Potential for Migration of Coastal Redwood to British Columbia

Maryam Majidian

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Abstract

The recent economic recession combined with the mountain pine beetle epidemic had a negative impact on forestry sector in British Columbia. The damage they caused could be a sign to look for new markets for future. Although in recent years new markets have been opening up to the forestry industry no study has been done to look at the possibility of marketing a new tree species. Coastal redwood is one of the strongest and most insect resistant species in North America. This species lives in coastal California and a small part of Oregon and its timber is highly valuable and can be used for several purposes. Redwood can consume and store large amount of carbon, which makes it a profitable species in the carbon market. The purpose of this paper is to examine the possibility of growing redwood in BC while comparing BC's future climate to the past climate of California coast. The data utilized in predicting BC's future climate is extrapolated from ClimateBC Software from 2020 to 2080. California historical data is taken from the Western Regional Climate Center and a long-term research trial that investigated the ecological implications of summer fog decline in coastal California. The result of comparison shows that BC can compete with coastal California in terms of precipitation and warm temperature. However, the future predictions show that BC is much too cold to support redwood's survival for the next 70 years. Nevertheless, this result is faulty since there is no available data related to BEC Units' zonal site or fog in BC. Future studies that examine the role of fog in BC can increase the chance of redwood's introduction in this province. Although ClimateBC is sophisticated it uses data collected only until 2002. Future software improvements that include more recent data may result in more accurate predictions. The software also doesn't include the "microclimatic effects" such as the effects of nearby lakes or snow pack on temperature. In addition, redwood habitat requirement criteria are biased due to the lack of historical data. Additional information about the past could modify our perception of redwood's tolerance of BC's environment.

Keywords: Climate, California, Habitat, Ecosystem, Carbon Market, Forest, Fog, BEC Unit.

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Introduction

Rationale

For the past decade global warming has been one of the biggest problems we have been facing. This phenomenon is expected to increase the temperature ranging from 1 to 6 °C by the end of twenty-first century (Chiang 2008). If the temperature changes, most of the habitats become unsuitable for local species to survive.

Coastal Redwood (Sequoia sempervirens), the keystone species of narrow range of coastal California (CA), faces the same problem, but to an even greater extent (Libby 1996). According to recent modeling done by researchers at the California Academy of Sciences “the climate of the southern end of the redwood range will become unsuitable for redwood growth by 2100” (Rogers Scientists 2010). This could result in a substantial reduction in redwood’s already limited habitat.

In addition, recent fog reduction in coastal California has raised concerns regarding the risks future climate would potentially have on redwood species (Johnstone 2010). Currently, many studies are being conducted to examine the effect of global warming on redwood and its habitat in California (Kovner 2010; Bourne 2010).

In response to climate change, redwood could migrate; adapt to the new climate of its local habitat; or extirpate (Aitken 2008). However, studies show that redwood has a migration speed of approximately 0. 75 km per century (Chennel, et al.2010). Therefore, redwood cannot migrate fast enough by itself and it would require facilitated migration in order to successfully become established in BC. In addition, introducing a small population as a “founder population” to a new location may provoke the “longevity and phenotypic plasticity” characteristics of the species and result in an increase in populations’ chance of survival in future (Aitken 2008).

Having similar tree species associated with redwood as in CA, British Columbia (BC) may provide redwood habitat in the future (Stone 1965). However, BC is much colder than the California coast.

Nevertheless, the mountain pine beetle epidemic combined with the 2007 economic recession damaged the BC forestry industry in a way that looking for new products for the future may be necessary.

Objectives

The purpose of this paper is to investigate the benefits of marketing coastal redwood in the BC forestry industry and to explore the possibility of growing redwood in this province.

Organization

The organization of this paper is in the following order; first, coastal redwood's physical characteristics and market value is compared to the valuable tree species in BC. These, combined with the current and future redwood market will be used to determine the redwood market potential in BC. Later, redwood's habitat and ecosystem criteria are described, and BC's climate compatibility to CA is investigated using ClimateBC Software. The software assesses areas more suitable for redwood in BC's future. The conclusions and recommendations discuss the final result and describe the errors involved in determining the future prediction.

Coastal Redwood Potential in the BC Forestry Industry

Redwood's Physical Characteristics Compared to BC Tree Species

Redwood is one of the most valuable tree species in the world. One of the primary reasons is that it has high wood quality, similar to some other species native to BC. Due to polyphenols in the bark and heartwood, a component that bugs and decay fungi don't like, the wood is insect and pathogen resistant (Bourne 2009). According to Nels Nielsen, a forester working for Western Forest Products in Gold River, redwood's resistance qualities are similar to western redcedar (Cw) making it very comparable to Cw in that regard (personal communication, August 25, 2010). He believes that redwood's timber strength is among the greatest of tree species in BC; "Redwood's wood is stronger than Western redcedar, but not as strong as Douglas fir, confirming it to be a very valuable tree species" (personal communication, August 25, 2010). Another advantage this wood has is its cylindrical shape. Trees such as giant sequoia (*Sequoiadendron giganteum)* that live in interior California have the same wood qualities except their stem form is conical making them less desirable for timber use. In addition, the timber is light and dimensionally stable, which makes it perfect to work with (Webster 2007).

Advanced Adaptation

Although redwood has a shallow root system it can spread 18-24 meter. In a flooding event, it can intertwine with other trees, making it flood resistant (Hemmerich 2009). Loam and clay are the components of Californian northern redwood forest's subsoil, which implies redwood can adjust to added layers of silt after flooding (Hemmerich 2009; qtd. in Snyder 1996). Due to its high water content and tannins in the bark, mature redwood is fire resistant. However, trees less than twenty years old can easily burn because of thin bark (qtd. in Snyder 1996).

Redwood's high resistance to insect and disease is particularly important. The recent mountain pine beetle epidemic that destroyed hundreds of hectares of pine forest illustrates the importance of having resistant species.

In the future however, some species such as lodge pole pine would likely migrate to northern areas, including the Yukon (McKay 2011). Nicholas Coops, a professor in Faculty of Forestry in University of British Columbia (UBC) that is studying these changes believes that species selection for the future is very important; "We don't want to plant for now, we want to plant for 80 years from now" (McKay 2011).

Redwood Log Value Comparison

As previously mentioned, redwood's wood quality is comparable with valuable tree species in BC. Table 1 shows a comparison between redwood and other tree species' timber value in California[1] (California 2010).

Table 1: Green* and Salvage Harvest Values in redwood regions in California (dollar)** [2]

Species	Volume per Log	Timber Value Area			
		Size Code	**1*****	2	3
Ponderosa Pine	Over 300	1	150- 200	110- 150	50- 70
	150- 300	2	110- 150	80- 100	40- 50
	Under 150	3	80- 100	40- 50	10- 20
Hem/ fir	N/A	N/A	80- 100	1	N/A
Douglas fir	Over 300	1	170- 230	80- 100	1
	150- 300	2	130- 180	50- 70	1
	Under 150	3	120- 160	40- 50	1
Incense Cedar (Cw)	N/A	N/A	100- 130	80- 100	N/A
Redwood	Over 300	1	560- 720	520- 700	410- 550
	150- 300	2	450- 600	460- 610	380- 510
	Under 150	3	430- 570	380- 510	370- 470

*Green timber refers to the healthy trees that can survive 12 months or more if not harvested.

**Salvage timber refers to removal of dead/ or dying trees that are expected to survive less than 12 months if not harvested.

***area 1 refers to Del Norte and Humboldt county, 2 refers to Mendocino to Marin, and 3 refers to San Francisco to Monterey county

According to Table 1, even smaller trees (under 150 m^3 per log) of Coastal redwood have much higher value than Douglas fir and Western redcedar (Average $455, 90, and 100 respectively).

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[1] Table 1 is taken from California Suggested Harvest Values Schedules.

[2] Since old growth logging has been strictly restricted in California; the assumption is that the harvested redwood is the second growth.

Current and Future Redwood Market Potential

Forest Industry

Previously, old growth redwood was an important product in the American market. In the past decade however, new conservation law, protecting almost all the publicly owned old growth redwoods in California, imposed more stringent rules that limited the redwood production to a greater extent (Webster 2007). According to Janet Webb, an employee of Big Creek Lumber Co. in California, the production has dropped to 50% compared to a decade ago (Webb 2007).

However, the secondary growth species market is successful. According to Rob Webster, managing director of NZ Forestry Limited, currently 95% of the lumber sold in the US market is composed of second growth species (Webster 2007). He believes that there is still a strong demand in the United States (U.S.) and could have a potential in Asia; "Redwood has unlimited markets for products and ... it has low silvicultural costs throughout rotation" he adds. The timber can be used for several purposes including interior design. For example, it was used in NBC broadcasting studio for Olympic 2010 in Vancouver (Lepisto 2010). In addition, new marketing strategies in California are trying to inform customers that redwood is a unique species and it should be treated as an affordable specialty product, not a commodity (Driscoll 2010).

Due to high redwood demand in California, Webster believes that New Zealand is determined to join the U.S. redwood market (Webster 2007). The redwood plantation trials in New Zealand confirm that wood quality is comparable to Californian second growth redwood (Webster 2007).

Richard Carrick, a Forestry Commission Wales representative, believes that redwood high quality timber accompanied by its resilience towards insect and disease makes it a valuable species to grow in Wales (Forgrave 2011).

Carbon Market

In the last few years, reducing carbon emissions is becoming increasingly important. Carbon markets are developed to control the reduction and reward the ones that do it properly. Many forest companies have joined these carbon markets, profiting through carbon offsets. The studies show that since redwoods grow for a very long time without being affected by disease or any insects, the "redwood forests are the best of all forests at capturing carbon dioxide from the atmosphere" (Bourne

2009). Scientists believe that younger redwoods absorb lots of carbon to grow faster, but when they reach 30 to 70 years, they absorb less, and store carbon instead (Blumenthal 2010).

Therefore, since it can store massive amounts of carbon, redwood would be a perfect species for reducing carbon in the atmosphere. Consequently, it can be a profitable species in the carbon market.

Coastal Redwood Ecosystem Criteria, and Climate

Historical Range

Coastal redwood is a species that has been around for 120 million years (Rogers Redwood 2010). Although they used to live across Canada, Utah, and Montana their current habitat is limited to the stretch from Monterey, California to Chetko River in Oregon (Zinke 1964; Rogers Redwood 2010).

Ecosystem Criteria

As a unique species, redwood needs a unique ecosystem. Location, fog, soil, and tree species associations seem to be the most important contributors to the redwood ecosystem and hence, are being discussed in this section.

Location

As the name suggests, coastal redwood lives on the coast of California and Oregon. However, redwood absorbs salt water in a form of salt spray near the ocean; therefore, it can't grow near the Pacific Ocean (Baker 1965). In addition, redwood needs a significant amount of precipitation and fog, and because lower elevations have low amounts of these requirements, abundance of this species near the shore is rare (Baker 1965). However, the elevation range can be from sea level to more than 980 m (Snyder 1996). Redwood can live on different topography ranging from flat to steep, abrupt mountain ranges (Snyder 1996).

Uprooting is the primary cause of death in redwood species and it restricts the habitat to less wind-prone areas (Stone 1965). Redwood has shallow roots and when it is combined with wet, unstable soil, the possibility of uprooting increases (Stone 1965). However, lateral roots "interlock" (qtd. in

Snyder 1996), “allowing individual trees of great height and massive crown to resist windthrow” (qtd in Snyder 1996).

Fog

Fog is one of the most important redwood ecosystem requirements. Fog along the coast of California is affected by three factors; California current upwelling that is driven by wind, ocean temperature pattern, and northerly wind speed along the north west of U.S. coast (Johnstone 2010). The strongest fog pattern is at the current redwood distribution, mainly the Oregon- California border (Johnstone 2010). The fog usually occurs in the summer due to “strong subsidence, inversion conditions and upwelling” accompanied by the clouds remaining at the coastline (Johnstone 2010).

Drought Assistance

Redwood is one of the most drought sensitive species in the world and that is one of the reasons that fog is so important in the redwood ecosystem (Burgess 2004). Redwood has poor stomata control in dry condition and it can lose “up to 40% of midday summer water” on very dry nights (Burgess 2004). Various studies show that fog reduces the “canopy stress”, which helps redwood by decreasing its transpiration rate (Burgess 2004; Ewing 2009). In addition, redwood is able to absorb fog water through the leaves, which becomes an important function during the summer. (Dawson 1996).

Shallow Root Assistance

Redwood has shallow a root system and during the summer it has difficulty accessing deeper water in the ground (Dawson 1998). Even though summer fog contributes only 19% of the foliar uptake of the tree, it contributes to reverse water flux, thus improving the water status of redwood (Burgess 2004; Dawson 1998). Although 97% of the precipitation occurs between October and May, redwood water uptake is two to four times higher in the summer than in winter and, therefore, the 19% represents a major portion of tree water use (Burgess 2004; Dawson 1998).

Nutrient Source

Fog can trap carbon dioxide which could enhance photosynthesis (Dawson 1998). Moreover, nitrogen that fog holds regulates ecosystem processes such as “soil nutrient cycling via microbial activity and below ground respiration” (Ewing 2009).

Soil

Studies show that redwood’s most suitable soil is rich in calcium and nitrogen, and has a moisture index of 20-80 (Zinke 1964). Redwood is adapted to podzolic soils with medium and coarse soil texture (Zinke 1964). According to Paul Zinke, professor at the University of California Berkeley, redwood soil should have a pH of 5- 7.6 and low organic matter content (Zinke 1964). Soil disturbances in newly harvested areas contain a high amount organic matter that is not suitable for redwood (Zinke 1964). Redwood has no tolerance for salt or magnesium, which excludes it from shore sites (Baker 1965).

Tree Associations

Redwood is a keystone species and it supports many animal and plant species (Libby 1996). The Redwood forest is a home to many endangered species such as Northern Spotted owl, Marbled murrelet, and Coho salmon (Bourne 2009). Even at higher elevation, limbs of older trees can hold a massive amount of canopy and support species such as huckleberry and salamanders (qtd. Bourne 2009). The trees associated to redwoods are usually Douglas fir, Grand fir, Spruce, and Hemlock (Stone 1965). According to Herbert Baker, professor at the University of California Berkeley, Douglas fir could be a potential competitor to redwood since it can live at higher elevation (Baker 1965). Spruce can also compete near the coast due to its tolerance to salt (Hemmerich 2009). However, redwood can stay suppressed under bigger redwoods for a long time once the dominant trees are removed, and light enters the forest, the suppressed redwood starts to grow (Bourne 2009). The hardwood tree species in redwood forests are vine maple, big leaf maple and red alder (Hemmerich 2009). Fortunately, both hardwood and softwood trees that are associated with redwoods are common in BC.

Climate

This section describes the climate of California redwood habitat and compares it to the future climate in BC to determine BC's suitability for planting redwood in future. The data from the Western Regional Climate Centre and the Johnstone study[3] are used to compile California historical habitat data shown in Tables 2, 3, 4, and 5. The data is focusing on four redwood ranges[4]. The future BC climate data shown in Tables 2, 3, 4, and 5 is extrapolated from ClimateBC Software for 2020, 2050, and 2080 over the entire province. Since global warming has an unpredictable effect on temperature, the temperature increase can be drastic within the next 70 years. Therefore, the entire BC can be a potential for redwood growth, and is being evaluated in this section.

To make an accurate decision about the future redwood ecosystem it is important to consider the entire ecosystem limitations as illustrated in previous section. Although the fog occurrence has increased in northern BC and decreased in the south part of the province (Wang at al. Dev. 2006), lack of fog data in BC excluded this necessity from the analysis. In addition, BEC Units are the units that are used in ClimateBC Software. Since the zonal site information[5] for BEC Units are not accessible this information is being neglected. Therefore, the climate comparison only includes temperature and precipitation evaluation between CA and BC.

The following tables show the climate difference between past[6] California and future BC (2020-2080).

Table 2: The Driest Months'* and Annual Precipitation comparison between past CA and future BC

	CA	BC
Driest Months' Precipitation (mm)	1-40	70- 560
Total Annual Precipitation (mm)	600- 1800	290- 4700

*The driest months are July, Aug, and September

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[3] The paper is "Climatic Context and Ecological Implications of Summer Fog Decline in the Coast Redwood Region".

[4] The historical data is for four main redwood habitats; Crescent City, Sonoma, Oakland and Monterey in California

[5] Zonal site information refers to the data such as site slope, soil texture and nutrient regime

[6] The California historical data is for various 60-year periods that started during 1899 to 1961.

Table 3: Annual Soil Moisture Index comparison between past CA and future BC

	CA	BC
Annual Soil Moisture Index	20- 80	50- 711

Table 4: Seasonal Temperature and Precipitation range comparison between past CA and future BC

	CA		BC	
Season	Fog Season*	Rain Season**	Fog Season	Rain Season
Temp (°C)	15 +35	8 +12	-1 +22	-16 +8
Rain (mm)	13- 220	960- 1360	70- 560	Up to 8830

*Fog season is Aug, Sep, and Oct

** Rain season is Dec, Jan, and Feb

Table 5: Monthly Average Temperature range comparison between past CA and future BC

	CA	BC
Monthly Average Temperature (°C)	8 +21	-16 +23
Extreme Maximum Temperature (°C)	18 +39	16 +47
Extreme Minimum Temperature (°C)	-3 +9	-50 -18

Assessment of Redwood's Compatibility with BC Climate

As previously mentioned, due to the lack of fog and soil data, these variables are excluded from the analysis. According to Table 2 and 3, BC has neither a precipitation nor a soil moisture deficiency compared to CA. Referring to Table 2, even in the driest months of July, August, and September, BC receives about 15 times more amount of precipitation than does CA (assuming the average amount of precipitation is 20 mm in CA and 315 mm in BC).

Although the result of 1953-2004 climatology study shows that BC would have less freezing temperature in the south (Wang et al. Dev. 2006), the extreme minimum temperature in BC seems to be drastically different compared to coastal CA. While in August- February the temperature in California ranges from 8 to 35 °C, it is -16 to 22 °C in BC (Table 4). According to historical data demonstrated in

Table 5, both BC and CA have similar extreme maximum temperatures, ranging from about 17 to 43 °C. However the extreme minimum temperature between these two regions is drastically different; the minimum temperature in CA ranges from -3 to 9 °C whereas it is -50 to -18 °C in BC.

Most of the locations that have extremely cold temperature in BC also receive considerable amounts of snow. Even though snow packs can provide some level of air and soil insulation (Wang et al. Dev. 2006), factors such as canopy cover and aspect can alter the snow distribution in an area. Having most of his redwood plantation killed by the -10 °C temperature in early February, Nielsen states that seedlings might have survived the freezing temperature if the surrounded snow was covering the plantation, providing some level of insulation (personal communication, March 10, 2011). However, the extreme minimum temperature difference between CA and BC is so significant that the snow pack insulation may not be sufficient to compensate for this temperature difference.

To avoid frost days, ClimateBC Software is used to identify the BEC Units with the least number of frost days. The result shows that the frost free period in BC ranges from 30- 265 days annually. The following Table shows the 10 best suited BEC Units that have the longest frost free duration for the years 2020, 2050, and 2080.

Table 6: 10 Best Suited BEC Units with the Longest Frost Free Period (days/ year)

BEC Units	2020	2050	2080
CDF mm	231	265	192
CW Hdm	200	230	250
CW Hxm1	210	242	251
CW Hxm2	187	213	238
CW Hwh1	196	226	218
CW Hwh2	162	185	217
CW Hvm1	190	210	190
CW Hmm1	177	200	232
CW Hmm2	155	174	201
MH mmp	144	165	192

Table 6 suggests that even BEC Units with the shortest frost period (CDF mm, CW Hdm) could have about 100 days of frost annually. Redwood species may not be able to tolerate this period since the extreme minimum temperature in California redwood habitat is -3 °C (Table 5).

Conclusions and Recommendations

In conclusion, although the 2020-2080 climate prediction shows there is sufficient rain precipitation for Coastal redwood growth in BC, the future extreme minimum temperature is far too low to provide a suitable condition for redwood's survival.

The lack of BC's zonal site and fog data made the British Columbia and California coast comparison unrealistic. More research on the frequency and intensity of fog in BC can result in a better evaluation.

The ClimateBC Software uses the data from 1961 to 2002 (Wang et al. Climate 2006). The usage of recent data could affect the derived variables that were used to predict future climate in this software. Any future improvement in the software may change the climate prediction and increase/ decrease BC's suitability for redwood growth. In addition, the software doesn't take into account the effect of nearby lakes and rivers (Wang et al. Dev. 2006). Nor does it take into account the effects of canopy and snow pack on temperature (Wang et al. Dev. 2006). As a result, in some areas, temperature could be slightly different than the extrapolated data.

Lastly, although the recently initiated researches that are studying redwood's future habitat would help with the prediction, historical habitat data is very limited. This species has been around for 120 million years, but the data used in this paper is for 60-year periods. Additional information about the past could modify redwood's tolerance towards BC's restricting condition and alter the results.

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