Impacts of the drought in Southern Europe on the German grape juice industry in 2017/2018

A case study

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1 Scope and Relevance

This case study analyses the impacts of the global climate change on grape juice production in Germany. The focus lies on European countries of origin, especially Italy – since most grapes for grape juice production in Germany are imported from there.

This case does not cover the consequences of climate change for wine production – although many aspects covered here are relevant for both wine and grape juice.

Although the fruit juice market in general and the grape juice market in particular are – at least from an economic perspective – not amongst the most relevant sectors of the German economy, there are several reasons why this sector was chosen for this case study. One main reason is that there was a key event (in 2017) illustrating how extreme weather conditions in the land of cultivation of an agricultural product can lead to rising prices for the “end-product” in Germany. Moreover, the value chain of grape juice is relatively simple, making it easier to identify relevant climate factors and to comprehend cause and effect relations. The analysis of this case thus helps to draw conclusions that can be transferred to other agricultural products.

1.1 History of the vine

The products of wine and grape juice are very different in many aspects – nevertheless, they rely on the same resource: the vine. Vines were first cultivated about four thousand years BC, South of the Caucasus and the Caspian Sea (VdF n. d.). Two millennia later, the vine arrived in Ancient Greece, where a wine culture evolved, which was continued by the Romans. Winemaking has been the most popular use of the vine ever since: The Romans brought viticulture to the areas conquered by them: Bourgogne, Bordeaux, Alsace, Rhine and Mosel. From the first century AD, wine was distributed all over the area that is now Germany. When the Roman Empire ended, the Catholic Church cultivated wine for about 1000 years – the most important wine experts were monastery winemakers (VdF n. d.). Today, wine is popular around the globe and especially in Europe. In most European countries, more than 3 litres of wine were consumed per person and year in 2014 (Ritchie and Roser 2018).

In contrast, grape juice has a much shorter history than wine. For a long time, it was unknown how to prevent the wine from fermenting, a process which starts quickly after pressing the juice. It took until the 1960s when Louis Pasteur invented pasteurization, which is a short-term heating of the grape juice that destroys the microorganisms responsible for the fermentation. Thereby, the juice can be preserved and an alternative to wine without alcohol was created (Verband der deutschen Fruchtsaft-Industrie e.V. 2013).

2 Overview on the Sector and the Supply Chain

2.1 The Fruit Juice Industry in Germany

In Germany, there are about 360 fruit juice producers, out of which 96 % are organized in the German Association of the Fruit Juice Industry (VdF).[1] The VdF is the federal association of fruit juice/nectar and vegetable juice/nectar producers in Germany (VdF 2019). There are about 7,500 employees in this industry, and the yearly turnover is about 3.53 billion EUR. With regard to the entire German industry,[2] this corresponds to about 0.0002 % of the turnover (Deutschland in Zahlen 2019). Imports of the German fruit juice industry amount to 1.62 billion EUR and exceed the exports, which amount to 1.21 billion EUR. Both constitute less than 0.002 % of the entire German industry's imports and exports, respectively.

2.2 The Grape Juice Market in Germany

2.2.1 Relevance

Grape juice only has a share of 5% of the entire fruit juice consumption in Germany, with an annual production of about 203 million litres of grape juice[3]. Approximately 1.3 kg of grapes are needed to produce one litre of grape juice, meaning that approx. 263 thousand tonnes of grapes are needed each year by the German fruit juice industry. Regarding the worldwide exports of grape juice, Germany plays a rather small role since it contributes to the world market with only 2%. The countries importing grape juice from Germany are mainly the Netherlands (24%), France (22%) and Belarus (9%) (Simoes 2017a).

Despite this rather small market share, the analysis of grape juice remains highly relevant for a number of reasons. Firstly, the reliance of grape juice on agricultural production abroad and subsequent vulnerability to the impacts of climate change provides significant insight into the effects of climate change on agriculture and production. Products with a reliance on crop yield might be affected from comparable impacts of climate change, which create similar patterns of vulnerability. Secondly, in contrast to other products, e.g. industrial goods, the value chain of grape juice is rather straightforward (see below), data is readily available, and the impacts of climate change are clearly visible. Thirdly, raw material generally accounts for more than 50% of the cost in fruit juice production. Therefore, an increase in prices has an immediate effect on the prices paid by – often price-conscious – consumers (CBI Ministry of Foreign Affairs 2018b). In 2017, the decrease in grape yield has even forced a German grape juice producer to adapt by increasing prices, and thus, caused an impact for consumers (beckers bester GmbH 2018). Fourthly, German fruit juice consumption is higher than in many other European countries and the US (VdF 2019). Lastly, the consumption of grape juice has also increased, as explained below. Its yearly turnover amounts to 395 million EUR in 2019 and is expected to rise by about 3% per year up to 438 million EUR in 2023 (statista 2019).

[1] This corresponds to about 96%, which is why in the following, information by the VdF is taken as a proxy for the entire industry.

[2] The term industry refers to mining, processing trade, energy generation and utility networks. Statistisches Bundesamt 2019, retrieved from: https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Industrie-Verarbeitendes-Gewerbe/_inhalt.html#sprg232662.

[3] Own calculations based on VdF 2019

2.2.2 Imports and Exports

When looking at trade flows of both raw grapes and processed grape juice, Germany's imports exceed the exports by far (import: 85% and export: 15%). Germany imports 7.8% of grapes worldwide (3rd largest importer after US and UK), corresponding to a value of 736 million EUR, with a growth rate of 3% per year (Simoes 2017b; International Trade Centre 2019b). Not only grapes, but also grape juice is imported, with a value of 66.5 million EUR, which equals to only a tenth of the grapes imported. About 95% of the grape juice produced in Germany is imported as juice and not as fresh fruit (Kumpf 2019; Koeppel 10/16/2019). Therefore, it can be assumed that a vast majority of the grapes imported are sold as fresh fruit and not further processed. Thus, we focus on grape juice (as opposed to grapes) in our analysis.

According to the TradeMap database, about three quarters of Germany's grape juice imports (Brix value <= 30) have their origin in Italy followed by Spain (17%) and Austria (10%) (Simoes 2017b) (International Trade Centre 2019a). More than half of Italy's grape juice exports go to Germany. Globally, Italy contributes to 20% of the trade, with Spain being the largest exporter of grape juice (27%) (Simoes 2017c). Within the past years, Italy's grape juice exports to the world have slightly, but continuously grown, in parallel to Germany's imports from the world. In contrast, the share of Italy's grape juice exports going to Germany has decreased by about 30%[4]. However, as can be seen in Figure 1, the total area and yield of grapes in Italy has decreased continuously during the past 20 years.

Research within individual companies on the provenience of their grapes gave limited results. Few grape juice producers indicate where their grapes come from exactly as there is - except for organic juices - no obligation to do so (Holzmüller 2013).

Eckes-Granini, one of the biggest corporations specializing on fruit juice production, indicates that their grapes originate from Italy, Spain and France (Eckes-Granini Deutschland GmbH 2017). Voelkel in turn communicates obtaining their grapes only from Italy (Voelkel 2019). Rapp provides information on where they obtain their grapes even with regard to different best-before dates, stating for all available best-before dates that the grapes grow in Apulia, Italy (Kumpf 2019). Other relevant companies such as Refresco, Riha-Wesergold and Valensina do not provide any information on the provenience of their grapes. `However, it can be assumed that most of the grapes that are used for grape juice production in Germany come from the Mediterranean, with a high percentage from Italy. This is supported by the fact that two thirds of the processed juice stems from Italy (see above). A possible reason for this focus could be that Italy is more adapted to mass production of grapes than e.g. France, which focusses more on quality and thus on the production of wine (Koeppel 10/16/2019).

[4]own calculations based on ITC 2019

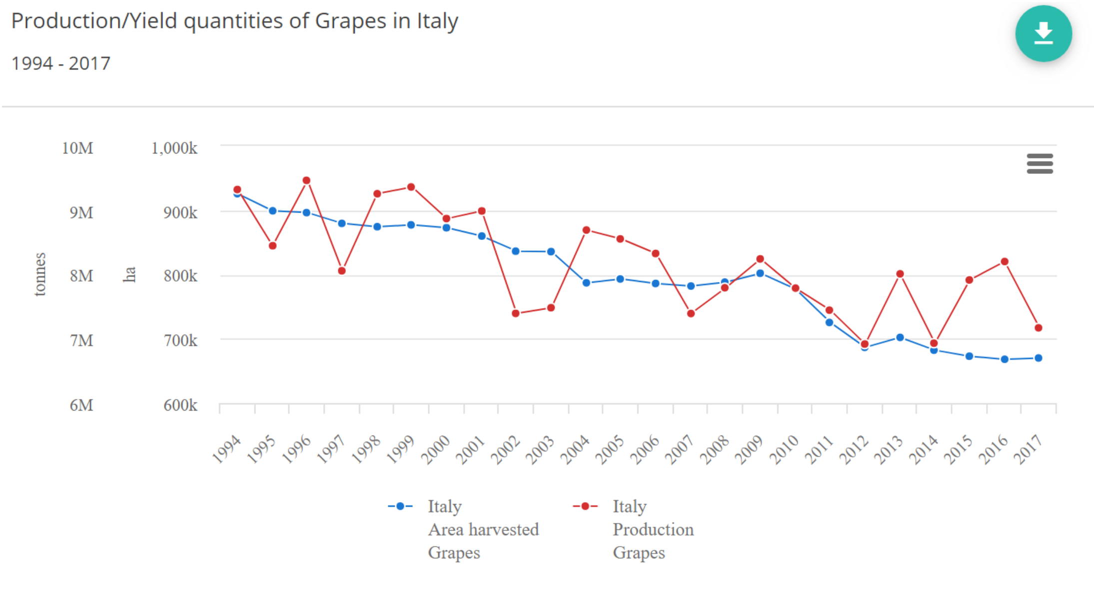

Figure 1: Production/Yield quantities of Grapes in Italy (FAOStat)

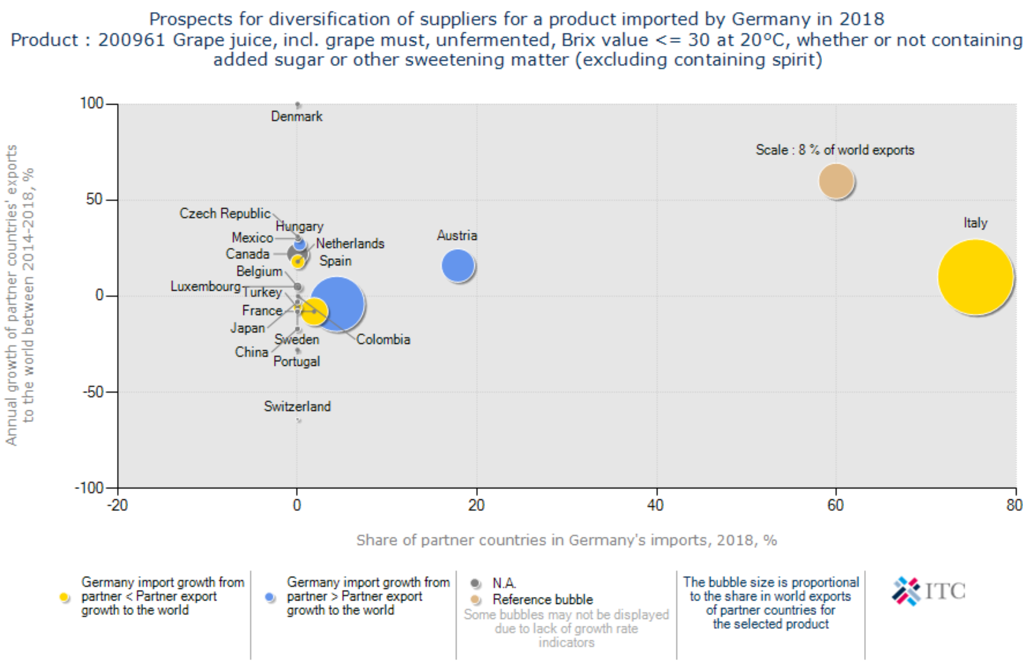

Figure 2: Prospects for diversification of suppliers for grape juice imported by Germany in 2018 (International Trade Centre 2019c)

Figure 2 shows that Italy has - by far - the highest market share in Germany's grape juice imports. Looking at the competitiveness of supplying countries (i.e. growth rates), Italy ranks in the middle, due to a lack of growth of Germany's imports, and a relatively low growth rate in Italy's world grape export (International Trade Centre 2019b). Austria ranks higher here, as well as Spain, which has a high growth rate regarding the trade with Germany (34% p. a.). A prospective diversification of suppliers is possible; however, Italy still has a very high market share.

2.2.3 Grape Juice Demand and Consumption

The VdF assumed a provisional value of 4 billion litres for the industrial production of fruit juice for the fiscal year of 2017. Compared with the US and many European countries, Germany shows by far the highest per-capita-consumption of fruit juices and nectars with about 32 litres per person and year (VdF 2019). Several sources state that the consumption of fruit juice has decreased in the past years (Stracke and Homann 2017).

Fruit juice sales are benefitting from the trend that consumers like to buy regional products – allowing especially small and medium-sized enterprises to position themselves successfully. They offer local fruit juice mixtures, meadow orchard apple juice and single-origin fruit juices (Deutsche Landwirtschafts-Gesellschaft 2014). Another view on this is that the fruit juice industry tries to reverse negative trends started by health concerns by focussing on sustainability and new formulations with exotic ingredients, e.g. by campaigns such as “Natürlich mit Saft” (CBI Ministry of Foreign Affairs 2018b).

The VdF itself acknowledged recently that **grape juice** is rather a niche fruit juice, since consumption is around 1-1.5 litres per person and year. Yet, it has risen from about 0.8 litres in 2014 to 1.5 litres in 2019 (VdF 2019; statista 2019). More popular fruit juices are apple and orange juice with a consumption of 7.6 and 7.4 l/year (2016).

2.2.4 The Corporate Landscape of Grape Juice Producers in Germany

The corporate landscape in Germany shows that about 45% of the total turnover is created by the 18 biggest fruit juice producers (Redaktion LZ 2018). Similarly, the VdF shows that 35% of the companies have a relatively low turnover with 0.26 million EUR or less, and 8 “big players” have a turnover of >100 million EUR, contributing to 75% of the total turnover. This means that there is a large number of individual companies with low significance and some major companies dominating the market. The biggest one is Eckes-Granini, followed by Refresco, Riha-Wesergold and Valensina (Redaktion LZ 2018). Looking at their distribution within Germany, the centre of Western Germany is most important regarding turnover, since 35% of the turnover is located in Rhineland-Westphalia and 29% in Rhineland-Palatinate/Saarland. The geographic distribution of the 15 biggest companies with regard to turnover can be seen in Figure 3.

Since a few years, juice producers, mineral springs and breweries are not separated as much as before. Several breweries and mineral springs now produce juices and soft drinks. Fruit juice producers also start to enter the market for soft drinks in order to stabilize their returns (Stracke and Homann 2017).

Another trend is the verticalization of big supermarket chains, i.e. the introduction of more and more store brands. This is aggravated by the new acquisition of Albi by the Edeka group. The supermarket chains reserve space for their store brands and have limited space for fruit juice producers. Koeppel assumes that in five years only half of the fruit juice brands available now will have survived (in an interview with Dünnebacke 2018).

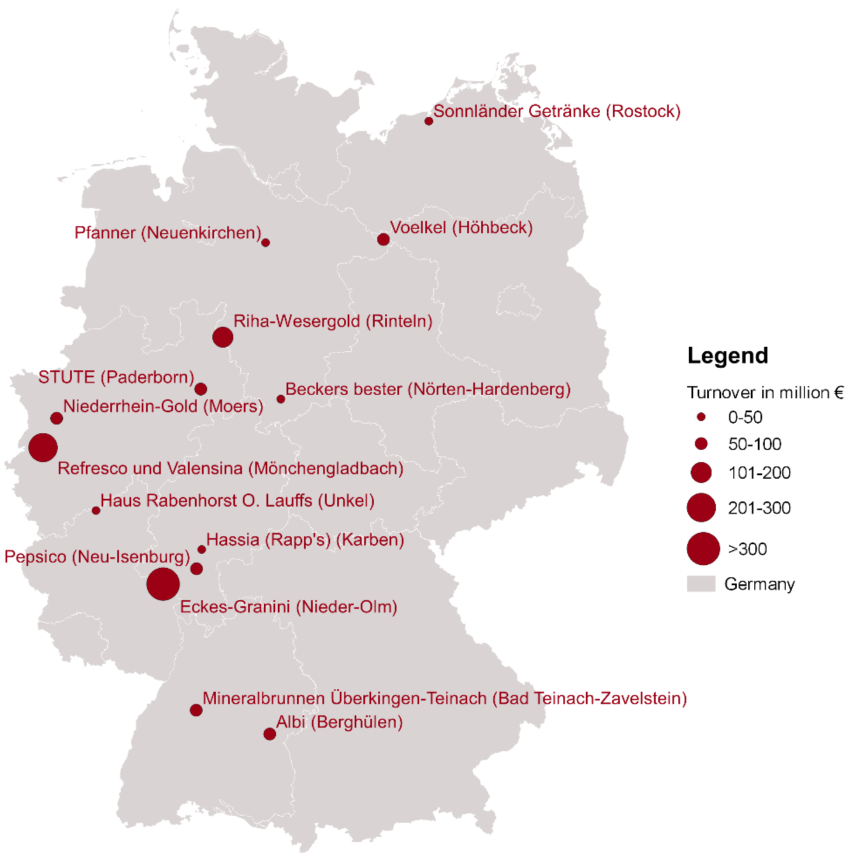

Figure 3: Distribution of fruit juice producers within Germany (Redaktion LZ 2018), map design by adelphi, basemap (modified): © GeoBasis-DE / BKG 2019, dl-de/by-2-0 online available at www.govdata.de/dl-de/by-2-0

2.3 Fruit Juice Supply Chains

2.3.1 Fruit Juice Types and Production

Within the production of different fruit juice types, an important distinction needs to be made between fruit juice, nectar and fruit juice drinks (Rabenhorst 2019). An overview on this can be found in Figure 4**Fehler! Verweisquelle konnte nicht gefunden werden.**.

Fruit juice can be categorized into direct juice and fruit juice from concentrate. Both of these products need to contain 100% of fruit, as specified by German law (Bundesministerium der Justiz und für Verbraucherschutz, Bundesamt für Justiz 2004). They are not allowed to contain preservatives or dyes, and a maximum of 15g of sugar.

A market research showed that a vast majority of **grape juices** on the market is direct juice and not made from concentrate. 18 direct juices were found on the market, whereas only one fruit juice from concentrate could be identified, which was a mixed juice (Amecke Eisen +), however. Fruit juice drinks are not common within grape juices, neither are nectars, of which only four could be found after an extensive internet search.

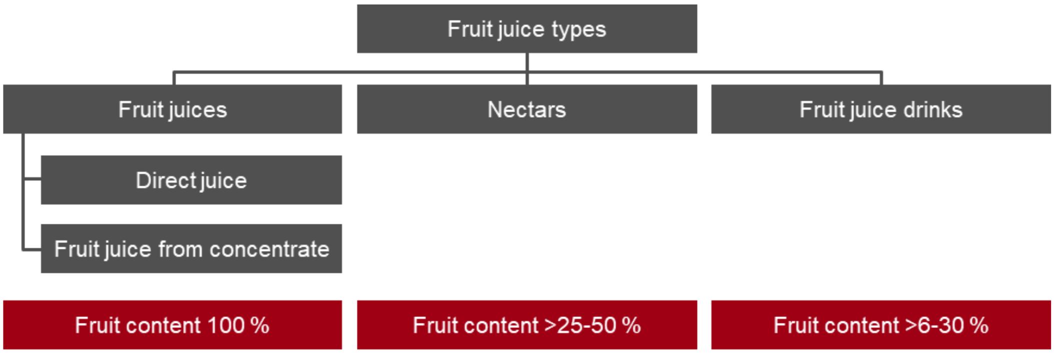

Figure 4: Fruit juice types (own graph adapted from VdF n. d.)

Direct juice is directly made from fruits, which are harvested, pressed, filtered, pasteurized and bottled (Maschkowski et al. 2019). Pasteurization helps to preserve the juice by heating it up. Afterwards, the juice is deep-frozen and shipped to the destination country, where it is defrosted. The juice needs to be pasteurized again before it can be bottled.

Water is extracted from fruits to generate **fruit juice from concentrate.** This technique is most known from oranges, which typically have a far way to travel – to save costs, the concentrates are produced in the country of origin and then shipped to Germany. Since it saves transport and storage costs, most fruit juices on the market are made from concentrate (Maschkowski et al. 2019).

Nectars and fruit juice drinks are allowed to be added with water, sugar, honey, aromas or acids. For nectar, the minimal percentage of fruit is between 25 and 50%, depending on the fruit - and 50% for fruit which is also suitable for direct juice, and thus, also grapes (Deutsche Landwirtschafts-Gesellschaft 2014). Fruit juice drinks are required to have a minimum of 6-30% (>30% for grape juice or stone fruits) fruit content (Deutsche Landwirtschafts-Gesellschaft 2014). A very common drink in Germany is spritzer ("Schorle"), which is a refreshing drink referring to a mixture of fruit juice with sparkling water. Spritzer is a special case and requires fruit juice made from 100% fruit (i.e. direct juice or fruit juice from concentrate) mixed with sparkling or still water.

A different kind of fruit products are **smoothies**, which are created from entire fruit, pulp and fruit puree, and added with fruit juice and have no fixed definition – they can contain sugar or be mixed (Maschkowski et al. 2019).

2.4 The Grape Juice Supply Chain

Grape juice can be produced from fresh grapes, grape must, concentrated grape must or concentrated grape juice (Vitipendium - Wissen über Rebe und Wein 2017). Grape must is the sweet liquid from freshly pressed grapes.

2.4.1 Cultivation

Grapes are the berries of vine (Vitis vinifera L.), belonging to soft fruit and to the family of vitaceae. Originally, the vine is one of the oldest culture plants of mankind, originating from the Southwest of Asia (Gesamtverband der Deutschen Versicherungswirtschaft e.V. 2019). Nowadays, it is disseminated as a cultural plant in about 16,000 species along suitable regions around the world. Grapes can be eaten as a raw fruit (table grapes), they can be dried into raisins or be processed into juice, spirit or wine (wine grapes) (CentroSan B. V. 2018).

To produce grape juice, no specific vines are required, but they have to be classified. Because of consumers' preferences for characteristics in colour, flavour and aroma, grape juice is primarily produced from American cultivars of *Vitis labrusca* species (Cosme et al. 2018).

Grapes are cultivated on open land as well as in greenhouses or tunnel-grown with the usage of plastic sheets. Greenhouse and tunnel-grown grapes enable the prolongation of harvest times (TIS 2019). To balance yield with vigour, vines should be pruned soon after leaf fall and together with moderate applications of fertilizers and water (Ryugo 1988).

A commercial distinction is made between wine grapes and table grapes (CBI Ministry of Foreign Affairs 2018a). Table grapes have a thinner skin, are larger in size and taste less sweet than wine grapes. In fresh trade, mostly table grapes are on the market for raw consumption. Grape juice is also mainly made from table grapes (Pigott 2014).

An overview of the following supply chain steps can be found in Figure 55:

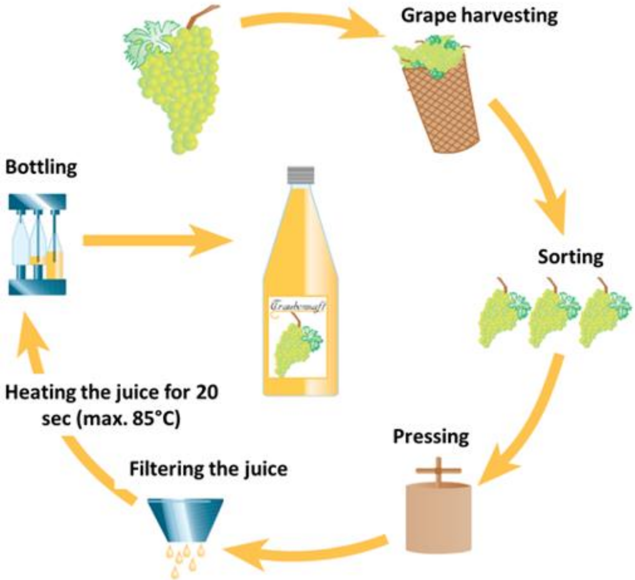

Figure 5: Overview of the supply chain for grape juice (illustration by VdF n.d., translated by adelphi).

2.4.2 Harvesting

Table grapes are carefully cut per hand and single sick or damaged grapes are removed (Gesamtverband der Deutschen Versicherungswirtschaft e.V. 2019). They are harvested fully ripe (late vintage, climacteric), i.e. in the menopause, since they mature badly when harvested in the premenopausal period. The harvesting date is defined by the Brix value. The Brix value is a measure of density and an approximation for the sugar content. The sugar content increases with time if the leaves are intact, acid is reduced, and the quality of the juice rises with every day (Pfeiffer 1997). Grapes are typically harvested between mid-September and end of October (VdF n. d.).

2.4.3 Sorting and Pressing

Grapes are separated from their stem with a destemming machine and grinded. The result is then heated to about 50°C for red grapes, where the skin will transfer some of its red colour.

The first fresh grape juice is then collected in big draining tanks without any pressing. This already provides 70% of the end product. With the help of big presses, the remaining juice is extracted. The result is the “mash”, i.e. pressed grapes: A mixture between pulp, skin and cores. This mashing often already happens in the vineyard since the fermentation can already start on the way to the fruit juice producer (Thönges 1996). These processing steps are typically done on-site.

When producing wine, after pressing, SO_2 and yeast are added to help the fermentation process of the grape must. The yeast produces alcohol, CO_2 and aromas from the different sugars in the grape must (Rütschlin 2009). SO_2 helps to protect against oxidation and microorganisms. Since SO_2 is not added when producing grape juice, the lack of protection needs to be outweighed by a rapid processing. Moreover, only healthy grapes can be used since damaged grapes enhance enzyme activity and increase acid content (GFDK Gesellschaft für digitale Kaufberatung mbH n. d.).

2.4.4 Further processing

The clearing of the juice happens through centrifugal skidding, where the trub (= coarse substances) is removed, and through subsequent filtering, which removes suspended matter (= fine substances). As a next step, the juice is heated to about 80-85°C for only 20 seconds to pasteurize it, i.e. to hinder the fermentation (VdF n. d.). Finally, the juice is usually stored in high-grade steel tanks or directly bottled.

The grape juice is transported to Germany by making use of tank vehicles. This is of economic and ecological advantage, since the space is more efficiently used: Shells are removed before transporting and no “air” is transported between grapes. Furthermore, additional ripening during transport can be prevented like this (Koeppel 10/16/2019). The German fruit juice producer beckers bester buys the grapes like this, in the form of juice. Due to the high degree of specialization of the grape juice producers, more specific knowledge is required for grape production than for e.g. apples. Furthermore, the capacities for pressing are much higher (e.g. cooperatives or sharing of machines etc.) (Koeppel 10/16/2019).

Bottling, screw connection and labelling works fully automatically. Up to 20.000 l/h can be bottled (VdF n. d.). At beckers bester, bottling works in blends, i.e. grapes from different harvest dates are mixed together in order to achieve a stable quality and taste throughout the year. This is because the grapes taste differently depending on their harvest date – when harvested in the beginning of the season, they are sour. The riper they get, the sweeter is the taste. Some small juice producers in turn do not use blends but make different tastes throughout the year (Koeppel 10/16/2019).

3 Relevance of Extreme Weather and Impacts of Climate Change for the Grape Juice Sector

In this chapter we will first show the impacts of weather and climate parameters on grape production in general (section 3.1) before focusing on the effect of climate change and extreme weather events (section 3.2). We will use the example of the drought in Southern Europe in 2017 to show the impacts of extreme weather on the grape juice sector.

3.1 Environment, Climate and Grapevine in General

The pollinated flowers of grapevines (genus *Vitis*) turn into grape berries – a fruit crop that has been consumed in a variety of ways over the centuries, for instance as wine, vinegar, jam, grape juice or as table grapes. Grapes are a natural product of their environment, and as such, their overall quality and characteristics are determined by multiple environmental factors. Their development is inextricably linked to the climatic conditions in which they grow, making the impacts of climate change a highly relevant issue for sectors such as viticulture, winemaking and grape juice production. Climate change has the potential to strongly affect the growing conditions for grapevines, with negative implications for both yield and quality of the grapes in some regions of the world (van Leuween & Darriet, 2016). Understanding these implications is important since grapes are an economically and culturally important fruit crop.

The suitability of a region to cultivate grapes largely depends on its climate, which is argued to be the "most critical aspect in ripening fruit to optimum characteristics" (Jones et al., 2012). Grapes can be grown in various climates and *Vitis varieties* are located in both the Northern and Southern Hemisphere, though predominantly "between the 35th and the 50th parallels […] and between the 30th and the 45th parallels" respectively (van Leuween & Darriet, 2016: 151). The weather and climate of these regions is particularly suitable to the agricultural production of grapes, as the mean climatic conditions of the different areas within these regions favour the production of popular grapes cultivars, such as Chardonnay, Merlot, Pinot Noir or Riesling (van Leuween & Darriet, 2016; Doughtery, 2012). While many grape varieties are cultivated within the same regional climate, their respective site-specific climate might differ, thereby creating fine nuances in the overall composition of the grapes (see Jones et al., 2012).

Grape ripening and fruit quality are linked to a range of climate parameters, most notably **average temperatures, solar radiation, atmospheric pressure and wind, precipitation, humidity as well as water balance** (Jones et al., 2012). The amount of solar radiation (insolation) determines the rate of photosynthesis and overall development of the grape berries (Jones, 2015). Average temperatures have a major influence on the annual growth cycles of grapevines (i.e. vine phenology); including the length of growing seasons as well as the stages at which "bud break, flowering, and véraison (onset of ripening) occur" (van Leuween & Darriet, 2016: 151). Sugar and acidity levels are also driven by temperatures, with higher temperatures causing an increase in sugar accumulation and a decrease in grape acidity (van Leuween & Darriet, 2016). Thus, average temperatures define the general suitability of grape production, and strongly affect grape ripening as well as fruit quality (Jones, 2015).

Water is essential for the development of grapevines, and the water status of the vines depends on climate characteristics, such as local precipitation patterns, humidity, evapotranspiration, as well as the water-holding capacity of the soil (Jones et al., 2012). Adequate water availability is necessary for photosynthesis, drives vine growth and affects berry bloom, size and yield (van Leuween & Darriet, 2016; Williams, 2000). Though many *Vitis* species have a considerable tolerance to droughts and a certain degree of water deficit conditions can even be desirable, e.g. for high quality red wine, excessive water stress can cause losses in yield and overall quality of the grapes (van Leuween et al., 2009).

3.2 Impacts of Climate Change and Extreme Weather Events on Grape Production with a Special Emphasis on Italy 2017

In the past 10-15 years, 2017 was a unique year regarding the climate effects on grape production in Southern Europe (Koeppel 10/16/2019). However, other years have also affected grape harvests and challenged their adaptation possibilities, such as 2003's harvest in France (Carbonneau 2004).

According to a survey amongst more than 1100 winemakers conducted by Loose and Pabst (2019) almost all small wineries experienced effects of climate change in their company over the last 5 years. Most common effects were reduced yields due to extreme weather events such as late frost, heavy rains or hail, increased volatility of grape yields and water scarcity - more than half of the surveyed grape and wine producers experienced these effects (Loose and Pabst 2019).

Globally, the year 2017 was the third hottest year on record (National Oceanic and Atmospheric Administration 2018). In Southwestern Europe, 2017 was a year of extremes – regarding both dry and wet conditions**.** Overall, an outstandingly low precipitation, dry soils and repeated fire events have been recorded, as well as a record-breaking high average temperature of 0.9°C above the 1981-2010 period. Soil moisture was observed to have the largest negative annual average in record (Copernicus Climate Change Service 2018).

Italy in particular showed a specific combination of weather events at different times of the year, which jointly led to an extraordinary low grape harvest. The immense yield loss was covered by various press articles (Dusi 2017; Mercer 2017) and a website of a German grape juice producer (beckers bester GmbH 2018). Table 1 provides an overview of weather conditions throughout the year 2017.

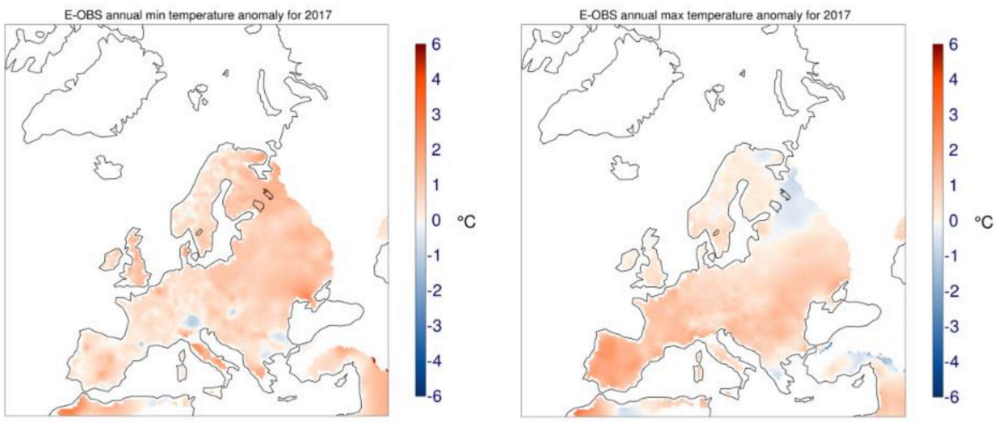

Figure 6: Map of anomalous annual averages of daily minimum and maximum temperature for 2017 relative to the period 1981-2010. Data source: E-OBS. Credit: Copernicus Climate Change Service/ECMWF/KNMI

Table 1: Weather conditions in Italy in 2017

Time	Event	Consequence
Winter	Drought	Reduced soil water-holding capacity, plants cannot draw on water in summer
Early months of the year/spring	High temperature anomaly	Acceleration of grape ripening, earlier harvest dates
Spring (end of April)	Frost and hail	Reduction of grape quantity
Summer (esp. July)	Drought and fires	Smaller or withered grapes (lower quantity)
August	7 heat waves, esp. „Lucifer“	Smaller or withered grapes (lower quantity)
August	Hail events	Damage to vines
From 15th August	Harvest	Earlier harvest dates to achieve as big harvest as possible

At first, winter was much drier than usual. Therefore, the soil's capacity to store water was considerably reduced (beckers bester GmbH 2018). As a consequence of these winter events, the change in water balance caused a water deficit for the plants during summer. In 2017, the harvest dates were even more influenced by the warm winter than by the summer temperatures (Dusi 2017).

In the early months of the year, a temperature anomaly of about +1-3°C occurred in Italy, as shown in Figure 7. This led to a faster ripening of the grapes, which provoked earlier harvest dates. Spring in overall Southwestern Europe was considered warmest or second warmest on record, with close to 1.7°C above the 1981-2010 average, as can be seen in figure 8 (Copernicus Climate Change Service 2018). 3BMeteo also acknowledges that the central phase of the winter was very mild, with a January anomaly of +2.4°C above the 1971-2000 period (Berlusconi 2018).

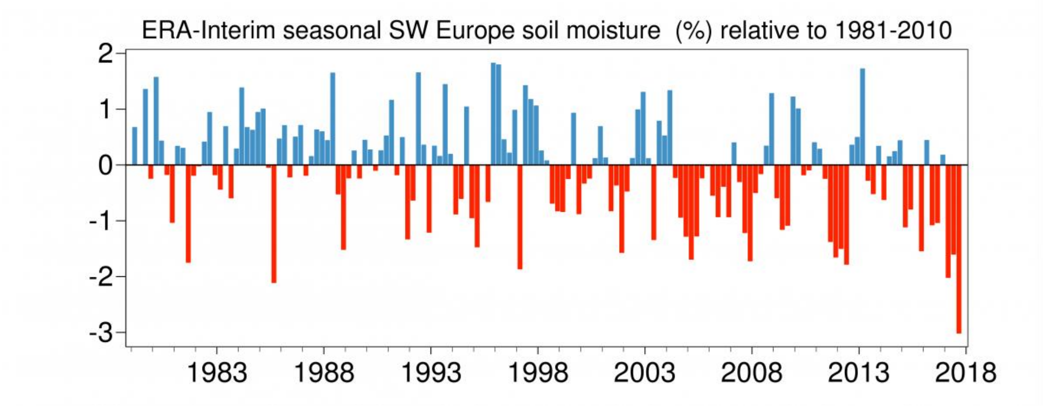

Figure 7: Seasonal soil moisture anomaly for southwest Europe for spring 1979 to autumn 2017 relative to the respective seasonal average for the period 1981-2010. Data source: ERA-Interim. Credit: Copernicus Climate Change Service/ECMWF

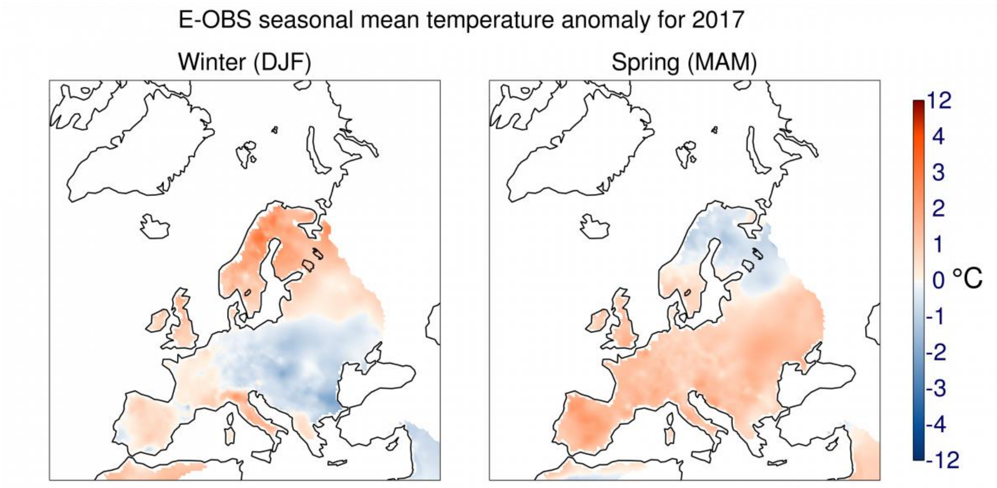

Figure 8: Surface air temperature anomaly for winter, spring, summer and autumn 2017 relative to the respective seasonal average for the period 1981-2010. Data source: E-OBS. Credit: Copernicus Climate Change Service/ECMWF/KNMI

At the end of April, “heavy hailstorms and hard frosts” (European Commission 2017) caused major damages. These were mainly caused by the early vegetation period, which is advanced due to global warming (Fondazione Edmund Mach di San Michele all'Adige 2017).

The 2017 summer in Italy was characterized by drought and heat. Data from the European Drought Observatory (EDO) makes use of the Combined Drought Indicator (CDI), which identifies areas with potential to suffer from agricultural drought, areas where vegetation is affected by drought and areas, which are in recovery after a drought episode (see Figure 9). The map shows that a large area of Italy suffered from a severe rainfall deficit – especially the areas on the Western side of the mountain range crossing the peninsula. A look at the soil moisture anomaly (soil water availability in 2017 compared to the long-term average) shows that especially Northern Italy was affected by a deficit of soil moisture in 2017 (Masante and Vogt, J., McCormick, N., Cammalleri, C., Magni, D., de Jager, A. 2017).

These long-lasting dry conditions, combined with high temperatures, also caused an increase in wildfire activity throughout entire Southwest Europe in 2017 (Copernicus Climate Change Service 2018).

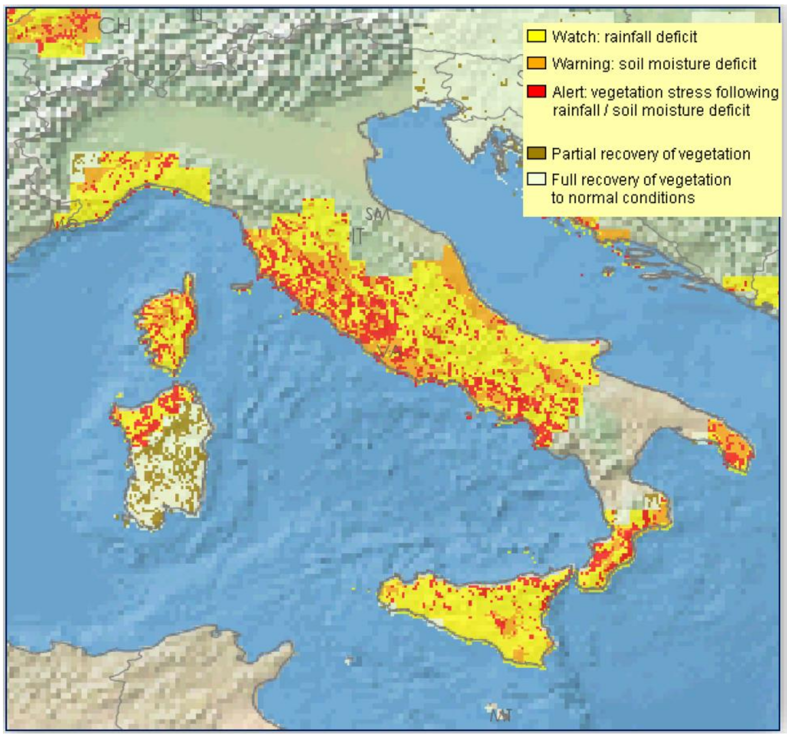

Figure 9: Combined Drought Indicator (CDI) for the first 10 days of July 2017 (Masante and Vogt, J., McCormick, N., Cammalleri, C., Magni, D., de Jager, A. 2017)

Winegrowers also had to deal with several heat waves during summer, especially heat wave "Lucifer" in August. In addition to the drought, the heat waves caused a withering of the grapes and a decreased crop yield. Lucifer affected large areas of Southern and Eastern Europe with temperatures of >35°C on 3rd of August 2017. In Spain, Croatia and Hungary temperature even climbed to >40°C (Smith 2017) and 11 countries issued "danger" warnings. In Italy, the maximum number of consecutive summer days exceeded the average for the climate-normal period of 1981-2010 by far (Copernicus Climate Change Service 2018).

In addition, many "large hail" events took place throughout August. The data from the European Severe Weather Database indicates that 45 hail events were reported only between 1st and 31st August 2017 in Northern Italy. To compare, in August 2018 there was no single hail event, in 2016, there were 10 and in 2015, only 4 large hail events took place during the month of August (European Severe Storms Laboratory 2019). For example, on 10 August 2017, a severe thunderstorm took place in Northern Italy, which injured 48 people and caused significant damage. It was named one of the 5 worst storms in the last 30 years by the Veneto Province (Blašković 2017). The number of hail events rose again in 2019. For example, on July 9 and 10, a violent hailstorm took place over parts of Italy, with hail in the size of oranges, injuring 18 people and causing considerable damage to cars and homes. Crops in Emilia-Romagna were severely damaged from Piacenza to Rimini (Blašković 2019).

Thus, the harvest date of grapes had to be advanced due to all these weather events described, which led to a boosting of sugar levels prompting early harvesting (Mileham 2017). Grape ripening was boosted due to higher spring temperatures and the heat in July – although the harvest was lower due to frost and hail, this led to a higher quality harvest and a lower vulnerability to fungal diseases (Mileham 2017).

In many Italian regions, grape harvest in 2017 was earlier than usual:

- Asti: 10 days earlier (Kleine Zeitung 2017).
- Lombardy:12 days earlier (Eads 2017)
- Spumante: 20 days earlier (Horowitz 2017)
- Piedmont: harvest in the last week of July (Petrini 2017)
- Sicily: three weeks earlier (Mileham 2017)
- Franciacorta: 10 days earlier (Mileham 2017).

The trend of advancing harvest dates can also be observed in other European regions. Cook and Wolkovich (2016) compare grape harvest dates in Switzerland and France from 1600 to 2007 (cf. figure 10). Researchers discovered harvests began shifting dramatically earlier during the latter half of the 20th century. These finding is important because higher-quality wines are typically associated with earlier harvest dates in cooler wine-growing regions, such as France and Switzerland (Michael Cabbage and Leslie McCarthy 2016).

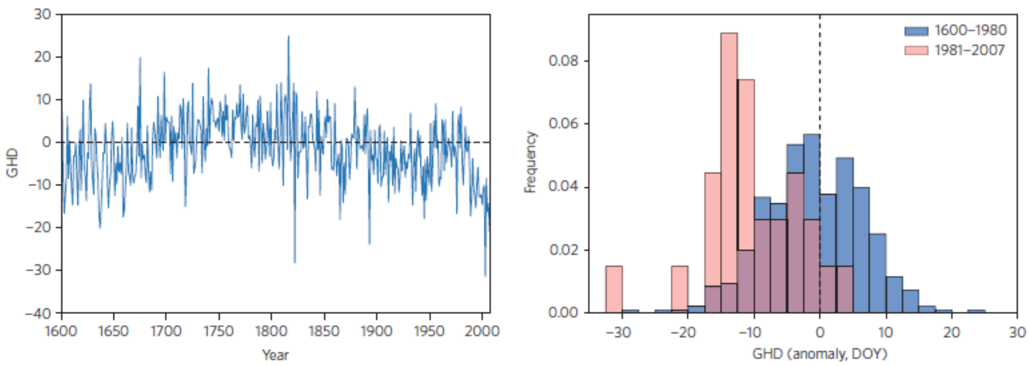

Figure 1 | Grape harvest date anomalies (GHD-Core). Left panel: time series of grape harvest date anomalies, composited from the Alsace, Bordeaux, Burgundy, Champagne 1, Languedoc (Lan), Lower Loire Valley (LLV), Southern Rhone Valley, and Switzerland at Lake Geneva regional harvest date time series in the Daux data set[4]. All anomalies are in units of day of year, calculated relative to the average date from 1600–1900. Right panel: normalized histograms of GHD-Core harvest date anomalies from 1600–1980 (blue) and 1981–2007 (red).

Figure 10: Grape harvest date anomalies (Cook and Wolkovich 2016)

3.2.1 Impact on Wine Production

In 2017, as a result of the worst global harvest since 1961, the worldwide wine production was reduced by 8%, compared to 2016 (Wood 2018). In the EU, wine production reached a historical low of 143 Mio Hectolitres (Mhl) (European Commission, Directorate General for Agriculture and Rural Development 2019).

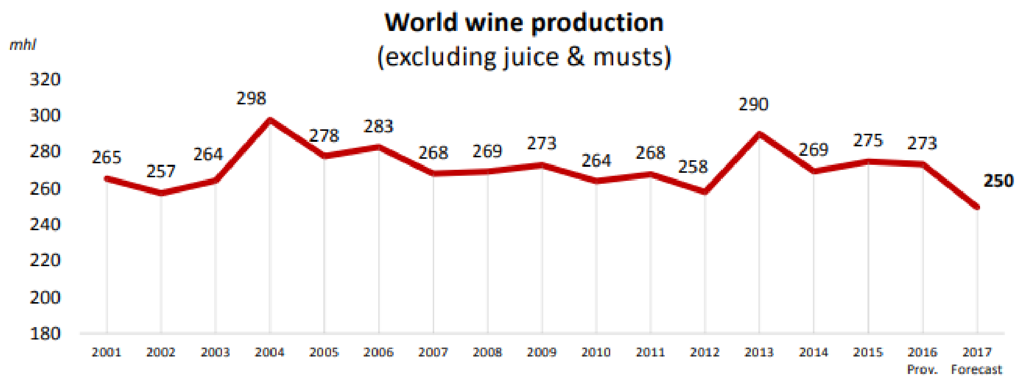

Figure 11: World wine production excluding juice and must (Organisation Internationale de la Vigne et du Vin 2017)

The EU Commission stated that in May 2018, the total wine production in Italy only reached a level of 42.5 Mhl in 2017/18, which equals a 17% lower production than in 2016/17 and a production of 14% below the 5-year average (European Commission, Directorate General for Agriculture and Rural Development 2018).[5] The International Organization of Vine and Wine (OIV) estimated a wine production of 39.3 Mhl and a yield reduction of 23% compared to 2016 (Organisation Internationale de la Vigne et du Vin 10/24/2017). This equals one of the smallest grape harvest yield in 60 years in Italy (Mercer 2017). In particular, Tuscany, Sicily, Puglia, Umbria and Abruzzo experienced a yield of at least 30% less than the year before; while in Northern Italy, harvests were about 15% lower than the previous year (Piedmont, Veneto, Friuli). Due to better weather conditions, crop yield increased again in the following years (cf. figure 12) (Teatro Naturale 2018; WineNews 2019).

[5] This includes self-consumption and the volume reduction determined by the production of concentrated musts.

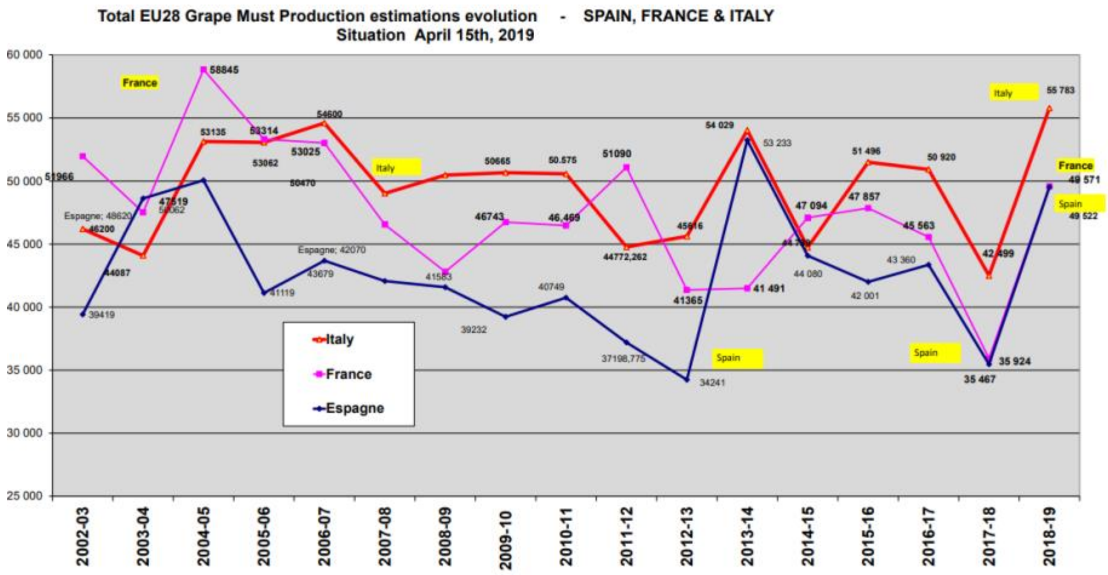

Figure 12: Total EU28 Grape Must Production estimations evolutions in Spain, France and Italy on April 15th, 2019 (European Commission, Directorate General for Agriculture and Rural Development 2019)

3.2.2 Impact on Grape Price

It has to be noted here that wine is usually prioritized among winemakers – grape producers often see themselves as winemakers and are proud of making (high-quality) wine. Furthermore, the price the winemakers can achieve for wine is much higher than the price for grape juice (Koeppel 10/16/2019). This leads to a lack of flexibility for the grape juice producers, since they often only get what is left, which might also not be the grapes of highest quality.

In mid-July 2017, the damage to Italian agriculture due to extreme weather events was already as high as 2 billion Euros (La Repubblica 2017). As a German grape juice producer states, the sale of grapes takes place in the following order: First, the raw grapes are sold to the fresh fruit market, then to wine production and the juice market is served last (beckers bester GmbH 2018). In 2017, the heavily reduced yield led to an increase of about 50% in the price of raw grapes.

The Italian grape market in general shows a high price for grapes, e.g. due to high costs for infrastructure and labour. In 2017, the consumer price per kilo was at about 4.50 EUR, while it is about 1.50 EUR to 2 EUR for the producer. When working under high temperatures, a greater number of labourers are necessary because the grapes must be harvested faster to minimize heat damages (Aguilera 2017). However, in May 2017, the price was similar to the one recorded at the same time the year before. Typically, it falls during the campaign (Aguilera 2017).

The director of the German Wine Institute (DWI), Monika Reule, stated that price increases were caused by the low harvest of 2017 in all European wine regions: in 2018, sales of wine in Germany decreased but turnover increased – thus, the value of wine rose according to the DWI by about 17 Cents per litre (Getränke News Omlor & Rademacher GbR 2019).

3.2.3 The case of beckers bester

beckers bester is a family-owned fruit juice business based in Northern Germany which also offers grape juice. In response to the bad harvest in 2017, the company increased its grape juice prices, accompanied by a marketing campaign and a promise to reduce the prices again.

This price increase originated from the winemakers, who had the same total costs but a lower quantity (Marks 2017). This led to higher costs per unit – the costs rose by about 12 to 60 cents per litre, which equals about 400.000 EUR additional costs per month (Dünnebacke 2018). More specifically, the price for conventional grape juice rose by 14-20 cents, whereas the price for organic products rose by more than 50 cents (Koeppel 10/16/2019). For apple juice, the situation was especially bad: There were weeks in which prices for "old" already processed and bottled juice in stores were lower than prices for "new" unprocessed apple juice. (Koeppel 10/16/2019). This shows that the price increase was passed on to the grape juice producers such as beckers bester, who then passed it on to the retailers and consumers (Koeppel 10/16/2019). The price increase was justified with the campaign „Trockene Ernte" (i.e. dry harvest, https://www.beckers-bester.de/lp/trockene-ernte/) as well as with hints on the packaging of the fruit juices (Koeppel 10/16/2019).Consumers reacted surprisingly positive: beckers bester received letters on a daily basis after the campaign – however, this only worked because of the promised price decrease (Koeppel 10/16/2019).

Regarding sales, 2017 was a very good year. The brand had been declining in the preceding 15 years and 2017 was the first year in which beckers bester grew again. However, it is not clear what triggered the increase in sales in 2017. It could be because of customers valuing the open communication but at that time, other changes like a new design and the drop out of a big competitor took place. Any of these factors or a combination of all could have triggered the increase in sales.

The Impact of Weather Extremes on Other Fruit Juices: The Example of Orange Juice Production and Hurricane Katrina

90% of the world's orange juice originated from the state of Sao Paulo, Brazil or from Florida, USA in 2009. This means that global orange juice production is highly vulnerable to weather conditions in these regions.

Hurricane Katrina in Florida thus had a severe impact on the price of oranges - it quadrupled between 2004 and 2007 (Braun and Pfeil 2009). Furthermore, Katrina and preceding hurricanes led to a spread of a bacterium, which is the causing agent of citrus canker. Citrus canker is a disease that leads to the wilting of citrus trees and an advanced falling of the fruit. In preceding years, the government of Florida took severe measures: All trees infected were burnt down – which led to a decrease in supply in the next years (Stanzl 2005).

This has also led to a larger dependence on Brazil - even the US had to import from Brazil after hurricane Katrina (Braun and Pfeil 2009). Nowadays, the entire world market depends mainly on Brazil. Furthermore, there are only three major corporations in the production of orange juice. This is problematic in many ways – also because of human rights issues in the working conditions (Wöstmann 2015).

Beckers bester promised that when the harvest got better, they would decrease the prices again (Koeppel 10/16/2019). Consequently, in January 2019, the price decreased again, as the price for the raw goods had decreased. This was also accompanied by a marketing campaign. This was done although it was already clear to the company that the prices would increase from January 2020 (Koeppel 10/16/2019). This increase is expected to trigger fewer positive reactions.

The price decrease by beckers bester could not be forced upon supermarket chains and thus consumers, since they are not allowed to oblige them to certain sales prices (Koeppel 10/16/2019). Therefore, beckers bester communicated the price decrease again through the packaging on which beckers bester thanking their customers and announcing a new harvest – this put pressure on the retailers to pass on the price decrease to consumers as well.

3.2.4 Outlook

A study on the heat wave in 2017 shows that the return period is about 20 years, while in 1950, the return period for such an extreme event was about 3000 years. This study showed that since the 1950s, the risk of such a heat wave has at least quintupled, but probably increased much more. (Kew et al. 2019). Therefore, it is worth to look at possible future trends of climate change and their impact on grape juice production.

4 How will Climate Change and Extreme Weather Events Affect the Sector in the Future?

A changing climate can have far-reaching implications for any agricultural system, as crop cultivation depends on suitable environmental and climatic conditions. Current and projected changes in temperatures, temperature extremes, precipitation patterns, humidity as well as more frequent and intense natural hazards are key challenges for grape growing. These impacts of climate change have the potential to affect both yield and quality of the grapes negatively (van Leuween & Darriet, 2016). Global warming is also causing a shift in suitable viticulture regions, with Northern regions becoming more suitable to the cultivation of grapes. The effects of climate change on the sector predominantly occur during grape cultivation since the processing or transportation stages are far less affected.

This chapter outlines several key projected impacts of climate change on grape cultivation, including the impacts of rising temperatures and water scarcity, diseases and extreme weather events. Yet, it remains difficult to predict exact impacts of climate change on grape growing in terms of biomass production, fruit development, and subsequent consequences for grape juice production.

4.1 Climate Change and Viticulture

Since grapes have been cultivated over the past centuries, several regions of the world have become firmly established as growing regions. Based on these historic developments, legal frameworks have been developed to delineate such growing regions. However, boundaries

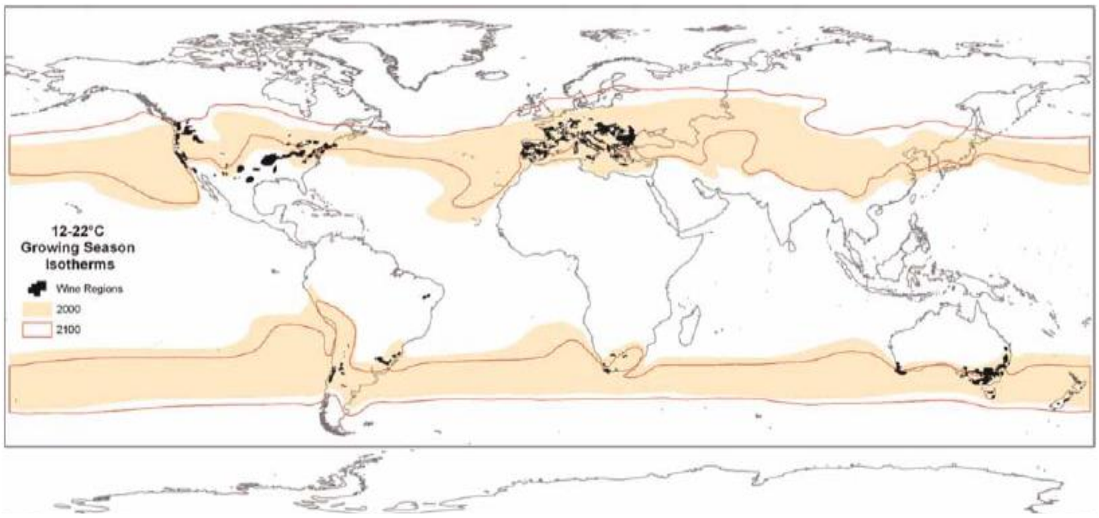

Figure 13: Latitudinal shifts in suitable viticulture regions (Schultz & Jones, 2010: 140).

for grape cultivation are beginning to shift and the geographic distribution of suitable viticulture regions is projected to change further due to global warming (Schultz & Jones, 2010). Figure 14 shows the current and projected regional suitability to cultivate grapes. While these shifts in regional suitability entail new opportunities to cultivate grapes in Northern regions, they also go along with changes in currently suitable viticulture regions.

Many of the currently well-established viticulture regions in (Southern) Europe are confronted with the impacts of climate change in terms of rising temperatures, changing water balance

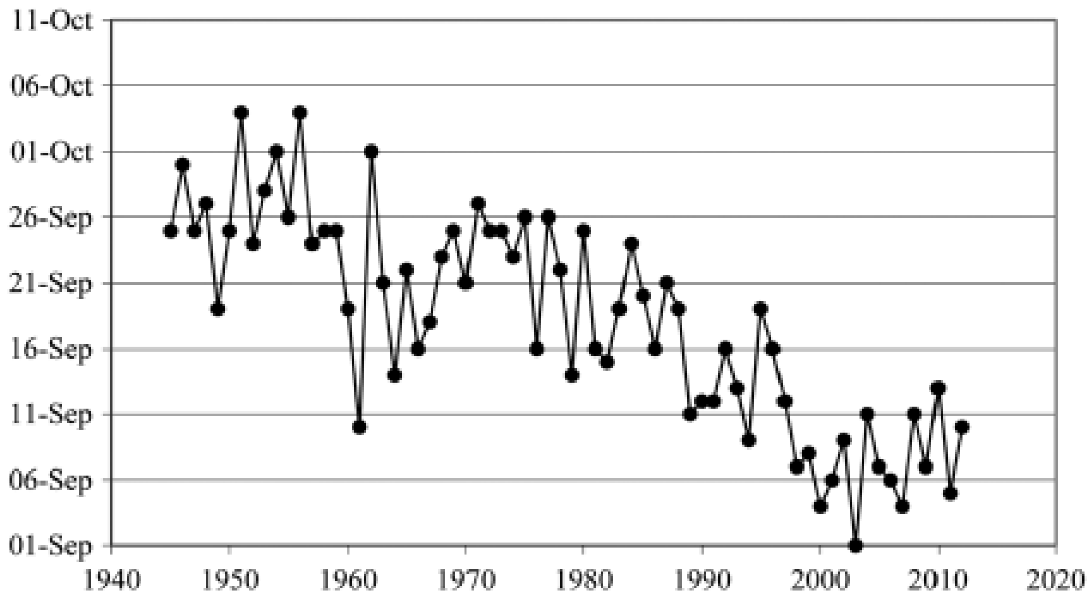

Figure 14: Harvest Dates in Châteauneuf du Pape from 1945 to 2012 (van Leuween & Darriet, 2016)

and extreme weather events, all of which can severely affect the harvest outputs. Grape ripening as well as fruit quality is strongly affected by temperature. Rising temperatures advance the phenological stages, causing an earlier onset of the flowering and ripening process (Jones et al., 2012). For instance, flowering is projected to advance by "15 days in the near future (2020-2050) and by 30 days at the end of the century" (van Leuween & Darriet, 2016: 155) in Bordeaux, France. According to Schultz and Jones (2010), the strong correlation between increasing temperatures and earlier grape harvest dates is most pronounced in higher latitudes, e.g. from Burgundy (France) to Rheingau (Germany). Figure 14 exemplifies the continuous advance of harvest dates in Châteauneuf du Pape, France – a trend that can be observed in other grape-growing regions as well. This shift in harvest dates has occurred at an unprecedented rate over the past 25 to 30 years, and is expected to further advance as global warming proceeds. The advancing harvest dates put pressure on growers – especially in regions where grapes are typically hand-picked – because the available time window to harvest becomes increasingly compressed (Loose and Pabst 2019).

Furthermore, changing precipitation patterns and increased evapotranspiration due to rising temperatures will expose most of the current wine-growing regions to increased water deficits (van Leuween & Darriet, 2016). Especially Mediterranean and other dry climates might experience "excessive water stress, which can lead to impaired photosynthesis and leaf necrosis" (van Leuween & Darriet, 2016: 161). Water deficits and summer dryness are likely to further increase across Southern Europe causing an overall decreased harvest yield. Extreme temperatures and water stress during summer are especially problematic after dry winter and spring periods because of the reduced soil water content, as was the case in 2017 (see above).

Another significant impact of climate change is the increased risk of extreme weather events. Especially heavy rainfall, hailstorms and extreme heat can all have detrimental effects on harvest yields. Hailstorms in particular have the potential to rapidly devastate entire vineyards. While the exact links between climate change and hailstorms remain subject to uncertainty, there has been a significant increase in the number of hail events in Europe over the period of 1979 to 2015 (Faust & Rädler, 2018). However, this rise is unevenly distributed and most notable in northern Italy and along the Adriatic coast. In contrast, hail events have slightly decreased across southwestern France and the Iberian Peninsula (Faust & Rädler, 2018). Heavy rainfall events are another form of extreme precipitation with the potential to damage vineyards.

4.2 Climate Change Adaptation

While many of the world's viticultural regions face various climate change impacts, adaptation options are far from limited. A dedicated scientific community works to understand the implications of a changing climate for grape cultivation, thereby providing a valuable knowledge base. Such understanding of environmental change coupled with the recognition of risks and the anticipation of future impacts forms the basis upon which adaptation strategies can be designed. Furthermore, grape cultivation is an age-old practice with a vast amount of experience in managing environmental condition, and viticulturists can utilize on a range of technologies and resources to remedy changing environmental conditions. Consequently, the sector can draw on an existing knowledge, capacity and resource base, which is instrumental in planning and implementing adaptation measures. Moreover, grape growers have few restrictions regarding the grapes they cultivate, and are – theoretically – not limited in their choice to grow grape cultivars that have less difficulty with adapting to climate change.

Measures of climate change adaptation can generally be implemented in a reactive or anticipatory manner. Reactive adaptation responds to an observed change or event experience while while anticipatory adaptation seeks to plan and implement measures before negative impacts take place. Additionally, adaptation measures occur along a temporal scale, ranging from short-term to long-term (Neethling et al., 2016). The following describes potential measures to adapt to the aforementioned impacts of climate change and highlights some of the key challenges associated with climate change adaptation in viticulture. It is crucial to point out that no blueprint adaptation strategy or one-size-fits-all approach exists since the "spectrum of vineyard sites, climatic conditions, soil types and varieties across the world's grape growing areas" is extremely diverse (Schultz & Jones, 2010: 143). Moreover, various adaptation measures should be combined since the impacts of climate change occur across different timescales and vary depending on the locality (see van Leuween & Destrac-Irvine, 2016: 149).

4.2.1 Short-Term Measures

Annual harvest management practices are a common way to address climate change impacts, e. g. by reorganizing the grape harvest, by advancing harvest dates or mechanically picking grapes at night. Canopy management practices can be used to avoid sunburn damage (van Leuween & Destrac-Irvine, 2016), and delay grapevine phenology by several days. Canopy management practices to delay veraison include the spur pruning of grapevines at a later stage in winter instead of mid-winter pruning, increasing the trunk height of vines, and reducing the leaf area to fruit weight ratio (Neethling et al., 2016; van Leuween & Destrac-Irvine, 2016). The soil water-holding capacity (SWHC) can be increased through certain soil management practices.

While short-term adaptation measures are relatively easy to implement, their effects are comparatively small. Depending on the extent of global and local climate change, short-term measures are potentially insufficient to offset adverse impacts on current grape cultivation in certain regions.

4.2.2 Medium- to Long-Term Measures

Medium- to long-term adaptation options might be associated with greater initial expenses and/or efforts to implement but have the potential to achieve better adaptation results. One such medium- to long-term adaptation measures is vineyard site selection. For instance, protecting grapevines against damages from late spring frost might become an important adaptation measure depending on the extent of climate change and the vineyard's current location. To reduce the detrimental impacts of frost damage, less frost-prone vineyard sites can be selected. Similarly, moving vineyards to higher elevations might become an important adaptation measure wherever possible (Fraga et al., 2016). Biophysical modelling and suitability maps can be used to support site selection by identifying “changes in the suitability of land for viticulture under future climate conditions” (Mosedale et al., 2016: 3816).

Additionally, irrigation might be a necessary adaptation measure in response to increasing water stress. In contrast to other measures of climate change adaptation, irrigation methods can have considerable economic, environmental and social costs. Drip irrigation systems are more sustainable in their use of water resources as they offer greater control over water management, but are usually associated with greater costs (Neethling et al., 2016). For instance, with the support of beckers bester, local winemakers introduced drip irrigation systems and built water basins in response to the increased water stress and yield losses during 2017 (Koeppel 10/16/2019). However, because of the considerable financing gap, many smallholder farmers typically cannot afford the expensive installation costs of drip irrigation systems.

Crop diversification is a crucial adaptation strategy within the agricultural sector in general. For grape cultivation, the diversification of crop species and grapevine cultivars is a valuable adaptation strategy (see Fraga et al., 2012). Currently, only 13 grapevine varieties “cover more than one-third of the world’s vineyard area and 33 varieties cover 50%” (OIV, 2017: 4). In contrast, over 10.000 known grapevine varieties exist worldwide, leaving vast opportunities to test lesser-known grape varieties. However, since grape cultivation is largely driven by consumer demand, the choices of which grape varieties to grow are limited if a profit is to be made. If possible, a portion of the cultivated land can be dedicated to varieties with genetic and morphological traits that are better adapted to certain impacts of climate change, such as increased water stress and drought (Fraga et al., 2016; van Leuween & Destrac-Irvine, 2016).

4.2.3 Adaptation Challenges

Climate change adaptation is inevitably linked to a range of uncertainties since the impacts of climate change occur at different spatial and temporal scales. A key challenge lies in the anticipation of how global warming interacts with the site-specific microclimate of existing vineyards in different viticulture regions. The impacts of climate change on a vineyard also depend on how local ecosystems respond to climate change. Hence, climate change adaptation in viticulture also requires adapting to “the change in the environment caused by climate change” (Viguie et al., 2014: 57). Furthermore, due to a greater degree of inter-annual variability, grape growers might be confronted with multiple and even contrary impacts as a vineyard can be damaged “by hail one year, whereas extreme heat or rain may occur the next” (Renée & Thach, 2014: 87). These uncertainties generally complicate decisions regarding the appropriate adaptation strategy.

In addition, maintaining grape quality and yield through transitions in grape production systems can be costly and time intensive (see Viguie et al., 2014). Growers have to carefully assess the associated costs as well as benefits of adaptation measures, which can be rather intricate given the social dimension of grape cultivation. Besides the economic importance of grapes as a fruit crop, regional and cultural identities are also linked to the cultivation of grapes as well as winemaking (see Jones et al., 2012). Consequently, growers might be reluctant to switch to different grape cultivars, or even apply new methods that could alter the quality of the grapes. However, Growers will have to decide which level of change, risk, and adaptation they deem acceptable.

5 Reflection

Overall, grape juice is not a highly relevant product for the German economy in terms of overall monetary value. However, it is a good example of how climate change and extreme weather events can affect supply chains and prices. The effects of climate change on the grape juice industry occur predominantly during the agricultural production of grapes. Currently, the most notable effects are the continuous advancement of harvest dates and shifts in suitability of current viticulture regions as well as emerging opportunities for Northern regions. Overall, a majority of actors in the wine and grape juice industry expect a strong effect of climate change on their business.

Our findings suggest that small wine or juice producers suffer more from the impacts of climate change compared to larger juice producing companies. The income of smaller actors often directly depends on a supply of certain agricultural products. Due to their smaller product range and less suppliers, smaller producers are more vulnerable to harvest losses with less options to substitute the agricultural products. Moreover, we found that an open communication on a climate-related price increase can minimize negative economic consequences since consumers understand the price change and are less prone to substitute the brand.

Nevertheless, various measures can facilitate an adaptation to climate change in the viticultural sector. The existing knowledge on different adaptation measures, such as drought-resistant varieties, planting material or irrigation options, and the regional importance of viticulture are strong drivers for climate change adaptation. Yet, adaptation measures can also be expensive and cultural barriers might inhibit the introduction of new grape varieties. Additionally, there is a considerable level of uncertainty regarding the best adaptation strategy due to inter-annual weather variabilities and the general lack of knowledge about the impacts of global warming on site-specific microclimates.

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