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ASEV CATALYST REPORT

# Worth the Hype? Tall Vines Raise Profits for Some – Tradeoffs for All

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## Summary

**Goals:** The sudden popularity of tall vines among grape growers took some nurseries by surprise. Is this popularity rooted in economic reality? This analysis quantifies the claimed benefits of tall vines relative to regular vines from the grower's perspective using a net present value (NPV) model. We leverage these potted green vine value estimates to discuss the forces that explain the recent emergence of tall vines in the California grape industry and their prospects for the future.



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**Key Findings:**

- The NPV of planting tall vines instead of regular vines varies widely by grape variety and region in California because of regional differences in input costs and grape prices.
- Under reasonable assumptions, the estimated profit differential of tall vines over regular vines ranges from \$1.64/vine to \$7.31/vine.
- A break-even analysis indicates that tall vines are more profitable if the yield drag (i.e., reduced future yield due to pushing young vines into early production) is less than 15%, while regular vines are more profitable if the yield drag is greater than 21%.

**Impact and Significance:** The expected future profits generated by a grapevine at the time of planting accrue slowly over its productive lifespan, which can complicate growers' investment decisions. Our NPV model captures key elements of a grower's decision to plant tall vines versus regular vines. While the true value of planting tall vines may vary by grower depending on their production conditions and market circumstances, the model, results and discussion of this paper can help growers to evaluate more objectively the potential benefits of tall vines. This paper also informs stakeholders more generally about the potential impact of vine height differentiation in the broader industry.

**Key words**: economics, grapes, grapevines, net present value, nurseries, tall vines

## Overview

This paper evaluates the benefits of tall vines relative to regular vines – both green potted rather than dormant benchgrafts – among winegrape growers in the North and Central Coast regions of

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California. Such tall vines, which at 36 inches are three times taller than regular vines, have been vigorously promoted by some nurseries in recent years and have become quite popular with many growers.[1-5]

Key informants working directly with nurseries provided cost information associated with producing tall vines, which suggests that producing a tall vine requires the nursery to use three times as much rootstock as a regular vine. In addition to this significant 3:1 opportunity cost of producing tall vines, tall vines require more growing space and more soil, suffer higher mortality rates during nursery propagation, and are more difficult to transport. While tall vines consequently imply much higher production costs for nurseries, they do not currently command a commensurate profit difference in the market, which begs the question: Do tall vines really provide growers the significant benefits claimed by their proponents?

Proponents of tall vines claim that they both increase revenue and reduce costs for growers. These claimed benefits and their effects, summarized in Table 1, have yet to be evaluated and verified. This project seeks to identify and analyze the added value to growers that result from the use of tall vines as opposed to regular vines. We use a Net Present Value (NPV) model to estimate the overall relative benefits of tall vines.

Our research approach consisted of:

a) reviewing current literature on existing benefits and collecting data on regular vine costs, yields, and grower revenues to construct our baseline model,
b) conducting interviews with key experts in the California vineyard industry,

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c) constructing and distributing a survey to growers and industry experts throughout the North and Central Coasts of California,
d) determining and constructing case analyses based on grower and industry expert feedback,
e) establishing theoretical yield drag rates due to premature harvesting,
f) and constructing a NPV model that summarizes these elements by calculating potential profit differential cases for tall vines over regular vines using a 20 year time horizon of a vineyard.

Accounting for variance in costs and revenues among growers, we focus on differences by region and wine grape variety. The regions of interest are California's North Coast and Central Coast as defined by the United States Department of Agriculture's (USDA) National Agricultural Statistics Service (NASS).[6] The wine grape varieties are divided into red wine and white wine grapes. For simplification, we restrict the scope to the top five varieties grown in each region according to the 2018 bearing acreage. We rely on datasets gathered from the USDA NASS California Field Office, University of California Agricultural Issues Center (UCAIC), and a 2011-2014 study conducted by the University of California Cooperative Extension (UCCE). Section 4 provides a detailed explanation of the methodology undertaken to construct our key output variables. These datasets allow us to parameterize our NPV model and determine per vine profit differentials across cases.

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## Major Observations and Interpretations

As tall and regular vines differ in maturation time and the impacts (i.e., yield drag) associated with early harvesting of tall vines is not yet fully understood, our analysis focuses on comparing a Regular Vine Base Case to three distinct hypothesized cases for tall vine harvesting. Case 1 assumes harvesting of tall vines will occur in year 3 and tall vines will begin peak production in year 4. The only difference between Case 1 and the Regular Vine Base Case is that tall vines reach peak production one year earlier than regular vines. Case 2 allows for harvesting of tall vines beginning in year 2 with peak production beginning in year 4. Case 2 differs from the Regular Vine Base Case as it allows for harvesting to occur one year sooner while also reaching full production one year earlier.

Based on feedback received from industry experts through interviews and a grower survey, we found that some growers familiar with tall vines felt very confident in taking harvests in year 2, and even believed that a tall vine harvest in year 2 was equivalent in yield to the regular vine harvest in year 3. Other farmers felt that yields from tall vines were consistently higher than regular vines in the first four years, but only by about 20%. This relationship is seen in the only available scientific analysis of tall vine yields.[10] Several growers expressed concern that harvesting grapes in the second year is damaging to the plant and that early harvesting is assumed to reduce the productivity of tall vines in the early years of vineyard establishment, delaying full production until year 6. We defined this delayed production due to early harvesting as a “yield drag,” an exogenously occurring effect to production in years 2 to 5, which is our Case 3. There have not been any previous studies to the authors’ knowledge that assess potential

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yield drag levels associated with the early harvesting of tall vines. Thus, we examined four yield drag scenarios: each of the yield drags corresponded with a distinct break-even point of profitability for each of the four regional-variety subsets compared to the Regular Vine Base Case. This analysis provides growers with a reasonable risk metric to determine the potential tall vine profitability on a case-by-case basis, based on region (North Coast or Central Coast) and variety (red or white). Table 2 below provides a brief summary of the Regular Vine Base Case and Cases 1-3 considered in our analysis.

**Finding 1: The NPV of planting tall vines instead of regular vines varies strongly by case, grape variety, and region in California because of pronounced regional differences in input costs and grape prices.**

The annual discounted potential profit was summed across all cases to observe the per-acre net present value (NPV) of regular and tall vines across regions and varieties for the Regular Vine Base Case, Case 1, and Case 2. Figure 1 demonstrates the key differences across NPVs for tall and regular vines. The importance of this graph is to examine the proportional differences between the two vine types (regular and tall) across cases. Clearly, the NPV of tall vines in both Case 1 and Case 2 dominate regular vines regardless of region and variety. The greatest difference in NPV per-acre between the Base Case and Case 1 was observed in the North Coast Red varieties, at an extra $9,630/acre in profit for tall vine production. The smallest difference was observed in the Central Coast White varieties at $2,419/acre. Similarly, the greatest difference in NPV/acre between the Base Case and Case 2 was seen in the North Coast Red varieties, at an extra $14,097/acre in profit for tall vines. The smallest difference between the Base Case and Case 2 profits is in the Central Coast White varieties at $4,803/acre.

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**Finding 2: The estimated profit differential of tall vines over regular vines ranges from $2.83/vine to $14.38/vine.**

The potential profit differential between tall and regular vines occurs in the first five years of vineyard establishment. Therefore, any market profit difference between the two types of vines will be driven by profit differences over this early time frame. Figure 2 below displays the yearly per acre discounted profit differential between the regular vine Base Case and Cases 1 and 2 respectively. We see in the left hand panel of Figure 2 that tall vines generate a negative profit differential in year 1 and a positive profit differential in years 2-4 when harvesting first occurs in year 3. However, in the right hand panel of Figure 2, we see that tall vines have a negative profit differential in year 1 and have a positive profit differential in years 2-4 when harvesting begins in year 2, with a much greater profit increase in year 2.

To estimate the potential profit differential of tall vines, we took the difference in NPV between tall vines and regular vines in each grower category and divided the value by the total number of vines/acre. This allowed us to estimate the maximum profit difference, which represents the price differential most growers should be willing to pay for tall vines on a per-vine basis. Figure 3 demonstrates the tall vine price differential across region and varieties. The premium ranges between $2.83 for Central Coast White varieties and $14.38 for North Coast Red varieties.

Similar to the NPV findings, the ability to harvest beginning in year 2 without stalling vine growth allows Case 2 to dominate Case 1 across the board. On average, the profit difference in Case 2 is $9.71 while the profit difference in Case 1 is $6.03, a difference of $3.68/vine. Clearly, the possibility of harvesting a year earlier without damaging the vine makes the adoption of tall vines immensely appealing.

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**Finding 3: Tall vines are more profitable if the yield drag is less than 35% across specification, while regular vines are more profitable if the yield drag is greater than 55%.**

Applying a hypothetical yield drag from years 3 to 6 after harvesting in year 2, we determined the break-even yield drag for each region-variety subset. Table 3 below displays the per vine profit difference for each region-variety subset across the four different yield drag scenarios. If the yield drag in Case 3 is less than 35%, it will be at least as profitable to plant tall vines over regular vines across the four subsets (since we observe a breakeven price differential for Central Coast-White, and positive profit differences for the three other region-variety combinations). However, if the yield drag exogenously increases to 38%, it is not profitable to invest in tall vines for Central Coast White varieties, nor is it profitable to invest in tall vines for North Coast White varieties when the yield drag further increases to 53%. It would take a yield drag as large as 55%, however, before it becomes unprofitable to plant tall vines for North Coast Red varieties.

## Broader Impact

This analysis uses a variety of assumptions and abstractions for tractability. To situate these results in a broader context and to consider broader implications of these findings, we revisit these assumptions in this section and discuss the broader role tall vines might play in the California winegrape industry. First, we emphasize that tall vines are relatively new to California and best practices for incorporating them into California vineyards are still emerging. In this regard, ongoing field trials or empirical studies on existing plantings of tall vines will surely help generate a more reliable evidence base on which growers can exploit the advantages conferred

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by tall vines. Our analysis offers a systematic evaluation of many of the key considerations that such experimental evidence might help to elucidate.

Second, we structured this analysis as a comparison between regular and tall vines, but at least in principle this is more of a continuum than a dichotomous choice. As nurseries have attempted to differentiate their vines from those of competitors, medium-sized vines created from rootstock that, at two feet in length, splits the difference between regular and tall vines have recently been introduced to the market. These medium-sized vines represent a compromise between the tradeoffs we explore in this analysis. We cannot determine with confidence at this point whether two feet is the optimal rootstock length when weighing these tradeoffs; more careful investigation of this relationship could be valuable to nurseries and growers alike.

Third, we assume future prices and profits are known, which – although unrealistic – is necessary to simplify the NPV calculations. In practice, yields and grape prices can vary significantly from year to year due to climate conditions and market shocks, but to the extent these sources of uncertainty apply to both regular and tall vines the effects of this uncertainty on grower demand is comparable and therefore drops out of the comparison. There is, however, one way in which price uncertainty may have different impacts on regular and tall vines: earlier harvests as enabled by tall vines may allow growers to respond more quickly to unanticipated shifts in consumers' wine preferences (e.g., the increase in demand for Pinot noir in the wake of the film *Sideways* in 2005[7]). Such a market responsiveness represents an additional potential benefit to tall vines that is not reflected in our analysis.

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Fourth, we have not distinguished in detail between initial planting and replanting of vines, but tall vines may be particularly valuable as replanted vines. Per-vine labor costs are likely much higher with selectively replanted vines that must immediately compete with surrounding existing vines. The advantages of tall vines are likely amplified in re-planting contexts due to these factors, but quantifying these advantages is difficult given the limited data available.

Finally, consider how the emergence and promotion of tall vines reflects and affects the competitive forces in play among the nurseries that supply planting material to Californian vineyards. Although more speculative than our core analysis, the role of nurseries in this case is interesting and potentially insightful – particularly given that tall vines were the creation of nurseries in the first place. Tall vines are more expensive to produce than regular vines primarily because they require three times as much rootstock (they also have lower survival rates in nurseries, but this seems to be less important than the cost of producing the rootstock). Although the costs associated with producing rootstock from scratch may not vary significantly from one nursery to the next, the opportunity cost of rootstock produced from existing mother vineyards can vary widely depending on the current demand for a given nursery's vines. For nurseries that produce a surplus of rootstock (e.g., because current demand for their vines falls short of their vine production capacity, which is based on production decisions made several years previously), the opportunity cost of their rootstock could be quite low. In contrast, nurseries that have a *shortage* of rootstock will face a much steeper opportunity cost of shifting to tall vine production. Duarte Nursery, the first to market and promote tall vines in California (as Ubervines™), not surprisingly, faced a surplus of rootstock at the time they introduced this new product. In this context, Ubervines™ seem to have been an effective upsell strategy that enabled Duarte to leverage something it then had that its competitors may not have had: a rootstock surplus. The emergence of tall vines was, in this way, likely a strategic move in a competitive industry. In equilibrium, as rootstock surpluses are used up, it also seems likely that market prices of tall vines relative to regular vines will increase to reflect the average opportunity cost of rootstock over the longer term, which is higher than with a (short-run) rootstock surplus.

## Experimental Design

### Industry Expert Interviews

We conducted key informant interviews and received survey responses from approximately 32 individuals with various fields of knowledge including growers, vineyard managers, nursery operators, and plant scientists who are familiar with tall vines. Because survey responses were limited in quantity, we used the feedback received from the surveys and interviews to establish reasonable parameter values for our model.

There was consensus that tall vines produce fruit earlier than regular vines, but some growers felt confident that tall vines produced much larger yields than regular vines in years 2, 3, and even 4 after vineyard establishment, while others felt that harvesting fruit in year 2 would endanger the long-term health of the vineyard. According to the interviewees, the perceived benefits associated with deep rooting, increased vineyard uniformity, and long-term labor savings may not be particularly significant for most growers. Additionally, there was no difference between North Coast and Central Coast growers in their belief that long-term labor savings may not be a significant factor in the decision to use tall vines, even when considering regional differences in

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labor costs. These benefits have been excluded from the study due to a lack of data to support these claims or estimate their benefits.

There were also differing opinions on whether tall vines have a shorter lifespan or are sturdier than regular vines, or whether the tall vine rootstock quality results in higher rates of replanting in the future. Finally, all growers with significant experience with tall vines indicated that best practices differ with tall vines, resulting in changes in production practices as growers gain more first-hand experience. All vineyard managers confirmed short-term labor and materials savings related to training passes and cartons for tall vines. Based on the information obtained from these interviews, we narrowed our focus on impacts deemed to be significant and measurable: improved yields in the early years of planting, and reduced training costs.

**Literature Review and Data Sources**

After narrowing our focus to the impacts of increased initial yields and reduced training costs, we conducted a literature review to estimate cost and revenue scenarios. Earlier yields result in increased revenue, but the degree of the revenue increases depend on baseline yields and prices for grape varieties. Additionally, early yields will increase costs associated with production, such as pruning and harvesting, so baseline cost estimates are needed as well. Reduced training costs associated with tall vines also depend on baseline training labor expenditures.

All of these costs and revenues vary by grower. Two factors were considered to account for this variance: region and wine grape variety. We focused on two regions in this study: California's North Coast and Central Coast, as defined by the United States Department of Agriculture's

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(USDA) National Agricultural Statistics Service (NASS).[6] The crush reports published by the USDA NASS California Field Office list 33 varieties of white wine and 42 varieties of red wine grapes grown in California. To simplify the scope, we selected the top 5 whites and top 5 reds grown in the North Coast and Central Coast, as of the reported 2018 bearing acreage.[8,9]

*Sources and Processing: Revenues, Yields, and Costs*

Wine grape revenues were determined from data by the USDA NASS California Field Office, which publishes publicly available annual grape crush reports and grape acreage reports.[8,9] We calculated acre revenues for each of these varieties from 2018 in crush districts 1-8 using the reported tons crushed, revenue per ton, and bearing acreage. We then calculated total revenue for each variety by district and year. Next, we aggregated across the districts to determine acre revenue weighted averages for the varieties at the North Coast and Central Coast levels. We further aggregated these acre revenues into four categories: red and white for both North Coast and Central Coast regions, and inflated to 2019 dollars using the BLS inflation indices.[12] We use these 2019 acre-revenue projections through 2019-2038 (constant year dollars), a 20-year time horizon with the appropriate discount factors.

To estimate a yield profile for regular vines we relied on the UCAIC cost studies and a tall vine trial conducted by UCCE from 2011-2014 on Chardonnay grapes.[10,11,13-18] The trial demonstrated that tall vines on Chardonnay grapes produce 2.8 tons per acre in the second year after planting, 6.6 tons per acre in the third year, and 7.5 tons per acre in the fourth year.[10] Regular vines on Chardonnay grapes, meanwhile, produce 5 tons per acre in the third year, and 7 tons in the fourth year, and 7.5 tons in the fifth year.[14,15,17,18] The cost studies show that regular vines on Cabernet

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Sauvignon grapes produce 1.5 tons per acre in the third year, 3.5 tons per acre in the fourth year, and 5 tons per acre in the fifth year.[11,13,16] We assume tall vines of Cabernet Sauvignon grapes have the same production proportion as tall vines of Chardonnay grapes. Specifically, we assume tall vines of Cabernet Sauvignon grapes produce 1.87 tons per acre in the second year, 4.4 tons per acre in the third year, and 5.0 tons per acre in the fourth year. With the absolute value of yield profile of Cabernet Sauvignon grapes and Chardonnay grapes demonstrated above, we take Cabernet Sauvignon as the representative for red grapes and Chardonnay for white grapes. Then, we calculated the yield proportion using yields per acre in a specific year divided by yields per acre when vines become mature. Specific calculations will be explained in the *Proportional Yield Levels for Different Cases* sub-section below. We applied these results to the red and white grape yield data of the UCAIC cost studies. We also relied on the UCAIC cost studies to inform the cost data input of our NPV model.

The baseline costs for the North Coast were modeled from a 2010 cost study by UCAIC of vineyard establishment and wine production in Sonoma County, adjusting for inflation at a total rate of 16% from 2010 to 2019.[11,12] There have not been any cost studies conducted for vineyards in the Central Coast since 1996 and it was therefore necessary to estimate costs for the region based on the available data. To accomplish this, the 1996 San Luis Obispo cost study was adjusted for inflation at a total rate of 6% to 1999.[12,13] We then compared this San Luis Obispo County cost study, adjusting for inflation, to a 1999 Sonoma County cost study and determined a cost ratio between the two counties to be 0.703:1 for SLO:Sonoma.[13,15] This ratio was then applied to the 2010 Sonoma County cost study, giving an estimate for 2010 Central Coast costs. The 2010 Central Coast estimate was then adjusted for inflation by 16% to 2019.[12] We justify this comparison between costs in Sonoma County and the Central Coast due to the similarities in climate and production processes of the two regions, limiting potential production cost differentials and mitigating the likely omission of technology adoption if production practices form 1996 were incorporated. While a 2019 Napa cost study[16] and a 2016 Sonoma cost study[18] were available, Napa County is viewed as an outlier among the areas under examination and the 2016 Sonoma cost study was not used as it omits establishment costs, an integral component of our analysis. We made a validity check between the annual operating costs of a hypothetical 2016 Central Coast cost study and the 2016 Sonoma cost study and determined that the ratio held, justifying this method.

The costs in the tall vine NPV model have several parameters that differ from the baseline model. The main differences in parameters are realized in the first three years during vineyard establishment. In the remaining years following establishment (years 4-20 in our model), the only differing parameter is the costs of replanting vines with tall vines and the labor and material costs associated with this activity.

**Methods**

Using the UCAIC cost studies and USDA NASS crush reports to obtain regular vine yield, cost, and revenue data, we collected and aggregated data into four regional-variety subsets: North Coast Red, Central Coast Red, North Coast White, and Central Coast White. We then determined the per acre net present value of tall versus regular vine for these four region and variety subsets

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over a 20-year time horizon. Finally, we calculated the tall vine profit difference by dividing the per acre net present values by vine planting densities.

*NPV Model: Parameters & Assumptions*

In order to quantify the perceived benefits of tall vines, we constructed a net present value model comparing the estimated per acre discounted profits between tall vines and regular vines. The NPV framework was chosen as the main method of analysis for several reasons. A NPV model allowed direct comparison of tall and regular vine profitability while also weighing inflation and discount rates across the entire time horizon of a vineyard. Modeling under this framework also allowed for sensitivity analysis and case analysis, an integral component of our study. This model also allowed us to easily manipulate NPV results to determine estimated tall vine price differences, the initial impetus for this research.

The NPV model assumed an annual discount rate of 6%, as recommended by industry experts. This rate assumes a higher risk than a low-risk U.S. Department of Treasury Bill (~2-3% interest), and closely reflects a representative cost of capital rate. We assumed planting densities of 980 vines/acre for red grapes and 856 vines/acre for white grapes; based on averages from San Luis Obispo[13] and Sonoma[11] (for red wine grapes) and Santa Barbara[14] and Sacramento Valley[17] (for white wine grapes) UCCE cost studies. We assumed a b-section yield profile for regular vines and tall vines based on the Bettiga study[10] and UC Davis Cost Studies, which is discussed in the *Proportional Yield Levels for Different Cases* sub-section below.

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The NPV model consisted of both revenue and cost data inputs, normalized to constant year 2019 dollars, using the appropriate U.S. Bureau of Labor Statistics inflation indices.[12] The 6% annual discount rate was applied to years 2-20 of the model (2020-2038). To determine revenues, we aggregated the average growers' acre revenue for red and white grapes in two regions (California's North Coast and Central Coast) and two types of grapevines (red and white).

The grower costs were categorized into three sections: Labor Costs, Material Costs, and Other Costs. Within Labor Costs, we focused on pruning, training, thinning, and harvesting. In Material Costs, cartons and fertigation were our main costs of interest. We categorized all remaining costs into the Other Costs section, informed by the cost studies and industry expert feedback. Other Costs include costs such as replanting, water (water and labor), taxes, and management fees.

*Proportional Yield Levels for Different Cases*

Production, and therefore revenue, was identical across cases in years 6 to 20. Thus, we restricted interest to production in years 1 to 5. The proportional yield levels in years 1 to 5 were dependent upon yield profile assumptions we had developed from the University of California Cooperative Extension cost studies [11,13-18] and the Bettiga study[10]. We denote $b_t^{type}$ as the yield from vines of an age *t* starting in year 2019 as a proportion of yield from mature vines:

$$b_t^{type} = \frac{yield\ at\ given\ year\ for\ corresponding\ type}{total\ yield\ from\ mature\ vines}$$

As we have three cases for tall vine proportional yield levels, and one case for regular vine proportional yield levels, we define the *type* as an indicator with two parameters (cases,

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varieties), where cases are chosen from *tall1*, *tall2*, *tall3*, and *regular*. Varieties in the proportional yield levels would not have the location/region difference according to Bettiga study, and it can only be chosen from *red* and *white*. With this *type* definition, for example, $b_3^{tall1,white}$ represents the yield from white tall vine in case 1 in year 3 as a proportion of the yield from mature vines, which is 88.0% shown in Table 4. We applied this proportional yield to each of the first five years when harvesting occurs across all three tall vine cases defined in Section 2 as well as the Regular Vine Base Case.

We referred to the UCAIC cost studies for 1996[14] and 2010[11], which provided the yields (tons/acre) for chardonnay and cabernet sauvignon respectively. So, we use chardonnay as a representative for all the white vines, and cabernet sauvignon for red vines. We again followed Bettiga's lead by averaging the regular spur and trunk yields in his study to determine the percentage of regular vine yields in years 1-5 as displayed in Table 4.

In Case 1, as seen in Table 4, we assumed harvesting began in year 3, and we used the findings in the Bettiga study[10] to determine a yield of 88.0% of full production for white and red grapevines respectively (for year 3). The vineyard then reaches full production by year 4, one year earlier than regular vines.

In the proportional yield levels considered under Case 2, the first harvest occurs in year 2 and years 3-5 have identical yields to Case 1 as no yield drag penalty is imposed. According to Bettiga's study[10], the yield occurring in year 2 for chardonnay was 37.33% compared to the mature full production. Similar to regular vine yields, we referred to the UCAIC cost studies for 1996[13] and 2010[11], and inherited the representative pattern for red tall vines (Cabernet

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Sauvignon) and white tall vines (Chardonnay). Then, we assume that red grape vines have a proportional yield level to white grape vines for tall vines, which is 37.33% in Case 2. The proportional yield levels under Case 3 considers harvesting in year 2 and imposing a yield drag penalty for harvesting before the vines have fully matured. The yield drag was assumed to be a constant 35.15% of the existing yield percentage in years 3-5, established in Case 2. For example, the yield of white variety tall vines in year 3 after the yield drag is 88.00% * (1-35.15%) = 57.07%. The yield drag penalty prevents the vineyard from reaching full production until year 6.

*Revenue ($/acre)*

We generated a per-acre revenue function for each region, at year *t*, for each *type* as shown in equation 1:

$$\mathrm{R}_{\mathrm{t}}^{\mathrm{region,type}} = \mathrm{b}_{\mathrm{t}}^{\mathrm{type}} * \mathrm{P}^{\mathrm{region,type}} \qquad \mathrm{t} = 1,2,3,\ldots,20 \qquad (1)$$

where $R_t^{region,type}$ represents the per acre revenue ($/acre) for wine grapes at a specific region (chosen from Central Coast or North Coast) at year *t* adjusted by the proportional yield levels $b_t^{type}$. $P^{region,type}$ assumes a weighted average of 2019 variety of regions revenue ($/acre) for full production (100%).

*Cost ($/acre)*

The grower costs were categorized into 3 sections: Labor Costs, Material Costs, and Other Costs. Within Labor costs, we focused on pruning, training, thinning, and harvesting, which can be represented by subscript *i* of Labor in both equation 2 and equation 3. In Material Costs, subscript

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*j* represents cartons and fertigation. We bucketed all other cost items under Other Costs, subscript *k*. Other Costs include replanting, water (water and labor), taxes, and management fees.

We constructed a per-acre cost function for each type in each year based on the three main categories for start-up costs (years 1-4) and the following standard production time period (years 5-20). For Tall Vine: Case 1 and the Regular Vine: Base Case, there does not include an early harvesting and this per-acre cost function contained general portion parameters to gather different input weights. However, cost differences for tall and regular vines also occurred if tall vines were harvested in the second year (Case 2 and Case 3). Therefore, we refined our cost model with the proportional yield levels (yield percentage) considering different time periods and cost-differences based on production differences instead of "Cost-Shifting".

*Cost for year* $1 \leq t \leq 4$:

$$C_t^{region,type} = \left(\sum_{i=1}^{3} Labor_{it}^{region,type} + Cartons + \sum_{k=1}^{3} Others_{kt}^{region,type}\right) + \left[b_t^{type} * (Thinning_t + Harvesting_t + Fertigation_t + Water_t)\right] \quad (2)$$

*Cost for year* $5 \leq t \leq 20$:

$$C_t^{region,type} = \sum_{i=1}^{5} Labor_{it}^{region,type} + \sum_{j=1}^{2} Materials_{jt}^{region,type} + \sum_{k=1}^{5} Others_{kt}^{region,type} \quad (3)$$

In the first 4 years, our cost model from equation (2) isolated harvesting and thinning in the Labor Costs category, fertigation in the Material Costs category, and water (water & labor) in the Other Costs category as defined in the UCCE cost studies, as these cost items showed a more significant relationship to harvesting time. From year 5-20, we continued to use the cost function

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in equation (3). Combining equation 2 and equation 3, we constructed a piecewise function with two production periods for early harvesting cases (Tall Vine: Case 2 and Tall Vine: Case 3).

*Profitability ($/vine)*

We used the following profit function to determine per-vine profitability for tall and regular vines by region and variety:

$$\Pi_t^{\mathrm{region,type}} = \left(R_t^{\mathrm{region,type}} - C_t^{\mathrm{region,type}}\right) * (\mathrm{PlantingDensity})^{-1} \quad (4)$$

where $\Pi_t^{region,type}$ denotes the variable per-vine profit for grapevines with specific type of a region in year *t*, $R_t^{region,type}$ denotes the total per-acre revenue with specific type of a region in year *t*, and $C_t^{region,type}$ denotes the total per-acre costs with specific type of a region in year $t$, divided by the planting density.

**NPV Comparison**

We estimated the "profit difference" of tall vines compared to regular vines. We defined the total difference in per-vine profits between tall vines and regular vines as:

$$\Delta\Pi_{\mathrm{NPV}}^{\mathrm{region,type}} = \frac{1}{20} * \sum_{t=1}^{20} \frac{1}{(1+r)^t} \left(\Pi_t^{\mathrm{region,tall}} - \Pi_t^{\mathrm{region,regular}}\right) \quad (5)$$

$\Delta\Pi_{NPV}^{region,type}$ is the per-vine premium for tall vines for each region and variety. On the right-hand side of the equation above, we first took the difference of the per-vine profit for grapevines in year $t$ for both tall vines and regular vines. Then, we summed all 20 years' per-vine profit for grapevines using a constant discount rate $r$ under the regular NPV framework. Finally, we used the arithmetic average of the 20 years' per-vine profit to determine the per-vine profit difference for tall vines.

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**Table 1** Claimed benefits of using tall vines compared to regular vines.

| Benefit | Effect |
|---|---|
| Shorter time to first harvest | Results in additional revenue in the first few years after establishment [1, 2, 5] |
| One pass training | Reduces vine training costs [1, 2, 4, 5] |
| Deep rooting | Improves plant resilience in early years due to hardier roots [1, 2, 5] |
| Increased vineyard uniformity | Reduces management costs and improves mechanization [1, 2, 5] |
| Long term labor savings | Higher uniformity reduces labor costs in long-term [1, 4, 5] |
| Re-planting dead/diseased vines | In established vineyards, tall vine re-plants will be more uniform with existing vines and therefore not get shaded out by older adjacent vines [3] |

**Table 2** Production profile details of the regular vine base case versus three tall vine cases (all assume green potted vines rather than dormant vines).

| Case | Description |
|---|---|
| Regular Vine: Base Case | Regular vines to be harvested starting in Year 3, reaching full production starting in Year 5 |
| Tall Vine: Case 1 | Tall vines to be harvested starting in Year 3, reaching full production starting in Year 4 |
| Tall Vine: Case 2 | Tall vines to be harvested starting in Year 2 (a year earlier than a typically normal harvest), reaching full production starting in Year 4 |
| Tall Vine: Case 3 | Tall vines to be harvested starting in Year 2 with yield drag, reaching full production starting in Year 6 |

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**Table 3** Profit difference of tall vines ($/vine) for each region and variety with harvesting occurring in year 2 under four yield drag scenarios.

| Region and Variety | Yield Drag (%) | | | |
|---|---|---|---|---|
| | 35% | 38% | 53% | 55% |
| North Coast-White | $0.64 | $0.00 | -$3.56 | -$4.03 |
| North Coast-Red | $5.20 | $4.49 | $0.53 | $0.00 |
| Central Coast-White | $0.00 | -$0.44 | -$2.86 | -$3.18 |
| Central Coast-Red | $3.35 | $2.84 | $0.00 | -$0.38 |

**Table 4:** Proportional yield levels for all scenarios by varietal through year 1 to year 6.

| Case | Type | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 |
|---|---|---|---|---|---|---|---|
| Regular Vine: Base Case | White | 0.00% | 0.00% | 46.7% | 93.3% | 100.0% | 100.00% |
| | Red | 0.00% | 0.00% | 30.0% | 70.0% | 100.0% | 100.00% |
| Tall Vine: Case 1 | White | 0.00% | 0.00% | 88.00% | 100.00% | 100.00% | 100.00% |
| | Red | 0.00% | 0.00% | 88.00% | 100.00% | 100.00% | 100.00% |
| Tall Vine: Case 2 | White | 0.00% | 37.33% | 88.00% | 100.00% | 100.00% | 100.00% |
| | Red | 0.00% | 37.33% | 88.00% | 100.00% | 100.00% | 100.00% |
| Tall Vine: Case 3 | White | 0.00% | 37.33% | 57.07% | 64.85% | 82.43% | 100.00% |
| | Red | 0.00% | 37.33% | 57.07% | 64.85% | 82.43% | 100.00% |

*Note: Proportional yield levels for Tall Vine Case 3 uses a 35.15% yield drag ratio as an example.*

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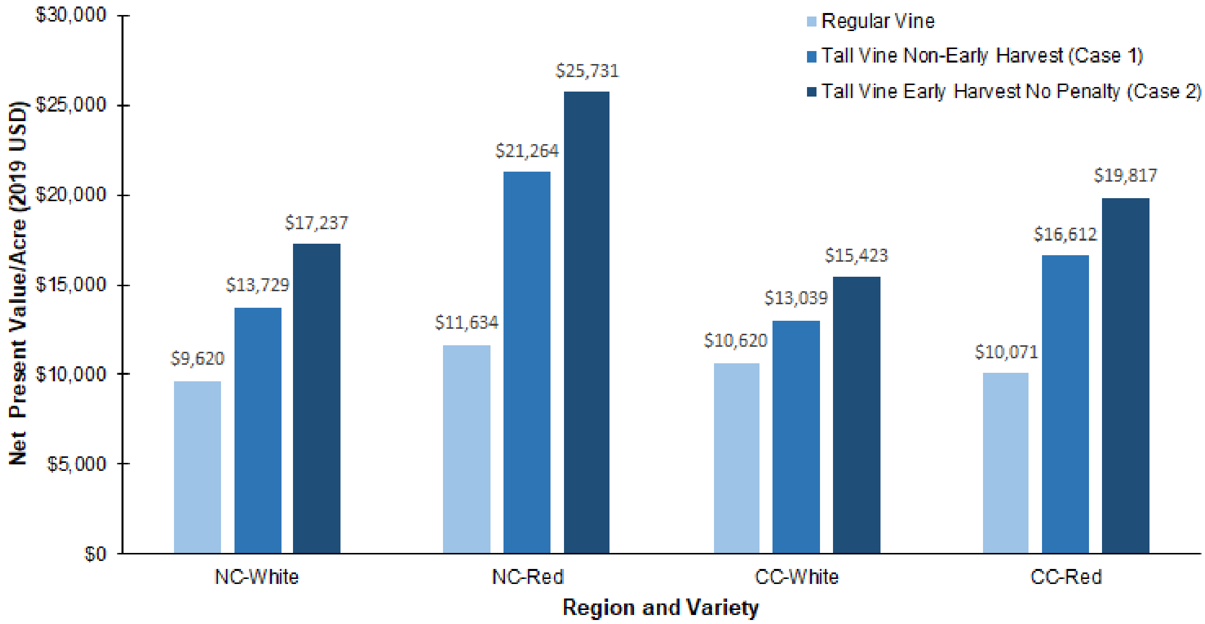


**Figure 1** Net present value of tall vines (medium and dark blue) and regular vines (light blue) by region and variety in 2019 USD.

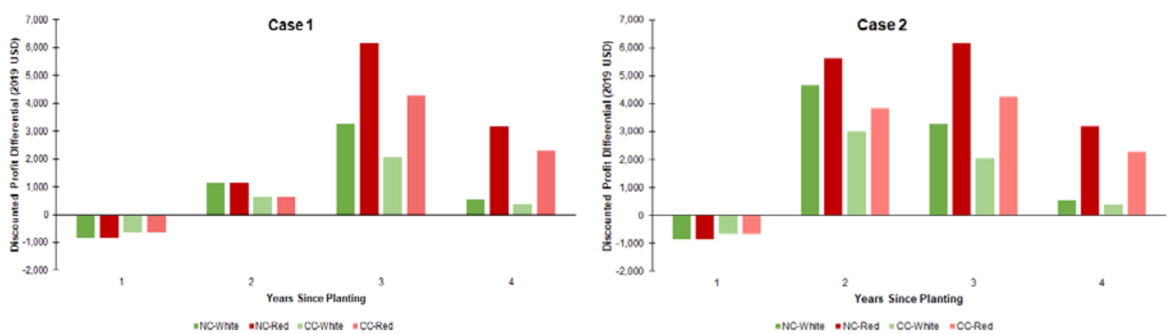


**Figure 2** Discounted profit differential between tall vines and regular vines by region and variety in the first six years of vineyard production for Case 1 (left) and Case 2 (right).

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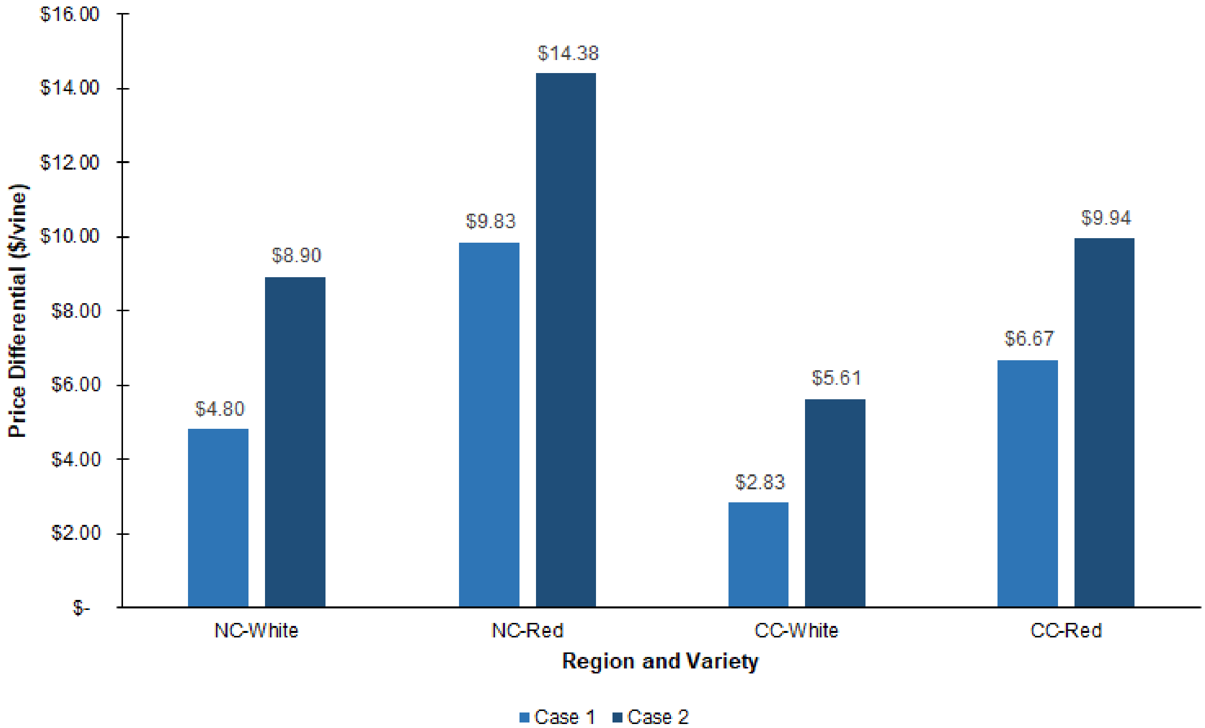


**Figure 3** Tall vine profit difference ($/vine) by region and variety under Case 1 (blue) and Case 2 (dark blue).