

JOHN GLADSTONES

Wine, Terroir and Climate Change



*For anyone interested in the future interaction
between climate, climate change and
viticulture, this book simply has to be read.*

*Dr John Gladstones's painstaking research is
the foundation for his equally carefully
constructed conclusions that robustly challenge
mainstream opinions.*

James Halliday



Wakefield Press

Wine, Terroir and Climate Change

John Gladstones is a leading Australian agricultural scientist, with a distinguished record in the breeding, agronomy and botany of crop and pasture legumes that has earned him many scientific and community awards, including Member of the Order of Australia (AM). His pioneering work in viticulture led to the establishment of Margaret River as a premium wine-producing region. His earlier book *Viticulture and Environment* (1992) was awarded 'Special Distinction in Viticulture' by the Office International de la Vigne et du Vin, Paris. He lives in Perth with his family.

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Preface

The stimulus for this book came out of an invitation to present a paper at the Viticultural Terroir Conference held at the Davis campus of the University of California in March 2006. In the event I was unhappy with the coverage I was able to give to my topic, and noted that although many of the other papers were interesting and worthwhile, most dealt only with limited aspects. Nor did the extant literature contain much on terroir that was enlightened by modern research. Older French writings were still valuable: indeed, I found little in them to contradict. But questions remained as to details and explanation, and to how universally the French experience applied. Moreover, the concept of terroir was becoming overshadowed by fears of drastic climate change.

All this posed an irresistible challenge. My earlier book *Viticulture and Environment* (1992) had covered the subject in part, but much had happened since. I therefore resolved to explore more deeply the topics of both terroir and climate change, and some interrelations between them promised to throw new light. In doing so I have tried to follow only the scientific and historical evidence, and what flows logically from it. This book is the result.

The new research for it was conducted during tenure of an Honorary Research Fellowship at the University of Western Australia, Perth. I particularly acknowledge the facilities and staff help of its Biological Sciences, Physical Sciences and Reid libraries, and of the library of Curtin University, Perth, which among them carried nearly all the relevant scientific journals.

My thanks are due to Caroline Wallace (née Criddle), June Thom-Allen and Val Hall for secretarial assistance at various stages, and to Neil Delroy and Dennis Criddle who in part facilitated it; also to Steve Barwick for his work on the illustrations. My daughter Helen helped with some of the proof-reading. Peter Dry kindly provided the front cover illustration. And it was a pleasure again to work with Michael Deves as editor, who saw the book through press in his usual professional manner and mostly tolerated my idiosyncratic style preferences.

Above all I thank my wife Pat for her unfailing support and encouragement, both through the research and writing of the book, and through a long and often distracting scientific career. To her I gratefully dedicate this volume.

J.S. Gladstones
Perth, December 2010

Chapter I

Introduction and Definition of Terroir

This book tackles two contentious subjects that underlie the future of viticulture. Terroir is much spoken of, but nobody, to the best of my knowledge, has attempted a comprehensive definition and integration of its elements in the light of modern science. To do so is an ambitious task, given the many remaining gaps in knowledge. Some of my conclusions may prove to be wrong. But I trust at least that they will help lead to a fuller understanding.

Climate change, which takes up much of the book's latter half, must obviously influence all planning for future viticulture. But in approaching the subject it became evident that neither public understanding nor the 'official' position of the Intergovernmental Panel on Climate Change (IPCC) was necessarily accurate. Much in the argument for global warming by anthropogenic (man-caused) greenhouse gases appeared questionable. I therefore undertook as deep a study of the basic scientific evidence as I was able. The result was disturbing, though more as to the science underlying the global warming thesis than to the future of viticulture.

Establishing my conclusions on climate unavoidably requires extensive referencing. Some readers will prefer to by-pass this, but I would encourage those seriously interested to look further for themselves. Most is in standard scientific books and journals, and readily enough accessible. Some of the most interesting evidence comes from viticultural history.



The French term *terroir* has no exact equivalent in English, and when transferred to the English language has been given a bewildering array of meanings depending on user perspective. Turner and Creasy (2003) discuss these in detail. In *Viticulture and Environment* (1992) I deliberately avoided the word for that reason, although the book was in fact largely about terroir.

Since then the word and the concepts it conveys have become mainstream world-wide.

Here I use the term in what I believe is its original and correct sense, as set out by French writers such as Laville (1990). That is, simply, the vine's whole natural environment, the combination of climate, topography, geology and soil that bear on its growth and the characteristics of its grapes and wines. Local yeasts and other microflora may also play a part. Indeed, the naturally-occurring yeasts on grapevines and around the wineries may well prove to play an important, and hitherto unappreciated, role in the subtler aspects of wine *terroir* characteristics both locally and regionally. I do not discuss them further here, but future research and practical experience could add much of interest, particularly for the New World where the use of cultured yeasts has become the norm. All these factors interact with management in the vineyard and winery to shape the wine. Treatment (or mistreatment) in storage and commerce then further influences final drinking qualities. But these latter influences are not properly part of *terroir*. To include them creates complexities that largely preclude *terroir* definition.

Two part-exceptions must be admitted. The first is soil modification by, for instance, drainage (as in Bordeaux), terracing, or progressive fertility change related to soil management. But these in turn become semi-permanent features of individual sites, and can broadly be considered to become parts of their *terroirs*. The second is possible man-caused climate change.

Terroir, then, describes the unique geography of a wine's origin. It is not a property of the wine itself. Good wine *reflects* the *terroir(s)* of its origin.

Terroir scale varies depending on its controlling factors. A defined *terroir* can range across many kilometres if the land is flat and there is little variation in climate, geology and soil. More broadly it can encompass an entire region with substantially uniform soils and climate. On the other hand it can be confined to within tens or hundreds of metres, as in Burgundy, where localized soil and drainage differences can be decisive. In practice there must be some flexibility of definition, depending on site variability and commercial purpose.

The important thing is that a wine's defined origin conveys a meaningful message to buyers and consumers, mostly as to its style though not necessarily as to quality, which depends on other factors as well. (The more restrictive European appellation schemes try to combine the two concepts, but with limited success.) Obviously a detailed assurance of a wine's origin is critical for wines of great repute, individuality and price. But it remains important also for lesser wines defined simply by grape variety (or blend)

and region, which will comprise much of the commercial wine of the future. Some predictability of character is still needed for these if they are to achieve market differentiation, recognition and success.



Several recent publications have concentrated on particular aspects of terroir, e.g. Pomerol (1989) and Wilson (1998) on geology, White (2003) on soils, and my own writings (Gladstones 1992, 2004) principally on climate. All have been useful, but none has fully encompassed the complex interactions that go to make up terroir. That is what I attempt in this book.

The book's plan is first to deal with climate in its broad sense, starting with the central role of temperature (Chapter 2), then its other elements (Chapter 3). Chapter 4 looks at geographic effects on macroclimate or regional climate, followed by those of local factors on mesoclimate. The coverage to there is on similar ground to that of my previous publications (Gladstones 1992, 2004), but with more specific focus on terroir. It also brings into account some important later research.

The following several chapters delve more deeply into terroir as an integrated concept taking in the vine, climate, the soil and its underlying geology. Central to this discussion is the development of a hypothesis that relates grape ripening to root-produced hormones, influenced by a combination of both soil and atmospheric conditions. Chapter 9 brings in organic and biodynamic viticulture.

Chapter 10 presents a revised and expanded list of grape maturity groups, a necessary provision for predicting maturity dates and ripening conditions for varieties across the range of climates. It also touches on some implications of maturity rankings for wine style.

Chapter 11 describes a revised method for constructing comprehensive viticultural climate tables, including estimated average maturity dates and ripening conditions for the respective grape maturity groups. As compared with that previously described in *Viticulture and Environment* (1992) the method is (I hope) a little clearer and more logical. It introduces the additional criterion of cloudiness, which recent evidence has suggested more and more to be an important terroir descriptor. There are also new indices for spring frost risk and summer heat stressfulness. Appendix 2 gives reference examples of completed tables, while Table 3.1 lists suggested 'ideal' sets of ripening conditions for the different wine styles, against which any site's estimated ripening conditions for each grape maturity group can be compared.

Chapters 12 and 13 deal with the prospects of climate change and its

potential impact on viticulture. Finally Chapter 14 paints a speculative picture of viticulture's global future in the 21st century.

One point needs to be made for the sake of clarity. Throughout I use the term 'mean' in its strict sense, i.e. as being half way between two (and only two) extremes. Thus a day's mean temperature is its (maximum + minimum)/2. An average can be that of any number of values. A day's true average temperature can only be derived from continuous recording, or, less accurately, from recordings at twenty-minute, hourly or other intervals; the results differ significantly among themselves and from the mean. While true averages may be more accurate for detailed local or within-season studies, I have preferred to use means for the practical reason that only records of maxima and minima are as yet widely enough available, from long enough records, to give comprehensive and reliable world-wide comparisons. Monthly, seasonal or annual average means, then, are here the averages of daily means over the specified periods.

Chapter 2

Temperature: The Driving Force

2.1 Temperature and vine phenology

Temperature is central to all aspects of viticulture. The evidence is now clear that, with only minor other influences, it alone controls vine phenology, i.e. the vine's rate of physiological development through budbreak to flowering, setting, veraison, and finally fruit ripeness. Light interacts with temperature to govern photosynthesis, dry matter production and potential yield; but as will be discussed in subsection 2.1.3, it does not bear directly on phenology.

High and low extremes of crop load and water availability can advance or retard veraison a little, but within environments and with management for quality wine production these differences are mostly very small. In that context they can safely enough be neglected for the purpose of predicting average phenology from average temperatures.

The relationship between phenology and temperature is not linear. But with certain adjustments to recorded temperatures, based partly on known plant physiology and partly on practical observation, it is possible to estimate 'biologically effective' temperatures and heat summations that do give a linear fit across more or less the full range of viticultural environments. This section describes these adjustments.

2.1.1 *The 19°C mean temperature cap*

As will be discussed in Section 2.2, growth of vines and most other temperate plants *as measured by dry matter increase* rises from nil a little below 10°C mean temperature, reaches a maximum at means around 22–25°C, and falls again to nil as means reach about 40°C (Figure 2.1).

However, rate of phenological development, measured by production rate of new stem nodes and times between phenological stages, follows a different response pattern. It is unrelated to photosynthesis and dry matter production.

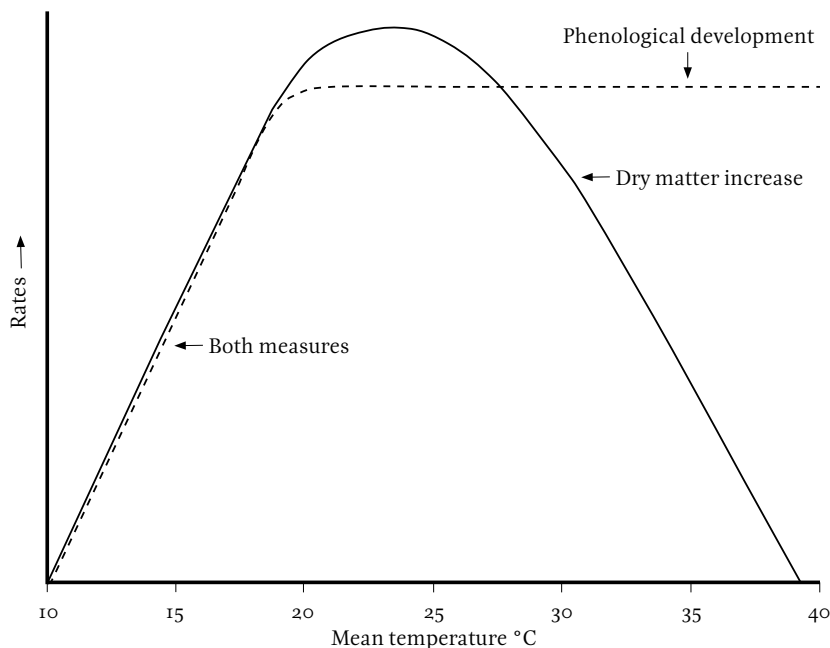


Figure 2.1. Generalized temperature responses of vine dry matter increase and phenological development.

As Figure 2.1 shows, it responds similarly to mean temperatures up to about 20°C, then plateaus. Buttrose (1969), Buttrose and Hale (1973) and Schultz (1993) all present evidence showing such a plateau response for vines.

The shape of the phenology response curve can be represented, as a first approximation, by a positive straight-line response in the lower temperature range and flat above a mid-temperature inflection point (Figure 2.1). While this does not fit the true curve perfectly, it does so with minimal error when averaged over the seasonal range of mean temperatures that grapevines normally encounter. Temperatures effective for predicting maturity dates can be fairly approximated by simple capping at a temperature giving best overall fit to the curve.

In developing the concept for *Viticulture and Environment* (1992) I tried matching different inflection temperatures against known combinations of climate and vine phenology throughout the world, measured by average maturity dates of known grape varieties for dry table wines. Inflection at 19°C mean temperature gave the best match, and proved to be a serviceable starting point for estimating grape maturity dates over the range of climates reported in that work.

Two corollaries are in order. First, the shape of the phenology response curve explains why neither raw (uncapped) degree days, such as those of Amerine and Winkler (1944), nor the curve of dry matter increase, is useful for predicting vine phenology. As a result many viticultural researchers, e.g. McIntyre et al. (1987), have tended to dismiss the relevance of temperature summations to vine phenology. We can now see this to have been mistaken.

The second corollary is that a 19°C mean temperature cap goes far to explaining a widely observed phenomenon: that temperatures of the first two or three growing season months, or alternatively the date of flowering, can usually predict quite closely the dates of veraison and maturity to follow. This comes from the fact that in most climates the temperatures up to flowering are in the range to which phenology is highly responsive. After that they are mostly in, or close to, the range of flat response. The later phenological intervals therefore show little response to temperature, and tend to be constant from year to year.

2.1.2 *Adjustment for diurnal temperature range*

Discussion so far has been in terms simply of mean temperature, i.e. (maximum + minimum)/2. Many studies, mostly in relation to greenhouse floriculture, have shown that where diurnal temperature ranges are narrow, as is normal in such culture, mean temperatures quite accurately predict rates of node or leaf appearance. The relationship continues to apply where controlled night temperatures are higher than those during the day, as is now often done to produce compact potted plants with short internodes: see Karlsson et al. (1989); Grimstad and Frimanslund (1993); Myster and Moe (1995). Besides confirming the primacy of temperature in controlling phenological growth processes, their data show that these proceed continuously day and night and that day and night temperatures control in identical ways.

Plants growing in the open generally experience wider and much more variable temperature ranges than those in greenhouse culture, with more likelihood of effects on plant development. The early phytotron research of Went (Went 1953, 1957; Went and Sheps 1969) showed that, with some variation among plant species, a narrow diurnal range is optimal for growth and that night temperatures are critical. Wide ranges retard development.

The shape of the grapevine phenological response curve to mean temperatures (Figure 2.1) can readily be related to these findings. A 24-hour period with wide diurnal variation can experience day temperatures well into the plateau response range, whereas plunging night temperatures reach into the range of greatest restriction by temperature. The latter must then be the

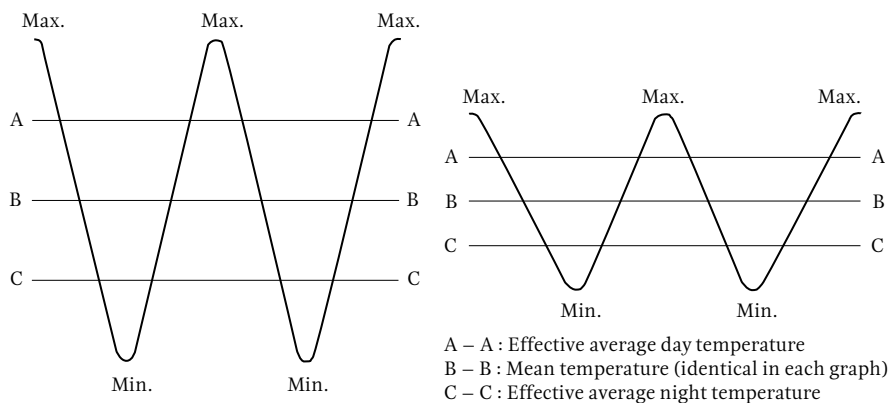


Figure 2.2. Effect of diurnal temperature range on effective night and day temperatures. From Gladstones (1992), after Went (1957).

prime limiting factor.

Langridge and McWilliam (1967) reported that control by night and/or minimum temperatures is indeed common among temperate plants. It makes particular evolutionary sense for perennial deciduous species that recommence growth in spring, by helping to delay budbreak until the worst danger of frosts is over. After budbreak, a slowing of growth by low night temperatures favours the accumulation of protective compounds in the new tissues that will enhance their resistance to later frosts. Field experience suggests that grapevines conform to this pattern.

Figure 2.2, after Went (1957), shows the relationship between diurnal range and effective night temperature, which is half way between the minimum and the mean. For every 1°C increase in diurnal range, effective night temperature falls by 0.25°C.

In *Viticulture and Environment* (1992) I used this to adjust for diurnal range in calculating monthly effective temperature summations; but because its application across all diurnal ranges appeared to over-compensate, I confined it to the widest and narrowest ranges. That is, for every 1°C wider range than 13°C the effective mean reduced by 0.25°C, while for every 1°C narrower range than 10°C it increased by 0.25°C. This procedure significantly improved the fit between climate data and observed average ripening dates. Capping the resulting effective means at 19°C automatically confined the influence of diurnal range to months when temperature directly limits phenological development.

In the present work I have modified the adjustment to be simpler and

seemingly more logical. Comparable adjustments apply over all diurnal ranges, subtracting from the mean 0.25°C per 1°C wider range than 12°C and adding 0.25°C per 1°C narrower range than 12°C ; but they do so only for the first four months of the growing season, i.e. April–July in the Northern Hemisphere and October–January in the Southern Hemisphere. There are two reasons for this.

First, these months include the periods of budbreak and early spring growth, when the retarding effect of low minima is ecologically most logical and best established. They extend to about the latest dates (in cool climates) when growth of the fruit is by cell division: a process that continues through the night and may tend to be concentrated then. Capping the resulting monthly effective means at 19°C again ensures that the adjustment registers only in months with low enough mean temperatures to retard phenological development. In warm to hot climates this will include no more than the first month or two of the growing season.

Second, no such clear argument exists for the ripening period. It is true that the metabolism of forming flavour compounds, which we can assume to continue day and night, is likely to be most limited by low night temperatures. Also, high day temperatures can be counter-productive through evaporative or degradative losses of flavour components and pigments. We will examine these aspects more closely in Section 2.3. But contrary to flavour ripening, sugar ripening depends primarily on daytime warmth and sunshine. For the total process of ripening, therefore, neither day nor night temperatures can be claimed as definitive.

There is furthermore the special case of ripening at viticulture's cool limit, where often much of the night is too cold for ripening activity of any kind. Ripening then depends more or less entirely on daytime warmth and fruit sunshine exposure, both of which are best provided by sunny weather. This, for a given site and time of season, tends to have the widest diurnal temperature range.

Given these mixed responses, phenology post mid-summer seems best related simply to the temperature means. Combined with adjustments as just described for the growing season's first four months, and for daylength as described below, this appears to have given at least as good and probably a better fit between climate and average grape maturity dates than my previous method.

2.1.3 *Adjustment for daylength*

There is universal agreement in the European literature that the rate of

vine phenological development varies in proportion to a product of temperature and daylength. The Heliothermic Index of Branas (1946) multiplies summations of mean temperature over a 10°C base by daylengths through the season, and has long been accepted as defining the northern limit of viticulture in Europe. That of Huglin (1983) uses instead summations based on effective daytime temperatures, i.e. half way between the means and the maxima. Its argued rationale is that phenology and dry matter growth depend alike on photosynthesis, and therefore that the operative temperatures are those of the day. Also, because photosynthesis reaches a maximum at light intensities well below those of full sunlight, daylength is more important than hours of bright sunshine.

But as we saw in subsection 2.1.2 above, and as found in much field crop research not cited here, rates of plant phenological development as measured by those of node or leaf appearance depend quite strictly on temperature, with no significant influence of either light intensity or its duration. (Photoperiod does govern times of flower initiation in many plant species, but that is not relevant to vine phenology.) In the grapevine, experimental results such as those of Buttrose (1969) and Schultz (1993) confirm the lack of any relationship of phenology at least to light intensity. To the extent of such a seeming relationship in northern Europe, part is probably because maturation there is as often limited by slow sugar accumulation as it is by true 'physiological', or 'flavour', ripening. Also there are reasons to suggest that much of the apparent association with daylength results from indirect relationships to temperature. At least two mechanisms exist for this.

The first is that adjustments proportional to daylength correct an inaccuracy caused by using temperature means rather than true averages. Under long days, temperatures will tend to plateau close to the maximum for longer than in short days. The mean, or (maximum + minimum)/2, then underestimates true daily average temperature as would be derived by continuous measurement. The opposite happens under short days.

The second is that phenology will logically be more directly related to vine and fruit temperatures than to air temperatures. This applies especially to fruit ripening. Adams et al. (2001) showed that expansion and ripening of tomato fruits depended on the temperatures of the fruits, not those of the air or leaves. A similar relationship seems likely for grapes, although the literature has little to say on the point. Certainly, as Smart and Sinclair (1976) have shown, sun-exposed grape clusters attain temperatures many degrees above those of the air or the leaves, because unlike the latter, the berries have few stomata for cooling transpiration. Moreover, berry and