SUITABILITY OF NEW ZEALAND CROPPING REGIONS TO SUPPORT HOP PRODUCTION

Christine Stark
Julie Gillespie

Bio-Protection Research Centre
Faculty of Agriculture and Life Sciences

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Contents

1. Introduction

1.1 Background

Hāpi Research Ltd. (a joint venture between Freestyle Hops Limited and Garage Project), together with the Ministry of Primary Industries, is undertaking a seven-year Primary Growth Partnership (PGP) programme aiming to promote the development of the New Zealand hop growing and craft brewing industries. One objective is to support the expansion of hop growing in New Zealand outside of the Tasman District and in particular help potential new growers.

Hops are an increasingly important ingredient for breweries around the globe and growing consumer demand for locally produced hops drives a worldwide move to increase production and acreage as well as explore new growing areas. This explains the growing interest in developing hop production areas outside of New Zealand's main production area, the Tasman District. The purpose of this report is to provide horticulturists who are interested in growing hops entry level information on hops production requirements and the suitability of the different horticultural regions around New Zealand with regard to their environmental parameters. This report will give growers an initial indication whether their location is suitable for hop cultivation.

New Zealand-based references and research publications on the production of hops are rare; however, there is a range of international literature, including books and online material, on hops and their cultivation around the world. Hence, much of the information presented here is adapted from mostly international resources. A complete list of literature used in this report is listed in the reference section.

Note: This report is not a complete guide to growing hops and is not directed at new or inexperienced growers. We want to emphasise that the information presented here assumes a degree of pre-existing knowledge about horticulture and crop management. A grower's intimate knowledge of their land, including microclimates and other site-specific aspects that can vary within a region (e.g. soil properties, slope, aspect, altitude), needs to always be taken into consideration and should ultimately guide site selection and layout of the hop yard.

1.2 Limitations of this report and points to note

- This report focuses primarily on above-ground environmental parameters and their potential effects on hops growth and productivity and is aimed to support experienced commercial growers rather than provide a guide for novice or amateur horticulturists: choosing the right site and establishing a productive and profitable hop yard requires pre-existing knowledge of cropping and an understanding of environmental and site factors and their effect on crop growth and development. All readers are expected to go beyond the recommendations of this guide and undertake their own due diligence by investigating in detail the requirements of hop growing and site suitability before making any decisions or investments into hop farming.
- We have only evaluated New Zealand regions and locations that are at present under horticultural production and thus known to provide overall favourable cropping conditions. The selection of the locations (weather stations) focussed on

data readily available online[1; 2]. Additional spatial (GIS) analysis is possible to provide more local detail at a higher resolution.

- All environmental data is variable in time and space and many of their effects on crop growth and productivity are not definite. All sites considered for a hop yard need to be assessed individually as specific environmental, soil and site conditions might differ from the wider regional data presented here.
- There are other site characteristics that will greatly impact hop growth and quality, e.g. soil conditions and properties, terrain and topography, aspect and site history, which have not been analysed in detail for the respective locations but will play a major role when selecting a hop yard site and layout within a site.
- Soil conditions and properties, such as texture, rooting depth, presence of permanent barriers / pans, water holding capacity and drainage, water table level, total and available nutrient levels, pH, etc., are also not discussed in detail for the various regions. Because of their huge inherent variability, the suitability of each potential hop yard site will need to be determined separately with these in view. Table 3 gives an overview of the desired and unsuitable levels of selected soil properties with regard to hops growing requirements.
- Impact of the various parameters on the quality of the hops produced has not been taken into account as this is predominantly determined by individual cultivars as well as interaction between cultivar and environment, an analysis that is beyond the scope of this study.
- Global change scenarios, including climate warming, leading to longer-term changes to global and local climate and prevailing weather patterns are likely to affect the suitability of different regions and sites to grow hops productively in the future.

1.3 Considerations beyond a suitable climate

It is also crucial for growers to consider and evaluate the available social and economic infrastructure in any given location[1].

Other aspects that should be taken into consideration before embarking on establishing a hop yard and when selecting a site include:

- Availability of a work force: Hops is a labour-intensive crop and it is vital that sufficient labour is available nearby, especially during peak times.
- Cultivars: A detailed understanding of which cultivars grow and ripen best in a given location will improve productivity.
- Municipal infrastructure: Setting up a horticultural enterprise from scratch requires public facilities, services and resources, such as access to water of suitable quality and electricity, roads and transportation, social infrastructure and public institutions (access to schools, towns, shopping, doctors, accommodation for staff).
- Specialised infrastructure: A hop yard requires facilities for storage, chilling, drying and processing (either onsite or nearby).

[1] The detailed analysis of the regions in regard to these is outside the scope of this study and would fall within the expertise of, for example, a social geographer.

- Market: Another factor vital for site and cultivar selection is awareness of the market (who are the buyers and what do they want and need?).
- Understanding and knowledge of different trellis designs, layouts, and heights and how they interact with the growing requirements of various cultivars.
- Costs, including the price of land and establishment of the hop yard, and their impact on the profitability of hops production.

2. Key findings

New Zealand's cropping regions were assessed for their suitability to support commercial hops production based on selected environmental and site properties.

Some parameters are critical requirements that impact plant development, growth and flowering. For hops, these include growing temperature, number of frost-free days, length of winter chilling period and daylength.

In short, hops demand

- average temperatures at or above 8 °C to grow well;
- 10- to 16-hour days to flower and produce cones (but optimum daylength varies among cultivars and flowering will not be induced if days are too long);
- a vernalisation period (temperatures ≤ 4 °C for at least 30 days) to guarantee even and abundant growth in the next growing season (some cultivars will not start growing again at all);
- a sufficiently long growing period, i.e. frost-free days (commonly accepted to be at least 120 days but can vary from < 100 to > 150 days among cultivars).

Not meeting these parameters will severely impact productivity or could even make hop growing impossible in a chosen location.

Moreover, sites should ideally

- support a north-south row orientation with a northern aspect (to make full use of the available sunlight); and
- be on flat to mildly undulating terrain for easier crop establishment and management (but this needs to be weighed up with drainage and wind shelter provision of the site which might be better in a hilly area).

Other environmental and site parameters reported on in this guide include rainfall and number of wet days, wind speed, air and ground frosts during the growing season, maximum air temperature and number of days > 25 °C, as well as soil properties. The effect of these parameters on hop growth and site productivity is more ambiguous and often inadequate conditions can be alleviated or improved through management interventions.

Table 1 matches up all environmental parameters (put into an approximate order of importance) with all regions assessed. The shading in the body of the table corresponds with the shading and information presented in Tables 7 to 15, while the shading in the first two columns (Regions and Locations) endeavours to interpret all information provided and give an overall summary regarding the regions' suitability for hop production.

In summary, the evaluation suggests that:

- Most of the North Island regions and most of the West Coast of the South Island are unlikely to be able to provide the winter chilling requirement of >30 days at 4 °C or less.
- That said, specific locations in the Manawatū-Whanganui, the Waikato, the Hawke's Bay, Gisborne and the more southern parts of the West Coast (Hokitika) might be suitable, especially if they are at higher altitudes, and should be assessed on a case-by-case basis.
- Of the South Island regions, the current main growing area of Nelson/Tasman is as close to a perfect location as possible, meeting all of the critical and most of the non-essential requirements.
- Other potentially suitable regions for consideration are Canterbury, coastal and possibly Central Otago and Southland (in Central Otago, early / late frosts and hot summer temperatures could pose a problem and sites need to be assessed on a case-by-case basis).

Table 1: Summary table showing suitability of NZ regions and locations (weather stations) for commercial hops production based on assessment of environmental parameters.

Region	Location	Daylength[2]	Growing temp[3]	Winter chilling[4]	Winter chilling[5]	Frost-free days[6]	Air frost[7]	Ground frost[8]	Wind speed[9]	Max air temp[10]	Days >25 °C[11]	Rainfall total[12]	Rainfall Oct-Feb[13]	Wet days[14]
Northland	Whangarei													
Auckland	Auckland													
Bay of Plenty	Tauranga													
Waikato	Hamilton													
Waikato	Taupo													
Gisborne	Gisborne													
Hawkes Bay	Napier													
Taranaki	New Plymouth													
Manawatū-Whanganui	Palmerston North													
Wellington	Masterton													
Wellington	Wellington													
Nelson/Tasman	Nelson													
Marlborough	Blenheim													
Canterbury	Christchurch													
Canterbury	Lake Tekapo													
Canterbury	Timaru													
Otago	Alexandra													
Otago	Dunedin													
West Coast	Greymouth													
West Coast	Hokitika													
West Coast	Westport													
Southland	Invercargill													

[2] 10 – 16 h daylight (Table 6) - critical
[33] > 8 °C (Table 7) - critical
[4] air temperature (Table 10) - critical
[5] ground temperature (Table 9) - critical
[6] >120 days (Table 11) - critical
[7] during growing season (Table 12) - possible impact
[8] during growing season (Table 11) - possible impact
[9] Table 15 - possible impact, wind shelter to overcome
[10] <35 °C (Table 8) - possible impact
[11] <30 days (Table 8) - possible impact
[12] >750 mm per year (Table 13) - irrigation to overcome impact
[13] >560 mm in growing season (Table 13) - irrigation to overcome impact
[14] < 10 per month (Table 14) - possible impact

3. Hops

Hops (*Humulus* sp. L.) are herbaceous plants in the family Cannabinaceae (which also includes the genus *Cannabis* (hemp)) that have become a sought-after and essential ingredient in brewing adding aroma, bitterness, flavour, and antimicrobial properties to beer. While there are three distinct hops species (*Humulus lupulus*, *H. japonicus* syn. *H. scandens* – native to Asia, and *H. yunnanensis* – native to China) the only commercially relevant species is the common hop, *Humulus lupulus* L., which originates from Europe and western Asia[3].

Characteristically, hops consist of annual climbing vines, also called bines, and a perennial rootstock (rhizome; "crown"). They can grow up to 10 m tall and rootstocks continue to produce growth for 10 to 20 years, although there is evidence of crowns surviving for up to 50 years[4]. They are known as bine plants because, unlike true vines which climb by means of tendrils and other mechanisms, they use hooked stiff downward facing hairs for stability.

The main vegetative growth phase is usually May through June (northern hemisphere) (NZ: October to December / January[5]) followed by the reproductive or flowering phase during July / August (app. January / February in New Zealand[5])[6; 7].

Hop bines grow very rapidly, at times up to 25 cm a day, and commercially grown hop plants are trained to grow up on a high trellis framework, typically 3.5 – 5.5 m tall, although commercial production using lower trellis systems of only 2 m height does exist as well[7]. Only the female plants produce clusters of flowers that are called strobiles or cones. This is the part of the plant used in beer production. The male plant serves only as a pollen source, but is not essential for the female plants to produce hop cones.

Commercial hops are harvested in autumn by cutting bines at the base, after which the plants return to the juvenile phase: when exposed to shortening daylight hours during autumn the plants enter a dormant phase; the rootstock in the ground remains dormant during winter; and new shoots will develop from the crown and rhizomes in early spring starting a new production cycle. This dormancy is broken, and re-growth is triggered, by subjecting the rootstock to a phase of low temperatures (commonly 4 °C or less for 30 to 60 days)[7-13].

Table 2: Durations of hops growth cycle phases (FAO method) for April sown hops. A: sowing to 20% ground cover, B: 20% to 80% ground cover, C: 80% ground cover to start of leaf senescence, D: start of senescence to harvest (after Sadras et al. 2016)[14].

Sowing date April*	**Hops growth cycle phases**				
	A	B	C	D	Total
Duration of crop stage (days)	25	40	80	10	155

* Northern Hemisphere

3.1 Hop growing regions around the world

The areas in which hop can be grown commercially are limited by daylength and specific temperature requirements for growth and flowering (i.e. cone production) and most production occurs between 35° and 55° N and S, respectively (Figure 1).

Figure 1: Main global production areas at latitudes between 35 and 55 degrees north and south (reproduced with permission from Beer Maverick[15]).

Hops are grown commercially in many countries worldwide, most commonly in Germany (especially in the Hallertau region of Bavaria, located at 48°N) and the United States (in the Pacific Northwest: Washington (Yakima Valley, 46°N), Idaho, and Oregon), the two largest regions of hop production worldwide: ¾ of the total hops production and $^{2}/_{3}$ of the total surface area used for hop-growing worldwide are shared between the USA and Germany (Figures 2 and 3).

Other notable hop producers include China, the Czech Republic (Žatec area, 50.2°N), Poland (Lublin, 51°N), Australia (Victoria, 36.5°S; Tasmania, 42.7°S), United Kingdom (51-52°N), Slovenia, New Zealand (Nelson, 41.2°S) and Spain (Villanueva del Carrizo, 42°N), as well as France, Slovenia, South Africa (George, 33.9°S), Japan, Canada, Chile, Argentina and the Ukraine[15-17].

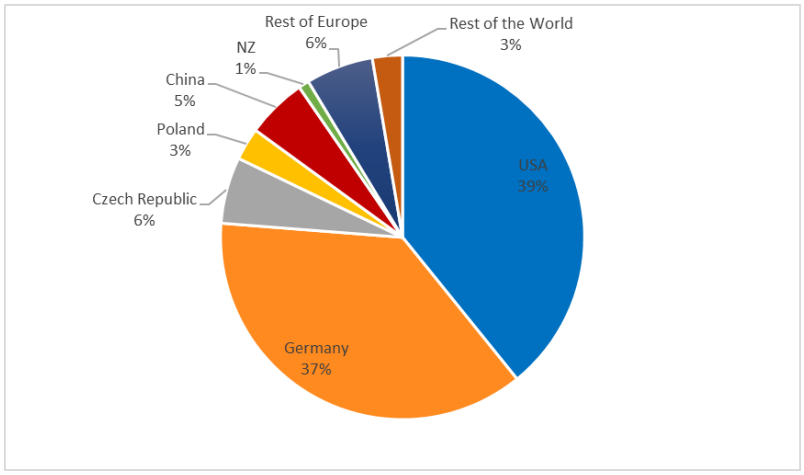

Figure 2: Production volume distribution for hops worldwide[18].

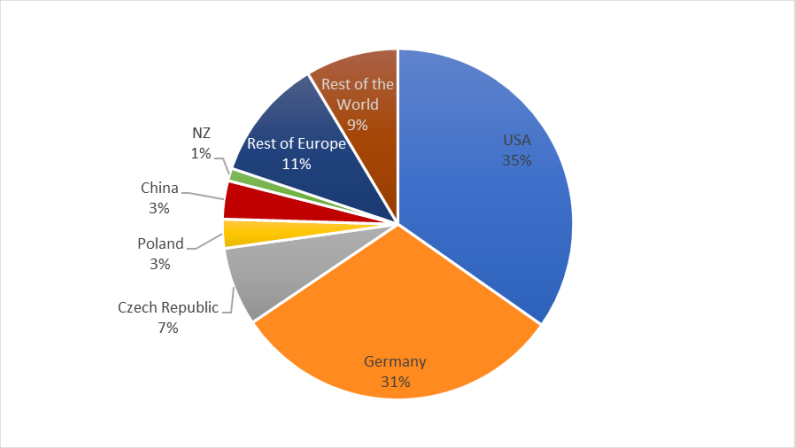

Figure 3: Production area distribution for hops worldwide[18].

3.2 Main horticultural regions of New Zealand

Due to its fertile soils and temperate climate, most of New Zealand is suitable for horticultural production, growing fruit, nuts and vegetables. New Zealand therefore does not have one or even several regions that could be classed as the main cropping area(s) as horticultural production occurs all over the country (Figure 4). However, some regions have developed into the primary production areas for certain crops for climatic and / or historical reasons.

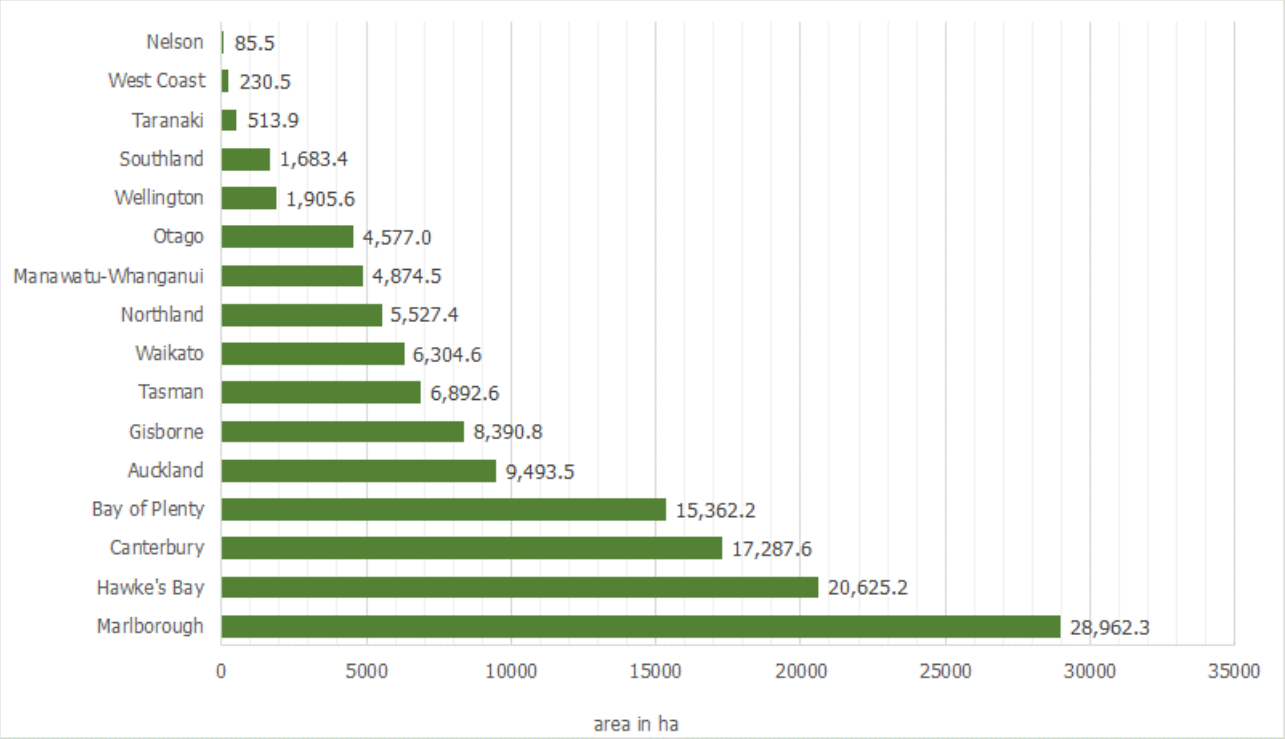

Figure 4: Area of land (ha) under horticultural production by region in New Zealand in 2019[19].

Stone fruit (peaches, nectarines, plums, apricots and cherries) are produced in the Hawke's Bay and Otago regions, while apples and pears grow well in the Hawke's Bay and

Tasman district and kiwifruit are mostly grown in the Bay of Plenty. Main production areas for citrus are Northland, Gisborne and Auckland and for avocado Northland and the Bay of Plenty regions, while grapes are grown in Marlborough, Hawke's Bay, Gisborne, Martinborough, North Canterbury and Central Otago. Canterbury produces the majority of arable crops (e.g. wheat, oats, peas)[20].

Because hops, as all crops, have specific requirements on climate and environmental conditions for optimum growth it is not possible to compare or group hops with other crops in order to easily recommend suitable regions. Each region, and sites within each region, need to be assessed separately for their suitability to grow hops with regard to soil properties and above-ground environmental conditions.

4. Site selection criteria

The literature and anecdotal evidence from growers suggest that hops are a sturdy and forgiving plant, which loves moist temperate climates and grows best in full sun at moderate temperatures. They thrive in fertile, deep and well-drained soils. However, hops are susceptible to a range of mildews and blights. This makes growing them successfully in some (humid) regions particularly challenging or impossible. Other key climate constraints that limit hop growth and flower production are daylength and temperature, which restrict the areas suitable for commercial hops production[7; 21; 22].

4.1 Environmental factors influencing hop growth and development

We developed a tiered classification system to help assess the potential suitability of different growing regions and sites for hops production (for details see Table 3). This system also allows conducting spatial analysis in the future, using a geographic information system (GIS) framework to produce maps. This would indicate the most suitable hops growing regions in New Zealand in more detail and with greater resolution than could be provided in the present report. In particular the requirements of hop plants of soil and site properties, specifically pH, soil depth and texture, salinity, soil moisture deficit, topography (slope) and aspect are explained below but not included in the assessment of region suitability due them being highly site dependent, even within regions and farms / orchards / hop yards.

For soil and landscape properties, a four-tier system was used with level 1 offering ideal conditions for hop growing and subsequent tiers being less suitable (levels 2 and 3) and unsuitable (level 4). The four tiers were chosen in line with other land-suitability classifications used in New Zealand, e.g. the assessment of land for orchard crop production and the evaluation of rural land[23; 24].

Table 3: Classification system for soil parameters and terrain (to form basis for GIS analysis).

	pH	**Drainage**	**Soil depth (to slowly permeable horizon)**	**Salinity**	**Soil moisture deficit (in days)**	**Slope (in degrees)**
Suitable	6 - 7.5	Well drained	Very deep	Very low	0	0-7 (flat)
Moderately suitable	5.5 - 6	Moderately well drained	Deep	Low	0.1-21	7.1-11 (mildly undulating)
Slightly suitable	5 - 5.5	Imperfectly drained	Moderately deep, slightly deep	Medium	21.1-42	11.1-15 (hilly)
Unsuitable	>7.5, <5	Poorly drained, Very poorly drained	Shallow, very shallow	High to very high	>42	15+ (mountainous)

4.1.1 Latitude and photoperiodism

While hops require plenty of sunlight and reasonably long days for vegetative growth, they are considered a true short-day plant[11], meaning they only flower once daylengths are sufficiently short (i.e. less than the so-called *critical daylength*). They react strongly to daylength or photoperiod, which is why commercial production is generally restricted to areas between 34° and 55° latitude in both hemispheres, where the best growing conditions occur. However, even within this range, at the lower end (34/35° latitude), daylight hours are often too limited to guarantee optimum yields and much of the world's production occurs at latitudes >40° N and S, respectively[7; 10; 11].

The overall range of daylengths in which hops will flower seems to be between 10 and 16 hours of daylight[25] but there are three factors that drive both, vegetative growth and reproductive development (flowering):

- minimum daylength;
- critical daylength; and
- critical growth.

Minimum daylength

If the days are shorter than the required minimum, the hop plant becomes dormant and completely fails to flower, so increasing day length serves as a cue for flowering but if daylength only slightly increases above the minimum, only the terminal bud will form a flower, while lateral flowers will not develop. Optimum daylength will result in maximum flowering but as it takes longer to reach days with longer daylight hours, there could be a trade-off between number of flowers and time till flowering commences.

Critical daylength

But it is not simply a matter of 'the more, the better': Flowering will not be induced if days are too long and exceed the so-called critical daylength. This means that the optimum lies somewhere between the minimum and the critical daylength and cone production is greatest at just below the critical threshold.

Critical growth

The critical growth requirement necessitates that before flowering can be initiated, the bines need to reach a specific length with a certain number of nodes.

It is worth noting that the exact requirements are extremely cultivar specific, e.g. cv. Fuggle has been found to have a critical growth requirement of 23 nodes and a critical daylength of 16.5 hrs whereas cv. New York Hop requires 20 nodes and 15.5 hrs, respectively, to come into flower[7; 11].

4.1.2 Temperature, winter chilling (vernalisation) and growing season

Hops perform well in temperate regions with a mean annual temperature around 8 to 10 °C. Vegetative growth of above ground parts is limited to between 8 and 35 °C.

Hops are winter-hardy and dormant rootstocks can withstand temperatures to -30 °C. Importantly, the plants require a vernalisation or chilling period, that means winter temperatures at or below 4 °C are needed for 30 to 60 days to overcome dormancy and be able to start growing normally and abundantly in spring. If the chilling period is too short, some hop plants are known to remain dormant and do not properly reset back to the juvenile spring phase[26]. As with daylength, the requirements of hops for winter chilling vary by hop cultivar[7].

It is important to note that winter chilling remains a critical requirement for growing hops, as plants enter dormancy when daylight hours are reduced below a critical threshold. A recent publication by Bauerle (2019)[27] challenged this notion and reported that cold periods "do not influence hop flower yield and quality". However, this research was conducted based on the (false) assumption that winter chilling is necessary to induce flowering. It is widely accepted that in hops, a sustained cold period triggers plants to overcome dormancy and allows them to start growing again the next year, while winter temperatures do not affect bud setting or flowering. In fact, as hop plants die down in autumn and overwinter as rootstocks only, at the time the plants experience winter chilling, no flower buds are present on the plant. In Bauerle's research[27], the hop plants were grown in glasshouses under environmentally controlled conditions and exposed to continuous artificial light in successive crop cycles; consequently, they did not die down, did not enter dormancy and did not require winter chilling to re-start growth.

In New Zealand, the growing period for hops, from sprouting to maturity of cones, is usually from early October until harvest in late February[5] but the exact time will depend on the local climate and hops cultivar, which can be early, mid or late-maturing. Generally, hops need to be harvested before the first severe frost of the season[7]. Many grower guides, websites and reports state that hops need a growing season of at least 120 frost-free days to fully ripen before harvest but it is not clear if this is based on research findings or anecdotal evidence; we could not establish where this suggestion for the length of the growing season originated. Research suggest that hops can require less than 100 and up to 150 days from transplant or start of spring growth to reach harvest, and the actual duration will vary from year to year and depend upon the local climate, in particular temperature and daylight hours, as much as on the variety grown[28] (also see Table 2). Certain climates have the potential for two flower flushes and thus two harvests, before and after the longest day[29].

For convenience, for the classification system, we followed the commonly accepted convention and considered locations with fewer than 120 frost-free days and fewer than 30 days with soil temperatures below 4 °C unsuitable for hop production (Table 3).

4.1.3 Soil type and site properties

Hop plants prefer light to heavy loams, but are known to grow well on a wide range of soil types, including light, sandy soils if sufficient water / irrigation is supplied. It is worth noting that different cultivars seem to be better suited to specific areas and soil properties than others[7] and that soil type has been found to interact with environmental variables like temperature and in combination they can impact cone yield and quality (Table 4).

Table 4: Effects of the soil and climate conditions on hops cone yield and quality (Zelenka (1965) cited in Rybáček (1991, p. 113)[10]).

Climate*	***Soil type***	***Yield***	***Quality***
Warm areas	sand-loamy and loamy soils	high	low
	clay-loamy soils	middle to high	high
Cold areas	sand-loamy and loamy soils	middle	high
	clay-loamy soils	low to middle	excellent

*Refers to the observed dominant climate within an established and suitable growing region.

pH

Soil pH is known to influence several biological and chemical processes, including nutrient availability and toxicity and prevalence of root disease and effect of amendments to change the pH will differ depending on soil texture (proportion of clay and sandy particles, respectively)[30-33].

Hops are best suited to weakly acidic to neutral pH conditions between 6 and 7 with an optimum around pH 6.5[7; 10]. Strongly alkaline soils are considered more problematic than acid soils as it is easier to raise soil pH than lower it.

For the purpose of the classification system, a soil pH between 6 and 7.5 is considered most suitable, while between pH 5 and 5.5 and between 5.5 and 6 are considered to be of low and moderate suitability, respectively. Soils with pH <5 or >7.5 are classed as unsuitable.

Soil depth

The root system of mature hop plants can penetrate soils to a depth of 1.5 m or more and extend sideways for 2 to 3 m with a preference to grow down rather than laterally, especially on deep soils. Most feeder roots can be found in the top 20 to 30 cm[7]. Very deep soils are therefore considered the most suitable for hop production, while very shallow soils are unsuitable.

Soil texture

Soil texture (i.e. the proportional distribution of sand, silt and clay particles) is of lesser importance in hop growing, providing the soil is sufficiently deep, well-drained (no potential for water logging) and has a low water table, especially in winter[7]. Soil texture is therefore not included in the classification system as a separate variable and well-drained soils are considered the most suitable while poorly drained soils are classed as unsuitable.

Salinity

More saline (salty) soils should be avoided for hop production[34]. In the classification system, soils with a very low level of soluble salts are considered suitable for hop

production while those with a very high content of soluble salts have been classified as unsuitable.

Soil moisture and rainfall

While hops need a low ground water table (150-200 cm), free draining soil and do not respond well to water-logging, they also require a lot of water to grow well and are known to use up to 750 mm of water per year[35; 36]. The majority (75-80%) of this total demand is needed during the growing season, with irrigation commonly beginning around May or early June in the Northern hemisphere (app. equivalent to November / December in New Zealand) and the greatest daily amounts required in late July to early August (January / February)[36; 37]. Water stress can lead to a decrease in cone yield, while it does not appear to affect cone quality[38]. In contrast, too much water too late in the season can slow down ripening and harvest[10].

It is worth noting that Evans and Leib (2003)[36] consider hops to be moderately drought tolerant and average yields can be expected even when only limited irrigation is applied, especially on deeper soils as hop roots can grow to, and access moisture at, great depth.

In New Zealand, spring and summer rainfall can be unpredictable and any site selected to establish a hop yard is likely to require an irrigation system.

Topography, terrain and altitude

Hops are best grown in flat or gently sloping terrain where it is easier to establish and manage the crop and the ideal layout for a hop yard is a north-south row orientation with a sun-facing (north) aspect to capture maximum sunlight and allow for even light distribution across the hop plants during the day. A sun-facing slope also maximizes the exposure to sunlight, which helps to warm and dry the soil faster and allows for plants to dry off more quickly thus reducing the risk of fungal diseases[8].

Suitable slope gradients have been selected depending on their suitability and safety for machinery use[23; 24]: slopes of less than 7° incline can support the full range of mechanical harvesters and machines for topdressing, spraying and weeding. The upper limit from losses from harvesters is an 11° incline and the upper limit for safe use of harvesting machinery is 15°. The upper limit for the cultivation of arable crops with regard to safety of machine use and erosion hazard is 20°[23; 24].

Altitude (elevation) does not affect hop growth and production in itself and is thus not included in the classification system. However, altitude can impact on environmental conditions, in particular temperature-related variables (average, maximum and minimum air temperatures and the number of frost-free days), wind speed (greater at higher altitudes) and type of precipitation (snow vs. rain). Consequently, the length of the growing season will be different at higher elevations compared to lower levels and might not be sufficiently long to grow hops. On average, air temperature decreases by approximately 0.65 to 1 °C per 100 m[1] increase in altitude (depending on air moisture saturation and the current weather conditions). However, even New Zealand locations at higher elevation that are generally not suitable or used for horticultural production reach mean monthly air temperatures above 8 °C during the growing season, e.g. in Mount

[1] based on information of a temperature decrease of 6.5 to 10 °C per kilometre published by NIWA[39]

Cook Village at 750 m a.m.s.l. average temperatures range from 9 to 12 °C between October and March[40], suggesting that in New Zealand no location is to be excluded as a potential hop growing site based on elevation.

Wind conditions / shelter

Hops are susceptible to wind damage and exposure to strong winds can cause damage to leaves, bines and cones, which can lead to fungal (esp. *Fusarium*) infections. While the overall preference is for a sheltered site without excessive winds, hops require good air circulation and too little air movement in the hop yard and amongst the plants also increases the risk of fungal diseases when dense fogs or moisture in the canopy cannot dissipate quickly. Establishing a windbreak (e.g. shelterbelts or mesh) will help minimise wind damage and the risk of disease infection where sites are not naturally sheltered by, for example, mountain ranges or hills[8; 10; 41].

For the classification, an annual mean windspeed of 12.5 km/h (slightly above the recorded wind speeds for the Nelson/Tasman region (Table 5)) was chosen as a cut-off point below which wind speeds should definitely allow successful hop production and beyond which growing hops might not be feasible or profitable. The wind speed threshold was selected based on a comparison between the windiness of Motueka, Marlborough and Taranaki and their perceived suitability for hop growing based on wind as reported by Ward et al. (2020)[42], who considered Marlborough too windy for hops production (average daily windrun of 291 ± 66 km). In contrast, the hop growing region of Motueka has an average daily windrun of 120 ± 27 km[42]. For comparison, Table 5 shows annual and monthly minimum and maximum wind speeds observed at the same locations (according to NIWA[1]).

Table 5: Mean annual and monthly minimum and maximum wind speeds for selected regions (km/h)[1].

Region	Weather Station	Annual mean	Min	Max
Marlborough	Blenheim	13.7	11.2	16.6
Nelson/Tasman	Nelson	11.6	7.8	15.1
Taranaki	New Plymouth	18.8	17.0	21.3

4.2 Hop cultivars / varieties and relevance to site selection criteria

Hop cultivars vary widely with regard to their ripening date, yield, quality and susceptibility to diseases. Moreover, requirements and responses to environmental variables are cultivar specific and hop yields and quality can be expected to differ depending on each cultivar's optimum requirement of

- minimum and critical daylength;
- critical size / number of nodes;
- chilling period;
- sunshine hours;
- total annual temperature; and

- frost-free days.

Even site conditions and soil properties, including altitude, soil moisture content, soil composition / texture, sun exposure, site aspect, are known to impact characteristics of the hops produced[7; 10; 28; 41; 43].

Before choosing one or several cultivars for a specific site, it is crucial to find out about their specific environmental requirements to be able to achieve optimum productivity and quality. Neve (1991) also found that varieties should not be grown too far from where they were bred because the further away from their place of origin hop plants were grown the greater the reductions in yield[7].

5. NZ regions offering required conditions

All environmental data has been sourced from the NIWA website[2] or the report on New Zealand climate and weather (published as part of the NIWA Science and Technology Series)[1]. All numbers are based on 30-year averages (1981-2020).

5.1 Latitude

"commercial production is generally restricted to areas between 34° and 55° latitude in both hemispheres" (p. 14)

> New Zealand extends from approximately 35° to 42° S and should thus provide suitable light conditions in all regions.

"much of the world's production occurs at latitudes >40° N and S, respectively" (p. 14)

> Any location south of Wanganui (39°55' S) would meet the >40° latitude requirement.

5.2 Daylength

"The overall range of daylengths in which hops will flower seems to be between 10 and 16 hours of daylight." (p. 14)

- The daylengths at the start and end of the growing period in northern (Kaitaia: 12 h 26 min and 12 h 53 min, respectively) and southern (Invercargill: 12 h 36 min and 13 h 17 min, respectively) locations of New Zealand indicate that all cropping regions throughout the country are suitable for hop production.
- The southernmost regions of New Zealand might not be equally suitable for all cultivars with daylengths approaching 16 h during the middle of summer, potentially impacting flowering of cultivars with a shorter critical daylength (Table 6).

5.3 Growing temperature

"Hops perform well in temperate regions with a mean annual temperature around 8 to 10 °C." (p. 14)

New Zealand lies within the temperate zone of the southern hemisphere, so all of the country can be expected to fulfil this general growth temperature requirement.

"Vegetative growth of above ground parts is limited to between 8 and 35 °C." (p. 14)

- All regions reach mean monthly temperatures of >8 °C during the months of the growing period (Table 7).
- Some regions or areas within regions can reach summer temperatures above 35 °C (Table 8):

  Gisborne, Hawke's Bay, Marlborough, Nelson / Tasman, Canterbury, and Otago; however, if these higher temperatures only happen occasionally, they would not impact or limit hop production in those areas.
- Table 8 also shows the average number days (annually) where temperatures exceed 25 °C. While 25 °C is not a threshold temperature in hop production, this can give some indication which regions are more prone to frequent high summer temperatures and thus potentially limit productivity:

  Northland, Waikato, Gisborne, Hawke's Bay, Marlborough, Central Otago (Alexandra).

5.4 Winter chilling (vernalisation)

"Importantly, the plants require a vernalisation or chilling period, that means winter temperatures at or below 4 °C are needed for 30 to 60 days to overcome dormancy" (p. 15)

- Regions that seem to provide sufficient winter cold to break dormancy based on their 10-cm soil temperatures during winter months are

  Waikato (around Taupo), Nelson / Tasman, Marlborough, Canterbury, Otago and Southland (Table 9).
- In addition, there are other regions that could potentially fulfil this requirement based on their minimum winter air temperatures, especially when considering microclimates and local variations:

  Gisborne, Hawkes Bay, Manawatū-Whanganui (Palmerston North), Waikato, Wellington (Masterton), and the West Coast.

5.5 Growing season

Frost-free day requirement of > 120 (or 150) days. (p. 15)

"Hops need to be harvested before the first severe frost of the season."

"Hops can require less than 100 and up to 150 days from transplant to reach harvest"

- All of New Zealand provides a minimum of 250 frost-free days (Table 10).
- Potentially unsuitable regions due to possible air and / or ground frost occurrence during the growing season are

  Waikato (Taupo), Canterbury (Lake Tekapo, Timaru), Otago (Alexandra, Queenstown), Southland (Tables 11 and 12).

5.6 Rainfall

"they also require a lot of water to grow well and are known to use up to 750 mm of water per year. The majority (75-80%) of this total demand are needed during the growing season" (p. 17)

- All but a handful of locations meet the overall requirement of 750 mm of rain per year (the ones that do not are Marlborough and the Canterbury locations) (Table 13).
- Examining the mean rainfall during the growing season, however, reveals that only the West Coast locations have the potential to supply enough water through precipitation between October and February. Hop production in all other regions would require an irrigation system to guarantee a continued and reliable water supply.

"In contrast, too much water too late in the season can slow down ripening and harvest" (p. 17)

- Regions where a lot of wet days, in particular late in the growing season, could have a negative impact on growth, cone ripening and plant health are potentially

  Waikato, Taranaki, Manawatū-Whanganui, West Coast, Otago (Dunedin), and Southland.
- Other areas experience a lot of wet days over winter (Table 14), which might or might not have a negative effect on hops growth and health.
- The actual impact wet days have on hop growing will depend on soil type, soil depth and terrain, and how well the soil is drained or if there is a potential for ponding.

5.7 Wind conditions

"Hops are susceptible to wind damage and exposure to strong winds can cause damage to leaves, bines and cones" (p. 18)

"Marlborough is too windy for hops production" (p. 18)

- Regions that could be too windy for hop production are

  Auckland, Bay of Plenty, Canterbury, Hawke's Bay, Taranaki, Manawatū-Whanganui, Wellington, Marlborough, Otago, and Southland (Table 15).
- This doesn't mean, production of hops can't be considered in these areas but they would almost certainly require the use or establishment of winter shelter (natural

terrain features, artificial or natural shelter belts), while in some of them even with winter shelter, the prevailing winds might cause too much damage to the hop plants making hop growing too difficult and / or unprofitable.

6. Summary

Prevailing environmental conditions in selected locations of New Zealand's main cropping regions were assessed for their ability to support commercial hops production. As the name suggests, environmental variables are very changeable by nature and can differ greatly from year to year and from location to location, even over small distances where microclimates exist due to changes in local vegetation, topography or altitude.

Some environmental parameters are essential requirements that impact plant development, growth and flowering of hops if they are not met. These include the growing temperature (above 8 °C), frost-free days (greater 120 days), winter chilling period (at least 30 days at or under 4 °C), and daylength (10- to 16-hour days), although exact needs vary for different cultivars.

The effect of other environmental parameters reported here, including rainfall and number of wet days, wind speed, air and ground frosts during the growing season, maximum air temperature and number of days > 25 °C, is not as clear cut.

There are several reasons for this: they are more weather- than climate-related making them more variable in the shorter term; their impact on hops plants might be less pronounced (e.g. only a few wet or hot days will not prevent the plants from growing or flowering, they might just not grow as well) and they often interact with the wider environment, including soil properties, with the potential to alleviate some negative effects, e.g.

- a greater number of wet days will have no or a less severe effect on a lighter soil;
- hotter days will be more easily tolerated if the terrain allows for air movement and if irrigation is in place;
- the impact of frosts very much depends on their timing and plant developmental stage and frosts might be preventable or impacts lessened through management measures;
- frost severity is also affected by topography and can be lessened if air movement leads to the dispersal of cold pockets;
- the impact of wind speed is not only made up of annual or seasonal means but also severity and frequency of gust and has to be assessed for a single site and the cost of setting up windbreaks (financial and regarding increased disease pressure) has to be put in proportion with the expected benefit;
- installing an irrigation system will help supplement potential rainfall shortages and mitigate unpredictable weather patterns.

To conclude,

- The current main growing area of Nelson/Tasman meets all the critical and some of the non-essential requirements, making it is as close to perfect a location as seems possible in New Zealand.

- Canterbury, coastal and possibly Central Otago and Southland can also be considered potentially suitable regions (in Central Otago, early / late frosts and hot summer temperatures could pose a problem and sites need to be assessed on a case-by-case basis).
- Most North Island regions and the South Island West Coast are unlikely to be able to provide the winter chilling requirement of at least 30 days under 4 °C.
- Specific locations in Manawatū-Whanganui, the Waikato, the Hawke's Bay, Gisborne and the more southern parts of the West Coast (Hokitika) might prove suitable and need to be considered on a case-by-case basis.

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Appendix

Detailed tables containing all environmental data that is presented in condensed form in Table 1.

Table 6: Daylength at the start and end of the growing season (October to February) in Kaitaia (35°06′ S)[44], Nelson (41°16′ S)[45] and Invercargill (46°23′ S).[46]

	Kaitaia	**Nelson**	**Invercargill**
1 October	12 h 26 min	12 h 31 min	12 h 36 min
28 February	12 h 53 min	13 h 05 min	13 h 17 min
Longest day (21 Dec)	14 h 31 min	15 h 09 min	15 h 48 min

Table 7: Mean monthly temperature during the growing season. Green shading, meeting the main growth requirement > 8 °C.[40]

Region	**Weather Station**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**
Northland	Whangarei	14.6	16.4	18.5	19.9	20.2
Auckland	Auckland	14.2	15.7	17.8	19.1	19.7
Bay of Plenty	Tauranga	13.9	15.8	18.0	19.4	19.6
Waikato	Hamilton	13.2	14.9	16.9	18.4	18.8
Gisborne	Gisborne	13.9	15.8	18.1	19.2	19.1
Waikato	Taupo	11.1	13.1	15.6	17.0	17.1
Taranaki	New Plymouth	12.8	14.5	16.3	17.8	18.0
Hawkes Bay	Napier	14.3	16.1	18.4	19.5	19.4
Manawatū-Whanganui	Wanganui	13.3	14.8	16.9	18.3	18.5
Manawatū-Whanganui	Palmerston North	12.4	13.8	16.2	17.8	18.3
Wellington	Masterton	12.3	14.2	16.4	18.1	17.7
Wellington	Wellington	12.0	13.5	15.4	16.9	17.2
Nelson/Tasman	Nelson	12.4	14.3	16.4	17.8	17.9
Marlborough	Blenheim	12.2	14.2	16.5	18.0	17.6
West Coast	Westport	11.8	13.2	15.0	16.3	16.7
Canterbury	Kaikoura	11.7	13.2	15.2	16.4	16.4
West Coast	Hokitika	11.1	12.6	14.4	15.6	16.0
Canterbury	Christchurch	12.2	14.1	16.1	17.5	17.2
Canterbury	Lake Tekapo	8.8	11.1	13.2	15.2	14.8
Canterbury	Timaru	10.4	12.3	14.4	15.9	15.5
Otago	Queenstown	9.8	11.6	14.0	15.8	15.6
Otago	Alexandra	11.7	14.0	16.3	18.0	17.4
Otago	Dunedin	10.9	12.4	13.9	15.3	15.0
Southland	Invercargill	9.9	11.4	13.0	14.2	13.9

Table 8: Highest recorded air temperature (Max air temp), average number of days per year where maximum air temperature exceeds 25°C (Annual days >25 °C) and average number of frost-free days per year for NZ regions. Orange shading, maximum air temperature >35 °C and more than 30 annual days >25 °C (potentially not favourable for hop growth).[1]

Region	Weather station	Max air temp (°C)	Annual days >25 °C
Northland	Whangarei	31.5	33
Auckland	Auckland	30.5	22
Bay of Plenty	Tauranga	33.7	21
Waikato	Hamilton	31.3	37
Waikato	Taupo	32	15
Gisborne	Gisborne	38.1	48
Hawkes Bay	Napier	36	39
Taranaki	New Plymouth	30.6	5
Manawatū-Whanganui	Palmerston North	32.8	23
Wellington	Wellington	30.1	3
Nelson/Tasman	Nelson	36.3	8
Marlborough	Blenheim	37.8	39
West Coast	Greymouth	29.7	1
Canterbury	Christchurch	41.6	26
Canterbury	Lake Tekapo	33.5	17
Otago	Alexandra	38.7	46
Otago	Dunedin	35.7	8
Southland	Invercargill	32.1	5

Table 9: Mean 10-cm soil temperature at 9 am during NZ winter months (°C). Green shading, soil temperature < 6 °C considered suitable to achieve winter chill requirement.[47]

Region	Weather station	May	Jun	Jul	Aug
Northland	Whangarei	15.2	12.4	11.6	11
Auckland	Auckland	12.9	10.7	9.4	10.2
Bay of Plenty	Tauranga	12	9.7	8.4	9.4
Waikato	Hamilton	11.2	8.7	7.3	8.3
Waikato	Taupo	8.5	6.2	5	6
Gisborne	Gisborne	10.2	7.8	6.9	8
Hawkes Bay	Napier	10.9	8.2	7.6	8.1
Taranaki	New Plymouth	11	8.8	7.8	8.6
Manawatū-Whanganui	Palmerston North	10.3	7.9	6.8	7.7
Wellington	Wellington	9.9	7.6	6.7	7.4
Nelson/Tasman	Nelson	8.5	5.6	4.5	5.9
Marlborough	Blenheim	8.6	5.8	5	6.4
Canterbury	Christchurch	7.4	4.5	3.8	4.8
Canterbury	Timaru	7.0	3.8	3.1	4.4
Canterbury	Lake Tekapo	4	1.3	0.2	1.4
Otago	Alexandra	4.8	1.9	1.2	2.5
Otago	Cromwell	5.2	2.3	1.5	2.8
Otago	Dunedin	7.9	5.5	4.4	5.3
West Coast	Greymouth	10.6	8.3	7	8.4
Southland	Invercargill	7.1	5	3.8	4.6

Table 10: Mean daily minimum air temperature during winter months (°C). Green shading, air temperature <5 °C (to achieve winter chill requirement); yellow shading, temperature between 5 and 6 °C (potentially still suitable to reach requirement).[48]

Region	Location	Apr	May	Jun	Jul	Aug	Sep
Northland	Kaitaia	13.0	11.1	9.2	8.5	8.6	9.7
Northland	Whangarei	12.8	10.8	8.7	7.8	8.2	9.3
Auckland	Auckland	12.1	10.3	8.1	7.1	7.5	8.9
Bay of Plenty	Tauranga	11.0	9.0	6.6	5.9	6.4	8.0
Waikato	Hamilton	9.1	6.9	4.7	4.0	4.9	6.7
Waikato	Taupo	6.8	4.8	3.0	2.1	2.7	4.5
Gisborne	Gisborne	9.8	7.5	5.6	5.3	5.6	7.0
Hawkes Bay	Napier	10.0	7.4	5.1	4.7	5.4	7.3
Taranaki	New Plymouth	10.4	8.5	6.8	5.8	6.6	8.0
Manawatū-Whanganui	Wanganui	10.3	8.5	6.8	5.6	6.4	8.1
Manawatū-Whanganui	Palmerston North	8.6	6.9	4.9	4.6	5.0	6.6
Wellington	Masterton	7.5	5.5	4.0	3.1	3.7	5.6
Wellington	Wellington	10.7	9.1	7.2	6.3	6.7	7.9
Nelson/Tasman	Nelson	8.3	5.5	2.7	1.9	3.4	5.7
Marlborough	Blenheim	6.9	4.5	2.2	1.5	2.6	4.7
Canterbury	Kaikoura	9.9	8.2	6.1	5.3	5.8	7.0
Canterbury	Christchurch	7.7	4.9	2.3	1.9	3.2	5.2
Canterbury	Lake Tekapo	3.5	1.1	-1.8	-3.0	-1.1	1.1
Canterbury	Timaru	5.1	2.5	-0.2	-0.6	0.8	2.8
Otago	Queenstown	4.3	2.3	-0.3	-1.7	0.2	2.5
Otago	Alexandra	3.8	1.5	-1.5	-2.4	-0.5	2.2
Otago	Dunedin	8.2	5.9	4.0	3.1	4.2	5.9
West Coast	Westport	9.5	7.5	5.5	4.8	5.5	7.2
West Coast	Hokitika	8.3	6.1	4.0	2.9	4.1	5.9
Southland	Invercargill	5.8	3.8	1.9	1.0	2.2	4.0

Table 11: Mean monthly days of occurrence of ground frost during the growing season. Green shading, required number of frost-free days (> 120 d); orange shading, potentially problematic number of ground frosts during the growing season.[1; 47]

Region	Weather station	Oct	Nov	Dec	Jan	Feb	Frost-free days
Northland	Whangarei	0.4	0.0	0.0	0.0	0.0	365
Auckland	Auckland	0.2	0.0	0.0	0.0	0.0	364.7
Bay of Plenty	Tauranga	2.1	0.5	0.3	0.0	0.0	362
Waikato	Hamilton	2.6	0.7	0.2	0.0	0.1	343
Gisborne	Gisborne	0.9	0.3	0.0	0.0	0.0	360
Waikato	Taupo	5.3	2.6	0.7	0.8	0.8	320
Taranaki	New Plymouth	0.3	0.2	0.1	0.0	0.0	363
Hawkes Bay	Napier	0.6	0.1	0.0	0.0	0.0	357
Manawatū-Whanganui	Wanganui	0.2	0.0	0.0	0.0	0.0	
Manawatū-Whanganui	Palmerston North	2.3	0.7	0.2	0.1	0.0	347
Wellington	Masterton	4.8	1.4	0.4	0.3	0.2	
Wellington	Wellington	0.4	0.0	0.0	0.0	0.0	365
Nelson/Tasman	Nelson	4.9	1.2	0.3	0.0	0.1	334
Marlborough	Blenheim	2.1	0.3	0.1	0.0	0.0	328
West Coast	Westport	0.5	0.1	0.1	0.0	0.0	363
Canterbury	Kaikoura	0.4	0.0	0.0	0.0	0.0	
West Coast	Hokitika	1.5	0.3	0.0	0.0	0.0	
Canterbury	Christchurch	4.6	1.4	0.2	0.0	0.1	332
Canterbury	Lake Tekapo	10.3	6.1	2.5	1.1	1.3	266
Canterbury	Timaru	5.2	1.1	0.1	0.1	0.0	
Otago	Queenstown	9.6	3.6	0.4	0.0	0.1	
Otago	Alexandra	8.5	2.1	0.3	0.0	0.1	277
Otago	Dunedin	2.7	0.4	0.0	0.0	0.0	357
Southland	Invercargill	7.0	4.0	2.1	1.3	1.5	325

Table 12: Frost occurrence during the growing season: mean number of air frost days per month. Orange shading (>0.5 air frost days per month), regions with potentially damaging air frosts during the growing season.[1]

Region	Weather station	Oct	Nov	Dec	Jan	Feb
Northland	Whangarei	0	0	0	0	0
Auckland	Auckland	0	0	0	0	0
Bay of Plenty	Tauranga	0	0	0	0	0
Waikato	Hamilton	0.1	0	0	0	0
Waikato	Taupo	1.2	0.4	0	0	0
Gisborne	Gisborne	0.1	0	0	0	0
Hawkes Bay	Napier	0	0	0	0	0
Taranaki	New Plymouth	0	0	0	0	0
Manawatū-Whanganui	Palmerston North	0.2	0	0	0	0
Wellington	Wellington	0	0	0	0	0
Nelson/Tasman	Nelson	0.2	0	0	0	0
Marlborough	Blenheim	0.1	0	0	0	0
West Coast	Greymouth	0	0	0	0	0
Canterbury	Christchurch	0.3	0.1	0	0	0
Canterbury	Lake Tekapo	4.6	1.9	0.5	0.2	0.2
Otago	Alexandra	2.1	0.5	0	0	0
Otago	Dunedin	0.1	0	0	0	0
Southland	Invercargill	1.1	0.4	0	0	0

Table 13: Rainfall in NZ regions: annual mean and during the growing season (October to February) (mm) (75% of 750 mm = 560 mm). Green shading, optimum amounts of rainfall during the growing season; orange shading, annual mean rainfall < 750 mm: potentially too dry for hops production.[49]

Region	Weather Station	Annual mean	Growing season mean
Northland	Whangarei	1304	435
Auckland	Auckland	1212	418
Bay of Plenty	Tauranga	1181	419
Waikato	Hamilton	1108	423
Gisborne	Gisborne	996	323
Waikato	Taupo	960	393
Taranaki	New Plymouth	1386	531
Hawkes Bay	Napier	785	267
Manawatū-Whanganui	Wanganui	918	384
Wellington	Masterton	928	339
Wellington	Wellington	1207	442
Nelson/Tasman	Nelson	960	389
Marlborough	Blenheim	711	279
West Coast	Westport	2121	879
West Coast	Hokitika	2901	1235
Canterbury	Christchurch	618	229
Canterbury	Lake Tekapo	592	223
Canterbury	Timaru	548	250
Otago	Queenstown	749	320
Otago	Alexandra	359	187
Otago	Dunedin	738	339
Southland	Invercargill	1149	493

Table 14: Average monthly wet days (days where at least 1 mm rainfall is measured) for NZ regions. Orange shading, regions that could have too many wet days per month.[50]

Region	Weather Station	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Northland	Whangarei	10	9	9	8	8	9	10	13	14	15	15	13
Auckland	Auckland	12	9	9	7	7	8	9	13	14	15	14	12
Bay of Plenty	Tauranga	10	9	8	6	7	8	8	9	11	11	12	10
Waikato	Hamilton	12	11	10	8	7	8	8	11	13	13	14	13
Waikato	Taupo	11	8	9	8	7	7	7	9	11	11	11	11
Gisborne	Gisborne	8	8	7	6	7	9	9	10	11	12	11	9
Hawkes Bay	Napier	8	6	7	6	6	7	7	8	9	9	8	7
Taranaki	New Plymouth	13	11	11	9	8	9	10	13	14	14	15	13
Manawatū-Whanganui	Palmerston North	12	10	10	7	7	8	8	11	12	12	13	12
Manawatū-Whanganui	Wanganui	11	9	10	7	7	8	8	10	12	11	12	10
Wellington	Wellington	12	9	9	7	7	9	9	11	14	13	13	11
Nelson/Tasman	Nelson	9	8	9	7	6	7	6	7	8	8	9	10
Marlborough	Blenheim	8	7	7	5	5	5	5	7	8	8	8	9
West Coast	Greymouth	18	15	16	13	11	13	13	15	15	14	16	17
West Coast	Hokitika	17	15	17	12	11	13	13	15	15	13	15	17
Canterbury	Christchurch	7	7	7	6	6	6	7	8	9	8	8	6
Canterbury	Lake Tekapo	8	6	7	6	5	6	6	7	7	7	7	7
Canterbury	Timaru	7	7	8	7	7	6	6	6	5	6	6	6
Otago	Alexandra	6	5	8	7	6	5	5	6	6	5	5	5
Otago	Dunedin	10	10	12	10	9	9	8	10	9	9	10	9
Southland	Invercargill	14	13	14	13	10	12	12	15	16	14	13	13

Orange shading >9 days of late season wet days and >10 wet days during winter months – these values have been chosen being app. $^{1}/_{3}$ of a month but are not based on information available in the literature. They are only indicative of areas where there could be problems with or limitations to hop production due to wet soils.

Table 15: Wind speed in NZ regions: mean annual and mean monthly minimum and maximum measurements (km/hr)[1]. Green shading, regions with windspeeds deemed acceptable; orange shading, regions with potentially problematic or unsuitable windspeeds; red shading, regions considered unsuitable for hops production due to high windspeeds.[42]

Region		Annual mean	Minimum	Maximum
Auckland	Auckland	17.5	15.1	20.9
Bay of Plenty	Tauranga	14.4	13.0	17.1
Canterbury	Christchurch, Lake Tekapo	14.7	11.0	17.7
Gisborne	Gisborne	12.6	11.1	14.4
Hawkes Bay	Napier	14.5	12.9	16.6
Manawatū-Whanganui	Palmerston North	15.1	12.9	17.8
Marlborough	Blenheim	13.7	11.2	16.6
Nelson/Tasman	Nelson	11.6	7.8	15.1
Northland	Whangarei	11.5	9.8	13.4
Otago	Alexandra	11.9	6.1	13.1
Otago	Dunedin	14.1	12.1	15.7
Southland	Invercargill	16.8	12.5	20.4
Taranaki	New Plymouth	18.8	17.0	21.3
Waikato	Hamilton	10.7	8.8	13.4
Wellington	Wellington	20.4	18.4	22.8
West Coast	Greymouth	13.2	11.1	14.5