Sustainability in Viticulture
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Agroforestry and Organic Wine Production in the Mosel Region, Germany

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von

Nicklas Riekötter
aus Warstein

Erstgutachter: Prof. Dr. Markus Hassler
Zweitgutachter: PhD Michael den Herder

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„Hier wie dort wird Freiheit von Natur zelebriert und bleibt dabei mythisch befangen.“
Theodor W. Adorno, Minima Moralia

As my work on this dissertation draws to a close, I would like to thank the people who have accompanied me on this journey.
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Annotation:
The formats of the research papers entailed in this dissertation follow the respective author's guidelines of the journals they have been published by or were submitted to. The format of citation and references in the remaining sections differs from these, yet is consistent in itself. The figures follow a continuous enumeration.

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List of Abbreviations

AFN	Alternative Food Networks
AOP	Appellation d'Origine Protégée
BLE	Bundesanstalt für Landwirtschaft und Ernährung
BMEL	Bundesministerium für Ernährung und Landwirtschaft
DOP	Denominación de Origen Protegida
EU	European Union
FRV	Fungus Resistant Grape Variety
LER	Land Equivalent Ratio
MKUEM	Ministerium für Klimaschutz, Umwelt, Energie und Mobilität
OIV	Organisation Internationale de la Vigne et du Vin
Piwi	Pilzwiderstandsfähige Rebsorte
RLP	Rheinland-Pfalz
SFSC	Short Food Supply Chains
UK	United Kingdom
UN	United Nations
USA	United States of America
bn	billion
e.g.	exempli gratia
et al.	et alia
etc.	et cetera
ha	hectare
kha	kilohectare
hl	hectolitre
m.	million
mhl	million hectolitre
ssp.	subspecies
z.B.	zum Beispiel

1. Introduction

From the second half of the 20th century onwards, the development in global food production can be characterized as marked by the industrialisation of the agricultural sector. Throughout the 1960s and 70s, the predominant productivist narrative led to an intensification of food production, which was driven by an effort to avert mass starvation (Campbell 2013, Evans 2003). The growth of land under intensive agricultural use and industrial processing, distribution and consumption largely left matters of sustainability behind since the availability of resources for food production did not seem affected by agriculture at all (Brady 2020). The increased productivity and intensified land use were driven by technological developments and the idea of a reliable supply of food and fibre for a growing world population (Thompson 2005, Antle 1999, Ilberry & Bowler 1997). Growth rates in the aggregate world food production from the 1960s to the early 2000s ranged from 100% in the USA and 68% in western Europe, to 200% growth rates in South America and 280% in Asia (Pretty 2005). Further, in the 21st century, the growth of the world population is ongoing and the demand in food production rises accordingly (Beltran-Peña et al 2020, Rask & Rask 2011). Recurring patterns of productivism, sometimes referred to as "neo-productivist" (Wilson & Burton 2015), thus still dominate the global agricultural landscape.

Despite the ongoing expansion in population and intensification of agricultural use for food production, the agricultural sector's dependency on fossil fuels and pesticides remains an increasing current and future problem (Leoci & Roberti 2021, Tauger 2020). Together with resource consumption, the surging environmental degradation by agriculture is causing extreme weather events, resulting in floods, landslides, heat periods and draughts, that are aggravating the conditions under which farming takes place. Due to its embeddedness in the natural surroundings, agriculture itself is regarded as a major driver behind climate change and is subject to discussion regarding a development towards preserving natural resources and creating a global landscape of food production that is sustainable and habitable for future generations (Campbell et al 2017, Beddington et al 2012, Foley et al 2005). Following the overall intensification of agriculture, the scholarly critique on its productivist patterns comprises work on the profits obtained through intensified land-use together with high-output crops and work that engages with the non-sustainable nature of current food

production systems, stressing the endangered livelihoods of today's and future generations (Harwood 2020, Vos & Bellù 2019, Reganold et al 1990).

The origin of modern-day thought on the interface of limited natural resources and human population growth can be traced down to the Malthusian population theory of the late 18th century (Mensah 2019, Dixon & Fallon 1989, Malthus 1872). At the time Thomas Malthus juxtaposed that the geometric growth of the human population would eventually outmatch the arithmetic pattern of subsistence from natural resources. He argued that if the development of human expansion and the accompanying resource consumption would be left unattended, severe consequences to the population like war and hunger could be inevitable (Malthus 1872, p. 63). Conceivably due to firm belief in technological development and the focus on quantitative food supplies throughout the following 18th and 19th century, the successive industrialisation of agriculture and food production took place without grand consideration of sustainability (Pretty 1991, see also Jones 2016, p. 107f).
The first policy concept of the 20th century that indicated a wider public reception of sustainable development, based on the 1972 Stockholm declaration and the 1987 Brundtland Report, was the report conceived at the 1992 UN Conference on Environment and Development in Rio de Janeiro, Brazil (UN 1992). The conference, also known as the 'Earth Summit' and its report are since referred to as a turning point in sustainability development because it first formulated sustainability as a central and global issue to be addressed by policy on a systemic level (Stevens & Kanie 2016, Redclift 2005).

Throughout the 1990s and in conjunction with the discussion on sustainability, the notion of an alternative to the predominant intensification of agriculture coined as 'post-productivism' was discussed as a subject of farming and policy (Morris & Evans 1999, Inui & Bowler 1995, Shucksmith 1993). The idea of post-productivism, in essence, consisted of a shift veering from a quantitative focus in food production to farming enterprises that put food quality and safety at the centre of production, an increase of alternative farms ('pluriactivity') and a shift in agri-environmental policy and regulation (Ilbery & Kneafsey 1997, Ilbery & Bowler 1998). The concept was largely criticized for being too limited in scope, foremost discussing matters of the UK's and western European agricultural production, further missing out on complex interactions by favouring a dualistic perspective on agricultural change, leading to a short-sighted differentiation in either productivism or post-productivism (Evans et al 2002).

Following the absence of empirical evidence on the 'post productivist era' at the time (Clark et al 1997) today's persistent trend of economic interest in agriculture, especially visible in phenomena like land grabbing and investments of non-agricultural actors (Yang & He 2021, Edelman et al 2016), is accompanied by a rising societal awareness to sustainability in food production (Sánchez-Bravo et al 2020).

The discussion on food production thus implies dynamic processes in which there is a continuation of concentration of agricultural capital and an entailed intensification of farming (van der Ploeg et al 2015) similar to the high times of productivism of the 20th century. While on the other hand, a broad societal spectrum increasingly engages with sustainability from activists to policy makers and economic actors (Mäkelä & Olkkonen 2021), lining the discussion on the development of sustainable agriculture in the 21st century.

Agricultural Sustainability

The vivid discussion on sustainability in agriculture and food production is connoted with manifold terminologies, such as "sustainable, ecoagriculture, permaculture, organic, ecological, low-input, biodynamic, environmentally-sensitive, community-based, wise-use, farm-fresh and extensive" (Pretty 2005 p. 2, see also García-Oliveira et al 2022). Alongside the development of individualisation in society (Ewinger et al 2016), matters of food consumption increasingly gain an identity shaping quality (Chen & Antonelli 2020) and expand the sustainability discussion from institutional to public and personal realms. The nexus of food, identity and sustainability represents a vivid field with impactful research reaching from ethnographic approaches of the 1980s to research on the sustainability perception and the afterborn 'Generation Z' today (Gibson et al 2023, Soron 2010, Fischler 1988).

Especially with the emergence of climate change movements in recent years, public attention is being drawn to the food-producing sector and agriculture as among the main drivers behind global CO2 emittance (Han & Ahn 2020, Marris 2019). Following that the popularity of foods associated with sustainability such as the above terms 'organic', 'ecological' or 'green' is rising (Katt & Meixner 2020). Therefore means of sustainable food production are successively being employed in large-scale production networks. While the positive effects of upscaling sustainable and organic farming are commonly appreciated because the integration into the

mainstream yields potential to reduce climate change effects more effectively (Gabriel et al 2010, Bengtsson et al 2005), on the other hand, critics of mainstreaming sustainability in food production raise accusation of a 'greenwashing' process that undermines the idea of sustainable development in favour of economic interests (Boncinelli et al 2023, De Freitas Netto et al 2020). This field of discussion is recently becoming more differentiated with performance-oriented approaches which are stressing the context dependency of organic farming as a sustainable farming method (Tamburini et al 2020, Seufert & Ramankutty 2017). Given the controversial positions in food production spanning between economic interest and natural preservation, the discourse on sustainability in food production, its potential to mitigate climate change and sustain natural resources are yet to be concluded. Throughout the contestation and since the 1992 UN conference sustainability has however become an integral part of society, policy and economic decision-making in addressing the productivist dilemma between the growing world population's food supply and the preservation of natural resources (e.g. see Trabelsi et al 2016).

Velten et al (2015) followed a systematic review of sustainable agriculture and found that the heterogenous nature of sustainability research is best to be embraced and employed in transdisciplinary work to respond to and resolve scientific issues (Velten et al 2015 p. 7857). For this research, this position was also employed in order to increase the detailed understanding for sustainability development. Nevertheless, a circumscription hinting at the realms of sustainability would leave this work inchoate. Thus, the following list is not exhaustive, as the development in terminology and agricultural practice is an ongoing process, yet it should serve as an orientation to what is meant when dealing with issues of sustainability in agriculture and food production in this dissertation. Additionally referring to the EU Commission's Catalogue of Indicators for Food and Nutrition Security and Sustainable Agriculture (European Union 2018) aimed at minimizing the negative impact of agricultural practice and following Pretty (2005) the key principals of agricultural sustainability can be outlined as practices to:

- "integrate natural processes such as nutrient cycling, nitrogen fixation, soil regeneration and natural enemies of pests into food production processes;
- minimise the use of non-renewable inputs that damage the environment or harm the health of farmers and consumers;

- make productive use of the knowledge and skills of farmers, so improving their self-reliance and substituting human capital for costly inputs;
- make productive use of people's capacities to work together to solve common agricultural and natural resource problems, such as for pest, watershed, irrigation, forest and credit management" (Pretty 2005, p. 2).

History of Wine Cultivation

Wine is one of the oldest agricultural products in human history and arguably laid the foundation for human civilization and expansion in providing nutritious, valuable and transportable produce for several millennia (Anderson 2018, McGovern & Fleming 2005, Unwin 1991). Fermented foods like wine are regarded as among the oldest foods (Campbell-Platt 1994), regularly found in evidence of early human settlement (McGovern et al 2017). Due to its alcoholic and polyphenolic contents wine made for a storable and decent drink as part of historic societies that used it as a supply of hydration and nutrition throughout global human settlement. Alongside cannabis and opioids, wine also served as a means of ritual intoxication and a popular means of anaesthesia in wound treatment since antiquity (Dabbagh et al 2014, Dumas 1932) and is still subject to medicinal research today (e.g. the effect of red wine on cardiovascular health, see Golan et al 2019).

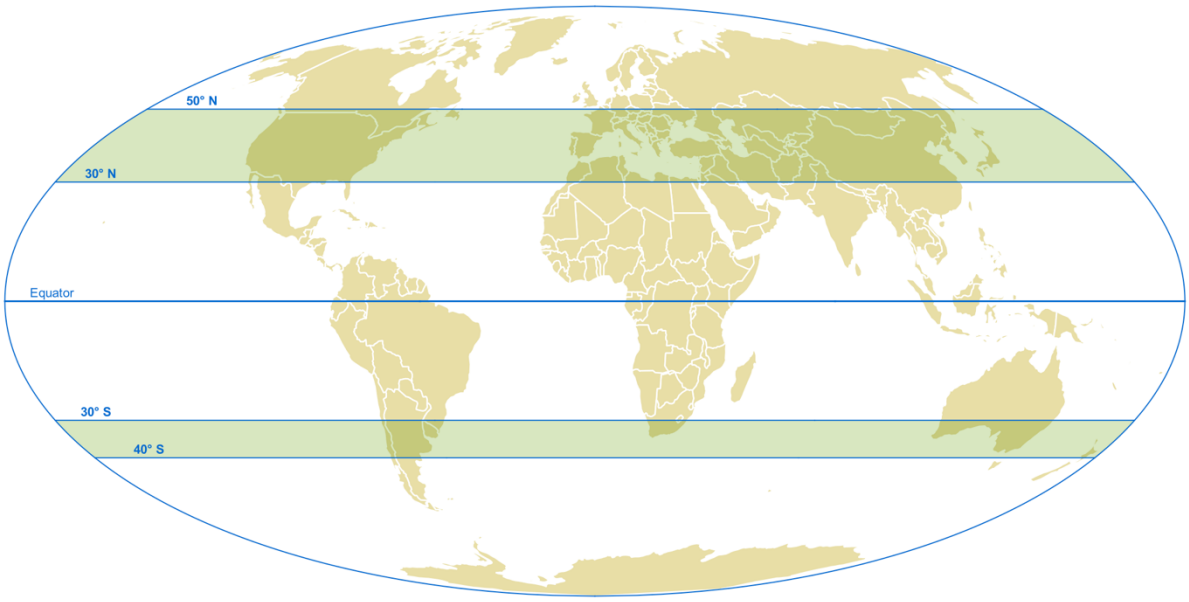
For most of history wine has travelled together with humans in vessels like amphoras or wine bags, acting as a staple food where sources of drinkable water were scarce and the storability of wine was sublime to any other liquid (Grigg 2004). Furthermore, wine always has been subject to trade around the world, spreading its cultivation and consumption from the middle east to today's dissemination across every continent of the globe. The cultivation of wine gained high significance in tradition and aesthetic pleasure but also lined economic development and the spread of human settlement. The Romans are commonly regarded as the first large-scale, pan-European cultivators, spreading their knowledge and technique across their empire by bringing vine plants from the Levant into Europe up to the border of the Rhine in Germania Magna in the 1st Century A.D. (Brun 2011, Gilles 2001) and southern England afterward (Brown et al 2001). Techniques of curing, maturing, grafting and pruning led to the subsequent professionalization of vine cultivation within Roman settlements and their successors. In the following centuries wine produced in the Rhineland (including the Mosel Region) became increasingly well-known and subject to international trade as well as

literary testimony throughout Antiquity, the Middle Ages and modern times (Jaboulet-Vercherre 2022, Rose 2011, Goethe 1808, p. 141).

A developmental landmark in modern times, preceding the current era of global climate change, can be found in the independence from alcoholic beverages as everyday food due to the establishment of drinking water supply systems in the 19th century (Vallee 1998). At least in Europe and most of the western world wine has since developed from an indispensable antiseptic source of nourishment and hydration into a leisure product that endorses traits of heritage, handcraft and knowledge in complex and increasingly globalized production and trading processes (e.g. see Pütz et al 2020).

The global economy evolving around wine as an agricultural product has dynamized significantly in the 20th century, especially after the end of World War 2. While during the 1950s and 60s, close to all of the worlds wine exports hailed from Europe, with Great Britain being the largest wine-consuming market in the world (Insel 2014), the ongoing industrialisation and globalisation of wine production and consumption in the 21st century led to an extensive growth area that today increasingly exceeds the 'traditional' northern hemisphere's latitudinal zone of between 30° and 50° and the southern hemispheres zone between 30° and 40° (Schultz & Jones 2010).

Figure 1.1: Wine growing zones of the northern and southern hemisphere (green).



Based on Schultz & Jones 2010. Cartography by C. Enderle.

2. Theoretical Framing of Sustainability in Wine Production

Leverage Points for Sustainability Transformation

In the face of fundamental challenges to the way humans live and produce on planet earth, research in sustainability science investigates the complex nature of problems like climate change, water scarcity or environmental pollution (Miller 2014, Wiek et al 2012). Research in this transdisciplinary field identifies a general urgency for systematic transformation to sustainable practices in order to avoid human and environmental disaster (Becker 2014, Kates 2010). To be "solution oriented" and to avoid atomized approaches such as mere fixes using technology (Abson et al 2017, p. 31), the notion of leverage points represents an integrated approach to researching the complex nature of food production systems. In order to identify system characteristics where intervention cause an overall lift rather than a punctual change in sustainability, David Abson et al (2017) draw on work from Donella Meadows (1999) to identify different systemic qualities of leverage points for sustainability transformation. Recognizing leverage points that range from shallow to deep, Meadows' approach seeks to investigate points in food production systems which have the potential to lift the overall sustainability within the system, referring to beneficial outcomes for consumers and the environment. Abson et al (2017) enhance this leverage points approach by introducing three realms of leverage that expand the systemic description to creating an indication scope for identifying transformational potential.

The three realms of *re-structure*, *re-connect* and *re-think* are formulated as interlinked and aim to indicate fields of sustainability leverage intervention (Abson et al 2017, p. 33). *Re-structure* stresses the role of institutions in systemic change and refers to restructuring institutional decision-making with reference to sustainability transformation. The theory tries to not only take institutional emergence, but also institutional decline and failure as a point of departure for analyses. *Re-connect* aims at re-establishing a connection between humans and the natural processes surrounding them to facilitate sustainability transformation through increased environmental awareness. The reestablishment of a connection with nature points at the mission consciousness that underlies sustainability transformation research in general. *Re-think* promotes a mutual learning process between science and society that integrates a solution-oriented and socially embedded production of knowledge.

The wine producing sector as part of global food production is being held accountable for multiple negative climate impacts that can be linked to a lack of systemic change towards sustainability. Especially referencing environmental hazards through pesticide use and soil degradation, facilitating floods, erosion and the environmental footprint (Litskas et al 2020, Fraga et al 2012), deep points of leverage can be identified in the wine sector producing with fundamentally unsustainable premises regarding deep leverage points such as *intent* and *design* of the production system (see Abson et al 2017, p.32). However, Abson et al stress that not only points of deep leverage work as sole levers to improve sustainability in systems such as the wine sector. The authors stress that the interaction between deep and shallow points of leverage are interdependent, in the sense that changes in deeper system characteristics (design, intent) relate to how transformation happens at shallower levels (material flows, feedback loops) (Abson et al 2017, p.36). Systemic transformation of the wine sector can thus be made visible through assessing different depths of system characteristics. The sustainability practices which are being researched in this dissertation can be related to these characteristics, e.g. via statements by the interviewed farmers regarding aspects of *design* and *intent* of their production system, or changes in material flows, wine pricing or customer feedback at shallower levels. Establishing sustainable practices and thus transforming system characteristics is widely pursued in the organic wine producing sector. Especially vintners who are already engaged in certified production or are looking at changing their production patterns do show the will to systematically transform their way of practice according to their way of thinking about producing wine. Manifestation of such transformative sustainability practices were most visible in the researched farms of this dissertation where the implementation of livestock in vineyards and trees into the parcels profoundly changed the vineyard as a landscape feature and the entailed function of the production system.

Understanding the interdependency of system characteristics in the production of wine as a means to identifying systemic points of intervention for sustainability transformation, the theoretical basis for understanding sustainability practices in viticulture also requires an understanding of interaction with the ecosystems in which wine is being produced. To lay the basis for understanding the potential of agroforestry and fungus resistant grape varieties as sustainability practices, the concept of ecosystem services is used as an ecological frame of understanding to emphasize the process of value creation in viticulture.

Ecosystem Services

Since products from sustainable viticultural production are marketed to feedback value into sustaining the future production, innovations in this sector are researched for their potential to improve existing value activities. For this purpose, the concept of ecosystem services is being employed in this dissertation in order to understand the process of value creation from vineyards as ecosystems and look at the value dynamics of innovative viticultural practices, including their effect on marketing and distribution. To inform and contextualize empirical data, ecosystem services allow for a description of specific outputs stemming from sustainable practices in ecosystems that provide beneficial outcome to be located and valued for their positive effect on the sustainable development of a food production system.

Stemming from an educational background that pursued to establish knowledge of human dependence on a functioning natural environment, ecosystem services were originally engaged as a teaching tool (Ruppert & Duncan 2017, Hernández-Morcillo et al 2013, Ehrlich & Ehrlich 1981). From the origin in the second half of the 20th century onwards, the thought of human dependency on nature and its ecosystems sprawled to other fields of sciences and became increasingly popular, especially in natural sciences, social sciences and policy (Heal 2000, Daily 2003, Virhervaara 2010, Gómez-Baggethun 2013). Today, sciences engaged in environmental and sustainability research rely on the concept in order to make the in- and outputs of ecosystems and their potential use for improvement in relation to human production and consumption visible. In research on agricultural matters, the original educative purpose and the ability to indicate improvements for value creation of ecosystem service theory informs both the food production and the societal endeavour for sustainable development (Daily & Matson 2008). Following a call from UN Secretary-General Kofi Annan in 2000 a group of researchers compiled the *Millennium Ecosystem Assessment* report, which found that there are a multitude of different ecosystem services, namely: *provisioning*, *regulating*, *cultural* and *supporting* ecosystem services (Reid 2005 et al, p. 39f).
1) Supporting ecosystem services are regarded as the basis for all other ecosystem services and comprise the accumulation of energy and provision of oxygen, e.g. through photosynthesis, soil formation or nutrient cycling. The processes of supporting ecosystem services take place over long periods of time and are oftentimes affecting human life in indirect ways. Emerging from the basis of fertile soil through soil formations as a supporting

ecosystem service, 2) provisioning ecosystem services provide products like food and fibre, water, wood or fuels that are being extracted by humans from ecosystems. 3) Regulating services refer to the beneficial outcomes of ecosystem processes like the ocean's ability to sequester carbon or the prevention of soil erosion through vegetational cover in steep terrain (see also Boyd et al 2019, Egoh et al 2008). The nonmaterial outcomes from ecosystems humans benefit from are 4) cultural services, which add to richness of knowledge, foster recreation or represent cultural value through traditional landscapes (e.g. see Plieninger et al 2015, Bieling 2004).

The economic valuation of ecosystem services can be traced beginning in the 1970s and led to a development of two perspectives in ecosystem services research (Goodland & Ledec 1987, Westman 1977). One focusing on beneficial relationships in and among ecosystems from a biological perspective, the other focusing on human relationships with ecosystems (Bennett 2009). The latter, anthropocentric perspective allows for a problematisation of human use of ecosystems, for the supporting and regulating ecosystem services are often exploited by a societal minority, e.g. policymakers fostering intensive land use or farmers applying increased amounts of pesticides in order to increase crop yields, altering natural cycles and the ecosystems abilities to regulate themselves. The depletion of ecosystem functions and the exploitation beyond natural limits lead to negative externalities like environmental pollution and biodiversity loss with which in turn a majority of human society is confronted (Reid et al 2005). While provisioning services regularly are associated with their role in describing the degradation of ecosystems (Delgado & Marín 2020), environmental value added to products reaped from ecosystems can also be used to promote and foster ecosystems. Under modern capitalist agri-food conditions, these possibilities to employ ecosystem services in favour of nature are predominantly realised on the market level via certifications in farming that appear as organic, biodynamic or else, indicating customers that these products have less negative environmental impact (Bellassen et al 2021, Gomiero et al 2011).

Given the unsustainable pathways also present in viticulture, sustainable farming practices are sought after by farmers with certified production who experience negative externalities in forms of health hazards, environmental degradation and dependencies on agribusiness

actors. As a consequence, practitioners in sustainable farming make use of ecosystem services both to regain and maintain benefits obtained from ecosystems services for economic viability and future generations. Thus ecosystem service theory is being applied to viticultural practice in this dissertation to prove its viability for making sustainable development indications and research the beneficial relations that are being build, once innovative niche developments like agroforestry and FRV are being employed. In detail, evaluating products obtained from ecosystems allow to attend to the process of restoration (Bullock et al 2011) and benefits of sustainability development in the viticultural sector, distinguishing in use- and non-use values (Pandeya et al 2016, TEEB 2010). Use values are defined as consumptive elements obtained from ecosystems in the form of nutritional products or recreation. Non-use values closely relate to ideals of environmental protection as a value and do not require direct contact to the ecosystem or its products (Goulder & Kennedy 2009). As ecosystem services merely describe processes in and between ecosystems and how humans relate to those processes, this ecological understanding demands for an economic substructure that facilitates an understanding of economic processes linked to sustainable practice involving ecosystems. Alternative food networks provide an understanding of how produce from ecosystems in food production are treated in distinction to mainstream food production in order to establish an authentic, sustainable distribution and consumption of food.

Alternative Food Networks

The process of industrialisation in agriculture and food production throughout the 20th and 21st century carried along several negative effects on the natural and social environment and promoted a development of an increasingly dispersing relationship between producers and consumers. Hence the growing number of actors that are engaged in successively global and complex food production networks, there is a growing alienation between the loci of initial production, the consumer and the places of consumption. In a strict spatial understanding, especially highly processed food products with long value chains (e.g. frozen pizza) regularly cover vast distances during their lifecycle (e.g. see Capozzi et al 2021), using resources in one place to produce, process and sell a product in several different distant places. In the case of wine from spatially dispersed production, it is often produced in conjunction with subcontractors, globally traded and shipped in bulk vessels to be assembled, bottled and labelled at the continent of destination before being subject to further trade and consumption

(e.g. see Rainer et al 2021, Pütz et al 2020). Such complexity makes for increased profits, often obtained due to scaled-up production (Pütz et al 2020) and the different cultural settings of local foods that are embedded in global production networks (e.g. see Franz & Hassler 2010).

Yet overall, the several post-farm processes of such scale make for a high environmental impact of products from such large-scale global production networks. Beyond wine, mainstream food production networks generally comprise numerous stages after the initial on-farm production such as processing, distribution, trading, retail, preparation, consumption and waste-cycling. Numerous actors and processing steps in production networks make for emerging hierarchical orders in status quo food production and thus the decisional power of large-scale food companies and retailers turns out to be high in dictating product pricing and production methods down the value chain (Monteiro et al 2013, Dobson 2003). Following the alienation of producer and consumer, further given the power to dictate conditions of production along the value chain, intermediary institutions like the retail sector harvest a majority of profits that are generated in food production (Sexton & Xia 2018, Bonanno et al 2018).

Contestation of this condition from the consumers' side emerged mainly during several food scandals of the 20th century, predominantly from the 1980s onwards, sparking the development of alternative food networks, originating from a demand for increased transparency and safety in food production (Edwards 2016). One of the first major food scandals in the German food sector happened to take place in wine production, named the ‘glycol scandal’, after in 1985 the use of diethylene glycol as a means of large-scale adulteration of wine became public (Anderson & Pinilla 2018, p 116f, Skinner 1993). The aftermath of this scandal resulted in intensified controls of wine production and trade and a nearby collapse of the German wine market (Deutschlandfunk 2015). Catalysed by such crisis, the upcoming development of societal consciousness on product quality, environmental matters and sustainability led to a niche development among winemakers who increasingly laid focus on lower outputs and quality wine production as well as direct relations to consumers (e.g. see Willer 2008). As such alternative food networks can be regarded as an outcome of consumer driven demand for transparent and sound production methods.

Alternative food networks are used in this context to describe food production systems that differ from the above-mentioned conventional and production systems characterized by industrial production and long value chains with power concentration in intermediary institutions such as retail and distribution. Alternative food networks alter from these mainstream production patterns in that they are set to redistribute value and power, further altering the social dynamics and perceptions of quality regarding food (Whatmore et al 2003). The alteration to mainstream production is conducted via different models of agricultural production and distribution, namely farmers' markets, cooperative productions, community-supported agriculture, self-harvesting etc. (Venn et al 2006). These forms of alternative food networks all share the approach of trying to bypass intermediary actors and channel the value flows directly between producer and consumer.

Short food supply chains (SFSCs) play a focal role in these different production models and denote the process of 're-socializing' and 're-spatializing' food (Marsden et al 2000, p. 425) to capture value within the alternative food network, hindering drift off to intermediaries by close relationships and short spatial and social distances (Barbera & Dagnes 2016). Short food supply chains as the crucial component in AFNs are characterized by a bottom-up marketing approach, identifying 3 types that differ in the way of shaping the value chain (Renting et al 2003, 399f): 1) *Face-to-Face* value chains consist of direct marketing relations where produce is sold directly by the producer, for instance on farmers markets or direct marketing on the respective farm with face-to-face customer contact. Selling their produce locally is also a traditional practice for most of the wine regions of the world, especially present in the dominant small-scale farming of the Mosel Region. The practice of face-to-face sales is traditionally used to explain product traits of wine and authenticate the production methods used by the winemakers to the customers by sight and explanation. Beyond the direct local sales by the farmer, value chains of 2) *spatial proximity* focus on the regional scale, e.g. through specialized shops that market produce with mission consciousness on the spatial proximity to the products' origin. In the distribution of locally produced wine, specialized farm shops and local shops often compile wine product ranges stemming from a limited geographical area in order to represent the regions qualities to their consumer and promote the local preservation of value added. 3) *Spatially extended* value chains do not imply direct physical interaction of consumers with the producer or place of origin but rely on symbolic

representation of the products' descent via certification logos or depiction on labels. For potential wine consumers, these representations of origin are most common when browsing through large-scale supermarket chains' wine portfolio. There, the labels of e.g. AOP (France), DOP (Spain, Italy & Portugal) or the German *Prädikatswein* indicate high value wines from geographically limited winegrowing regions.

As a means of describing the flows of value in the wine sector, SFSC's in alternative food networks do show strong relations with sustainability practices in wine production. As an example, farmers are confronted to take part in the expansive trend of global bulk wine production which sets out for large-scale outputs from globally dispersed regions whose produces are commissioned, traded and assembled to different wine styles and sold internationally (see Rainer et al 2021). These long value chain production pattern oppose the motivation of many farmers such as those from the Mosel region, as their capabilities both do not match the high outputs required for large-scale export production and they disagree with the environmental impact underlying intensive management and long export routes. In contrast to the anonymous production in bulk wine, trust and authentication acts as crucial components in the marketing of local and sustainably produced wine, taking an integral role in building the relationship between producer and consumer. Vice versa, relationships of trust are also easier to be built in networks with shorter social and value chains (Thorsøe & Kjeldsen 2016, Bonn et al 2016). Compared to conventional wine production the employment of large-scale intermediaries e.g. commissioners in bulk wine, is thus rendered largely unattractive for farmers working in sustainable viticulture. Personal relationships as central to alternative food networks connect to the way sales and marketing take place in small to medium farm size dominated wine regions such as the Mosel region. A benefit of close customer relations despite the communication on products and production methods can be found in that the touristic attraction of regional farming increasingly stabilises and diversifies the vintners' incomes who regularly provide on-farm accommodation for visitors and have the opportunity of on-farm sales, using short food supply chains in alternative food networks. Understanding the concept of leverage points for sustainability intervention which, in conjunction with ecosystems services, build the understanding frame for sustainability practices in this dissertation, alternative food networks should be regarded as the economic foundation from which value is generated and fed back into organic viticulture engaged with sustainability

practices. After having outlined the major theoretical concepts related to the research articles comprising this dissertation, the next section formulates the role of sustainability in wine production, giving special attention to the sustainability practices of agroforestry and the implementation of fungus resistant grape varieties.

Sustainability in Wine Production

In agricultural crops, vine (*Vitis vinifera*), together with hops (*Humulus*), asparagus (*Asparagus*) and others are regarded as specialty crops. These crop types usually do not fit in standard workflows of large-scale root crop or grain farming and have high requirements in crop management, climate and soil conditions in order to flourish. Specialized machinery and frequent implementation of manual labour in the management and harvesting of specialty crops result in higher production costs per hectare compared to standard crops (Zhang & Wilhelm 2011). Planting specialty crops oftentimes is attractive to farmers due to the added value compared to standard crops, yet the vulnerability towards environmental change also tends to endanger the profitability for farmers who focus solely on cultivating specialty crops (Kerr et al 2018). Hence the agricultural sector's dilemma between the dependency on environmental resources and negative impact on them, research in specialty crops is generally concerned with techniques of biotechnology, production and climate change effects (Kerr et al 2018, Miller & Bradford 2010, Ruiz-Altisent et al 2010, Fennimore & Doohan 2017).

Vine as the central crop to this dissertation arguably represents the most well-known specialty crop worldwide and thus the modern-day wine sector represents no exception from the discourse on sustainability in agriculture. Given the trend of agricultural intensification that is also present in viticulture, environmental harm due to production patterns that entail large amounts of mechanical and chemical treatments are successively subject to discussion in wine-related institutions, academia and the public (Maicas & Mateo 2020, Santini et al 2013). While the predominant ways of producing wine are contested and the circumstances of production are altering depending on location, due to the streamlining of distribution and consumption, as a locally produced commodity wine is marketed globally and often associated with status and enjoyment, commonly linked to depictions of nature and treasured origin (Warman & Lewis 2019, Patterson & Buechsenstein 2018, Overton & Banks 2015).

Despite appealing through traits of craftsmanship and natural descent, developments of intensified agriculture make viticulture account for a vast amount of pesticide consumption relative to its share of planted area (Robert 2019), which increasingly raises awareness in consumers and researchers (Schäufele & Hamm 2017, Forbes et al 2009, Barber et al 2009). The large-scale pesticide use that is common in viticulture can be understood as a farmer's response to the vine plants proneness to pests, primarily to fungi infections in conventional farming and the tendency of the plant to alter its fruit quality depending on climatic changes (de Orduna 2010).

In that sense, the predominant conventional wine production regimes, which are engaging high degrees of mechanised agriculture, including steady pesticide use to increase product quality, quantity and profits, are successively undermining the foundation of sustaining future viticultural production by posing a problem to the environment, natural resources and wine production's reputation in society. Research on sustainable development in viticulture thus targets the potential to resolve the sector’s dilemma in relation to natural resources while also meeting customers' demand for quality wine that is produced in a sustainable way (Cataldo et al 2021, Zambon et al 2018).

With the emergence of wine as a status commodity in a society characterised by individualised consumption (e.g. see Niklas & Sadik-Zada 2018), the producer's and consumer’s consent with the respective production methods becomes increasingly focal as wine is subject to narrative value creation as an integral process to authenticate the producer-consumer relations (Joy et al 2021, Szolnoki & Tafel 2020). Given these outlines, the more than 7000-year-old tradition of wine in human history (Harutyunyan & Malfeito-Ferreira 2022) presents a research field in which practitioners are challenged to develop techniques that balance the negative effects of viticulture in order to preserve natural resources and provide wine as a product of high value and meaning to culture and trade across multiple regions around the world.

The process of sustainable development in viticulture as subject to this dissertation comprises all steps from production to processing, distribution and consumption (Gerling 2015) and represents a growing field of research (Baiano 2021, Litskas et al 2020, Maicas & Mateo 2020). Sustainable wine production is pursued widely across the wine sector to mitigate negative

outcomes of producing with chemicals and under changing climate conditions. Agroforestry represents a new practice in modern viticulture, introducing woody perennial plants such as trees and livestock into the vineyard, further adding to the resilience, quality and productivity of production systems. With the potential to meet the sustainability challenges mentioned above, agroforestry as a cultivation form has a focal role for its potential to transform production, processing and distribution within the viticultural sector.

Agroforestry

Historically, agroforestry systems in viticulture can be found in Roman grape cultivation, commonly named *arbustum* as the practice of vine plants being supported by trees (Decker 2009 p. 125). As plants from the Vitis family generally tend to grow as liana ranking on objects towards the sun, the ancient innovation of combining vine plants with trees allowed for a natural growing support of the vine plants with by-products from the trees. In figure 2.1 one can see the depiction of a *Bacchanal*, which is a ritual wine feast, with a fruit tree supporting a vine plant in the picture background. This is one of the forms of ancient agroforestry as they would have been applied. Additionally to single trees supporting vine plants, there is also evidence of several trees pruned to systems in which the vines could be hanged more systematically and are still used today as a traditional cultivation practice (e.g. in Portugal, see de Almeida-Costa et al 2021).

Figure 2.1: Drawing entitled “Bacchanal with a wine vat” by Andrea Mantegna, ca. 1475.

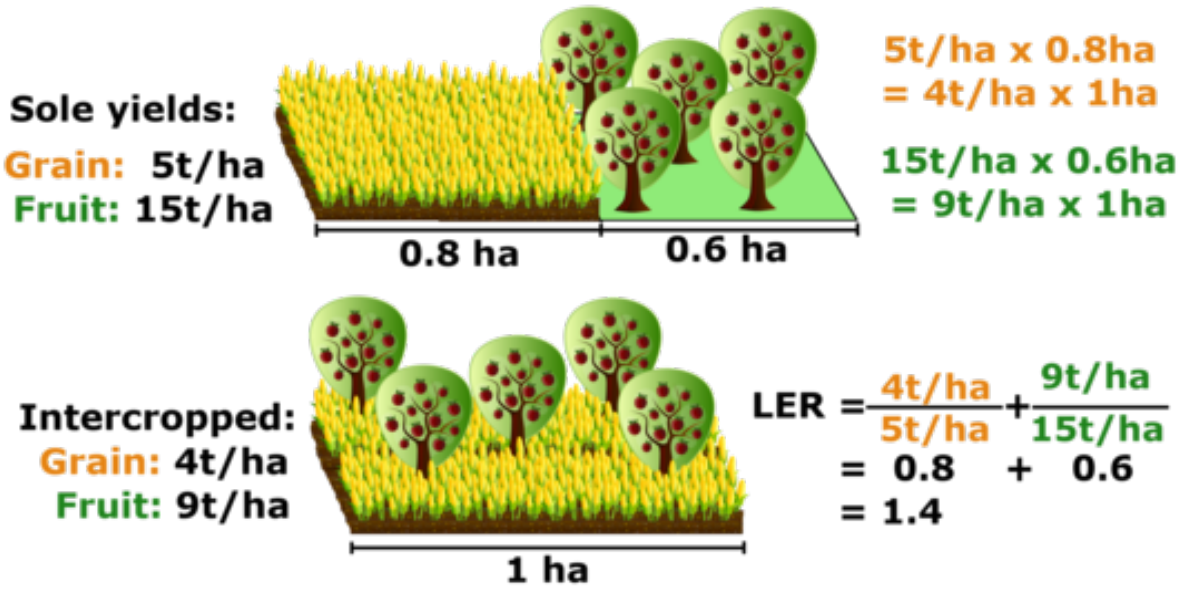
Source: The Metropolitan Museum of Art, https://www.metmuseum.org/art/collection/search/337057 .

Perceived as an intensive practice in the days of antiquity (Decker 2009 p. 125), over the course of millennia agroforestry as a standard practice in viticulture gave way to more intensified forms of use via monoculture plantations with artificial supporting systems comprising steel poles and wireframes. Compared to ancient methods of viticulture, the exclusion of agroforestry practices lead to a relatively ‘clean’ look of the modern-day vineyard, since the production focus in viticulture shifted from making use of the ecosystem services in agroforestry to an intensification and maximisation of the parcels’ output. Outside of viticulture, agroforestry outlasted over centuries mainly being applied in extensive agricultural use forms such as grazing livestock systems surrounding the Mediterranean. With combinations of olive orchards and livestock or crops (Eichhorn et al 2006), those systems are making use of mutual benefits within the plantation area due to the reciprocal provision of nutrients sub- and above soil, increased product value, carbon sequestration, increased climate resilience and enhanced landscape value (den Herder et al 2017, Wilson & Lovell 2016). Predominantly surviving in regional niches, agroforestry as the intentional combination of trees or woody perennial plants with crops or livestock on the same agricultural land (Rodríguez-Rigueiro et al 2021, Mosquera-Losada 2009) is a practice which is being

rediscovered recently for its potential to systematically establish sustainability practices in wine production.

The obtainable benefits from agroforestry systems can be differentiated in material and immaterial outcomes. The former material outcomes are mainly present in beneficial relations of actors within the ecosystems and improved output quality and quantity such as the above-mentioned provision of nutrients. For example, the combined plantation of trees and grains on the same agricultural land yields a higher output compared to separate plantations. This effect of an improved land equivalent ratio (LER) is displayed in figure 2.2 below. The figure is showing a separate plantation of fruit trees and grains on 1.4 ha and an intercropped agroforestry system consisting of the same crops and trees on 1 ha. The exemplary calculation in figure 2.2 indicates that the agroforestry site increases the LER to 1.4 and thus pairs the above-mentioned positive effects within the ecosystem with an improvement in land use efficiency by 40%. Meaning that the yield of intercropped plantation is higher than separated plantation for which more surface area is required to achieve the same yield.

Figure 2.2: Illustration of the Concept of Land Equivalent Ratio (LER).



Source: Creative Commons, Kellner T. (2022).

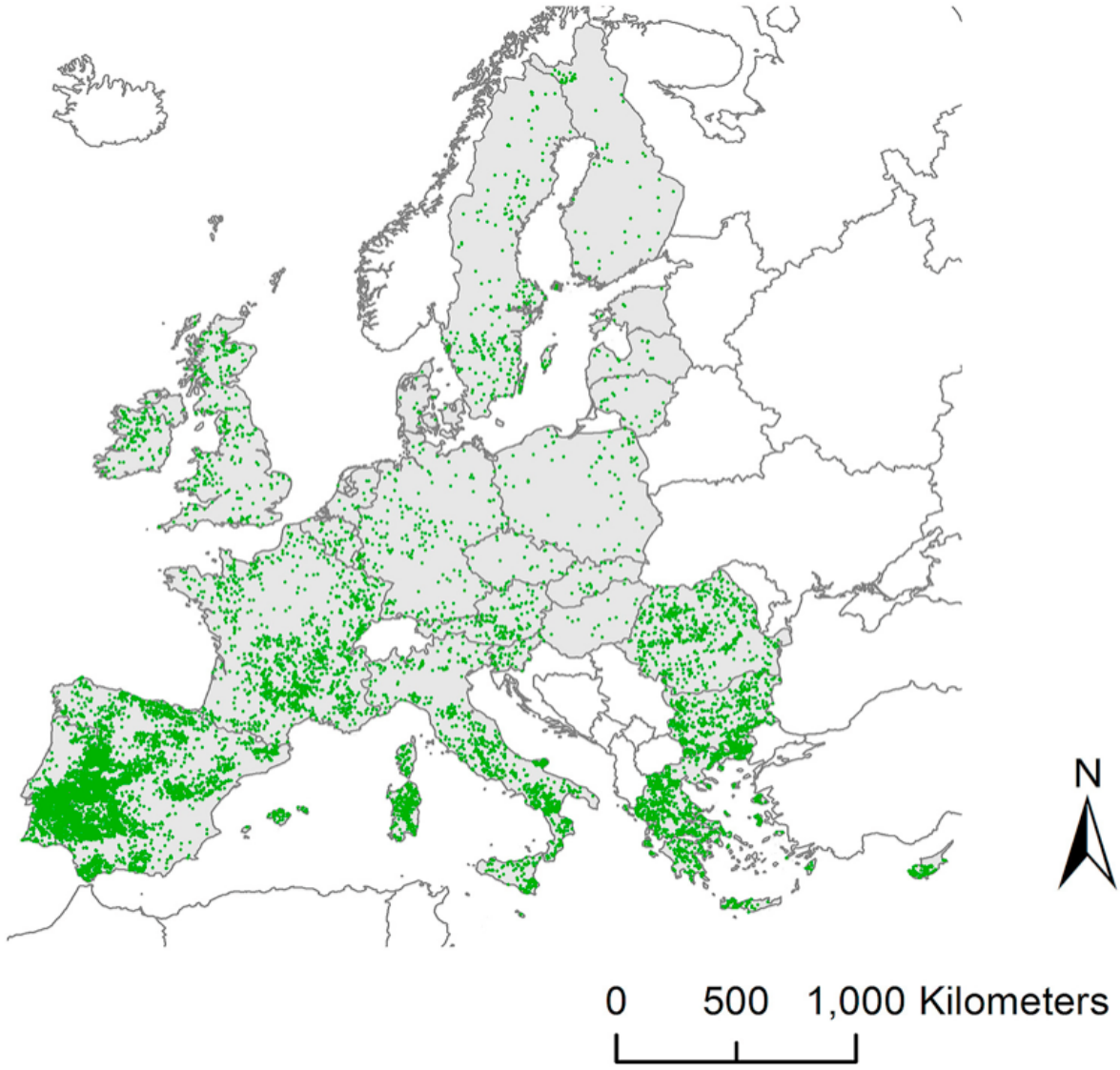
https://commons.wikimedia.org/wiki/File:Land_Equivalent_Ratio_v2_0_simple.png

Besides the water lift effect present in agroforestry due to the deep rooting trees, the displayed system also provides shelter to the crops from sunburn in heat periods due to the shading from the tree canopies. Thus several interactions between plants being intercropped make for benefits in nutrient and water supply that potentially increase the land use efficiency and yield in agroforestry systems. On the material output side of agroforestry systems, farmers thus profit from a higher productivity compared to spatially separated farming with an improved land equivalent ratio (Smith et al 2022, Seserman 2018), meaning that the crops cultivated in an intercropped agroforestry system can provide more yield relative to the planted area than monoculture plantations.

Material outputs from agroforestry systems are usually easy to market for producers, especially those engaged in short food supply chains, who are being able to impart their practice to consumers by sight and word. While immaterial outcomes regard the aesthetic value of agroforestry systems like touristic or traditional applications, they require further processing for value creation, e.g. in the form of further knowledge transfer and marketing. Besides the additional produce that can be obtained from agroforestry, touristic attraction acts as an integral part in the sustainable creation of value, especially for viticultural farms that are genuinely coupled with tourist accommodation and in other landscapes where agricultural business models are interlinked with the geographic scenery (e.g. viticulture, fruit orchards, primeval forest, etc.). Seeing combined plantations of trees and other agroforestry use forms as aesthetically pleasing (García de Jalón et al 2018), the production system often acts as a visual representation of close-to-nature farming and sustainable thought, able to raise appeal, especially in touristic contexts. Thus agroforestry systems can be regarded as attractive to farmers that work with organic or biodynamic certification, since the visual representation of sustainability represents an integral part of their way of production. The added product variety of silvopastoral agroforestry systems comes in the form of animal produce, when livestock is integrated, or wood and fruit products obtained from silvoarable systems. These products help diversify the farmer's income and generally stabilize agricultural businesses (see Moreno et al 2017). Given the potential improvements to innovate agricultural practices, agroforestry systems are diverse in shape and composition, accordingly their capability to improve status quo viticulture is largely dependent on local, geographic, edaphic and climatic conditions (e.g. see Torralba 2016) as well as the skill and willingness of the farmer to adapt to and maintain the agroforestry system.

The advantages of agroforestry which are being researched and increasingly applied in the EU and worldwide (den Herder et al 2017) can be transferred to the field of modern-day viticulture in which the process of rediscovering agroforestry as a practice to mitigate current challenges such as climatic change, pesticide consumption and increased demand for sustainably produced wine is ongoing (e.g. see Favor & Uddawata 2021). Figure 2.3 below shows the total extent of Agroforestry in the EU in the year 2017, giving an overview of where such systems are traditionally established and climatically favourable.

Figure 2.3: Extent of agroforestry in the EU.



Source: Den Herder et al (2017, p. 126).

While the majority of regions in which agroforestry in Europe is present today are dominated by wood pastures, systems comprising livestock and trees or perennial plants correlate with the high density concentrated around the Mediterranean. In this European region, the advantages of agroforestry, namely the reduction of mechanized work to maintain grassland, the workload for farmers regarding fertilization and pesticide application have long tradition and are often applied in olive agroforestry and oak tree systems (Den Herder et al 2017, p.122). This can be attributed to the management systems of agroforestry responding to the needs of farmers working under Mediterranean climate comprising hot, dry summers and mild, wet winters. The area is known for its long periods of sunshine, low humidity, and moderate temperatures throughout the year. Alongside reduced human workload, enriched biodiversity, farmers facing climate change, phenomena of heat, sun radiation and extreme weather events make agroforestry applications successively attractive beyond the Mediterranean both in agriculture and viticulture.

Fungus Resistant Grape Varieties

Together with agroforestry systems, fungus resistant varieties (FRVs) of vine make for a recent rediscovery of a practice to implement into viticulture with high potential in levering the overall sustainability of wine production. FRVs as vine varieties that are immune to certain pests and their potential of interworking with agroforestry systems is being laid out in the following.

Since the origins of cultivating wild vine (Vitis vinifera ssp. sylvestris) in ancient times, the selection of new seedlings for breeding new varieties of vine was successively dominated by quantitative (e.g. yield, flowering regularity) and qualitative aspects (e.g. aroma, colour) (Yobrégat 2018). In an effort to further improve the plant and fruit quality, centuries of selection from wild vines via these categories produced several thousands of different varieties, whose adaptedness to local microclimates and soils made for an estimated 10,000 cultivated vine varieties (Vitis vinifera ssp. sativa) (Robinson et al 2013), of which 1,368 are identified as producing in commercial quantities (Robinson et al 2013). From this vast amount, 301 named species are officially recognized by the German Federal Office for Agriculture and Food (Bundesanstalt für Landwirtschaft und Ernährung 2023) today. The majority of these official varieties are so-called standard varieties in distinction to fungus resistant varieties. The

latter are an outcome of breeding and historical plant migration by human hand, which resulted in the involuntary spread of pests across plantations inside and outside of Europe. With the rise of steamships, global travel and the subsequent import of exotic plants from overseas in the 19th century, soon enough the vine louse (Phylloxera vastatrix) and other pests found their way into Europe (Stevenson 1980). Following the international spread of vine pests, fungus resistant grape varieties were the outcome of human efforts to mitigate the pest-related crop failures and retain product quality. The first incident of pest infestation with large effect was the involuntary migration of powdery mildew to Europe from North America. Reported to first occur in 1845 it decreased the French wine harvest of 1854 by 80% (Gianessi & Williams 2011). The disease led to increased efforts of finding resistant varieties across the world, which according to Yobrégat (2018) subsequently resulted in an increased introduction of other pests to Europe.

For Germany, reports state the discovery of the vine louse in the 1870s (Jansen 2000, Ritter 1893) on imported American vine varieties, which led to large-scale crop failure following an uplift in grafting European varieties onto American rootstocks as a successful means to retain the existent varieties with immunity to the American-born pest in Europe. Efforts to make vine plants immune to pests via selection or hybridisation in modern times thus reaches back into the 19th century, yet after finding a momentarily sustainable solution in pesticide use and abandoning own-rooted vines in favour of grafted European vine varieties onto American vine rootstocks, further development and refinement of resistant vine varieties somewhat fell into hibernation.

However, recently rising external pressures on the wine sector in the wake of climate change and cost-benefit calculation regarding pesticide use as well as the pursuit for sustainable practices drive a re-emergence of pest-resistant grape varieties since the 1990s (Korbuly 1998, Staudt & Kassemeyer 1995, Roy & Ramming 1990). Fungus resistant grape varieties are subsequently being worked on to improve their qualitative and quantitative output in order to reach a competitive advantage over the standard vine varieties available today (e.g. see Bove et al 2019). Practitioners and scholars see the implementation of FRVs as beneficial for viticulture in numerous ways (Pedneault & Provost 2016, see also Chapter 6):

First, the varieties' ability to prosper without excessive applications of fungicides makes for a reduced environmental impact on the ecosystem of the vineyard and surrounding area, including reduced health hazards for humans working in the wine plantations. For the organic wine sector this is especially relevant, since the main substance for plant protection remains copper. As a heavy metal, the long-lasting contamination of organically managed vineyards is looked to be disestablished by vintners with the use of FRVs. Second, hence the reduced pesticide input in FRV viticulture, the amount of working hours spent in plant protection is reduced which makes for an overall cost reduction added to the reduced costs for pesticides. Third, the absence of harmful chemicals creates opportunities for introducing livestock as an agroforestry practice into the vineyard, which further entails benefits in the form of dung provision, defoliation, weeding, soil consolidation, meat, leather, wool and the antagonising of grape browsing game animals from adjacent forests.

Agroforestry together with fungus resistant grape varieties creates potential for transformation in viticultural development which addresses the above-mentioned challenges and adds to systematically developing sustainable wine production further. Addressing the impact of agroforestry and FRVs with regard to the sustainability in wine production is thus recognized as a focal point to the analysis in this dissertation. Accordingly the theoretical contribution of this dissertation lies in providing a systematic review of sustainability practices in regional wine production, using the notion of leverage points for sustainability transformation as a systems approach, perspectivising the ecosystem services obtained in viticulture and linking them to alternative food networks as an approach to make use of produce in production patterns aimed to be environmentally and economically sound. Thus, with regard to the understanding of social, ecologic and economic sustainability, this research is focused on the latter two aspects.

3. Research Design and Methodology

The research of this dissertation investigates sustainability practices in the wine producing sector of the Mosel region in the southwestern German state of Rhineland-Palatinate. The research looks at agroforestry and FRVs as viticultural practices and investigates their effect for I) an improvement to status quo sustainable viticultural practice, II) improved value activity and III) takes a look at systemic change through the researched sustainability practices.

Given the explorative nature of this study, a qualitative research approach was found advantageous to gather and analyse data from viticultural farms in the Mosel region. Wine growth and production have been part of this region's landscape and its management at least since the roman colonization (Gilles 2001). The region comprises difficult conditions for the cultivation of wine due to the steep slopes on the riverbanks which make intensive manual labour necessary and mechanized work dangerous. Embedded within the region's cool climate, to which the predominant variety of Riesling and its marketing is well adapted, climate change alongside the labour-intensive and dangerous vineyard maintenance put the Mosel at what can be called the difficult end of cultivation in German wine regions. Due to this relative volatility and proneness to environmental change, wine regions are generally considered a good case for studying the impacts of agricultural change (Hannah et al 2013).

The Mosel region stands as an example of cool climate wine growth conditions of which similar can be found in other regions of the world such as New Zealand’s Marlborough region, Canada’s Nova Scotia or Champagne in France. The challenged foundation of cultivating grapes in the Mosel region as a backdrop promises to show whether innovative practices of agroforestry and FRV cultivation can succeed in mitigating current and future challenges to the sector. The region's distinct geographical traits together with the researched wine producers' experience make for a focal point in viticultural and sustainability research where practices of cultivation are applied to an area that is under stronger pressure of innovation compared to wine regions where flat terrain makes for easier maintenance and adaptation. Further, research results from indicative regions like the Mosel yield the potential to be applicable to other wine regions and their climate change affected production.

Organic farming in the Mosel region emerged in the 1980s when first vintners started to associate signs of bodily illness with themselves to pesticides they were applying in the vineyards (see Chapter 4, 5 & 6). Subsequently opting for different managing practices, associations for ecologic production of wine were formed and grew to a yet small fraction (e.g. around 33 farms in the largest association *Ecovin* (ECOVIN 2023)) compared to the overall number of around 2850 vintners in the region (Moselwein e.V. 2023). Though conventional wine producers also claim to pursue sustainable farming methods, the overall approach of conventional wine production has to be separated from the sustainability definition in this research on viticulture as valuing profit increases over sustainability. Especially given the absence of sustainability certification comprising regular governmental control and the allowed use of mineral fertilizer and pesticides render sustainability claims in conventional viticulture out of scope for this research.

As such, certified organic viticulture is identified as a focal sector to research agricultural innovation. That is because its products are being globally produced and sought after while its productive patterns are especially prone to environmental change yet consuming a large quantity of pesticides compared to its global planted area. Certified organic and biodynamic farming are regarded as means of sustainable viticulture and are researched regarding their sustainability development towards agricultural forms of production in which resources are maintained and the economy is being carried out responsibly with respect to current and future generations. Agroforestry and FRVs in viticulture are accordingly studied as sustainability practices delimiting current patterns of viticultural production with the potential to lever sustainability transformations in organic viticulture and beyond (Wilson & Lovell 2016, Pedneault & Provost 2016). Thus, applying a regional scope, this dissertation aims at deepening the understanding of sustainability and sustainable development in organic wine production in the Mosel region as an emblematic German wine-producing region. The special geography and economic structure of the region lead to the position of smallholder farms with distinct transformational potential, the use of which and the potential to be part of a sustainable viticulture future will be researched in this work.

Sustainability in the wine sector, comprising the production and distribution of wine products, is a field prone to discourses on how to produce and sell products that are not only being globally sought after as a high-value product, but which are also representing status, identification and tradition to consumers and locals. The conditions under which viticulture takes place are everchanging and currently affected by climate change as a factor touching on the very foundations of viticulture. Changing the microclimates and foremost typical regional traits that locally produced wine is known for, drives farmers and policy makers towards innovations that aim at preserving and adapting local conditions and ways of production. Further, the overall change in international trade relations is affecting the wine sector, also influencing producers mindsets on innovating production patterns. Given the increased demand for environmentally sound and sustainably produced wine, thus laying the necessity for change to sustainable practice in viticulture as a base for this dissertation, the papers entailed are investigating innovative developments in sustainable organic wine production that are aimed at mitigating challenges arising from climate change and altering conditions on global markets, set to improve the understanding of sustainability in wine production and distribution with a focus on the German Mosel region.

After a review on literature from different academic fields on the topics of regional economy, sustainable viticulture, wine trade and history, the research design was developed relying on different theories from the field of sustainability research. The different concepts of leverage points, ecosystem services and alternative food networks were found to be most suitable for the analysis. This is because the different concepts allow for a nuanced understanding of sustainability practices via different perspectives within the numerous layers of wine production, marketing and distribution. The concept of leverage points was added to the approach in order to trace developments of sustainability transformation within the farms ways of production, linked to their production networks. Further the concept allows for a systems thinking approach, enabling the consideration of the impact of the researched sustainability practices in a wider context. The ecosystem services theory adds to that in building an understanding of services obtained from ecologic processes in viticulture which provide value for human production and consumption. The theory on alternative food networks acts as an economic foundation which is able to look at the make use of ecosystem services provided in food systems which are characterized by niche development of

sustainability practices. Alternative food networks further were considered, to assess the economic effects sustainable practices have on wine as the central product driving the food production system.

Viticulture on a Global Scale, in Germany and the Mosel region

Starting from a global perspective on wine production, currently, Spain presides global viticulture with the largest vineyard surface area, followed by France and China. While Spain, France, Italy, Portugal, and Germany have long been revered for their wine production, they are now joined by growing and competing countries from outside Europe. These newcomers, such as China, Turkey, Iran, and India are gaining increased recognition which is often attributed to their growing middle-class societies and valuable export business.

In India especially, regions such as Nashik and the Nandi Hills have become renowned for their production of white and sparkling wines. Meanwhile, China's Ningxia, Xinjiang, and Shandong have emerged as major wine-growing areas as well, catering to both domestic and international markets. Turkey, with its long-standing tradition of winemaking, has revitalized its industry by focusing on indigenous grape varieties and producing high-quality wines in regions like Thrace and Anatolia. The muslim countries Turkey, Algeria, Iran, Afghanistan, and Egypt besides producing grapes for wine production also focus on table grapes and raisins production. Wine production in these countries mainly exists due to having non-Muslim populations, catering to international markets, promoting tourism and having historical and cultural ties to winemaking that predate the introduction of Islam. Additionally, some Muslim-majority countries allow the production and consumption of alcoholic beverages within certain legal frameworks or for non-Muslim communities.

Figure 3.1 below shows a listing of the Top 25 wine growing countries by vineyard surface area in kilohectare and their share of the global vineyard area in percentage. The list indicates that the traditional European dominance in world wine growing has been replaced by a mix of traditional wine producing countries and emerging competitors.

Figure 3.1: Top 25 wine growing countries by vineyard surface area in kha and percentage.

Country	kha	%
1. Spain	964	10.86%
2. France	798	8.99%
3. China	783	8.81%
4. Italy	718	8.09%
5. Turkey	419	4.72%
6. USA	400	4.51%
7. Argentina	211	2.38%
8. Chile	210	2.36%
9. Portugal	194	2.18%
10. Romania	189	2.13%
11. Iran	170	1.91%
12. India	151	1.70%
13. Australia	146	1.64%
14. Moldova	138	1.55%
15. South Africa	126	1.42%
16. Uzbekistan	112	1.26%
17. Greece	109	1.23%
18. Germany	103	1.16%
19. Afghanistan	100	1.13%
20. Russia	98	1.10%
21. Brazil	81	0.91%
22. Egypt	77	0.87%
23. Algeria	75	0.84%
24. Bulgaria	66	0.74%
25. Hungary	64	0.72%
Other Countries	826	9.30%

Source: OIV (2021).

Yet, apart from a prevailing European dominance in production in terms of vineyard area and output (OIV 2023), China's immense growth in vineyard area, and new plantations in South and North America, Africa and Australia indicate an expansive global development of viticulture in which every continent partakes in the global production and consumption of wine. Currently, the top consuming nation in wine is the USA (OIV 2021), followed by France, Italy and Germany. With the latter three being European countries, Europe is mostly regarded as the nucleus for large scale wine production and still today remains at the top with Spain and France taking up the largest shares of the global viticultural area (OIV 2023). The challenge to sustain European wine production are generally met by applying strategies looking at increased sustainability and the production of high-quality products given the growing spatial share of wine producing nations outside of Europe.

Germany in this context represents a small-sized actor with a total vineyard area of 103.391 ha in 2022 (Statsistisches Bundesamt II 2023), which as a producer is specialized in cool-climate wine production at the border of the northern hemisphere's vine belt (see Figure 1.1). Taking up around 1.4% of the global vineyard surface area, Germany's viticultural area size is comparable to that of Greece (96.000 ha), Moldova (122.000 ha) or South Africa (126.000 ha) (OIV 2023). Comprising 13 wine regions in total, especially in the southern and central states of Germany, there are wine-growing regions with traditional viticulture. The warmer climate in these regions make wine production particularly successful, despite their location in a cool-climate area (Anderson 2017). In 2020, the largest wine-growing regions in Germany by area size were Rheinhessen (26.900 ha), Pfalz (23.700 ha), Baden (15.800 ha), and Württemberg (11.400 ha) (Statistisches Bundesamt 2023).

Figure 3.2: The 13 German wine regions by vineyard area in kha.

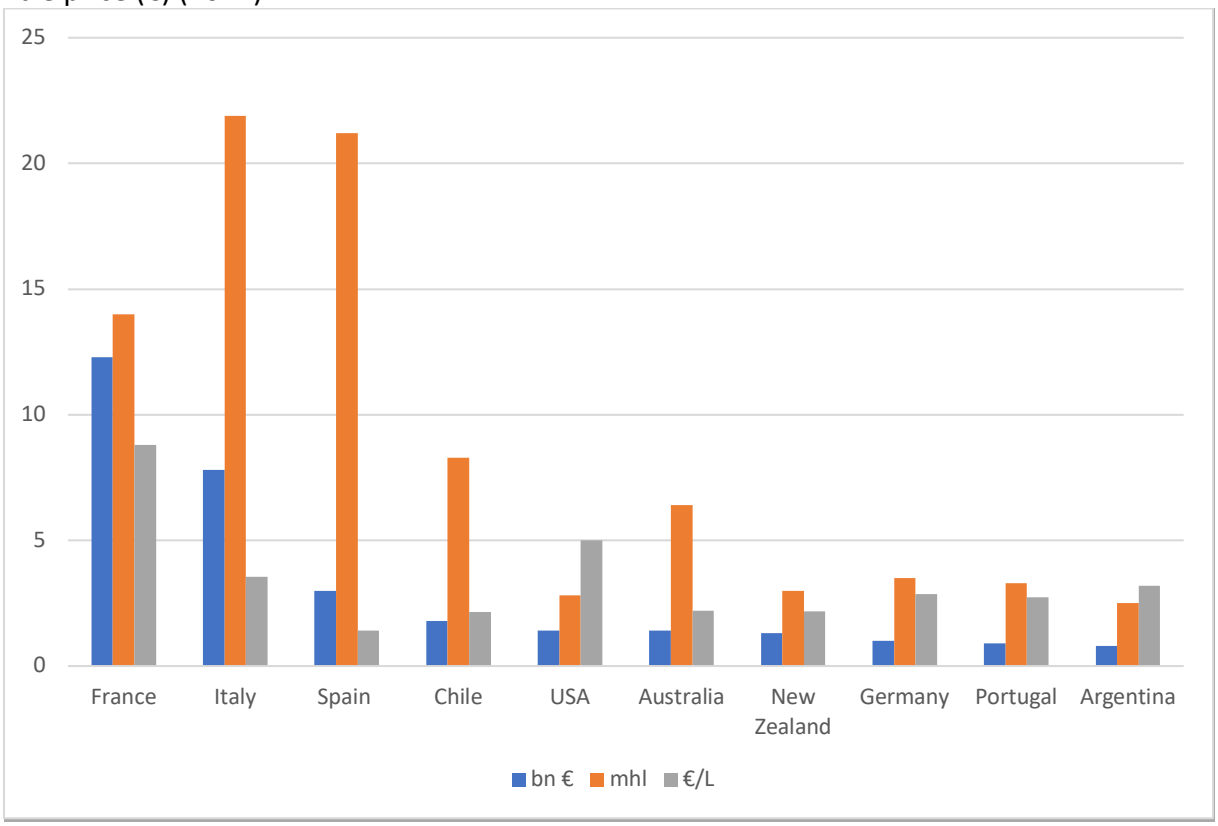
Region (*Ger.*)	**Vineyard area in kha**
Rheinhessen	26,9
Palatinate (*Pfalz*)	23,7
Baden	15,8
Württemberg	11,4
Mosel	8,7
Franconia (*Franken*)	6,2
Nahe	4,2
Rheingau	3,2
Saale-Unstrut	0,8
Ahr	0,6
Saxony (*Sachsen*)	0,5
Mittelrhein	0,5
Hessische Bergstraße	0,5

Source: Statistisches Bundesamt (2023).

Predominantly engaged with the production of wine from white grape varieties (e.g. Riesling, Rivaner, Pinot Gris etc.), the white Riesling accounted for about one-fourth of the total vineyard area in Germany in 2022 (Statistisches Bundesamt II 2023). Internationally significant grape varieties such as Chardonnay and Sauvignon Blanc (both white) as well as Merlot and Cabernet Sauvignon (both red) are successively cultivated as well. Riesling, also reflected in its share of cultivational area, is the variety for which Germany is best known with regard to export markets. While in the international context the German vineyard area is rather small,

the export value and volume stemming from German viticulture is considerable, putting Germany in the top 10 of the most valuable wine exporting countries worldwide. For orientation, the figure below displays Germany in 8th position by total value of produce, producing 3,5 million hectolitres of wine for exports with a value of about 1 bn € in 2022. The price of about 2,86 € per litre of exported wine puts Germany in the 5th position between Argentina and Portugal.

Figure 3.3: Top 10 countries sorted by export value (bn €) with production volume (mhl) and litre price (€) (2022).



Source: OIV (2023) & datamarnews.

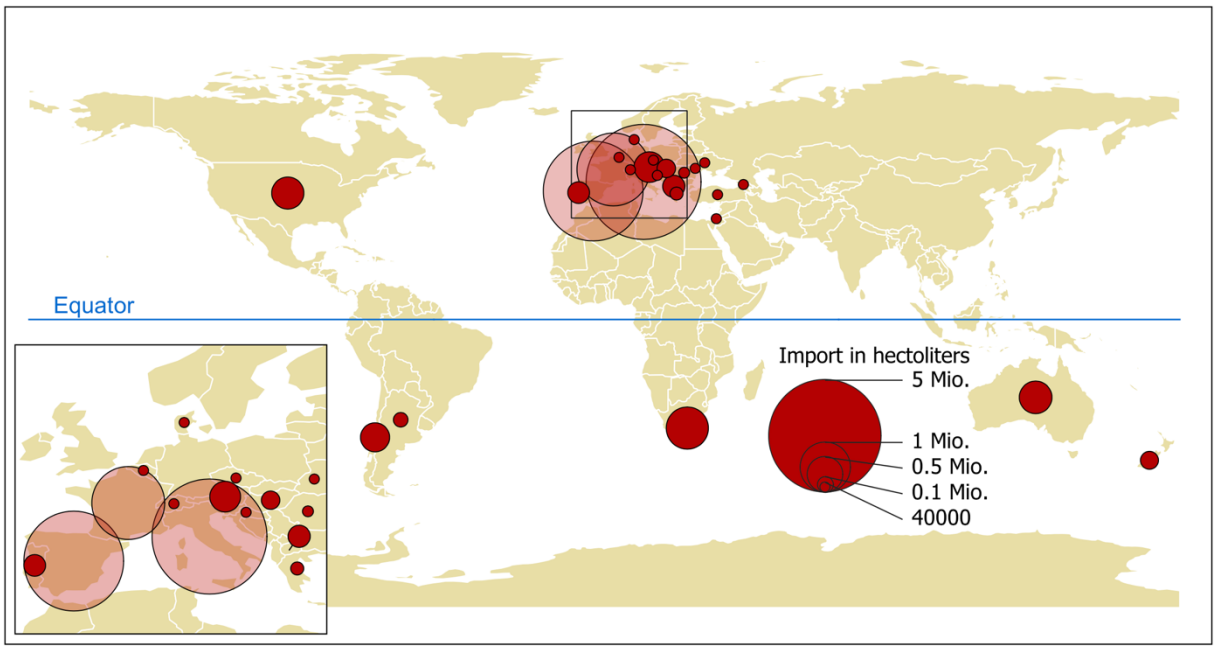
The largest growing export markets for German wine are the U.S.A., United Kingdom and the Scandinavian Countries (Deutsches Weininstitut 2023). While Germany remains small in terms of vineyard area, the value of German wine reflects in high quality products with about 83% of export still and sparkling wines being sold in bottles, while other high value export countries like New Zealand (41%) and Australia (58%) heavily rely on bulk qualities (OIV 2023 II, p. 15).

Today's status quo of Germany in global wine trade can be attributed to the developments of the 20th century following the second world war. Throughout the 1950's and 60's the German

wine industry faced the task of rebuilding and re-establishing itself. Riesling, with its distinctive character, played a crucial role in attracting attention and establishing Germany as a producer of high-quality wines. In the 1970s and 1980s the industry underwent a quality development, shifting away from the mass production of inexpensive wines towards a more quality-focused approach. This involved improvements in vineyard management, reduced yields, and a renewed emphasis on terroir-driven wines. In the 1990s and 2000s, German wine exports continued to expand, with a growing emphasis on diversifying export markets. While traditional European destinations remained crucial, Germany actively pursued opportunities in emerging wine markets globally. Asian markets, such as China and Japan, became increasingly important for German wine exports due to rising affluence and evolving consumer preferences.

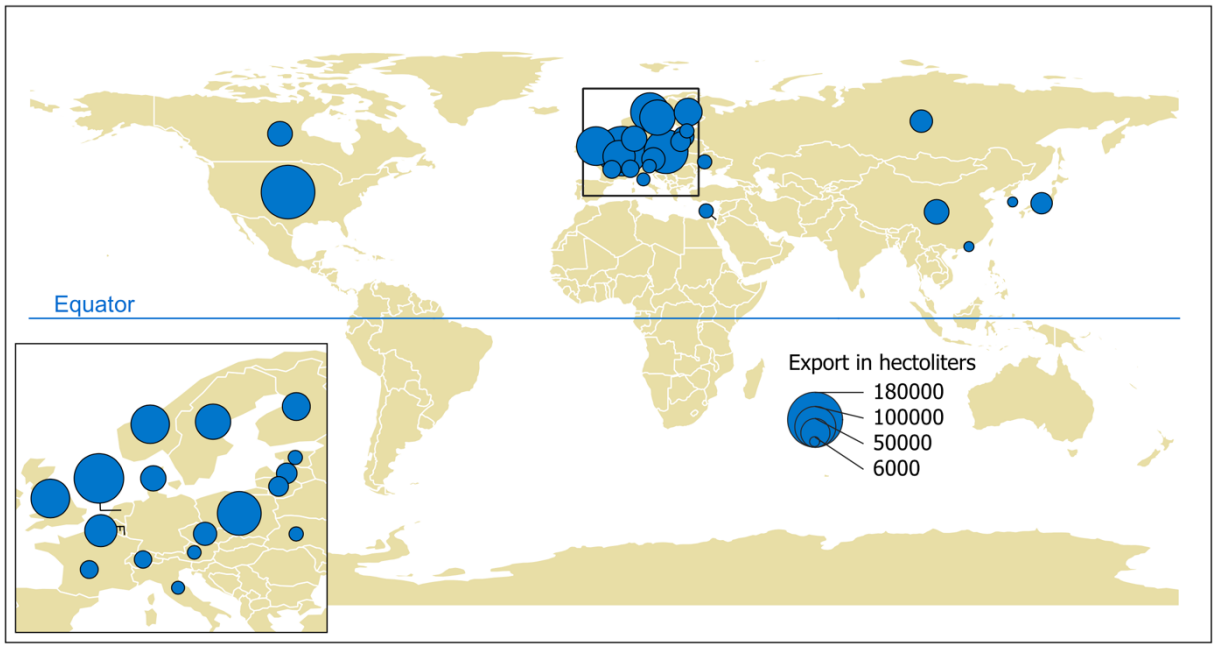
In recent years, German wine exports have maintained their growth trajectory. Thus, Germany's wine import and export play a vital role in the global wine market today. As an importer, Germany brings in wines from various countries to offer consumers a diverse selection. Notably, the Riesling holds a prominent position in the global wine trade. Additionally, German wine regions attract tourists, supporting wine tourism and further promoting German wines globally. Germany’s 25 largest wine export and import countries by volume in the year 2021 can be seen in the figures below.

Figure 3.4: Top 25 wine Import sources for Germany (2021).



Source: Deutsches Weininstitut (2023). Cartography by C. Enderle.

Figure 3.5: Top 25 Export markets for German wine (2021).



Source: Deutsches Weininstitut (2023). Cartography by C. Enderle.

Thus overall Germany appears as a small-sized wine producing country specialized in cool-climate viticulture, focused on producing white grape varieties with a growing amount of red varieties. The production is generally focused on producing high quality, bottled wines that are being exported with international success. The German wine production, despite the considerable export value, remains challenged given that climate change alters the fundamental conditions of cool climate viticulture with rising average temperatures alongside the prevalent natural degradation and pesticide use in vineyard management. As indicated above, conventional viticulture increasingly becomes contested due to rising societal awareness and negative effects for production itself. The rise of consumer demand and institutional effort in Germany towards sustainably produced wine consequently involve actors that are seeking to deviate negative impacts on the sector in conjunction with sustainable development (e.g. see Mariani & Vastola 2015).

While the overall German vineyard area follows the European trend in expanding slowly, the concentration of land and decreasing number of farms producing in Germany is changing in that larger farms prosper while the number of small wine-producing farms decreases (BMEL I 2022). This holds especially true for the southwestern state of Rhineland Palatinate which accounts for more than 62% of the German vineyard area, making the area a hotspot for German wine production (BMEL I 2022). The state in which the Mosel region is situated further comprises the winegrowing regions *Rheinhessen*, *Pfalz*, *Nahe*, *Ahr* and *Mittelrhein*. Figure 3.6 below displays the state if Rhineland-Palatinate including the 6 wine regions.

The high abundance of wine regions in this Germanstate can be attributed to several reasons: Rhineland-Palatinate benefits from a geographically favourable location for viticulture. Its proximity to the Rhine River and its tributaries, such as the Mosel, ensures ample water supply for vineyards and excellent soil drainage. The wine-growing regions in Rhineland-Palatinate enjoy a temperate climate with mild temperatures and sufficient rainfall. The region is influenced by the Atlantic Ocean, which serves for carrying rain and creating relatively mild weather conditions. Further Rhineland-Palatinate boasts a diverse range of soil types suitable for growing different grape varieties. The soils range from limestone and clay soils to slate and loess soils. This diversity allows winemakers to produce a variety of wine styles and flavor profiles.

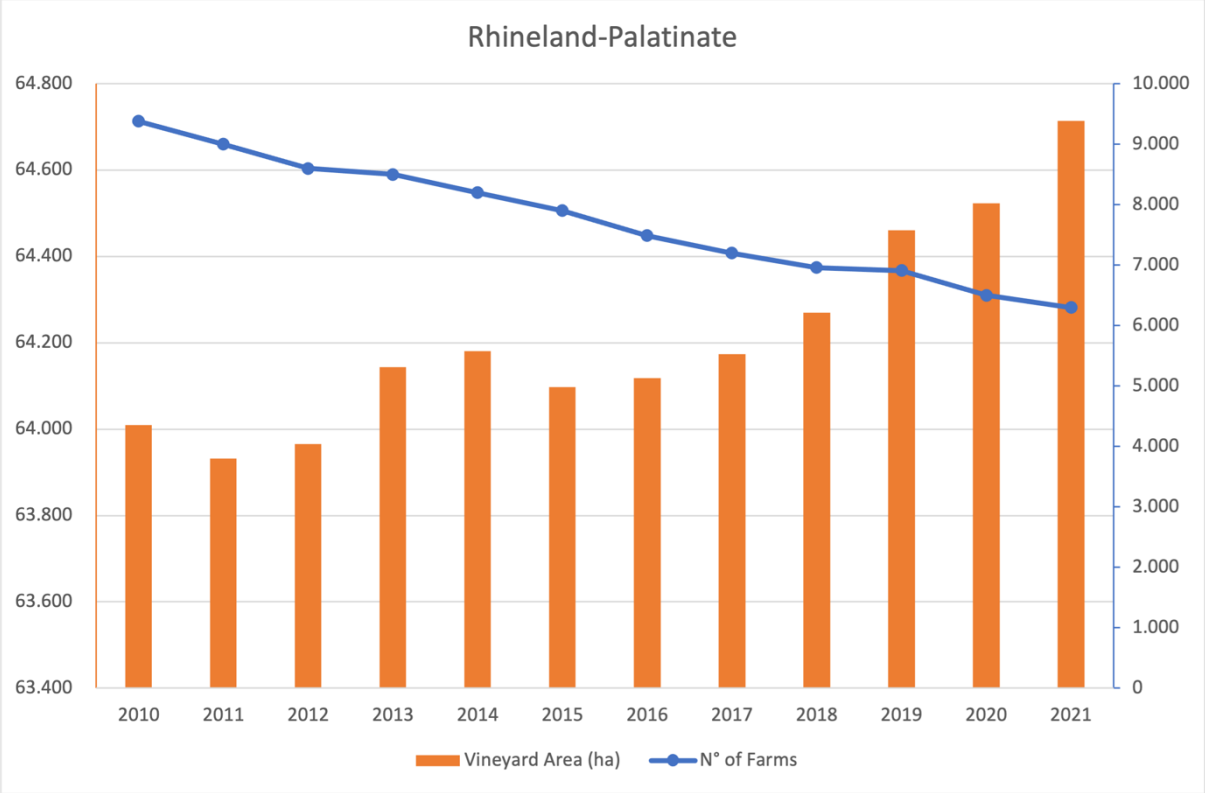
Figure 3.6: Rhineland-Palatinate's wine regions and position in Germany.

Weinbaugebiete: Web Feature Service Landwirtschaftskammer Rheinland-Pfalz. Weinlagen. 2023 (dl-de-by-2.0 - Datenlizenz Deutschland Namensnennung 2.0)
Basiskarte: © GeoBasis-DE / BKG 2021, modified.

Cartography by C. Enderle.

As indicated above, the overall structural trend in German wine production is also prevalent in the Rhineland-Palatinate wine sector with a concentration of landownership entailing a slow-growing vineyard area and a declining number of farms carrying out viticulture. Figure 3.7 below displays the same trend of land concentration for Germany's top producing state of Rhineland-Palatinate between 2010 and 2021. The N° of farms displayed in the figure drops in the period from around 9500 to just above 6000 farms in 2021, while the vineyard area only expands slightly with an accumulated vineyard area growing from around 64.000 ha to 64.700 ha.

Figure 3.7: Development of vineyard area and farms in Rhineland-Palatinate (2010-2021).



Source: BMEL I 2022.

The Mosel region within Rhineland-Palatinate stands out among the 13 German wine regions especially because of its long tradition of human settlement accompanied by viticulture, e.g. with the oldest German City of Trier and large-scale winemaking reaching back into Roman times (Gilles 2001). The region makes for an interesting case to study sustainable viticultural practice given its steep terrain with slate-dominated soils which in order to produce the region's typical wines demand more intensive and work compared to other German regions

that are predominantly flat. While the two largest winegrowing regions Rheinhessen (2,57 m. hl) and Pfalz (1,75 m. hl) make for the highest output, the Mosel Region already comes in third place (1,35 m. hl) (Statistisches Bundesamt 2022), not least because the angled vineyard slopes allow for a higher density of planted vines per hectare, but the intense work in the parcels oftentimes results in grape yields of high quality and quantity as well. The working force carrying out the physical demanding tasks on and off the vineyard consist of around a third of family members while more than half is made up of seasonal workers (BMEL II 2022). Given the position of viticulture as an already indicative field of agricultural change (Hannah et al 2013), the Mosel's extraordinary conditions of steep slope viticulture in a predominantly cool climate wine region render the region's susceptibility to climate and agricultural change a great basis to research sustainability practices aimed at maintaining wine production under challenged conditions.

Thus, research was carried out in early 2022 in the German Mosel region. This region was found most suitable for the research because of three aspects: *First*, the region's geography, situated on the northern border of commercial wine regions both in Germany and the world, the region is known for its steep sloped river valleys of the Mosel, Saar and Ruwer rivers. The wine region is moderate in vineyard area size compared to other German wine regions (see Figure 3.2), while ranging at the top end of production in terms of quality, quantity and reputation. The steep riverbanks of the region are shaping everyday production by requiring manual labour and intensive work in the vineyards. Compared to other German wine regions, the distinct trait of steepness embedded the Mosel region on the intensive end of the workability scale, whereas compared to flat regions like Palatinate or Rheingau, large-scale mechanization and automatization of vineyard management processes are hardly possible, rendering adaptations of workflows and techniques necessary because changing climate conditions already showed substantial impact earlier then in regions whose vineyards are comparably easy to maintain. While these conditions put bigger innovation pressure on farmers, techniques that are tested under these conditions can be considered for their innovation potential in comparable regions with easier vineyard conditions. *Second*, the region's main grape variety Riesling is a German standard variety that represents a well-known product for international trade. Wines from the Mosel are especially popular in North American, Scandinavian and Asian markets for exports and are well sought after on regional

and national scales. The researched innovations are thus also evaluated for shaping the wine production future-ready with regard to the main driving varieties on the market. *Third*, the geographical traits and conditions of production are driving farmers who already practice sustainable viticulture in successively aggravated conditions towards sustainability practices that veer from sustainable mainstream via already existent applications of agroforestry and fungus resistant grape varieties.

Qualitative Data Collection and Analysis

The discussion on methods in empirical social sciences is traditionally split into quantitative and qualitative approaches that differ substantially in the way data on social phenomena is being collected, processed and analysed. Tuli (2010) differentiates the qualitative and quantitative position by different underlying paradigms regarding ontology, epistemology and methodology, dividing researchers into either positivist or interpretivist-constructivist. The traditional positivist approach regards the social sciences as largely similar to the natural sciences and sets the goal of social research as to discover laws in human behaviour (Tuli 2010 p. 99). The underlying ontology, the way of perceiving reality, here is that the social reality exists largely decoupled from individual dynamics and that the social reality is stable whilst knowledge of it can be viewed as additive (Tuli 2010, Marczyk et al 2005, Crotty 1998). To research social phenomena, positivist research predominantly engages quantitative methods of research such as statistical analysis, e.g. multivariate statistics and null hypothesis testing as the tools of analysis pursuing to research a quantifiable reality. Also apparent in the type of research question, positivist research agendas tend to ask for the `what?` related to the research topic, whereas interpretivist-constructivists who are following a qualitative agenda tend to try and answer the 'how' and 'why' of a researched case. Qualitative research is thus not concerned with statistical representativity, but with the deepening and understanding of a problem that cannot be quantified (Queirós et al 2017).

The ontological position here sees an entanglement of individual dynamics as crucial for the emergence of larger social interrelations. Methods of collecting data on such interrelations in qualitative research are thus manifold and comprise participatory research, focus groups, review of data from literature, archives and media documents as well as qualitative interviews. These different methods are requiring different skills in the researcher and are

further differently well suited to respond to specific research questions. Since the research of this dissertation was occupied with investigating farmers' experience with innovative farming practices in viticulture, a qualitative narrative approach was chosen over participatory and observing methods in order to gain insight into the practitioners' understanding of sustainable farming. Visiting farmers on their farms for interviews and spending extensive time before and after the interview made for a comfortable setting to gather extensive information on their everyday farming practice and experience.

The method of grounded theory applied in this dissertation comprised a workflow in which the empirical data was first gathered based on a thematically broad interview guideline. A total of 19 qualitative Interviews was conducted, using a semi-structured interview guideline (see Appendix). Topics that were covered in the interview guideline regarded information on the winery, development of agricultural land, organization of the production process, inputs, marketing and distribution of final products as well as questions on the benefits and challenges regarding the use of innovative farming practices such as agroforestry systems and fungus resistant grape varieties. All interviews were conducted on owner-operated farms in early 2022 and were lasting between 45 minutes and 2 hours each.

After recording the interviews, the spoken words were transcribed, coded and analysed using MAXQDA Software which created a coding system of 7 first-level (e.g., Production, Distribution), 51 second-level (e.g., Vineyard, Spatial Development) and 39 third-level codes (e.g., Export Countries, Grape Varieties) with a sum of 987 codes (see Appendix). While reviewing and processing the qualitative data, categories were built from the coding system and thematic focuses were identified. The thematic blocks then served as a basis on which the concepts for the research papers were built. The topical theory was chosen according to the thematic foci from the qualitative data. The translation of the interview quotes has been moderated through triangulation.

Overview of Interview Partners

The Interview Partners were selected after a thorough review of the Mosel regions viticultural structure. Relying on organic farmers associations members lists, farmers were contacted directly via mail and phone. Resulting in the scheduling of appointments for qualitative Interviews and contact recommendations to other farmers using agroforestry, fungus resistant varieties etc. The interviewees were granted anonymity; thus the following characterization follows an anonymized numeration.

Farm 1 was a farm comprising 6 ha of vineyards in the Mosel region. The farm had a wide grape variety, with a comparably low Riesling share of 40%, followed by pinot varieties, Rivaner and several white and red fungus resistant varieties. <90% of sales took place via direct marketing. The farm produced certified organic wine since 2003 and the owner introduced an own bottle deposit system in order to reduce packaging costs and reduce waste. Regionally unusual, most of the parcels were flat, thus mechanization in the vineyard maintenance was high.

Farm 2 was the farm with the biggest vineyard area covering 80 ha throughout several municipalities on the Mosel river. With 98% Riesling and 2% Pinot Blanc, the farm was running a highly specialized production in premium parcels including an extended amount of manual labour relying on seasonal workforces. The farm had over 200 years of viticultural history and exports 80% of its produce, mainly to North America and Asia.

Farm 3 was a biodynamic farm with 3 ha of vineyards that were exclusively managed by family members. The farm had more than 40 years of experience with certified biodynamic farming. The share of grape varieties was typical for the region with 90% Riesling and 10% Pinot Noir. The farm's wine was well known internationally, especially in the biodynamic niche. Thus the majority of produce (90%) was sold in international export.

Farm 4's 1,2 ha parcels were solely worked by the farm owner who had two generations of winemakers in his family. The farm was one of the earliest in the region to start organic production in the 1980s and employed 90% direct marketing and local self-delivery for

product distribution. 80% of the planted area comprised Riesling and the farm had one of the oldest FRV (Johanniter) parcels in the region.

Farm 5 was led by the farm owner and managed under organic certification together with 7 employees. The farm's vineyard area was 12 ha with additional 3 ha being planted for agroforestry purposes. The farm engaged in agroforestry with combined plantations of vines, trees and the implementation of sheep grazing in the vineyards. The owner had an international education in viticulture and focused on export business, mainly to North America. Apart from 70% Riesling, the farm had a diverse repertoire of red and white FRVs and put an emphasis on traditional winemaking methods like spontaneous fermentation. The farms had the longest heritage in this research with the oldest evidence stemming from the mid 9th century.

Farm 6 was a 12-ha certified biodynamic farm. The owner held a technician degree and since taking over the farm in the 1990s profoundly changed the predominant production regime from conventional to biodynamic, significantly increasing the production of wines with high added value. Apart from employing silvopastoral viticulture with an own goat herd, an unusual storing strategy allowed for 4 different vintages to be stored simultaneously, which made the farm's product repertoire more resilient to bad vintages. More than 70% of the produce was being sold in international exports. 95% of the planted area was Riesling and 5% white FRV (Sauvignac).

Farm 7 was run by a couple that transitioned to organic production 20 years ago. They worked an aggregated area of 11 ha together with 2 employees and family members. The farm specialized in FRV varieties and the owner couple regularly took part in international conferences and excursions on the topic. 60% of sales were made via their own online shop, 30% were being sold in direct marketing and the rest 10% were being sold to retail and local gastronomy.

Farm 8 was an over 370-year-old farm that was producing under organic certification since 2012. The farm’s 6 ha of vineyards comprised over 90% Riesling and a small share of pinot noir. 60% of the wine was sold via direct marketing and 30% to supermarkets. The farm

produced solely with spontaneous fermentation and had a large consumer basis in northern Germany.

Farm 9 was run by a family of 3 adult children and their father. The farm was producing under organic certification and had currently been in transition to biodynamic production. The farm included a small agroforestry plot with intercropping of vines, trees, herbs and shrubs. The farm also integrated grazing livestock into their vineyards. The 3 ha are planted with 60% Riesling, 20% Pinot Noir and other varieties were being marketed as direct sales (80%) and retail and gastronomy (20%).

Farm 10's owner held a degree in viticulture and ran the farm together with his retired parents and 4-6 seasonal workers. The 12 ha of vineyards parcels comprised 60% Riesling, 20% Pinot Noir and 20% FRVs. The farm had a comparably high degree of mechanization in that the majority of vineyards could be maintained by a tractor. The sales were dominated by international exports to North America and Asia, followed by direct marketing, gastronomy and retail. The owner strongly adhered to sustainable thought and practiced intermediate greening with extensive herb plantations in the vineyard in order to enrich the local biodiversity and provide for bees.

Farm 11 was led by the owner in the 4th generation. After graduating with a technician's degree and taking over the farm, the owner quickly focused on the transition to organic production. The farm's sales were focused on local gastronomy and direct sales. The majority of production came from Riesling (90%) which was regularly awarded in wine competitions which made up the lion’s share of marketing. The farm's income was secured and diversified by several apartments adjacent to the farm used for tourist accommodation which led to perpetuated sales relations.

Farm 12 was run by a couple of whom both had academic backgrounds in agriculture. 90% of the farm's vineyards were steep slopes, thus a lot of manual labour was required to maintain the 4 ha of parcels comprising 80% Riesling and several FRVs. The farm ran in a family tradition of over 130 years of viticulture. 80% of produce was sold in direct marketing, and 20% was sold to local retail shops.

Farm 13 had 90% of Riesling and 10% Pinot noir planted on its 7 ha parcels. The farm owner had a university education and recently took over the farm from the family in 3rd generation, The farm lately had been certified biodynamic coming from conventional production. The marketing predominantly took place via the farm's online presence and the visiting of thematic fairs. The distribution was specialised in Germany with a focus on private consumers, 20% of the produce was sold to gastronomy.

Farm 14's owning father and son were engaged in the local viticulture association and focused on producing Riesling. Thus their grape varieties share consisted of over 99% Riesling, with a small fraction of Sauvignon Blanc that came from an agroforestry site, the management of which rotated within the local municipalities' viticulture association. The farm's production was characterized by efforts of waste reduction and renewable energy, e.g. resulting in selling bottles without plastic capsule covers and engaging in photovoltaic energy production.

Farm 15 consisted of 8.5 ha, 80% Riesling, 10% Pinot Blanc and 10% regionally atypical varieties like Traminer or Sauvignon Blanc. The farm was led by a middle-aged family father who took over the farm migrating his business from a neighbouring village. The farm produced in close proximity to organic certification, yet the owner was hesitant as to the pesticidal restrictions that come with certification. The sales relied 100% on direct marketing.

Farm 16 was a 3-ha farm, run by father and daughter who recently transitioned to certified biodynamic production. 95% of the produce was marketed through self-delivery mainly to regional customers and within Germany. Riesling as the main Variety (60%) was being accompanied by 20% FRVs, Pinot Blanc and Rivaner. The farm employed silvopastoral viticulture by letting sheep graze in one of their vineyards.

Farm 17 was a 10-ha farm that partook in agroforestry winemaking on a site consisting of Riesling intercropped with oak (*Quercus*) and poplar (*Populus*). The owning farmer had 260+ years of viticultural tradition in the family, originating from a mixed farm until the 1970s. Now specializing in wine and spirit production from local orchards the farmer was working on handing over the business to the next generation.

Farm 18 was a 25-ha farm planted with 90% Riesling and 10% Pinot Noir. A pending forestry area of several hundred ha was leased out. The marketing of the wine was spread in equal parts across direct marketing, export and local retail.

Farm 19 was a 23-ha farm that was being led by a young couple who just took over the business from the parental generation. The marketing of wine was spread equally across direct sales, international exports, catering industry and retail, while the couple wanted to put the focus on direct sales and enforce organic production cycles. The farm also engaged with agroforestry, managing a vineyard with intercropped vines and trees.

Aims & Objective of the Dissertation

Focussing on the German Mosel region, this dissertation pursues an explorative approach to research sustainability practices and development in regional viticulture and adds to the overall landscape in geographical research on agricultural phenomena and sustainability. As empirical examples, this research investigates the innovative agricultural practices of agroforestry and fungus resistant grape varieties in viticulture carried out by the Mosel region's farmers. Further, this dissertation's research seeks to understand how these practices shape and alter the predominant ways of production, what role different actors play in the formation of value activity and how the innovative practices lead to sustainability transformation in and beyond production in assessing value activities and markets. Considering the theoretical framework of this dissertation, the leverage points for sustainability transformation perspective serves for a systemic approach to thinking on transformative change in food production systems such as the viticultural sector. The perspective of ecosystem services allows for an assessment of the profits obtained due to the interaction of ecosystems with humans and among each other. Finally alternative food networks supply a theoretical frame to investigate the economic structure in which sustainability practices, transformative changes and ecosystem services in regional viticulture are situated. The overall theoretical contribution of the research papers lies in the demonstration of applicability of the theory on sustainability practices in regional viticulture. The theories are developed further by demonstrating their practicability in describing niche developments and their potential with regard to indicating areas of sustainability transformation.

The leading research questions therefore are:

1) Why do farmers implement innovative practices in sustainable viticulture?

2) How do agroforestry practices affect sustainable viticulture in the context of environmental and economic challenges?

3) Do niche developments in sustainable viticulture provide potential to pioneering new mainstream methods in the sector?

Paper Overview

The following three chapters present one of the research papers each which have been published or submitted for publication by a scientific journal. The three papers are based on the data collected in early 2022.

The first paper focused on climate change mitigation practices via the application of agroforestry in the viticultural landscape of the Mosel region. Considering the notion of leverage points for sustainability transformation the paper investigated points of deep leverage in the researched farms and discussed the production aspects. Challenges and benefits of agroforestry in viticulture were investigated as well as the marketing of agroforestry wine. Future challenges regarding the implementation of trees in viticulture as a sustainability practice to mitigate the negative effects of climate change on viticulture were considered as well.

The second paper researched the role of ecosystem services in silvopastoral viticulture. The farmers experience with producing wine from silvopastoral agroforestry systems, including sheep, goats and small bovine, were linked to ecosystem service theory. The analysis indicated that the use of livestock in vineyards yields the potential to improve organic viticultural production substantially. The use of livestock in the vineyards showed to raise the overall resilience of the vineyard to environmental hazards such as erosion. The overall lifted environmental richness further increased the product quality, while the livestock also produced additional produce which diversified the farmers' product portfolios.

The third paper reviewed the phenomenon of fungus resistant grape variety (FRV) application in sustainable viticulture. FRVs were researched as elements of the production system supporting alternative food networks in which the farmers veering from mainstream conventional viticulture engaged to stabilize and sustain their production. The paper concludes that alternative food networks entailing short food supply chains work in conjunction with FRVs in establishing the new varieties as viable alternatives with significantly reduced environmental impact, further facilitating the application of silvopastoral viticulture, for the absence of pesticides creates safe livestock farming conditions.

4. Agroforestry Systems in Wine Production - Mitigating Climate Change in the Mosel Region

Nicklas Riekötter and Markus Hassler

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Abstract: As Climate Change starts to show substantial impact on viticulture, winemakers are under pressure to implement sustainability transformation to maintain future production. This article deals with the effects of agroforestry system use on wine production and marketing in the German Mosel Region and reviews its challenges and benefits regarding sustainability transformation. The study is based upon qualitative interviews and field visits, researching farmers' experiences with an agroforestry vineyard in the cool climate wine growing region and reviewing the production methods on-site. Applying Sustainability Levers Theory, the article shows that the use of agroforestry in viticulture targets deep leverage points of the food production system, enabling sustainability transformation by providing positive effects on production and marketing. The article thus concludes that there's a potential of mitigating challenges of climate change, sustaining the wine production due to the implementation of agroforestry.

Keywords: agroforestry; cool climate viticulture; sustainability transformation; climate change; Mosel; wine

4.1 Introduction

Viticulture has millennia of history from roots in the middle east [1] (p. 26) spreading to today's expansion across every continent of the globe. Around two thousand years before now, the Romans spread the cultivation of vine grapes (*Vitis vinifera*) and vineyard work across their European Empire throughout Central Europe until the border of Germania Magna on the Rhine. The first Europeans to step foot on the American Continent in the 10th century allegedly called it *Vinland* after finding wild fruits growing in the forests [2]. The climate of both the landing area of Leif Ericsson in today's Canada and the German Rhineland region is what today we consider a cool climate region for wine growing [3] (p. 4), with average temperatures that are significantly lower than those Mediterranean conditions around California, Chile, Southern Europe, or Shandong. With the Romans introducing the vine plant to Germanic soil, the Mosel region was first taken under large scale management to produce wine for supply across the roman empire [4] (p. 95). With the local cool climate conditions, they perhaps unknowingly implemented varieties that slowly adapted to the extended vegetation period, humidity and lower average temperatures of the Mosel for centuries to come. This resulted in wine grapes that have a longer ripening period and thus the ability to represent more aroma and terroir [3] adding to their popularity in cultivation. Today's science assumes that the vine plant as a wild variety originally ranked on trees following its cirrus behavior and that the people of ancient civilizations adapted this system, letting vine plants grow next to trees, using them as a climbing aid [5], forming an agroforestry system.

With the currently unprecedented changes of the 21st century to viticulture regarding climate change [6–8], agriculture in general and viticulture especially is turning their attention back towards the implementation of growing systems that integrate trees into production to help mitigate the unfortunate outcomes of current developments. Looking back on the evolution of viticulture, the combination with agroforestry, adding trees with crops or livestock to the vineyard, has been largely done in a niche. Currently however, agroforestry in viticulture has re-entered the field of attention, gaining significance in potentially making farming sustainable for future generations, mitigating outcomes of climate change.

This article deals with sustainability levers and viticulture in an agroforestry vineyard in the Mosel Region in Germany. Sustainability Levers are "places in complex systems where a small shift may lead to fundamental changes in the system as a whole" [9] (p. 30). Using the Sustainability Levers perspective helps identifying the impact of Agroforestry System use on

wine production. Thus, the goal is to review current challenges the wine- makers are facing and research the sustainability effects of agroforestry system use on wine production, as well as consequences linked to sales and distribution of the wine. The article gives insight into an agroforestry site that has been in use for over 15 years and links the experiences of multiple involved farmers to sustainability levers theory by David Abson and Donella Meadows, giving a better understanding of the potential transformational change within the food production system. The agroforestry vineyard is located near the town Ayl on the Saar River ($49^{\circ}37'43.839''$ N, $6^{\circ}33'10.761''$ E) which is part of the Mosel Wine Region. The region is known for its cool climate grape production and high-class white wines, mainly from the Riesling variety. Increasing weather extremes, changing economic relations and concerns of company succession drive the local farmers towards dealing with fundamental challenges regarding economic, ecological and social sustainability to their ways of production. The article concludes that there's a potential of mitigating the challenges and sustaining the wine production within the rediscovery of agroforestry wine growing among farmers, who are still in the process of understanding its challenges and benefits.

Research on agroforestry use in cool climate viticulture and its potential to mitigate climate change has so far scarcely been done, thus this article provides new insights into ways of coping with current challenges towards making viticulture sustainable.

4.2 Materials and Methods

In total 19 qualitative interviews with winemakers were conducted in the Mosel region using a semi structured interview guideline as part of a bigger research project concerning sustainability in wine production. The topics covered in the interview guideline consisted of general information on the winery, development of agricultural land, organization of the production process, inputs, marketing and distribution of final products as well as questions on the advantages and challenges regarding the use of agroforestry systems. 7 of the interviews were conducted with farmers implementing agroforestry into their production process, 6 of which were managing the same site in a rotary system for over 15 years, taking turns with management and wine production for one year at a time. One farm had just started the implementation of agroforestry and thus could not provide relevant experience on the production process.

All interviews were conducted on owner-operated farms in early 2022, lasting be- tween 45 min and 2 h. This provided a comfortable setting for the interviewees and allowed a visit through the farm's facilities after the interviews. Visiting wine cellars, storages and agroforestry vineyards enabled an in-depth look into the wineries and their production methods, as well as an on-site review of the given information. The inter- views were conducted in German, granting anonymization, the recorded audio was transcribed and coded with MAXQDA coding software creating a coding system of 7 first-level (e.g., Production, Distribution), 51 s-level (e.g., Vineyard, Spatial Development) and 39 third- level codes (e.g., Export Countries, Grape Varieties) with a sum of 987 codes. All interview quotes have been translated by the author.

4.3 Theory

The theory referred to in this article draws from the field of sustainability transformation research investigating the process of value creation within sustainability transformation processes [10]. The sustainability transformation of the food production system, present in the interviewees' winemaking farms, demands for a theoretical frame that can link current challenges and development to categories of different transformational potential. Through the theory of sustainability levers, we will gain a better insight into the extent that agroforestry changes the fruit production system.

Sustainability Levers describe pivotal points of intervention within a food system, to impact transformational change. Donella Meadows originally identified 12 leverage points, divided in 4 system characteristics from shallow (parameters & feedbacks) to deep (design & intent), to describe points of impact on a given system [11]. Shallow leverage points do have less potential to create profound change throughout a system yet are easier to strive for. The deeper leverage points of design and intent of the system are targeted, the more fundamental transformational change can impact the entirety of a food production system. Such deep points of leverage can be found in our empirical findings, for instance where farmers' whole production system is dependent on their choice of plant protection.

The leverage points and system characteristics displayed in Figure 4.1 shall serve as a general orientation when linking findings from the interviews to aspects of sustainability transformation.

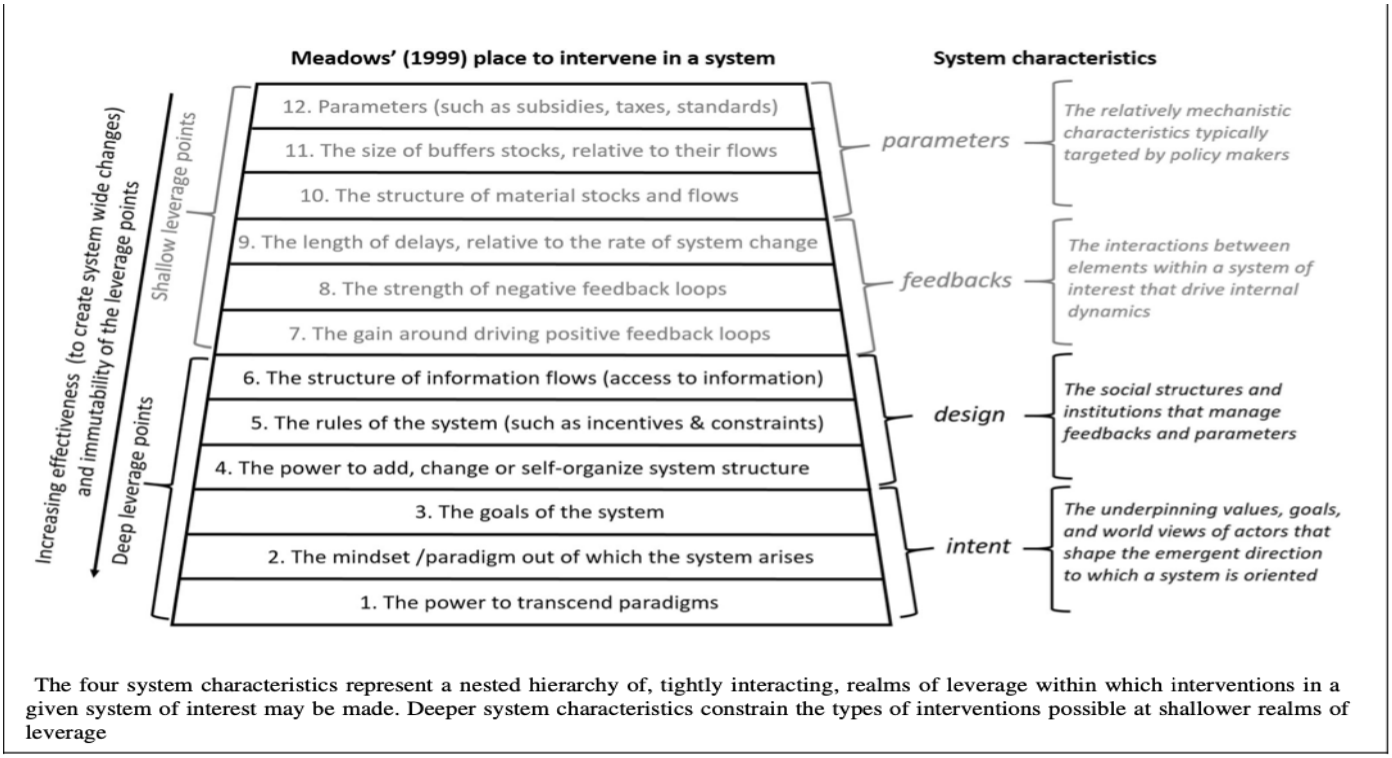

Figure 4.1: Displaying Leverage Points and System Characteristics [9] (p. 32).

Drawing on Donella Meadows` concept of sustainability levers, David Abson argues that most interventions for sustainability usually target tangible and easy to achieve goals. As mentioned in the parameters section of above's graphic, policy makers tend to prefer targeting these shallow points of leverage. Abson thus developed the notion of sustainability levers further and places the research around the three realms of "re-connecting people to nature, re-structuring institutions and re-thinking how knowledge is created and used" [9] (p. 30), representing a concept to identify deep points of leverage with high impact potential. Adding to Meadows theory, these three realms provide the ability to attribute deep transformational development to the farmers actions across the empirical findings. Applying the theory, we want to assume a more integrated perspective on the wine production with agroforestry that is taking place in the Mosel Region. Hence the following case study was conducted with qualitative Interviews, trying to understand the production process from vineyard to vinification and marketing, including the motivational genealogy of tree implementation into the vineyard. Sustainability is a term of which the definition will remain dependent on the individual winery's situation since the farmers perspective is predominant for our analysis. However, the interviewees regularly referred to the social, economic and ecological aspects

of their work, relating to the UN's Agenda 21 program resulting from the 1992 UNCED in Rio de Janeiro [12], this will be referred to as a base understanding of sustainability.

4.4 Results

4.4.1 Production Circumstances

The winemakers of the Mosel region are facing conditions veering from most circum- stances in modern winemaking, because about 40% of the ~8655 ha vineyards in the region are set up in steep slopes with gradients between 16.7° and 68° which makes the region globally predominant in steep slope vine growing [13]. This form of cultivation has a long history with evidence of the Celts and Romans already using the inclined plantation on the riverbanks of the region's rivers Mosel, Saar and Ruwer to produce wine [14]. The angled vineyards provide the positive effect of increased sun exposure while reducing the base area, allowing for a higher yield per hectare compared to flat vineyards, facilitating viticulture in a region where climatic circumstances differ from those in classic wine growing regions like the Mediterranean. The skeletal rich soil in the Mosel Region further adds to the microclimate in that it keeps the sun's heat at level, while making the vine struggle for nutrients and build deep roots, adding to the grape quality. Since the Mosel is a comparatively northern wine region, it lies within the zone of cool climate viticulture [8], comparable to New Zealand's Marlborough region or Champagne in France. Cool climate zones traditionally feature an extended vegetation period with long and slow ripening of the grape over the course of the year. Resulting in minerally, fresh and fruity wines, the cool climate is commonly perceived as adding to the complexity of taste and finesse, creating a valuable food production system for the region.

However, climate change, high gradient and low adhesion make maintenance of the region's vineyards challenging, leading the winemakers to rely on contractors and foreign workers, predominantly from Romania and Poland, to maintain most of their parcels by hand. While manual vineyard maintenance has been largely substituted with chemical and mechanical treatment in many wine regions, the Mosel region must rely on manual labour because of its landscape traits.

The annual handwork cycle consists of pruning the vines in winter, binding the rods, pesticide application, defoliating and pinching out shoots in spring and summer, harvesting in late summer to autumn. This is resulting in working inputs between 1000 and 3000 working hours per hectare and year, depending on the steepness, accessibility and production regime present in the respective winery. Compared to flat profile wine regions in Germany whose management is highly mechanised, the working input in the Mosel region is up to 4 times higher, referring to an interviewee who manages both land in and outside the Mosel region (see also [15]). Thus, the labour costs for vineyard management in the region make up more than half of the total operating costs and are regarded as a challenge to economic sustainability. Besides the manual labour in the vineyard by foreign workers, the winemakers owning the winery themselves participate in tractor work like harrowing, weeding and applying pesticides and rely heavily on family members to partake in their everyday work. While the majority of working hours are spent in the vineyard making up around two thirds of the aggregated working time in the winery, the winemakers focus lies on the vinification, marketing and distribution of the final product.

4.4.2 Current Challenges of Production

Besides challenges surrounding the field of labour and weather extremes, changes in economic relations and company succession were voiced as the main challenges regarding the sustainability of overall production within the group of interviewees. While the question for succession mainly was debated within the respective families of the winemakers and dependent on individual interests, development of climate change and economic relations were seen as related to each other and potentially threatening the interest of future generations to continue business. The following part thus deals with the economic and ecologic challenges towards production following the value chain as stated in the interviews and their linkages to sustainability levers theory.

Because of the difficulties in acquiring foreign workforce, one interviewee got really excited when being asked about the specificity of manual labour in the vineyard, responding:

“You are welcome to come, do that one day, then you don’t come anymore. It’s simple, who wants to do that? [Wine harvesting], it’s hard work. Who wants to dig asparagus? These are questions . . . Only workers with a high wage gap do that. Like it was in Poland 20 years ago.

As it was in Romania 10 years ago. But that is being compensated for more and more through EU membership. For a 12€ minimum wage that they want to raise from 9.80 or 9.50."—Farmer J.

Increasing wages for manual labour are thus representing a growing problem to winemakers. Not only does the demanding management of vineyards by hand require a monetary incentive for foreign workers. With changing production regimes and necessary adaptation of manual labour to the changing conditions in the vineyard, farmers are reporting that sensitizing staff for environmental change and teaching new techniques of sustainable vineyard treatment takes up an increased time amount. Labour costs growing to up to two thirds of the overall production costs does add a major concern for sustaining profitability and future production among the interviewed farmers. By experience of the interviewees, the increasing of prices accompanies a concern among them and their col- leagues that the production costs could exceed the scale of economic sustainability, affecting the oftentimes adolescent successors in the family businesses to remain hesitant towards future takeover. This is both because customers might not accept an increase in price, opting for cheaper products by competitors and a subsequent development to insufficient funding for future production cycles. Thus, the farmers are holding back on passing the current price increases, induced by supply chain interruptions, crisis and inflation on to the customers. According to the farmers, targeting the issues of subsidies, work force and expenses on material flows from a top-down perspective could relieve the pressure on their economic sustainability. Meaning there is an increased wish for governmental intervention in the sector of rising production costs among the Mosel winemakers. Applying our theory here to understand the respective point of intervention this would target in the food system, governmental intervention via subsidies represents a shallow point of leverage represented in the Parameters [11]. Though a subsidy of foreign work could reduce pricing pressure in the short- to midterm, it cannot be regarded as viable over time. In the longer run, being reliant on external workforce is an integral part of the predominant way of wine production in the Mosel Region, expenses for foreign manual work force thus seem inevitable unless the production pattern can be changed on a deeper level, targeting the design and intent of the system.

Labour costs however are not the only challenging development the farmers have to deal with. Climate Change plays an ambiguous but challenging role in the wine producers'

perception as well. The increase in annual average temperature associated with climate change has partially played out in the favor of most interviewed winemakers, resulting in the improvement of wines for the last 30+ years [7]. Hotter summers and extended vegetation periods have reportedly resulted in higher sugar contents in the grapes, enabling higher alcohol contents and different styles of vinification. When being asked about effects of climate change on the wine production, one winemaker reflects on the past development:

"We have benefited so far. When I was young, there was one super vintage in a decade, so in ten years there was one super vintage and two or three very good ones and then mediocrity and then one or two really bad ones, as the grapes were not ripe. And since the end of the 80s, the last really bad year was '84 and then it got better every year, so the grapes became riper, the Öchsle, the sugar values increased, the budding tended to be earlier. I know the figures from Bernkastel, there is a test station there, they have compared the vegetation data of the vines in the last 50 years and now find that in the last 50 years the Mosel has moved 400 km south, climatically."—Farmer P.

When we translate this statement into percentages, we see that the decades between World War 2 and the 1980s consisted of around 30%–40% good to very good wine harvests, while the rest 60%–70% was either of mediocre quality or was not ripe at all. Compared with a response to the same topic, another winemaker stated:

"1984 was the last real bad vintage I witnessed. Since the 90s, there have been no more miserably bad vintages."—Farmer I.

This being said, the vine ripening earlier and more consistently presented a long- term addition to the overall produce value of each vineyard in the last 30+ years. For the mentioned period, all winemakers reported that in contrast to their predecessors' experience, climate change happened to increase the wine quality significantly from the late 1980s and early 1990s until the present time. The tipping point of this development however seems close, when considering other farmers' statements regarding the additional effects of climate change. For instance, when asked about weather events like heavy rain and flooding a farmer responded:

“Big issue. Three years ago, we had a heavy rainfall event here and the mulch cover was ruined, too. When it comes out of the forest half a meter wide, the mulch cover can no longer compensate for it.”—Farmer B.

Mulch covers consisting of shredded green waste are frequently used to mitigate the already existing issues of drought and erosion within the Mosel region, building a protective layer to the soil, lessening evaporation. Adding to extreme rainfall and flooding, sunburn on grapes due to increased periods of solar radiation raises concerns among the farmers:

“[. . .] that is becoming more and more critical where sunburn occurs like in 2018 and 2019. You have to be very careful and we are already training our staff very well. The entire fruit-growing scene is actually familiar with the problem of sunburn. It occurred for the first time on a significant scale in ’99. Before that, it was virtually unknown; it probably also occurred in ’59 and perhaps in ’76, but that was only on a small scale. At the time, these were the so-called century vintages.”—Farmer G.

One more challenging effect of climate change indicating an end to the period of beneficial temperature to wine growth is displayed in deficiencies during the ripening process of the grape prior to harvesting:

“Some of the grapes already start to ferment before they are processed. Say a later harvest always brings more aroma. And if you have to harvest Riesling early in September because otherwise, they would start to rot, then that’s not the optimum. And you have to react much more in the cellar because there are also higher pH values, which means that the musts are more susceptible to certain microorganisms that you don’t want. That has a lot to do with the high Öchsle degrees. And partly because of the dry summers, the nutrient supply for the grape’s own yeasts is no longer so good. Then the musts also ferment less well.”—Farmer Q.

The increase in annual average temperature has thus led to the vine plant entering a stress zone in years where drought and heat are especially present. While for over 30 years, sugar contents increased, adding to the wine quality while the vegetation period of the vine was still sufficient to build enough acids and other ingredients relevant to taste. Now deficient ripening and premature fermentation start to indicate major problems to the way of wine production linked to climate change. With the quote above mentioning a climatic shift 400 km to the

south, not only the grape varieties and technical aspects of production are being challenged, but the whole production concept seems to be at stake. Yield losses through sunburn and an increased UV radiation result in the white wines producing phenols, which result in defective taste. Increased periods of heat lead to a shortening of the normally extended ripening period exclusive to cool climate wine growing regions. While extreme weather events such as flooding and hail threaten the plantations physical continuity. Being on the northern border of climate regions in wine production, the Mosel Region has been well adapted for the last 120 years but is facing major issues present in its production systems. Relying on Meadows' and Absons remarks on system characteristics, the challenges mentioned by the farmers can be linked to deep leverage points within the production, since the current development seem to target the overall design and intent of wine making. In Section 3.3 we focus on the group of winemakers using agroforestry, discussing their experiences around sustainability in production. After that we focus on agroforestry wine making and how it potentially can target the aforementioned challenges in the lights of sustainability levers.

4.4.3 Agroforestry & the Vineyard

Figure 4.2: Author's photography of the agroforestry vineyard.

Agroforestry means the combination of livestock, crops and trees on the same agricultural area (e.g. see the combination of vines and trees in Figure 4.2). Forms of Agroforestry can be regarded as an outcome of the neolithic revolution, when grazing pastures and field cultivation with livestock became a necessity for sedentary humans and date back more than 6000 years [16].

The production system's roots in wine production can be traced down to the early bronze age, where there's evidence for European Wild Grapes (*Vitis sylvestris*) being intercropped with willow (*Salix*), who's trunks acted as a climbing aid for the grape plant [6]. Nowadays agroforestry in viticulture is being made use of in traditional farming [17] and as a research subject to the potential of mitigating climate change effects, carbon sequestration and other challenging aspects of viticulture [18].

Current research has shown that the intercropping of deep rooting trees with vines produces an increase of water availability in the soil, resulting in an aquatic lift, making water accessible to the vine plants from depths they couldn't reach on their own [19]. The root system in addition provides an increased richness of the soil while preventing erosion through mechanised management or floods. The shading effect of the trees canopy minders sun radiation and provides cooling, resulting in normalisation of the grapes vegetation phase alongside preventing sunburn.

The agroforestry site referred to in this article was initiated by the University of Freiburg in collaboration with local authorities and winemakers in 2005 to research the interaction between trees (*Populus & Quercus*) and vine plants (Riesling & Sauvignon Blanc) on an area of 0.8 ha.

The parcel lies within the municipality of Ayl on the Saar River in Rhineland-Palatinate and is managed by the 5 winemakers within the same town. Resulting in each winery managing and harvesting the wine of one year, then handing the parcel over to the next winery.

All of the winemakers are working with conventional production systems without EU/Organic certification and have experienced the agroforestry system from the beginning. One winery works with the label of the "Association of German Prädikat Wine Estates", which recommends ecologic production for their members. All of the agroforestry winemakers however pursue conventional vineyard management, leaning on what is referred to as "integrated wine growing" [20]. This production method is not standardised but goes in the wine growing jargon as a management type that integrates ecologic thinking in the process of conventional wine growing. This results in an input of conventional pesticides into the parcel if deemed necessary by the farmer. The fertilization of the vineyards, including the agroforestry site, does exclude mineral fertilizer, opting for organic materials like pomace, green waste, or woodcuts, which are collected from local compost stations, fed by local residents. Confronted with the challenged production patterns in the face of climate change and weather extremes, the interviewees voiced a need for sustainability transformation and brought up the discussion of production patterns and the legitimacy of sustainable work within certified and non-certified wineries. All of them considered their ways of production superior compared to EU certified/organic production, explaining that especially the pesticidal varieties are less delimited while the additional bureaucratic effort to manage organic certified production is omitted. They were seeing it as an asset being able to transcend

production regime boundaries if necessary, integrating agroforestry into their fruit production patterns. When asked for his perspective on certification and production methods one winemaker responded:

> "[EU certified/Organic Production] often excludes sustainability. The simplest example is herbicide, the glyphosate discussion. Several people will have told you that producing and applying glyphosate requires much less energy, resources, etc. than carrying out the same work mechanically. Mechanical application has a much worse ecological balance than chemical application. Now the question is simply how do you judge this chemical story, as the WHO has done, as probably carcinogenic, others say it is not carcinogenic at all. That is the only question, but in terms of sustainability there is nothing that is superior to the herbicide in terms of sustainability. So resource efficiency. If you define sustainability in terms of resource efficiency and fossil footprint, then that's the way it is. Nevertheless, we have said that there is no way around it, but we no longer use herbicides, we no longer use insecticides and we have not used agricultural pesticides for 20 years. So we use the means of organic viticulture. Except for downy mildew."—Farmer C.

Taking the necessity of manual labour from foreign workers for granted, he voices a dilemma between mechanical vineyard maintenance, that requires more work intensity and chemical treatment that might induce carcinogenic compounds. Where organic production would limit the pesticide range to the use of copper preparations, the Farmer sees an advantage in lessening the mechanical work in the vineyard due to the exceptional use of conventional pesticides in the case of downy mildew. Rather opting for the conventional way of managing pests chemically has its representation in deeper leverage points, such as parameters and the goal of the system in sustainability levers theory. Understanding that means it is a decision of systemic quality to opt for conventional instead of certified production, the pesticide policies regarding the latter emerge as a key decision factor for the agroforestry winemakers to remain conventional. Sustainability as a concept to establish and promote within their production system is a clear goal among the farmers, however a homogeneous definition of the term was not provided. The implication of the quote above though is that a sustainable way of vineyard maintenance does exceed the frame of official certification. The farmers claim that due to their work with the agroforestry system, their perspective towards sustainable vineyard management such as practices of certified organic/ecologic and beyond production opened

up. This results in the introduction of pomace and green waste used as fertilizer, a pruning style that demands less work and does less damage to the plants as well as a clear goal to reduce pesticides wherever possible. Regarding the issue of pesticidal limitations in certified organic viticulture though, all of the interviewees agreed on copper as the only possibility to mitigate mildew infection in organic production as being unattractive.

This ambiguity arises because mildew endangers the vine plant mainly around the blossom in late spring. During this time rain fosters the development of the pest, while the copper compound, solely permitted in ecologic winemaking, is easily being washed off the plants by the rain. Because of the lack of adhesion working with copper as a sole pesticide against mildew the cadence of application is increased, while time spent on tractor work, labour costs and working input are rising as well. Applying our theory here, again the systemic choice to not certify their production can be linked to two aspects in the food production system.

First, there are input aspects which were commonly mentioned early on in the interviews regarding monetary and work time efforts that are increased with certified production. Adding to the excess work and labour costs, the increased costs an implementation of ecologically certified wine making would carry along is regarded as unattractive either.

Second, the surplus gained by a certified product output which could justify higher product pricing is not fully believed, since the farmers rely on narratives of sustainability surrounding their sales practices already, linking their products prices to sustainable wine production and agroforestry specifically. While all farmers showed an extended understanding of their vineyards' natural substance and interplay between organisms, the main argument for remaining in conventional production, despite understanding agroforestry as part of sustainable agriculture, lies in the EU regulated restriction to copper products when dealing with mildew. This policy seems to shape the mindset out of which the production system of the agroforestry winemakers gains stability and constitutes a deep leverage point linked to the system's intent. The quote above also shows that besides the reduced chemical vineyard treatment with pesticides, the production process relies little on mechanisation and mainly on manual work. Apart from this being more cost intensive and requiring more material flows on a shallower level of the production system, the mechanised work serves a narrative of sustainability shaping an intent that connotes indulgent treatment of the vineyard, especially beneficial when justifying production patterns, marketing and selling the final product.

This means even though organic certification is rather unapproachable to the interviewees who are managing the agroforestry site, sustainability is a concept they adapt for themselves as narratives of design and intent surrounding their production. Thus the experience-driven management of the vineyard, also regarding pesticide application, was frequently used to explain the individual farmers' way of production as superior to certified organic production. This narrative represents a way of showing the intent of the food system towards sustainability in the lights of the *re-connect* realm. As Abson notes about it, "a shift in the emergent intent in a given system of interest demands concurrent changes in its design" [9] (p. 35). If organically certified or not, through societal discussion about the remains of pesticides in the final product, the winemaker's awareness towards minimizing the pesticide input and their drive towards sustainability transformation is observable across all interviews. According to the farmer's experience, especially younger customers will frequently confront winemakers regarding their way of production, asking about pesticide use and production regime.

Contributing to the realm of *re-think*, the farmers show a distinct way of knowledge production in their process of sustainability transformation, that supports justifying and explaining the individual work flows as "real" sustainability in contrast to the supposed trade-offs that come with certified production. Despite the dilemma of pesticide use and resource consumption, negative press and societal perception potentially decrease the value of the winemaker's final products. All of which add to sustainability as a justification narrative and idea to increase resource efficiency.

On and off the agroforestry site resource efficiency is thus being closely linked to matters of sustainability by the winemakers, present in the majority of interviews. Through benefits regarding these factors, agroforestry as a means to exalt sustainability in wine production presents a major point of interest to the interviewees.

4.4.4 Challenges and Benefits of Agroforestry Wine Production

The wine production with agroforestry posits both challenges and benefits to the winemakers regarding their production regime and the potential of sustainability trans- formation. In parallel to the scientific findings mentioned above, drought resistance is a key benefit acknowledged among all interviewees involved in agroforestry. After 3 years of high heat and drought in the years 2018–2020 the winemakers were seeing advantages of the tree shades

and water supply the agroforestry system provides. As stated by the interviewees, the sunburn was resulting in an approximate 30% loss of grapes due to sunburn on regular vine plantation in 2018, while only around 3% loss on the agroforestry site was perceived, increasing the yield in hot and dry years:

“Yes, you can simply say that the yield is higher when nothing burns. If nothing burns due to sunburn, which is the most extreme form of solar radiation, then of course they also die. This was very clearly seen in 2018. Up to a third of the grapes in the control plants died and under these trees in the Arbustum project it was just 3%, which is very little. That was a beautiful effect.”—Farmer C.

Reducing crop losses while protecting the vineyard from extreme solar radiation are features the interviewees link to both the ecologic and economic sphere of sustainability. The overall design of the agroforestry plantation provided systemic change to what the winemakers were used to, which resulted in major production benefits during changing climate circumstances as well as improvement of the final product. The shade provided by the tree branches and canopies mitigates the premature ageing process white wine sustains when being overexposed to intense sun radiation. A process that is looked after in red wine, being responsible for the typical taste, is regarded as a wine failure in commercial white wine, causing bitter tastes reminiscent of petrol:

“Increased UV radiation has the consequence that more carotenoids and xantho- phylls are formed. These are the yellow and red pigments that are in turn broken down in the next metabolization step into substances that cause the wine to fir or age more quickly. In addition, the formation of phenols also sets oxidation processes in motion more quickly.”—Farmer C.

The shading of the agroforestry system thus reduces the UV radiation and adds to the product quality and longevity by mitigating premature oxidation and wine failure such as deficient taste. Besides that, farmers reported that the ability to provide windbreak and soil stability through bigger root systems decreased erosion, visible when visiting the vineyards.

Furthermore, the farmers stated that the agroforestry system helps cool down the microclimate within the vineyard, reintroducing longer grape ripening periods, common and

distinctive to the region prior to the phase of climate change induced heat. Apart from that, the enrichment of the soil within the agroforestry system through foliage and general production of biomass and roots leads to higher water capability and resilience to extreme weather, as the winemakers observed. This, in addition to the roots capability to mitigate erosion, adds to the ability of flood resistance while increasing the amount of water available to the vine in periods of drought.

Referring to the challenging production circumstances mentioned above, pesticide use within the agroforestry vineyard could be decreased due to the grape architecture design that's being used. The perennial cordon pruning system, where the grapes are hanging higher above the ground make splash infection with mildew less likely. This pruning system is a novelty to the farmers in the region which allows them to reduce working inputs, subsequently benefitting to the economic sustainability when revisiting the annual labour input, which was deemed to be less than half of the average 1000+ h necessary on regular parcels. While the predominant vine training system relies on a short perennial stem of max. 1 m height, with several annual shoots of up to 2 m length, the perennial cordon establishes a solid horizontal wood stem on a height of ~1.4 m from which shorter shoots grow and create a hanging wall of leafs with the grapes on top. This training system allows for a less intensive management of the vine leafs over the course of the year, reducing labour and pesticide input, effectively reducing the operational costs compared to monoculture vineyards. The positive aspects of the cordon system are mentioned by a winemaker who currently managed the site:

"The grapes hang upwards and the leaves hang downwards, which is actually quite nice, because then I don't need to lift the leaves, which is also a form of labour saving that we find very important. It is also sustainable, because at that moment we don't need to drive through it with the machine, but it falls down by itself. And then it hangs there, but this Peronospora is a soil-borne pathogen which, when it splashes up from the ground, always infects what hangs closest to the ground, the grapes have not been affected."—Farmer D.

Due to the increased height of the cordon system, the grapes are less prone to splash infection with mildew and downy mildew, resulting in a decrease of pesticide use. Besides the reduced danger of infection, the higher grape architecture allows for a more relaxed body position

while working in the vineyard, which makes the work less tiring. According to the winemakers, this is well received by the seasonal workers, especially during hot summer periods.

Subsequently the winemakers are saving labour cost, fuel and emissions by decreasing both chemical and mechanised treatment with more efficient manual work. Concluding, the positive effects perceived by the winemakers on the wine production with agroforestry consist of drought resistance, lessened input for vineyard management, increased product quality and stability, labour cost savings, pesticide reduction and an increase of biomass. The implementation of agroforestry to the wine production can thus be seen as a systemic change targeting deep leverage points of design and intent in terms of an altering of the production patterns which helps to shift the farmers perspective from monoculture wine production to alternative methods. Shallower leverage points are targeted too, with changes in structure of material stocks and flows referring to the lessened work and material input, as well as a gain around positive feedback loops from customers appraising the product as visible in Section 4.4.6.

4.4.5 Output

For the Agroforestry Site, an annual yield of 750–1250 L/ha is estimated by the interviewees, depending on the management intensity. This is about a fourth of the average yield expectancy that other winemakers, mainly from biodynamic and ecologic production regimes, within the case study reported (3000–5000 L/ha/y). Explanations for the smaller yield can regard the specificity of the rotary management system. When asked about this issue and how to potentially increase the output, one farmer responded:

“One would have to think about the humus supply. Since it’s someone else’s job every year, everyone thinks it’s the flood after me. I don’t see it that way, but no one necessarily does more than they have to.”—Farmer B.

The winemaker is indicating that due to the annual change of management, the agroforestry site’s external supply with humus as a plant nutrient is low. As a result, the low annual yield is comparable to that of an extensively managed vineyard, other than of a vineyard that is regularly provided with humus. The increased input of fertilizing material however could potentially raise the output in harvest quantity.

Harvesting the grapes along with other fieldwork requires more knowledge than in conventional vineyards because the Riesling and Sauvignon Blanc varieties are planted randomized, not compromising the quality of the harvest, but adding to the workload upon harvest:

“I was very happy with the grapes. It’s a hell of a race though, we really jump from vine to vine and I look at them, say this is Sauvignon Blanc, this is Riesling and it is then harvested separately and the others, [. . .] they do it that way too.”—Farmer E.

This quote shows reference to the issue of deficient ripening process mentioned above. Despite climate change and extreme weather events, the grapes within the agroforestry site meet the winemakers’ expectations. Apart from being satisfied with the parcels results in quality, the farmers tend to dial down the overall management inputs of the parcel. They reason it is because they don’t get returns in yield the year after due to the rotary management system. Meaning the parcel tends to be less intensely fertilized and maintained than neighboring areas producing more yield. Despite lower efforts in maintenance, the agroforestry system is well received by the farmers and shows an increase in product quality:

“I say in hot years I have natural shading, which is of course very good. This natural shading effect on the grapes has direct qualitative effects and consequences, so that one says the aroma remains somewhat brighter, does not go so much in the direction of early ageing notes, remains somewhat fruitier, somewhat brighter in the fruit. The entry of phenols and bitter substances in the skin is reduced.”—Farmer C.

Upon harvest, the grape varieties are selected and picked by hand. After hauling to the winery, the grapes are being pressed on site with a mash rest of up to 6 h, then being fermented in steel tanks using either spontaneous or cultured yeast for fermentation, whereas the latter was more common. While the Sauvignon Blanc was processed into a dry wine, the Riesling was altered either dry or semi dry depending on the year’s quality. After finishing fermentation, the wines are filtered, sulphured and filled into corked 0.5-L clear glass bottles, with the label sharing the same format and depiction of the antique servant indicating R for Riesling and S for Sauvignon Blanc. The depiction of the responsible winery on the side of the label changes with each year:

“Exactly, it is vinified separately, which is then called Arbustum R and Arbustum S. For Riesling and Sauvignon Blanc. And the Arbustum R is a fine-tart Riesling and the Arbustum S is a dry Sauvignon Blanc. That’s the concept behind it, these wines are labelled separately and with a label like this with a Roman servant on it carrying an amphora. And so, everyone markets their yields from this plant in the respective year with the same label. There’s just a different name printed on it, who was the producer in that year.”—Farmer B.

4.4.6 Agroforestry Wine Marketing

The Riesling and Sauvignon Blanc varieties stemming from the agroforestry site are marketed under the label name of “Arbustum” (engl. ‘grove’, or ‘tree plantation’). With the label depicting an antique servant carrying an amphora on his back the label works as a reference to originality and authenticity, alluding to the wine being made like in the antiquities. As marketing instruments, the winemakers use online and direct marketing as their main channels, partaking in local events, national fairs and international trade meetings. Own websites as well as social media platforms are used to advertise the wines and touristic visits to the area. Farm 1 relies on exports for 60% of production, followed by national gastronomy and retail, farm 2 & 3 have a split in thirds among export, gastronomy and end consumers. Farm 4 uses a caravan site to market the majority of the products whilst the rest of wineries (Farm 5 & 6) sell to direct customers via self-collection and mail order alike. While all wineries have regular Riesling wines in their portfolio, the Sauvignon Blanc does introduce a new variety into 5 out of 6 product ranges.

The Winemakers say that the label’s reference towards antiquity works as a strong marketing factor for the Arbustum products, adding to the narrative of agroforestry pro- duction, which leads customers to buy the annual produce quickly. The customer group consists of international tourists and the local tourist information as an intermediary.

“Wine doesn’t speak”—(Farmer L), as one of the winemakers stated when asked for his marketing strategies. This statement exemplifies that the marketing of the wines implies direct sales practices including tastings and narratives being attached to the product surrounding the production and quality of the wines. Each winery had their own on-site tasting rooms for such purposes. In order to sell the agroforestry wine product within the individual winemaker’s range, narratives of antiquity, craftsmanship, originality and sustainability were

added into the sales process. This works in a way that customers, after buying wine stemming from the agroforestry system, occasionally make their way uphill out of town to enjoy their wine at the agroforestry site, adding an interactive experience to the wine sale. According to one winemaker, this experience increases the likelihood of customers returning. Finally, the winemakers are marketing the agroforestry wines successfully with an increased value of +10%–15% compared to the regular assortment. Hence the comparably low average annual yield of the agroforestry parcel facing a high demand, the production is sold out rather quick:

"The demand is high. It's very limited, if you offer it, it's gone straight away. The people from the village or the tourist information take it immediately and with a big hand because the story is good and people can walk there, experience it and then open a bottle that comes from this vineyard, that's an experience for people."—Farmer C.

Experiencing the vineyard as a visitor can represent a deep leverage point within the realm of *re-connect* as mentioned in the theory by David Abson. Understanding that customers experience not only the wine but the place of origin in spatial proximity, represents a focal point for customers to deepen their knowledge of product origin. The positive aspects accompanying the vine growing and vineyard maintenance on the agroforestry site are being communicated by the winemakers so that there is mutual benefit in terms of general education about wine for the customer, but also in terms of potential long term customer relationship, which consolidates the winemakers' sales. Summarizing, the *re-connection* that happens through the agroforestry system entails an increase in social, ecologic and economic sustainability.

4.4.7 Future Implementation

Asked for their willingness towards extending the use of agroforestry into further parcels in the future, the interviewees responses remained ambiguous:

"First of all, we have to say that it has no negative influence, which is good. It has no negative influence, neither in terms of quality nor quantity. And in the end, the water availability is higher when there is a tree next to it than when there is not. That surprised us, but of course we are grateful for such a result. Because, of course, if it were to get drier, there are various

climate models of how things would develop here in northern, western Europe. If it were to get drier, that would be a thing."—Farmer C.

Despite acknowledging the benefits generated by the agroforestry system, the interviewees seemed unsure whether the climate change would really turn out to result in future years with intensified weather extremes. The quote above shows that the effects of climate change, turning the region into an overall dryer area are not yet completely believed. Pre- dominantly speaking subjunctive, the winemakers remained hesitant towards approving future plans on planting an agroforestry parcel themselves. The non-use of by-products from the present oak and poplar trees within the agroforestry site was mentioned as a challenge regarding the need for extra maintenance compared to regular monoculture vineyards. Poplar and Oak did not provide resources the winemakers are attracted to integrate in their production patterns. Alternatively, Fruit trees like plum, cherry or apple are of interest to them. Since the fruit trees offer the base for juice, spirits, or direct marketing of the fruits, they were imaginable to be integrated into the winery's everyday production cycles. The marketing and distribution of implemented fruit trees was deemed attractive for it allowed the combined production and direct sales of fruits, juice and cider.

"That would make sense, I could imagine apple trees, for example. That would make sense to me. Otherwise, for me the experience is also about the cultivability, does it all work, can you get through with the tractor, [. . .] This mechanizability just goes in the direction that we have seen, trees don't bother us."—Farmer B.

The overall impression given by the farmers involved in agroforestry wine growing seems to be impressed with the positive effects of the site as mentioned above. While the critique among all interviewees tends towards the preservation of accessibility and a more integrated agroforestry system. The latter meaning that the tree and vine combination is wished to be more adapted to the production capacities of the involved winemakers. Despite the farmers positive experiences, the idea of different tree varieties other than poplar and oak was thought of as a secondary option. Most farmers anyways did prefer agro-photovoltaic installations as a future innovation over the current agroforestry system. In this they found advantageous, that with agro-photovoltaics it would be possible to have electricity as a valuable by-product of the production site. While on the other hand uncertainty prevailed

regarding the ripening of the grapes underneath the imagined photo- voltaic enclosure because the shading effect of the photovoltaic surface could be too strong. The preferability of agro-photovoltaics could indicate potential development towards a combined production pattern that involves multilevel usage of vineyards, co-producing fruits, timber and electricity while benefiting soil and climate. The ambiguity towards implementation seemed to be of twofold motivation:

First, the agroforestry site in presence is acknowledged with its advantages, yet criticized for not producing comparable output to monoculture vineyards. Via the theoretical understanding of agroforestry as an alternative production system with deep leverage impact to viticulture, this problem points both to shallow points of intervention which mean the material in and output of the plantation and the ideal or intentional level of the food production system. Overall, this process embodies what the *re-think* realm is aiming at, by a problem oriented and mutual learning process of which the results are being voiced via critique by the winemakers

Second, the farmers' concerns about the lack of economic incentives regarding the work with agroforestry can be linked to the underlying mindset of profiteering, induced by the challenges mentioned in the introduction regarding climate change, changing business relations and succession. Contrasting deep and shallow points of intervention, could shed light on the issue that besides the financial threat put to the winemaker's situation by current developments, an opting for the implementation of agroforestry could diminish the base for their struggle substantially.

4.5 Conclusions

In the light of climate change, increased costs of production and environmental issues, agroforestry with viticulture seems like a cultivation form targeting deep leverage points within the food production system of wine. Agroforestry in Agriculture has reportedly increased land use efficiency for making the harvest of several crops on the same site possible, creating higher output per crop compared to separate plantations, thus fostering product diversity. In the case of the agroforestry site treated in this article, the land use efficiency could not be made full use of, since poplar and oak are not integrated as by- product producing entities in the production process of the local farmers. Also due to the specific management

system, the production potential of the site was not exhausted. How- ever, the challenges mentioned by the interviewees, consisting of labour costs, vineyard management, climate change effects and pesticidal choices were affected positively by the agroforestry system. The specific pruning regime on the parcel allowed for a management style that was more cost efficient and demanded fewer working hours with less input of pesticides than on regular parcels. However, the manual and mechanised maintenance in the vineyard required an adaptation from the involved work forces, resulting in teaching the pruning teams and carefulness when maintaining via tractor. Through the trees' roots and their function as windbreaks, the amount of erosion in the agroforestry vineyard was decreased. The drought resistance experienced by the farmers marks another deep leverage point in the agroforestry system that addresses the food production systems design and intent in the realm of *re-structure*. The use of agroforestry reportedly helped mitigate insufficient ripening that occurs as a result of climate change. Further rise in sustainability as indicated by the winemakers happened through increased water supply, shading and space for biodiversity the plants provide each other. In Addition to the major transformations to the standard ways of production, the variety of Sauvignon Blanc diversified the product range of the involved wineries. Sustainability and authenticity as a marketing narrative accompanied the agroforestry products that were being sold, adding to the popularity of the wines. This can be linked to the power of feedback loops described by Meadows and the *re-connect* perspective by Abson to re-establish a connection between production origin and consumer. The theory helped see that the unassertiveness towards the extended implementation of agroforestry in wine growing can be linked to matters of deep leverage points such as the intent and design of the agroforestry system.

To give an overview, the following Table 1 indicates the impact of agroforestry wine production found in this research, attributing it to the realms of deep leverage represented in sustainability levers theory:

Figure 4.3: Relating Realms of Deep Leverage and Impact of Agroforestry Wine Production. Author's own work.

Realms of Deep Leverage	Impact of Agroforestry Wine Production
re-structure	• Creating an openness towards implementation of novel production patterns through agroforestry (alternated pruning patterns, use of green waste, benefits of extensive management, draught resistance, soil improvement, increased biodiversity etc.). • Enforcing and stabilizing local distribution patterns (increased sales through tourist information and on farms).
re-connect	• Reestablishment of a connection between production origin and consumer through spatial proximity of agroforestry vineyard and wineries, as well as educational work from the producers. • Increased attention of external winemakers and governance institutions.
re-think	• Annual change in management induces a reciprocal learning process about agroforestry winemaking. • Contrasting the ordinary wine production, the winemakers appreciate the agroforestry site and rethink their way of production, aiming at further sustainability transformation in the future.

It was apparent that the winemakers do see advantages regarding sustainability and mitigating the challenges regarding social, economic and ecological sustainability, implied in labour cost struggles and weather extremes. Meaning there is an understanding of the agroforestry system's advantages compared to the winemaker's regular parcels. Yet the agroforestry system was not favored to be extended in the future for three reasons. First, the existing system was not tailored to the wine production patterns so that forestal by-products could be made use of. Second, the farmers remained unassertive to whether the climate change experienced in recent years would remain permanent. And third, the present agroforestry site was sufficiently integrated as a narrative supporting the individual ways of production and product sales with the notion of sustainability.

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5. Ecosystem Services in Silvopastoral Viticulture – Regional Farmers' Perceptions

Nicklas Riekötter and Markus Hassler

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Abstract

In the face of global climate change and economic change, alternative agricultural practices aimed at sustaining business are increasingly being employed in the wine-producing sector. Especially small to medium viticultural farms seek sustainability innovations in their viticultural practice. To increase sustainability in their production cycles, smallholder viticultural farms in the German Mosel Region started to implement livestock into their vineyards, making use of ecosystem services in silvopastoral agroforestry systems. Linking the findings from qualitative interviews to ecosystem service theory, the article concludes that the application of silvopasture in viticulture may help facilitate sustainable farming, diversify product ranges and increase the resilience of the food production system.

5.1 Introduction

Viticulture is a specialized and widespread agriculture with its high-value products being traded across all continents (Santos et al 2020). Due to the sensibility towards climate change, vine plants (Vitis vinifera) are changing their annual growth cycles (Quénol & Le Roux 2021), affecting the wine product and subsequent trading patterns to customer bases. Since the production of wine is generally regarded as an indicative field to research change in agriculture in general (Hannah et al 2013), especially given the impact of climate change on agricultural production (Malhi et al 2021), it is a highly tangible subject and thus motivation of this research to apply ecosystem services theory to review the potential of improving viticultural business via silvopastoral management.

Being close to 50° on the northern hemisphere's latitudinal border of wine growing, the German Mosel Region was taken under large-scale viticultural management during Roman colonization around 2000 years ago. With around 8000 ha of vineyards today, predominantly Riesling and other white wine varieties prevail in production with only a small share of red varieties (Statistisches Landesamt Rheinland-Pfalz, 2022, p. 10). The high amount of direct marketing is regarded as the reason for the region's economic success, ranging at the top end of added value compared to other German Wine Regions (Oberhofer 2022). The high added value of the local product is commonly referred to by considering the specific terroir. Viticulture in steep, slated and sparse soils which, alongside intense manual labour, enables the production of delicate and mineral wines ranging from dry to sweet with international exports and reputation (Moselwein e.V. 2022).

A profound change to the region's landscape and farming tradition occurred during the 20th century via agriculture intensification with the introduction of mechanization, fertilization and pesticides. Causing not only an immense increase in output per ha but also human poisoning

by driftage, rising greenhouse gas emissions and environmental degradation of soil and biodiversity (Moreau et al, 2018; Cech et al 2022). Thus, starting from the 1990s and early 2000's, concerns have been raised among winemakers and scholars that farming under conditions of specialized monoculture, conventional vineyard maintenance, mainly relying on chemical treatment and machine use, cannot be sustainable for the future (Romero et al 2022; Moscovici & Reed 2018). Hence the establishment of sustainable viticultural practices including agroforestry are being explored for their potential to mitigate current challenges (Favor & Udawatta 2021). Facing depleted demand in export markets, surging prices for producing goods and the effects of climate change, a small amount of farmers from the Mosel Region have started silvopastoral applications by implementing livestock into their production, letting animals graze in their vineyards and on neighbouring parcels. This allows them to diversify their production and gain ecosystem services in the form of added value, pest resilience, defoliation, fertilization and further factors that drive their production toward sustainability. This development can be understood as a consequence of farmers veering from mainstream intensive winemaking and orienting towards sustainable production (Nave & do Paço 2021), which combines the benefits of ecosystem services with the production of high-quality and high-value wines.

The research on livestock application in vineyards is growing and has lately been occupied with diverse studies, e.g. on general aspects of the practice (Schoof et al 2021), mainstreaming (Ryschawy et al 2021) or the suitability of different breeds (Conrad et al 2022). Taking a look at silvopastoral viticulture through the perspective of ecosystem services enhances this field of research and allows us to address the challenges and benefits of the production system from a theoretical standpoint while investigating the potential for making practitioners' everyday work more sustainable.

Thus, this article aims at exploring the application of silvopasture in viticulture in the German Mosel Region as a means to respond to aggravated conditions in wine production, characterized by drastic changes in climate and global economy using ecosystem services as a contextualizing theory. To better understand the process of valorisation and orientation for ecosystem service use, the understanding of ecosystem services stated in the following theory section will be applied to silvopastoral viticulture, aiming at identifying functions, locating value and recognizing providers and users connected to the researched viticultural practice.

The leading research questions therefore are:

1) In how far are the challenges and benefits perceived by the farmers working with silvopastoral viticulture linked to ecosystem services?

2) Are ecosystem services provided by silvopastoral viticulture potential drivers for sustainable wine production?

After briefly outlining the theory and method, the article investigates the interviewees' silvopastoral production systems, analysing the ecosystem service's use- and non-use values, evaluating the animal produce as well as the marketing of silvopastoral wine. Relying on our theory, a conclusion is drawn that links the empirical findings to the leading research questions.

5.2 Theory

Early theory on ecosystem services can be traced from the second half of the 20th century onwards, originating in the fields of bioeconomy, ecology and agrology (Ehrlich & Ehrlich 1981; Lawton 1997). Initially used as a pedagogic tool for education on the benefits that functioning ecosystems provide to humans, the underlying thought of a dependent relationship between nature and humans gained increasing popularity across natural and social sciences afterwards (Jose 2009; Salzman et al 2018; Bratman et al 2019). Recent research on ecosystem services

considers a biologic perspective of beneficial relationships in and between ecosystems and a perspective focusing on human interaction with ecosystem services (Vihervaara et al 2009). Thus distinguishing between biocentric and anthropocentric perspectives on ecosystem services, opting for the latter allows us to assess the productive advantages that regulating services from ecosystems such as soil consolidation and increase in biological diversity provide in the context of wine production. Further distinguishing in use- and non-use values (TEEB 2010), use values of ecosystem services can be consumptive, like nutritional items or recreational opportunities. Theorizing use values obtained from production regimes like silvopastoral viticulture makes the allocation of productive advantages from ecosystem services within the interaction of animals and vine plants possible. While products of use-value from animals and plants like meat or wine have a clear consumptive value, the non-use values from ecosystem services are non-consumptive, yet they can present worth to human production as well. Non-use values can for instance regard the worth humans assign to protecting nature for future use without direct physical contact with production and are thus described as option values (TEEB 2010, p. 23; Goulder & Kennedy 2011). Including animals in vineyards is an example of such non-use option values, for they represent close-to-nature farming practices that add to the perceived value of the farm. Theoretical work with ecosystem services in agriculture is especially popular in research concerned with pasture and livestock (Alders et al 2021; Röhrig et al 2020; Accatino et al 2019). Scholars find that the integration of livestock into silvopastoral systems, e.g. pigs in woodlands or poultry in olive groves, results in farmers perceiving a significant reduction in the use of chemical plant protection and fertilizer, while experiencing an increase of biodiversity and overall reduction of disease and pests (Röhrig 2020, p. 4). Besides that, humans profit from working with

livestock in gaining stress relief, increased social contacts and facilitated workflows (see Alders et al 2021; Hassink et al 2017).

Thus the synergies and benefits between and from livestock production combined with other agricultural elements fundamentally inform the research perspective of this article.

Building upon the theoretical approach of ecosystem services, silvopastoral viticulture as a practice of agroforestry is the scope of agricultural application, which will be theorised in the following.

Agroforestry describes the spatially integrated agricultural management of trees or perennial plants with either crops for silvoarable systems, or with livestock, creating silvopastoral systems (Mosquera-Losada 2009; Rodríguez-Rigueiro et al 2021). Integrating livestock into farming, silvopastoral systems in wine production are part of agroforestry farming that has the potential to provide ecosystem services of both use- and non-use values.

Connecting to nowadays issues with monoculture farming in viticulture, ecosystem services provided by silvopastoral systems can provide increases in carbon sequestration, accompanied by enhanced nitrogen supplies due to enriched biodiversity and soil life (Hübner et al 2021). Alongside providing ecosystem services, silvopastoral practices as production regimes have developed over millennia and are gaining more popularity together with the increased interest of farmers in sustainable viticulture (Deutsches Weininstitut 2020). Despite rising interest in the field of practitioners and scholars, the success of agroforestry applications is highly dependent on each system's composition related to the local conditions and the skill of the involved farmers (Jose & Dollinger 2019).

Given the large amount of research related to defining sustainability (e.g. see Salas-Zapata & Ortiz-Muñoz 2019; Béné et al 2019; Caradonna 2014;), we argue that sustainability in viticulture is best understood as a *modus operandi*, comprising numerous mental and physical

actions, aiming at sustaining the environment and production for future generations. Following that, the successful establishment of sustainable viticulture is best described as one that is “conscious of the social and environmental impact of its supply chains, operations, products and services, and reacts responsibly to minimize any negative impacts and remain in business” (Gilinsky, 2016, p.38).

While scholar’s results engaged with silvopastoral systems, whose focus is on meat and milk production, are claiming an overall increase in biodiversity, land use efficiency and animal welfare (Lemes et al 2021; Broom et al 2013), research on systems integrating pasture into viticulture are yet rare. Thus this research seeks to contribute to the understanding of silvopastoral systems in viticulture as a means to improve sustainability in viticulture by engaging ecosystem services as a theory deepening the understanding of challenges and benefits obtained from this type of production.

5.3 Method

To research innovative development in viticulture, an explorative approach comprising qualitative interviews with farmers was found to be most suitable to investigate practitioners' perspectives on developing innovations in production, processing and marketing of wine in the Mosel Region (see van Esch & van Esch 2013). Because of the dominance of small to medium owner-operated farms, all interviewed farmers were the respective owners of their farms, which facilitated receiving hands-on insight from viticultural practice. As part of a bigger research project engaged with sustainability in the wine sector, 19 qualitative interviews were conducted on farms in early 2022.

The sampling for this article was limited to 6 farms because the practice of silvopastoral viticulture was not established on more farms yet. Having animals directly in the vineyard and on neighbouring parcels, the silvopastoral systems of this research consisted of vine plants as

permanent cultures planted in dip-line vineyards on the riverbanks of the Mosel and Ruwer River within the Mosel Region. In these vineyards spread across the Mosel Region's subsector Bernkastel (see Figure 5.2), three different animal species were implemented on 6 different organic and biodynamic farms, building silvopastoral systems of grazing animals and vine plants. The interviewed silvopastoral farms were all producing under standards of biodynamic or organic certification (see Figure 5.1). The interviews lasted between 45 minutes and 2 hours, allowing for visiting facilities, vineyards and animal shelters. The anonymized interviews were conducted in German using a semi-structured interview guideline, the recorded audio was transcribed and coded with MAXQDA coding software creating a coding system of 7 first-level (e.g. Production, Distribution), 51 second-level (e.g. Vineyard, Spatial Development) and 39 third-level codes (e.g. Export Countries, Grape Varieties) with a sum of 987 codes. All interview quotes have been translated by the authors and moderated through triangulation.

5.4 Results

5.4.1 Silvopastoral Production

All 6 farms implementing silvopastoral farming were engaged with sustainable wine production, 3 farms worked as EU-certified organic (following 'organic') wine producers while the other 3 produced with biodynamic Demeter (following 'biodynamic') certification. One of the organic wine-producing farms was in the transition toward biodynamic certification in 2023 (see Figure 5.1). The silvopastoral area in ha in Figure 5.1 indicates how much vineyard area per farm was under silvopastoral management. The aggregated area under silvopasture of the researched farms was 42 ha of owned vineyards, while there was occasional lending of the animals to foreign parcels for added fodder and landscape maintenance, adding to the

area under animal pasturing. The animal varieties used as herds of min. 6 animals comprised of mixed goat and sheep breeds (Farm E & B), Shropshire Sheep (Farm F & D), Ouessant Sheep (Farm A) and a Zebu cattle variety (Farm C). The approximate positions of the interviewed farms under silvopasture can be seen indicated by yellow markers in Figure 5.2. All farms are lying in the Mosel Wine Region in the subsector Bernkastel, ranging from the City of Trier in the southwest, following numerous river meanders bordering next to Zell (Mosel) in the northeast (see Figure 5.2). Since the average farm size in the Mosel Region ranges around 3 ha (Moselwein e.V., 2021) the interviewed farmers' silvopastoral vineyard area was larger than average farm sizes and with a median of 7 ha close to the German average of ~6.9 ha (Bundesministerium für Ernährung und Landwirtschaft 2020, p. 32).

Organic and biodynamic farms both did only use fertilizers produced on-site such as green waste, pomace or dung. For pesticidal treatment, both production schemes relied solely on copper-based pesticides to react to mildew and downy mildew as the most common diseases in viticulture. Apart from that, preparate made from horn manure, field horsetail (Equisetum arvense), tea (e.g. chamomilla) and others were commonly used to strengthen the plants and their environment. The biodynamic scheme as displayed in the German Demeter Guidelines (Demeterrichtlinien 2022, p.71) explicitly recommended keeping livestock alongside wine and fruit production, to maintain the holistic approach of producing within a closed, circular economic system for each farm. Thus, when asked for the motivation towards implementation of animals into farming one farmer responded:

> "For many years I said that we should actually bring animals to the winery, otherwise things are not round." – Farmer E.

Showing strong reference to the Demeter Guidelines, optimising production patterns for the farmer included the effort to strengthen the circular economy within his farm, e.g. "doing

what is “right” for the environment and it’s inhabitants” (Gilinsky 2016, p. 38). Apart from ideal reasons induced by working with organic and biodynamic certifications and their edifice of ideas, the Covid 19 pandemic’s economic change was mentioned as a cause and motivation for silvopastoral viticulture as well:

> “With Covid hitting, you could see the exports went down, our idea to market more locally got a strong push. Also with organic winemaking, it’s like that we have a good margin and don’t rely on quantity as much but on quality for our production. That’s where the animals make a lot of sense, we have less work and healthier vineyards. Even when one of us gets sick, the animals will still maintain the parcels.” – Farmer A.

Making use of ecosystem services, here in the form of reduced working input, made the production patterns more resilient towards sudden changes in the economy. Alongside applying rules set in actual guidelines, the striving for sustainable viticultural practices affected the workload as well as the quantitative output. As an example, Farmer A voiced that the silvopastoral system allowed for less work in the vineyard without loss in margins, while the output of the interviewees’ parcels was significantly lower than on conventional farms:

> „In biodynamic production costs are a bit higher compared to conventional production, the only thing is that we only harvest half“ – Farmer A.

Despite the reduced work in the vineyard, the added livestock altered the known working patterns of the interviewed farmers by adding work time to feed and move the animals, take care of their health and build shelters and fencing. Despite there being lesser output and more diverse work compared to conventional farming, the farmers were not concerned with lower income, since the prices for biodynamic and organic labeled wines could be higher while the production costs did not multiply. The perceived gain for the farmers furthermore could be

found within the animal component increasing diversity in the vineyard and adding to the overall health of plants as well as the quality of wines:

> "We work with rather low yields, the vital elevation by the animals is already enormous though. It is nice to see that my vineyards are more vital today than 20 years ago, even though the vines are 20 years older. That is quite a development." – Farmer E.

The mentioned vitality was perceived by the majority of interviewees and appreciated as an added factor that allowed to reduce working inputs in the vineyard, in the following statement that is in the form of pesticidal application:

> "We simply see that there are diverse insects compared to earlier and that pest infestation is lower. I think the plants have become more resilient, but maybe insects also compete harder I don't know. Fact is we must spray less as long as the weather is gracious." – Farmer D.

So, the farmers' motivation to introduce silvopastoral viticulture was generally linked to sustainability in production patterns of organic or biodynamic production, initially resulting in diversified working patterns with less pesticide application and elevated vitality in the vineyard while taking care of livestock required farmers to accomplish new tasks.
The following section engages with the regulating services as part of use values deriving from ecosystem services obtained in silvopastoral viticulture.

5.4.2 Regulating Services

All animals treated in this research shared the purpose of grazing weeds in sloped conditions between 5° and 45°, which provided regulating services as use values deriving from ecosystems services (TEEB 2010, p. 23). These services were present in the form of soil

maintenance, fertilizing via dung, defoliating of vine plants and the antagonizing of browsing game animals.

The animals used for silvopastoral management in the sloped Mosel Region's vineyards were smaller in size than common breeds of their species and thus had the capability of standing in angled terrain without problems of fatigue or skeletal damage. Furthermore, the light animals, especially sheep, provided the so-called "Goldener Tritt". Translated as 'golden step', the pattern that the sheep left in the ground when grazing was packing the upper soil level so that erosion was minimized while the low weight of the livestock did not compress lower layers of soil. The pattern comparable to that of a prism roller further did not harm the sod so that plants purposely introduced by the winemakers could flourish. In the case of the planted Rye (Secale cereale) (Farm F), Pannonian vetch (Vicia pannonica) (Farm D, E & F), Clover (Trifolium) (Farm C & D) and other Leguminosae, the livestock grazing and 'golden step' omitted mechanical work to prevent erosion, helped clear weeds and optimised nitrogen supply for the vine plants:

> "In principle, the sheep just eat the green stuff that grows, i.e. the greenery that is partly planted by us. Legumes that also store nitrogen in the soil and the sheep then make fertiliser out the back. And the nice thing is, besides their 'golden step', these Shropshire are particularly well suited for the vineyard because they also eat away the foliage around the grapes. We have to clear the grapes anyway so that the spray can get to them better and so that the sun can dry them better. And that normally would have been done by hand." Farmer - D.

The Shropshire sheep referred to in this quote apart from providing positive grazing effects and fertiliser facilitated the application of pesticides in the lower section of the vine plants. Farmer F also used Shropshire sheep, describing their advantage for silvopastoral viticulture:

> “These Shropshire sheep are a Scottish breed. They are relatively low, short-legged, that’s why they are able to walk under the wireframe. This breed has a good feed conversion, they get along with meagre feed. I have had the sheep since November 2020. They come to the vineyard after the grape harvest. They live in our main vineyard. It's an area of 7 hectares in total. Of this, 1 hectare is fallow land and 6 hectares are planted with vines. Let's say they come in at the end of October and then they stay until the end of March, when it gets warm and the first shoots come out, then we move them in and out depending on the progress in plant growth and grass. There are very small plots and you have to move them every four weeks, which is a lot of work. During the summer we move them a lot anyways. For two reasons, because they eat the leaves, which is good and because the sheep are very sensitive to copper, which we then apply in plant protection.” – Farmer F.

The defoliation mentioned here helped the farmer to reduce the working input, supplementing manual labour with the sheep, so that mechanised weeding and defoliating could be substituted. Furthermore, the sheep’s defoliation enabled plant protection to work more efficiently. The Shropshire variety used by Farm D and F comes in two subspecies, namely English and Danish. The Danish subspecies was preferred by the farmers for use in vineyards for it showed the inability to perform bipedal grazing (see also Conrad et al 2022). This was a major benefit for vineyard management because the sheep couldn’t reach the upper parts of the vine plants that the farmers wanted intact as leaf areas for photosynthesis and infructescence for berries. The sheep defoliating and clearing the lower parts of the vines hindered the above-mentioned mildew diseases from infecting the plant because they are soilborne. Adding to that it eased the application of pesticides that could reach the leaf’s

bottom side easier. Regarding damage to vines and grapes by sheep grazing, the above farmer stated:

> "There are only two to three weeks per year where they don't go in because they would then eat the young shoots from the grapes, but as soon as the berries have reached a certain thickness, they no longer tackle the grapes because they are too acidic for them." - Farmer D.

Farmers reported that their original concern with animals in the vineyard was that the copper-based pesticides predominant in organic and biodynamic wine production could negatively affect the sheep's health. While copper is proven to especially shorten sheep's lifespans, attentive management styles had been developed by the interviewed farmers where the sheep were let into the vineyard throughout the year, while in pesticidal season (Spring & Autumn) they were only let in after rain had washed off the water-soluble preparates, making for "close-to save" conditions for the livestock (see Trouillard et al 2021). For the high season in pesticidal application and fruit ripening the livestock was moved to neighbouring parcels mainly consisting of meadows and meadow orchards from acquaintances or relatives. This reliance on social structures further relieved management intensity from the farmers' workload. From the 6 farms interviewed, only one farmer stated that he found the silvopastoral application to be more time-consuming than expected:

> "Goats are very susceptible to parasites, goats eat a lot, so they have to be fed in winter, there has to be enough water. They need something dry. They don't like water from above. That became clear after I got them and I did build a shelter for them immediately. And I am actually there every day and look after my goats." – Farmer E.

While Farmers E, F and C owned their herds of animals and took care of work all year around, the other three farms used contracted shepherd's herds to graze their vineyards.

Farm A used a contracted herd of Ouessant sheep to graze their 3 ha of vineyards. Ouessant sheep are reportedly among the smallest breeds in the world (Dieker 1993) and were thus able to walk underneath the wire frames used for vine training easily, changing between rows of vine.

Farm B recently started implementing a sheep herd of mixed breed via a contracted shepherd on 3 ha of their farm. Consisting of predominantly lesser steep vineyards (<16.5°) the experience with the breed so far had been satisfying and showed a profound impact on weeding efficiency compared to the former method of mechanized weeding:

> "The sheep they just trot along, it is very relaxing to watch, and they eat weed all the time, thus we have a way more consistent green cover which helps us with maintaining water and nutrients in the vineyard" - Farmer B.

Farm D used a herd of Shropshire sheep, also via contracting from a shepherd for 6 ha of their vineyards. The resilience of the breed led to Farmer D being able to terminate additional mechanized work by tractor in the silvopastoral parcels. This was only possible in the vineyards where fungus-resistant vine plants were cultivated:

> "We are using satin noir, that is a fungus-resistant variety that we don't have to treat with pesticides. Since the vine plants are big enough and have lignified, we can simply omit working with the tractor there." – Farmer D.

Since pesticides were the major reason for the temporary removal of livestock from the vineyard, vineyards with fungus-resistant vine plants could be used for silvopastoral viticulture more easily. A final regulating ecosystem service of non-use value identifiable from the farmers' statements was the biodiversity increased due to the silvopastoral application (see also Lemaire et al 2014):

> “You can describe it very well with the beautiful word biodiversity project. We cut the pasture in half, spend a few months on one and then on the other. And the flowering meadow on the pasture where they are not standing at the moment is really impressive. As people who are concerned with this, we know that land that is kept open has a greater diversity of species than land that is overgrown with bushes, as far as butterflies and insects are concerned. Yes, I am quite proud of what we are doing and it makes our vineyards more resilient.” - Farmer E.

5.4.2.1 Game Animal Repelling

Unlike the other 5 farms working with sheep and goats, Farm C engaged a cattle variety originating in Asia for their silvopastoral vineyards:

> “They are small cattle, they are not that heavy, they weigh 250 kg when full grown, which is not heavy at all for a cow. And that's why they are sure-footed and don't trample so much in terms of weight. And they are a bit more primal. They have such a hump. Most people know zebu cattle from films from India, where they stand around on the street like rattle-dry cattle, these are big zebus. We have them in a smaller version, they come from the Caucasus or from Ceylon.” - Farmer C.

The Zebu cattle were mostly used for grazing meadow parcels surrounding the vineyards of Farm C. The farm owned most of their 11 ha of vineyards bordering Forests on the hilltop side of the Mosel Valley. Apart from providing moisture and cooling for the vineyards, the proximity of the forest led to the intrusion of wild boar into the parcels:

> „They destroy everything, they are a problem all year round because they plough up everything in the rows of vines and also in the flatlands, and when you want to drive through the row with a narrow-track tractor, you have huge holes everywhere and then you wobble through them with the machine. Until you get it smooth, you always

have work to do and in autumn it's a huge pest, the pigs eat an unbelievable amount of grapes and then it's also the case that while they're eating the grapes, they bump into them with their bodies and then a lot of grapes fall down and are broken. And the pigs then pull the grapes off from below, the truss is still hanging there and the grapes are gone. They really have an acquired taste.“ – Farmer C.

Adding to damages to the grape yield, attracted by the ripening fruits, boars left Farm C with added workload to clear damages induced by their digging and wallowing behaviour. To mitigate the game problem, Farmer C introduced the Zebu herd on neighbouring parcels. Due to the smell of the Zebu, the surrounding area was covered with big animal odour that repelled wild boar and diminished damage to the vineyards. Additionally, the Zebu herd feasted on undergrowth on the forest border and thus minimized space for retreat that the boars like to settle in. The Sloped Vineyards in the Mosel Region are generally planted in rows parallel to the gradient, Farm C owned one of the few exceptions with a terraced plantation, allowing for easier management in steep conditions. Thus, the Zebu could be implemented with grazing inside the terraced vineyard, for they have enough space to manoeuvre without damaging the plants.

Farm F was in a similar situation as Farm C, with the majority of their parcels directly bordering the hilltop forest. Enduring deer intrusion and grape browsing, they discovered that not only the presence of livestock but also the clipped wool acted as an antagonizer to secure their harvest:

“Wool so I would have thrown away part of it, part of it is stuffed into bags in the back of the shed and that was the idea, but we haven't done that yet, because it's very good against game, we hang them up and then deer bite stays away.” – Farmer F.

Thus use values from regulating services provided by the silvopastoral application in the interviewees' vineyards (see TEEB 2010, p. 23) comprised of positive impact on the soil condition via the 'golden step' minimizing soil work, which was prior carried out by tractor and work reduction via defoliation in the lower regions of the vine plantations. Subsequent savings in production costs added to the farmers perceiving an elevation in biological diversity, reporting positive effects in overall vineyard condition and resilience. Adding to the aforementioned, the startling of the intruding game from surrounding forests, using shaven wool, or the presence of animals in the vineyards, antagonized browsing and thus secured the amount of harvest. Further, the repelling quality of animal presence prevented soil damage by wallowing boar.

5.4.2.2 Animal Produce

Adding to the animal repellent effect from the silvopastoral ecosystem, animal produce represented a direct use value for farmers to make use of. Farmer F had started selling wool to a local person processing it into yarn and textiles. While the sheep's milk was solely for consumption by the lambs, the herd had grown strong and thus use value was created through slaughter and marketing the meat to customers further diversified the farm's product portfolio. Concerning marketing the animal produce from silvopastoral viticulture, all farmers were in the process of establishing distributional pathways to market their surplus products. Prosperous herds of those farms owning their animals were driving the development of slaughter and marketization:

> "And meat, so far I have not had any sheep slaughtered. But that's coming up now because we now have 23 animals and that's too many. I can't keep them all. And I also get requests for meat regularly." – Farm F.

While Farm F was only starting its production and distribution of meat, Farm C stored and consumed parts of their first slaughter cycle while looking at increasingly selling products via

their farm's store. The slow reproduction and growth rate of the Zebu species did take time, yet required no special attention for birthing:

> "The Zebu, they need three years until they have slaughter weight. We learned the hard way because we slaughtered the first Bull at 2 years and that was only 90kg of meat. But in the third year they have around 120-130 kg. That's no comparison to regular livestock that's way younger than 2 years when butchered. But those also have complications in birthing because the calves are so big at birth that they need a lot of attention. Our Zebu, they just birth on the pasture, they are independent." - Farmer C.

Since the breeds used in silvopastoral viticulture were smaller and had lower outputs compared to mainstream farming breeds (e.g. Holstein Friesians (Bos primigenius)) in meat and milk, the latter was no potential branch of marketing for all farms, yet with the sheep keeping farms, wool was the dominant by-product when not used for antagonizing, requested by locals for further processing:

> "No milk, that goes into the lambs. A woman from the village is very enthusiastic about the wool though, she got herself a spinning wheel and turns it into wool and then we get some of it spun back and so on." – Farmer F.

5.4.2.3 Marketing of Silvopastoral Wine

Wine being the main use value product from the silvopastoral vineyards, an added aspect of cost efficiency besides less working intensity and secured harvest could be found within the marketing of the wines descending from silvopastoral vineyards. The animal component did not only reduce farmers' workload and pesticidal input but the presence of animals, apart from the perceived elevation in vitality, was being channeled into marketing narratives that put the organic and biodynamic wine production in the silvopastoral context closer to an

imagination of nature and originality. This can be regarded as an ecosystem service's option value, as "the value people place on protecting nature for future use" (TEEB 2010).

The animal's presence and activity added to the value of silvopastoral production in the sense that the wine could be marketed at higher prices than conventional products with reduced production costs. The reconnection of natural surroundings and food production resulted in an added value for the winemakers, while all of the parcels under silvopasture in this research were accessible to the public, by public roads which transverse the Mosel Slopes. Creating access to a close-to-nature farming approach pictured by animals in the vineyards thus added to the perceived quality of wine and the landscape from a customer's perspective:

> "Our customers see the animals and are quite amazed that it works, some may be hesitant but we explain the benefits of having animals in the vineyard to them and they really appreciate it and want to know about them." – Farmer B.

Since the interviewed farms were working with either organic or biodynamic certification, the majority of their marketing and distribution aimed at local and regional sales, with customers from the surrounding area or repeatedly visiting tourists, relationships to the wineries and their ways of production were strengthened following the thought of sustainable viticulture to establish stable sales conditions for future generations.

5.5 Conclusion

Responding to the leading research questions:

1) The benefits perceived by the farmers who worked with livestock in their vineyards showed strong links to the values of ecosystem services. Challenges regarding silvopastoral vineyard management predominantly concerned added work for livestock care.

2) Implementing silvopastoral viticulture and making use of its ecosystem services showed to be a potential driver for diversification and sustainable viticulture, making farms increase their potential margin while preserving natural resources and fostering resilience in their food production system.

5.5.1 Managerial Implications

The introduction of livestock into wine production provided several challenges and benefits to the management in sustainable viticulture:

Originally motivated by developing viticulture that is sustainable and resilient for future generations, the farmers experienced that moving and providing for their livestock is more labour intensive than originally expected. Aspects of herding, like additional fodder in winter, building space for retreat and medicinal issues added to the variety of work that farmers conducted daily. Besides these novelties to the farmers' production patterns, the benefits from silvopastoral management through ecosystem services led to major advantages in production and marketing, supporting sustainable agricultural business via ecosystem services through the animals' terrain ability, landscape maintenance and fertilization.

5.5.2 Theoretical Contribution

This research found that findings about ecosystem services in prior research concerned with livestock systems (Alders et al 2021, Röhrig et al 2020, Accatino et al 2019) can be confirmed when transferred to silvopastoral viticulture. Farmers integrating livestock into their production perceived an overall lift of biodiversity, product diversity, pesticide reduction and synergic outcomes like dung fertilization, soil consolidation, weed grazing and desirable defoliation, while further gaining marketing arguments linked to close-to-nature farming practice connoted with animal use. The benefits perceived by the interviewees were overall outweighed by the added workload necessary to adapt their production to working with livestock. Making extended use of use- and non-use ecosystem services helped the farmers

strengthen their production patterns comprising less intensive vineyard management while increasing added value through high-quality, certified production and products. The effort to reduce chemical inputs into the vineyard and preserve natural cycles between plants and animals made for sustainable farming practice among the farmers which reportedly reduced energy, labour and carbon expenses. This was facilitated by the use values emerging from ecosystem services comprising the soil maintaining grazing, fertilization and the 'golden step' conducted by livestock. Further, capitalizing on the non-use option values in ecosystem services theory, narratives of protecting nature for future use by animal application, also present in the edifices of biodynamic and organic certification, enabled farmers to increase product prices and add to the overall value of the silvopastoral viticulture applied on the researched farms.

On the marketing and distribution side, the farmers gained product diversity by being able to additionally sell wool and meat and rely on shorter distributional chains, strengthening their customer relations and attracting customers with close-to-nature production methods, further making use of option values.

As Lee et al (2019) suggested, the use of ecosystem services can accompany a shift from agricultural production to conservation agriculture which results in decreased crop yields, the same development can be found in this research. However, while the farmers' focus incorporated the thought of conservation into their agricultural practice, the lessened crop yield did not endanger their economic well-being, hence it was balanced by lessened working input and higher product prices as the farmers perceived.

For their main product of wine, the farmers reported positive feedback from customers appreciating the implementation of animals into their farming. Besides the wine quality and thus increased potential margin, tourists and customers were likewise attracted by the option

values represented by animals visible close to the wineries, on the vineyards and on social media. Apart from that, ecosystem services were shared on a social level where livestock was lent for grazing on non-viticultural area during pesticidal applications which created mutual benefit among fellow farmers and landowners.

With all farmers producing under certifications that transport ideas of preservation of nature, thoughtful farming and eco-friendly behaviour, making use of ecosystem services in silvopastoral viticulture can be regarded as an enhancement of sustainable viticulture.

5.5.3 Limitations & Future Research Directions

Limitations of this research regard the understanding of how biodiversity was increased by the livestock following a change in the relation between beneficial organisms and pesticides, further the perceived increased resilience of the vineyards linked to this. Additionally, the repellent effect of livestock being kept in parcels next to wild game habitats should be investigated to a larger extent. Overall, the transferability of the farmers' perceptions laid out in this article are object to further research regarding their application to other wine regions and conditions.

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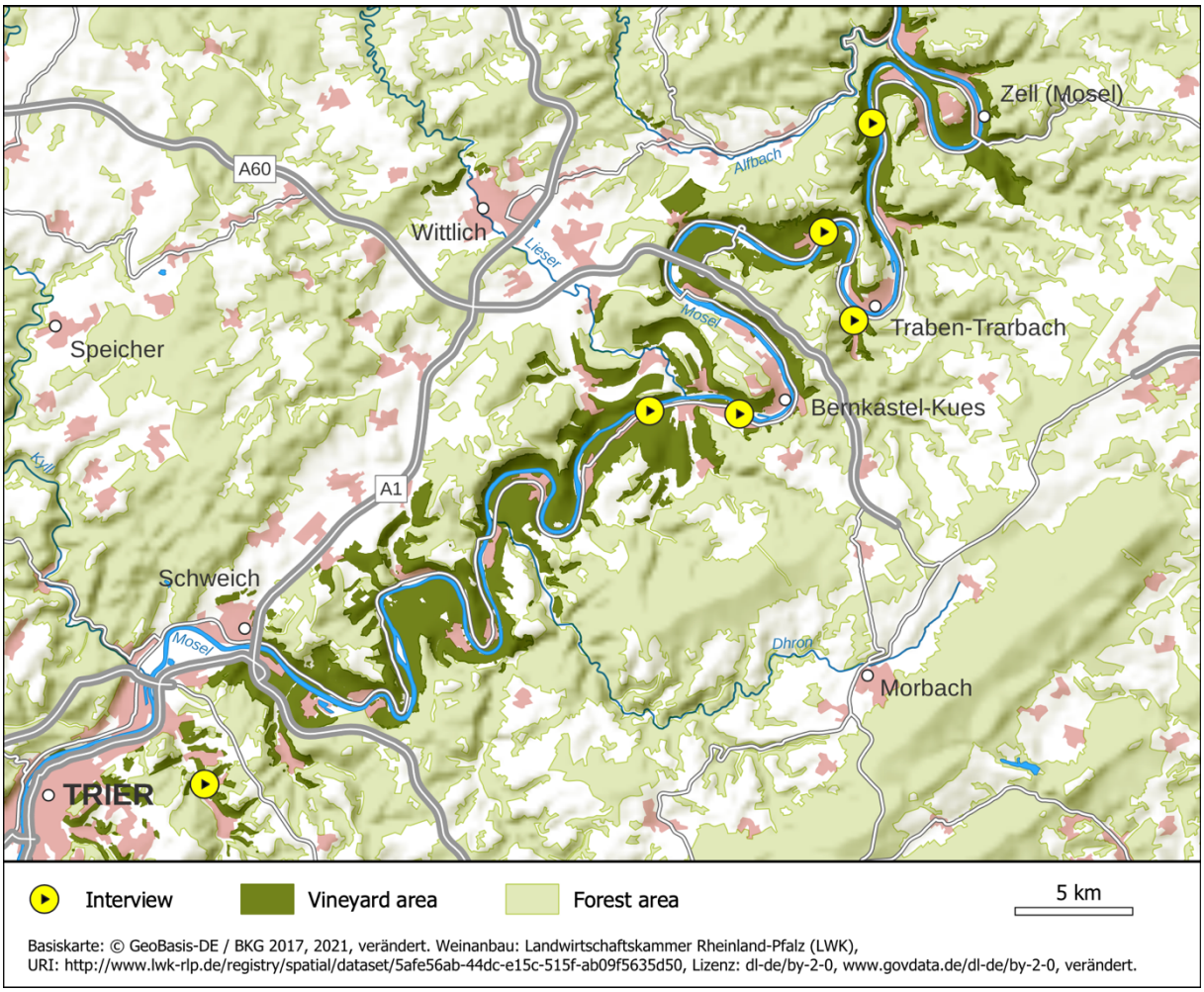
5.7 Appendix

Figure 5.1:

Farm (certification)	Animal Type	Silvopastoral Area in ha	Ownership
A (biodynamic)	Ouessant Sheep (Ovis aries)	3	Contracted
B (organic, transition to biodynamic)	Sheep, Mixed Breed (Ovis aries)	3	Contracted
C (organic)	Zebu (Bos Indicus)	11	Owning
D (organic)	Shropshire Sheep (Ovis aries)	6	Contracted
E (biodynamic)	Goat, Mixed Breed (Capra aegagrus hircus)	12	Owning
F (biodynamic)	Shropshire Sheep (Ovis aries)	7	Owning

Author's own work.

Figure 5.2:



Basiskarte: © GeoBasis-DE / Bundesamt für Kartographie und Geodäsie (BKG) 2021, verändert. Weinanbau: Landwirtschaftskammer Rheinland-Pfalz (LWK), URI: http://www.lwk-rlp.de/registry/spatial/dataset/5afe56ab-44dc-e15c-515f-ab09f5635d50 , Lizenz: dl-de/by-2-0 , https://www.govdata.de/dl-de/by-2-0 , verändert.

Bundesamt für Kartographie und Geodäsie (BKG) 2017: Digitales Geländemodell Gitterweite 200 m (DGM200). - https://daten.gdz.bkg.bund.de/produkte/dgm/dgm200/2016/ . (Stand: 29.11.2017) (Zugriff: 15.12.2022).

6. Enhancing Sustainability in Regional Wine Production: Fungus Resistant Grape Varieties and Alternative Food Networks

Nicklas Riekötter and Markus Hassler

Submitted to *Area*

Keywords: Sustainability, Alternative Food Networks, Mosel Region, Viticulture, Fungus Resistant Grape Varieties, Qualitative Research

Abstract

European vignerons are increasingly adopting organic viticultural practices. The number of certified producers has steadily grown in the past decade, indicating the integration of organic viticulture into mainstream wine production. However, the production of organic wine faces challenges such as the continued use of pesticides and insufficient value creation for local farmers due to intermediaries in large-scale production networks. This article explores sustainability practices in the German Mosel region, focusing on the use of fungus resistant grape varieties (FRVs) to reduce pesticide usage and innovate value creation through alternative food networks (AFNs) in organic viticulture. By examining these practices, the article aims to enhance the understanding of sustainable viticulture and its components. Qualitative research conducted in the German Mosel region supports the theoretical framework presented.

The data that support the findings of this study are available from the corresponding author upon reasonable request.

6.1 Introduction

Although conventional farming still dominates the majority of wine production, farmers in Europe increasingly adopt sustainable production practices in order to meet the challenges posed by climate change and societal demand for environmentally sound production. As such, the European production of organic wine is a growing market for vignerons engaging in sustainable methods with an average growth of certified organic vineyard area by nearly 13% between 2005 and 2019 (OIV 2021) and further double-digit growth rates of the organic sector in the European Union in general (FIBL 2022). With a growing area under organic management, the wine production using EU organic certification labelling is gaining increased popularity (Willer 2013). Organic certifications as common labels to market wine allow for added value compared to conventional production (Dans et al 2019, Abraben et al 2017) and are especially attractive to retailers, since customers oftentimes show a willingness to pay a premium for sustainably produced wine (Nesselhauf et al 2020, Schäufele & Hamm 2017). However, the profits obtained from premium-priced wine seldom transfer directly to the producers and are dispersed in intermediaries of production networks in the wine sector (e.g. Montaigne & Coelho 2012). Yet, the readiness to apply innovative and sustainable farming practices appears to be higher in certified farms, hence studies show that farmers increasingly introduce organic viticulture for altruistic reasons and as an instrument for quality improvement (Hauck et al 2021, p. 67, Rauhut & Micheloni 2010, p. 275). Given the deficient value creation for organic wine producers engaged in standard markets with intermediaries consuming the majority of profits, this article investigates the role of fungus resistant grape varieties (FRVs) as a niche development promoting alternative food networks (AFNs) in which produce and value are exchanged in short food supply chains (SFSCs).

Research on FRVs started around 20 years ago when scholars began to engage with progress in wine cultivars that showed resistance to common pests in wine production (Basler & Pfenninger 2002, Gál 1998). FRVs originally derived from biotechnological development in horticulture and were obtained through crossbreeding *Vitis vinifera* and other Vitis species (e.g. *Vitis amurensis*) to make the emerging grapevine varieties resistant to fungal pests like mildew and downy mildew (Pedneault & Provost 2016).

Fungal pests pose a significant threat to wine production, as they can compromise both the quantity and quality of the final product (Thind et al 2004). In response to this challenge, conventional farming practices have emerged, employing mechanized vineyard management techniques and the use of pesticides to increase the yield and improve the overall quality of wine production. However, such approaches often raise concerns regarding environmental impact and long-term sustainability (e.g. Cech et al 2022).

Organic farmers, recognizing the need to reduce the ecological footprint of their farming practices, have sought alternative methods to protect their crops and improve the sustainability of wine production. One of the fundamental principles of organic farming is to avoid the use of conventional pesticides, which can have detrimental effects on the environment and potentially harm human health. However, this commitment to organic production presents a limitation for vintners: the reliance on copper-based pesticides (Karimi et al 2021).

Although copper has been widely used as a fungicide in organic farming, its long-term impact on the environment is a cause for concern. The accumulation of copper in soils over time can lead to soil degradation, water contamination, and negative effects on non-target organisms. Consequently, the overuse of copper-based pesticides poses a threat to the sustainability of organic wine production and the reputation of the organic sector as a whole (Kovačič et al 2013).

To address this challenge, the development and cultivation of fungus resistant grape varieties has emerged as a promising solution. These grape varieties possess inherent genetic resistance to fungal pathogens, rendering the use of copper-based pesticides largely redundant. By integrating the resistant varieties into their vineyards, organic farmers can mitigate the risks associated with copper pesticide use, ensuring the long-term sustainability of their production while upholding the environmental standards of organic farming.

Thus, this article explores the potential of fungus resistant grape varieties as a sustainable alternative for organic wine production. The study focuses on two key components: the application of fungus-resistant grape varieties and the engagement of farmers in alternative food networks. The primary aim is to understand how FRVs and AFNs help mitigate the

negative effects of viticulture on the natural environment while simultaneously enhancing value creation for farmers. As such the article aims to assess the effectiveness of fungus-resistant grape varieties in reducing the reliance on pesticides and minimizing environmental impacts within viticultural systems. Further, the research aims to investigate the engagement of farmers in AFNs as a means to enhance sustainability in viticulture and promote local and regional markets in conjunction with the application of FRVs. Prior work regarding FRVs and AFNs comprising short food supply chains has been conducted relying predominantly on survey data (e.g. see Finger et al 2022). The research of this article adds to the field of research via a qualitative approach to broaden the understanding of FRV applications in conjunction with AFNs.

The paper is structured as follows: Section 2 provides a theoretical background of sustainable viticulture for the analysis. Section 3 presents the Mosel region as the empirical field of research. Section 4 analyses the empirical findings by looking at the motivational aspects of FRV implementation in the Mosel region's wine production. Section 5 investigates the marketing of FRV wines in AFNs. Finally section 6 draws a conclusion on the results obtained in this research. The empirical sections are based on 19 qualitative interviews conducted on owner-operated farms in early 2022.

6.2 Sustainable Viticulture

Sustainable development in agriculture has gained momentum as an urgent response to environmental concerns and the need for long-term viability in food and beverage production. This approach seeks to balance economic profitability, environmental stewardship, and social responsibility. In viticulture, sustainable practices have emerged to minimize environmental impacts, optimize grape quality, and preserve the unique characteristics of wines (Daane et al 2018).

Sustainable viticulture integrates practices such as alternative pest management, soil and water management, biodiversity conservation, energy efficiency, and social responsibility. (Cataldo et al 2021). These practices aim to reduce pesticide use, improve soil fertility, conserve water, support biodiversity, and engage with local communities. By adopting sustainable viticulture, vintners can reduce their ecological footprint, enhance grape quality,

and meet the growing demand for environmentally conscious products. The adoption of sustainable viticulture not only mitigates environmental impacts but also contributes to the long-term viability and reputation of wine production. Consumers increasingly seek wines produced sustainably, creating market opportunities for vintners that prioritize environmental and social responsibility.

Besides the implementation of FRVs as a means to minimize negative environmental impacts and foster the reputation and sales of wine from organic production, sustainable viticulture additionally embraces the concept of alternative food networks (AFNs) as a means to enhance the resilience and sustainability of the wine production system while providing an economic fundament to the distribution of sustainably produced wine. AFNs are a conceptual framework to describe interlinked food production systems that share the notion of altering from conventional production (Corsi et al 2018) in redistributing value through their network against the logic of large-scale food producers, as well as creating new social dynamics and quality perceptions (Whatmore et al 2003). AFNs emphasize short supply chains, direct producer-consumer relationships, and local sourcing, thereby reducing transportation distances and associated carbon emissions. Through AFNs, vineyard owners can establish direct connections with consumers, fostering trust, transparency, and a sense of community. Consumers, in turn, gain access to high-quality, locally produced wines while supporting environmentally and socially responsible agricultural practices. AFNs provide a platform for consumers to engage with the vineyard's production processes, promoting awareness and appreciation for sustainable viticulture and its associated benefits.

In AFNs, short food supply chains (SFSCs) enable the creation of value regarding organic products through narratives like commodity biographies (Franz & Hassler 2010) to be shared more effectively and thus foster the process of value creation through relationship and meaning (Renting et al 2003). Three different types of SFSCs are defined by Renting et al (2003, 399f) as 1) “Face-to-Face”, 2) “Spatial proximity” and 3) “Spatially extended”. *Face-to-face* chains imply direct marketing of products that are bought straight from the producer, for example through on-farm sales. SFSCs of *spatial proximity* extend the marketing area to the regional scale, raising awareness of the local descent of the product during retail, selling via specialized regional shops or farm shops, direct contact with the producer is not necessarily

implied here. *Spatially extended* chains span over distances beyond the regional and transport value mainly via symbols of authenticity like certification logos or descriptive labels. These three types of SFSCs are highly relevant in order to understand the way value creation is driven and altered in AFNs of organic wine production.

The integration of AFNs fosters local economic development, supports small-scale producers, and enhances social equity within the wine industry. By supporting sustainable viticulture AFNs promote the conservation of natural resources, such as water and soil, and contribute to climate change mitigation through reduced carbon emissions associated with transportation.

By adopting sustainable viticulture practices, vineyard owners and wine producers demonstrate their commitment to environmental stewardship and social responsibility. They contribute to the preservation of biodiversity, the conservation of natural resources, and the mitigation of climate change impacts. Additionally, sustainable viticulture fosters a closer connection between consumers and the agricultural landscape, enabling them to make informed choices that align with their values of sustainability and support local economies.

6.3 Sustainable Viticulture in the Mosel Region

The German winegrowing landscape is diverse and renowned for its quality wines. Rhineland Palatinate, located in southwestern Germany, is a prominent wine region, producing over 62% of the annual wine produced in Germany (BMEL 2022). Within Rhineland Palatinate, the Mosel region stands out with its steep slopes, slate-rich soils, and production of acclaimed Riesling wines. The steep vineyards of the Mosel region present unique conditions to viticulture, resulting in wines that reflect the region's terroir and winemaking heritage.

Figure 6.1: Position of the Mosel Region in Rhineland-Palatinate and Germany.

Weinbaugebiete: Web Feature Service Landwirtschaftskammer Rheinland-Pfalz. Weinlagen. 2023 (dl-de-by-2.0 - Datenlizenz Deutschland Namensnennung 2.0)
Basiskarte: © GeoBasis-DE / BKG 2021, modified.

The landscape of grape varieties in the Mosel Region is typically dominated by the non-fungus-resistant white Riesling variety. Feeding from a tradition of plantation reaching back over 580 years (Röckel et al 2016), Riesling became a hallmark of German wine in general. For the Mosel Region, Riesling can be regarded as emblematic for numerous reasons, comprising its long-term adaptation to the local cool climate and the traditional cultivation on the steep and slate-rich slopes along the river valley, which traditionally results in mineralic and fresh wines that are internationally sought after.

The farmers reported that due to climate change resulting in especially hot and dry years between 2018 and 2020, they started to increasingly get bad results in Riesling and other white varieties for they require cooler temperatures to produce quality wines. Red varieties are commonly better adjusted to increased solar radiation and heat, thus the farmers wanted to diversify their range by increasing the share of red FRVs in their portfolio as a strategy that both adjusts to a hotter climate and does not compete with the dominant Riesling in the short term.

6.4 Background Motivation of FRV Use

All winemakers who implemented FRVs on their farms reported their motivation to use them in correlation with experience in organic and biodynamic production. The historical experience of the farmers, often rooted in viticulture for several generations, resulted in an awareness on negative impacts of conventional farming, which laid the motivational foundation to go organic and later implement FRVs:

> When I was 21, I took over the farm from my father. By then it was clear that I was going to do things differently because the crop protection outside was solely relying on me, I was at the sprayer and I got all the chemicals in my face, with nausea and headaches and all that. It started when I was 15 when I read through the texts on the package and thought, "Don't spray against the wind, don't breathe in the spray mist, how is that supposed to work?" At that time nobody had a mask, I was the first one to dress up like a bank robber. And when I took over, I wanted to make sure things change. – Farmer A

Since the farmers were not willing to further apply chemicals, the introduction of grape varieties that are immune to fungi pests appeared like 'a revelation' to Farmer A. The negative experience with the application of pesticides regarding the physical health of the winemakers

was shared among the interviewees. Despite the negative effects on humans, the farmers further reported that prior conventional farming also included degrading the ecological health of their vineyards:

> Even as a relatively young man, I noticed that I couldn't cope at all with the chemical-synthetic sprays, that I often had terrible headaches, rashes, sores, itching, massive headaches. And also these materials, when you put them away somewhere in the barn, they smelled disgusting and of mothballs. […] It also annoyed me to spray the soil with glyphosate and other products. In the end, the more you sprayed, the more problems you had because new weeds always came up. When they were all gone, the field bindweed came and finished us off, because it no longer had any natural cover and it loves the light. […] Now we don't work against the weeds but with them. – Farmer G

In contrast to this way of vineyard maintenance where the farmer applied pesticides in a way of symptomatic treatment, introducing FRVs allowed to largely abandon pesticides and the entailed disadvantages regarding costs and health. Farmer G referred to a short time after introducing organic production and FRVs to his farm when a family member, responsible for accounting, positively mentioned how low the costs for spraying had become.

Another benefit of FRV production was the fostering of interim greening between the grape trunks of the vineyard ('working with the weeds'). According to the interviewees, the interim greening that was possible due to the reduced use of pesticides following FRV application eased the vineyard maintenance with an increase of water capacity, prevention of erosion and a unique addition to the quality of the wine:

> Especially on the steep slope, we have beautiful plants that have formed there, wild carrots, mint, lemon balm, nettles, it all smells very good and gives our FRV wines that special kick in taste. – Farmer F

Culminating in several positive effects for the winemakers, introducing FRVs, pesticides could be largely abandoned which resulted in reduced danger to human health and a major direct-cost benefit in production. Farmers A & C stated that the reduction in workload especially created headroom to attend to other farm issues that often were postponed before, e.g. evaluating the farm's financial productivity. The absence of pesticides in FRV wine production implied a labour and wage reduction and also enabled the introduction of animals into the FRV vineyards. The livestock consisting of sheep, goats and small bovine had been introduced by Farms A, D, E and G and worked in conjunction with the FRVs, resulting in further cost

reductions for vineyard maintenance. The grazing of animals in the parcels reduced human effort to clear weeds, because the livestock also cleared the vine plants' lower leaf area, the vignerons' workload was further reduced. This silvopastoral practice was widely considered by the other farms already using FRVs:

> Yes, we are looking at getting animals too now. Back then animals just like humans would have been exposed to poisoning. Now with FRV that is not a problem anymore. - Farmer B

Further providing fertilizer, complying with sustainable thought and fostering marketing via close-to-nature attributes attached to the wines, the combination of FRV and livestock was regarded as a sustainable innovation to productivity as well:

> In our biggest parcel we only planted FRVs and are working completely without machinery. The sheep eat the interim greening and produce fertilizer. It is a very good system for us since the wine is also well sought after. Farmer E

Overall the farmers reported FRV as a distinct innovation to their production patterns, because the cost and workload from maintaining standard varieties were significantly decreased, whereas the work with silvopastoral applications further fostered sustainable methods. Reducing pesticides was regarded as a relief by the farmers working the vineyards. Minimizing the wine's overall environmental impact in turn showed positive effects beyond production when marketing the wine.

6.5 Marketing FRV wines in Alternative Food Networks

With the above-mentioned negative experiences in conventional farming preceding organic production and the implementation of FRVs, the interviewees reported to consciously differ from the logic that was present in large-scale mainstream wine production and searched for approaches that integrated the natural processes in the vineyard as well as involving customers into production and marketing processes. As a participatory practice, regular customers were invited by the farmers for helping on-farm and in the vineyard during the harvesting season. Accompanied by wine tasting and guided tours, the interviewed farmers invested considerable amounts of time in raising awareness on their ways of producing wine by increasing the participation of consumers in the production process. Providing tourist accommodation and engaging consumers in vineyard work was as much driven by the intention of authenticating the winemakers' work as establishing customer relationships.

Due to the minority position in the competing conventional wine-producing environment of the Mosel region, a notion of self-reliance had established among the interviewees which motivated the production as well as the distribution of wine in Alternative Food Networks. Thus the interviewed farms showed strong initiative in marketing their products making use of their historical and cultural heritage alongside establishing face-to-face marketing and spatial proximity supply chains.

In the wake of altering their distributional pathways to shorter supply chains, the share of FRV wines sold by the interviewed farmers was growing and had risen between 5% and 20% from 2012 to 2022. The farmers reported that taking up organic production was the foundation for implementing the FRVs, initially challenging them by having to justify their production to traditionally oriented consumers. While on the other hand an increasing share of young customers actively searched for sustainably produced wine:

> Our customer basis, increasingly younger people, requests the FRV varieties. Me and my partner, we regularly visit seminars on new developments and think they have advanced to a really great taste. Unlike 30 years ago, when FRV tasted somewhat strange. – Farmer D

Despite the FRVs driving a development towards attaching meaning to the product by face-to-face interaction and increased spatial proximity, Farmers reported that the Covid-19 pandemic with decreased international trading activity further motivated them to alter the marketing focus from export orientation towards the local:

> Before the pandemic, we had 20% direct sales from the farm and 80% via post or international shipping. Now that has turned around. 80% come to us and buy here, which is great, especially with the FRVs, they can taste them and overcome their doubts and I can explain. – Farmer C

The farmers reported that the sales of wine generally required a lot of oral marketing, explaining the wine in face-to-face situations, in tastings, giving guided tours or representing their farm on thematic fairs. With this predominant way of marketing as very time-consuming, the farmers found that the quality of consumer-producer relations after opting for AFN practices made for more consistent sales, especially in a regional context. Thus, introducing FRVs as a practice implying SFSCs reified the increasingly strong social ties of wine production in the region:

> When we are talking about marketing sustainable wine, FRVs, luckily a lot is changing in the customers' consciousness. I try and frame it to them as an investment, where do

you want to put your money? They, the customers have the power in their purses. – Farmer B

Throughout the interviews, it became apparent that producers were increasingly aware of raising consciousness on production circumstances and integrating them into their marketing through intensified relationships in regional distribution. As a means of establishing AFNs with the benefits from SFSCs, the consolidation of relationships between regional customers and farmers provided a way of capturing the value provided by FRVs in organic wine production and distribution.

6.6 Conclusion

Reviewing the changes in organic viticulture, the implementation of FRVs in AFNs lead to significant shifts in on-farm management and product sales. These changes included the reduction of pesticide use on FRV parcels, resulting in reduced workload and popularizing sustainable viticultural practices among the interviewed farmers, further enhancing their abilities of establishing AFNs for marketing wine more efficiently.

The interviewed farmers increasingly chose to market their products in AFNs to retain more value and bypass intermediaries like large retailers and commission agents in the wine production network. This transition to AFNs with short food supply chains (SFSCs) predominantly involved face-to-face interactions and spatial proximity between customers and farms. Shorter supply chains granted farmers greater control over selling their produce and the ability to directly explain the motivation behind planting FRVs to a wider audience. This fostered trust and relationships with regular customers, while promoting transparency and knowledge about the production circumstances. Moreover, farmers reported minimal income loss compared to previous distribution methods, as SFSCs allowed for better value capture in the sales process.

Linked to the benefits of AFN wine marketing, the application of FRVs showed the potential to reduce pesticide use, enhance value creation, and strengthen the marketing of related wines in AFNs, making it a driver for sustainable viticulture. Especially regarding the use of copper pesticides, viewed as a long-term threat to the reputation of organic farming and the environmental health, FRVs provided an alternative to copper use without compromising the

quality of wine production. This niche development enabled improved value activity in organic viticulture and in conjunction with AFNs helped solidifying regional socio-economic ties, further enhanced the marketing of organic wine.

In conclusion, sustainable viticulture offers a promising path forward for the wine sector, integrating alternative farming practices like FRVs and AFNs decreased the environmental impact, making use of natural processes while, improving the creation of value for farmers. Applying sustainable viticulture as a comprehensive framework thus successively mitigated the negative impacts of conventional farming, leading to improved environmental sustainability, social resilience, and closer producer-consumer relationships. Sustainable viticulture aligns economic viability with ecological integrity, ensuring a more sustainable future for the wine industry and the planet.

As found in previous work, this study supports the finding (Finger et al 2022) that FRV application increases with reduced distance between farmers and consumers. The decreased pesticide use in applying FRVs further complemented the increase in value activity in SFSCs. Thus, FRVs can be used to adapt wine production to environmentally friendly practices and target environmentally conscious consumers while improving value activity in AFNs. However, challenges remain in marketing FRV wines due to the limited knowledge among traders and consumers, who tend to stick to traditional wine attributes associated with origin and sensory characteristics (Borrello 2021). Future research should further explore the qualitative and quantitative potential for FRVs and AFNs to enhance viticultural practices and expand the concept of sustainable viticulture as a driver for sustainability in the field of wine production.

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Data Availability: The data supporting this study's findings is available on request from the corresponding author. The data are not publicly available due to privacy and ethical restrictions.

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6.8 Figures

Figure 6.1: Position of the Mosel Region in Rhineland-Palatinate and Germany. Cartography by C. Enderle.

7. Summary & Discussion

The past decades have introduced profound changes to agricultural practices in many parts of the world. The rise of mechanization, pesticides, genetic manipulation and selection of high-yield varieties still drive an overall intensification in the agricultural sector and food production today. The continuous productivist trend that is accompanying this development is surging across all continents and drives the agricultural sector to be one of the major emitters of methane, carbon dioxide and a driving force behind natural degradation and climate change (e.g. see Ritchie et al 2020). Besides the exploitation of natural resources, the farming system development in agriculture is accompanied by a trend of land concentration, which leads to an increased impoverishment of affected farmers, landowners and rural communities. Under the impression of such negative impacts on nature and society, farmers and communities seek change to the predominant agricultural and food regimes present in our times. Sustainability as a means to minimize the negative environmental and societal impacts of food production while providing for future generations has become a central goal for agricultural innovation. The overall sustainable development in food production gained broad recognition from the 1990s onwards, since becoming an integral part of international policy and society.

The societal demand for sustainability finds recent expression in political movements and protests, e.g. the 'last generation' or the Fridays for Future movement, demanding profound change to governmental action on climate issues and agricultural development. Accompanying this development, the demand for environmentally sound and sustainable food production rises in society, inducing a double-etched development in which on one hand the productivist narrative protrudes with large-scale companies entering organic food production, which are regularly accused of 'greenwashing' by applying sustainable imagery to largely unsustainable production pathways. On the other hand, there is an increasing spread of sustainability practices, predominantly engaged by smaller scale agriculture, which reflects in alternative forms to industrial food production systems, e.g. community supported agriculture, direct marketing or the implementation of agroforestry systems.

Wine is a product of a multifaceted agricultural process that is entangled in socioeconomic networks of large-scale production (e.g. Rainer et al 2021) to small-scale farming innovations (e.g. Losada et al 2019). As a plant and product vine and wine have developed slowly and accompanied human culture for millennia. The production of wine today represents profound economic value, transports traditions of century-old landscapes, demanding vast amounts of manual work, mechanical treatment and chemical input. As an agriculture that is especially prone to environmental change, viticulture represents a field of research that is necessary to be investigated for methods that can make this sector more sustainable and resilient towards current and future challenges while preserving the livelihood of the people connected to it.

In relation to the research questions of this dissertation, this chapter provides a reflection on the results concluded from the research. Afterwards, the findings are linked to the notion of sustainability, agroforestry and the theoretical structure laid out in Chapter 1 & 2. The chapter ends by presenting an outlook and potential future research prospects.

1) Why do farmers implement innovative practices in sustainable viticulture?

There are several aspects of viticulture to be considered when reviewing the motivational background behind innovative practices in sustainable viticulture. Foremost reflecting on the results obtained from this research, the motivation to carry out sustainable viticulture in general can be understood as a foundation to apply techniques that provide an improvement regarding the current and future state of natural resources as well as human livelihood. This assumption was first found in the literature review prior to the empirical research which aimed at investigating the motivational background of practitioners of sustainable agriculture and was confirmed through the empirical data later on.

In this research especially, sustainable viticulture was motivated by the effort to provide for the respective farms and the entailed future generations of the family businesses. This can be attributed to the Mosel Region being dominated by small to medium size farms, the majority of which were family owned and managed. Making use of this notion of intergenerational dependency, throughout the interviews farmers that were not certified under an official governmental label such as organic or biodynamic at an earlier stage also made use of the image that sustainable practice and thought drew on viticulture. Meaning that the use of

sustainability image and practice is not limited to the officially certified production of wine. Clearly the authentication of products from sustainable viticulture thus required the farmers to directly engage with their customers, which despite the added workload was widely perceived as a beneficial variety in everyday working life. Now with the majority of researched farmers, the notion of producing under organic certification was perceived as an upgrade to prior non-certified or conventional farming in that the personal outsets of preservation of natural resources could be achieved, further goals included a thoughtful farming that included an understanding approach to cultivation, harvesting, processing and marketing wine instead of a pouring-can-principle that could often be found in large-scale agriculture and conventional farming.

However, the limitation of pesticide use in certified sustainable viticulture was an additional aspect which could be identified as a focal point when trying to understand what was driving innovative practices in sustainable viticulture. Apart from an improvement of the farmers' more general concerns that referred to an improvement in economic viability, easier access to markets or stabilization of sales, the limitation of pesticides to mainly copper compounds due to the abandonment of phosphonic acids as of 2013 (Otto et al 2022) clearly induced a shift in the self-perceived sustainability of the organic and biodynamic winemakers. As laid out in Chapter 1 & 4, the application of copper was much less effective than prior pesticides allowed in viticulture, whilst copper as a heavy metal was not deemed viable by the farmers to be the go-to solution for continued standard variety cultivation, because they remain prone to Mildew, Downey Mildew and other common pests of vine. The unresolved situation with copper use in certified organic and biodynamic viticulture can be regarded as a downside that was yet unresolved and deserves further attention in future research. In this context, research engaged with fungus resistant grape varieties should be especially considered, since these varieties provide a potential solution to the sustainability issues with copper use in viticulture. Yet the farmers interviewed in this research partially remained hesitant as to the consumers acceptance of the new varieties and raised concerns on added efforts of consumer education additive to the already existent practice of oral marketing.

A key to understanding a driving dynamic behind the implementation of silvoarable and silvopastoral agroforestry systems and the increasing use of FRVs, could be found in the

general motivation of farmers to sustain production for future generations. Understanding the natural surrounding as a limited resource factor and incentivised by consumer dynamics that indicated rising awareness and demand of environmentally sound production, the farmers focused on implementing innovative practices in trying to reduce farming inputs, while the output quality was stabilized or increased, together with an effect of resource conservation and improvement all of which supported the narratives surrounding and authenticating sustainable development in viticulture.

2) How do agroforestry practices affect sustainable viticulture in the context of environmental and economic challenges?

The researched group of farmers carrying out sustainable viticulture in the Mosel Region was generally concerned with producing in a minority role compared to the surrounding conventional competition. As the farmers reported the governmental process of rounding off vineyard parcels in the preceding decades laid the base to initially certify and switch to organic production under EU organic or biodynamic labels. This was because organic farming only made sense to the farmers from a certain parcel size upwards, since with smaller fragmented vineyards drift-off from neighbouring conventional parcels would cover their vines and subvert sustainable farming.

However, challenges to the heterogeneous farming methods and practices that were reviewed throughout this dissertation comprised for the majority pesticide limitations to copper compounds and overall reduced outputs which made the justification of increased production costs with less output to customers a necessity. Further challenges regarded the establishment of stable distributional pathways, establishing organic wine as a mainstream product in a landscape of successful non-organic competition and the process of adapting to alternative crop management.

The research showed that agroforestry as an innovative practice with a long tradition in human agriculture was in the wake of being rediscovered in viticulture for its agricultural properties that veer from mainstream production systems in being able to mitigate the effects of environmental and the above-mentioned economic challenges. Agroforestry in viticulture can be regarded as a field of multi-faceted practices whose successful application depends on

site specificities like soil, geographic and climatic conditions. However dependent, the versatility of agroforestry in viticulture lies in the sheer endless possibility of combining vine, livestock and woody perennials into systems of agroforestry. The scholarly mainstream on the subject finds that the challenges consisting of extreme weather situations present in the development of global climate could be addressed using agroforestry (e.g. Schoeneberger et al 2012). Linked to the findings of this dissertation these challenges were attributed to the categories of production, processing and marketing and are reviewed in the following.

In the production of grapes in the Mosel Valley, climate change showed substantially in unprecedented dry years between 2018 to 2020. During this time, the lack of rain and overabundance of heat and sun radiation made for young vine plantations in the vineyards of the region to wither, while substantial amounts of grapes in regular parcels burnt, due to a lack of shading and natural water supplies. While in the first of the three years, there was still partial delight among farmers who eventually harvested wines that were rich in sugar given the hot year, the succeeding years proved to have depleted the vineyards ecosystems' abilities to regulate the occurrence of heat and draught on their own. This led to efforts of artificial irrigation by the farmers who installed drip irrigation lines, especially in vineyards with younger plants. This practice was unknown to be applied in the region prior to the phase between 2018 and 2020.

The silvoarable agroforestry practice which was the main subject of the first article (Chapter 4) of this dissertation, showed that the intercropping of trees with vine plants provided an example of a successful mitigation practice with regard to heat and draught. The poplar (Populus) and oak (Quercus) trees in the vineyard served for extended shading area above the vine plants which regulated the amount of evapotranspiration, further made for a microclimate that gathered humidity in comparison to regular vineyards. Underground, the extensive root system of the trees happened to decrease the soil erosion by wind or mechanized maintenance and further showed the ability to retain more water, which alongside the shading resulted in a significantly reduced crop loss rate due to drying out or sunburn compared to the neighbouring non-agroforestry vineyards. As reported by the farmers, the overall impression of the vineyards biodiversity due to the agroforestry system appeared to be lifted. However the extended workload associated with pruning the trees and

alternating the mechanized and manual maintenance of the vine plants were a distinct critique by the practitioners on the way the agroforestry system was set up, which leaves room for further scientific investigation on how to optimise the application of agroforestry in viticulture related to specific agricultural location and requirements.

The production with silvopastoral agroforestry systems, comprising vine plants as the perennial woody component and livestock herds consisting of sheep, goats or small bovines (bos indicus) happened to show positive effects, also reflected in the yet growing amount of literature on silvopastoral viticulture (Schoof et al 2021, Tognola 2020, Niles et al 2018). The introduction of animals in the vineyard made for natural grazing of the interrow spaces in the vineyards, which decreased the necessity of human effort to execute manual, chemical or mechanical weed control. Some animal breeds executed the decimation of excess vine shoots in the lower stem area of the vine plants, which was a task that was priorly carried out by human hand in order to concentrate the sap flow and increase the grape quality. The natural provision of dung by the animals further served for the possibility of decreased human interference into the vineyard and a cost reduction for externally produced fertilizer.

The overall concept of silvopastoral viticulture proved to produce an agricultural ecosystem, who's interrelated services made for a more autonomous production system in which workloads for humans were vastly reduced, while surplus value had been created due to the introduction of animals. The perceived lift in sustainability could be further amplified by farmers who started the use of fungus resistant grape varieties. The varieties obtained through the crossbreeding of Vitis vinifera with other varieties from the Vitis family made for a vegetation cycle in which the vine plants were naturally immune to common pests such as Mildew and Downey Mildew. Since these pests are the main reason for global pesticide consumption in viticulture and a subsequent threat to livestock kept in the vineyards, the practice of moving livestock out of the vineyards during spraying season was further made redundant in farms that combined silvopastoral viticulture with fungus resistant grape varieties. Once the grapes were harvested, processing the wine from agroforestry systems did not differ substantially from common methods in the Mosel region. Due to the steepness of the vineyards, mechanised harvesting was close to impossible in most parcels for either the machines were unable to operate the terrain or vintners scepticism as to the unharmed condition of the grapes made them opt for manual harvest. Apart from that, the grapes

obtained from agroforestry were reported to substantially differ from pre- and non-agroforestry management in that the grapes overall health and typicity was preserved due to the above-mentioned shading, increased biodiversity, water provision, weeding and excess shoot control. The processing of the grapes took place on-farm or in close proximity on sites of farmers associations, consisting of de-ribbing, pressing and fermenting in either spontaneous fermentation or with cultured yeasts.

Linked to the research question, the agroforestry researched in this dissertation proved to maintain or improve the grape quality which supported the sustainable development of the wine production process. Climate effects were perceivably mitigated due to the reciprocal provision of ecosystem services in the vineyard. Farms who were combining livestock and FRVs reported the highest improvement in sustainability and efficiency. Thus the interface of FRVs and agroforestry can be regarded as especially facilitating sustainable viticulture. The researched manual workflows had been eased or made redundant, while the processing workflow of short distances and on-farm fermentation, bottling and sales remained largely unaffected. The use of agroforestry and FRVs however had a serious impact on the marketing end of wine production. The raised quality of wines was generally used as a marketing argument by the farmers, accompanied by narratives of originality, handcraft and environmentally sound production which reportedly attracted customers and helped build long-term sales relations. Apart from a raise in marketing arguments and product quality, the interviewed farms further gained product diversity in being able to market products from their agroforestry systems that were non-wine, such as meat, wool and wood.

3) Do niche developments in sustainable viticulture provide potential to pioneering new mainstream methods in the sector?

As stated above, the researched sustainable production patterns in viticulture were situated in a region where not only conventional viticulture was in a majority and prospering position, but also the narratives of sustainable viticulture had established in the mainstream of wine production. So much that narratives of sustainability had become an integral part of the communication surrounding the researched wine production, even with competitors that were opposing organic or biodynamic certification. Among the interviewed farmers, the spread and intensity of organic and biodynamic production patterns had introduced an

increased awareness towards the effects of viticulture on the surrounding. The farmers' awareness however also covered the broadening of sustainable viticultural practice to large-scale farming as threatening to shallow the effectiveness of sustainable farming via greenwashing. As a niche group who practiced sustainable viticulture under certification, the farmers were in a constant process of elaboration on how to further develop and reify their practices in order to raise sustainability and establish their production pathways. In fact the niche development of agroforestry practices as well as the use of fungus resistant grape varieties can be regarded as main drivers in this attempt to further improve ways in which grapes are produced and coproduced in ecosystem configurations that engage mutual benefits in order to lead viticulture into production patterns that minimize negative externalities whilst providing quality and high value produce. The number of interviews conducted in this dissertation does not provide statistical representativity for extra-regional scale, the depth of insight into the innovative farming practices however indicated a low level of saturation regarding the satisfaction with status quo organic viticulture in the Mosel Region. Thus while the optimum of system configuration such as in the case of silvoarable production with the case of Article I (Chapter 4) was still debated, the overall search and discussion on how to further improve sustainable viticulture towards a future livelihood was vivid and indicated a tendency to be broadened, eventually establishing agroforestry and FRVs as mainstream methods in viticulture, especially given the current development and rediscovery of agroforestry in other agricultural production types.

Sustainable Viticulture

The results from this research showed to have differently strong relations to the sustainability outlines that were given in the introduction of this dissertation (p.4f) and are displayed again here:

• "integrate natural processes such as nutrient cycling, nitrogen fixation, soil regeneration and natural enemies of pests into food production processes;

• minimise the use of non-renewable inputs that damage the environment or harm the health of farmers and consumers;

• make productive use of the knowledge and skills of farmers, so improving their self-reliance and substituting human capital for costly inputs;

• make productive use of people’s capacities to work together to solve common agricultural and natural resource problems, such as for pest, watershed, irrigation, forest and credit management“ (Pretty 2005, p.2).

Related to these outlines the research showed the following outcomes:

I. Applying innovative farming, processing and marketing, the integration of natural processes was indeed accompanied by the farmers' development of sustainable viticulture. With reference to agroforestry as a novel practice especially, nutrient cycling and soil health were increased, while pest pressures dropped due to the abundance of natural enemies to them.

II. The presence of animals in vineyards made for a substitution of manual work for farmers, which did not only minimise the input of mechanised work, hence the use of non-renewable fuel used in tractors, but also relieved the farmers and vineyard workers physically, while supporting the idea of a holistic viticulture that endorsed animals as part of sustainable viticulture.

III. The productive use and ideal thought behind engaging silvopastoral, but also silvoarable agroforestry was explicitly part of the farming associations behind organic and biodynamic farming in this research. As a community, the use of Agroforestry and FRVs in farming made for a reduction of external inputs to the farm, mainly in the form of reduced or abandoned pesticides. This especially fostered the farmers' self-reliance, together with the implementation of self-made compost, sharing of animal and human work force.

IV. The practices researched in this dissertation made for the farming community using innovative practices in organic and biodynamic viticulture to grow, yet also consolidated under the exchange about what kind of method was applicable and how to further raise awareness of consumers for their practices while also refining the latter. In all, according to the outlines given above, the researched farms from the Mosel Region showed to improve the sustainability within their viticultural practice via applying different methods of agroforestry, fungus resistant grape production and constant improving of existing production regimes. This made for an overall improvement in the farmers’ goals to carry out sustainable viticulture.

Agroforestry in Viticulture

Agroforestry in viticulture can be regarded as a re-emerging agricultural practice with long tradition, especially in pastoral farming, that has a rich variety and high potential of contributing to sustainable development with several forms of application. Dependent on the combinations of livestock, perennial plants and vine, the research on agroforestry in this dissertation showed that a cool climate wine growing region like the Mosel, whose climate is shifting to an overall higher abundance of heat and extreme weather events (see MKUEM RLP 2021), profits from the applications. This was reflected in the above articles results in several aspects, namely:

The silvoarable systems containing vine plants and trees created major change and benefits in production and marketing of the wine. The large tree canopies saved the white grape varieties from extensive heat and radiation in summer, which secured the final white wine product from defective taste and substantial crop loss due to sunburn. The trees further served as a windbreak that decreased soil loss through drift-off. The soil was also consolidated by the tree roots, decreasing the risk of landslides with regard to recent flood events and the soil degradation by heavy machinery. The tree roots also increased the water capability and provision of nutrients for the vine plants as the farmers perceived. The farmers found the working with trees in the vineyard a novelty which added to their workload, which despite the advantages made adaptions in tractor work, knowledge on tree pruning and manual harvesting necessary. Marketing the wine from agroforestry was facilitated for the farmers, as the representation of sustainable and traditional attributes due to the systems visibility was a catalyst for consumers interested in sustainable wine. The farmers praised the advantages silvoarable viticulture presented to them, yet the majority was open to systems integrating trees with by-products that were better suited for their farming like fruit or nut trees. Linked to agroforestry, the farmers considered the application of agrophotovoltaic systems for energy production as attractive as well.

The silvopastoral systems integrating livestock into the vineyards represented substantial change and enhancement to the winemakers production patterns too. Where the silvoarable systems advantages mainly performed in retaining landscape, farming type and product typicity alongside enhancing the biological richness, product diversity and marketing aspects,

the silvopastoral systems shared an increase of product diversity, biological richness and close-to-nature marketing aspects. Yet the effect on the production consisted of reciprocal provision of dung and feed between vine plants and animals, further side effects regarded a wished-for defoliation by the animals performed on the vine. Altogether this resulted in a decrease of the workload for farmers and was widely regarded as the biggest advantage together with decreased pesticide use and increased product diversity. The livestock element made for a lift in biological diversity and provided the vine plants with dung from the animals while these kept weeds from growing by feeding on them. The research found that the synergic effects of livestock and viticulture is further boosted by the use of fungus resistant grape varieties. FRVs made the application from pesticides largely unnecessary, which in turn made for safer conditions for animals to graze in the parcels, while the pesticide abandonment together with livestock again served as an extra marketing argument for wine and animal products alike. The marketization of FRV wine again was found to often connect to alternative distributional pathways, namely alternative food networks (AFNs), whose specialization is to distribute the wine from farmer to consumer without intermediaries so that the profits stay with the producer while the product can be authenticated with a decreased carbon footprint compared to wine traded in large scale networks. All of the above represents crucial innovations to sustainable viticulture that relates to the understanding of sustainability development in agriculture underlined by climate and economic hazards. This has also been reflected in the applied theoretical frameworks, to which this research's contribution is being discussed in the following.

Leverage Points for Sustainability Transformation

The theoretical contribution of the leverage points for sustainability transformation lied in the applicability of the framework to agroforestry in viticulture as a practice with innovative potential that proved to engage points of deep leverage within the exemplary field of wine production. Applying sustainability levers in viticulture represented a new field of application for the theory. The theoretic concept of deep leverage, namely separated into re-think, re-connect and re-structure turned out to be useful categories that strike out the impact of agroforestry as an innovative farming practice to the status quo wine production. The re-think realm was linked to the way the farmers who engaged the innovative practices happened to alter and reflect on their ideal pathways with regard to their everyday work. The intention to

reshape their own way of food production entailed a conscientiousness that aimed at educating consumers and colleagues on how to conduct viticulture more sustainable, while selling and improving the overall wine production. The re-connect realm from the sustainability levers theory was especially present in the silvopastoral but also the silvoarable applications of agroforestry in the researched viticultural farms. The systems as visible indicators of alternativeness in that livestock or trees were part of the vineyard landscape showed to stand out the region that is usually dominated by clean looking dip-line plantations. The agroforestry systems sparked interests in consumers and tourists to engage with the way wine is being produced and thus enforced a reconnection to natural processes in food production. Finally the re-structure realm was applicable to the researched practices as well, for it showed to alter existing structures of distribution, in increasing the local sales of wine due to the attraction of customers. Further an aspect of restructuring could be identified in an increased openness towards production systems that are alternative to the predominant viticultural production systems.

Ecosystem Services

The concept of ecosystem services has been proven to be applicable to the field of agroforestry in viticulture during this dissertation's research. Ecosystem services have been well tried in striking out the advantages the mutual provision of actors in ecosystems and their outputs in product or immaterial form have. This research has further shown the applicability of ecosystem services theory in viticultural niche practice, especially in silvopastoral viticulture. The theoretical understanding of ecosystems' provisions among ecosystems and to humans alike, made for a deepened understanding of natural processes, that could be linked to the re-think realm mentioned in the sustainability levers theory. Re-thinking viticultural production in an integrated system of vine plants, livestock and trees, the perspective of ecosystem services enabled the benefits from ecosystem interaction in viticulture to be more visible, which in turn opened the possibility to evaluate innovative practices like silvopastoral agroforestry with regard to their ability of raising the overall sustainability of the production regime. Apart from that, the presence of ecosystem services' use in viticulture increased farmers motivation to further educate themselves, their peers and their customer in the context of an overall increase of sustainability in viticulture and agriculture.

Alternative Food Networks

As indicated in Chapter 2, the use of large-scale global production networks in food production leads to an increasingly alienated relationship between the producer and consumer of food. Wine as subject to large-scale production and international shipping is also part of such alienating food networks in which oftentimes the wine bottle's label is the only medium of communication to the customer. Farmers in organic and biodynamic viticultural production that were interviewed for this dissertation largely opposed the partaking in global production networks as they understood this practice as counteractive to their intentions in farming. Alternative Food Networks are used to describe networks that deviate from the above-mentioned global production networks in relocalising production, processing and distribution. Further, the goal of AFNs is to re-establish a direct relationship between consumers and producers by direct sales that happen on-farm, in local organizations or specialized shops.

The concept of alternative food networks showed to be applicable in this research, as farmers voiced increased efforts to adapt their organic and biodynamic farming methods to support AFNs. This was deemed attractive by the farmers mostly because of an increased value creation process and an easier communication of the respective farming methods and production philosophy due to the shorter supply chains that genuinely involved more direct contact between farmers and customers. Farmers who applied the niche development of silvopastoral viticulture alongside the introduction of short food supply chains into the sales of wine products showed to especially gain benefits from their farms because of the mutual cost and workload reduction both the silvopastoral viticulture and short food supply chains in AFNs provided (see also Finger et al 2022). The majority of the interviewed farmers also ran hospitality business with on-farm tourist accommodation which further profited from alternative food networks. Thus, an additional benefit to the close customer relations from AFNs could be identified in the increased touristic attraction, raised by livestock in viticulture. The farmers reported that visitors of the region were especially attracted by the close-to-nature imagery that was created by the livestock's presence.

Sustainability Transformation in Wine Production

Reflecting on the sustainability transformation processes laid out in this research, each of the three papers comprising this dissertation researched an aspect that farmers introduced into their production patterns which pioneered the predominant way of viticulture and organic viticulture. The innovations researched in the papers emerged through farmers that introduced novel techniques to their viticultural practice as pioneering actors. The introduction of new cultivational methods and crops created niches that veered from the mainstream which in turn represented a point of departure for sustainability transformation.

For the first article the niche created can be identified as that of silvoarable agroforestry production in the Mosel region's viticultural sector. The implementation of trees into vine cultivation led to the production of new knowledge on the interaction and alternative methods included in agroforestry. Identifying the farmers' experiences with agroforestry and linking them to the sustainability levers theory, an in-depth understanding of transition within the viticultural production was enabled. The trees and vines shaping the pioneering agricultural system predominantly provided resilience and improvement to the farming system compared to conventional farming, while the adaption of workflows was reported as a downside to the initial introduction of the system. Article two reviewed the introduction of animals into the vineyard areas, forming a silvopastoral agroforestry system. This article reflected on ecosystem services obtained from the use of livestock in vineyards. The practice can be regarded as another radical innovation for the Region's viticultural sector since the outcomes of the application affected the use of pesticides as a central issue for organic viticulture. Inducing a transition of sustainable development, the increased visibility of beneficial silvopastoral management through the ecosystem service perspective proved to indicate a transition of sustainable development. The third article reviewed the introduction of fungus resistant grape varieties (FRV) into organic and biodynamic farming and the relation to using alternative food networks. How the transitional techniques influenced product quality and the marketing of the wines was researched and put into relation with the overall insights from the qualitative Interviews.

Outlook & Future Research Prospects

Overall, sustainable viticulture is a pressing concern for the wine sector as it seeks to minimize environmental impact while maintaining quality and profitability. Within this context, two promising future areas of research have been shown in this dissertation: the integration of agroforestry practices and the utilization of fungus-resistant grape varieties. Besides the potential of future research to further investigate the full potential of these practices, additionally, broader implementation and consumer awareness of sustainable production patterns using fungus resistant grape varieties and agroforestry, especially in conjunction with organic wine production are crucial for the long-term research on sustainable viticulture.

Agroforestry has shown potential in enhancing the sustainability of viticultural production systems. In the context of viticulture, agroforestry can provide multiple ecosystem services, such as improved soil quality, enhanced biodiversity, and increased resilience to climate change. Despite these potential benefits, there is a lack of comprehensive research on the specific design, implementation, and management practices of agroforestry systems in vineyards. Further research is needed to understand the optimal tree-crop configurations, plant-livestock combinations, tree species selection, and the potential trade-offs and synergies with vineyard management practices.

Fungal diseases, such as powdery mildew and downy mildew, pose significant challenges to viticulture, requiring the extensive use of fungicides that can have detrimental environmental impacts. Fungus resistant grape varieties offer a promising alternative to reduce chemical inputs. However, the utilization and acceptance of these varieties in commercial viticulture are still limited. Research is needed to develop and evaluate a wider range of fungus resistant grape varieties, assessing their potential for broadened cultivation, also linking the wine quality to consumer preferences. Furthermore, studies on the long-term sustainability and resilience of these varieties in different climatic conditions and vineyard management systems, especially in conjunction with agroforestry, are essential.

While sustainable viticulture practices are crucial, consumer awareness and demand for sustainably produced wines play a pivotal role in driving industry-wide adoption. Although organic and biodynamic certifications indicate certain sustainability traits, the general public's

understanding and awareness of these certifications and their associated benefits remain limited. Further research is needed to investigate consumer perceptions, preferences, and willingness to pay for sustainably produced wines. Additionally, effective communication strategies and marketing campaigns can help bridge the gap between sustainable viticulture practices and consumer understanding, fostering demand for certified wines and promoting sustainable agricultural systems.

The interlinkage of agroforestry practices and the utilization of fungus resistant grape varieties hold tremendous potential for improving the sustainability of viticulture. However, addressing the research gaps outlined above is crucial to unlock the full benefits of these practices. By conducting comprehensive studies on agroforestry design and management, expanding the range of fungus-resistant grape varieties, and enhancing consumer awareness of sustainability traits, the wine industry can progress towards a more sustainable and resilient future.

Zusammenfassung

Seit Mitte des 20. Jahrhunderts zeigt sich eine zunehmende Industrialisierung und Intensivierung der Landnutzung im Agrarsektor. Diese Entwicklung geht einher mit der Steigerung der Produktivität in prosperierenden Volkswirtschaften seit dem 2. Weltkrieg und dem insgesamten Wachstum der Weltbevölkerung. Neben der flächendeckenden Versorgung mit Lebensmitteln hat die Industrialisierung des Agrarsektors auch zu einem hohen Ressourcenverbrauch und bleibenden Umweltschäden geführt. In der Folge wächst insbesondere seit den 1980er und 1990er Jahren das gesellschaftliche Bewusstsein für die negativen Auswirkungen der Landwirtschaft auf Umwelt und Ressourcen.

In der Weinbauregion Mosel in Rheinland-Pfalz, die aus den Weinbergen entlang der Flüsse Mosel, Saar und Ruwer besteht, begannen wenige Winzer in den frühen 1980er Jahren nach Alternativen zu den gängigen industriellen Anbaumethoden und Pestiziden zu suchen. Sie passten ihre landwirtschaftliche Praxis im Sinne der Nachhaltigkeit an und organisierten sich zunehmend in wachsenden Ökoverbänden. Diese wenigen Winzer wurden Teil einer wachsenden Szene nachhaltig arbeitender Weinbauern in Deutschland. Heutzutage stellen nachhaltig produzierte Weine einen stark wachsenden Anteil des deutschen und internationalen Weinmarktes dar. Die ökologisch bewirtschaftete Weinbergsfläche Deutschlands hat sich seither ebenfalls vergrößert, obwohl aufgrund der Anfälligkeit des Weins für Krankheiten und Schädlinge weiterhin Maschinen und Pestizide eingesetzt werden. Dies stellt zusätzlich zu den Auswirkungen des Klimawandels ein grundlegendes Dilemma für die Betriebe von Ökowinzern dar, welche bemüht sind ihre Weinbaupraktiken anzupassen.

Eine der Praktiken, die eine zentrale Rolle in der Erforschung von Nachhaltigkeitspraktiken dieser Arbeit spielen, ist die Agroforstwirtschaft. In der Agroforstwirtschaft wird zwischen silvoarablen und silvopastoralen Systemen unterschieden. Silvoarable Systeme kombinieren Bäume oder mehrjährige Pflanzen und Gehölz mit Feldfrüchten. Silvopastorale Systeme kombinieren Bäume und mehrjährige Pflanzen und Gehölze mit Tierhaltung. Agroforstwirtschaft ist ein Begriff, der im 20. Jahrhundert geprägt wurde, aber seine Ursprünge in frühen Landnutzungsformen, beginnend mit neolithischen Kulturen vor etwa 10.000 Jahren hat. Agroforst-Praktiken wie die Beweidung von Obstwiesen oder das Pflanzen von Hecken zum Schutz der Feldfrüchte wurden über Jahrhunderte hinweg gepflegt, sind aber

aufgrund der Intensivierung und Mechanisierung der Landwirtschaft im 20. Jahrhundert zunehmend in den Hintergrund gerückt. Die Kombination von Bäumen mit Ackerpflanzen oder Tieren in Agroforstsystemen bietet verschiedene Synergieeffekte, wie beispielsweise die Beschattung von Weinbergen durch in den Rebzeilen gepflanzte Bäume. Dies hilft, den Wassergehalt der Böden bei Trockenheit zu erhalten und die Trauben vor Sonnenbrand zu schützen. Agroforstsysteme ermöglichen auch Einsparungen bei Arbeitsaufwand und Kosten, da die Tierhaltung eine kontinuierliche Versorgung mit Dung und Unkrautbekämpfung durch Beweidung bietet. Angesichts der Veränderungen der Anbaubedingungen durch den Klimawandel und der gesellschaftlichen Forderung nach nachhaltigen Methoden zur Lebensmittelproduktion, gewinnt die Agroforstwirtschaft wieder an Bedeutung und wird als innovative Praxis in dieser Dissertation zur Nachhaltigkeitsentwicklung im Weinbau untersucht. Zusätzlich zur Anwendung von Agroforstmethoden im Weinbau wird auch die Nutzung von pilzwiderstandsfähigen Rebsorten (Piwis) in dieser Dissertation behandelt.

Die Selektion von Rebsorten für den Weinbau hatte bisher vor allem die Quantität und Qualität des Pflanzenmaterials im Fokus. Doch aufgrund des Klimawandels sowie Schädlingen und Krankheiten ist die Weinrebe zunehmendem Druck ausgesetzt. Daher wurden beginnend im 19. Jahrhundert gezielt Rebsorten mit Resistenz gegen Krankheiten gezüchtet. Heutzutage gewinnen Piwis für Winzer und Konsumenten an Attraktivität, da sie den weitgehenden Verzicht auf Pestizide ermöglichen und somit Kosten und Arbeitsaufwand reduzieren. Gleichzeitig eröffnet der Verzicht auf schädliche Chemikalien die Möglichkeit einer dauerhaften Nutzung von Tieren im Weinberg. Agroforstsysteme in Verbindung mit Piwis bieten somit Möglichkeiten, die Weinproduktion nachhaltig und zukunftsfähig zu gestalten und gleichzeitig die Produktvielfalt der Winzer durch neue Rebsorten und tierische Produkte zu diversifizieren.

Diese kumulative Dissertation umfasst drei Forschungsartikel, die auf qualitativen Interviews basieren. Artikel 1 untersuchte die Nutzung von Agroforstsystemen im Weinbau und ihr Potenzial, den Auswirkungen des Klimawandels auf die Weinproduktion und den Vertrieb zu begegnen. Die Bepflanzung von Rebzeilen mit Bäumen führte zu stabilerer Produktqualität während trockener Jahre, was gleichzeitig zu geringeren Schäden durch Sonnenbrand und reduzierter Bodenerosion führte. Angesichts ihrer gemachten Erfahrungen bevorzugten die

interviewten Winzer jedoch ein besser angepasstes Agroforstsystem, das auch Teil der Wertschöpfung oder mit Agro-Photovoltaik kombiniert sein könnte. Artikel 2 untersuchte Ökosystemdienstleistungen in silvopastoral bewirtschafteten Weinbergen, in denen Tiere den Weinberg beweideten, Unkraut reduzierten und den Arbeitsaufwand maßgeblich verringerten. Die silvopastoralen Weinberge erhöhten die biologische Vielfalt, die Weinqualität und ermöglichten ein erweitertes Produktportfolio. Artikel 3 befasste sich mit alternativen Lebensmittelnetzwerken und Piwis im nachhaltigen Weinbau. Alternative Lebensmittelnetzwerke zielen auf die Beseitigung von Intermediären in Wertschöpfungsketten ab und fördern direktere Interaktionen zwischen Produzenten und Konsumenten. Der Artikel kommt zum Schluss, dass pilzwiderstandsfähige Rebsorten nicht nur die Bewirtschaftung der Weinberge, sondern auch die Etablierung kurzer Wertschöpfungsketten erleichtert. Die Artikel dieser Dissertation zeigen insgesamt, dass Agroforstsysteme, Piwis und alternative Lebensmittelnetzwerke Möglichkeiten für die Weiterentwicklung des nachhaltigen Weinbaus bieten.

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Appendix

Interview Guideline German

Interviewleitfaden

Einleitung

Begrüßung, Danksagung für das Interview, Überblick über die zu behandelnden Themen.

Anonymisierung anbieten, Aufnahmegenehmigung erbitten, etwaige Fragen klären.

I. Allgemeine Informationen zum Betrieb

Zu Beginn würde ich Sie und den Betrieb gerne etwas kennenlernen.

Können Sie bitte die Geschichte und Entwicklung des Betriebes und ihre Rolle und Tätigkeiten darin beschreiben?
Was genau machen Sie im Betrieb?
· Eigentumsverhältnisse, Alter, Gebäude

Bitte beschreiben Sie das Land, dass sie bearbeiten in Hinblick auf Größe, Qualität und Besitzverhältnisse.
· Größe in Hektar; Eigentum/Gepachtet
· Schwierigkeiten bei der Beschaffung/Bewirtschaftung des Landes
· Qualität der Flächen

Welche Akteure sind involviert?

Sind die Flächen ausreichend, für was Sie damit machen? Was würden Sie gerne noch machen?

Welche unterschiedlichen Landnutzungsformen gibt es im Betrieb?
· Weinbau, welche Sorten, Anbauform, Lagen; Weiden, Obstwiesen, Feldfrüchte, Weiden, Wälder, Brachen, Blühstreifen, Naturdenkmäler, historische Bauten, Tierhaltung etc.

Wie genau verteilt sich der Anteil der unterschiedlichen Nutzungsformen in ihrem Betrieb?
·Prozent, Anteile, gemischte Bepflanzung, ökologische/konventionelle Bewirtschaftung.

Soll die flächenmäßige Zusammensetzung des Betriebes geändert werden? Was ändert sich?

Wie wird die Arbeit auf dem Betrieb organisiert?
· Mitarbeiter; Anteil an Familienmitgliedern, Qualifikation (Wer braucht welche Qualifikation, wie lange dauert eine Ausbildung), Arbeitszeiten
·Saisonarbeitskräfte; Herkunft, Bezahlung

· Welche Arbeit machen die Angestellten/der Winzer; Kosten für Angestellte im Monat/Jahr

II. Nachhaltiger Weinbau, Betriebsentwicklung & Gesellschaft

Welche Rolle spielt Nachhaltigkeit in ihrem Betrieb?

Welche Maschinen nutzen Sie im Betrieb?

Welche Betriebsmittel müssen Sie kaufen? Wie viele und was kostet das in etwa?
· Kriterien für die Auswahl von Lieferanten
· Setzlinge, Wasser, Pflanzenschutz, Düngung, größter Kostenpunkt, Tauschwirtschaft
· Fortbildung: Zeitaufwand & Kosten, in welchem Feld?

Welche Betriebsmittel können Sie im Zuge der Betriebsumstellung wegfallen lassen/ ersetzen? Durch was? Wie wirkt sich das auf den Betrieb aus?

Haben Sie das Gefühl, dass das was sie tun von der Gesellschaft unterstützt wird?

III. Produktion & Distribution

Welche Produkte produzieren Sie? Wie und Warum?

Wein: Welche Sorten? Weinausbau selbst, wenn nein wieso nicht und wo, wenn ja wie?

Wie unterscheidet sich der Verarbeitungsprozess zu anderen Betrieben?

Stellen Sie Produkte mit Gütesiegeln her, wenn ja welche? Was für Gütesiegel? Wieso diese Gütesiegel?

Werden Abfallprodukte wiederverwendet?

Wie kosten-/ und arbeitsintensiv ist die Produktion?
· Wie sind die Produkte in ihrem Sortiment aufgeteilt?
· Welches ist das Lohnendste, persönlich und finanziell?
· Welches Produkt ist am arbeitsintensivsten?
· Welches Produkt produziert das meiste Einkommen?
· Wie hoch sind die Erträge für die jeweiligen Produktgruppen?

Planen Sie eine Vergrößerung oder Verkleinerung der Produktion?

Befolgen Sie in ihrem Betrieb ein bestimmtes Produktionsschema?
· *Demeter*, was bedeutet das für die Produktion konkret?
· *Ecovin*, was bedeutet das für die Produktion konkret?
· *Bioland*, “ ?
· *Naturland*, “ ?
· Welche Vorteile ergeben sich für Sie aus dieser Produktionsweise?

Sind Sie Mitglied einer Kooperative, Weinbauverein oder Genossenschaft? Wenn ja, warum?

Wie wichtig sind Interessenvertreter (NGOs, Genossenschaften) für die Entwicklung in ihrem Betrieb? Was leisten diese?

Spüren sie im Betrieb Auswirkungen durch den Klimawandel? Wenn ja, welche?

Welche Änderungen ergeben sich durch den Klimawandel im Betrieb?

Passen Sie den Betrieb auf die sich ändernden Umweltbedingungen an? Wenn ja, wie?

Betreiben Sie Anlaufstellen für den Tourismus, Übernachtungsmöglichkeiten, Besenwirtschaften, Gastronomie? Wenn ja, beschreiben Sie wie es dazu kam und ob sich der Betrieb rentiert.

IV. Agroforst/ Mischkulturen

Beschreiben Sie bitte ihr Verhältnis zu Agroforst/ Mischkulturenanbau. Wie sind Sie zur Nutzung dieser Anbauform gelangt? Welche Erfahrungen haben Sie bisher damit gemacht?

Bitte beschreiben Sie den Jahreszyklus im Agroforstsystem/ Mischanbau.
·Informationen über Sorten, Erträge, Verwaltung, Pflege und Artenvielfalt der Fläche.

Welche ökonomischen und ökologischen Vorteile ergeben sich aus dem Agroforstsystem/ Mischanbau?

Ergeben sich ihrer Meinung nach Synergieeffekte aus der kombinierten Bepflanzung?

Soll die Fläche vergrößert/verkleinert werden? Wenn ja, wieso?

Erleben Sie Schwierigkeiten im Zusammenhang mit dieser Anbaumethode?

Welche Effekte hat das Agroforstsystem/ der Mischanbau auf die Produktion und die Produkte ihres Betriebes?

Werden Sie in Zukunft weiter mit Agroforstsystemen/ Mischanbau arbeiten? Warum?

V. Vertrieb und Marketing

Bitte beschreiben Sie Marketing und Vertriebswege ihrer Produkte. Können Sie den Weg des Produktes bis zum Konsumenten nachvollziehen?

Wie kosten/ und arbeitsintensiv ist der Vertrieb?
· Wie und an wen verkaufen Sie ihre Produkte? Welcher Anteil der Produktion wird durch die jeweiligen Vertriebskanäle verkauft?
· Welcher Vertriebskanal ist der lohnendste, persönlich und finanziell?

Wieso nutzen Sie diese Vermarktungswege?

·Würden Sie an den Vertriebswegen gerne etwas ändern?

Wie entstehen die Preise für ihre Produkte?
· Sind die Preise angemessen sowohl für Winzer als auch für Konsumenten?
· Spiegeln die Preise die echten Kosten der Produktion wider?
· Verlangen Sie mehr oder weniger Geld als in einem konventionellen Betrieb?

Sind Sie Mitglied in Weinbauverbänden wie VdP, Bernkasteler Ring, Ecovin o.ä.?

Nutzen Sie Gütesiegel auf dem Produkt? Wenn ja, hat das den Absatz ihres Produktes und die Wahrnehmung verändert?

Betreiben Sie Mischanpflanzungen; Hecken, Blühstreifen, Zweitfrüchte (Weinbergspfirsich, andere Obstbäume) oder Tierhaltung zur Diversifizierung ihres Betriebes?

Wenn Sie etwas verändern könnten, was würden Sie ändern um ihre Situation befriedigender zu gestalten?

Würden Sie ihren Betrieb als nachhaltig bezeichnen?

Wie wichtig wird ihre Einschätzung nach Nachhaltigkeit für die Zukunft sein?

Vielen Dank für das Interview!

Interview Guideline English

I. General information about the company

To begin with, I would like to get to know you and the company a little…

Can you please describe the history and development of the company and your role and activities in it?
What exactly do you do in the business?
- Ownership, age, buildings

Please describe the land you work in terms of size, quality and ownership.
- Size in hectares; owned/leased
- Difficulties in obtaining/managing the land
- Quality of the land

Which actors are involved?

Is the land sufficient for what you are doing with it? What else would you like to do?

What are the different forms of land use on the farm?
- Viticulture, which varieties, type of cultivation, locations; pastures, orchards, field crops, pastures, forests, fallow land, flower strips, natural monuments, historic buildings, animal husbandry, etc.?

What is the exact distribution of the different types of use on your farm?
-percent, shares, mixed planting, organic/conventional management.

Is the composition of the farm in terms of area to be changed? What is changing?

How is the work on the farm organised?
- Employees; proportion of family members, qualifications (who needs what qualifications, how long does training take), working hours.
-Seasonal workers; origin, payment
- What work do the employees/vintner do; costs for employees per month/year?

II. Sustainable viticulture, farm development & society

What role does sustainability play on your farm?

What machinery do you use on the farm?

What inputs do you need to buy? How many and what are the approximate costs?
- Criteria for the selection of suppliers
- Seedlings, water, plant protection, fertilisation, biggest cost item, barter economy.
- Training: Time required & cost, in which field?

Which inputs can you omit/replace in the course of farm conversion? With what? What is the impact on the farm?

Do you feel that what you are doing is supported by society?

III. Production & Distribution

What products do you produce? How and why?

Wine: Which varieties? Vinification itself, if no why not and where, if yes how?

How does the processing differ from other farms?

Do you produce products with quality labels, if yes which ones? What kind of quality labels? Why these labels?

Are waste products reused?

How cost- and labour-intensive is the production?
- How are the products divided in their assortment?
- Which is the most rewarding, personally and financially?
- Which product is the most labour intensive?
- Which product produces the most income?
- What is the income for each product group?

Are you planning to increase or decrease production?

Do you follow a particular production scheme on your farm?
- *Demeter*, what does this mean for production in concrete terms?
- *Ecovin*, what does this mean for production in concrete terms?
- *Bioland*, " ?
- *Naturland*, " ?
- What are the advantages of this production scheme for you?

Are you a member of a cooperative, winegrowers' association or cooperative? If yes, why?

How important are stakeholders (NGOs, cooperatives) for development on your farm? What do they do?

Do you feel any effects of climate change on your farm? If so, what are they?

What changes will climate change bring to the farm?

Do you adapt the farm to the changing environmental conditions? If so, how?

Do you operate any tourist information centres, overnight accommodation, wine taverns, restaurants? If yes, describe how this came about and whether the business is profitable.

IV. Agroforestry/ mixed crops

Please describe your relationship with agroforestry/mixed cropping. How did you come to use this form of cultivation? What is your experience with it so far?

Please describe the annual cycle in agroforestry/mixed cropping.
-Information on varieties, yields, management, maintenance and biodiversity of the area.

What are the economic and ecological advantages of the agroforestry system/mixed cultivation?

In their opinion, are there synergy effects from combined planting?

Should the area be enlarged/reduced? If yes, why?

Do you experience difficulties in connection with this cultivation method?

What effects does the agroforestry system/mixed cropping have on the production and products of your farm?

Will you continue to work with agroforestry systems/ mixed cropping in the future? Why?

V. Sales and marketing

Please describe the marketing and distribution channels of your products. Can you trace the path of the product to the consumer?

How cost/ and labour intensive is the distribution?
- How and to whom do you sell your products? What proportion of production is sold through each distribution channel?
- Which distribution channel is the most rewarding, personally and financially?

Why do you use these marketing channels?
-Would you like to change anything about the distribution channels?

How do the prices for your products come about?
- Are the prices reasonable for both winemakers and consumers?
- Do the prices reflect the real costs of production?
- Do you charge more or less than a conventional farm?

Are you a member of winegrowing associations such as *VdP, Bernkasteler Ring*, *Ecovin* or similar?

Do you use quality labels on the product? If yes, has this changed the sales of your product and the perception?

Do you practice mixed planting; hedges, flower strips, second crops (vineyard peach, other fruit trees) or animal husbandry to diversify your farm?

If you could change something, what would you change to make your situation more satisfactory?

Would you describe your farm as sustainable?

How important do you think sustainability will be in the future?

Thank you very much for the interview!

List of Interview Partners

Code	Information	Interview Date	Duration
Farm 1	**Farm Owner, who recently took over the Farm from his father**	**21.01.22**	**00:58:10**
Farm 2	**Farm Owner, vivid best ager with large export network**	**27.01.22**	**01:13:51**
Farm 3	**Farm Owner, studied viticulturist**	**28.01.22**	**01:03:21**
Farm 4	**Farm Owner with long family heritage**	**24.02.22**	**00:53:31**
Farm 5	**Farm Owner, with international education in viticulture**	**24.02.22**	**01:12:22**
Farm 6	**Farm Owner with technician degree and strong innovative mindset**	**24.02.22**	**01:19:29**
Farm 7	**Farm Owning Couple with long family heritage**	**25.02.22**	**01:08:54**
Farm 8	**Farm Owner working on generational transfer to his son**	**25.02.22**	**00:52:59**
Farm 9	**Farm Owning Family of 3 adult Children and Father**	**25.02.22**	**01:18:49**
Farm 10	**Farm Owner with long family heritage**	**28.02.22**	**01:02:24**
Farm 11	**Farm Owning best ager with adjacent tourist accommodation**	**14.03.22**	**00:44:04**
Farm 12	**Farm Owning Couple with academic background**	**16.03.22**	**01:28:32**
Farm 13	**Farm Owner with university education, who recently took over the farm from her family**	**16.03.22**	**01:00:58**
Farm 14	**Farm Owning Father and Son engaged in local viticulture association**	**17.03.22**	**00:58:43**
Farm 15	**Best ageing Farm Owner**	**17.03.22**	**01:20:06**

Farm 16	**Farm Owning Father and Daughter**	**18.03.22**	**00:48:12**
Farm 17	**Best ageing Farm Owner working on generational transition**	**18.03.22**	**00:44:19**
Farm 18	**Farm Owner with pending forestry**	**18.03.22**	**00:57:28**
Farm 19	**Young Farm Owning Couple who just took over business**	**18.03.22**	**00:45:05**

Code System

First Level	Second Level	Third Level
Covid (15)		
Costs (27)		
Climate Change (32)		
Tourism (10)		
Production (395)	**Consulting (3)**	
	Staff (74)	**Other (17)** **Volunteers (11)** **Family (16)** **Foreign Worker (14)** **Students (5)** **Contractor (7)** **Apprentice (14)**
	Production Scheme (63)	**EU Organic (18)** **Biodynamic (36)** **Conventional (9)**
	Livestock (34)	**Challenges (6)** **Advantages (11)** **Use Type (11)** **Animal Type (6)**
	Vineyard (113)	**Waste (4)** **Greening (13)** **Crop Quantity (12)** **Grape Varieties (25)** **Technology (16)** **Crop Protection (29)** **Fertilization (13)**
	Basement (60)	**Wine Maturing (55)** **Capacity (1)** **Distillery (4)**
	Other Land Use Type (15)	
	History (34)	
Sustainability (97)	**Alternative Energy (6)**	
	Fungus Resistant Grape Varieties (12)	

	Recycling (21)	
	Ecology (30)	
	Economy (23)	
	Social (5)	
Area & Soil (100)	Erosion (8)	
	Area Development (23)	Future (15) Historical (8)
	Viticultural Area (20)	
	Let for Lease (2)	
	Leased (7)	
	Property (8)	
	Soil Quality (4)	
	Flat Field (4)	
	Steep Slope (24)	
Distribution (159)	Food Retailing (6)	
	Challenges (7)	
	Barreled Wine (2)	
	Specialist Retailing (10)	
	Gastronomy (10)	
	Private Customers (18)	
	Top Seller (14)	
	Export international (31)	Export Countries (31)
	Self-Delivery (8)	
	National Shipping (12)	
	Direktvermarktung (18)	
	Prices & Development (23)	
Marketing (74)	Societal Feedback (14)	
	Buzz Marketing (13)	
	Marketing Labels (32)	Ecostep (3) VDP (5) Klitzekleiner Ring (4) Demeter (5) EU-Bio/Öko (7) Ecovin (8)
	E-Mailing (1)	
	Online (9)	
	Trade Fairs (5)	
Agroforestry (51)	Marketing (4)	
	Maintenance (8)	
	Product Quality (7)	
	Grape Varieties (4)	
	Tree Varieties (2)	
	Size (2)	
	Challenges (9)	
	Advantages (15)	
Future Perspectives (27)	Plans (12)	
	Wishes (15)	

Eigenständigkeitserklärung

Hiermit versichere ich, dass ich meine vorliegende Dissertation

„Sustainability in Viticulture
-
Agroforestry and Organic Wine Production in the Mosel Region, Germany“

selbstständig, ohne unerlaubte Hilfe Dritter angefertigt und andere als die in der Dissertation angegebenen Hilfsmittel nicht benutzt habe.

Alle Stellen, die wörtlich oder sinngemäß aus veröffentlichten oder unveröffentlichten Schriften entnommen sind, habe ich als solche kenntlich gemacht. Dritte waren an der inhaltlich-materiellen Erstellung der Dissertation nicht beteiligt; insbesondere habe ich hierfür nicht die Hilfe eines Promotionsberaters in Anspruch genommen.

Kein Teil meiner Dissertation wurde und wird in einem anderen Promotions- oder Habilitationsverfahren verwendet und hat keinen sonstigen Prüfungszwecken gedient.

Mit dem Einsatz von Software zur Erkennung von Plagiaten bin ich einverstanden.

Vorname Nachname _____

Datum, Unterschrift _____