A Mathematical Model for the Urban Forest

Overview

Students collect leaves from the setting in which they live, a city or town, and identify them to genus or species with the help of field guides. (Note: A tree usually has a single, main stem while a shrub is often many stemmed.) When students collect leaves, they also collect information about the locations of the trees and their overall condition. This information will be entered onto data sheets for later analysis.The data will be analyzed by a Tree Health Index Model (a simple algebraic formula) that allows students to assess the overall health of each tree, of a five-tree "forest," and ultimately of the urban forest in their community. The exercise focuses on developing identification, observational, and data-acquisition skills and introduces students to a very practical use of elementary algebra.

Title

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Investigative Question

How can the health of an urban forest be determined with a simple mathematical model using data collected from street trees?

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Objective

Using a mathematical model, students interpret and critique the health of the urban forest in which they live.

Materials

Per student: five paper or plastic bags.

Per group: Student Pages 1, 2, and 3, tape measures or meter sticks, various field guides to trees, one or two plant presses (heavy books may be substituted).

Time

Two 50-minute class periods.

Advance Preparation

1. Copy student pages and assemble the necessary materials.

2. You may wish to contact your city arborist for a list of the trees in your community or those favored as street trees in your town.

Introducing the Activity

Ask students how many of them live in a forest. Probably very few will respond "yes" unless they live in a rural area or in a wooded suburban area. Introduce the concept of the urban forest as described in the first paragraph of Student Page 1.

Procedure

1. Schedule this activity as a homework assignment. Before students begin collecting data, review the concept of a descriptive mathematical model; see student page 2 for information. Distribute Student Pages 1, 2, and 3.

2. Read and discuss together the background material on Student Page 1. Distribute the paper bags. Ask students to write their names on each of the five bags (names will need to be taped on plastic bags).

3. Each student is responsible for collecting leaves from five different trees (each tree does not have to be of a different species) that grow along the streets or highways in their city or town. If possible, they should study trees in their own neighborhoods.

4. When a student selects a leaf, he or she places it in a bag, assigns it a number, and records that number on the bag. When the tree is identified, that information is recorded on Student Page 2. Before leaving the collection site, students should also complete the suitability, condition, and location ratings. Student Page 3 will help students assign suitability ratings.

5. Back in the classroom, discuss the urban forest in terms of tree health and suitability. Explain that a preferred tree, a tree that has desirable characteristics and will grow in an urban setting on an optimum site, is more likely to be in good condition than one growing in a "sea of concrete" or very near a major highway. Emphasize that such factors as broken branches (from ice or wind damage), wounds, soil compaction, or root damage (from heavy pedestrian traffic or from trenches dug nearby) are also indicators of tree health. Trees that are under stress are not likely to be in optimum condition.

6. Uing the information on Student Pages 2 and 3, each student reviews the ratings he or she assigned to each of the five trees in his or her data base and follows these instructions:

a. Rate each tree's suitability: Is it a good, intermediate, or poor choice for an urban street tree? A good tree is one that is known to grow and thrive in an urban setting An intermediate choice may do well for a while but may ultimately decline;

it may also have undesirable characteristics such as excessive fruit in fall or a tendency to drop branches. An unsuitable tree is one that will not do well in an urban setting or has many undesirable traits, such as the obnoxious fruits from a female gingko. For example, red maple = good = +1, buckeye = intermediate = 0, gingko = poor = -1. This value will be used to replace X when computing the Tree Health Index Value (THIV) for each tree. Any tree not listed on Student Page 3 should arbitrarily be placed in the poor choice category.

b. Review the ratings you gave for physical condition. This value will be used to replace Y when computing the Health Index.

c. Review the location ratings. This value will be substituted for Z when computing the index.

d. In our model, each of these three variables is not of equal importance and must be weighted based on its contribution to the final analysis. Thus, we must multiply each variable by a constant to adjust its importance relative to the other variables. In our model, the X variable's constant is 1, the Y variable's constant is 3, and the Z variable's constant is 2,

7. You are now ready to compute the Tree Health Index Value for each of the trees in your data base. The higher the value, the healthier the tree is likely to be. For example:

X =+1 (species = red maple = good)
Y = +1 (condition = healthy)
Z = +1 (location > 4 m from building or pavement)
Tree Health Index Value = IX + 3Y+2Z
THIV = 1(+1) + 3(+1) + 2(+1)
THIV =+1+3+2
THIV = +6

8. By referring to the THIV Scale, we conclude that this particular tree is a very healthy and an appropriate urban tree.

9. After students have calculated the THIV for their five trees, they calculate the average THIV of their "five-tree street forest." For example:

+1	0	+1
+1	0	+1
-1	0	-1
0	+1	+1
-1	+1	+1
X=0/5=0	Y=+2/5=0.4	Z=+3/5=0.6

THIV = IX + 3Y + 2Z
THIV = 1(0) +3(0.4) +2(0.6)
THIV =0+1.2+1.2
THIV for a five-tree forest =2.4

10. The final step is to combine the THIVs of all the five-tree forests rated by the class into a single Forest Health Index Value for their community. For example:

FHIV= $\frac{\text{THIV values for all five-tree forests}}{\text{number of THIVs calculated by class}}$

11. Finally, the class compares data on their Tree Health Index Values for individual trees and determines the percentage of trees in each of the five health index categories. This should be done as a class exercise with you serving as data coordinator and tabulator at the chalkboard. Students then present this information in graphic form. Encourage a variety of approaches: bar graphs, column graphs, line graphs, scatter graphs, pie graphs.

Assessing the Activity

Each student maps a four-city-block grid in his or her neighborhood. Using the characteristics of an ideal urban forest (the descriptors for the + values on Student Page 2), students design an "ideal" urban street forest by placing trees of appropriate species in appropriate locations. In each student's design, some less than appropriate locations must be chosen because city residents always desire tree-lined streets. What kind of a tree care program should the city establish to ensure the health of trees planted in less than desirable settings?

Extending the Activity

1. If your students are working with computers, they may create a program or use an available spreadsheet that will accommodate the data and model. Students can then run the program and generate the results with the data they have collected.

2. Students may press the leaves they collected in a plant press or large book. They then prepare herbarium labels that include species name, date of collection, site, condition of tree, and name of collector. In subsequent years students can compare their assessment of the urban forest with those made by students in previous years. Is the urban forest declining? Has the composition of the forest changed over time? What has happened to trees that previously received Health Index Values of -3 through -6?

3. Ask students to determine how many of the trees they used in their analysis are native to Illinois. Use *Forest Trees of Illinois* as a reference. Ask students to repeat their model analyses but designate each tree species that is not native to Illinois as a poor choice. How does this affect the model? Are there compelling reasons why we should plant native Illinois trees in our urban forest?

References

Miller, R.W. 1988. Urban Forestry: Planning and Managing Urban Greenspaces. Prentice Hall, Englewood Cliffs, NJ. 404p. Mohlenbrock, Robert H. 1983. Forest Trees of Illinois. Fourth Edition, Illinois Department of Conservation, Springfield. 332p.

State Goals

6, 11, 12 (Objectives 11.4.01-04, 11.7.01-03, 11.7.06, 12.7.01)

Concept

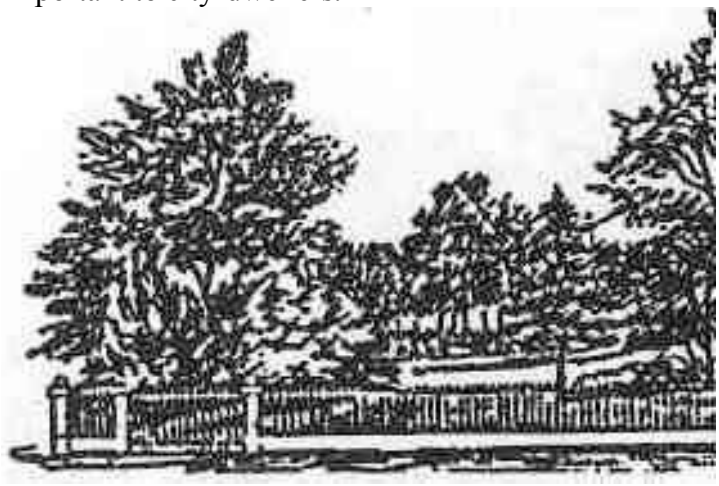
Mathematics is important in all aspects of scientific inquiry.

Safety and Waste Disposal

Students should be prepared to explain their research to homeowners who may question them about their activities along city streets.

Student Page 1: Background Information

Communities have a valuable but often overlooked resource—trees! Most city dwellers fail to realize that they live in a forest, an urban forest. It includes trees growing along the streets and in parks, yards, and wooded areas within the community. In fact, many Illinois counties have a higher concentration of trees within the city limits than outside! Urban or community forestry is the planting, care, and protection of trees in urban areas. As Illinois cities become more populated, the value of the urban forest becomes more important to city-dwellers.



We control the composition and density of trees in the urban forest and ultimately determine its overall health by the species of trees we plant, the locations in which we plant them, and the care we give them.

Urban and community forestry is important because it is related to almost every aspect of community development. Trees need to be chosen and planted according to a plan, much like a city's infrastructure (streets, sewers, sidewalks, utility lines) is planned. Thought must be given not only to the replacement and addition of trees but also to the survival of existing trees.

A mathematical model is an equation or series of equations with one or more variables into which we feed information that we have gathered from direct observation. A model can help us to understand how a natural process works. It can also help us to predict future events or trends or to assess a current condition in a quantitative way. Models can be quite complex or relatively simple. In this activity, you will use a simple algebraic statement to assess the health of the urban forest in which you live.

Student Page 2: Field Data—Urban Forest **Name** _____

	Tree 1	Tree 2	Tree 3	Tree 4	Tree 5
Species:	_____	_____	_____	_____	_____

Tree 1 Tree 2 Tree 3 Tree 4 Tree 5

X = Suitability for an urban environment
(+1) Good
(0) Intermediate
(-1) Poor

Y = Physical condition of tree
(+1) Healthy
(green leaves, no wounds, no yellow or brown leaves, few broken or dead branches)
(0) = Moderately healthy (mostly green leaves, a few yellow or brown leaves, no wounds, some broken or dead branches)
(-1) = Unhealthy
(yellowish or brown leaves, one or more wounds, many broken or dead branches)

Z = Location of tree
(+1) Growing in an open area with pavement >4 m away
(0) = Growing 2-4 m from a paved area
(-1) = Growing <2 meters from a paved area

Health Index Value (THIV or FHIV) = IX + 3Y + 2Z

Health Scale

-6 -5	-4 -3	-2 -1 0 +1 +2	+3 +4	+5 +6
Very Unhealthy	Moderately Unhealthy	Intermediate Health	Moderately Healthy	Very Healthy

Student Page 3: Common Street Trees Found in Illinois*

Good (+1)	Intermediate (0)	Poor(-1)
Honey Locust (thornless)	Eastern Hemlock	Gingko
Willow Oak	Bald Cypress	Norway Spruce
Pin Oak	Mimosa	Blue Spruce
Crabapples	Tree of Heaven	Serbian Spruce
White Oak	Buckeye	Firs Larch
Red Maple	Tulip Tree	Coffee Tree
Arbor Vitae	Eastern Redbud	Black Locust
Blue Beech	Sweetgum	Holly Sassafras
Ironwood	Other Oaks	White Mulberry
Norway Maple	Basswoods	Hawthorns White
Swamp White Oak	Dogwood	Birch American
	Black Walnut	Elm Beech
	Catalpa	Hackberry Silver
	Bur Oak	Maple Sugar
	White Ash	Maple Black
	Bradford Pear	Cherry Green
	Sycamore	Ash Scotch Pine
		Red pine
		Austrian Pine
		Eastern White Pine

*If a tree is not on the list, consider it to be in the Poor category.