EARTH
www.earthmagazine.org

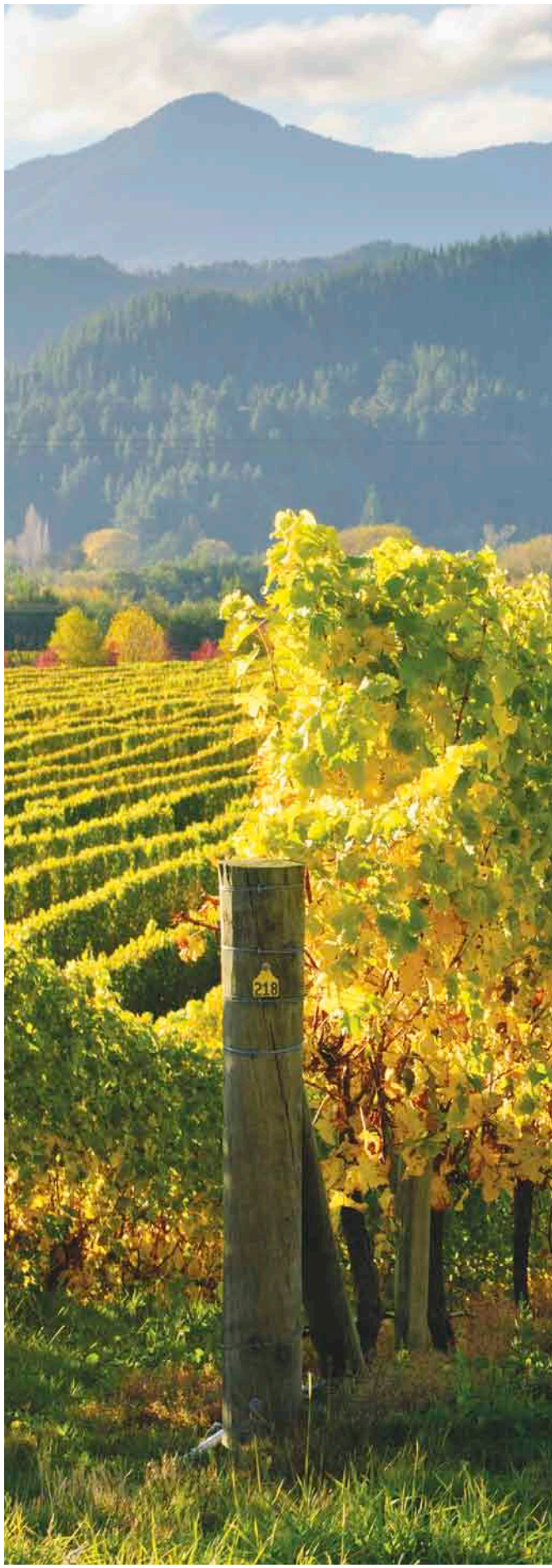
The American Geosciences Institute
4220 King Street, Alexandria, VA 22302-1502, U.S.A.
703-379-2480; Fax: 703-379-7563; subscriptions@agiweb.org

Climate, Terroir and Wine: What Matters Most in Producing a Great Wine?
Gregory V. Jones
EARTH Vol. 59 (No. 1), p. 36

EARTH is published monthly for a base subscription rate of $38.00 a year (single copies $5.99) by the American Geosciences Institute. © 2014 American Geosciences Institute. Standard mail, nonprofit postage paid at Denver, Colo., and at other mailing offices. Claims for missing issues will be honored only up to six months. Issues undelivered through failure to notify EARTH of address change will not be replaced.

CLIMATE, TERROIR & WINE

What matters most in producing a great wine?



Gregory V. Jones

Weather and climate have played decisive roles throughout human existence — where and how cultures developed, where they migrated and even how some died out. The most successful early civilizations were those that developed strong agrarian systems based on what crops were most compatible with the climate. If conditions changed for one reason or another, people migrated to areas with a more suitable environment to grow a certain crop or raise specific animals. Today, as in the past, climate is clearly one of the most important factors in the success of all agricultural systems, influencing whether a crop — including winegrapes — is suitable to a given region, largely controlling crop productivity and quality, and ultimately driving economic sustainability.

Today, wine is produced all over the world, from Australia to Scandinavia, Brazil to South Africa, and Argentina to Wisconsin. Although decisions about what crops to grow commercially are largely driven by regional history and tradition, they are also influenced by regional and international economics. However, both tradition and economics have ultimately been driven by the ability to grow the crops sustainably within a given climate.

Vineyards in the Marlborough district of New Zealand's South Island (shown here) can grow grapes similar to those grown in the Willamette Valley in Oregon.

©Shutterstock.com/JeffBanke

Top: Burgundy has more "appellations d'origine contrôlée" than any other French region and is often described as the most terroir-conscious of the French wine regions, potentially because the use of terroir as a defining aspect of landscapes grew out of the traditions of the Cistercian monks in Burgundy. Bottom: Like Burgundy, the Willamette Valley of Oregon is known for its pinot noir.

This fact is most evident with viticulture and wine production, in which climate is arguably the most critical environmental aspect in ripening fruit to its optimum quality to produce a desired wine style. Wine, which captures aspects of history, art, romanticism, geography, cultural identity, gastronomy, investment potential, and science — all in one agricultural pursuit — provides countless avenues for research and enjoyment, both academically and by wine aficionados everywhere.

TERROIR

The complex influences that result in a wine's unique traits are embodied in the concept of "terroir," a term that attempts to capture all of the myriad environmental and cultural influences in growing grapes and making wine. Terroir is derived from the Latin "terre" or "territoire," and its first modern definition appears as "a stretch of land limited by its agricultural capacity."

Historically, the use of terroir as a defining aspect of landscapes grew out of the traditions of the Cistercian monks in Burgundy, France, but the term was also broadly embraced by the French as an agricultural production concept tied to specific regions and numerous other crops or food products. Burgundians also used the concept to market their wine, promote tourism, affirm regional traditions and obtain a comparative advantage over other regions, leading some to see it as a centuries-old economic protection mechanism.

The concepts embodied in terroir eventually led to the "appellation d'origine contrôlée" (AOC) system in 1935 — a French certification system that legally delineates geographical regions and regulates agricultural products ("produits du terroir"). As applied to wine, this also led to the notion that a wine region is a collection of terroirs, some better than others. The concept has spread to other countries, including the U.S., where the regions are called American Viticultural Areas, or AVAs.

The importance of regional ties to the climate, soil and grape varieties is at the core of terroir. However, terroir remains one of the most intriguing and perplexing challenges in the world of wine today, largely because what terroir encompasses is not universally understood or accepted. Nonetheless, the concept has become woven into the thinking and commentary of nearly all journalists, winemakers and educators who discuss wine.

Perspectives on terroir tend to range from it being an all-encompassing concept (wine is a holistic result of nature and nurture), to nature in isolation (fixed and largely immutable by humans). In more general terms, public perceptions of terroir tend to associate it with "land" or "soil," a form of "geographic identity," "a sense of place," or as Matt Kramer of Wine Spectator eloquently put it, "somewhereness." As one might expect, there has also been controversy and debate in wine circles between the Old World (Europe) and New World (everywhere else), whereby terroir is discussed in production terms as either "traditional" in the Old World or "industrial" in the New World; as being "naturally endowed" (Old World) versus being used just for "marketing" (New World); or in terms of "protectionism" of a long-standing tradition (Old World) versus "experimentation" (New World) in approaches to growing grapes and making wine.

TERROIR AND SCIENCE

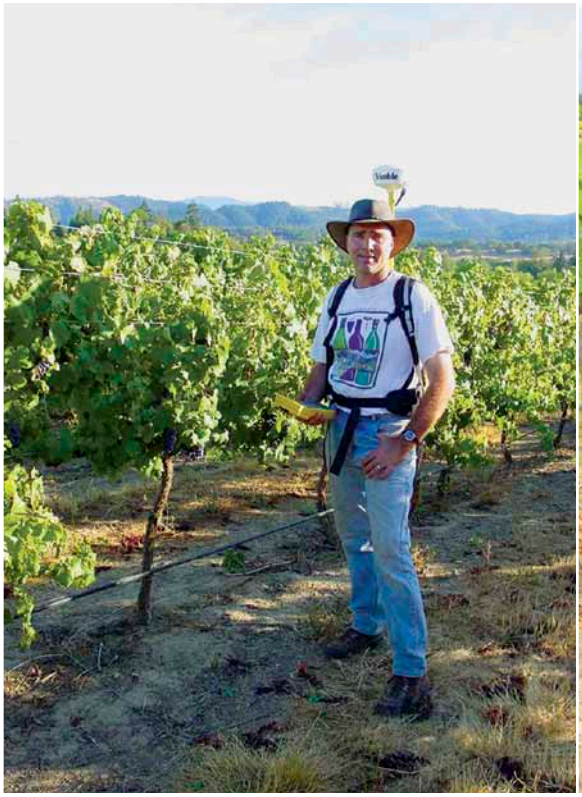
Increasingly, scientists have been asked to help identify the most important aspects of terroir and help define the boundaries between nature and nurture. As such, the study of terroir has developed tremendously over the last 20 years and has typically followed five main areas of study: quantifying terroir component influences on vine growth through the examination of climate-soil-water relationships; quantifying terroir component influences on fruit composition and wine quality; regional fingerprinting of wines (chemical signatures); viticulture zoning (finding the best terroirs); and precision viticulture (spatial technologies to manage and improve the crop).

From this call for a better scientific understanding of terroir, scientists have identified more than 400 aromatic compounds in wine, with most resulting from fermentation, yeasts, grape variety and the way wine matures. So far, research has shown very little evidence that these aromatic compounds come directly from the climate, soil or geology. But certainly the climate, soil and geology affect what's grown where, so they do indirectly impact the wines in that way. In addition, recent research has shown that chemical fingerprinting of wine from different regions may be possible, with more than 60 trace elements tied to soil and variety. Other research has shown that even after aging, wine still holds onto the chemical signature of the forest from which the wood in the wine barrel was harvested. These results are also being examined as a means to authenticate wine — detecting fraud — by region, variety, age and processing.

All that said, science has a long way to go in explaining the differences in taste and aroma that we experience in wine. This raises the question: Can you taste terroir? This has been difficult to prove due to the complex chemical processes that occur in wine production, but many wine drinkers say that you absolutely can taste it.

One example is with the growing use of the term "minerality" to describe some wines. Despite what people might think, minerals from the geology have no taste, as these are complex crystalline and insoluble compounds with no flavor. Even the mineral nutrients in wine — for example, magnesium, zinc, iron — are found largely in very low, undetectable concentrations, or are completely lacking flavor. Yet some magical permutation of complex organic compounds, whose production has been influenced by inorganic cations, has produced a characteristic that reminds us of minerals.

Another part of the challenge is that taste and/or aroma sourcing in wine is tied to human sensory abilities and psychological influences. Large variations in tasting abilities lead to "informed" tasters



Scientists (including the author, Greg Jones, shown in a vineyard in Oregon) help winegrape growers identify the "goldilocks zone" — the combination of water and soil types that is just right for grapes to produce the best wine. Trenching and studying the soils (shown at right in a Chilean vineyard) reveal key nutritional mineral contents.

Both: Gregory V. Jones

Winegrapes can grow all over the world, from the pre-Alps of the Veneto region in Italy where Prosecco is produced (left) to Napa Valley, Calif. (above), which is known for its cabernet sauvignon.

identifying wines from different localities and even down to the vineyard block, but what about the untrained or uninformed wine drinker? The difficulties are that taste and/or aroma judgment is intuitive and subjective, prone to experience, suggestion and expectation. A given wine might remind you of a taste or smell from your childhood, regardless of what anyone else thinks. Or because many people are intimidated by those "in the know," they may tend to believe a wine has the aroma or flavor they are told it does, even if that judgment is completely bogus!

But even if we can overcome these obstacles and scientifically identify a flavor or aroma in a wine, how do we know with any certainty it is because of the soil, geology, grape variety (or different clones of a variety) or other factors?

THE CLIMATE COMPONENT OF TERROIR

Climate provides the most identifiable differences in wine styles for nearly all wine drinkers. The general characteristics of wines from a cool climate vary distinctly from those from a hot climate. Grape varieties best suited to a cool climate tend to produce wines that are more subtle with lower alcohol, crisp acidity, a lighter body, and typically bright fruit flavors. Those from hot climates tend to produce bigger, bolder wines with higher alcohol, soft acidity, a fuller body, and more dark or lush fruit flavors. Geology and soil do not produce these broad differences, but they do produce the subtle expressions of these qualities within the same climate or region.

How climate affects wines, in a nutshell.

Wine Characteristic	Cool Climate	Intermediate to Warm Climate	Warm to Hot Climate
Fruit Style	Lean, Tart	Ripe, Juicy	Overripe, Lush
White Flavors	Apple, Pear	Peach, Melon	Mango, Pineapple
Red Flavors	Cranberry, Cherry	Berry, Plum	Fig, Prune
Body	Light	Medium	Full
Acidity	Crisp, Tangy	Integrated	Soft, Smooth
Alcohol	Low to Moderate	Moderate to High	High to Very High
Overall Style	Subtle, Elegant	Medium Intensity	Bold

All: Gregory V. Jones

There are theoretically ideal weather conditions for winegrapes: adequate precipitation at the right time, no weather extremes, no disease. Growing winegrapes in locations where climates are more prone to extremes, such as in cold locations like Ontario, Canada (above left) and in hotter locations like Brazil or Central California that are more prone to heat waves and droughts, takes some ingenuity, but it can be done successfully.

Wine production occurs over relatively narrow geographical and climatic ranges, most often in mid-latitude regions that are prone to high climatic variability (the vintage effect). The result is that wine production typically occurs within climates where the growing season averages 12 to 22 degrees Celsius. Furthermore, individual winegrape varieties have even narrower climate ranges, which further limit the areas suitable for their cultivation. For example, pinot noir is grown mostly in cool climates with growing seasons that range from roughly 14 to 16 degrees Celsius in places such as Burgundy or Northern Oregon. Across this 2 degree climate niche, pinot noir produces the variations in style for which is it known, with the cooler zones producing lighter, elegant wines and the warmer zones producing more full-bodied, fruit-driven wines. Although pinot noir can be grown outside these climate bounds, it readily loses the style and quality for which it is known.

Globally, these temperature limits are found mostly in the mid-latitudes; however, latitude as a comparison for climate suitability for viticulture and wine production has been misunderstood. The classic comment is that "we are on the same latitude as Bordeaux; therefore we can grow the same varieties and make the same quality and style of wine as Bordeaux." But the climate in Bordeaux is substantially more humid and receives much greater rainfall during the growing season than, say, the often-compared Napa Valley. Both are known for their cabernet sauvignon wines, but they produce them in quite different climates. Bordeaux has relatively low daytime temperatures and high nighttime temperatures due to higher humidity, whereas the Napa Valley has much higher daytime temperatures and much lower nighttime temperatures due to lower humidity.

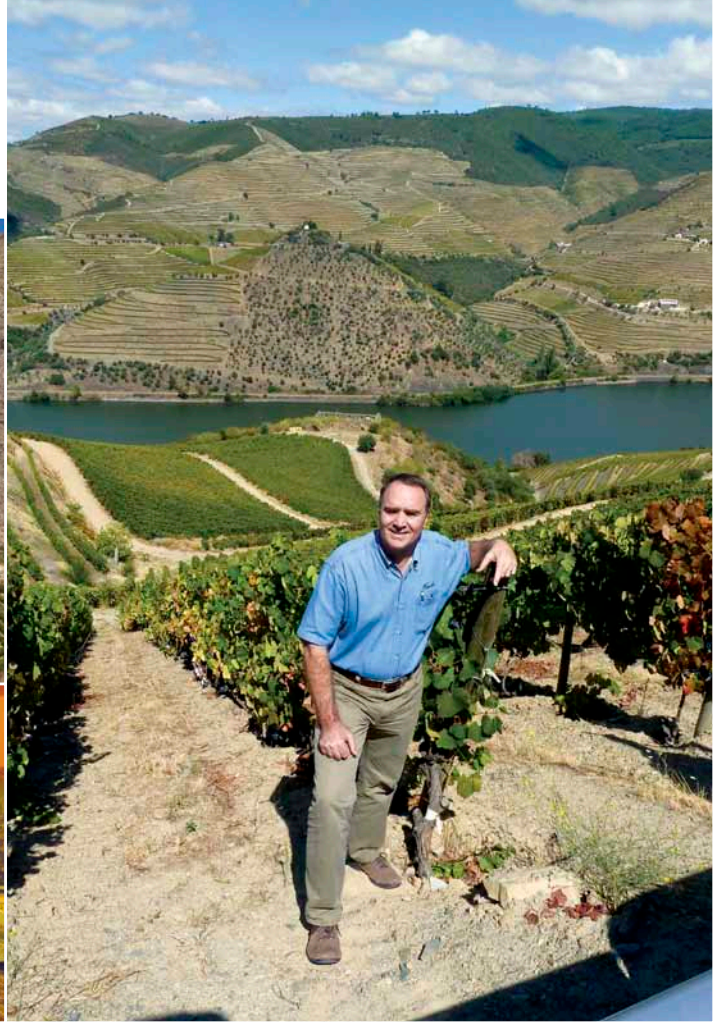
Furthermore, general comparisons with Mediterranean climates have also been misinterpreted. One of the reasons is that the Mediterranean region is influenced by two large bodies of water — the Atlantic and the Mediterranean — whereas most other regions that have comparable climates have a more linear coastline, cooler ocean temperatures, and typically one body of water (with the exception of South Africa). Another interesting example of climate differences is in Italy, where the dry, Mediterranean climate in the south gives way to more humid subtropical climates in the north. In the United States, a similar transition is found when one goes from California to the East Coast.

Given that many crops, including winegrapes, have relatively narrow climate niches for optimum production and quality, even small changes in climate could bring numerous challenges.

Even the limitation of wine production to Mediterranean-like climates has shifted. Viticulture has spread throughout much of the world, with vineyards found as far north as Scandinavia (helped by a warming climate) and even near the equator, such as in Brazil, where two crops per year are produced. In these regions, however, growing winegrapes is far riskier due to the potential for winter freezes, untimely rainfall, tropical cyclones and increased disease risk. But innovation and intent have developed thriving local to regional wine identities all over the world.

Are there ideal weather conditions for growing winegrapes? Although no two vintages in any region are exactly alike, growers everywhere would be ecstatic with adequate precipitation

Scientists and winemakers alike are studying how climate change will affect grapes grown everywhere from Portugal (right) to Chile (below) to South Australia (bottom).



and warmth to grow the vine and ripen the fruit, with no weather extremes (like frost, hail and heat waves) and disease. During the dormant period, this would equate to enough soil-replenishing rainfall and a cool to cold winter, without vine-killing low temperatures but with enough chilling to ensure bud fruitfulness the following year. The spring would be free from wide temperature swings and frost, and have enough precipitation to feed vegetative growth. During flowering, the weather would be cloud-free with moderately high temperatures and high photosynthetic potential to allow the flowers to fully set into fruit. The summer growth stage would be dry, with heat accumulation to meet the needs of the variety and few heat stress events. The ripening period would be dry with a slow truncation of the season toward fall, with moderately high daytime temperatures and progressively cooler nights.

Although conditions like these may happen in a given vintage, it's more likely that variation in one or more weather aspect will deviate from an ideal vintage, often changing the overall wine style, influencing one or more flavor and aroma nuance of the wine, or limiting yields and quality. The result is that no two vintages are exactly the same, either in their weather or wine.

A CHANGING CLIMATE

Given how important climate is to grapes and wines, climate change poses a challenge. Climates have changed throughout Earth's history, of course, but the rate and magnitude of change occurring today appear to be greater than what has been experienced in the past. Given that many crops, including winegrapes, have relatively narrow climate niches for optimum production and quality, even small changes in climate could bring numerous challenges. Fortunately, growers have already and will continue to apply numerous adaptations in both the vineyard and winery.

One of the most obvious adjustments is to change to a winegrape variety that is more suited to the new climate; however, knowing when to do this for long-term sustainability will be a challenge. Furthermore, changes to varieties will likely bring additional challenges in marketing new regional identities in an ever-competing international marketplace. Other adjustments include modifying vineyard row orientation, trellising and irrigation, as well as working with virus- and disease-free plant material and understanding the genetic diversity of grapevines. There is a wealth of potential adaptive strategies for growers. However, the next logical question in terms of terroir is then:

Top: The mountains of the Cape Town area in South Africa provide a stunning backdrop for the region's many vineyards. Bottom: Mount Etna rises behind a vineyard in Italy.

Are the terroirs that are best for one variety also best for another? Can you just switch winegrape varieties without consequences?

WHAT ASPECT OF TERROIR IS MOST IMPORTANT?

In the continuum of terroir influences, climate is the most basic and most profound in terms of what can be grown where and how. Geology, landscape and soil are important factors that mediate the interaction between climate and the vine, especially soil water supply and nutrition. Proof comes from observations that the same grape variety will not grow to the same quality in different climates; but locations with a similar climate but different geology and soils will often produce similar quality wines with flavors and aromas typical for that variety. This sequence also follows from observations that some vineyards consistently produce fine wine, no matter what the weather does, but when the weather is just right, these sites produce exceptional wines. However, it is important to remember that people play significant roles in the entire continuum — through choosing a variety that suits the climate and site, managing the vine within the vagaries of the climate, and processing the fruit into wine.

Even if we can make these statements about which aspects of terroir are most important, numerous questions surrounding the notion of terroir are still asked by wine writers, scientists and the public. One common question is whether terroir is real or simply a suite of purposefully vague, indefinable influences. Experiments have clearly shown that numerous aspects of terroir can be specified.

Another interesting question is whether the best terroirs have been found. Are there more out there like Romanée-Conti, where a mere 1.8 hectares of land in Burgundy planted with pinot noir can command some of the highest wine prices in the world? And how might a changing climate affect such terroirs?

But as terroir is further examined, we might ask ourselves whether we really want to fully quantify the effects and potentially lose the mystique that makes it an enjoyable debate topic over a glass of wine.

Jones is a professor and research climatologist in the department of environmental studies at Southern Oregon University who specializes in the study of climate structure and suitability for viticulture, and in the ways that climate variability and change influence grapevine growth, wine production and quality. He conducts applied research for the grape and wine industry in Oregon and has given hundreds of international, national and regional presentations on climate and wine-related research. He is the author of numerous book chapters, reports and articles on wine economics, grapevine phenology, site assessment methods for viticulture, climatological assessments of viticultural potential, and climate change. He was named to Decanter Magazine's 2009 Power List representing the top 50 most influential people in the world of wine, named the Oregon Wine Press's 2009 Wine Person of the Year, and has been in the top 100 most influential people in the U.S. wine industry in 2012 and 2013.