 C°) and Alentejo Central (26.09 C°) (*IGP Alentejano*). If the summer temperatures are compared with the average yearly temperatures, some similarities and differences can be detected. Whereas the annual temperatures (MAT) seem to be centered in the South of Portugal, the summer temperatures seem to be clustered around the IGP's *Terras da Beira* and *IGP Alentejano*.

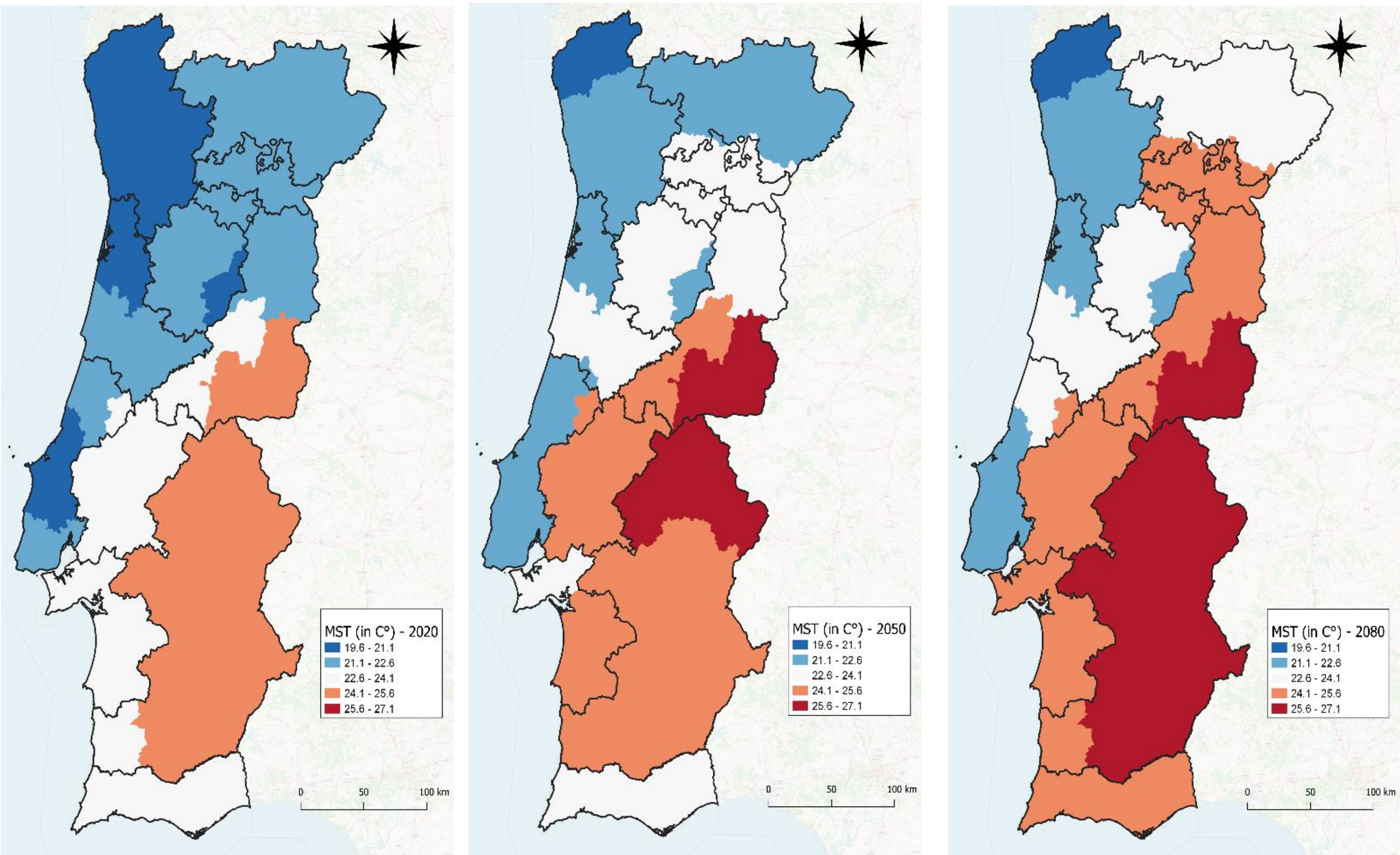


Figure 14: Average Mean Summer Temperature (MST) in C° for all the NUTSIII regions with the borders of the IGP's visualized for Continental Portugal – 2020 (left), 2050 (middle), and 2080 (right). Source: Own maps, data based on CMIP5-based climate data (2.5km resolution)

3.4.2.4. Increase

The highest increase of the SMT is visible in figure 15. The highest increase in temperature is projected to happen in the North-Eastern part of Portugal, in contrast to the North-South divide witnessed earlier for the maximum annual temperatures (MAT). The lowest increase in summer temperatures can be found close to the Atlantic Ocean, which could be explained by the attenuating effect on the ocean on local temperatures. The highest value for both the year 2050 and 2080 was the NUTSIII region of Beira Interior Norte, respectively 1.24 C° and 1.86 C°.

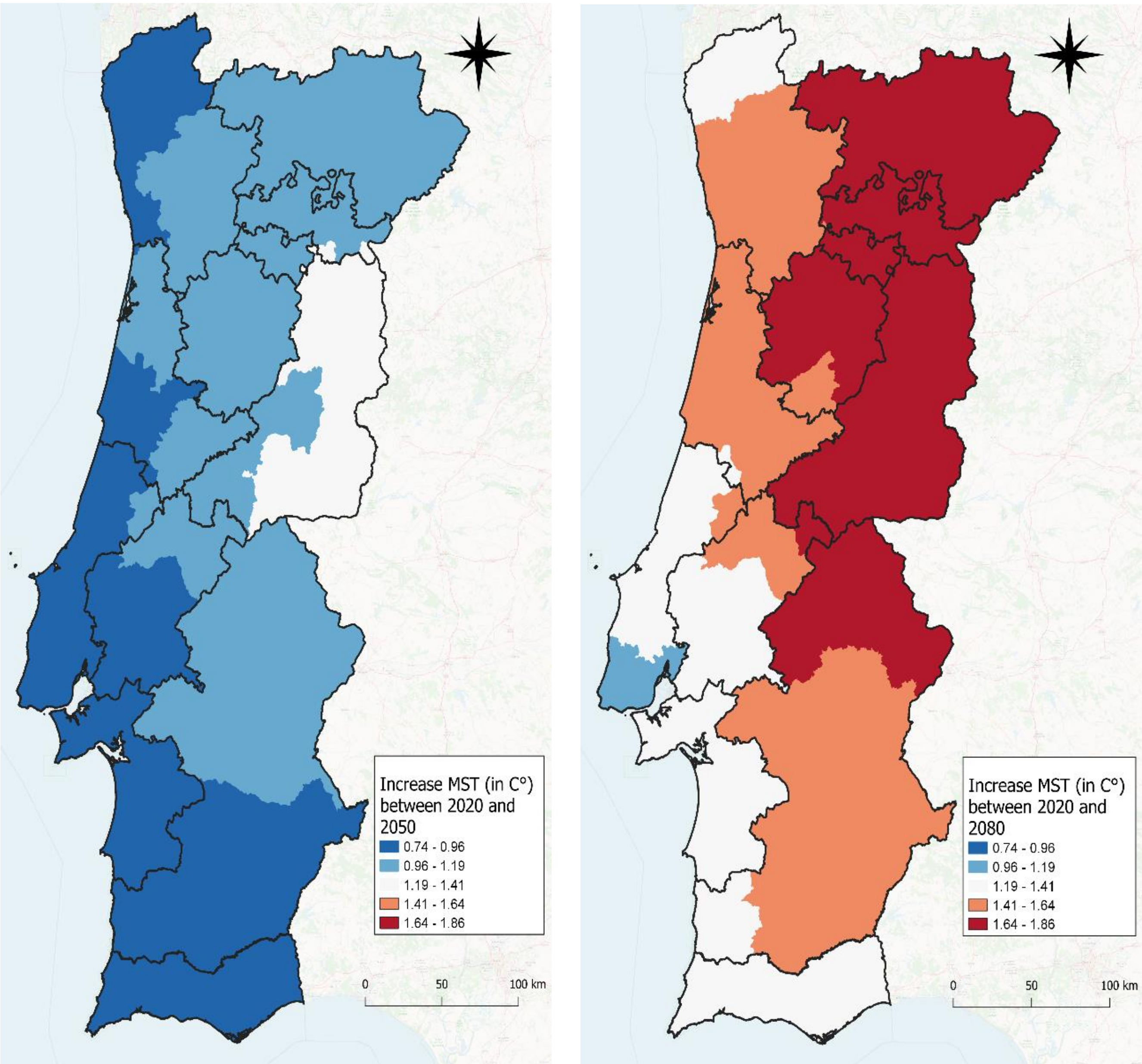


Figure 15: Rise in summer temperature (in C°) for all the NUTSIII regions with the borders of the IGP's visualized for Continental Portugal for the years 2020-2050 and 2020-2080. Source: Own maps, data based on CMIP5-based climate data (2.5km resolution).

3.4.3 Mean Annual Precipitation

3.4.3.1. Characterization

Figure 16 shows the current (2020) and future prospects of the mean annual precipitation (MAP) for Portugal, measured in millimeters (mm). As could be clearly visible, there is a clear difference in precipitation between the North-West and the rest of Portugal, with the North-West clearly showing higher levels of rainfall than the rest of Continental Portugal. Even though the future projections are not as sharply divided as the maps for the annual (MAT) and summer temperatures (MST), the projections for the future clearly show some differences. Special attention should be paid to the orange/red line in the center of the country, which is slowly creeping upwards. Also note the disappearing dark blue patches (precipitation of 1494-1677 mm) for the years 2050 and 2080, which is especially visible in the *IGP Minho*. The dark blue patch in the center of the country characterized by a high level of rainfall is the 'Serra de Estrela', the highest mountain range in Continental Portugal.

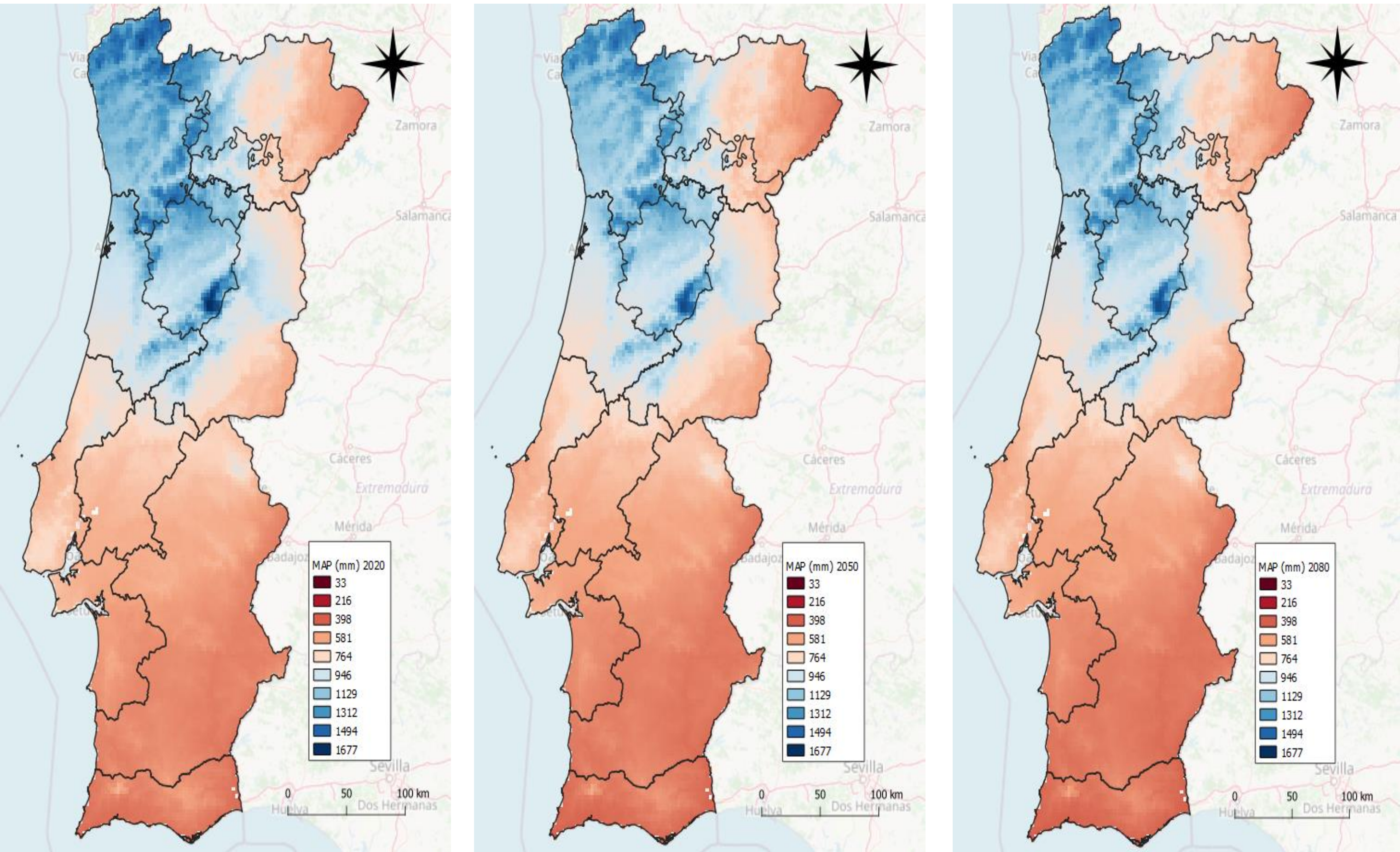


Figure 16: Mean Average Precipitation (MAP) in mm with the borders of the IGP's visualized for Continental Portugal – 2020 (left), 2050 (mid and 2080 (right). Source: Own maps, data based on CMIP5-based climate data (2.5km resolution)

3.4.3.2 Minimum values

A set of maps for the average rainfall was made again for Continental Portugal, visible in figure 17. These maps show a pattern where the total precipitation is slowly decreasing for Continental Portugal, with the lowest amount of rainfall currently (2020) in the Algarve (490.87 mm), followed by Baixo Alentejo (505.37 mm) and Alentejo Litoral (533.81 mm) (*IGP Alentejano*). The projections show an in increase in IGP's characterized by a low precipitation by the year 2050, which now also includes Lezíria do Tejo (*IGP Tejo*) and all the other NUTSIII regions of *IGP Alentejano*. By the year 2050, The regions characterized by the lowest precipitation will be Algarve (465.25 mm), followed by Baixo Alentejo (481.09 mm) and Alentejo Litoral (506.72 mm) (*IGP Alentejano*). This pattern is also confirmed by 2080, which show the minimum values for Algarve (453.58 mm), followed by Baixo Alentejo (741.32 mm) and Alentejo Litoral (497.48 mm) (*IGP Alentejano*). Interesting in this regard is also the fact that some regions in the North of Portugal show an increase of precipitation, instead of continuing the trend of decreasing precipitation. An example is the Minho-Lima (+8.47 mm) and Cávado (+5.39 mm) in *IGP Minho*.

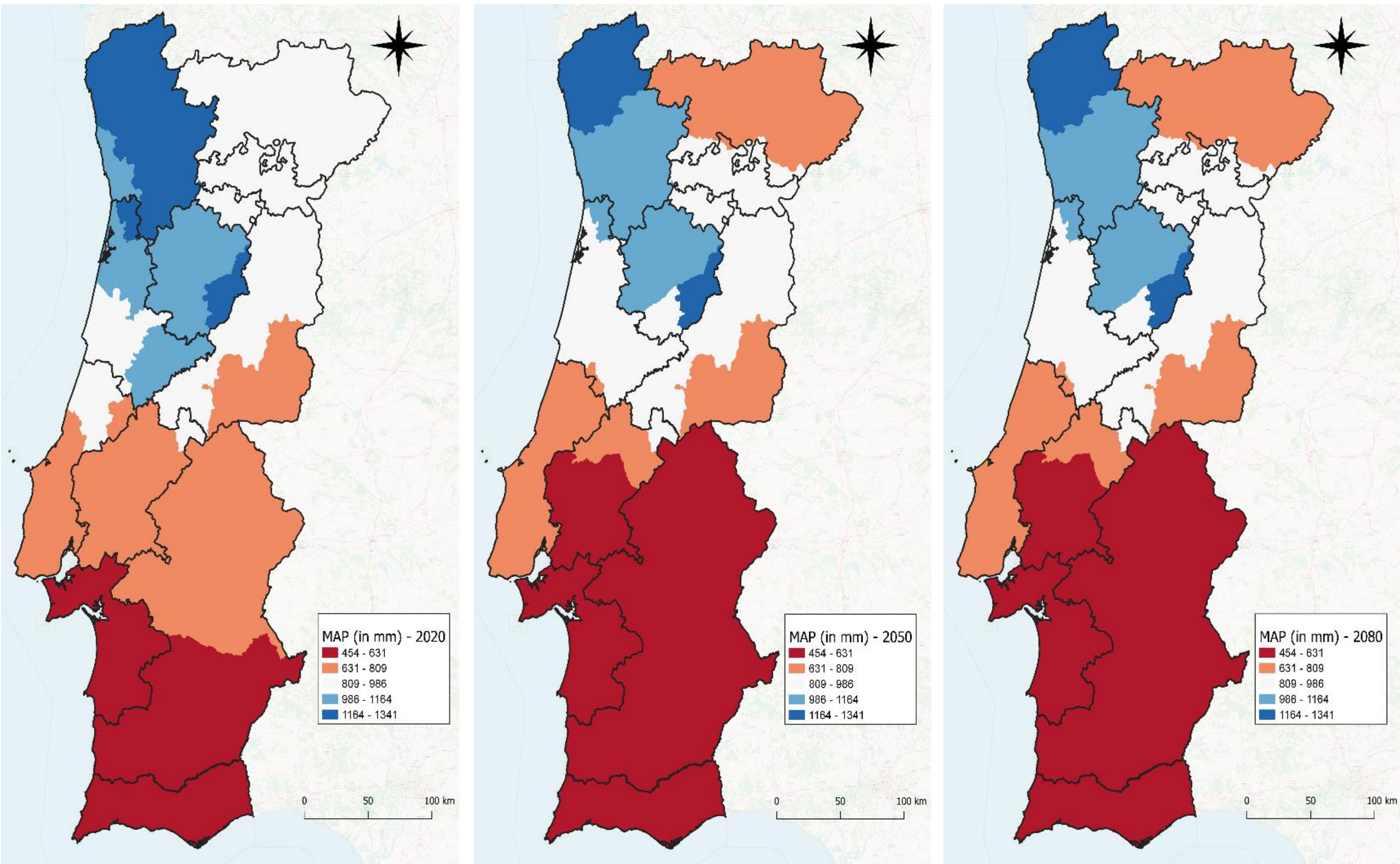


Figure 17: Mean Average Precipitation (MAP) in mm for all the NUTSIII regions with the borders of the IGP's visualized for Continental Portugal – 2020 (left), 2050 (middle), and 2080 (right). Source: Own maps, data based on CMIP5-based climate data (2.5km resolution)

3.4.3.3. Decrease

The highest decrease in average precipitation is projected to occur in the North-West of Portugal (see figure 18), which shows a trend completely opposed to the trend witnessed in the MAP. By the year 2050, the highest decrease is projected to happen in Minho-Lima (74.19 mm), Cávado (68.33 mm), Ave (66.74 mm) and Entre Douro e Vouga (65.8 mm) (*IGP Minho*). For the years 2080, the highest values were found in Entre Douro e Vouga (67.99 mm), Minho -Lima (65.72 mm) and Grande Porto (64.83 mm) (*IGP Minho*).

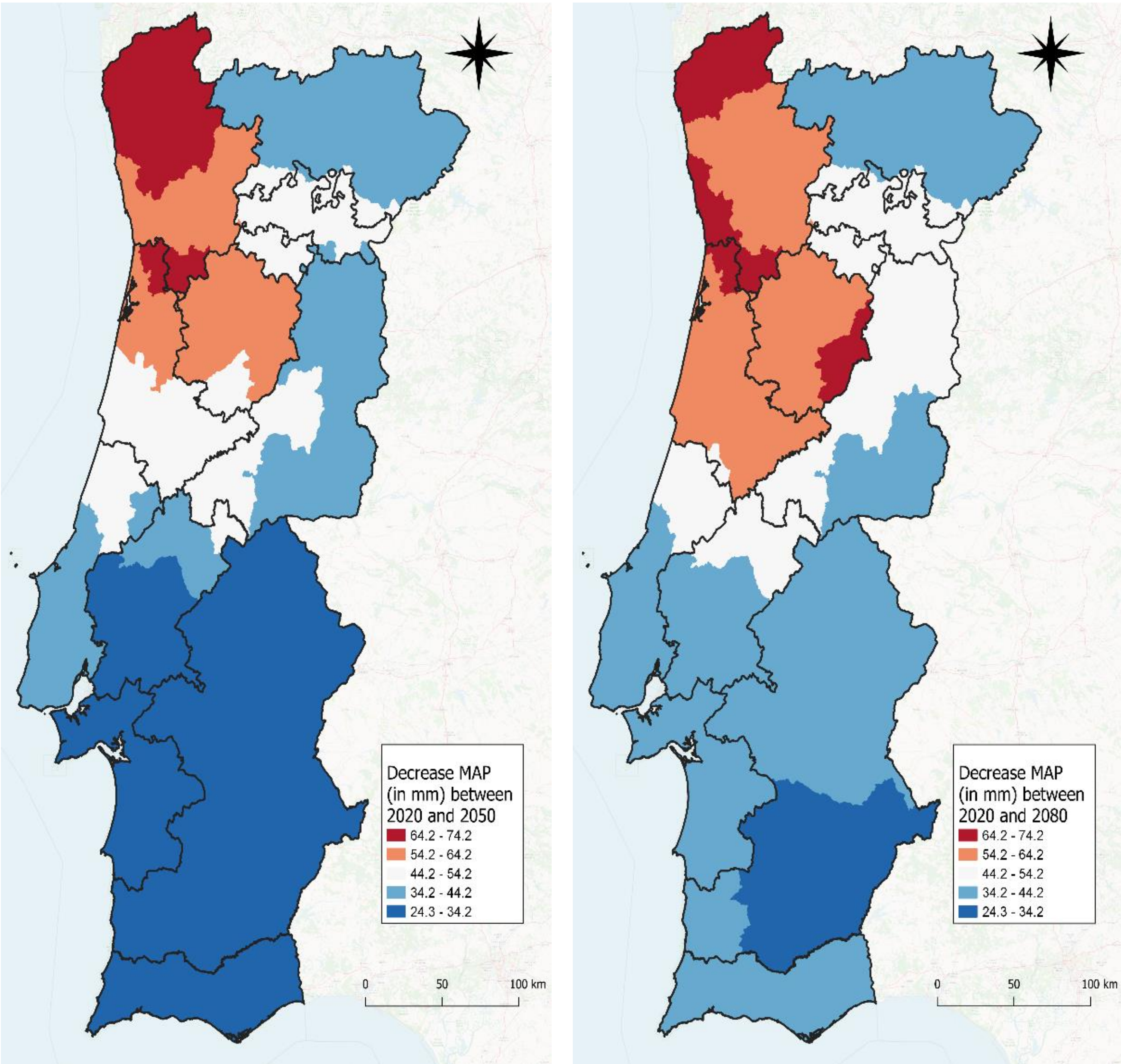


Figure 18: Rise in mean average precipitation (in mm) for all the NUTSIII regions with the borders of the IGP's visualized for Continental Portugal for the years 2020-2050 and 2020-2080. Source: Own maps, data based on CMIP5-based climate data (2.5km resolution).

3.4.4 Mean Summer Precipitation

3.4.4.1. Characterization

As could be visible in figure 19, the Mean Summer Precipitation (MSP) seems to follow a similar pattern as the mean annual precipitation (MAP). The South of the Portuguese continent seems to be characterized by a precipitation between 33-58mm for the South, with some outliers between 83-108 mm. The center of the country shows a wide range of different values, from 83 to over 259 mm of precipitation for the Serra de Estrela. The North-West has the highest values of precipitation, ranging between 184-259 mm, the precipitation values of the North-East range between 108-184 mm.

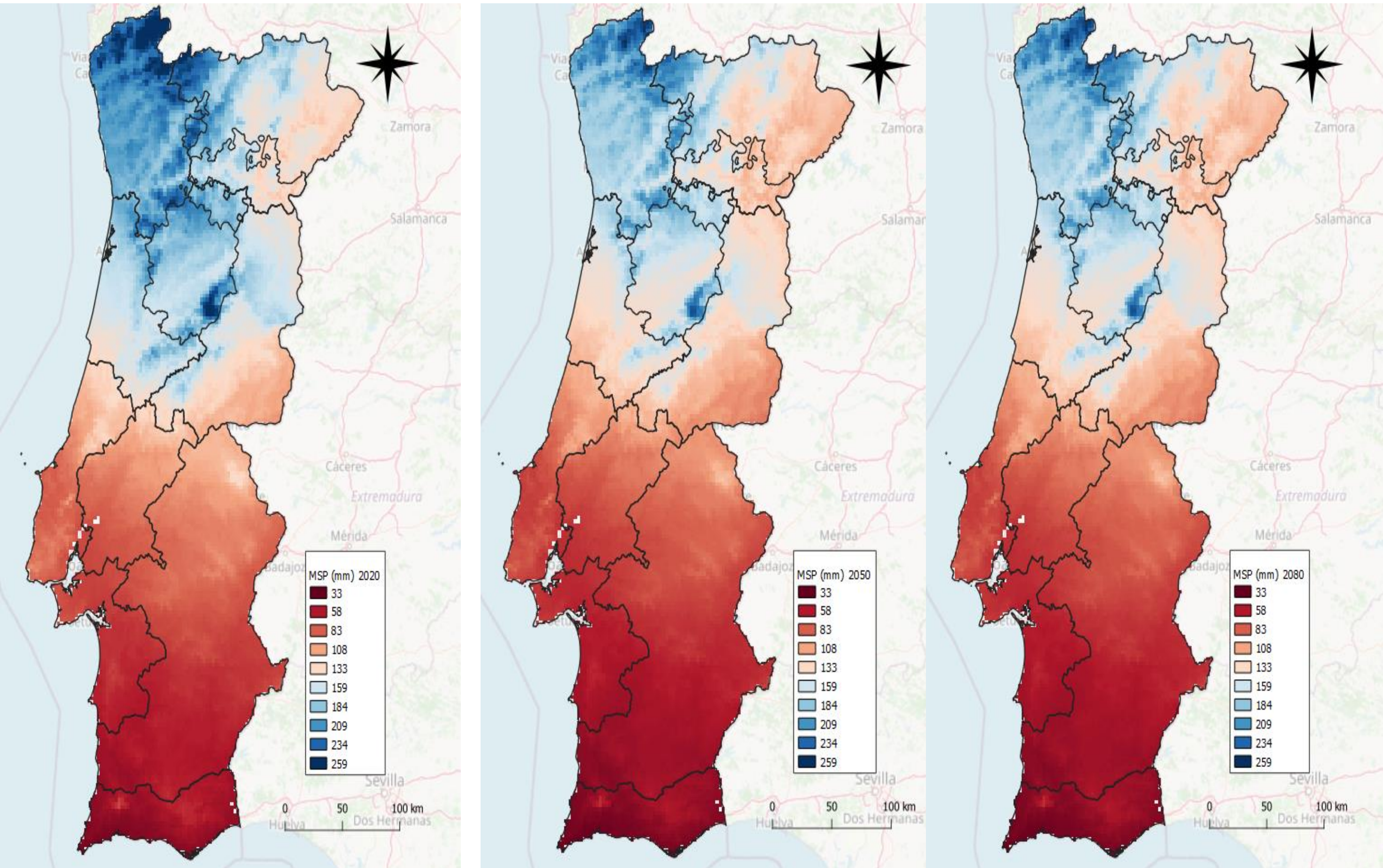


Figure 19: Mean Summer Precipitation (MSP) in mm for all the NUTSIII regions with the borders of the IGP's visualized for Continental Portugal – 2020 (left), 2050 (middle), and 2080 (right). Source: Own maps, data based on CMIP5-based climate data (2.5km resolution)

3.4.4.2. Minimum values

The next set of maps (figure 20) show the average value again for each NUTSIII region, but this time for only the summer precipitation. These maps clearly show a divide between the

South of Portugal (low precipitation) and the North-West (high precipitation). The map about the current situation (2020) shows that the lowest MSP is currently found in the Algarve (51.42 mm), followed by Alentejo Litoral (61.34 mm) and Baixo Alentejo (63.08 mm). The projections for the year 2050 and 2080 add Lezíria do Tejo (*IGP Tejo*), Oeste (*IGP Lisboa*) and Grande Lisboa (*IGP Lisboa*) to the group of NUTSIII regions characterized by the lowest precipitation. The lowest values for the year 2050 were found in the Algarve (45.79 mm), followed by Alentejo Litoral (54.09 mm) and Baixo Alentejo (56.24 mm). This same trend continues for the year 2080, which results in Algarve (44.56 mm), followed by Alentejo Litoral (52.57 mm) and Baixo Alentejo (54.59 mm).

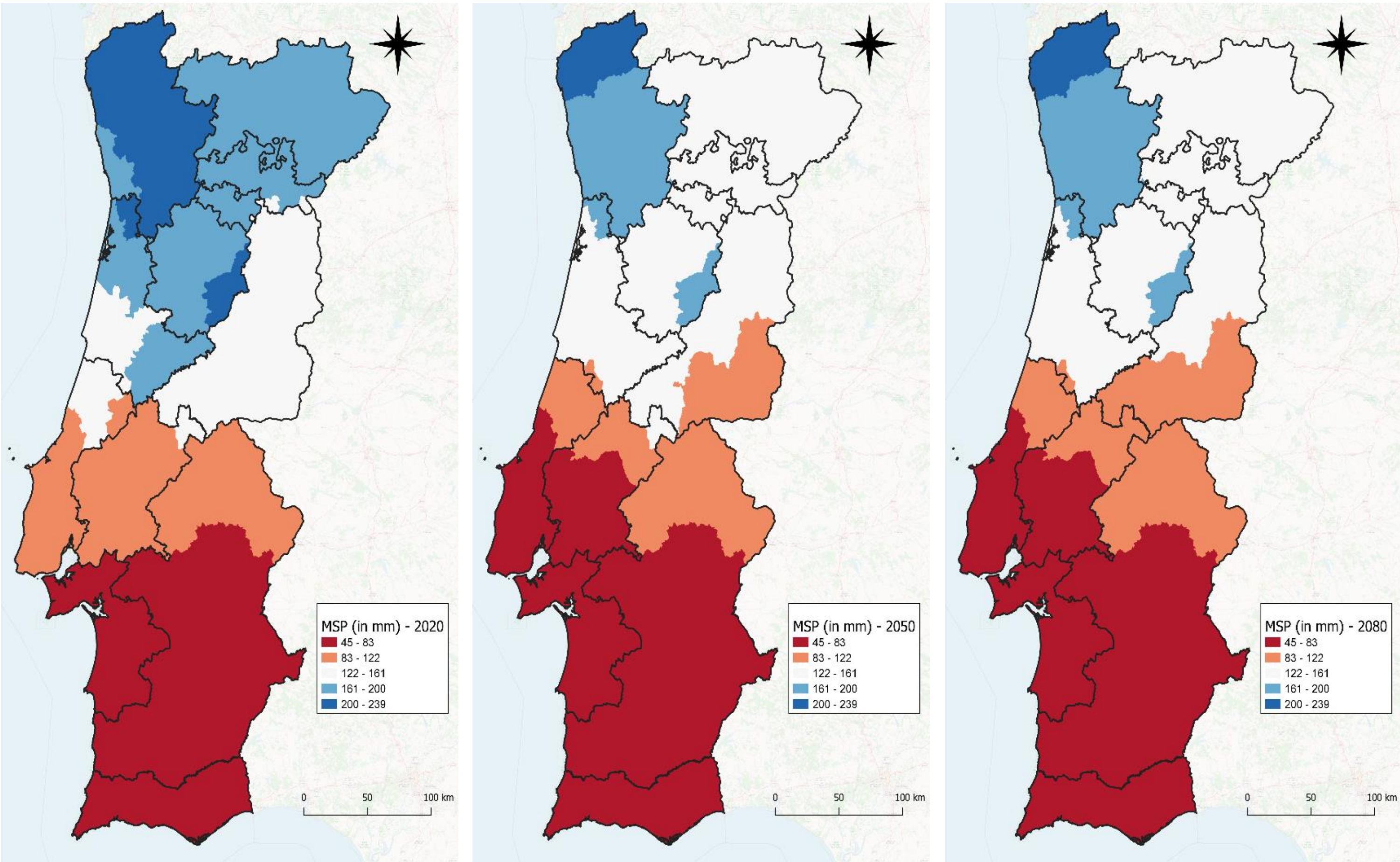


Figure 20: Mean Summer Precipitation (MSP) in mm for all the NUTSIII regions with the borders of the IGP's visualized for Continental Portugal – 2020 (left), 2050 (middle), and 2080 (right). Source: Own maps, data based on CMIP5-based climate data (2.5km resolution)

3.4.4.3. Decrease

Figure 21 shows the decrease in MSP for the years 2050 and 2080 compared to the year 2020. The highest decrease in MSP for the year 2050 is projected in Minho-Lima (30.73 mm), followed by Cávado (27.62 mm) and Ave (26.4 mm) (*IGP Minho*). This trend will continue up until the year 2080, with the highest values found again in Minho Lima (37.31 mm), Cávado – (33.29 mm), and Ave (31.64 mm). The lowest decrease in summer precipitation can be found in the Algarve, for both the years 2050 (-5.63 mm) and 2080 (6.86 mm).

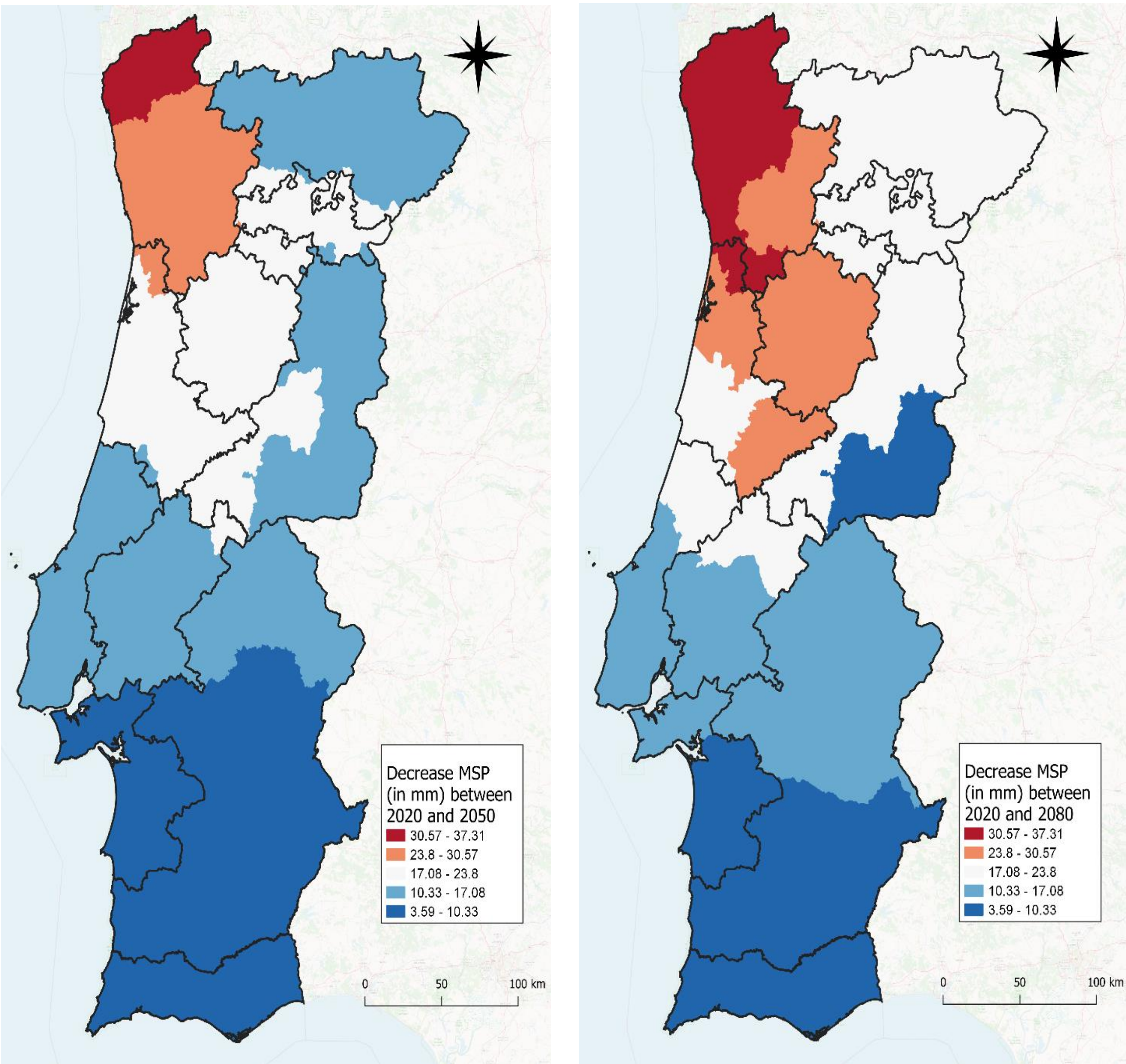


Figure 21: Rise in mean summer precipitation (in mm) for all the NUTSIII regions with the borders of the IGP's visualized for Continental Portugal for the years 2020-2050 and 2020-2080. Source: Own maps, data based on CMIP5-based climate data (2.5km resolution).

3.4.5 Climatic Moisture Deficit

3.4.5.1 Characterization

The moisture deficit is the combination of the effective precipitation and evapotranspiration, which is visible in figure 22 for Continental Portugal for the years 2020, 2050 and 2080. A moisture deficit is could potentially cause adverse impacts on vegetation, animals, and/or people through a shortage of water. On first eyesight, the set of maps seems to be quite similar to the earlier set of maps about the annual temperature and precipitation, but the impacted regions are different. Currently, the highest impacted region of Portugal is the South, which roughly embraces the *IGP Algarve*, the *IGP Alentejano*, the *IGP Tejo* and the Southern part of *IGP Península de Setúbal* and *IGP Terras de Beira*. The moisture deficit seems to have the most significant consequences for the *IGP Alentejano*. By contrast, *IGP Lisboa*, *IGP Beira Atlântico*, *IGP Minho* and *IGP Terras de Dão* seem to represent the lowest moisture deficit. Also interesting is the growing moisture deficit for *IGP Duriense* and *IGP Transmontano*, which is especially visible for the *IGP Duriense*.

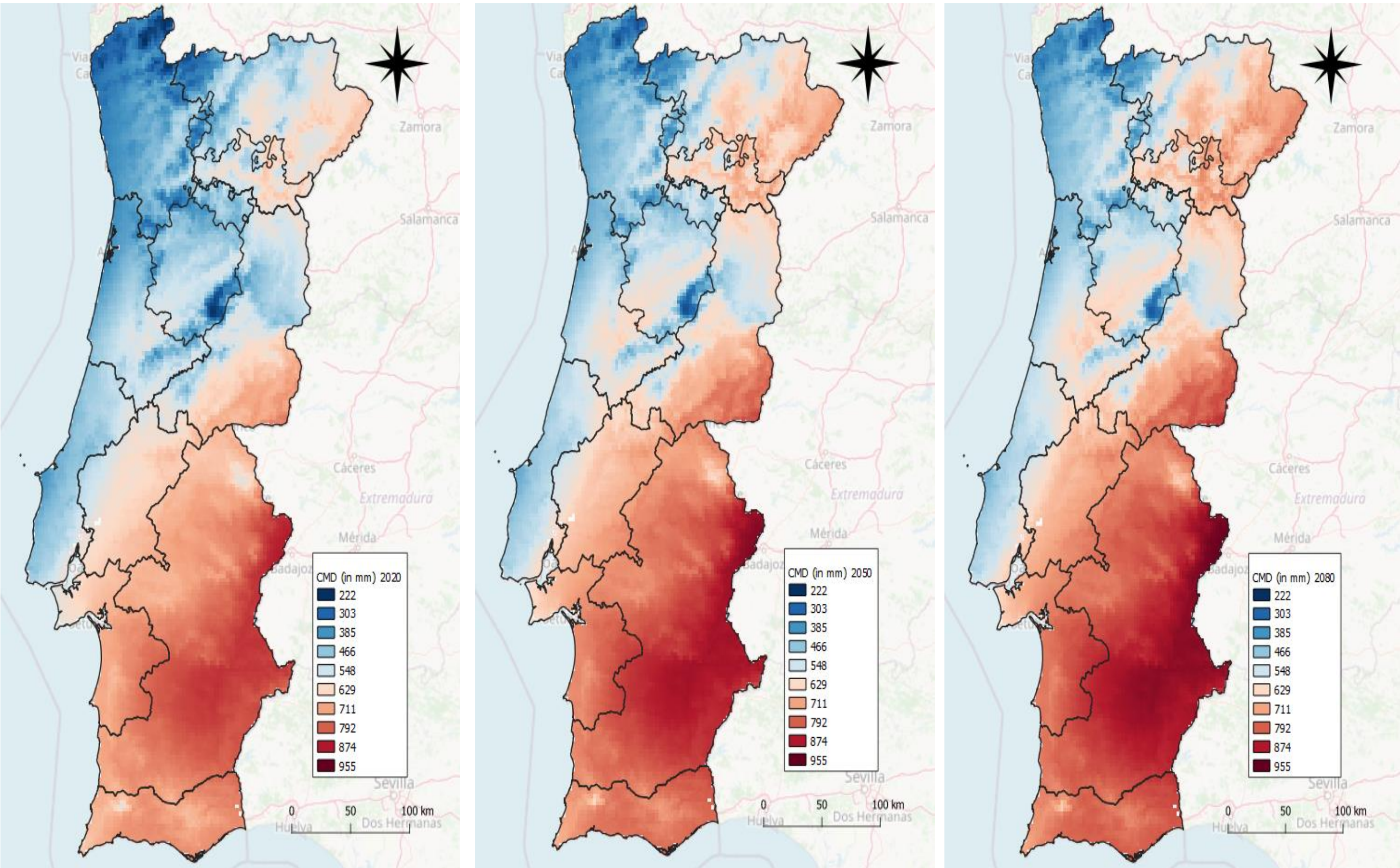


Figure 22: Climatic Moisture Deficit (CMD) in mm for all the NUTSIII regions with the borders of the IGP's visualized for Continental Portugal – 2020 (left), 2050 (middle), and 2080 (right). Source: Own maps, data based on CMIP5-based climate data (2.5km resolution)

3.4.5.2 Maximum values

Figure 23 shows the increase of the climatic moisture deficit (CMD), which will mostly impact the South of Portugal, comprising *IGP Algarve*, IGP Alentejo and IGP Península de Setúbal. Currently, the highest values can be found in Baixo Alentejo (799.78 mm), Alentejo Central (755.64 mm), and Alentejo Litoral (728.31 mm) (*IGP Alentejano*) The year 2050 shows a similar trend, with maximum values being found in Baixo Alentejo (845.95 mm), Alentejo Central (806.13 mm), and Alentejo Litoral (770.15 mm) (*IGP Alentejano*). The same trend continues until the year 2080, with maximum values being found in Baixo Alentejo (869.31 mm), Alentejo Central (831.48 mm), and the Algarve (795.42 mm).

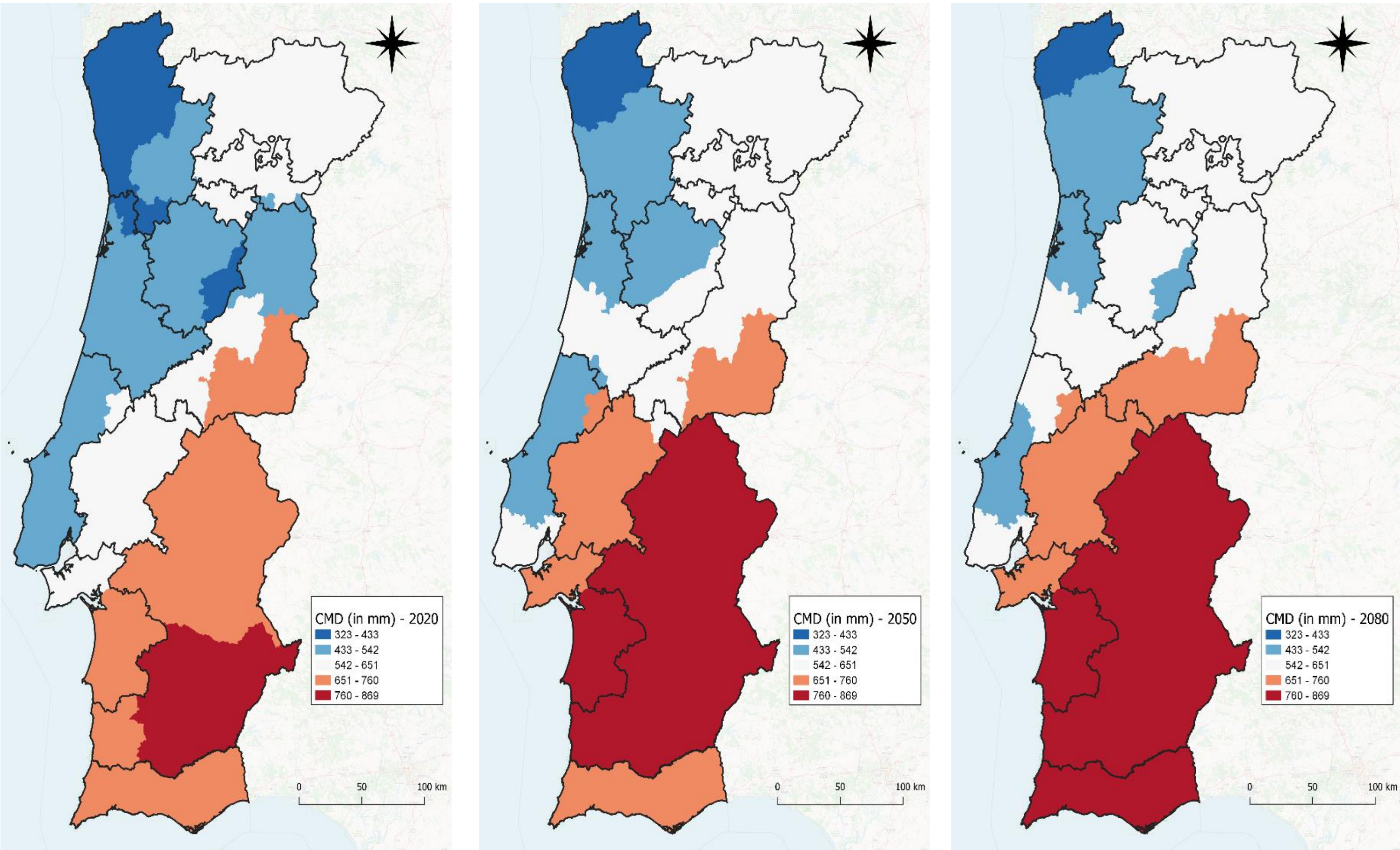


Figure 23: Climatic Moisture Deficit in mm for all the NUTSIII regions with the borders of the IGP's visualized for Continental Portugal – 2020 (left), 2050 (middle), and 2080 (right). Source: Own maps, data based on CMIP5-based climate data (2.5km resolution)

3.4.5.3 Increase

Figure 24 shows the moisture deficit for each IGP individually for the year 2050 and 2080 compared to the year 2020. The increase in the moisture deficit seems to be the lowest near the Atlantic Ocean (e.g. *IGP Algarve* and *IGP Lisboa*), and the highest for the regions located near the border with Spain away from the Atlantic Ocean. For the year 2050, the highest increases were found in Beira Interior Sul (53.84 mm) (*IGP Terras da Beira*), Alto Trás-os-Montes (52.24 mm) (*IGP Transmontano*) and Alto Alentejo (52.22 mm) (*IGP Alentejano*). Usually, the results were clustered around each other in specific regions, but this was not the case for the moisture deficit, the highest values comprise different parts of Portugal, but all away from the influence of the Atlantic Ocean. For the year 2080, the highest values were found in Beira Interior Sul (79.23 mm) (*IGP Terras da Beira*), Algarve (75.88 mm) (*IGP Algarve*) and Alentejo Central (75.84 mm) *(IGP Alentejano).* Interesting is the spatial distribution again of the regions with the highest values for the moisture deficit, with especially Beira Interior Sul, which was also the highest value found for the highest summer temperatures (MST).

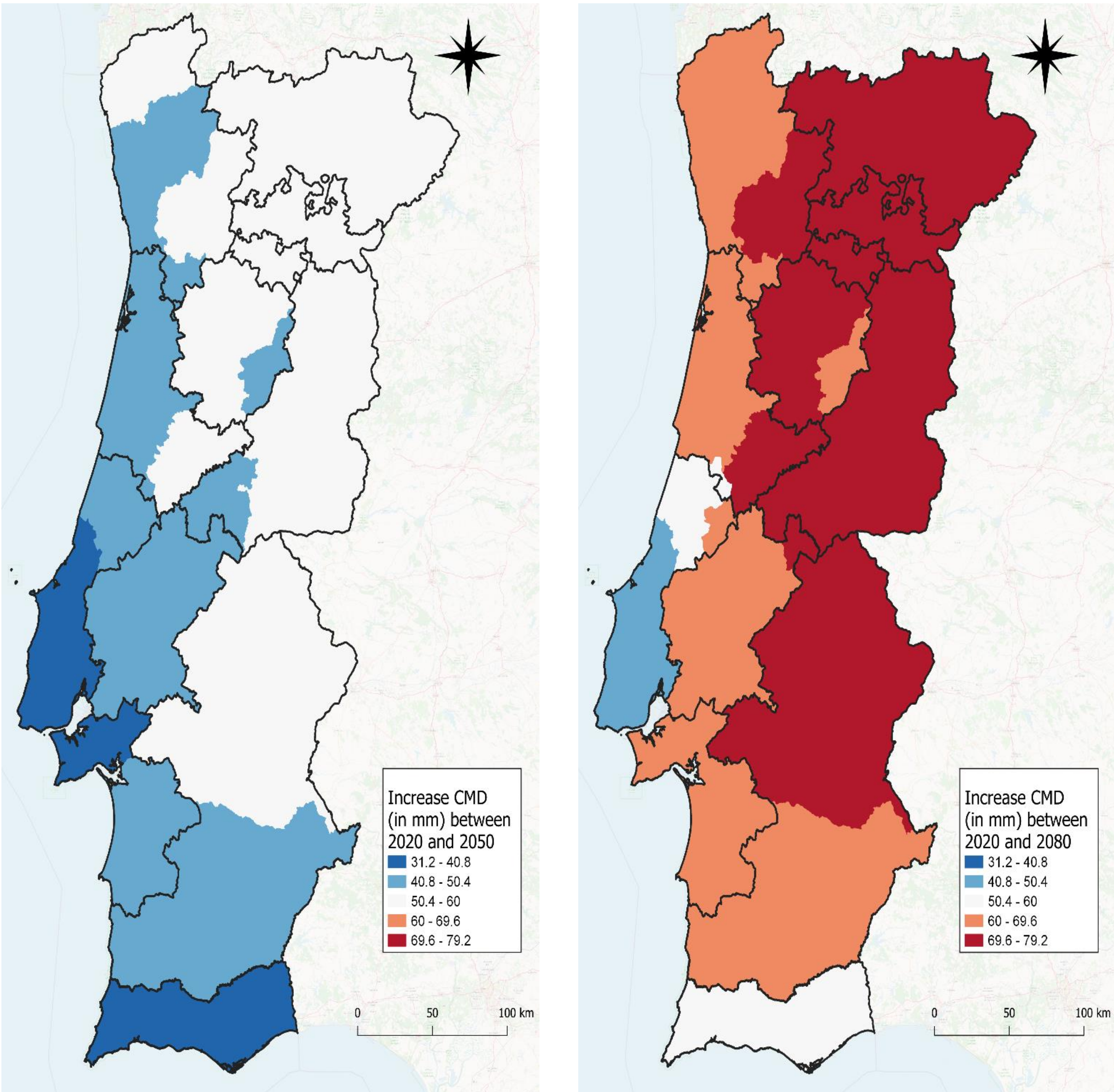


Figure 24: Rise in climatic moisture deficit (in mm) for all the NUTSIII regions with the borders of the IGP's visualized for Continental Portugal for the years 2020-2050 and 2020-2080. Source: Own maps, data based on CMIP5-based climate data (2.5km resolution).

3.5 Vulnerability

3.5.1 Introduction

The total vulnerability is measured through data made available by ESPON (2012), which is based on the AR4 where vulnerability is measured through the combination of the regional potential impacts of climate change (figure 25) and the regional capacity to adapt (figure 26). The final map shows the total vulnerability to climate change of each region for Continental Portugal (figure 27). The data is delivered in the regions according to the NUTSIII classification (see chapter 3.2.2) and available for the entire European Union. All maps for the 3 variables can be consulted here[8].

As the research only focusses on Continental Portugal, the rest of the values for other European countries were dismissed (Show attribute table > Toggle Editing Mode > Delete Selected Features). All values for Continental Portugal were transferred to an Excel and subsequently joined (Open Data Source Manager > add .csv document > Attribute table layer NUTSIII region > Properties > Joins > Add New Join > Choose the Excel file) to the shapefile with NUTSIII regions that was already cut before (see chapter 3.2.2). As has been done with all the maps before, the boundaries of the original NUTSIII regions were taken out (Properties > Symbology > Simple Fill > Match Fill Colour with Stroke Colour > OK) and subsequently the shapefile was covered by the boundaries of the IGP's (see chapter 3.2.2) These last layers were already made before (see figure 3.3.1) according to the Portuguese law. The total result is a map which allows the reader to see what parts of the different IGP's are characterized by what value for potential impact of climate change, capacity to adapt and the subsequent total vulnerability.

3.5.2 Potential Impact of climate change

The first variable is the potential impact of climate change, which was calculated as a combination of the regional exposure to climate change between 1961-1990 and 2071-2100 obtained from the 8 different climatic variables of the CCLM Model for the IPCC SRES A1B scenario, just as inundation depth changes for a 100 year return flood event (LISFLOOD model), storm surge height projections (DIVA model) and most recent data available on the weighted dimensions of physical, economic, social, environmental and cultural sensitivity to climate change. The final map of the potential impact of climate change shows a weighted combination of physical (weight 0.19), environmental (0.31), social (0.16), economic (0.24) and cultural (0.1) potential impacts of climate change for Portugal. According to ESPON (2012), these weights are based on a Delphi survey of the ESPON Monitoring Committee.

8 https://www.espon.eu/climate-2012

As could be visible in figure 25, the highest negative impact is mostly clustered to the South of Portugal, more specifically the *IGP Algarve, IGP Península de Setúbal* and the South of both *IGP Alentejo* and *IGP Lisboa*. A medium impact was found for *IGP Transmontano*, *IGP Duriense*, *IGP Terras de Cister*, *IGP Tejo*, the northern part of *IGP Alentejo* and small parts of *IGP Terras de Beira* and *IGP Terras de Dão*. A low negative impact is mostly found along the Atlantic Ocean, comprising *IGP Minho*, *IGP Beira Atlântico*, and parts of *IGP Lisboa*, *IGP Terras do Dão* and *IGP Terras de Beira*. The lowest value was found for Pinhal Interior Sul (South of *IGP Terras de Beira*), which represents a marginal to no impact at all.

3.5.3 Capacity to adapt

The capacity to adapt is measured by ESPON through a weighted combination of most recent data on economic (0.21), infrastructural (0.16), technological (0.23) and institutional capacity (0.17) as well as knowledge and awareness (0.23) of climate change. The weights are based again on the Delphi survey of the ESPON Monitoring Committee, just like the weights for the aggregate potential to adapt to climate change.

Figure 26 shows the capacity to adapt seems to follow a clear pattern: Almost all NUTSIII regions from Lisbon upward closely located to the Atlantic Ocean got the value 'low', and the rest of Continental Portugal the value 'lowest'. Already an interesting pattern arises out of this information if this map is compared with figure 25 about the potential aggregate effect of climate change on the different regions, just as the projections of the climate hazards for the MAT, MST, MAP, MSP and CMD from section 3.2. The highest impacted regions seem also to be the regions with the lowest capacity to adapt, such as the South of Portugal (*IGP Algarve*, *IGP Alentejano* and part of *IGP Península de Setúbal*) and *IGP Terras da Beira*, *IGP Duriense*, *IGP Terras de Cister* and *IGP Transmontano*.

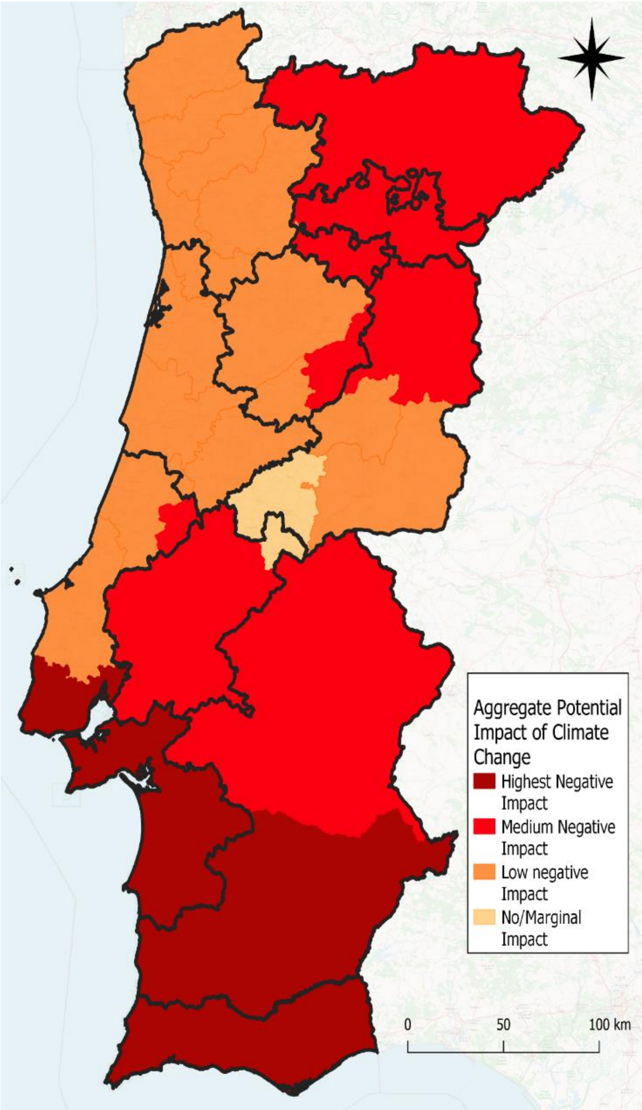


Figure 26: Aggregate Potential Impact of Climate Change on Continental Portugal, with the boundaries of the IGP's visualized. Source: Own map, data taken from ESPON (2012).

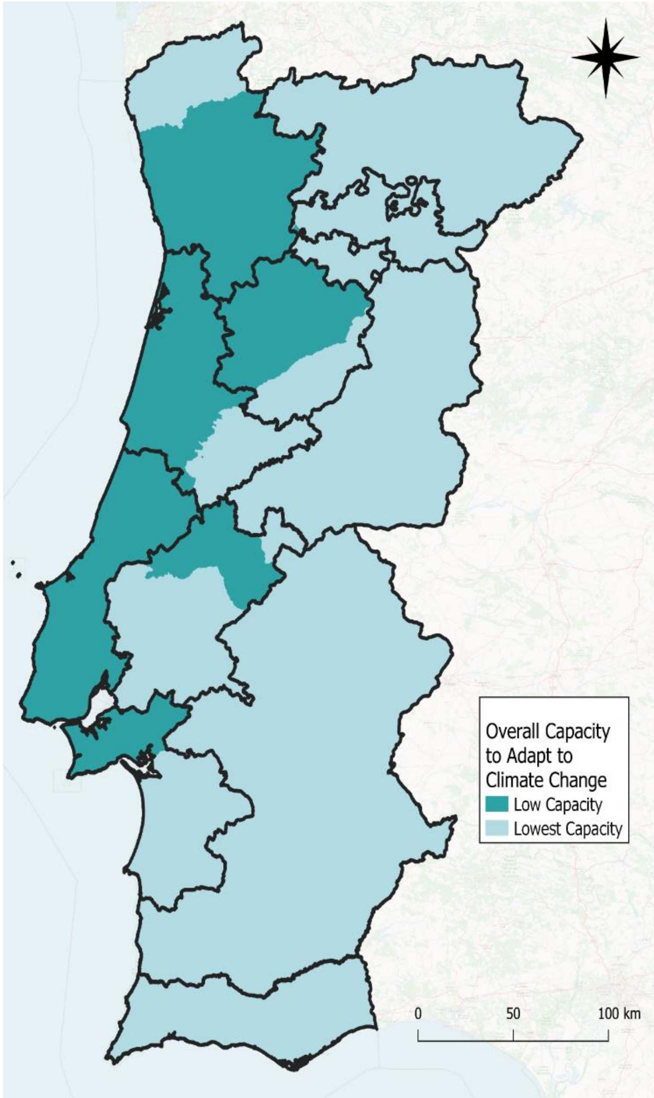


Figure 25: Overall Capacity to Adapt to Climate Change, with the boundaries of the IGP's visualized. Source: Own map, data taken from ESPON (2012).

3.5.4 Potential Vulnerability to Climate Change

Both the aggregate potential of climate change and the overall capacity to adapt are subsequently crossed to obtain the potential vulnerability to climate change. As could be visible in figure 27, the highest vulnerability can be found in the South of Portugal, which comprises *IGP Algarve* and parts of *IGP Alentejano* and *IGP Península de Setúbal*. A medium vulnerability is found for *IGP Transmontano, IGP Duriense*, *IGP Terras de Cister*, *IGP Tejo*, and parts of *IGP Alentejo*, *IGP Lisboa*, *IGP Península de Setúbal*, *IGP Terras de Dão* and *IGP Terras da Beira*. A low vulnerability is found for the regions and IGP's close to the Atlantic Ocean, which follows a pattern similar to the map about the capacity to adapt, but this time excludes the NUTSIII region of Grande Lisboa, Setúbal and Médio Tejo, and includes the NUTSIII regions of Pinhal Interior Norte, Beira Interior Sul and Minho-Lima.

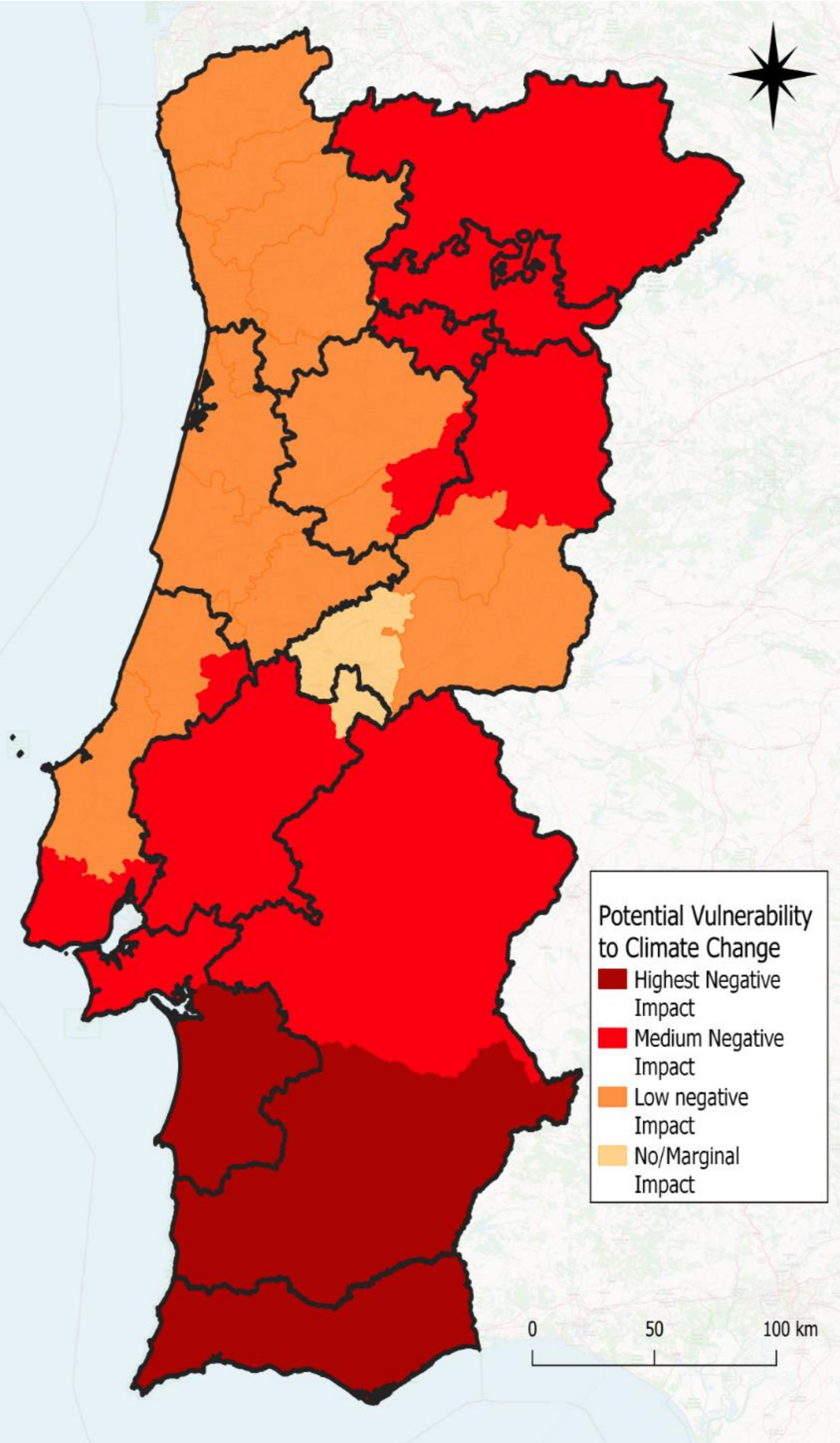


Figure 27: Potential vulnerability to climate change for Continental Portugal, with the boundaries of the different IGP's visualized. Source: Own map, data taken from ESPON (2012).

3.6 Methodology

The methodology for the total climate risks follows the AR5 from the IPCC discussed in chapter 2. All the three elements (exposure, hazards and vulnerability) are assigned exactly one third of the total weight, a conceptual model of the methodology is shown again in figure 27. For further information about the specific datasets and data analyzation methods used, please consult the respective chapters of each of these variables (chapter 3.3, 3.4 and 3.5)

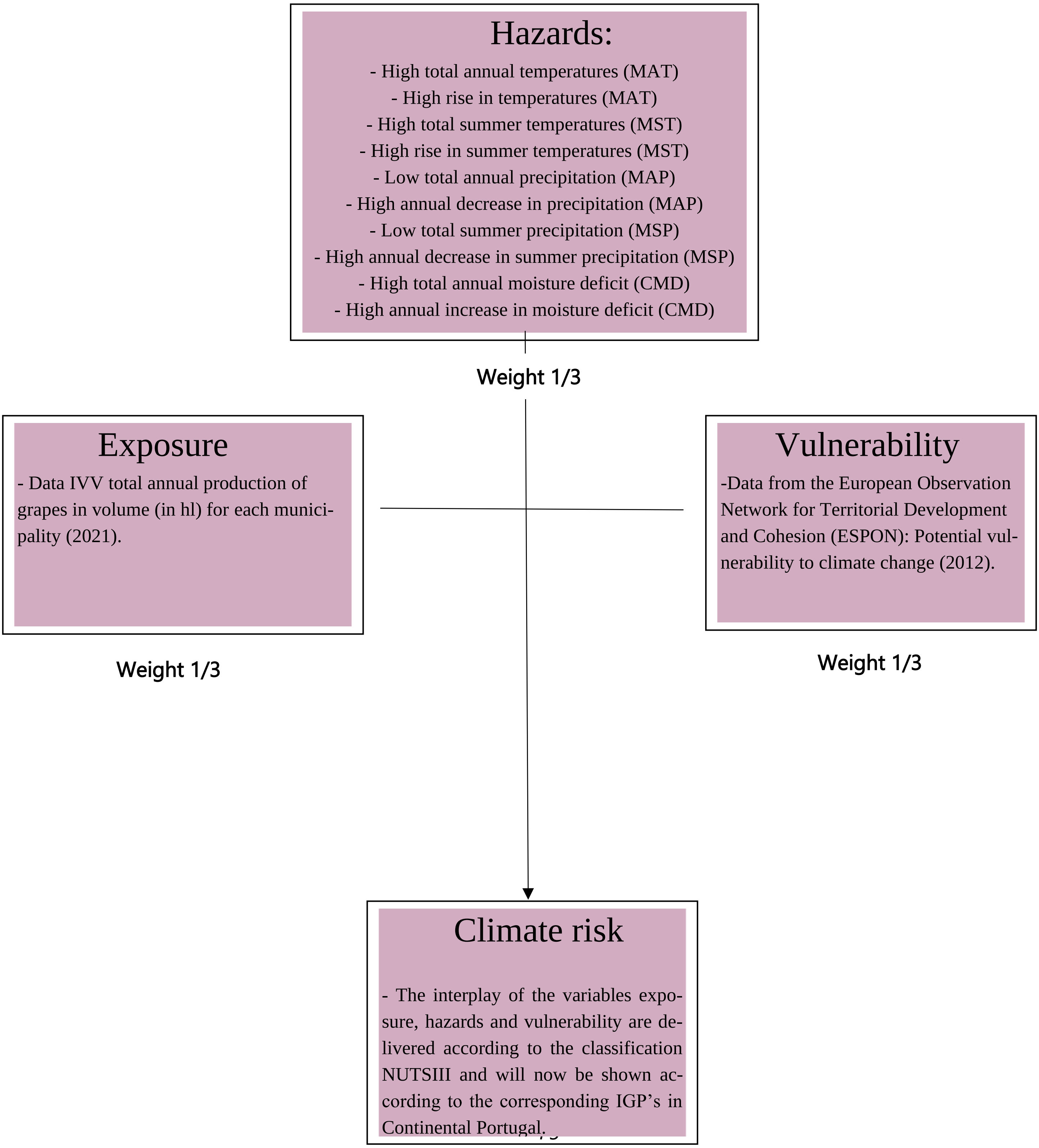


Figure 28: Conceptual model of the methodology used. Source: Own Model based on the conceptual framework of the AR5 of the IPCC (2014)

The variable 'hazards' is subdivided into 5 identified different hazards (MAT/MST/MAP/MSP/CMD) and subsequently further subdivided further into 5 different risks for each of these hazards::

1) The risk for a high maximum or minimum value for the year 2020
2) The risk for a high maximum or minimum value for the year 2050
3) The risk for a high maximum or minimum value for the year 2080
4) The increase or decrease between 2020 and 2050
5) The increase or decrease between 2020 and 2080

All variables and categories linked to the identified hazards are visible in table 29, in total there are 25 different identified risks, 5 for each variable. The first three risks are to reach a maximum temperature for the years 2020, 2050 and 2080, followed by the risks of a high increase/decrease of a specific variable between 2020/2050 and 2020/2080.

Variable	Identified Risk	Explanation
MAT	Max. Mean Annual Temperature (MAT) - 2020	Risk for a high maximum annual temperature in the year 2020
	Max. Mean Annual Temperature (MAT) - 2050	Risk for a high maximum annual temperature in the year 2050
	Max. Mean Annual Temperature (MAT) - 2080	Risk for a high maximum annual temperature in the year 2080
	Increase between 2020/2050	Highest rise in annual temperature for the year 2050 compared to the 2020.
	Increase between 2020/2080	Highest rise in annual temperature for the year 2080 compared to the 2020.
	Max. Mean Summer Temperature MST - 2020	Risk for a high maximum summer temperature in the year 2020

MST	Max. Mean Summer Temperature MST - 2050	Risk for a high maximum summer temperature in the year 2050
	Max. Mean Summer Temperature MST - 2080	Risk for a high maximum summer temperature in the year 2080
	Increase between 2020/2050	Highest rise in summer temperature for the year 2050 compared to the 2020.
	Increase between 2020/2080	Highest rise in summer temperature for the year 2080 compared to the 2020.
MAP	Min. Mean Annual Precipitation (MAP) - 2020	Risk for a low minimum annual precipitation (in mm) for the year 2020
	Min. Mean Annual Precipitation (MAP) - 2050	Risk for a low minimum annual precipitation (in mm) for the year 2050
	Min. Mean Annual Precipitation (MAP) - 2080	Risk for a low minimum annual precipitation (in mm) for the year 2080
	Increase between 2020/2050	Highest decrease in annual precipitation for the year 2050 compared to the 2020.
	Increase between 2020/2050	Highest decrease in annual precipitation for the year 2080 compared to the 2020.
	Min. Mean Summer Precipitation (MST) - 2020	Risk for a low mean summer precipitation (in mm) for the year 2020

MSP	Min. Mean Summer Pre-cipitation (MST) - 2050	Risk for a low mean summer precipitation (in mm) for the year 2020
	Min. Mean Summer Pre-cipitation (MST) - 2080	Risk for a low mean summer precipitation (in mm) for the year 2080
	Increase between 2020/2050	Highest decrease in summer precipitation for the year 2050 compared to the 2020.
	Increase between 2020/2080	Highest decrease in summer precipitation for the year 2080 compared to the 2020.
CMD	Max. Moisture Deficit (CMD) - 2020	Risk for a high mean moisture deficit (in mm) for the year 2020
	Max. Moisture Deficit (CMD) - 2050	Risk for a high mean moisture deficit (in mm) for the year 2050
	Max. Moisture Deficit (CMD) - 2080	Risk for a high mean moisture deficit (in mm) for the year 2080
	Increase between 2020/2050	Highest increase in moisture deficit for the year 2050 com-pared to the 2020.
	Increase between 2020/2080	Highest increase in moisture deficit for the year 2080 com-pared to the 2020.

Figure 29: Explanation of all the different risks identified, each of these risks will be visualized for Continental Portugal in chapter 3.4.2

Each and one of these sub variables are subsequently crossed with the data available about the exposure and the vulnerability through dividing each variable into 4 equal quartiles:

1) No or minimal effect (‘NO/MINIMAL’ = All values below 25%)
2) Low effect (‘LOW’ = Values between 25-50%);
3) Medium effect (‘MEDIUM’ = Values between 50-75%);
4) High effect (‘HIGH’ = Values > 75%).

These categories are determined through calculating the different quartiles, which divide the values found for the exposure, hazards and vulnerability into 4 equal groups. To exemplify, figure 30 shows the calculation for the risk related to the hazard Mean Summer Temperature (MST) for the year 2020. As could be visible below, the hazard is divided into 4 equal quartiles:

1) <20.76 C°
2) between 20.76 C° and 22.09 C°
3) between 22.09 C° and 23.38 C°
4) every value above 23.38 C°

To illustrate, a NUTSIII region with a temperature lower than 21.43 C° (e.g. Minho-Lima: 19.63 C°) gets assigned the value 1 because this region is within the 25% NUTSIII regions classified with the lowest summer temperatures. The same classification is applied to the variables exposure and vulnerability, which are also divided into 4 different classes based on the respective quartiles (see figure 30).

Risk high temperatures during summer (MST)			
Components	**Classification**	**Value**	**Specification**
Hazard	NO/MINIMAL EFFECT	1	<20.76 C°
	LOW	2	20.76-22.09 C°
	MEDIUM	3	22.09-23.38 C°
	HIGH	4	>23.38 C°

Exposure	NO EFFECT/MINIMAL	1	<24.991 hl
	LOW	2	24.991-108698.5 hl
	MEDIUM	3	118698.5-501952.75 hl
	HIGH	4	>501952.75 hl
Vulnerability	NO EFFECT/MINIMAL	1	Data ESPON
	LOW	2	Data ESPON
	MEDIUM	3	Data ESPON
	HIGH	4	Data ESPON

Figure 30: Example to Illustrate the methodology. Source: Own work.

The final result of the interplay of these 3 variables is the risk identified with the specific hazard. Table 31 below shows all the possible combinations to calculate the final risk score, which are added up in the last column called 'Total score (= risk)'. The lowest value possible is 3, which would mean that a specific NUTSIII region is in the bottom 25% quartile in every variable. To be more concrete, for the mean summer temperature (MST) this would mean that the NUTSIII region is in the bottom 25% of the risk variable, in the bottom 25% of exposure (low grape production) and in the bottom 25% of vulnerability. To put this into simple words: The region is likely not to have any significant grape production, nor seems to be exposed to a significant hazard, nor is classified as a vulnerable region. Needless to say, a region represented by the value 3 does not represent any form of risk according to this methodology. By contrast, a value of 12 means that the NUTSIII region is in the highest 25% of all values found for the different variables. Put in simple words again: The region is classified as a region with a high production, a high exposure to a climate hazard and also a high vulnerability. All the different combinations are visible below.

Vulnerability	Hazard	Exposure	Total score (= risk)
1	1	1	3

1	1	2	4
1	1	3	5
1	1	4	6
1	2	1	4
1	2	2	5
1	2	3	6
1	2	4	7
1	3	1	5
1	3	2	6
1	3	3	7
1	3	4	8
1	4	1	6
1	4	2	7
1	4	3	8
1	4	4	9
2	1	1	4
2	1	2	5
2	1	3	6
2	1	4	7
2	2	1	5
2	2	2	6
2	2	3	7

2	2	4	8
2	3	1	6
2	3	2	7
2	3	3	8
2	3	4	9
2	4	1	7
2	4	2	8
2	4	3	9
2	4	4	10
3	1	1	5
3	1	2	6
3	1	3	7
3	1	4	8
3	2	1	6
3	2	2	7
3	2	3	8
3	2	4	9
3	3	1	7
3	3	2	8
3	3	3	9
3	3	4	10
3	4	1	8
3	4	2	9

3	4	3	10
3	4	4	11
4	1	1	6
4	1	2	7
4	1	3	8
4	1	4	9
4	2	1	7
4	2	2	8
4	2	3	9
4	2	4	10
4	3	1	8
4	3	2	9
4	3	3	10
4	3	4	11
4	4	1	9
4	4	2	10
4	4	3	11
4	4	4	12

Figure 31: All the possible scores and calculations that could lead to a certain risk score. Source: Own work.

After having retrieved all the total scores for the climate risks associated with a specific hazard, it was chosen to simplify the categories, to be able to effectively distinguish the different values of the NUTSIII regions and make comparisons. Please note that no variable showed the value 3 or 12, therefore it was chosen to exclude these values out of the classification. The subsequent classification is used for the final risk maps:

Risk level	Total risk score
LOWEST RISK	≤5
LOW RISK	6
MINOR RISK	7
AVERAGE RISK	8
MAYOR RISK	9
HIGH RISK	10
HIGHEST RISK	≥11

Figure 32: Final categories of all the risk scores

3.7 Results

The results will be categorized into 2 parts:

1) The risk related to the highest (such as temperature) or lowest (e.g. precipitation) value for the year 2020, 2050 and 2080;

2) The risk related to the highest increase or decrease of a value between 2020 and 2050, and 2020 and 2080.

These are 2 completely different risks, whereas the first focuses on reaching maximum (e.g. temperature too high for current grape varieties) or minimum (e.g. not enough precipitation for viticulture) values, the second type of risk focusses on the respective increase of temperature of decrease of precipitation, which the entire value chain of the vine and wine sector will have to adapt to. To illustrate, take the summer temperature (24.17 C°) in Beira Interior Norte (*IGP Terras da Beira*), even though this is by far not the highest value found for all the different NutsIII regions, it did had the highest rise in temperatures for the year 2080 out of all the regions (1.86 C°). Put in different words, whereas it is unlikely that the maximum temperature for the production of grapes is attained in Beira Interior Norte, it will have to undertake substantial adaptation efforts (e.g. switch to more heat resistant grape varieties) to overcome the rise in temperature.

3.7.1. MAT

3.7.1.1. Risk maximum values

If the maps of the risk for the high annual temperature (MAT2020, 2050 and 2080) are studied, it becomes clear that there are no differences between the different projections. This can be easily explained by the fact that the production and vulnerability are fixed numbers (constants), and the rise in temperature follows a gradual trend for each region which will not show any significant differences with the current situation. This means that a region in the bottom quartile in the year 2020, will also be likely to be in the bottom quartile in 2050 and 2080. Take for example the region of Minho-Lima or Alto Trás-os-Montes in the North, whereas the temperature in these regions may rise at a faster rate than at the other regions, it is likely that these regions will continue to fall under the first quartile for the years 2050 and 2080 as well.

As could be visible in figure 30, the highest risk for maximum temperatures was found in Lezíria do Tejo (*IGP Tejo*), followed by Alentejo Central and Baixo Alentejo (*IGP Alentejano*). All of these regions show a total value of 11, which was attained in different ways. Whereas Lezíria do Tejo and Alentejo Central show a high production of grapes (> 75% of average), a medium vulnerability level (50-75% of average) and high temperatures (>75% of average), the

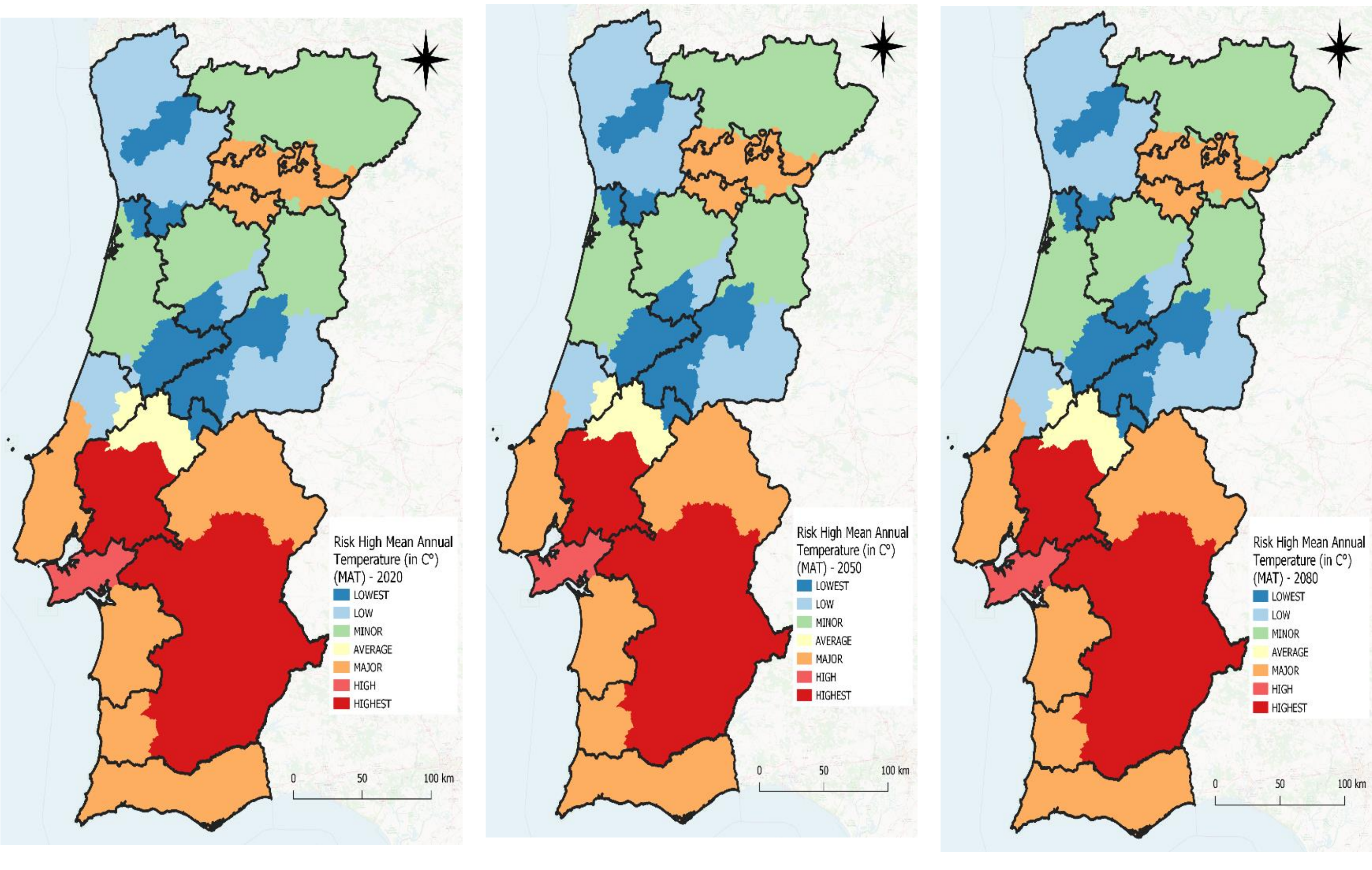


Figure 33: The final risk associated with maximum annual temperatures (in C°) in Continental Portugal. Source: Own maps, data from IVV (2021), ESPON (2012) and CMIP5-based climate data (2.5km resolution)

IGP Alentejo only showed a medium production of grapes (50-70% of average), but represented a high vulnerability level (> 75% of average) and high temperatures (>75% of average). The lowest values were found to the North near the Atlantic Ocean and in the middle of the country, which can partially be explained a low value for vulnerability (often <25%), exposure (often <25%) and hazards (<25%).

3.7.1.2 Risk Maximum rise

When it comes to the highest rise in annual temperature, a different pattern arises. Instead of showing the highest values in the South of Portugal, now Douro (*IGP Duriense* and *IGP Terras de Cister*) is identified as the IGP with the highest risk. Also, Alto Trás-os-Montes (*IGP Transmontano*) (only for the year 2050) and Beira Interior Norte (*IGP Terras da Beira*) show elevated values for the years 2050 and 2080, together with Alentejo Central and Baixo Alentejo (*IGP Alentejano*)

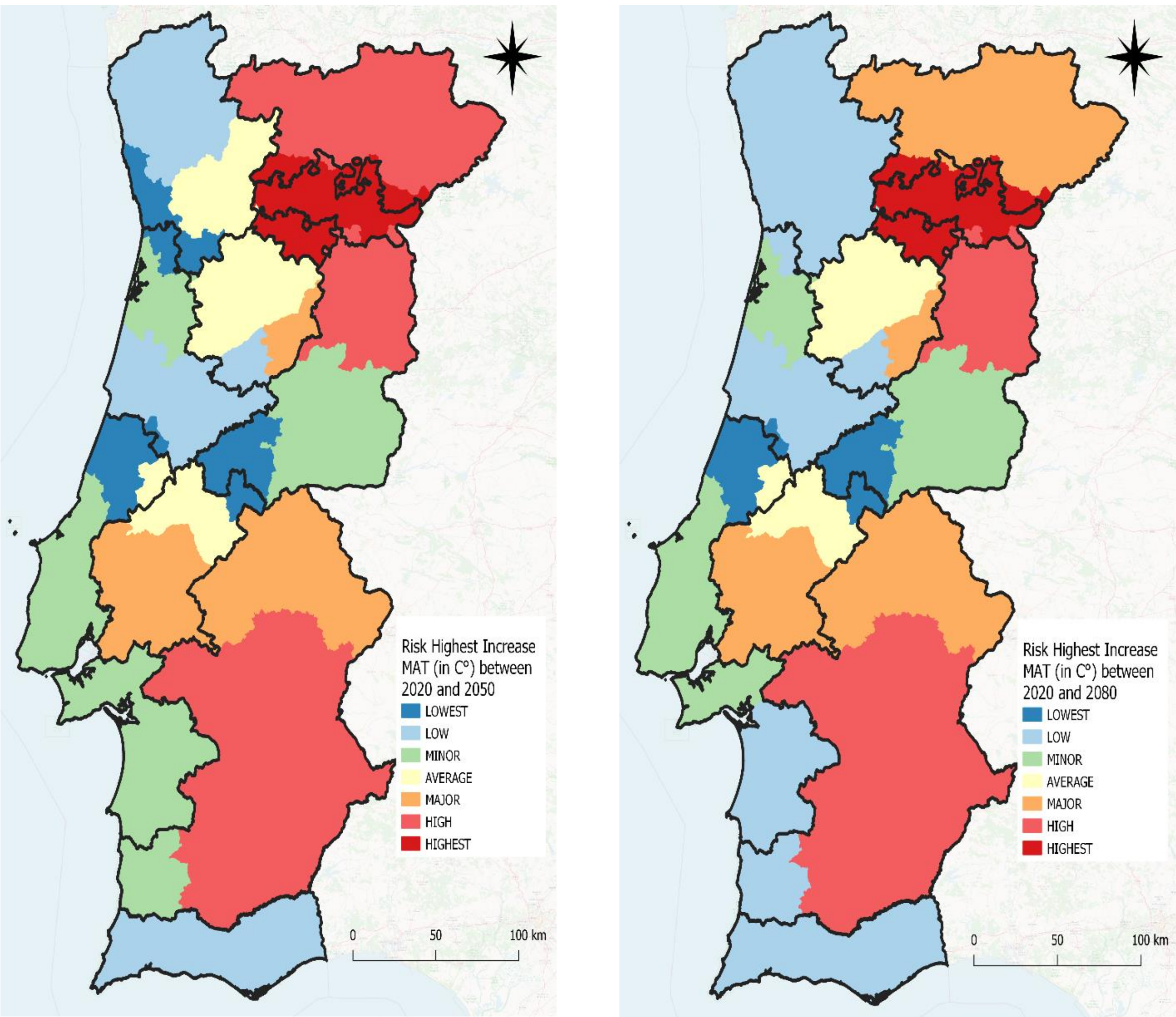


Figure 34: The risk associated with the highest rise in MAT (in C°) for Continental Portugal. Source: Own maps, data from IVV (2021), ESPON (2012) and CMIP5-based climate data (2.5km resolution)

3.7.2. MST

3.7.2.1 Risk Maximum values

The highest risk related with high summer temperatures are found in the Alentejo Central and Baixo Alentejo (*IGP Alentejano*), followed by Douro (*IGP Terras de Cister* and *IGP Duriense*), and Lezíria do Tejo (IGP Tejo). The regions directly located at sea seem to be have the lowest risk values. If the annual temperatures (MAT) and summer temperatures (MST) are compared, some interesting differences can be distinguished. An example is Beira Interior Norte (IGP Terras da Beira), which only shows minor risk for annual high temperatures, but got classified as 'major' for the risk of high summer temperatures. Another interesting results can be found in in Lezíria do Tejo (IGP Tejo), Cávado and Grande Porto (*IGP Minho*), Alentejo Litoral (*IGP Alentejano*) and the entire IGP Península de Setúbal and *IGP Lisboa*, which show a reduced risk for reaching maximum temperatures during the summer. By contrast, Tâmega (*IGP Minho*), Médio Tejo (IGP Tejo) and the entire IGP of Terras da Beira and *IGP Transmontano* show an increased risk during the summer compared to the annual temperatures.

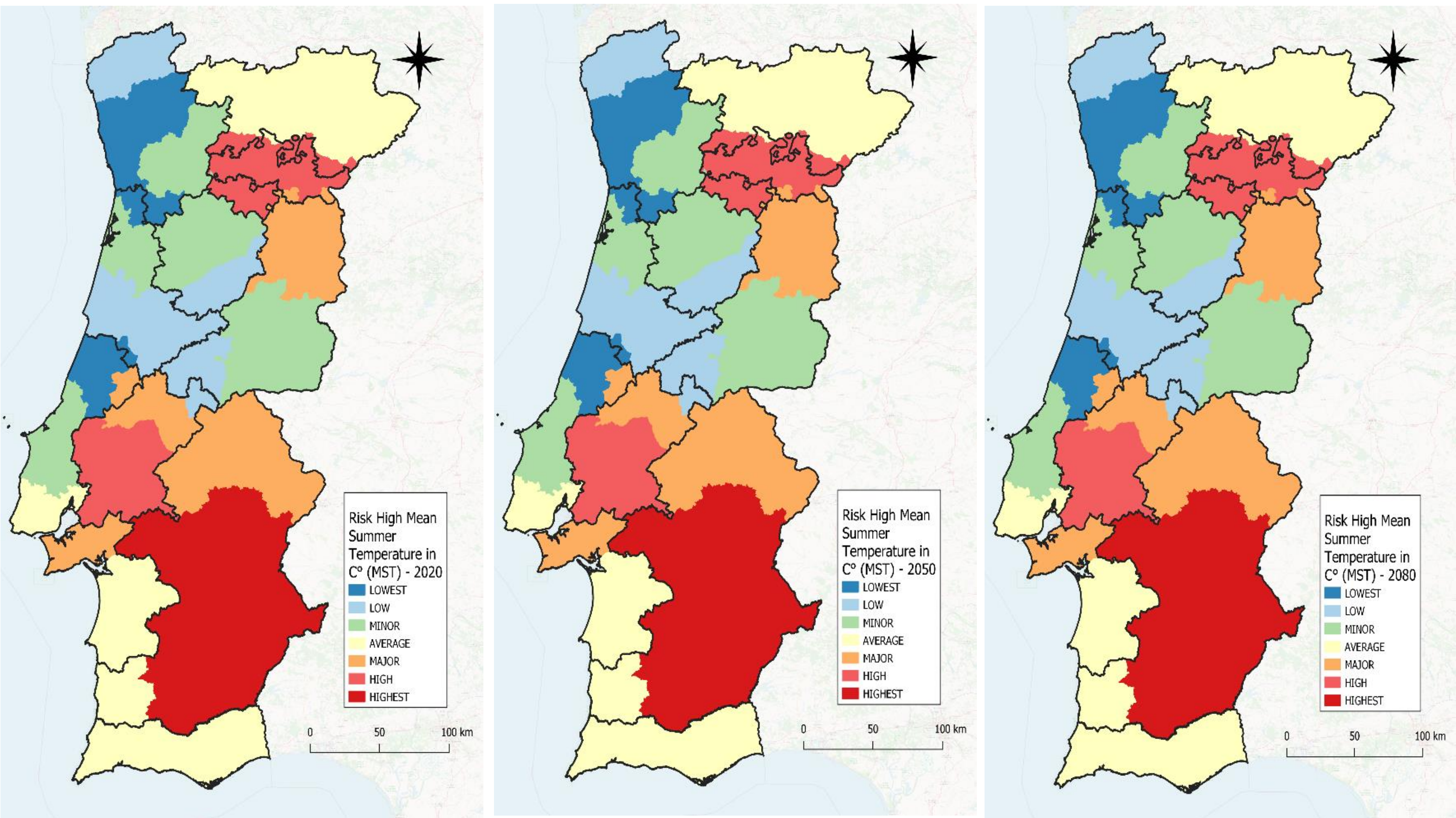


Figure 35: The final risk associated with maximum summer temperatures (in C°) for Continental Portugal. Source: Own maps, data from IVV (2021), ESPON (2012) and CMIP5-based climate data (2.5km resolution)

3.7.2.2 Risk Maximum rise

The highest risk for an increase in summer temperatures can be found in Douro (*IGP Duriense* and *IGP Terras de Cister*), followed by Alto Trás-os-Montes, (*IGP Transmontano*), Beira interior Norte (*IGP Terras da Beira*) and Alentejo Central (*IGP Alentejano*). The lowest risk for a high increase in MST is found in Pinhal Litoral (*IGP Lisboa*) and Pinhal interior Norte (*IGP Terras de Beira*) As a general rule, most values seem to be the lowest close to the Atlantic Ocean, just as already witnessed by the annual temperatures (MAT), with the only exception being the NUTSIII region of Grande Porto and Entre Douro e Vouga (*IGP Minho* and *IGP Beira Atlântico*).

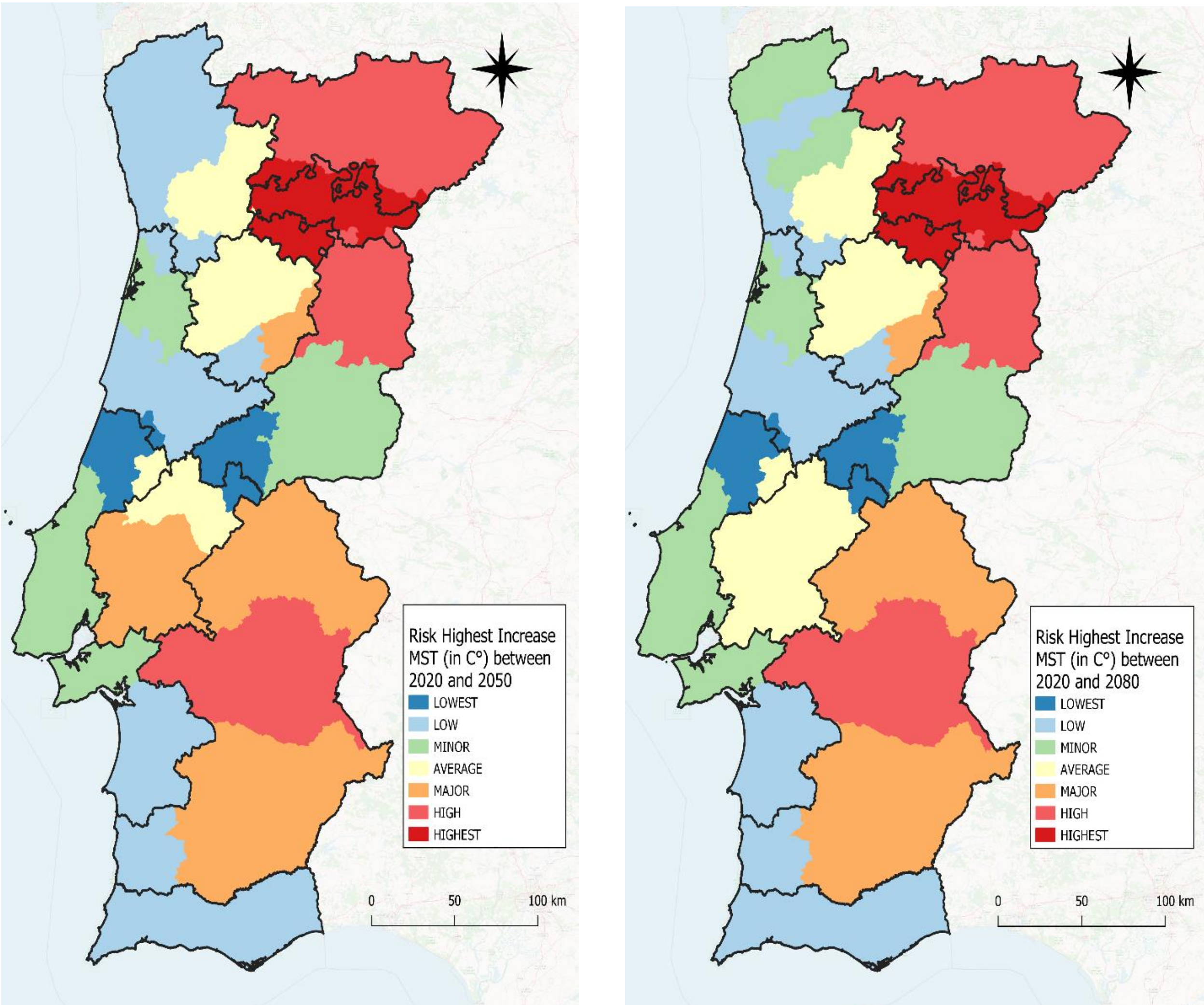


Figure 36: The risk associated with the highest rise in MST (in C°) for Continental Portugal. Source: Own maps, data from IVV (2021), ESPON (2012) and CMIP5-based climate data (2.5km resolution)

3.7.3 MAP

3.7.3.1 Minimum values

When it comes to the Minimum Average Precipitation (MAP), the highest risk was identified in Alentejo Central and Baixo Alentejo (*IGP Alentejano*) and Lezíria do Tejo (IGP Tejo), followed by the Peninsula de Setúbal (IGP Peninsula de Setúbal). The risks for the South of Portugal are exactly the same as the risks identified with high maximum annual temperature (MAT), but the North shows a completely different pattern compared to the MAT. Especially striking are Alto Trás-os-Montes (*IGP Transmontano*) and Beira Interior Norte (IGP Terras da Beira), which only showed a minor risk for high annual temperatures, but a major risk for a low annual precipitation. The lowest risks can be found in Cova da Beira and Pinhal interior Sul (IGP Terras da Beira), Pinhal Interior Norte (IGP Terras de Dão and IGP Beira Atlântico), and Cávado, Ave, Entre Douro e Vouga and Grande Porto (*IGP Minho*).

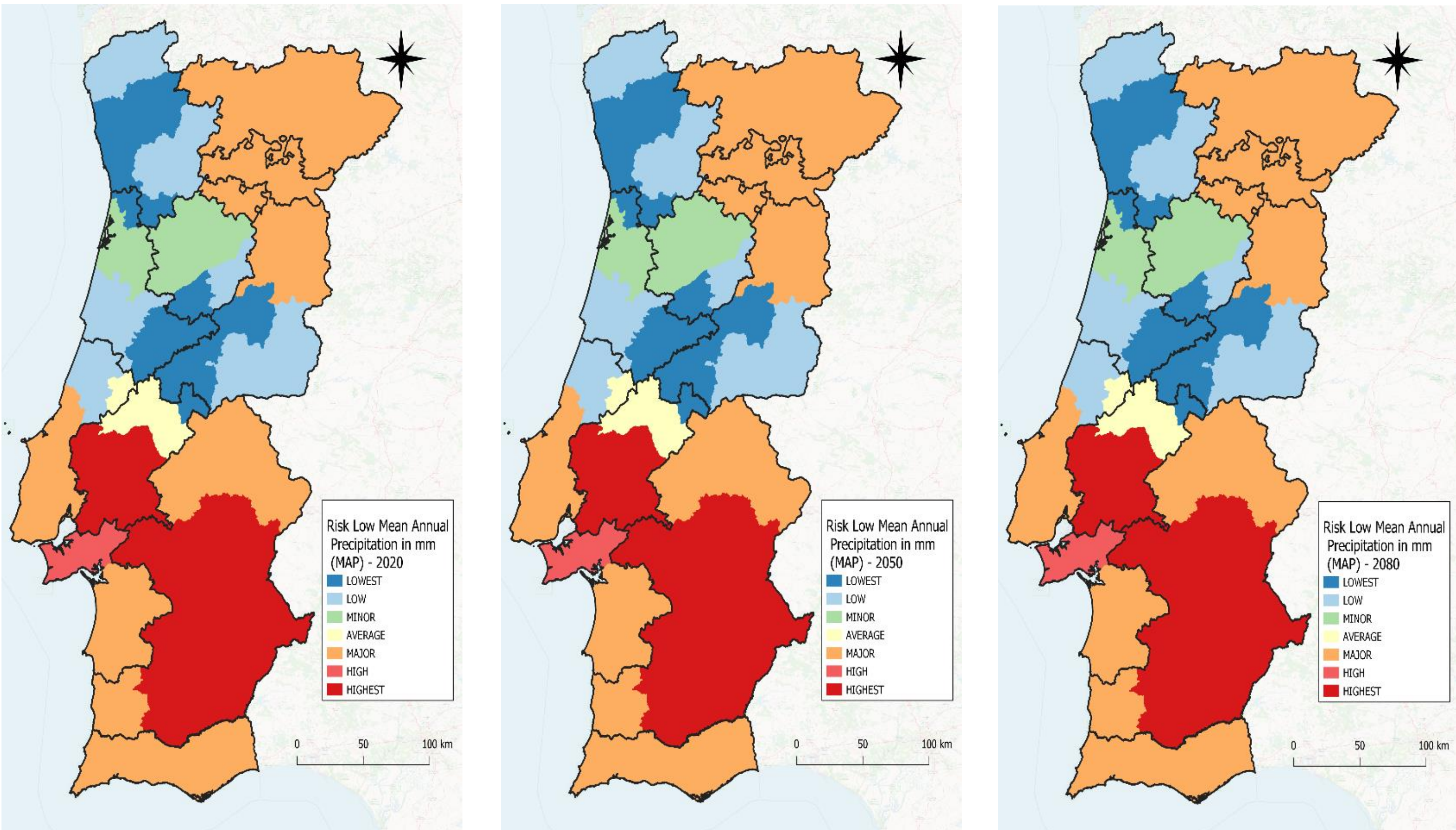


Figure 37: The final risk associated with minimum annual precipitation (in mm) for Continental Portugal. Source: Own maps, data from IVV (2021), ESPON (2012) and CMIP5-based climate data (2.5km resolution)

3.7.3.2 Risk Maximum Decrease

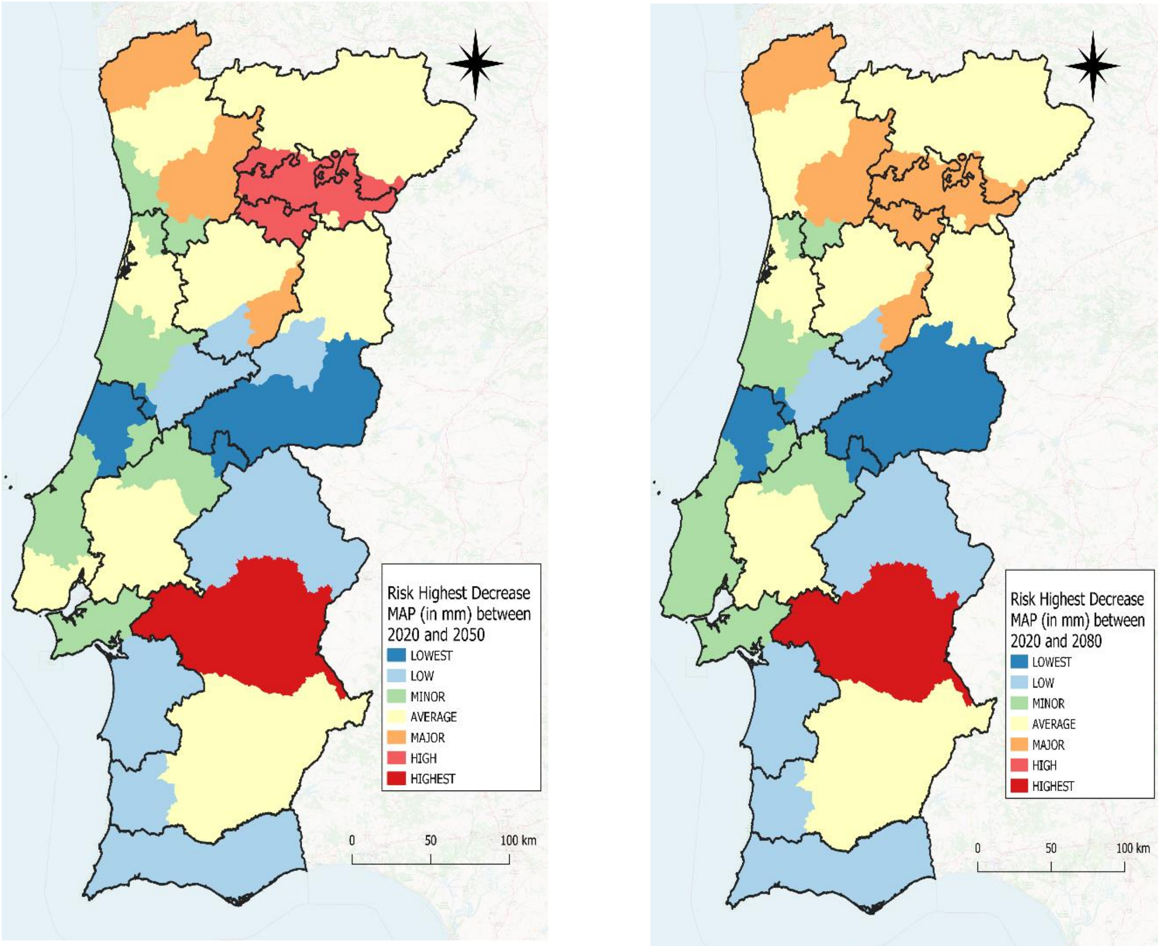


Figure 38: The risk associated with the highest decrease in MAP (in mm) for Continental Portugal. Source: Own maps, data from IVV (2021), ESPON (2012) and CMIP5-based climate data (2.5km resolution)

The highest decrease for annual precipitation was found for the Alentejo Central (*IGP Alentejano*), followed by Douro (*IGP Duriense* and *IGP Terras de Cister*). The lowest decrease was witnessed in Beira Interior Sul (*IGP Terras da Beira*) and Pinhal Litoral (*IGP Lisboa*). The trend seems to be partially inverted now compared to the annual precipitation (MAP): Relatively high values are found in the North of Portugal and low values in the South.

3.7.4 MSP

3.7.4.1 Risk minimum values

When it comes to the Minimum Summer Precipitation (MAP), the highest risk was identified for Alentejo Central and Baixo Alentejo (*IGP Alentejano*) and Lezíria do Tejo (*IGP Tejo*), followed by Grande Lisboa (*IGP Lisboa*) and Peninsula de Setúbal (*IGP Península de Setúbal*). Interesting in this regard is the NUTSIII region of Grande Lisboa, which has not shown any significant risk for any of the variables until now. The lowest risk related to low precipitation values was found for Cávado, Ave, Grande Porto, Entre Douro e Vouga (*IGP Minho*) nad Pinhal interior Sul, Pinhal Interior Norte and Cova da Beira (*IGP Beira Atlântico*, *IGP Terras do Dão* and *IGP Terras da Beira*). The MSP strongly resembles the MAP, but shows different risks for Alto Trás-os-Montes, Beira Interior Norte (IGP Terras da Beira) and Alto Alentejo (*IGP Alentejano*).

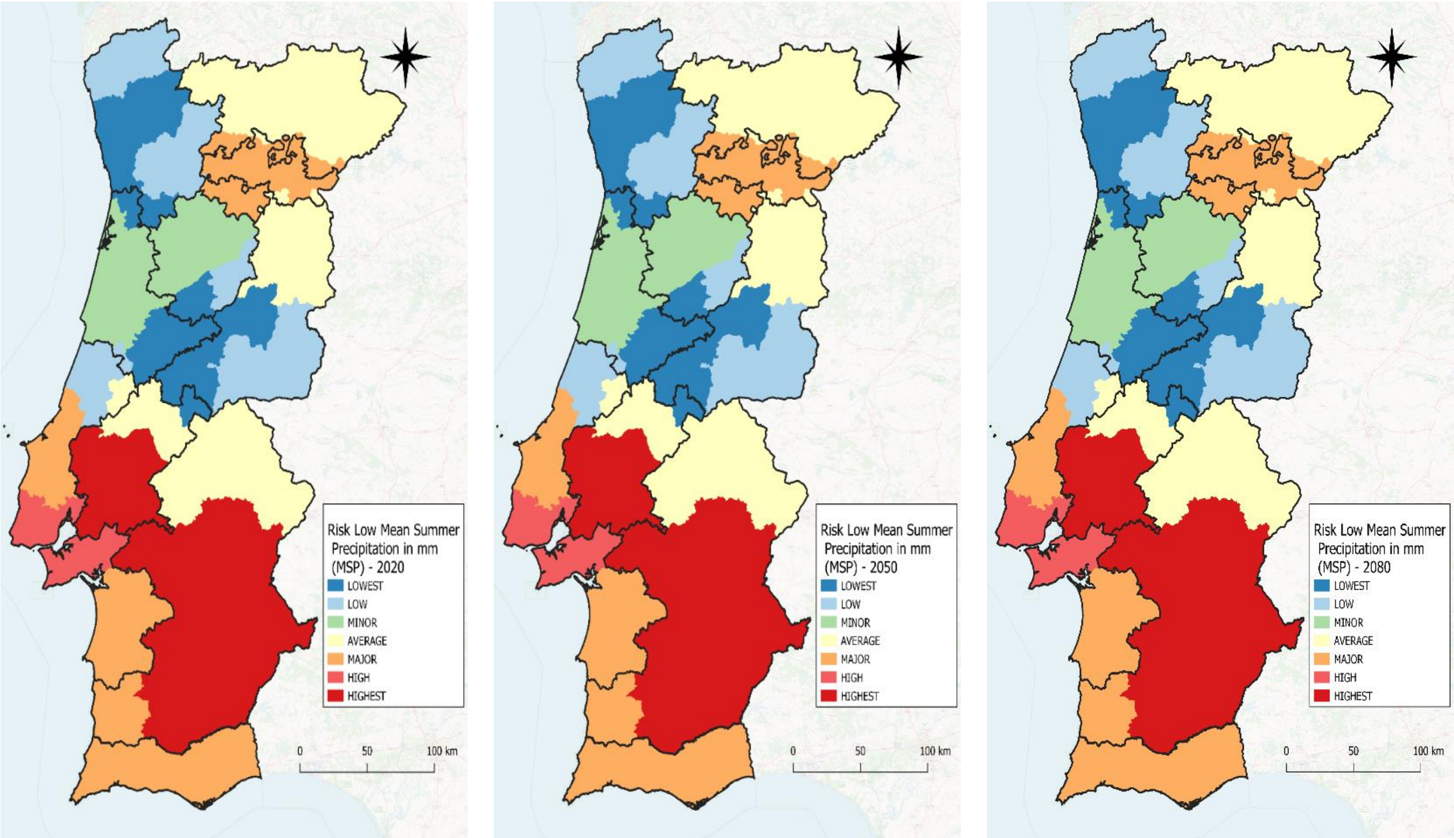


Figure 39: The final risk associated with minimum summer precipitation (in mm) for Continental Portugal. Source: Own maps, data from IVV (2021), ESPON (2012) and CMIP5-based climate data (2.5km resolution)

3.7.4.2 Risk maximum rise

The highest risk for a low summer precipitation was found in Douro (*IGP Duriense* and *IGP Terras de Cister*) followed by Minho-Lima and Tâmega (*IGP Minho*) and Serra de Estrela (IGP Terras de Dão). The lowest risk related to low precipitation was found in Pinhal Litoral (*IGP Lisboa*) and IGP Beira Interior Sul (IGP Terras da Beira). Compared to the annual values, the risk for a low precipitation seems to be significantly lower for many of the IGP's during the summer. Examples include Beira Interior Norte (IGP Terras da Beira), Grande Lisboa and Oeste (*IGP Lisboa*), and the entire IGP of Algarve, Alentejano, Peninsula de Setúbal and Trás-os-Montes. By contrast, other IGP's represent a higher risk during the summer, which includes Douro (*IGP Duriense* and *IGP Terras de Cister*), Dão-Lafões (IGP Terras de Dão) Baixo Vouga (IGP Beira Atlântico) and Grande Porto (*IGP Minho*).

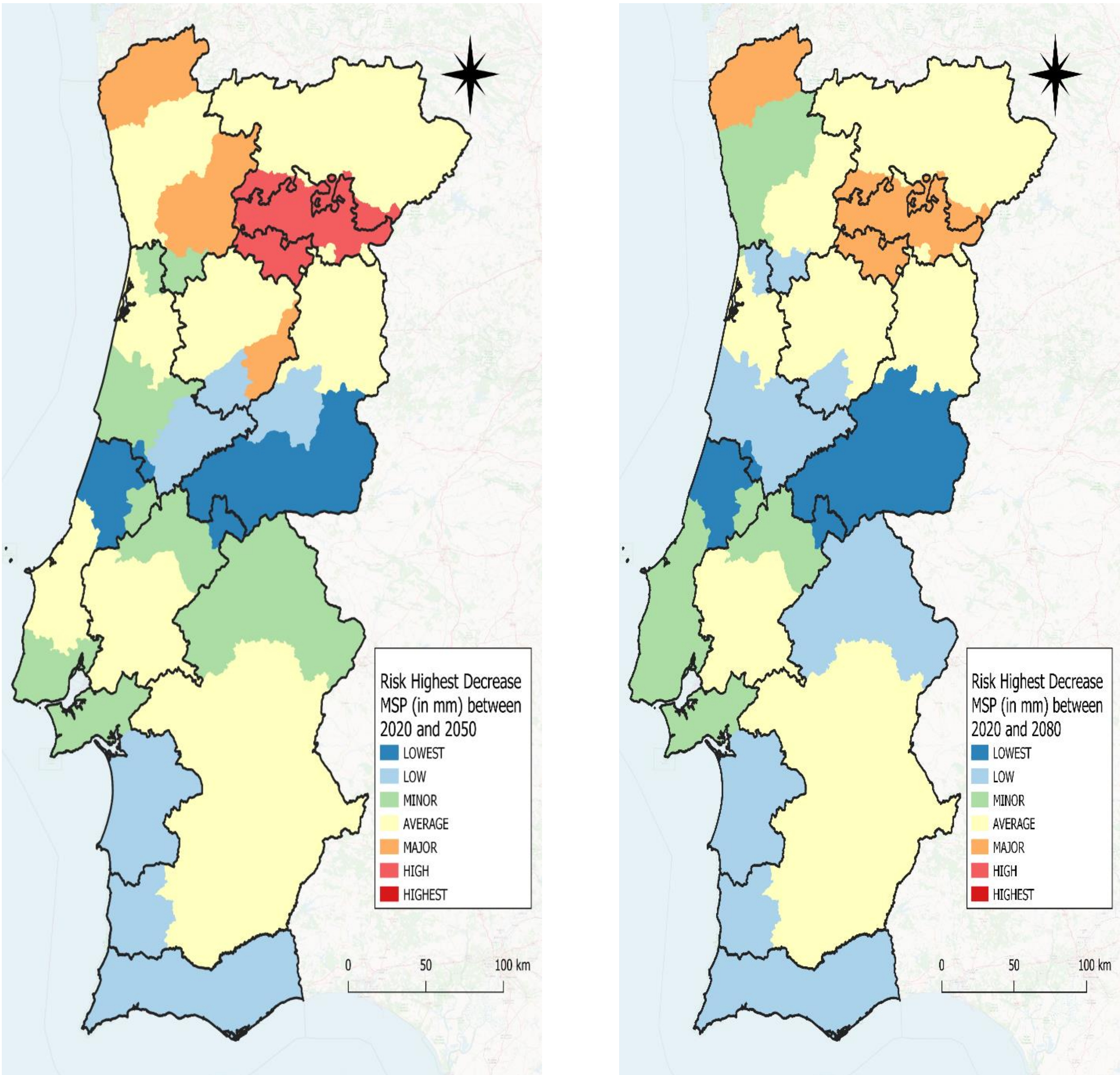


Figure 40: The risk associated with the highest decrease in MSP (in mm) for Continental Portugal. Source: Own maps, data from IVV (2021), ESPON (2012) and CMIP5-based climate data (2.5km resolution)

3.7.5. CMD

3.7.5.1 Risk maximum values

When it comes to the Moisture Deficit (CMD), the highest risk was identified for Alentejo Litoral and Baixo Alentejo (*IGP Alentejano*), followed Lezíria do Tejo (*IGP Tejo*), Península de Setúbal (*IGP Península de Setúbal*) and Douro (*IGP Duriense* and *IGP Terras de Cister*). The lowest values were found in Cávado, Ave, Grande Porto and Entre Douro e Vouga (*IGP Minho*), Pinhal interior Sul and Pinhal Interior Norte (*IGP Terras de Dão*, *IGP Beira Atlântico* and *IGP Terras da Beira*) and Pinhal Litoral (*IGP Lisboa*).

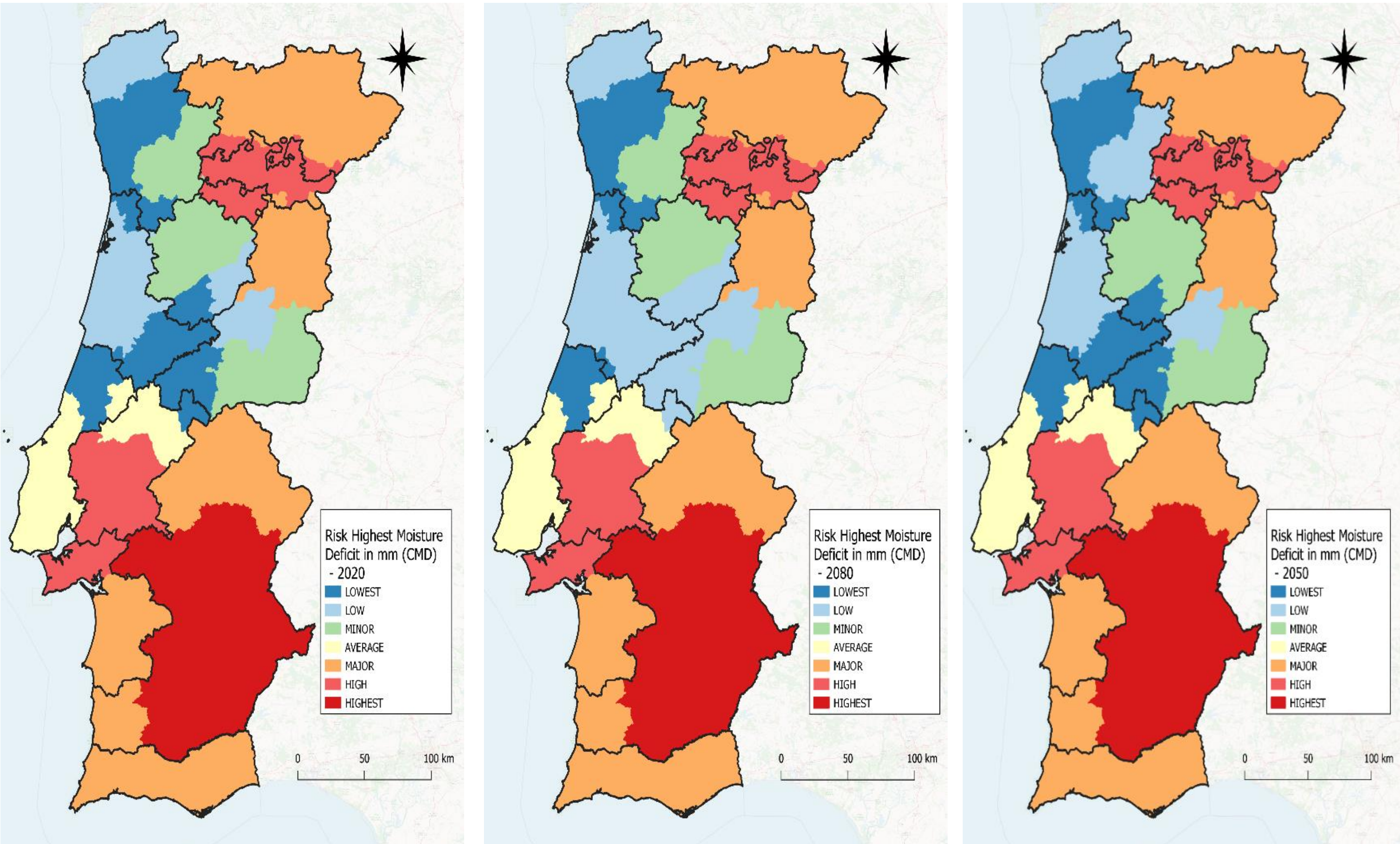


Figure 41: The final risk associated with a maximum moisture deficiti (in mm) for Continental Portugal. Source: Own maps, data from IVV (2021), ESPON (2012) and CMIP5-based climate data (2.5km resolution)

3.7.5.2 Risk maximum rise

The increase of the moisture deficit was one of the variables that did show a significant difference between the years 2050 and 2080. The highest risk for the increase of the moisture deficit in the year 2050 was found in Douro (*IGP Duriense* and *IGP Terras de Cister*), followed by Alto Trás-os-Montes (*IGP Transmontano*) and Alentejo Central (*IGP Alentejano*). For the year 2080, the highest risks were found again in Douro (*IGP Duriense* and *IGP Terras de Cister*), but this time also includes Alentejo Central (*IGP Alentejano*), followed by Alto Trás-os-Montes (*IGP Transmontano*), and Beira Interior Norte (IGP Terras da Beira). The lowest risks related to the moisture deficit in 2050 were found in Pinhal litoral (*IGP Lisboa*), Pinhal Interior Sul (IGP Terras da Beira) and Entre Douro e Vouga (*IGP Minho* and IGP Beira Atlântico) The year 2080 shows a similar trend, but this time Grande Porto (*IGP Minho*) is also identified as one of the regions with the lowest risk of a moisture deficit.

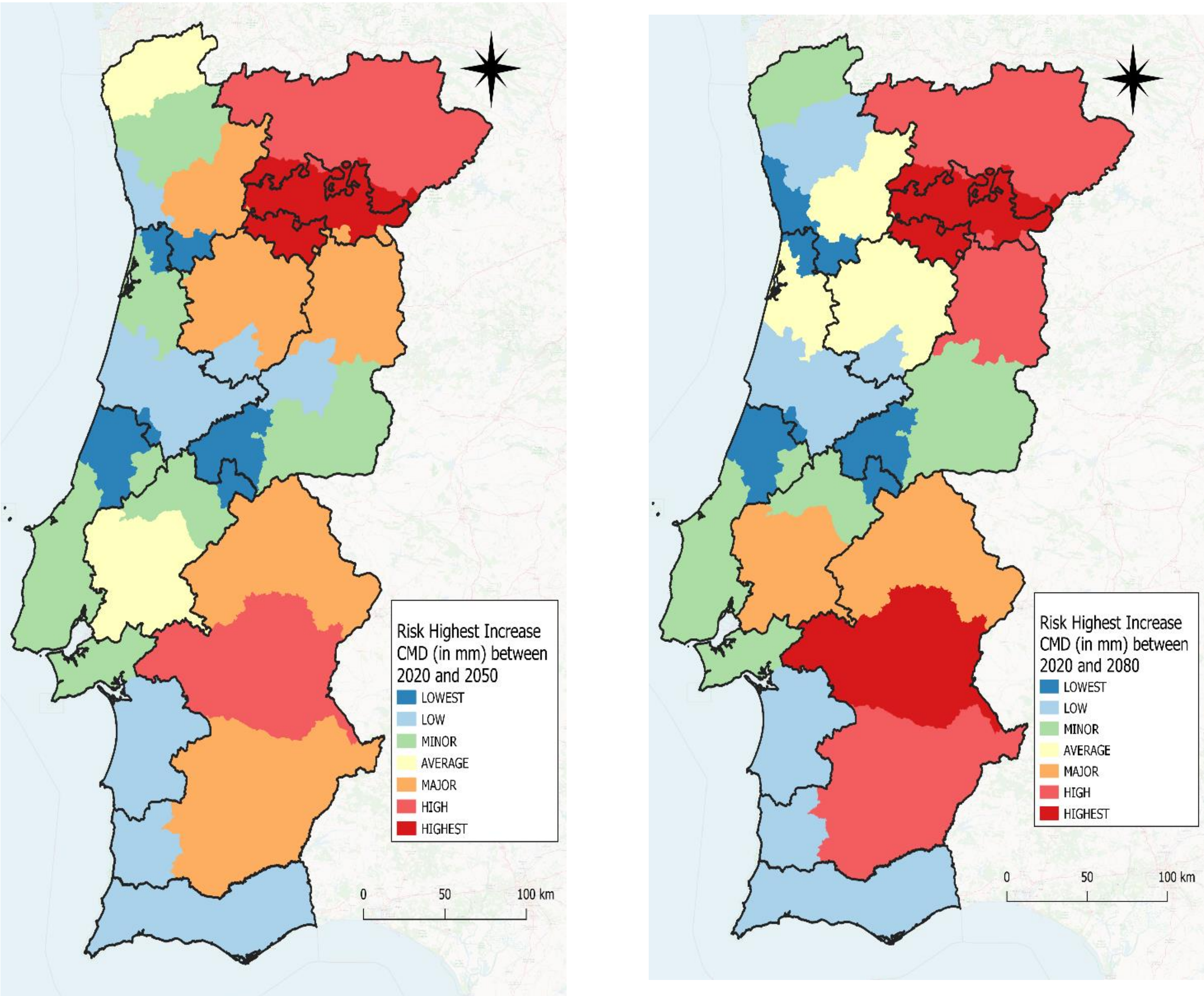


Figure 42: The risk associated with the highest increase in CMD (in mm) for Continental Portugal. Source: Own maps, data from IVV (2021), ESPON (2012) and CMIP5-based climate data (2.5km resolution)

3.8 Potential Impacts

3.8.1. MAT/MST

3.8.1.1. Quality of the grapes

One of the most important controlling factors for the growth and productivity of grapevines are the atmospheric conditions. According to Keller (2010), especially higher temperatures could impact the grapevine physiology and berry. More days with a high temperatures will reduce the photosynthetic activity, which can decrease the quality of the grapes because of the reduction of the acid component, which in turn will promote an imbalance between the concentration of secondary metabolites (Silvestre, 2016). The higher (expected) temperatures during the maturation phase are likely to result in a higher sugar content of the grapes, together with a decrease in acidity (Neethling *et al.*, 2012). This is also confirmed by Pinto et al. (2013), who explain that an increase in the number of days with temperatures above the optimum will result in the metabolic stop of the vineyards, which in turn will result in a reduction of sugar in the berry, decreasing the alcoholic content of the wine. The same authors show this through the example of Évora (IGP Alentejo), which shows a reduction of 10% in acidity for the years 2071-2100. High temperatures can also result in the formation of anthocyanins (Buttrose et al., 1971), which have an impact on the color and aroma of the berries. Therefore, climate change can jeopardize the maturity and sustainability of the existing varieties and wines. If this would be compared with the results of this research, the most adequate variable would be the highest values found for the mean summer temperature (MST) and the total associated risks for the different regions of Continental Portugal. As could be visible in figure 14, the highest summer temperatures for 2050 were found in Beira Interior Sul (IGP Terras da Beira) and Alto Alentejo (entire *IGP Alentejano*), followed by the Beira Interior Sul (IGP Terras da Beira) and the entire *IGP Alentejano* for the year 2080. When it comes to the highest risk calculated (which includes the current grape production and potential vulnerability of the region), the pattern is completely different. Now, the highest values for maximum summer temperatures were found for Alentejo Central and Baixo Alentejo (*IGP Alentejano*), Douro (IGP Douro and *IGP Terras de Cister*) and Lezíria do Tejo (*IGP Tejo*). Whereas Beira Interior Sul and Alto Alentejo represented the highest summer temperatures, the exposure was considered low (Grape production Beira Interior Sul: <25% and grape production Alto Alentejo: 25-50% of the average). In the case of Beira Interior Sul, also the vulnerability was not significant (25-50%), which resulted in only a minor total risk for this region. So when it comes for the risk of a higher sugar content of the grapes, a lower acidity level and different aroma and colour formation, the regions of Alentejo Central and Baixo Alentejo (*IGP Alentejano*), Douro (IGP Douro and *IGP Terras de Cister*) and Lezíria do Tejo (*IGP Tejo*) show the highest risk.

3.8.1.2. Grape production

Besides the quality, also the quantity of grapes could be affected. This phenomenon is mostly linked to an elevated number of days with a high temperature. Silvestre (2016) mentions the example of Alentejo, which will likely see parts that will become too hot for any grape production in the future. According to Fraga et al. (2016) the danger is greater for the South of Portugal, which is already represented by a warm climate. This is also confirmed by Hélder & Fraga (2019), who state that the productivity of both Alentejo and Douro is likely to be negatively affected in the future (2041-2070). A research by Pinto et al. (2013) shows the case of Évora (*IGP Alentejano*), where the productivity will likely decrease with 25% by the year 2080-2100. This is also confirmed by the investigation. If the average annual temperature (MAT) would be taken, the highest risk if found for Alentejo Central and Baixo Alentejo (*IGP Alentejano*), Lezíria do Tejo (IGP Tejo), and Península de Setúbal (IGP Península de Setúbal). Interesting in this regard is that Douro (*IGP Duriense*) is not present in the 2 highest classes (Impact = 'HIGH' and impact = 'HIGHEST'), which means that only high summer temperatures are a potential for risk for Douro, and not the average annual temperatures. As discussed in the last section, the highest impacted IGP's by a high risk associated with a high summer temperature (MST) will be the regions of Alentejo Central and Baixo Alentejo (*IGP Alentejano*), Douro (IGP Duriense and *IGP Terras de Cister*) and Lezíria do Tejo (*IGP Tejo*). Since the highest temperatures will occur during the summer months, there could be a potential danger for these regions that the production is and will be negatively impacted in the future (2050 and 2080).

3.8.1.3 Phenological stages

Another important effect of a rising annual temperature is the earlier onset of the vegetative cycle. This term could best be described as the moment of bud break (first stage of the vine's lifecycle where the vines start to break out of dormancy), flowering, maturation, and véraison (moment when the grapes start to ripe). The dormancy is a period where the plants lowers its metabolism temporarily to survive a period of low temperatures and other unsuitable growing conditions (Taylor, 2020). The vines normally enter dormancy before any damage could occur, using the decreasing day length (or better said, the increasing night length) to trigger the enter the state of dormancy. This is where the foliage will start to change color and where the nutrients from the leaves is stored in the woody tissue of the vines to be reused in the following years during budbreak. This process is mainly driven by air temperature, with spring temperatures helping the vines to break through winter dormancy (Centinari, 2018). According to Winkler (1974), a temperature around 10 C° is required to start the vegetative cycle of the vines.

Needless to say, if the annual temperatures are rising, the start of the vegetative cycle (the budbreak) is also more likely to occur earlier in the year. Several investigations have researched the effect of climate change on the phenological development of the vineyards, the results show that budburst and flowering is already occurring more early in different countries around the world. Van Leeuwen et al. (2019) mention the case of Alsace (France), where the budbreak has advanced by 10 days, the flowering by 23 days, the véraison by 39 days, and harvest by 25 days over the last 70 years. This could be especially problematic in combination with spring frost, even though this strongly depends on the climatic conditions of the vineyard. If figure 12 (rise in MAT) and figure 31 are compared, some interesting conclusions can be drawn. Even though most regions in the year 2080 (Alto Trás-os-Montes, Douro, Beira Interior Norte, Beira Interior Sul, Cova da Beira, Alto Alentejo, Alentejo Central, Serra de Estrela, Dão-Lafões, Pinhal Interior Norte and Pinhal Interior Sul) are located in the North and Centre of Continental Portugal, only the region of Douro is marked with the highest risk ('HIGHEST'), based on the high grape production (figure 9) and medium vulnerability (figure 27). Other regions that received a high score ('HIGH') are Alto Trás-os-Montes (*IGP Transmontano*), Beira Interior Norte (IGP Terras da Beira), Alentejo Central and Baixo Alentejo (*IGP Alentejano*). Even though special care needs to be taken with drawing solutions, there might be some evidence that the advancements of the phenological stages could have the highest impact on the earlier mentioned regions, with Douro representing the highest level of risk.

As also specifically the mean annual summer temperature (MST) was investigated, conclusions could also be drawn about the possible effects of maximum values of the MST and a high rise of the MST for the phenological stages that take place specifically during the summer. In Portugal, the most common phenological stage is the maturation ('amadurecimento'), and in some cases the harvest of the grapes ('vindima') (Quintas San Michel, 2021). As could be witnessed in figure 14, the highest rise in summer temperatures occurs in Alto Trás-os-Montes, Douro, Serra de Estrela, Dão-Lafões, Cova da Beira, Beira Interior Norte, Beira Interior Sul and Alto Alentejo, with the highest final risk associated with this hazard found in Douro (*IGP Duriense* and *IGP Terras de Cister*) ('HIGHEST'), followed by Alto Trás-os-Montes (*IGP Transmontano*), Alentejo Central (*IGP Alentejano*) and Beira Interior Norte (*IGP Terras da Beira*). Interesting in this regard is especially Alentejo Central, which did not get classified as the highest rise in summer temperatures, but because of the high production and vulnerability got classified as a region with a high risk for a high rise in temperature during the summer. The exact opposite occurs for Beira Interior Sul, which represented one of the highest rise in temperature for both the years 2050 and 2080, but did not represent a significant grape production (25-50%) compared to the other regions. So when it comes to the maturation (and to a lesser degree to the harvest), the regions of Douro, Alto Trás-os-Montes, Beira Interior Norte and Alentejo Central could potentially show the biggest advance.

3.8.1.4 Susceptibility to diseases

Another potential impact could come from heat waves. According to Silvestre (2016), the risks related to the frequency and intensity of heat waves will constitute one of the most important threats because of the greater susceptibility to diseases / pests and scalding of grapes. There is a direct relationship between the average air temperature and extreme heat, as not only the average temperatures are increasing, but also the average days with maximum temperatures. This is also confirmed by Perkins-Kirkpatrick & Gibson (2017), who found that per 1 C° of global warming, an increase between 4 and 34 days of heat wave days occurs. As already discussed before, the research found that the highest risk for maximum summer temperatures can be found in Alentejo Central and Baixo Alentejo (*IGP Alentejano*), followed by Douro (*IGP Duriense* and *IGP Terras de Cister*) and Lezíria do Tejo (*IGP Tejo*). Even though one needs to be difficult with drawing conclusions, these regions might also see a higher incidence of diseases, pests and scalding of the grapes. According to Bugaret (2010), the susceptibility to parasites is especially elevated between budding and flowering, which, as discussed earlier, will already be affected in several different ways as well by climate change. Bugaret (2010) calls the attention for three specific diseases: Excoriosis, downy mildew and powdery mildew. Several 'noble' grape varieties will be difficult to plant in the future, such as Touriga Nacional and Fernão Pires, due to the high sensitivity to Excoriosis. The IGP's exposed to the risk for warmer annual temperatures, and thereby also warmer winters, might need to take extra adaptation measures to fight the level of parasites in the future.

3.8.1.5 Change in location of the vineyards

The IPCC estimates that a temperature increase of 1,1-3.7C (IPCC, 2014) would even alter the current geographical distribution of the world's vineyards, especially the ones at low latitudes (Fraga et al., 2016). This is also confirmed by Bugaret (2010), which confirms that a raise of the average temperature with only 1 C°, will lead to a potential shift of vineyards around 180 kilometers towards the poles. During the investigation, the IGP's with the highest risk for an increase in annual temperatures (MAT) were Douro (*IGP Duriense* and *IGP Terras de Cister*) with 1.26 C°, followed by Alto Alentejo (*IGP Alentejano*) with 1.27 C°, Alto Trás-Os-Montes (*IGP Transmontano*) with 1.23 C° and Alentejo Central (*IGP Alentejano*) with 1.21 C°. If every 1 C° would cause a potential shift of 180 kilometres towards the poles, the following shifts could be expected for the regions characterized with the highest risk for a rise in annual temperature: Douro – 226,8 km, Alto Alentejo – 228,6 km, Also Trás-os-Montes – 221,4 km and Alentejo Central -217,8 km.

3.8.2 MAP/MSP

Besides the temperature, another important factor is the decrease in precipitation, which could contribute to an early stop of vegetative growth, which includes the growth of the berries and grapes (Fraga et al., 2017). This situation could possibly lead to water stress, which could have severe consequences for the cultivation of grapes. This is also confirmed by Silvestre (2016), who states that the reduction in precipitation may even end viticulture in the South of Portugal. This is also confirmed by the investigation, which was able to point out the regions characterized by the highest risk of a minimum precipitation. Interesting in this regard is to compare the MAP/MSP (figure 20 and 21) with the risks associated to these variables (figure 34 and 36). Whereas the year 2020 shows Península de Setúbal (IGP Península de Setúbal), Alentejo Litoral, Alentejo Central and Baixo Alentejo (*IGP Alentejano*), and Algarve (*IGP Algarve*) as the regions representing the lowest values found for a minimum precipitation, the projections for the years 2050 and 2080 add Lezíria do Tejo (IGP Tejo), and Grande Lisboa and Oeste (*IGP Lisboa*) to this. There is a clear pattern here, the minimum precipitation values are slowly creeping from the South to the North, which could have a potential negative effect on the grape production in these regions. The total risk associated with minimum levels of precipitation (figure 34) is the highest for Baixo Alentejo and Alentejo Central (IGP Alentejo), and Lezíria do Tejo (IGP Tejo) ('HIGHEST'), followed by Península de Setúbal (IGP Península de Setúbal) ('HIGH'). These regions will have to be extra careful with minimum levels of precipitations during the year. When it comes specifically to the summer precipitation (MSP), the highest impacted regions are still Península de Setúbal (IGP Península de Setúbal), Alentejo Litoral, Alentejo Central and Baixo Alentejo (*IGP Alentejano*) in 2020, with the addition of and Lezíria do Tejo (IGP Tejo), and Grande Lisboa and Oeste (*IGP Lisboa*) by the year 2080. A significant difference can be found in Alto Alentejo (*IGP Alentejano*), Alto Trás-os-Montes (*IGP Transmontano*) and Beira Interior Norte (IGP Terras da Beira) between the MAP and MSP, which all show significantly less risk for minimum precipitation values during the summer compared to the other regions.

The highest decrease in precipitation is found in Alentejo Central (*IGP Alentejano*), followed by Douro (*IGP Duriense* and *IGP Terras de Cister*) (only for the year 2050). As the region Alentejo Central reached maximum values both for the minimum precipitation values and the strongest decrease, special attention should be paid to this region to prevent any of the negative consequences associated with a lack of precipitation (e.g. an early stop of vegetative growth of the vines and the berries). The highest decrease during the summer (figure 37) shows an interesting result: During the summer, the highest decrease in precipitation is not found in Alentejo Central, but in Douro (*IGP Duriense* and *IGP Terras de Cister*) and parts of parts of *IGP Minho*. It is important to point that the grape varieties and agricultural practices need to be prepared to complement this high decrease in precipitation for 2050 and 2080.

Due to climate change, the winters are projected to become milder and wetter for Continental Portugal, which could potentially lead to a higher level of parasites. The research is not able to confirm if the winters are indeed getting wetter, but is able to confirm that the average annual temperature (MAT) is rising for Continental Portugal, which includes the winter. The highest risk for a rise in the annual temperature found for Douro (*IGP Duriense* and *IGP Terras de Cister*), followed by Alto Alentejo (*IGP Alentejano*), Alto Trás-Os-Montes (*IGP Transmontano*), and Alentejo Central (*IGP Alentejano*). Even though one needs to be careful with drawing conclusions since the annual temperature rise is studied (and not the rise in temperature specifically during the winter), there might be some evidence that these regions might see a higher impact of parasite attacks in the decades to come.

3.8.3 CMD

According to Bugaret (2010), the moisture deficit of soils could have a significant effect on viticulture in the future, which will have to be mitigated with a higher rate of irrigation. Water deficit is most likely to affect the vegetative and generative growth, depending on the severity of the moisture deficit and the season in which it occurs. If the vines are exposed to a mild moisture deficit, the vines will reduce the shoot growth. If the vines are exposed to a higher deficit, the plants will start to close the stomata to limit transpirational water loss. Subsequently, this will lead to a reduction in the photosynthesis, which, as already discussed in chapter 3.8.1., could impact the quality of the grapes. Also the quantity of the grapes seem to be affected, this is for example confirmed by Fraga et al. (2012), who state that the moisture deficits constrain grapevine productivity. Camps and Ramos (2012) give the example of Northern Spain, where the decrease in wine grape yield can be attributed to the moisture deficit. The research identified the different patterns of the moisture deficit for Continental Portugal for the years 2020, 2050 and 2080. As could be visible in figure 23, the highest moisture deficit (not the risk) was found in the South of Portugal, with the highest value currently found in Baixo Alentenjo (799.78 mm). The year 2050 also includes Alto Alentejo, Alentejo Litoral and Alentejo Central (*IGP Alentejano*), followed by the addition of the region of Algarve (*IGP Algarve*) by the year 2080. The highest risk related to these maximum values was found in Alentejo Central, Baixo Alentejo (*IGP Alentejano*) ('HIGHEST'), followed by Douro (*IGP Duriense* and *IGP Terras de Cister*), Lezíria do Tejo (IGP Tejo), and Península de Setúbal (IGP Península de Setúbal) ('HIGH'). Especially interesting here is the region of Douro, which did not represent a significant moisture deficit in figure 23, but due to the high production and high vulnerability still got included as an area with a potential high risk associated with the climatic moisture deficit. The highest decrease of the CMD is found in the North and Centre of Portugal (figure 24), with the highest associated risks found in Douro (*IGP Duriense* and *IGP Terras de Cister*), followed by Alentejo Central (only 'HIGHEST' for the year 2080), Alto Trás-os-Montes (*IGP Transmontano*), Beira Interior Norte (IGP Terras da Beira), and Baixo Alentejo (*IGP Alentejano*). In order to prevent a potential impact of the moisture deficit on the quality and quantity of the grapes, attention should be focused on both the regions characterized by the highest risk for reaching the maximum moisture deficit and the regions characterized by the highest risk for the increase of the moisture deficit in the future,

3.9 Conclusions and Recommendations

This part will discuss the recommendations for further research. This internship report has given the reader a basic introduction to the risks associated with the hazards mean average temperature (MAT), mean summer temperature (MST), mean average precipitation (MAP), mean summer precipitation (MSP) and the climatic moisture deficit (CMD) for Continental Portugal.

So what will be the future of viticulture with climate change? Different authors have already made different projections for the future of viticulture. According to Alejandro Fuentes Espinoza, the director of the OIV, It is likely that Portugal will continue to produce quality wines, but the wines will likely become different (Cardoso, 2019). This has everything to do with the earlier mentioned *typicity*. According to the National Confederation of Agricultural Cooperatives and Agricultural Credit of Portugal (2019), the typicity of the Portuguese (and also Spanish and French wines) are likely to change due to a necessary change in adaptation of the sector to a changing climate (e.g. different varieties of grapes/viticultural practices). Therefore, although there is a difference in the climate in the future, the impact of climate change on the production and quality of wine depends very much on our ability to adapt the sector to new conditions. As has been argued by several authors, the readiness to define and implement adaptation strategies and measures will result in minor harmful impacts for the sector wine industry. This is also confirmed by Fraga et al., (2016), who even state that the regions in the North of Portugal (e.g *IGP Beira-Atlântico* and *IGP Minho*) may actually become more suitable for the production of different grape varieties and higher quality wines in the future, which provides new opportunities.

These 'opportunities' and 'threats' of climate change have also been witnessed during this research. As could have been seen in chapter 3.4 with the maps of the total risk associated with the hazards, the risks are not equally spread around Continental Portugal. Whereas some regions are prone to many different risks, such as the *IGP Alentejano* which showed high values for all the variables (MAT, MST, MAP, MSP and CMD), other regions might only be prone to one or two of these risks, An example would be Alto Trás-os-Montes (*IGP Transmontano*) which only gave the value 'HIGH' for the increase in MST (Mean Summer Temperature) and CMD (Climatic Moisture Deficit). As a consequence, each region will have different hazards to further explore to be able to identify possible climate adaptation strategies for both the short and the long term. As indicated by the word '*terroir*', every vineyard has unique environmental conditions, such as a specific soil, topography, climate, landscape characteristics, and biodiversity. As a consequence, it might be difficult to make decisive conclusions without further exploring all the local characteristics and local conditions of the vineyards. As a consequence, this research could best be regarded as exploratory, which provides the reader with a basic understanding of the spatial variety of regions exposed to different climate hazards in Continental Portugal.

As a recommendation for the next step of research, I would suggest to apply the indexes mentioned in the Geoviticulture Multicriteria Climatic Classification System (MCCS), which includes indexes that are able to measure the climatic potentials of a specific region and subsequent qualitative potentials and characteristics of the grapes (e.g. levels of sugar, acidity, colour and aromas). In particular, the MCCS indicates 3 indexes commonly used in viticultural zoning studies and climate change impact evaluation, which are the Huglin Index (HI), the Cool Night Index (CI) and the Dryness Index (DI) (Conceição, Souza & Tonietto, 2016). Through the use of these indexes, it is possible to gather more specific information about the potential impacts and adaptation strategies for each of the regions.

Out of all these indexes, probably the most famous one is the heliothermal index, also colloquially called the Huglin Index (HI). This index is related to the thermic requirements of each grape variety and the capacity to mature (production of sugars). Put in other words, the HI can be used to calculate the suitability of different kind of grape varieties in the investigated region (Deutscher Wetterdienst, 2021). The specific formula used can be seen below, TG stands for the daily temperature a day and TX for the maximum a day concerning the period between the 1st of April and the 30th of September. The last part of the formula is completed through multiplying with the coefficient for day length ('*K*').

$$HI = \sum_{01/04}^{30/9} \frac{(TG_i - 10) + (TX_i - 10)}{2} K$$

The result is the Huglin Index, which ranges between 1500 and 2400 and indicates the grape variety that is worth cultivating for a specific area. If the index returns a value under 1500, it is deemed unsuitable for the temperature requirements of the grapes (Pilz, 2021).

Another famously used index is the Cool Night Index (CI), which was created to study the nocturnal conditions for grape ripening according to the different wine regions (Bonnefoy, 2017). Cool nights are especially important for the ripening of the grapes (called 'vintage') because grapevines are struggling to transfer compounds from photosynthesis with high temperatures during the night. As a consequence, the best result is often obtained in regions with an important diurnal thermal difference. This index is important to estimate the qualitative potential of a specific wine region, especially with regards to metabolites (e.g. polyphenols and aromas) (Tonietto & Carbonneau, 2003). For the Northern hemisphere, the minimum temperature of the harvest month is taken, which is in most cases September. In contrast, for the Southern Hemisphere the harvest month with the lowest temperature is often March.

The last index is called the Dryness Index (DI), which is about the potential soil water balance (Santos et al., 2020). In turn, this potential water availability directly influences the level of grape ripening and grape quality (Jackson and Cherry, 1988). To be more specific, the index enables the characterization of analyzing the hydric component of the climate in a specific wine region, which takes into account 'the climatic demand of a standard vineyard, evaporation from bare soil, and rainfall without deduction for surface runoff or drainage' (Tonietto & Carbonneau, 2003). The following formula is used to calculate the Dryness Index, where W stands for the estimate of soil water reserve, Wo for the initial useful soil water reserve, P for the precipitation, Tv for the potential transpiration in the vineyard, and Es for the direct evaporation from the soil (Tonietto & Carbonneau, 2003).

$$W = \mathrm{Wo} + P - T_{\mathrm{v}} - E_{\mathrm{s}}$$

Hence, all these indexes focus on a different component for assessing the suitability of a given region for grape cultivation and production for specific grape varieties, which will become paramount for climate change adaptation of the sector.

4.

INTERNSHIP AT THE FCT

By now, the reader should have a clear image of the viticulture sector and the potential risks associated with the climate hazards (MAT, MST, MAP, MSP and CMD). The report will now continue by showing what has been done during the internship to help the vine and wine sector to adapt to these possible impacts.

4.1. Introduction

The project MEDCLIV is a climate adaptation project funded by EIT Climate-KIC, Europe's main Knowledge and Innovation Community (KIC) to accelerate the transition to a zero-carbon, climate-resilient society. The initiatives from Climate-KIC help to build a climate resilient society, both through providing and integrating mitigation and adaptation initiatives to the adverse effects of climate change. The project MEDCLIV focused specifically on adapting the viticulture sector to the challenges posed by a changing future climate, since many local economies are dependent on wine production in the *Mediterranean*. The MEDCLIV project started with an experiment in France, which was consequently scaled up to more Mediterranean countries, including institutions from France, Italy, Spain, Portugal, Cyprus and Slovenia. As chapter 3 has shown, it is likely that different IGP's and different DOP's of Continental Portugal will be affected in the future by climate change, which could potentially have severe consequences. Through collective action and coordination of professionals and local players, it is possible to accelerate the transition to a climate resilient society. The MEDCLIV project officially took off in 2019 and will last until 2022, with the final objective of finding new pathways for a climate-resilient viticulture sector, with a special focus on adaptation, and to a lesser extent to climate mitigation options.

These options are co-constructed through a process of participatory approaches to share existing and create new adaptation and mitigation options. Important in this regard is that all institutions work both on a national and on a European level. On a regional and national level, there are the Living Labs, which are dedicated to the implementation of these participatory approaches, where stakeholders are engaged and the development of new collaborative projects is supported. All the involved regional and national Living Labs from all the countries involved have the ability to generate new knowledge and experience about the implementation of participatory approaches in different parts of the value chain and geographical regions. On a European level, this could potentially lead to more collaborative innovation and value chain concertation (Climate-ADAPT, 2021).

The exact partners involved in the project are:

- European Institute of Innovation and Technology (EIT)
- Climate-KIC
- Institute of BioEconomy - Biology, Agriculture and Food Sciences Department - National
- Research Council of Italy
- Cyprus University of Technology
- INRAE, French National Research Institute for Agriculture, Food and Environment
- L'institut Agro, agriculture, alimentation, l'environnement - Montpellier SupAgro, France
- NOVA School of Science and Technology (FCT NOVA), Lisboa, Portugal
- National Institute of Chemistry, Ljubljana, Slovenia
- Universitat Politècnica de València, Spain

The MEDCLIV project has the following official objectives (Agrisource, 2020):

- *Encourage and support participatory events aimed at provoking the meeting of stakeholders, and the emergence of projects for the vine and wine sector, in the face of climate change;*

- *Develop an online collaborative platform, called VINEAS, capable of mapping all the players in the sector involved in adapting to climate change, and thus facilitate networking, across the entire Mediterranean;*

- *Encourage local / regional stakeholder engagement for a coordinated adaptation strategy*

During the time of the internship, the most relevant objective of MEDCLIV was to create the collaborative platform Vineas about climate adaptation of the vine and wine sector, which has been construction collectively through constant revision and perfectioning over the course of these 6 months. Vineas could best be characterized and described as a "collaborative platform to share and get informed about actors, projects, solutions, news about vine, wine and climate change". Throughout the different functionalities of the platform developed over the course of the internship, users are able to find information about the potential effect of climate change on viticulture and possible ways for climate change adaptation and mitigation. These functionalities include currently the possibility to find publications about the interplay between climate change and viticulture, specific solutions in the area of climate change adaptation and mitigation, related actors, projects, news, events, and geographic information (GIS). One of the most important parts of the platform is the development of the potential adaptation and mitigation solutions, which can be filtered through the different criteria both through the search filters and through the different solution families (see chapter 4.4.3).. The platform is freely accessible for anyone interested on this website: www.vineas.net, for the version in Portuguese, please visit: https://www.vineas.net/pt/1/home.html.

4.2 Positioning of the internship

The transition towards a more climate resilient vine and wine sector needs to be done through a process of co-construction and collective action. This transition could be accelerated through coordination of professionals and the involvement of local actors. Through the participation of 5 most affected countries in the Mediterranean, the platform could bring new strategies and solutions to adapt to the adverse effects of climate change throughout the entire vine and wine value chain. Thus, the internship could best be positioned as an attempt to improve the adaptive capacity of Portugal and all the countries involved in the Mediterranean through international collaboration and exchange of potential ideas and strategies.

As discussed in chapter 2, the total vulnerability consists out of the potential risks and the adaptive capacity of the different Portuguese IGP's and DOP's. As could be visible in figure 26, the aggregate potential impact of climate change for Continental Portugal is the highest for the IGP's in the South (i.e. Algarve, Setúbal and parts of Alentejo) and the lowest for the Southern part of Terras de Beira (NUTS III – Pinhal Interior Norte). The adaptive capacity (figure 25) against climate change for Continental Portugal is the highest in the IGP's of Lisboa and parts of Setúbal, Tejo, Beira Atlântico, Minho and Terras de Dão and the lowest for the rest of the IGP's. Even though no specific predictions or conclusions could be drawn, the documents, geographic information and possible solutions in Vineas could potentially have a positive influence on the adaptive capacity through replicating existing solutions and strategies and renewed collaboration with other actors and areas. Especially since 0.23 of the total calculation for adaptive capacity consists out of knowledge and awareness, which is exactly what the platform Vineas is focused on. As the vulnerability is part of the total calculation of the risk to specific climate hazards, a reduced vulnerability could subsequently result in a reduction of the level of risk for different regions in Continental Portugal and the Mediterranean.

4.3 Development of the internship

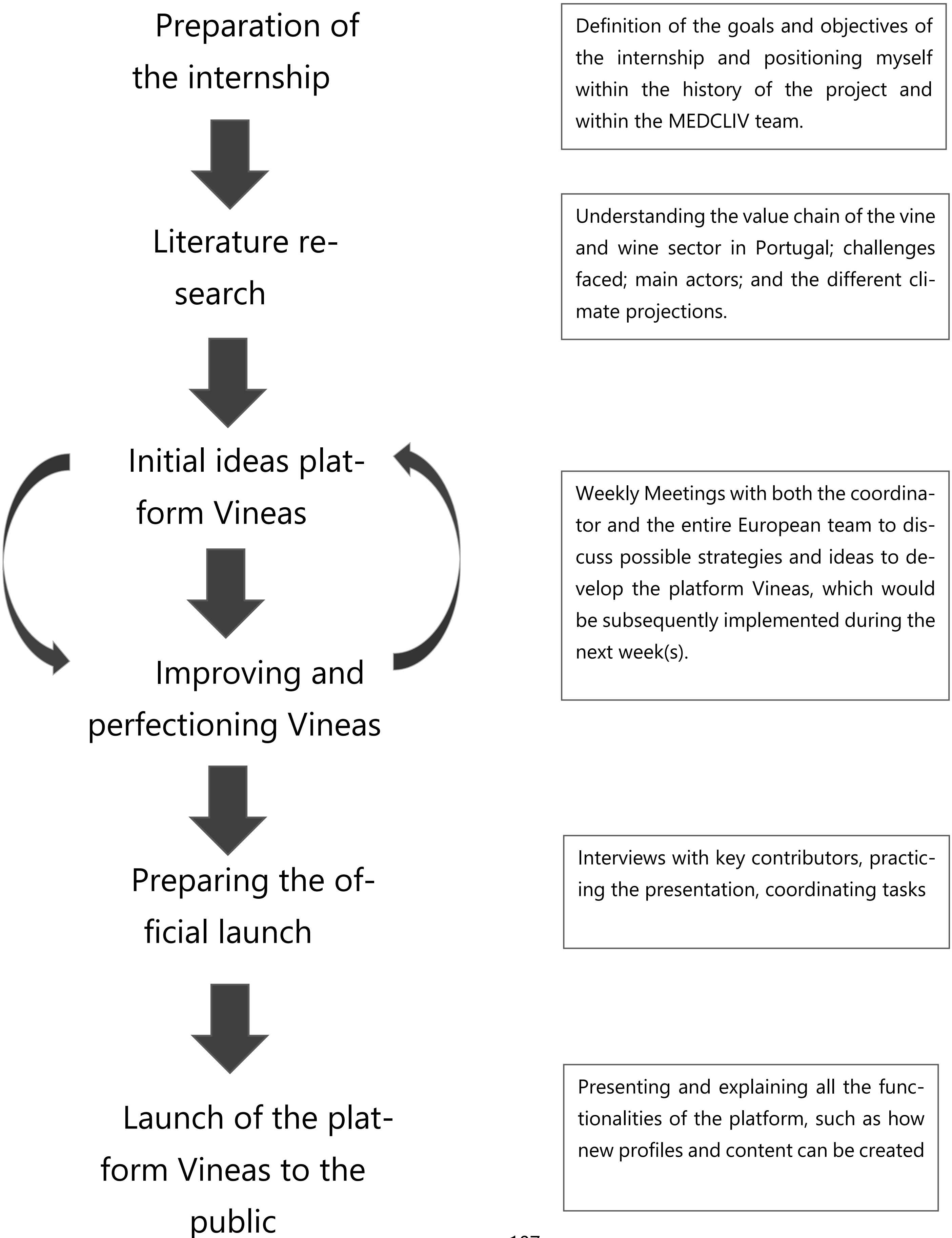


Figure 43: All the different stages of the internship followed. Source: Own creation.

4.4 Activities undertaken

4.4.1. Literature research

The internship started with a thorough literature research to understand more about the adverse effects of climate change on the viticulture sector and understand the value chain completely from grape to bottled wine. The literature about viticulture and viniculture could best be described as 'technical', as one needs to be familiar with the specific terminology to thoroughly understand the literature. An example of the first includes words such as terroir (the specific geographic characteristics of a vineyard), veraison (the onset of the ripening of the grapes), vintage (the year the wine is bottled) and typicity (the degree to which a specific type of wine expresses the inherent characteristics of the grape variety). To continue, the literature about the interplay of climate change and viticulture may also be difficult to grasp because of the second reason about the high levels of ecology, biology and chemistry knowledge used in the literature, examples include different phenological stages of the vines, phenolic compounds of the wine (e.g. tannins), acids (e.g. tartaric acids), different soil nutrients, microbial communities and aromas of the wines. This is even further complicated by all the different varieties of different grapes that are grown in different geographical locations and conditions, which means that specific literature that applies to one specific variety of grape in France, might be completely different for the exact kind of variety grown in Portugal.

Much research had to be done to completely grasp all the different processes pushed forward by climate change which may not only negatively impact the vineyards, but also the entire value chain of the sector. This was absolutely necessary to be able to participate and contribute to the team, such as in the formation of the solution cards (see chapter 4.4.3), which were designed to find solutions against the adverse effects of climate change. In order to assess if any solution cards were missing, needed adjustment, or were well translated, one had to be well-informed about the European and Portuguese viticulture and viniculture, both about past and future conditions and trends. During the literature research, I started to understand that vines are extremely vulnerable, yet adaptive to climatic conditions. At the same time, the climatic and vinicultural conditions in every vineyard seem to be unique, which is even further complicated by all the different varieties with different needs and preferences. As a consequence, climate change will likely have a different impact on different vineyards, which could not only damage the potential yield, but also the future quality of the berries. The changing quality of the wine could subsequently lead to less profit for the sector, because the attributes and typicity of the wine are not the same anymore. Understanding all the links between different actors and sectors within the vine and wine value chain proved to be quintessential for an active participation and integration in the team. During the internship, it was tried to contribute to the team with this knowledge obtained, especially through the uploading and spreading of missing literature, new solutions, and data related to climate mitigation and adaptation in the viticulture sector.

4.4.2. Infographics

The French department made a range of infographics about the effects of climate change on the viticulture in France (figure 44), which included infographics about the rise in temperature and difference in precipitation in different parts of France, extreme future weather, changing phenological stages, changing quality of the grapes and future favorable regions for viticulture. The teams idea was to find the same data available for every participating countries and replicate the infographics according to this data. Some of the infographics could be instantly translated, such as the infographics about the representative concentration pathways (RCP's), but others had to researched in detail.

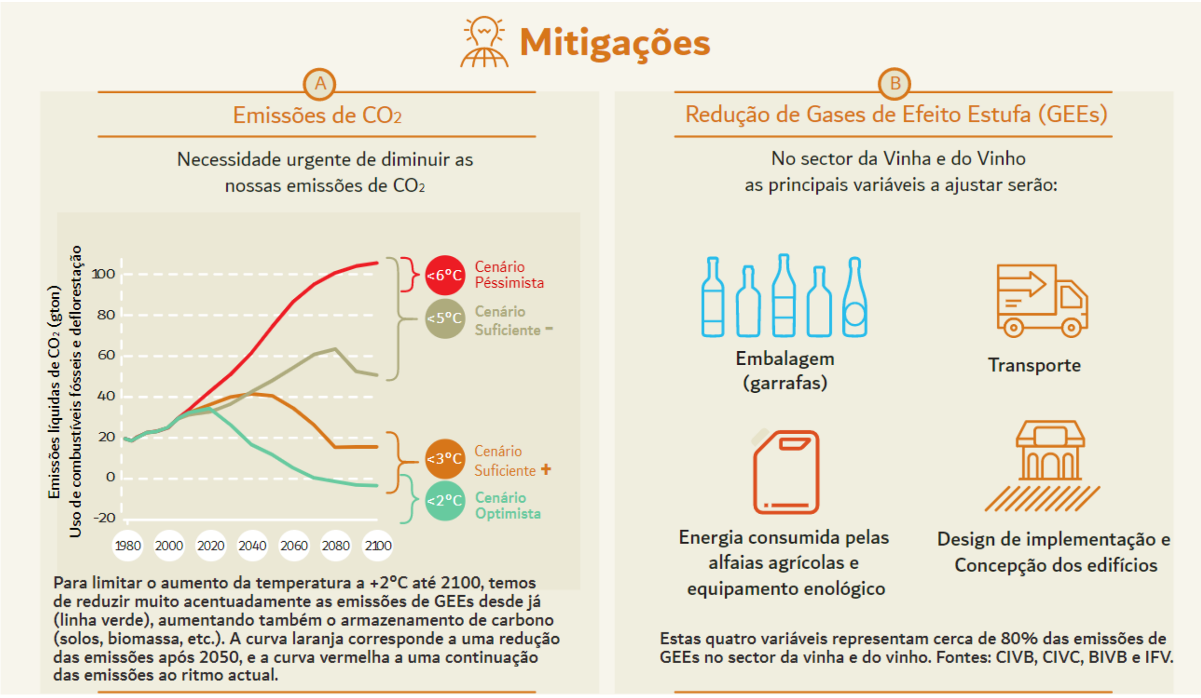


Figure 44: Example of infographics that are used for educational purposes. Source: Vineas (2021).

This is where a specific search had to be start to obtain trustworthy data about all these factors, which required delving into all the specific research about climate change and its potential impact on the berries. Whereas France, as a bigger country, is likely to have more data available, it was difficult to replicate all the infographics because of missing data in Portugal. An example includes the information about the change of the specific level of alcohol and acidity of the grapes of different kind of wines. As these effects are specifically measured for France, the infographics could not be simply translated. For Portugal, all the relevant academic and grey literature, just as the meteorological forecasts were profoundly investigated. Especially relevant for the climatic and meteorological infographics turned out to be the datasets retrieved from the national climate portal called 'Portal do Clima', where entire lists of historic and future climate prospects can be found. Infographics that could not be replicated perfectly had to be adjusted. Examples include datasets that used different years for projections (e.g. instead of the year 2080 only a projection for the year 2070 was available). All these infographics are currently being made for Portugal by the person responsible for graphic design in the team.

4.4.3. Adding content to the platform

Documents

One of the most important characteristics of the platform is the possibility to share documents, such as open access articles, research articles or books. The idea is to create a holistic knowledge base with information related to climate change and viticulture to facilitate the knowledge accessibility. Figure 45 shows the front page of Vineas, which is where most search for Information will begin.

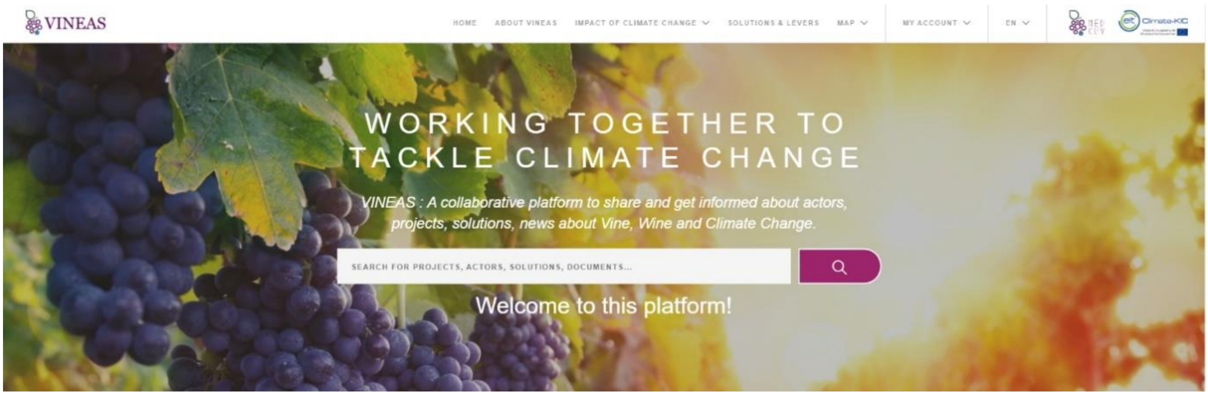


Figure 45: The front page of Vineas, through the search engine a user can start his journey. Source: Vineas (2021)

After putting the keywords and hitting the pink search icon, the platform will visualize all related content, which consists out of possible 1) solutions, 2) actors, 3) documents, 4) projects, 5) news and 6) events. For example, in figure 46 these different categories are visible after searching the word 'soil' in the search engine, which shows 5 solutions, 4 actors, 7 documents, 1 project, 0 news and 3 events. As all these categories will be treated in the following chapter, the focus of this section will be merely on the third category about documents. As visible in figure 46, 8 different documents are shown that are related to the word 'soil', such as the first 2 results about vineyard management systems and cover crops.
The search could subsequently filtered for the specific needs of the user.

The database functions through keywords (figure 48), which have to be added manually in all languages when the document is uploaded through the private profile. If the relevant keywords are added, the article will pop-up in the results when a match is found between the keywords of the documents and the keywords used in the search engine on the platform. As this may sound simple, the platform contains 7 different languages, which makes it necessary to translate all the keywords to any language (if the document was written in English) for the search engine to be able to pick up the search. On a typical day I would scan and read journals and articles to determine the added value to the platform, and consequently create profiles for the actors (see section 'actors') which were involved or related to the document, projects, events or news articles.

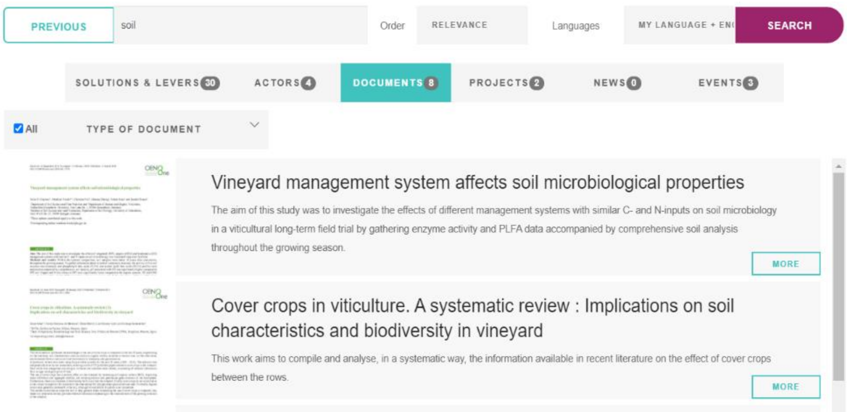


Figure 46: Excerpt of the platform Vineas based on the keywords 'soil'. Source: Vineas (2021).

During the weekly meetings the progress and stumbling blocks would be discussed. During my work of filling the knowledge base, important questions came up that had to be discussed with the entire team. An example includes the exact rules regarding documents that are copyrighted or have a commercial character, not all documents could be simply imported and transferred to the platform. Another question became the use of the VPN of the university to find documents, since these documents are normally not accessible for everyone. This question became especially pertinent to me, since I was scanning the literature and uploading it to the database. This came up several times during the meetings, which eventually got translated through a 'switch' included in the form in the private area that needs to be filled in to upload any content (figure 47). Without taking dragging the switch to the right and taking note of the right to disseminate and upload the document, it is not possible to continue in the process.

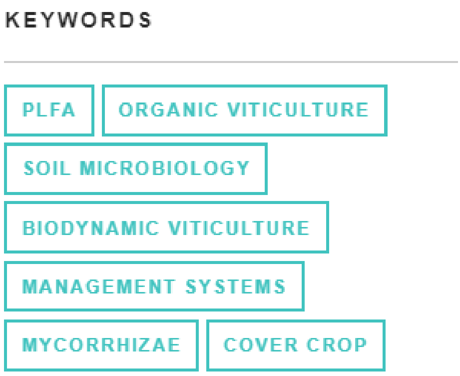


Figure 48: The integration of keywords to optimize search results for the user. Source: Vineas (2021).

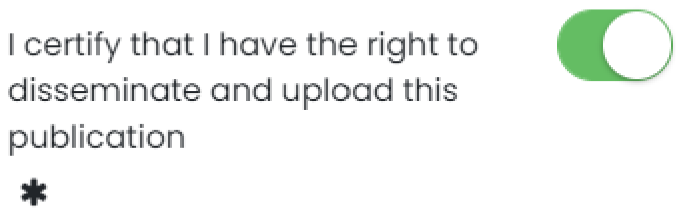


Figure 47: A strategy to overcome possible copyright issues. Source: Vineas (2021)

At the same time, during the meetings the new ideas and strategies would be discussed to further improve the platform, everyone was welcome to make suggestions for a new change or modification. In the case of the documents, it was decided to add some extra filters (Figure 49) to make a distinction between different kinds of articles, such as Popularization of science – (Communication), Reports (Minutes), Laws (Regulation), Tools/models/templates, strategical planification documents, methodological documents, studies (analyses), books, information systems (database), publications, working papers, online publications and courses (formations). Through these filters, it is possible to effectively and efficiently find the documents that one might be looking for. During the course of the internship, all these filters were discussed, changed and adjusted to get the most effective and efficient search result.

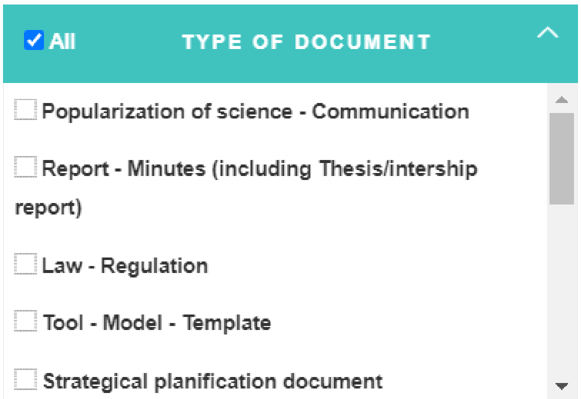


Figure 49: The specification of different kind of documents. Source: Vineas (2021).

Actors

One of the most important functions of the platform is to add actors, such as businesses, organizations, NGO's, research institutions, thinktanks and individual farmers. It is possible to add these actors through filling in a form with questions, which is automatically converted to a profile when finished. This profile can subsequently be linked to the different documents (is the actor in question also the author or one of the contributors to the publication?), solutions (is the actor involved in any of the specific solutions?), events (is the actor involved in any upcoming event), projects (is the actor owner or partner of a project?). All actors are assigned the corresponding geolocation, which can be consulted on the network map on the platform Vineas.

Adding projects, events and news

Another important part of the platform and of my responsibilities is posting relevant projects, events and news in the area of viticulture. All the time an event would be made, the responsible organization, geolocation and all the relationships with other documents or actors would be included. An important questions during the meetings became the language of all posts: There are 6 different countries and languages included in the platform and not all the documents can be translated to all 7 languages. At the same time, the idea behind the platform is collaboration and a better exchange of information, for which it is necessary to have a common language. Even though the platform does not have an English speaking country present, it was decided to also give the possibility to have an English version of the platform for everyone interested.

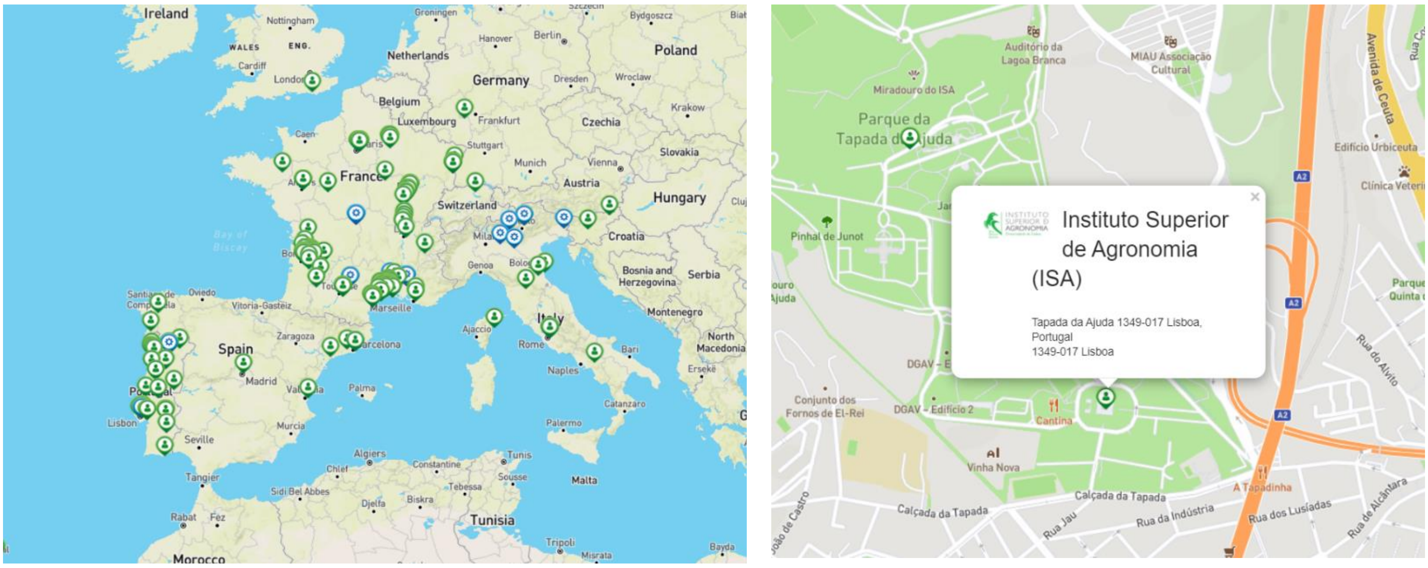


Figure 50: Example of how the geolocations work, in this case for the Instituto Superior de Agronomia (ISA). Source: Vineas (2021).

One of the most important functions of the platform Vineas is the possibility to filter different solutions for climate adaptation and mitigation. Over the course of the internship, an ingenious system was developed to filter really specific solutions in a specific area. During the meetings, one question would typically be if new categories should be added, blended together or be deleted. As not everyone had a background in chemistry, ecology or biology, proposing new solutions or new categories could not be done by everyone that easily, but everyone was still able to give their opinion during the meetings. As many of the solution cards would be developed by partners from other countries than Portugal, a big question was the translation of all these cards into Portuguese. During the course of the internship, I have been busy with translating all these cards into Portuguese, so the content would also become available for Portuguese users who do not speak English. Besides the translation of existing solution cards, I also made suggestions for solutions that I found about during my research for content for the platform, such as solutions in the area of Artificial Intelligence (AI) and robotics.

Over the course of the internship, two different systems of filtering specific solutions were developed. The first option is to search the solutions by search filters, based on the following categories: ‘Stakes’, ‘scale of action’, ‘field of action’, and ‘technical domains’. Figure 51 shows this first filter, the idea is that all categories could be selected here that are relevant to the user, which will result in a really specific solution for the issue. For example, when the option ‘adaptation’, ‘individual’ and ‘soil management’ is chosen, the platform shows 8 possible solutions, such as fertilizing the vineyard, changing agronomic practices and minimize soil disturbance. If the options ‘mitigation’, ‘industry/cooperatives’ and ‘soil management’ would be selected together, the platform advices only one specific solution, namely about changing agronomic practices. Like this, the user is able to find specific solutions based on the criteria chosen in the filters.

Field of generic solutions	Generic solutions	Some specific solutions	
Viticulture	**Vineyard management**	Row orientation, Density of plantation, Shading over the vineyard, Agroforestery in viticulture	MORE
	Cultural techniques related to canopy	Growth regulators, Antiperspirants, Gobelet pruning, Late pruning	MORE
	Varietal lever	Variety adapted to drought, Foreign varieties, Late varieties, Clone adapted to CC, Explore grafting system	MORE
	Soil management	Mulch, Compost, Biochar, Cover-crop management, Minimum tillage, Compost, Recycled plastic tiles	MORE
	Water stress management	Foliar pressure chamber, Thermal infrared imaging, Sap flow sensor	MORE
	Irrigation	Drip irrigation, Reuse of water, Irrigation management software, Impact of irrigation on monastrell	MORE
	Prevention of frost damages	Radiation, turbines, use of a sprinkler system	MORE
	Prevention of hail damages	Parahail nets	MORE
	Climate services	Decision Support Systems, Seasonal forecasts	MORE
	Reduction of GHG emissions in the vineyard	Tilling options, low-consumption mechanics, fertilizer reduction	MORE
Oenology	**Acidity management**	pH adjustment, tartaric acid	MORE
	Alcohol degree management	Desalcoholisation by spinning cone columns, Desalcoholisation by membrane, Watering the wines	MORE
	[illegible]	Building energy consumption, control of energy in the vinification process, CO2 capture in	[illegible]

Figure 51: The first set of filters used to search for climate adaptation and mitigation solutions.

The second filter (figure 52) is about exploring the solution families. There are 3 categories: The field of generic solutions (e.g. if the solution needs to be in the area of viticulture, oenology or collaboration), the generic solutions (the mother category for specific solutions) and finally the specific solutions (subcategories of the mother category). If the categories are followed linearly, the user will automatically end with the group of applicable specific solutions, where more information about these solution can be found when clicked on the button ‘MORE’. For example, in case the user would like to know more about the solution ‘irrigation’, the search would be as follows: Viticulture – Irrigation – ‘MORE’. Now, all the different specific solutions related to irrigation will be visualized.

Figure 52: The second set of filters used to search for climate adaptation and mitigation solutions.

Making connections

Many of the functions of the platform are interrelated, which can be consulted both on the individual page of each document, solution, project, event or news article, but could also be consulted through the network map. Figure 51 visualizes the entire network of documents, actors, projects, and solutions and levers of the network Vineas that was created over the course of this internship, which shows the content of the platform for 1) documents (red), 2) actors (green), 3) projects (pink), and 4) solutions and levers (blue). During the internship, it was tried to make as many connections, because valuable information could be deducted from this. It is possible to move parts of the network around to single out one of the 4 factors, visualize all the relationships and get more information about each.

This network might be a bit chaotic because of the high number of connections, during the meetings it was decided to put an on-and-off button to be able to deactivate some of the layers if necessary, which decreases the number of connections and improves the visibility. This map is the summation of all the individual maps that are shown when a document, solution, project, event or news article is opened. All these individual relationships are also visible through visiting the personal page of a document, actor, project or the solutions and levers. Figure 54 shows an example of the actor CREA, which is currently connected to 2 solutions and 6 different documents of the knowledge base.

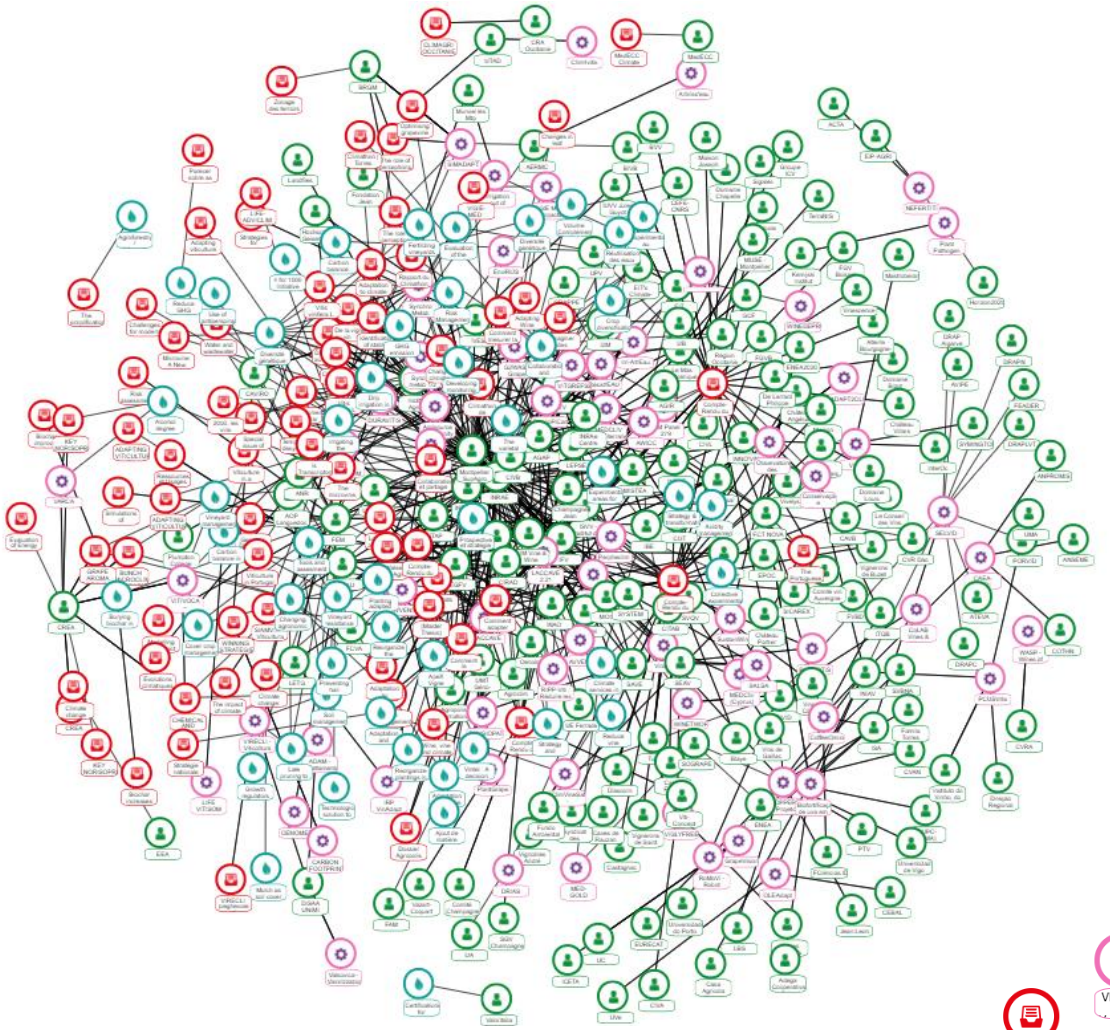


Figure 53: The network map (Map > Network Map) of Vineas. All the connections between solutions, documents and actors can be found here. Source: Vineas (2021).

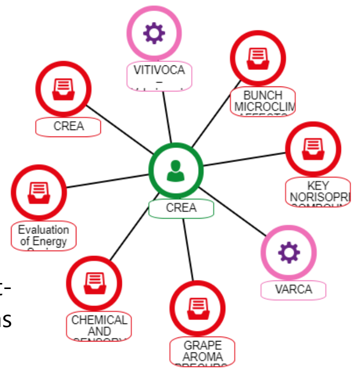


Figure 54: Excerpt of the network map. Source: Vineas (2021)

4.5 Meetings

4.5.1 Weekly meetings

During the week, the MEDCLIV team had meetings, normally once a week, and exceptionally more than once a week for special events or activities (such as the launch of our platform called Vineas). The meetings would be in Google Meet and lasted for about 2 hours, with some outliers towards 3 hours. On average, there would be around 8 to 10 people in the meeting, with normally at least one person representing each of countries involved. The meetings were led by Maddy Titinger from the French team and involved a lot of interaction from all participants. Normally, the meetings would be started with updates from Maddy about the progress that has been made with the platform Vineas and discuss the topics that were put on the agenda by the different participants in the Discord channel. During the meetings, these topics will be discussed in group to see if everyone is onboard. Also besides the topics put on the official agenda, it was always possible to ask questions, give feedback or share one's thoughts. The meetings were a really important moment for me to clear all the questions and doubts that I had during the workweek, just as to share my thoughts or ideas about certain topics. Coming up with new ideas or reflecting about possible ways or functionalities to develop the platform further was an important part of the meetings, which led to new development paths or ideas. The meetings were normally ended with a schedule for next week, which included planning the next meeting and the deadline for certain tasks. If Filipa was not able to assist the meeting completely, I would be there to take notes and send a summary afterwards.

4.5.2 Special meetings

During the internship, there were also some meetings that had a particular focus or objective. An example was the test meeting for the official launch of the platform Vineas, which served as an experiment for the actual launch. The French team made a Powerpoint presentation and showed the general guidelines for the presentation, which could subsequentially be adapted by every country to all the different contexts. Another example of a special meeting were the meetings with potential contributors, which are people which are potentially interested in becoming more active in Vineas. This platform is made especially for them, it could be used as a platform to upload and spread research, solutions and actors, which could lead to more publicity and visibility for the actor.

4.5.3 Meetings with coordinator

During the course of the internship, there were also meetings with Filipa Carlos to talk about potential ideas and strategies on how the platform could be developed further. These meetings were quite informal and consisted mainly about theorizing all the possible pathways or ideas that could be compatible with the vision of the MEDCLIV project. All these ideas would be written down and subsequently presented to the team through an email or during one of the weekly meetings. Filipa has also helped me over the course of the entire internship with the construction of this internship report through giving feedback and coming up with new ideas.

4.6 Geographic information

Besides the documents, actors, projects, solutions and levers, the team also came up with the idea to create an interactive map with all the relevant geographical data for the viticulture sector on the European level. The three categories in the platform are 'land use', 'soil carbon stocks', and 'water reserve mm'. The first category is already available on the European level, the last 2 categories are only for France. During the internship, a desk research was started to obtain the data for the geographical regions in Portugal, which led to learn how to work completely independently with GIS through the software QGIS. During the time of the internship, I focused on learning the basics of QGIS through existing literature and videos, which started with digitizing individual layers and georeferencing, to creating new layers based on expressions and calculations. As a matter of fact, all the layers that were shown during chapter 3 are fruits of this learning journey throughout the internship. During the internship, also new datasets and layer that were deemed to add an additional value to the existing geographic data were proposed to be taken up in Vineas.

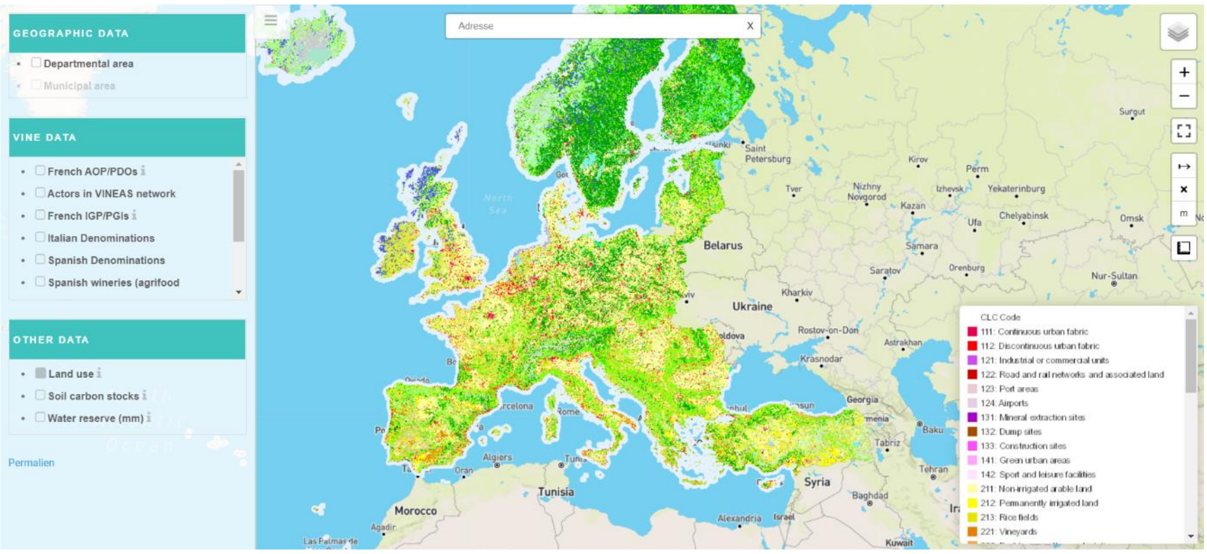


Figure 55: Geographical Information that can be found on Vineas (Map > Geographic Information. Source: Vineas (2021)

4.7 The official launch of Vineas

After months of perfectionating the platform, the moment had come to present it to the public. On the 30th of March 2021, a kick-off session was given to everyone interested in the platform Zoom, which attracted a total of 39 participants (FCT-NOVA team included). During this kick-off event, the main results of the MEDCLIV project were presented by professor Luísa Pinto Ferreira, the presentation about the platform Vineas by Filipa Carlos, followed by a live journey through the platform, which was done by me. During this journey, all the different functionalities and parts of the platform were discussed, such as how to search for specific projects, actors, solutions and documents. Special attention was given to the use of the filters to find specific solutions, as the goal of the platform was to improve the climate resiliency through information sharing about possible adaptation and mitigation options. The session included a part which shows everyone interested how a new account could be created, followed by a 'peak' behind the curtains, which showed how content could be created and uploaded to the platform and how the system translates it to the final result of the website. The kick-off session was finished by a survey, sent to each of the participants about the likelihood of them using the platform in the future. The survey revealed that 47% of the participants answered this question with 'yes', 40% with 'most likely', and 13% with 'eventually'. In addition, 46% of the users wanted to become a proactive user of the platform through uploading content, 47% only wanted to be registered and access the documents available and 7% did not want to become a user at all. It could be concluded that most participants appreciated the creation of the platform Vineas (87% of the participants are considering using it), whereas not everyone wants to have an active role within the platform (47%). The last question was about the language of the platform, the survey found that 60% would like to have content both in Portuguese and in English, 27% in all languages of the project and 13% only in Portuguese.

4.8 Lessons learned

The project MEDCLIV was a first introduction to project management, which both included working with partners on the national and European level. It was interesting to assist the entire process of developing Vineas completely from scratch together with everyone from the team. This resulted not only in a better understanding on how large-scale projects are developed and executed over time, but also about the pace and group dynamics of these large scale projects.

To continue, the project also showed me that a certain level of pro-activity is necessary to succeed in a project. In the beginning of the project, I was not completely sure if my opinion would be appreciated during the meetings as an intern so the main strategy was to take notes and keep quiet. After a couple of weeks, I started to engage more with the team, which actually resulted to an overall better experience and performance during the meetings. Besides this, the MEDCLIV project also gave me an introduction to working with climate data, climate change adaptation/mitigation and viticulture. Throughout the entire internship (but especially in the beginning), many documents were scanned to find new solutions or information that could be relevant for Vineas, which led to an introduction to new insights and knowledge of ecology, biology, chemistry, oenology and climate change.

But, by far the most important lesson learned or tool that has been acquired during the internship was to work with the software QGIS. The project MEDCLIV and this internship report were my first introduction to the of GIS, which has definitely been a fascinating journey.

To be more specifically, the following skills have been acquired in QGIS during the internship: Upload vector and raster layers; Create new vector and raster layers; Add basemaps; Digitize layers; Georeference layers; Use and manipulate symbology functions
; Use expressions; Measure distances; Add plugins; Calculate statistics; Group and merge layers; Use the clip function; Link data from Excel to QGIS; Use the different panels and toolbars; Use the field calculator for mathematical functions and expressions; Add/remove/modify attributes; Visualize data to Google Earth; Export files into different formats; Use the map layout function to add legends, scale bars and wind roses.

5. CONCLUSION AND RECOMMENDATION

This internship has shown both the theoretical and practical side of a concrete climate adaptation project, where the risks brought upon the vine and wine sector by climate change were analyzed and assessed. Both parts of this internship have been paramount for my final understanding of the impacts and risks related to different climate hazards. This chapter will briefly discuss the final conclusions and final thoughts of this internship report, which combines the information found in the research, with the further developments of the climate change platform Vineas.

The final conclusion of this internship report is that climate risks are highly dynamic and context-dependent, and should therefore be determined based on the local characteristics and circumstances of a specific place or region. As chapter 3.5 and 3.6 has shown, there are different risks identifiable for different NUTSIII regions, with some of the IGP characterized by several different hazards, and other simply by none. As a consequence, the potential impacts for each region will be different. As chapter 3.8 has shown, some regions might experience possible negative consequences for the quality or quantity of the grapes, and others different kind of diseases, pests, different timing of phenological stages or a necessary shift of the location of the vineyard. In order to assess what kind of possible climate adaptation and mitigation strategies could be possible or viable, all the local characteristics and circumstances of the vineyard need to be taken into account. Only after having made a complete analysis of the local situation for each vineyard, the most efficient and effective climate adaptation measure could be chosen.

This is also connected to my recommendations for the platform Vineas. Whereas information on the vineyard level might not be viable, the integration of a more local approach (instead of on the national or European level) might benefit users in finding climate adaptation/mitigation solutions. It was during this research done that I realized the big differences in exposure, hazards and vulnerability between different NUTSIII regions in Continental Portugal, which was not directly expected in the beginning. It could be useful to link publications and solutions to a specific location so users could directly see if Information Is applicable to them. To illustrate, instead of uploading a generic solution card such as 'irrigating the vineyards' or 'drip irrigation in the vineyard', it might be relevant to link these solution cards directly to the geographical information available, such as the maps made in figure 16 up to and including figure 24 about the projections for precipitation (MAP and MSP) and moisture deficit (CMD). Through the combination of this geographical information, it does not only become directly visible why irrigation is a good solution (because of a large precipitation/moisture deficit), but it also becomes possible for other regions with similar climatic conditions to replicate the solutions mentioned or undertaken by this specific region. The same could be true for research and projects, it could be useful if these would all be linked to a specific administrative unit. Perhaps it could be even possible to go to the section with the geographic information (Map > Geographical information), select the administrative unit interested in and see all the relevant information, such as projections for climatic variables (e.g. average temperature, precipitation, number of heat days, number of cold nights etc.), research published, solutions, events and projects. To illustrate, if a research is about a specific vineyard within the perimeter of *IGP Duriense*, then this document could be added to this local database. Over time, the database will contain more information with relevant documents and solutions that could help other local actors to adapt to the adverse effects of climate change. Now, instead of a generic solution that might not work for a specific local context, solutions or research will arise that has actually been executed at that location, which could improve the trustworthiness and replicability of the solutions.

6. LITERATURE

Agrisource (2019). MEDCLIV (Mediterranean Climate Vine & Wine Ecosystem). Accessed on the 24th of November 2020 from https://www.agri-source.org/en/7_113/5d931c5782937f0e19449fba/MEDCLIV%20(Mediterranean%20Climate%20Vine%20%26%20Wine%20Ecosystem).html

Agrisource (2020). MEDCLIV (Mediterranean Climate Vine & Wine Ecosystem). Accessed on the 10th of March 2021 from https://www.agri-source.org/en/7_113/5d931c5782937f0e19449fba/MEDCLIV%20(Mediterranean%20Climate%20Vine%20%26%20Wine%20Ecosystem).html

Akku, E.J. & Lynam, T. (2010). What is adaptive capacity? Report for the South East Queensland Climate Adaptation Research Initiative. Accessed on the 19th of June 2021 from https://www.researchgate.net/publication/259117037_What_is_adaptive_capacity

Bonnefoy, C. (2017). Bioclimatic indices of the ripening period (2) : Thermal conditions at night. Accessed on the 17th of June 2021 from https://blog.vintagereport.com/2017/10/05/1442/

Brooks, N. & Adger, W.N. (2004). Assessing and Enhancing Adaptive Capacity. Accessed on the 14th of June 2021 from https://www4.unfccc.int/sites/NAPC/Country%20Documents/General/apf%20technical%20paper07.pdf

Bugaret, Y. 2010. As mudanças climáticas e a cultura da vinha! Accessed on the 14th of June 2021 from https://cropscience.bayer.pt/internet/noticias/noticia.asp?id=545

Cambridge Dictionary (2021). "Risk". Accessed on the 23th of June 2021 from https://dictionary.cambridge.org/dictionary/english/risk

Camps, J. O., and M. C. Ramos. 2012. Grape harvest and yield responses to inter-annual changes in temperature and precipitation in an area of north-east Spain with a Mediterranean climate. Int. J. Biometeorol. 56:853–864

Cardona, O.D., M.K. van Aalst, J. Birkmann, M. Fordham, G. McGregor, R. Perez, R.S. Pulwarty, E.L.F. Schipper, and B.T. Sinh, (2012). Determinants of risk: exposure and vulnerability. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 65-108.

Cardoso, M. (2019). SOS clima: "Vamos continuar a ter vinhos de qualidade, mas é provável que sejam diferentes". Accessed on the 14th of June 2021 from **https://expresso.pt/economia/2019-03-06-SOS-clima-Vamos-continuar-a-ter-vinhos-de-qualidade-mas-e-provavel-que-sejamdiferentes**

Centinari (2018). Grapevine Bud Break 101. Accessed on the 18th of June 2021 from https://psuwineandgrapes.wordpress.com/2018/05/14/grapevine-bud-break-101/

Climate-ADAPT (2020). Mediterranean Climate Vine & Wine Ecosystem (MEDCLIV). Accessed on the 10th of April 2021 from https://climate adapt.eea.europa.eu/metadata/projects/mediterranean-climate-vine-wine-ecosystem

Climate-ADAPT (2021). Assessing risks and vulnerability to climate change: 2.4 How to assess adaptive capacity? Accessed on the 17th of June 2021 from https://climate-adapt.eea.europa.eu/knowledge/tools/adaptation-support-tool/step-2-4-t

Conceição, M.A.F., Souza, R.T. & Tonietto, J. (2016). Estimating MCC System Dryness Index using the Vineyard Water Indicator. In: BIO Web of Conferences, 7, pp. 1-2 Doi: 10.1051/bioconf/20160701037

Conceição, M.A.F., Souza, R.T. & Tonietto, J. (2018). Climatic water indices for viticulture: Índices hídricos climáticos para a viticultura. In: Pesquisa Agropecuária Brasileira, 53(6), pp 765-768. Doi: https://doi.org/10.1590/S0100-204X2018000600013

Cutter, S.L. (1996), “Vulnerability to environmental hazards”, Progress in Human Geography, Vol. 20 No. 4, pp. 529-39.

Denton, F., T.J.Wilbanks, A.C. Abeysinghe, I. Burton, Q. Gao, M.C. Lemos, T. Masui, K.L. O’Brien, and K.Warner, 2014: Climate-resilient pathways: adaptation, mitigation, and sustainable development. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1101-1131.

Deutscher Wetterdienst (2021). Huglin Index. Accessed on the 16th of June 2021 from https://www.dwd.de/EN/ourservices/germanclimateatlas/explanations/elements/_functions/faqkarussel/huglin.html

European Commission (2014). Concepts and Metrics for Climate Change Risk and Development - Towards an index for Climate Resilient Development. Accessed on the 14th of April 2021 from https://core.ac.uk/download/pdf/38627875.pdf

European Commission (2021). Communication from the commission to the european parliament, the council, the european economic and social committee and the committee of the regions. Accessed on the 13th of April 2021 from https://eur-lex.europa.eu/legal content/EN/TXT/PDF/?uri=CELEX:52021DC0082&from=EN

Eurostat (2017). Vineyards in the EU – statistics. Accessed on the 21st of June 2021 from https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Vineyards_in_the_EU_-_statistics&oldid=514761

Fraga, H. (2019). Viticulture and Winemaking under Climate Change. In: Agronomy, 9, 783; doi: 10.3390.

Fraga, H., Garcia de Cortazar-Atauri, I., Malheiro, A. C., & Santos, J. A. (2016). Modelling climate change impacts on viticultural yield, phenology and stress conditions in Europe. *Global Change Biology*, *22*(11), 3774–3788. https://doi.org/10.1111/gcb.13382

Fraga, H. & Santos, J.A. (2019). Impactos das alterações climáticas e medidas de adaptação para a viticultura portuguesa. Accessed on the 19th of June 2021 from https://www.infowine.com/pt/artigos_tecnicos/alteraes_climticas_medidas_de_adaptao_vin-ideas_infowine_sc_17362.htm

Füssel, H. (2006). Vulnerability: A generally applicable conceptual framework for climate change research. In: Global Environmental Change, 17(2), pp 155-167. Doi: https://doi.org/10.1016/j.gloenvcha.2006.05.002

Füssel, H. (2010). Review and Quantitative Analysis of Indices of Climate Change Exposure, Adaptive Capacity, Sensitivity, and Impacts. Washington, DC: World Bank

Gonzaga., L.S., Capone, D.L., Bastian, S.E.P. & Jeffrey, D.W. (2020). Defining wine typicity: sensory characterisation and consumer perspectives. Australian Journal of Grape and Wine Research, 27(2), pp. 246-256. Doi: https://doi.org/10.1111/ajgw.12474

Hélder, F., Cortazar-Atauri, I.G. & Santos, J.A. (2018). Viticultural irrigation demands under climate change scenarios in Portugal, Agricultural Water Management 196:66-74, Doi: 10.1016/j.agwat.2017.10.023

Impact Lab (2021). Climate Impact Lab, Accessed on the 03th of March 2021, from http://www.impactlab.org/map/#usmeas=absolute&usyear=1981-2010&gmeas=absolute&gyear=2080-2099&tab=global&gvar=tas-annual&grcp=rcp45

International Organisation of Vine and Wine (2019). 2019 Statistical Report on World Vitiviniculture. Accessed on the 16th of March 2021 from https://www.oiv.int/public/medias/6782/oiv-2019-statistical-report-on-world-vitiviniculture.pdf

IPCC (2001) Climate change 2001: Impacts, Adaptation and Vulnerability, Summary for Policymakers, WMO.

IPCC (2013). CLIMATE CHANGE 2013 The Physical Science Basis. Accessed on the 15th of March 2021 from https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_all_final.pdf

IPCC (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II

IVV (2021). Evolução da Produção Nacional de Vinho por Região Vitivinícola: Série 2009/2010 a 2019/2020. Accessed on the 14th of March 2021 from https://www.ivv.gov.pt/np4/home.html

IVV (2021). Quem somos. Accessed on the 19th of June 2021 from https://www.ivv.gov.pt/np4/26/

IVV (2020). Vendas no Mercado Nacional – Setembro 2020. Accessed on the 23th of June 2020 from https://www.ivv.gov.pt/np4/9493.html

Jackson, D.I., Cherry, N.J. (1988). Prediction of a district's graperipening capacity, using a latitude-temperature index (LTI). Am. J. Enol. Vitic. 1, 19–28.

Keller, M. (2010). The science of grapevines: anatomy and physiology. Elsevier, Inc.: Amsterdam.

Marchi, M., Castellanos-Acuna, D., Hamann, A., Wang, T., Ray, D. Menzel, A. 2020. ClimateEU, scale-free climate normals, historical time series, and future projections for Europe. Scientific Data 7: 428. Doi: 10.1038/s41597-020-00763-

National Confederation of Agricultural Cooperatives and Agricultural Credit of Portugal (2019). Diretor da OIV: «Vamos continuar a ter vinhos de qualidade, mas é provável que sejam diferentes». Accessed on the 04th of June 2021 from https://www.confagri.pt/sos-clima-continuar-ter-vinhos-qualidade-provavel-sejam-diferentes/

Neethling, E., Barbeau, G., Bonnefoy, C. & Quénol, H. (2012). Change in climate and berry composition for grapevine varieties cultivated in the Loire Valley. *Climate Research*, *53*, 89-101. https://doi.org/10.3354/cr01094

OIV (2015). Greenhouse gases accounting in the vine and wine sector – recognised gases and inventory of emissions and sequestrations. Accessed on the 16th of April 2021 from https://www.oiv.int/public/medias/4521/publication-bilan-ges-en.pdf

Perkins-Kirkpatrick, S.E. & Gibson, P.B. (2017). Changes in regional heatwave characteristics as a function of increasing global temperature. In: Scientific Reports, 7(1), pp. 1-12. DOI:10.1038/s41598-017-12520-2

Pidgeon, N. & Butler, C. (2009). Risk Analysis and Climate Change. In: Environmental Politics 18(5), pp 670-688. DOI: 10.1080/09644010903156976

Pilz, H. (2020). The impact of climate change on wine growing. Accessed on the 16th of June 2021 from https://blog.drinktec.com/wine/the-impact-of-climate-change-on-wine-growing/

Pinto, P.A., Lopes, C.M., Braga, R. & Egipto, R. (2013). SIAMVITI – Viticultura portuguesa num cenário de alterações climáticas: Impactos e medidas de adaptação. Accessed on the

22th of June 2021 from https://www.infowine.com/pt/artigos_tecnicos/alteraes_climticas_medidas_de_adaptao_vinideas_infowine_sc_17362.htm

Ponti, L., Boggia, A., Neteler, M. & Gutierrez, A.P. (2018). Analysis of Grape Production in the Face of Climate Change. In: Climate, 6(2), pp. 1-15. Doi: https://doi.org/10.3390/cli6020020

Preudhomme, N. (2019). Assessing Local Adaptive Capacity to Understand Corporate and Financial Climate Risks. Accessed on the 17th of June 2021 from https://427mt.com/2019/01/15/assessing-local-adaptive-capacity-to-understand-corporate-and-financial-climate-risks/

Quintas San Michel (2021). O ciclo da vinha. Accessed on the 22th of June 2021 from https://quintasanmichel.com/estorias/o-ciclo-da-vinha/

Ramos, M. C., Cots-Folch, R. & Martínez-Casasnovas, J. A. (2007). Effects of land terracing on soil properties in the Priorat region in Northeastern Spain: A multivariate analysis. *Geoderma*, 142(3), 251–261. https://doi.org/10.1016/j.geoderma.2007.08.005

Santillán, D., Sotés, V., Iglesias, A., & Garrote, L. (2019). Adapting viticulture to climate change in the Mediterranean region: Evaluations accounting for spatial differences in the producers-climate interactions. Accessed on the 24th of November 2020 from https://www.bio- conferences.org/articles/bioconf/full_html/2019/01/bioconf-oiv2018_01001/bioconf-oiv2018_01001.html

Santos, J.A., Fraga, H., Malheiro, A.C., Moutinho-Pereira, J., Dinis, Lia-Tânia, Correia, C., Moriondo, M., Leolini, L., Dibari, C., Costafreda-Aumedes, S., Kartschall, T., Menz, S., Molitor, D., Junk, J., Beyer, M. & Schultz, H.R. (2020). A Review of the Potential Climate Change Impacts and Adaptation Options for European Viticulture. In: MDPI, vol 10(1), 1-28. DOI: https://doi.org/10.3390/app10093092

Schneiderbauer, S., Baunach, D., Pedoth, L., Renner, K., Fritzsche, K., Bollin, C., Pregnolato, M., Zebisch, M., Liersch, S., López, M.R.R. & Ruzima, S. (2020). Spatial-Explicit Climate Change Vulnerability Assessments Based on Impact Chains. Findings from a Case Study in Burundi. *Sustainability* 2020, *12*(16), 6354; https://doi.org/10.3390/su12166354

Silvestre, J. (2016). Alterações climáticas: desafios e oportunidades para o setor vitivinícola. Accessed on the 5th of June 2021 from https://www.vidarural.pt/wp-content/uploads/sites/5/2016/06/Leia-o-artigo-completo.pdf

Smit, B. & Pilifosova, O. (2018). Adaptation to Climate Change in the Context of Sustainable Development and Equity. In: Houghton, J.T., Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell, and C.A. Johnson (eds.). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press

Smit, B. & Wandel, J. (2006). Adaptation, Adaptive Capacity and Vulnerability. Global Environmental Change, 16, 282-292. http://dx.doi.org/10.1016/j.gloenvcha.2006.03.008

Smith, J. B., Schellnhuber, J., Mirza, M. M. Q., Fankhauser, S., Leemans, R., Lin, E., Ogallo, L., Pittoc, B., Richels, R. G., Rosenzweig, C., Tol, R. S. J., Weyant, J. P., & Yohe, G. W. (2001). Vulnerability to climate change and reasons for concern: A synthesis. In J. J. McCarthy, O. F. Canziani, N. A. Leary, D. J. Dokken, & K. S. White (Eds.), *Climate Change 2001: Impacts, adaptation, and vulnerability* (pp. 913-967). Cambridge University Press.

Soanes, C. and Stevenson, A. (Eds) (2005), Oxford Dictionary of English, Revised 2nd ed., Oxford University Press, Oxford.

Strub, L. & Loose, S.M. (2021). The cost disadvantage of steep slope viticulture and strategies for its Preservation. Oeno one, 1, pp. 49-68. DOI:10.20870/oeno-one.2021.55.1.4494

Strub, L., Kurth, A. & Loose, S. M. (2021a). The effects of viticultural mechanization on working time requirements and production costs. *Am J Enol Vitic*, 72

Taylor, W. (2020). Wine Education 101: Winter Dormancy in the Vineyard. Accessed on the 19th of June 2021 from https://ocws.org/wine-education-101-winter-dormancy-in-the-vineyard/

Tonietto, J. & Carbonneau, A. (2004). A multicriteria climatic classification system for grape-growing regions worldwide [Paper presentation]. 39th World Congress of Vine and Wine. Bento Gonçalves, Rio Grande do Sul. DOI: https://doi.org/10.1016/j.agrformet.2003.06.001

TPN/Lusa (2021). Portugal one of the most vulnerable to climate change. Accessed on the 17th of June 2021 from https://www.theportugalnews.com/news/2021-08-13/portugal-one-of-the-most-vulnerable-to-climate-change/61659

UNFCCC (1992). Article 4: Commitments. Accessed on the 14th of June 2021 from https://unfccc.int/cop4/conv/conv_006.htm

U.S. Climate Resilience Toolkit (2021). Assess Vulnerability & Risk. Accessed on the 17th of June 2021 from https://toolkit.climate.gov/steps-to-resilience/assess-vulnerability-risk

U.S. Climate Resilience Toolkit (2021). Glossary. Accesed on the 13th of April 2021 from https://toolkit.climate.gov/sites/default/files/CRT_Glossary_03-02-21.pdf

UNISDR & WMO (2012). UN System Task Team on the Post-2015 UN Development Agenda. Accessed on the 14th of April 2021 from https://www.un.org/en/development/desa/policy/untaskteam_undf/thinkpieces/3_disaster_risk_resilience.pdf

Van Leeuwen, C. & Darriet, P. (2016). The Impact of Climate Change on Viticulture and Wine Quality. In : Journal of Wine Economics 11(01):150-167. DOI:10.1017/jwe.2015.21

ViniPortugal (2021). Statistics. Accessed on the 14th of June 2021 from https://www.viniportugal.pt/Statistics

Wines of Portugal (2021). PORTUGAL TOTAL WINE PRODUCTION PER REGION (HL). Accessed on the 15th of March 2021 from https://www.winesofportugal.com/en/press-room/statistics/other/

Winkler, A.J., 1974. General viticulture. University of California Press, California, USA.

Yu, J., Castellani, K., Forysinski, K., Gustafson, P., Lu, J., Peterson, E., Tran., M., Yao, A., Zhao, J. & Brauer, M. (2021). In: Environmental Health, 20(1), pp 1-20. Doi: DOI:10.1186/s12940-021-00708-z

Zebisch, M. Schneiderbauer, S. Renner, K. Below, T. Brossmann, M. Ederer, W. and Schwan, S. (2017), “Risk supplement to the vulnerability sourcebook. Guidance on how to apply the vulnerability sourcebook’s approach with the new IPCC AR5 concept of climate risk. Bonn”, available at: www.adaptationcommunity.net/wp-content/uploads/2017/10/GIZ2017_Risk-Supplement-to-the-Vulnerability-Sourcebook.pdf

7. ANNEXES

Annex 1. The regulations involved in one wine region: The case of *IGP Minho*.

Box 1: Example of the number of laws and legislations involved in the creation of one IGP and its DOP's: IGP Minho

Legislation: Portaria n.º 112/93, de 30 de Janeiro, Portaria n.º 1202/97, de 28 de Novembro, Portaria n.º 394/2001, de 16 de Abril, Reg. (CE) 1493/99, de 17 de Maio, e Decreto-Lei n.º 212/2004, de 23 de Agosto.

Geographical area: Abrange os distritos de Viana do Castelo e Braga, os concelhos de Ribeira de Pena e Mondim de Basto, do distrito de Vila Real; os concelhos de Santo Tirso, Vila do Conde, Póvoa do Varzim, Maia, Matosinhos, Gondomar, Valongo, Paredes, Paços de Ferreira, Lousada, Felgueiras, Penafiel, Amarante,

Subregion Baião:

Legislation: Decreto-Lei n.º 263/99, de 14 Julho, alterado pelo Decreto-Lei n.º 449/99, de 4 de Novembro e pelo Decreto-Lei n.º 93/2006, Portaria n.º 28/2001, de 16 de Janeiro, alterada pela Portaria n.º 291//2009, de 23 de Março, Decreto-Lei n.º 212/2004, de 23 de Agosto e Reg. (CE) 1493/99 de 17 de Maio.

Geographical area: Os concelhos de Baião, Resende (excepto a freguesia de Barrô) e Cinfães (excepto as freguesias de Travanca e Souselo).

Subregion Basto:

Legislation: Decreto-Lei n.º 263/99, de 14 Julho, alterado pelo Decreto-Lei n.º 449/99, de 4 de Novembro e pelo Decreto-Lei n.º 93/2006, Portaria n.º 28/2001, de 16 de Janeiro, alterada pela Portaria n.º 291//2009, de 23 de Março, Decreto-Lei n.º 212/2004, de 23 de Agosto e Reg. (CE) 1493/99 de 17 de Maio.

Geographic area**:** Os concelhos de Cabeceiras de Basto, Celorico de Basto, Mondim de Basto e Ribeira de Pena.

Subregion Cávado:

Legislation: Decreto-Lei n.º 263/99, de 14 Julho, alterado pelo Decreto-Lei n.º 449/99, de 4 de Novembro e pelo Decreto-Lei n.º 93/2006, Portaria n.º 28/2001, de 16 de Janeiro, alterada pela Portaria n.º 291//2009, de 23 de Março, Decreto-Lei n.º 212/2004, de 23 de Agosto e Reg. (CE) 1493/99 de 17 de Maio.

Geographic area: Os concelhos de Esposende, Barcelos, Braga, Vila Verde, Amares e Terras de Bouro.

Subregion Lima:

Legislation: Decreto-Lei n.º 263/99, de 14 Julho, alterado pelo Decreto-Lei n.º 449/99, de 4 de Novembro e pelo Decreto-Lei n.º 93/2006, Portaria n.º 28/2001, de 16 de Janeiro, alterada pela Portaria n.º 291//2009, de 23 de Março, Decreto-Lei n.º 212/2004, de 23 de Agosto e Reg. (CE) 1493/99 de 17 de Maio.

Geographic area: Os concelhos de Arcos de Valdevez, Ponte da Barca, Ponte de Lima e Viana do Castelo.

Subregion Monção e Melgaço:

Legislation: Decreto-Lei n.º 263/99, de 14 Julho, alterado pelo Decreto-Lei n.º 449/99, de 4 de Novembro e pelo Decreto-Lei n.º 93/2006, Portaria n.º 28/2001, de 16 de Janeiro, alterada pela Portaria n.º 291//2009, de 23 de Março, Decreto-Lei n.º 212/2004, de 23 de Agosto e Reg. (CE) 1493/99 de 17 de Maio.

Geographic area: Os concelhos de Melgaço e Monção

Subregion Paiva

Legislation: Decreto-Lei n.º 263/99, de 14 Julho, alterado pelo Decreto-Lei n.º 449/99, de 4 de Novembro e pelo Decreto-Lei n.º 93/2006, Portaria n.º 28/2001, de 16 de Janeiro, alterada pela Portaria n.º 291//2009, de 23 de Março, Decreto-Lei n.º 212/2004, de 23 de Agosto e Reg. (CE) 1493/99 de 17 de Maio.

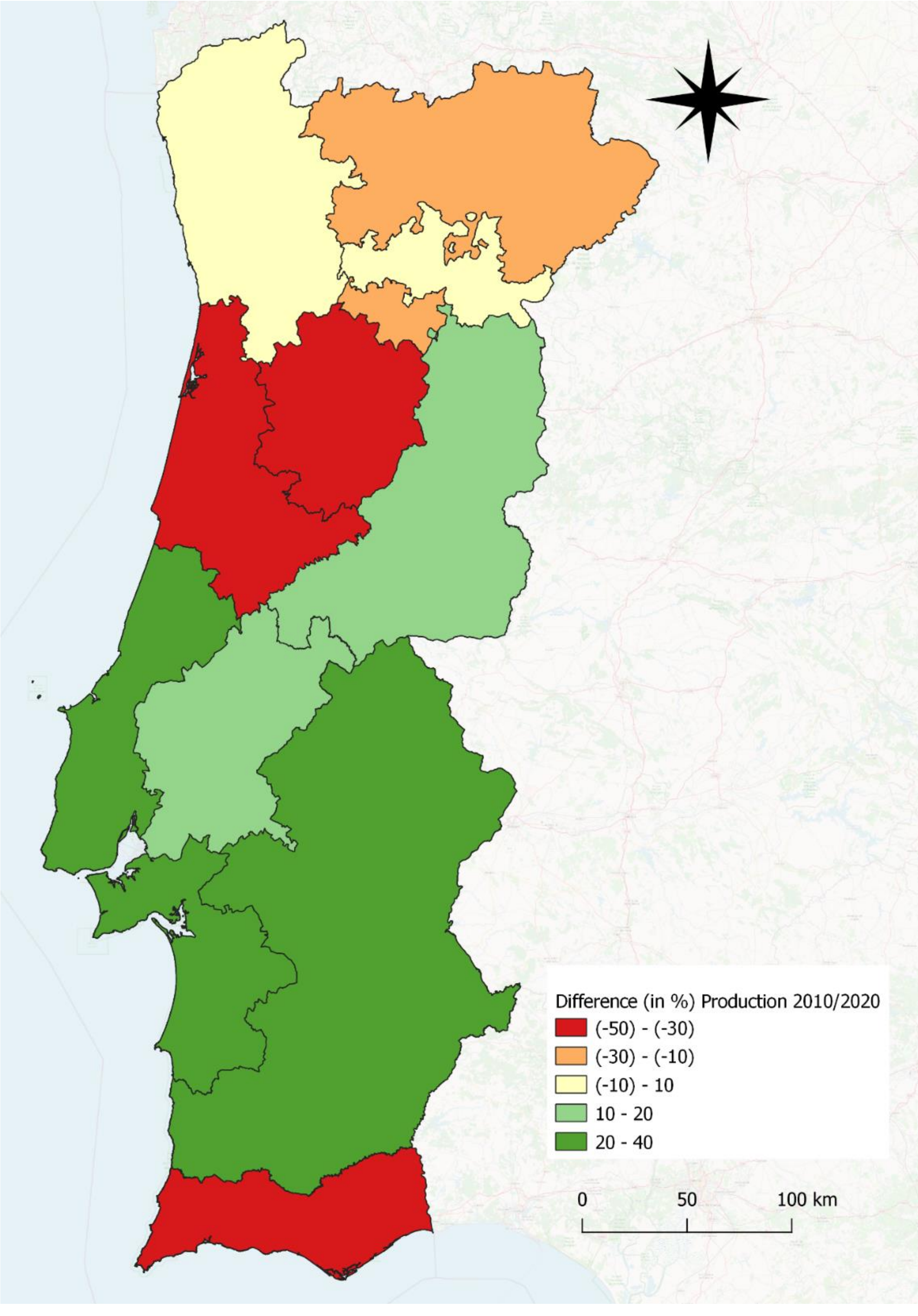
Geographic area: O concelho de Castelo de Paiva e as freguesias de Travanca e Souselo do concelho de Cinfães

Subregion Sousa

Legislation: Decreto-Lei n.º 263/99, de 14 Julho, alterado pelo Decreto-Lei n.º 449/99, de 4 de Novembro e pelo Decreto-Lei n.º 93/2006, Portaria n.º 28/2001, de 16 de Janeiro, alterada pela Portaria n.º 291//2009, de 23 de Março, Decreto-Lei n.º 212/2004, de 23 de Agosto e Reg. (CE) 1493/99 de 17 de Maio.

Geographic area: Os concelhos de Paços de Ferreira, Paredes, Lousada, Felgueiras, Penafiel e no concelho de Vizela as freguesias de Vizela (Santo Adrião) e Barrosas (Santa Eulália).

Annex 2: Percentual difference between grape production 2009/2010 and 2020/2021



Annex 3: Data Grape Production IVV (2021).

Evolução da Produção Total por Região Vitivinícola

Em Volume (hl)

Região Vitivinícola	2019/20	%	2018/19	%	2017/18	%	2016/17	%	2015/16	%	2014/15	%	2013/14	%	2012/13	%	2011/12	%	2010/11	%	2009/10	%
Minho	816,396	13	759,757	13	967,067	14	736,430	12	874,491	12	693,026	11	793,417	13	655,253	10	823,341	15	912,176	13	866,985	15
T. Montes	118,014	2	50,670	1	85,430	1	76,549	1	112,407	2	107,886	2	96,615	2	108,615	2	102,005	2	119,367	2	110,614	2
Douro	1,692,188	26	1,259,683	21	1,448,874	22	1,337,201	22	1,612,670	23	1,407,006	23	1,516,925	24	1,346,152	21	1,329,423	24	1,660,408	23	1,351,949	23
Beira Atlântico	159,063	2	177,782	3	260,668	4	195,534	3	272,680	4	225,076	4	255,333	4	283,897	4	292,596	5	297,704	4	246,705	4
Terras do Dão	257,481	4	178,409	3	312,462	5	237,186	4	342,316	5	240,516	4	304,824	5	356,454	6	293,537	5	355,687	5	297,483	5
Terras da Beira	255,658	4	162,032	3	190,394	3	255,818	4	226,203	3	216,531	3	215,783	3	217,693	3	184,759	3	224,735	3	192,084	3
Terras de Cister	59,417	1	37,307	1	54,052	1	69,560	1	67,052	1	53,074	1	64,731	1	64,655	1	45,959	1	61,036	1	47,872	1
Tejo	615,736	9	635,514	10	648,441	10	551,300	9	611,183	9	577,889	9	500,807	8	641,789	10	382,276	7	630,548	9	544,935	9
Lisboa	987,009	15	1,170,068	19	1,225,840	18	998,804	17	1,202,711	17	894,780	14	885,742	14	1,097,712	17	826,666	15	1,204,098	17	962,323	16
P. Setúbal	503,579	8	472,197	8	525,049	8	463,035	8	504,129	7	502,824	8	407,853	7	517,797	8	308,857	5	431,696	6	379,371	6
Alentejo	996,290	15	1,092,617	18	954,910	14	1,050,439	17	1,152,184	16	1,222,733	20	1,127,910	18	970,124	15	969,832	17	1,189,719	17	810,338	14
Algarve	13,926	0.2	17,042	0.3	15,777	0.2	10,419	0.2	13,630	0.2	10,665	0.2	11,676	0.2	12,338	0.2	13,150	0.2	19,190	0.3	23,650	0.4
Sub-total continente	**6,474,757**	99	**6,013,078**	99	**6,661,245**	99	**5,982,274**	99	**6,991,655**	99	**6,152,005**	99	**6,181,615**	99	**6,272,479**	99	**5,572,402**	99	**7,106,363**	99	**5,834,310**	99
Madeira	38,559	1	34,880	1	42,773	1	33,849	1	45,747	1	40,825	1	43,136	1	49,637	1	38,769	1	36,782	1	45,449	1
Açores	13,246	0.2	13,285	0.2	5,034	0.1	5,845	0.1	10,404	0.1	12,926	0.2	6,595	0.1	4,991	0.1	11,192	0.2	4,783	0.1	13,754	0.2
Sub-total ilhas	**51,805**	1	**48,165**	1	**42,908**	1	**39,694**	1	**56,150**	1	**53,751**	1	**49,731**	1	**54,628**	1	**49,961**	1	**41,564**	1	**59,203**	1
Total Geral	6,526,562	100	6,061,243	100	6,736,772	100	6,021,968	100	7,047,805	100	6,205,756	100	6,231,347	100	6,327,107	100	5,622,363	100	7,147,927	100	5,893,513	100

País / Ano	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Δ 2018-2017	Δ 2018-2000
Estados Unidos	21.2	21.3	22.5	23.8	24.8	25.9	26.7	27.9	27.7	27.3	27.6	28.3	29.2	30.8	30.6	30.9	31.7	32.6	33.0	▲ 1.2%	▲ 55.7%
França	34.5	33.9	34.8	34.1	33.2	33.5	33.0	32.2	30.8	30.2	29.3	28.3	28.0	27.8	27.5	27.3	27.1	27.0	26.8	▼ -0.7%	▼ -22.3%
Itália	30.8	30.2	27.7	29.3	28.3	27.0	27.3	26.7	26.2	24.1	24.6	23.1	22.6	20.8	19.5	21.4	22.4	22.6	22.4	▼ -0.9%	▼ -27.3%
Alemanha	20.2	20.0	20.3	19.7	19.8	19.8	20.2	20.8	20.7	20.2	20.2	19.7	20.3	20.4	20.3	20.5	20.2	19.7	20.0	▲ 1.5%	▼ -0.7%
China	10.7	11.0	11.4	12.0	12.1	12.3	13.0	13.9	14.0	14.5	15.8	16.3	17.1	16.5	15.5	16.2	17.3	19.3	18.0	▼ -6.7%	▲ 68.3%
Reino Unido	9.7	10.3	11.2	11.6	12.7	13.1	12.7	13.7	13.5	12.7	12.9	12.9	12.8	12.7	12.6	12.7	12.9	12.7	12.4	▼ -2.4%	▲ 27.9%
Espanha	14.0	14.2	14.0	13.8	13.9	13.7	13.5	13.1	12.2	11.3	10.9	10.0	9.9	9.8	9.8	9.8	9.9	10.5	10.7	▲ 1.9%	▼ -23.8%
Argentina	12.5	12.0	12.0	12.3	11.1	11.0	11.1	11.2	10.7	10.3	9.8	9.8	10.1	10.4	9.9	10.3	9.4	8.9	8.4	▼ -5.6%	▼ -32.8%
Federação Russa	4.7	6.1	6.4	8.7	9.2	9.8	11.3	12.7	11.8	10.4	12.2	12.2	11.3	10.4	9.6	9.2	9.1	11.1	11.9	▲ 7.2%	▲ 153.2%
Austrália	3.9	4.0	4.0	4.2	4.4	4.5	4.6	4.9	4.9	5.1	5.4	5.3	5.4	5.4	5.4	5.5	5.4	5.9	6.3	▲ 6.8%	▲ 61.6%
Portugal	**4.6**	**4.7**	**4.7**	**5.3**	**4.9**	**4.9**	**4.8**	**4.5**	**4.5**	**4.5**	**4.7**	**4.7**	**5.0**	**4.2**	**4.3**	**4.8**	**4.7**	**5.2**	**5.5**	▲ 5.8%	▲ 19.7%
Canadá	2.8	2.8	2.9	3.4	3.6	3.7	4.0	4.0	4.0	4.1	4.3	5.0	5.0	4.9	4.6	4.8	5.0	5.0	4.9	▼ -2.0%	▲ 77.8%
África do Sul	3.9	3.9	3.9	3.5	3.5	3.4	3.4	3.6	3.6	3.4	3.5	3.5	3.6	3.7	4.0	4.3	4.4	4.5	4.3	▼ -4.4%	▲ 10.5%
Roménia	5.2	4.7	5.0	5.1	5.8	2.4	5.5	5.5	5.4	4.0	1.6	4.1	4.3	4.6	4.7	4.0	3.8	4.1	4.5	▲ 9.8%	▼ -13.7%
Grécia	2.9	2.9	2.5	3.1	3.3	3.6	3.2	3.3	3.2	3.0	3.2	2.9	3.1	3.0	2.6	2.4	2.3	2.3	2.1	▼ -8.7%	▼ -26.6%
Outros	44.5	46.0	46.9	47.1	48.4	50.3	52.7	57.1	57.7	57.8	56.0	56.7	55.9	56.6	57.1	54.9	54.4	55.3	54.8	▼ -0.9%	▲ 23.1%
Total	226	228	230	237	239	239	247	255	251	243	242	243	244	242	238	239	240	247	246	▼ -0.3%	▲ 8.8%

País / Ano	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Estados Unidos	9.4%	9.3%	9.8%	10.0%	10.4%	10.8%	10.8%	10.9%	11.0%	11.2%	11.4%	11.7%	12.0%	12.7%	12.9%	12.9%	13.2%	13.2%	13.4%
França	15.3%	14.9%	15.1%	14.4%	13.9%	14.0%	13.4%	12.6%	12.3%	12.4%	12.1%	11.7%	11.5%	11.5%	11.6%	11.4%	11.3%	10.9%	10.9%
Itália	13.6%	13.2%	12.0%	12.4%	11.8%	11.3%	11.1%	10.5%	10.4%	9.9%	10.2%	9.5%	9.3%	8.6%	8.2%	9.0%	9.3%	9.2%	9.1%
Alemanha	8.9%	8.8%	8.8%	8.3%	8.3%	8.3%	8.2%	8.1%	8.3%	8.3%	8.3%	8.1%	8.3%	8.4%	8.5%	8.6%	8.4%	8.0%	8.1%
China	4.7%	4.8%	4.9%	5.1%	5.1%	5.1%	5.3%	5.4%	5.6%	6.0%	6.5%	6.7%	7.0%	6.8%	6.5%	6.8%	7.2%	7.8%	7.3%
Reino Unido	4.3%	4.5%	4.9%	4.9%	5.3%	5.5%	5.1%	5.4%	5.4%	5.2%	5.3%	5.3%	5.3%	5.2%	5.3%	5.3%	5.4%	5.1%	5.0%
Espanha	6.2%	6.2%	6.1%	5.8%	5.8%	5.7%	5.5%	5.1%	4.8%	4.6%	4.5%	4.1%	4.1%	4.0%	4.1%	4.1%	4.1%	4.3%	4.3%
Argentina	5.5%	5.3%	5.2%	5.2%	4.6%	4.6%	4.5%	4.4%	4.3%	4.3%	4.0%	4.0%	4.1%	4.3%	4.2%	4.3%	3.9%	3.6%	3.4%
Federação Russa	2.1%	2.7%	2.8%	3.7%	3.8%	4.1%	4.6%	5.0%	4.7%	4.3%	5.0%	5.0%	4.6%	4.3%	4.0%	3.8%	3.8%	4.5%	4.8%
Austrália	1.7%	1.7%	1.7%	1.8%	1.8%	1.9%	1.8%	1.9%	2.0%	2.1%	2.2%	2.2%	2.2%	2.2%	2.3%	2.3%	2.3%	2.4%	2.6%
Portugal	**2.0%**	**2.1%**	**2.0%**	**2.2%**	**2.1%**	**2.1%**	**1.9%**	**1.8%**	**1.8%**	**1.9%**	**1.9%**	**1.9%**	**2.1%**	**1.7%**	**1.8%**	**2.0%**	**2.0%**	**2.1%**	**2.2%**
Canadá	1.2%	1.2%	1.3%	1.5%	1.5%	1.6%	1.6%	1.6%	1.6%	1.7%	1.8%	2.1%	2.1%	2.0%	1.9%	2.0%	2.1%	2.0%	2.0%
África do Sul	1.7%	1.7%	1.7%	1.5%	1.5%	1.4%	1.4%	1.4%	1.4%	1.4%	1.4%	1.4%	1.5%	1.5%	1.7%	1.8%	1.8%	1.8%	1.7%
Roménia	2.3%	2.1%	2.2%	2.1%	2.4%	1.0%	2.2%	2.2%	2.2%	1.7%	0.7%	1.7%	1.8%	1.9%	2.0%	1.7%	1.6%	1.7%	1.8%
Grécia	1.3%	1.3%	1.1%	1.3%	1.4%	1.5%	1.3%	1.3%	1.3%	1.2%	1.3%	1.2%	1.3%	1.2%	1.1%	1.0%	1.0%	0.9%	0.9%
Outros	19.7%	20.2%	20.4%	19.9%	20.2%	21.1%	21.3%	22.4%	23.0%	23.8%	23.2%	23.4%	22.9%	23.4%	24.0%	23.0%	22.7%	22.4%	22.3%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

2021

Cornelis van Varik

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