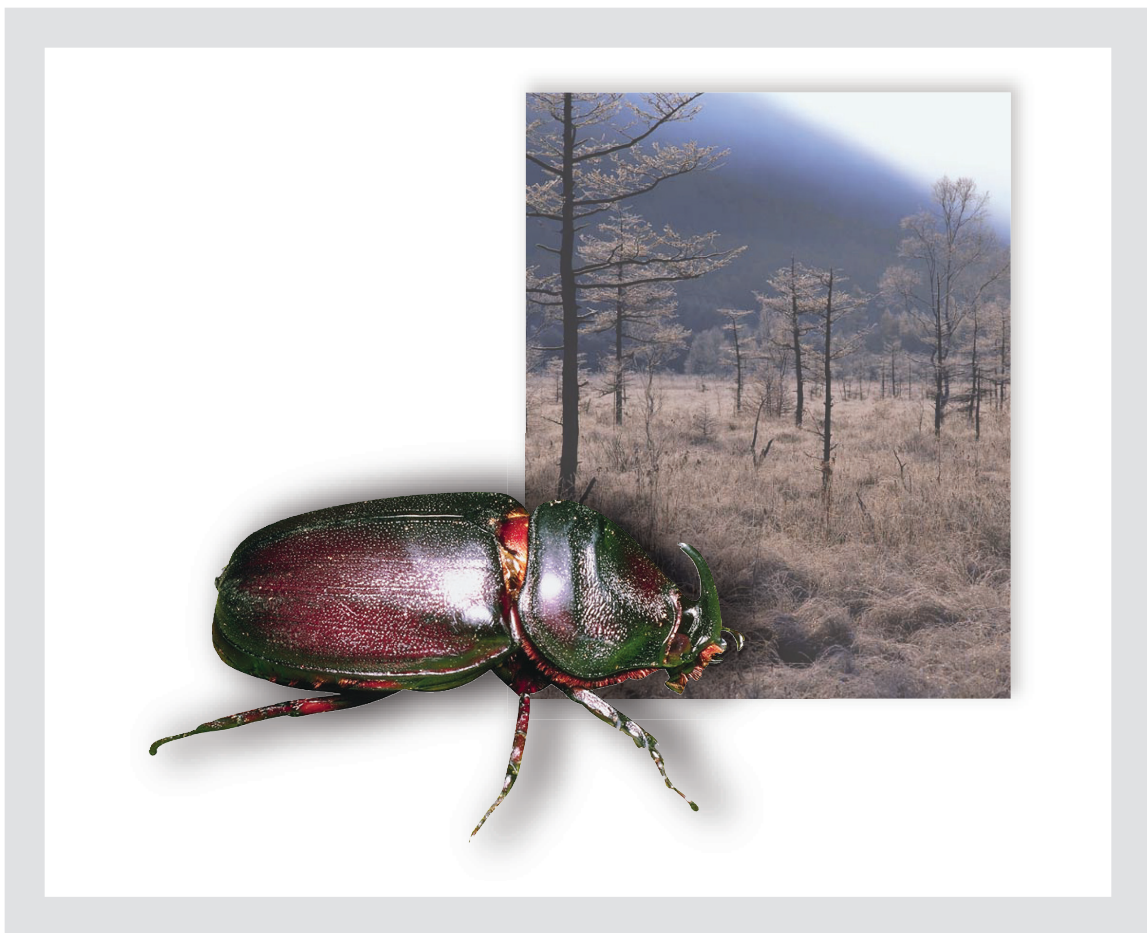


Applied Mathematics 30

Student Project: Mountain Pine Beetles



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Applied Mathematics 30

Project: Mountain Pine Beetles

Introduction

Mountain pine beetles (*Dendroctonus ponderosae*) are native to British Columbia and feed primarily on pine species, especially lodgepole pines. Under normal conditions, mountain pine beetles play an important role in attacking old, weakened pine trees so that younger pine trees can flourish. However, since 1997 the population of mountain pine beetles has been increasing dramatically. This outbreak has serious economic and social consequences for British Columbia, as well as Alberta, since mountain pine beetles are threatening some Alberta pine trees. In the fall of 2006, mountain pine beetles had attacked approximately 19 000 pine trees; by the fall of 2007, the number of pine trees under attack was estimated to be approximately three million, mostly in the northern part of the province. In this project, you will be investigating the spread of mountain pine beetles and their economic and social impact on the forestry industry.

Part A

The start of the infestation in central British Columbia can be traced back to 1993 and can be attributed to two factors—favourable climate conditions (British Columbia has not experienced a frigid winter in many years) and favourable stands of pine trees (due to many decades of forest fire suppression, the stands of forest are very similar in composition and age). Since 1996, extensive data on mountain pine beetle populations in British Columbia have been collected by federal and provincial forestry scientists. From 2003–2004, the population of mountain pine beetles increased fourfold in the interior forests of British Columbia. In 2006, aerial overview surveys in British Columbia estimated that 9.2 million hectares of pine trees were in “red attack.” The infestation has spread beyond the British Columbia central interior and is now threatening Alberta forests in the Grande Prairie and Grande Cache area, as well as the Bow Corridor near Canmore. Other Alberta forests may be less seriously affected, as the beetle does not adapt well to extreme cold and does not typically attack young trees or small trees near the northern edges of boreal forests.

Mountain pine beetles typically attack lodgepole pine trees that are at least 80 years old and that have a diameter of at least 24 cm. In the province of British Columbia, there are approximately 14.9 million hectares of lodgepole pine; approximately 8 million hectares are over 80 years old and therefore are susceptible to attack. Studies have found that the infestation level in different stands of trees varies from 15% to 100%, so it has been difficult for the Ministry of Forests to assess exactly how many of the trees have been affected.

In an attempt to monitor the infestation, different measurement models were used in British Columbia from 1999 to 2003. The spread of mountain pine beetles can be described by each of the following factors, as shown in the tables below: the area of infested pine trees in millions of ha, the volume of infested pine timber in m³, and the percent of mature infested pine trees.

Calendar Year	Infested Area (millions of ha)
1999	0.1
2000	0.3
2001	0.8
2002	1.9
2003	4.1

Calendar Year	Volume of Infested Pine Timber (millions of m³)
1999	no data
2000	48
2001	72
2002	108
2003	173

Calendar Year	Percent of Mature Infested Pine Trees
1999	no data
2000	5
2001	7
2002	11
2003	17

Data for the tables shown above have been adapted from *Evaluating Mountain Pine Beetle Management in British Columbia, Special Report, FPB/SR/20*, August 2004, published by the Forest Practices Board.

1.
 - Input these data into a graphing calculator or spreadsheet. Draw a scatterplot for each table of data.
 - Write an exponential regression equation to model each set of data.
 - Explain what the values of a and b represent in each regression equation.

2. If the infestation rate remains constant, predict the volume of pine timber that will be infested in 2009.

3. Once 50% or more of the mature pine trees become infested with mountain pine beetles, an exponential regression equation is no longer the most reliable model for the data. Explain how to determine when the exponential regression equation modelling the percent of mature infested pine trees as a function of time will become unreliable.

Part B

Many forest companies use economic models to predict the value of the areas where they have cutting rights, and they use spreadsheets to conduct analyses. The primary input variables in one of the spreadsheets are the infestation rate of mountain pine beetles, the salvage rate of infected hectares, the predicted profit per hectare from salvaged products, and the predicted value per hectare for the healthy hectares of pine trees.

1. Prior to the mountain pine beetle epidemic, a particular forestry company set up the spreadsheet shown below to predict how a forest with 100 000 ha of timber changes in value over a 20-year period. In its spreadsheet, the company used an annual mountain pine beetle infestation rate of 4% and a salvage rate of the infested hectares of 40%, and it predicted that the value of the salvaged hectares would be \$1 000/ha and the value of healthy hectares of timber would be \$1 500/ha.

Complete the spreadsheet shown below for the 20-year period. Supply two printouts of your spreadsheet: one printout showing all the values and the other printout showing the formulas within the cells.

	A	B	C	D	E	F	G	H	I
1		Total ha	100,000						
2		Infestation Rate (%)	4						
3		Salvage Rate (%)	40						
4		Value of Salvaged ha (\$/ha)	1,000						
5		Value of Healthy ha (\$/ha)	1,500						
6									
7	Year	Healthy ha at Start of Year	Ha Infested During Year	Healthy ha at End of Year	Value of Healthy ha at End of Year	Ha Salvaged During Year	Cumulative Number of Salvaged ha	Cumulative Value of Salvaged ha	Total Value at End of Year
8	0	100,000	4,000	96,000	\$144,000,000	1,600	1,600	\$1,600,000	\$145,600,000
9	1	96,000	3,840	92,160	\$138,240,000	1,536	3,136	\$3,136,000	\$141,376,000
10	2	92,160	3,686	88,474	\$132,711,000	1,474	4,610	\$4,610,000	\$137,321,000

2. If the infestation rate increases (for example, during a mountain pine beetle epidemic), predict how this will affect the number of healthy hectares, the value of the healthy hectares, the cumulative value of the salvaged hectares, and the total value at the end of the year. Justify your predictions using examples from your spreadsheet.

3. Forestry companies in areas where the pine beetle infestation is of epidemic proportion have changed their harvesting plans to try and harvest as much pine-beetle-infested wood as possible. Although the pine beetles carry a fungus that stains the wood blue or grey, the timber can be made into lumber and other products, if harvested in time.

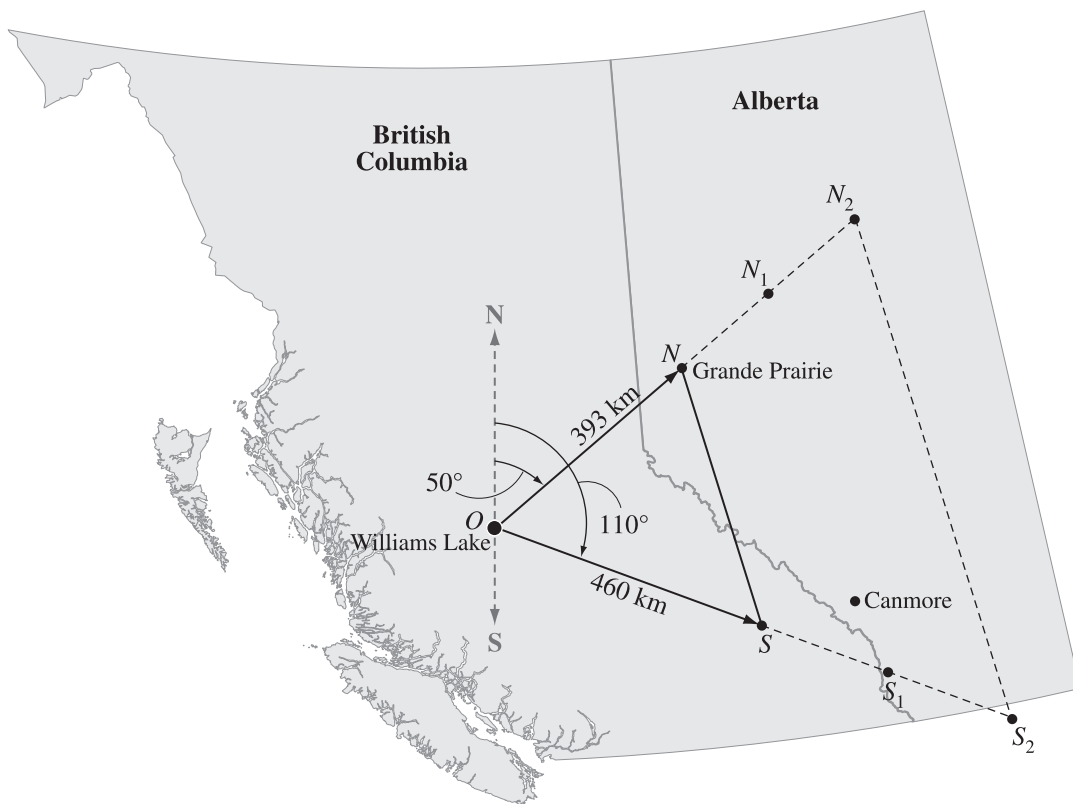
If the salvage rate of infested hectares is increased in your original spreadsheet, predict how this will affect the number of healthy hectares, the value of the healthy hectares, the cumulative value of the salvaged hectares, and the total value at the end of the year. Justify your predictions using examples from your spreadsheet.

4. A company analyst predicts that the value of healthy hectares will increase at a rate of 3.5%/a due to a decreasing supply of healthy timber. This projected growth can be modelled in your original spreadsheet by changing the formula in cell E9 to $=D9*\$C\$5*1.035^A9$ and then filling down.
 - According to this prediction, in what year will the company realize a maximum total value? What will this maximum value be?
 - Compare this maximum value with the maximum value the company will receive if the value of healthy hectares does not increase each year.

Part C

The front-line advance of the mountain pine beetle can be modelled by a vector that describes the speed of the advance in kilometres per year and the direction of the advance, either a bearing or a compass direction. The current front-line advance is on two fronts. One front is travelling on a bearing of 50° from the central interior of British Columbia toward the Grande Prairie and Grande Cache area, while a second front is travelling on a bearing of 110° toward the Bow Corridor region near Canmore.

The map below models the two fronts as they travel across the British Columbia–Alberta border. The points labelled N and S represent the northern and southern fronts of infestation at the end of 2005. If the direction and spread rate continue, then the northern and southern fronts at the end of 2010 will be N_1 and S_1 , respectively; at the end of 2015, they will be N_2 and S_2 .



1. According to the model, what was the straightline distance between the northern and southern fronts at the end of 2005?

2. The northern front is currently advancing at a rate of 32.8 km/a, and the southern front is currently advancing at a rate of 38.3 km/a.
 - Predict how many kilometres the northern front and the southern front will advance from 2005 to 2010. Justify your predictions algebraically.
 - Predict the straight-line distance between the two fronts in 2015. Justify your predictions algebraically.

Part D

Conduct an investigation into the effectiveness of different methods for controlling the spread of the mountain pine beetle. Describe how the methods work, and give some advantages and disadvantages of one particular method. The following list of web sites may help you in your research:

www.gov.bc.ca/for/
www.mpb.cfs.nrcan.gc.ca/index_e.html
www.fpb.gov.bc.ca/special/reports/SR20/SR20.pdf
www.srd.alberta.ca/forests/health/pestalerts/mpbfaq.aspx
www.srd.alberta.ca/forests/health/pestalerts/mountainpinebeetle.aspx
www.env.gov.bc.ca/bcparks/conserv/pine_beetle/pine_beetle.html

French-language resources can be accessed through:

www.mpb.cfs.nrcan.gc.ca/index_f.html

This web site has embedded links to additional French-language resources.

Note: Web site addresses sometimes change. If the web sites listed above are not available, use a search engine and type in keywords such as *mountain pine beetles*.