

Wine, which is among the most sensitive and nuanced of agricultural products, demonstrates how climate change is transforming traditions and practices that may be centuries old.

Around the wine-growing world, smart producers have contemplated and experimented with adaptations, not only to hotter summers, but also to warmer winters, droughts and the sort of unexpected, sometimes violent events that stem from climate change: freak hailstorms, spring frosts, flooding and forest fires, just to name a few.

Farmers have been on the front line, and grape growers especially have been noting profound changes in weather patterns since the 1990s. In the short term, some of these changes have actually benefited certain regions.

Places, like England, that were historically unsuited for producing fine wine have been given the opportunity to join the global wine world, transforming local economies in the process.

In areas like Burgundy, Barolo, Champagne and the Mosel and Rhine Valleys of Germany, where great vintages were once rare, warmer growing seasons have made it far easier to produce consistently exceptional wines. This run of prosperity has sent land values (and wine prices) soaring, and it has turned farmers and winemakers into global superstars.

Even with such success, the character of these wines has evolved in part because of the changing climate — in some cases subtly, in others deeply.

And more disruptions are coming, much faster than anybody expected. The accelerating effects of climate change are forcing the

wine industry, especially those who see wine as an agricultural product rather than an industrial beverage, to take decisive steps to counter or adapt to the shifts.

So far, these efforts are focused on five factors that are inherently crucial to growing and producing wine.

1. The Wine Map Is Expanding

Winemakers are growing grapes in places once considered too cold for fine wines.

Historically, many great wines have been made along the ragged edge of the possible. Grapevines seem to thrive where they are most challenged, whether in poor soils that force roots to plunge deeply to find moisture or in marginal climates where they must struggle to ripen.

For some of the world's best-known grapes, including pinot noir, chardonnay, nebbiolo and riesling, these borderline environments permit a combination of low yields and phenolic ripeness, in which sugar, acid and tannins are in balance for producing thrilling wine.

Conversely, if these grapes are planted in overly fertile soils in warm climates, the wines they make will seem dull and flabby, with little of the character and nuance that has made them so prized.

As the climate has warmed, regions that were once considered too cold are now demonstrating that they, too, can produce fine wine, as long as the other elements are in order. In pursuit of the best sites, wine producers are moving north in the Northern Hemisphere, and south in the Southern.

England is a perfect example. Thirty years ago, nobody had ever heard of English sparkling wine. But as the climate has warmed, a [world-class sparkling wine industry](#) has developed, with new vineyards being planted at a dizzying pace, primarily along the southern coast.

From Kent in the east through East and West Sussex, Hampshire, Dorset and as far west as Cornwall, fine sparkling wines are being made, produced by the same method as Champagne, but with their own character.

Many of the best vineyards are planted in chalky white soils that are geologically identical to the most prized soils of the Champagne region of France. Those soils have been in England for eons. But until recently, the climate was too cold. Now, Champagne companies like Taittinger and Vranken-Pommery Monopole have invested in English vineyards, hedging their bets as the once-marginal climate in Champagne has warmed.

It's not only England. Vineyards have been planted in Belgium, Denmark, Norway and Sweden, some with hybrid grape varieties bred specifically for colder weather, but others, like a [riesling vineyard](#) in Norway, with vinifera grapes, the species that accounts for all the classic European varieties. Grapes for fine wines are now being grown in northern Germany, and in the Canadian provinces of Ontario and British Columbia.

In the Southern Hemisphere, growers are pushing south, deep into Patagonia in Argentina and Chile. Some of the plantings are now experimental, but in coming years, expect to see these areas more deeply explored.

2. Winemakers Are Seeking Higher Ground

Producers are now planting vineyards at altitudes once considered inhospitable to growing wine grapes.

No hard-and-fast rules limit the altitude at which grapes can be planted. It depends on a region's climate, the quality of the light, access to water and the nature of the grapes. But clearly, as the earth has warmed, vineyards are moving higher.

In response to climate change, [Familia Torres](#), a global wine producer based in the Catalonia region of Spain, has planted vineyards at altitudes of 3,000 to 4,000 feet in the foothills of the Pyrenees.

“Twenty-five years ago, it would have been impossible,” Miguel Torres Maczassek, the general manager, told me in May.

At higher elevations, peak temperatures are not necessarily much cooler, but intense heat lasts for shorter periods, and nighttime temperatures are colder than at lower altitudes. This increased [diurnal shift](#) — the temperature swing over the course of a day — helps grapes to ripen at a more even pace, over a longer period of time, than where temperatures remain relatively stable.

But pushing altitudes also creates challenges. Soils, particularly on slopes, are generally poorer, water is scarcer and unexpected weather events like frosts and hailstorms are always a threat.

How high is high? It depends on the region. In the 1990s, Nicolás Catena Zapata of [Catena Zapata](#) in Argentina pioneered high-

altitude vineyards in the area, planting at nearly 5,000 feet the Adrianna Vineyard, in the foothills of the Andes.

His move was not a direct reaction to climate change, but an effort to find better terroirs for making more complex wines. The vineyard's success encouraged other high-altitude plantings, which in turn suggested one possible response to the warming climate.

Today, vineyards in the regions of Salta and Jujuy in northern Argentina are at altitudes of 5,000 to 11,000 feet, among the highest vineyards in the world. In the Walla Walla Valley of Washington State, growers are experimenting at 3,000 feet, higher than ever in the region.

Some long-established vineyard areas, once not well regarded because of their relatively high altitudes, are also looking better because of climate change.

The Hautes-Côtes regions of Burgundy, for example, divided between the Côte de Beaune and the Côte de Nuits in the heart of Burgundy, were not thought to have great potential because they are situated at the top of Burgundy's slope, about 1,200 to 1,300 feet up.

At that height, the grapes ripened a week or two behind those planted in the choicer areas. Sometimes it was too late, and the grapes would not ripen fully. Even in the best years, the wines were lighter and thinner.

Now, the grapes are ripening more consistently, and the wines have gotten better and better.

3. Growers Are Curtailing Sunlight

For centuries, a formula governed the placement of some of the world's greatest vineyards in the Northern Hemisphere. They would be planted on hillsides, with suitable soils, facing south or southeast, where they would receive the most sun and warmth, allowing grapes to fully ripen.

This was true whether in the Douro Valley of Portugal, the Mosel or Rhine Valleys of Germany, the northern Rhône Valley of France, in Burgundy or in Barolo. As areas in the Southern Hemisphere were planted with grapes, the reverse was true: North-facing slopes were most in demand.

As the climate has changed, however, the problem for wine producers is no longer how to ripen grapes fully but how to prevent overripening. This has caused many growers to reorient their thinking.

In the Yarra Valley of Australia, growers are rethinking the conventional wisdom of seeking north-facing vineyards. Mac Forbes, an exceptional grower and winemaker, signed a lease in 2017 for about 10 acres facing south. There, in [Don Valley](#), he planted chenin blanc, pinot noir and nebbiolo, all of which benefit from a relatively cool climate.

Don Valley, Australia John Laurie for The New York Times

In the Douro Valley, south-facing vineyards, particularly at lower altitudes, are still prized for port, which requires very ripe grapes. But to make the sort of fresh, unfortified reds and whites for which demand is growing worldwide, winemakers are looking for vineyards that [face north](#), as well as those at higher elevations.

All around the wine-producing world, particularly in places like California, where the status of vineyard areas has not been rigidly defined by history, growers are operating according to this new logic borne of climate change.

On a more granular level, that logic also affects how rows of vines are oriented. In new plantings, growers take great pains where possible to protect grapes from the afternoon sun, when the heat and light are at their most intense.

4. Regions Are Considering Different Grapes

For many producers, particularly small family estates or those in historic appellations, new vineyards in cooler environments are not an option. Instead, they must consider whether to change the essence of what they have been doing, in some cases for centuries.

That might mean leaving behind the grapes that have long been associated with their region, and selecting ones more appropriate for the changing climate.

It may seem impossible to imagine Bordeaux without cabernet sauvignon and merlot, or Champagne without pinot noir and chardonnay, but the prospect of a much warmer future may require even the most famous wine regions to rethink their methods.

This is already happening experimentally in Bordeaux and Napa Valley, two prestigious regions closely associated with cabernet sauvignon. In Bordeaux, where producers may use only grapes that are permitted by the appellation authorities, [seven additional grapes](#) have been selected for experiments to determine whether they can be used to mitigate the effects of climate change.

They include four red grapes, touriga nacional, a leading grape of port; marselan, a cross between cabernet sauvignon and grenache; castets, an almost forgotten variety that is resistant to certain diseases; and arinarnoa, a cross between cabernet and tannat that is late- ripening, which may protect against spring frosts.

The three whites include albariño, the main white grape of northwestern Spain, which may be a good alternative to sauvignon blanc; petit manseng, from southwestern France, which, like sémillon, can make both dry and sweet wines; and liliorila, a little-known cross between chardonnay and the obscure baroque that is highly aromatic.

The authorities will carefully monitor these grapes; for now, small percentages of them will be permitted in the Bordeaux and Bordeaux Supérieur appellations, but not in highly esteemed appellations like St.-Julien or Margaux.

No such restrictions exist in Napa Valley, where it is largely up to individual producers to decide what they grow and how they make their wines. But some producers, like [Larkmead](#) and Spottswoode, are already imagining a future in which cabernet sauvignon may not be the centerpiece of their wines.

At Larkmead, Dan Petroski, the winemaker, has started an experiment to test some possible alternatives over the next 21 years, including familiar California varieties like zinfandel, petite sirah and charbono, as well as grapes from warm European regions, like touriga nacional, tempranillo from Spain and aglianico from southern Italy.

Expect to hear of more experiments in many other regions.

5. Weather Is No Longer As Predictable

For farmers, and especially grape growers, experience counts for an awful lot. No two years are identical, but over time they will have seen many different weather events and learned how to respond in most cases. Meticulous records over decades, even centuries, can be a big help.

While weather always surprises, experienced farmers generally knew what to expect. With climate change, that is no longer true.

“It hails when it never used to hail, rains in the summer when it used to be dry, is dry in the winter when it used to rain,” Gaia Gaja of the Gaja Winery, which has made wine in Barbaresco and Barolo for generations, told me in April. She said the increased moisture in summer has caused vine pests to reproduce faster, with four cycles a year rather than two.

Forest fires, floods, droughts — wine regions will have to learn how to deal regularly with these once-rare devastations.

In California and Australia, where access to enough water can no longer be taken for granted, growers must consider either grafting their familiar grapevines onto drought-resistant [rootstocks](#), or selecting other grape varieties.

Drought goes hand in hand with forest fires, or bush fires, as they are called in Australia. Institutions there have [led the way](#) in researching how smoke from fires can taint grapes and wine, and in finding technological solutions that will at least render such wines drinkable.

In Burgundy, the Côte de Beaune region, which has had several disastrous recent vintages because of hail, has installed [a system](#) that

tries to prevent the formation of hailstones by shooting particles of heated silver iodide at storm clouds. If that method fails, farmers may also put up bird netting in an effort to protect their vines.

Viticulture by its nature is complicated. As the world's climates are transformed, it is only becoming more so.

This is the first of a four-part series on winemaking and climate change.