Tropical Four-est Inventory

Using Measurement To Understand the Condition of Forests in Micronesia

Photo courtesy of J. B. Friday.

Meet the Scientists

Photo courtesy of Julian Dendy.

◀ **Julian Dendy**, Geographic Information Systems (GIS) Technician and Biological Field Technician: My favorite experience related to science is the combined feeling of exhaustion, peace, and wonder after putting in a hard field day out in nature. However, the feeling most particular to doing science for me is a small excitement at having learned something new, confirming or rejecting a hunch based on field observations, or understanding a concept in a new way, after investing much time and effort collecting, organizing, and analyzing data.

USDA Forest Service photo.

◀ **Ashley Lehman**, Biological Scientist: My favorite science experience is collecting forest **monitoring** data. My favorite place to collect data is on the permanent Forest Inventory and Analysis (FIA) plots in the mangrove forests in the Federated States of Micronesia. You will learn about FIA research in this article.

I like studying mangrove forests because they provide important functions to the Pacific Island ecosystem and nearby human communities. Mangrove forests provide a natural barrier to the human and natural communities from large storm systems that cause surges and large wind events. These mangrove forests play an important role for cycling and storing carbon. These forests also provide habitat for the desirable mangrove crab and a diversity of juvenile fish species.

Monitoring mangrove forests is uniquely challenging because it requires moving through a tight web of aboveground root systems. Many mangrove forests have a maze of channels that flood with the incoming tides. This twice-daily flooding creates a limited work window and accessing the forests by boat becomes more difficult. Boating through this watery channel maze and through a web of mangrove roots is both fun and challenging! You can learn more about mangrove forests in this journal.

Photo courtesy of Wendolin Roseo Marquez.

◀ **Wendolin Roseo Marquez**, Senior Grants Officer & Micronesia Challenge Terrestrial Measures Lead: My favorite science experience is conducting the Forest Inventory and Analysis in Micronesia. I enjoy the whole process. This process includes research planning, community consultation, data collection, assuring quality, data analysis, reporting, community awareness, community feedback, and providing advice to support policy decisions. It is always interesting to couple modern science with the **indigenous** knowledge in Micronesia. It is also vital for policy and legislation to have science to support decision making.

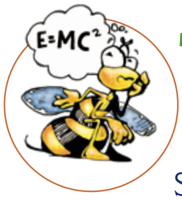
What Kinds of Scientists Did This Research?

Biological Scientist: This scientist studies living organisms and living systems.

Geographic Information Systems (GIS) Technician and Biological Field Technician: A GIS research technician creates and uses digital maps and data sets and maintains and updates geographic databases. He or she collects, organizes, and stores **geospatial** data and performs geospatial analyses using GIS software and tools to answer research questions. A biological field technician sets up and maintains field (outdoor) instruments and equipment. This technician gathers field data and biological samples, records data, and conducts tests and other kinds of analysis related to field research. Both types of technicians also write research papers and reports.

Senior Grants Officer & Micronesia Challenge Terrestrial Measures Lead: This professional provides support for research grants, contracts, cooperative agreements, and other awards involving money to make sure that all regulations are properly followed. This profession also provides leadership, technical, and financial support to the Micronesia Challenge terrestrial resources monitoring.

Glossary words are bold and are defined on page 112.



Thinking About Science

To understand how forests are changing over time, the Forest Service conducts yearly inventories and analyses of the Nation's forest and nonforest lands. First, scientists identify whether an area is forested or not forested. For forested land, scientists identify and record information that describes the forest. This information includes what kind of trees are growing; the height, size, and **density** of the trees; the trees' health; and how many trees have died or been removed.

An inventory is a list of all things in a place or business. For example, a store will keep a list of everything available for sale. This list, along with the items themselves, is called an inventory. When you buy something, the store's manager will take your item out of the inventory.

A forest inventory is similar, except that forests are usually too large to count every tree and plant. A forest inventory relies on measuring and counting plants in a sample. A sample is a small part of the whole. It is made in a way so that every item studied has an equal chance of being selected for study. A sample is, therefore, believed to be an accurate representation of the whole. If foresters sample one-tenth of a forest, they will multiply their measurements by 10 to establish an inventory of the entire forest.

The Forest Service has been conducting inventories and analyses of forest land since the 1930s. A sample of the Nation's land is examined every year. This continual inventory and analysis enables scientists to better understand how forests are changing over time. Beginning in the 2000s, the Forest Service began conducting forest inventories and analyses in the Pacific Islands.

In this research, scientists in Micronesia used the process developed by the Forest Service to describe and analyze forests growing on the Pacific Islands of Micronesia (**figure 1**). They increased the amount of forest land sampled and analyzed on these islands to get a better idea of the current condition of forests in these Pacific Islands.

Figure 1. Micronesia is a group of islands located in the southwestern Pacific Ocean. FIND Outdoors map by Carey Burda.

Thinking About the Environment

Micronesia is a region in the western Pacific Ocean (see **figure 1**). Micronesia includes five independent nations, two U.S. Territories, and four main island groups (**table 1**).

Table 1. Nations, territories, and island groups in Micronesia.

Independent Nations
Republic of Palau (pə **laů**)
Federated States of Micronesia (FSM)
Republic of the Marshall Islands (RMI)
Republic of Kiribati (**kēr** ə bäs)
Republic of Nauru (**nau** rū)
United States Territories
Guam
Commonwealth of Northern Mariana Islands (CNMI)
Island Groups
Caroline Islands
Mariana Islands
Marshall Islands
Gilbert Islands

What Is a Republic?

A republic is a form of government in which the State is ruled by representatives of the citizens. A direct democracy, in contrast, is ruled by the citizens themselves. Most modern democracies are republics. A republic is not ruled by a monarchy (**mä** när kē). A monarchy is the undivided rule or supreme power by a single person. Is the United States a republic? Why do you think so? Adapted from Encyclopedia Britannica, https://www.britannica.com/topic/republic-government.

What Is a United States Territory?

A United States Territory is an area of land that is partially self-governing under the authority of the U.S. Government. Citizens of U.S. Territories elect a representative to the U.S. House of Representatives, but this representative cannot vote on Federal legislation.

The five permanently inhabited U.S. Territories include American Samoa, Guam, the Northern Mariana Islands, Puerto Rico, and the U.S. Virgin Islands. American Samoans are U.S. nationals. Residents of the other U.S. Territories are U.S. nationals as well as U.S. citizens. A U.S. national who is not a citizen has all the rights of a U.S. citizen except he/she cannot vote in Federal elections or hold a Federal office.

Micronesia covers about 7.4 million square kilometers (km) of Earth's surface (**figures 2a** and **2b**). Of this area, less than one-half of 1 percent is land (see **figure 1**, page 98).

Micronesia has a high diversity of plant life. Over 350 plant species living in Micronesia are endemic (en **de** mik). An endemic species is one that is found only in a particular area. Micronesia's native forests have the highest number of endemic plant species per forest area in the world. Unfortunately, only 30 percent of Micronesia's and Polynesia's native forests remain. Micronesia, therefore, is one of the most **vulnerable** areas in the world to endemic plant **extinctions**.

Figures 2a and 2b. Micronesia's tropical landscape. Micronesia Conservation Trust photo by Roseo Marquez (2a) and USDA Forest Service photo by Rich MacKenzie (2b).

Introduction

In the early years of the 21st century, the U.S. Territories and independent nations of Micronesia recognized the importance of protecting their natural resources. To better protect these natural resources, the nations formed an agreement in 2006. They called this agreement the Micronesia Challenge (MC). The agreement identified 20 percent of land resources and 30 percent of nearshore marine resources that would be managed for natural resource **conservation** (**figure 3**). Each nation determined which of their own natural resources would be managed for conservation.

Natural resource conservation management means that actions are taken to protect the natural environment now and into the future. In Micronesia, many natural resources, such as nearshore resources, are managed as a public good. Managing these natural resources for conservation benefits everyone.

In the Federated States of Micronesia, Guam, and the Republic of the Marshall Islands, forests managed for conservation as well as forests not managed for conservation were included in the scientists' inventory and analysis.

In this research, the scientists wanted to describe and summarize the forests managed for conservation in the Federated States of Micronesia, Guam, and the Republic of the Marshall Islands. They wanted to compare this information with a description and summary of the forests not managed for conservation.

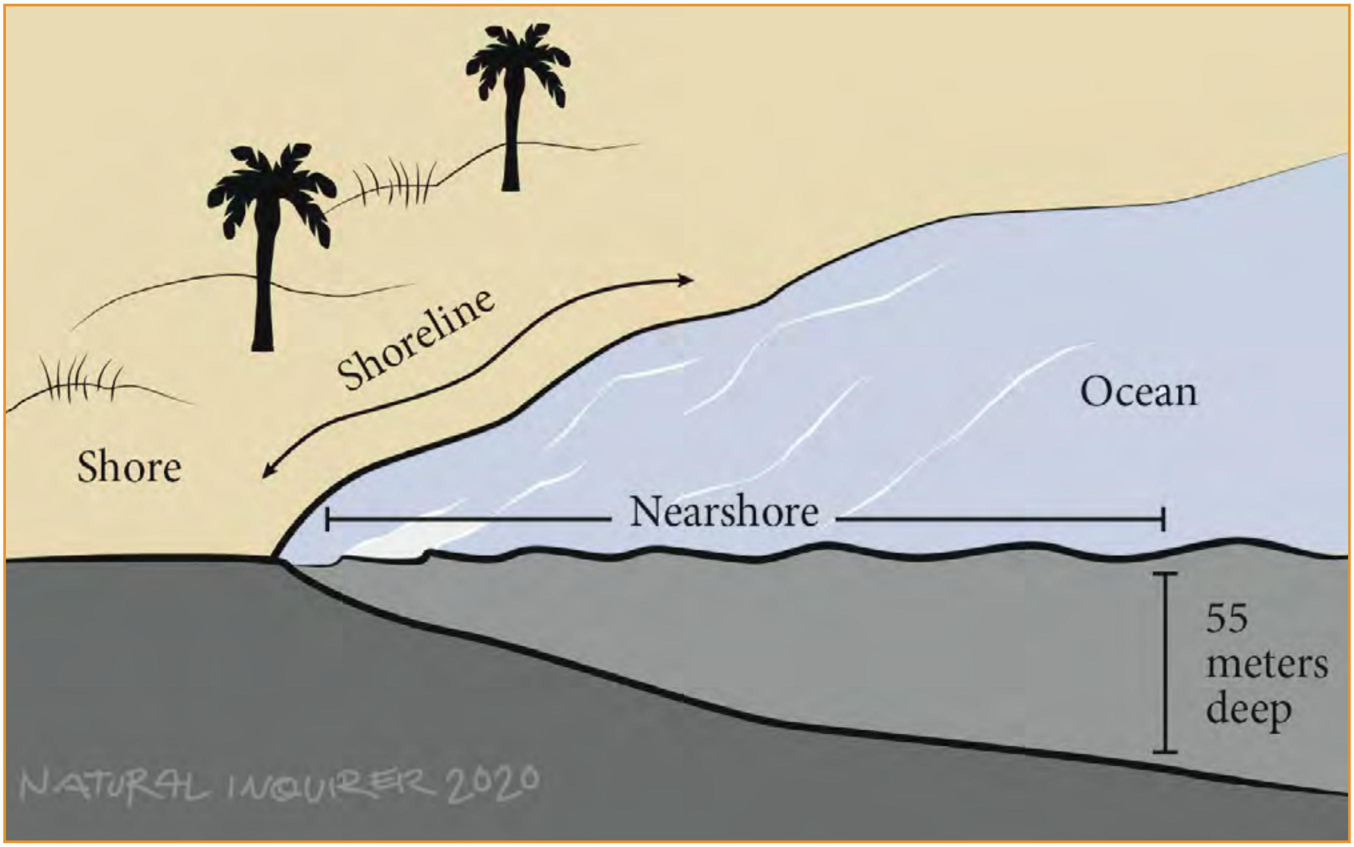
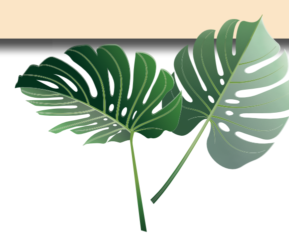


Figure 3. A nearshore resource includes the area from the high tide line to a water depth of 55 meters (m). FIND Outdoors illustration by Liz Sisk.

Reflection Section

- In the early years of the 21st century, the U.S. Territories and independent nations of Micronesia recognized the importance of protecting their natural resources. Name two possible reasons for this recognition. Are some of these reasons applicable to your own community? Why or why not?
- The scientists wanted to compare forests managed for conservation with forests not managed for conservation. What is one advantage of knowing how these different forests compare?



Methods

The scientists began by using satellite images of the islands (**figures 4** and **5**). A grid was laid over the islands' satellite images (**figure 6**). Any rectangle within the grid that had at least one acre of forest land was identified. The grid was also used to identify areas that were not forested. These nonforest areas were eliminated from the inventory. Each forest plot was chosen randomly. When something is chosen randomly, every possible choice has an equal chance of being selected.

Biological field technicians and other field crew members visited each forest plot. They collected data on the condition of the forest within the plot (**table 2**, page 104 and **figure 7**, page 105).

Coin Toss

When you toss a coin, each side has an equal chance of landing up. The result of a coin toss, therefore, is random.

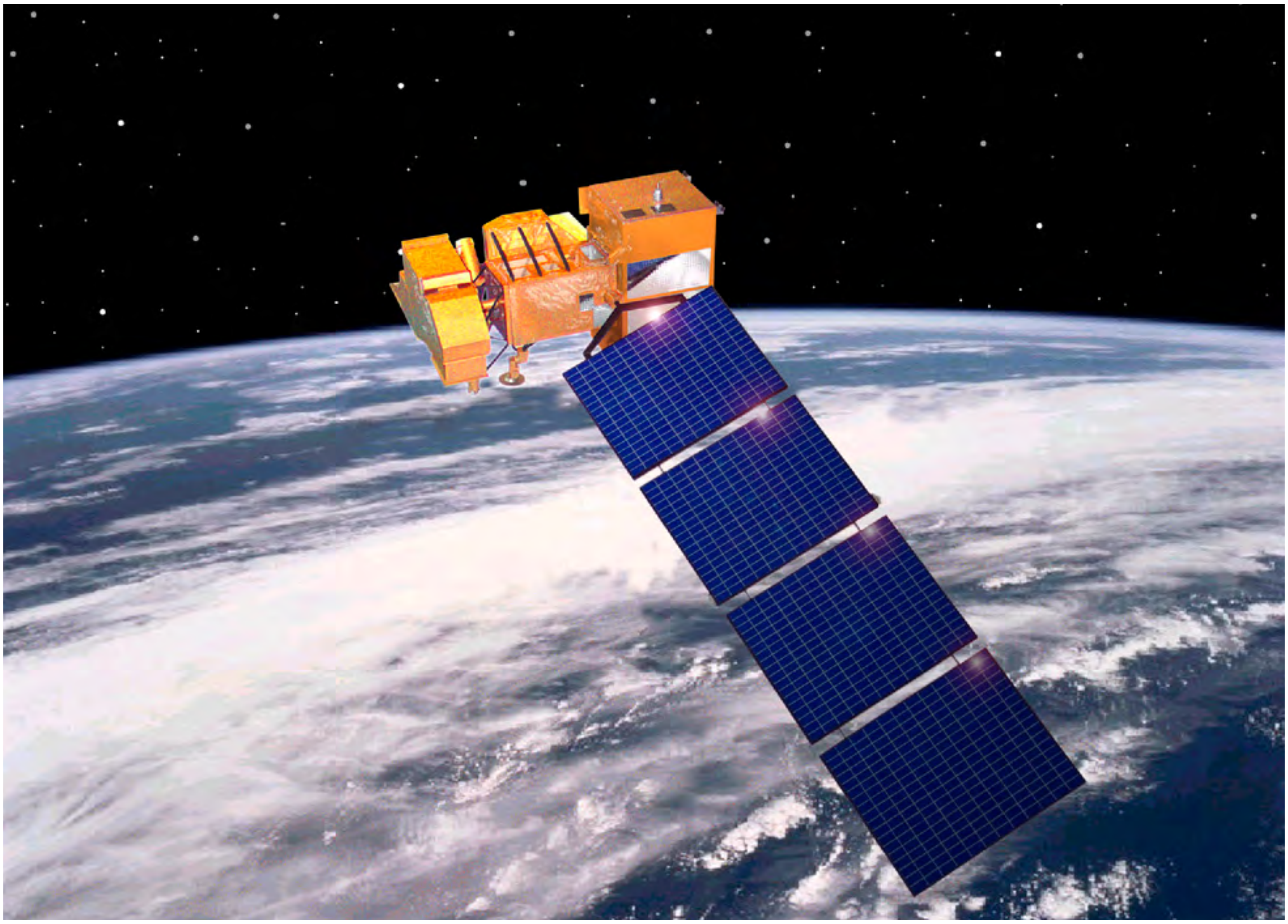


Figure 4. The National Aeronautics and Space Administration, or NASA, uses satellites to take photographs of Earth from space. This satellite is called Landsat. Scientists use Landsat to study Earth's land cover. NASA photo.

Figure 5. Satellite image of Guam. DigitalGlobe, Inc. photo.

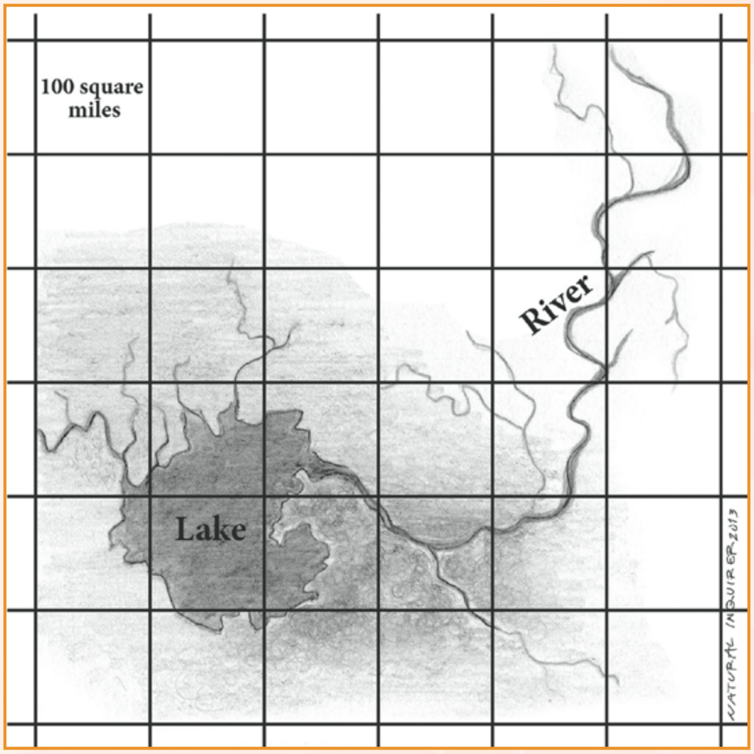


Figure 6. A grid is a network of evenly spaced horizontal and vertical lines. A grid is used to identify locations on a map. In this research, the grid was used to identify forest plot locations. FIND Outdoors illustration by Stephanie Pfeiffer Rossow.

Table 2. Information collected for forest land. (Note: When you see an asterisk, look below the table for an explanation.)

What was measured	Forest inventory and analysis data used	Acreage/number of trees	Percent of forest/ trees
Human disturbance	Human-caused impact and fire damage	Acreage (number of acres)	Percent of forest area
Plant species diversity	Tree species per plot	Not applicable (N/A)	N/A
	Vascular* plant species per plot	N/A	N/A
	Tree species	Square feet per acre	Basal area** of each species/basal area of all trees***
	Percent cover of understory species (understory includes plants under the tree canopy.)	Acreage	Percent of forest area
Forest structure	Tree diameter at breast height (DBH)	Number of trees	Percent by DBH class****
	Tree height	Number of trees	Percent by height class****
	Basal area	Square feet per acre	N/A
	Stem density	Number of trees per plot and acre	Percent of all trees
Invasive species	Species of invasive tree	Number of trees	Percent of all trees
	Invasive species vegetation cover	Acreage	Percent of forest area
Tree abundance	Tree species	Number of trees	Percent of all trees
	Tree rank order: Endemic and invasive species	Number of trees by category	Percent of all trees
Mangrove stem density	Stem density per acre	Number of trees per acre	N/A
Mangrove basal area	Basal area	Number of square feet per acre	Dominance of different tree species
Forest community	Forest community: the types of trees that make up a particular forest	Number of acres	Percent of forest area

*A vascular (**vas** skyə lər) plant has a channel for the movement of fluid, such as sap.

** The area of a breast-height cross section of a tree or of all the trees in a stand (see page 107 for an illustration of basal area).

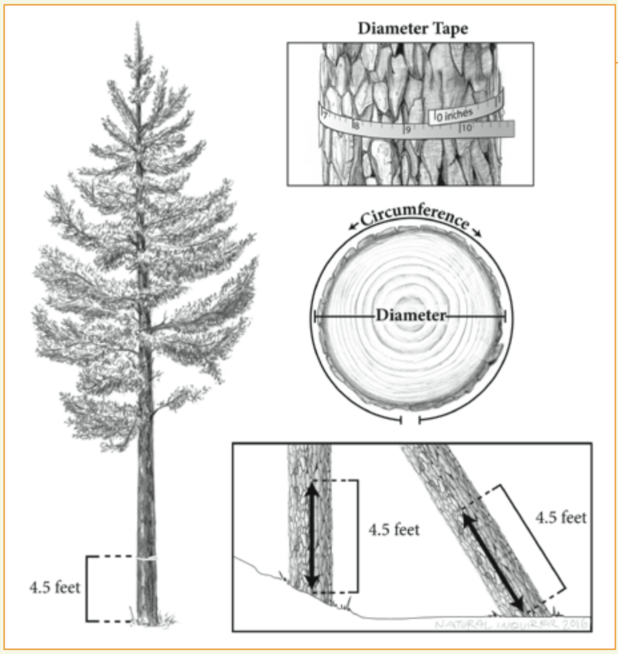
***Basal area of each species/basal area of all trees: This is a fraction, like ½. The number represented by the basal area for each tree species is divided by the basal area of all trees.

**** DBH class: A grouping of tree diameters into classes of a specified range. Height class: A grouping of tree heights into classes of a specified range.

Figure 7. Biological field technicians and other field crew members take measurements in a mangrove forest plot. USDA Forest Service photo.

What Is Diameter at Breast Height, or DBH?

The diameter at breast height (DBH) is the diameter of a tree trunk 1.37 meters (m) (4.5 feet) above the ground. Measuring DBH is a standard way to measure the size of trees. When the tree is growing on a hill, DBH is measured on the uphill side of the tree.



Measuring DBH provides a standard way to measure the size of a tree. FIND Outdoors illustration by Stephanie Pfeiffer Rossow.

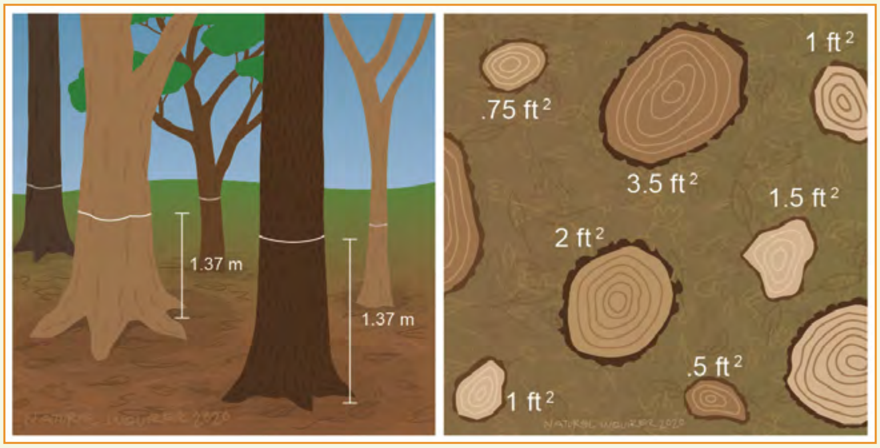
This field technician is measuring the DBH of a tree. USDA Forest Service photo by Paul Scowcroft.

Ashely Lehman, a scientist in this study, measures the DBH of a large tree. Notice that she is measuring the DBH from the uphill side of the tree. USDA Forest Service photo.

What Is Basal Area and Stem Density?

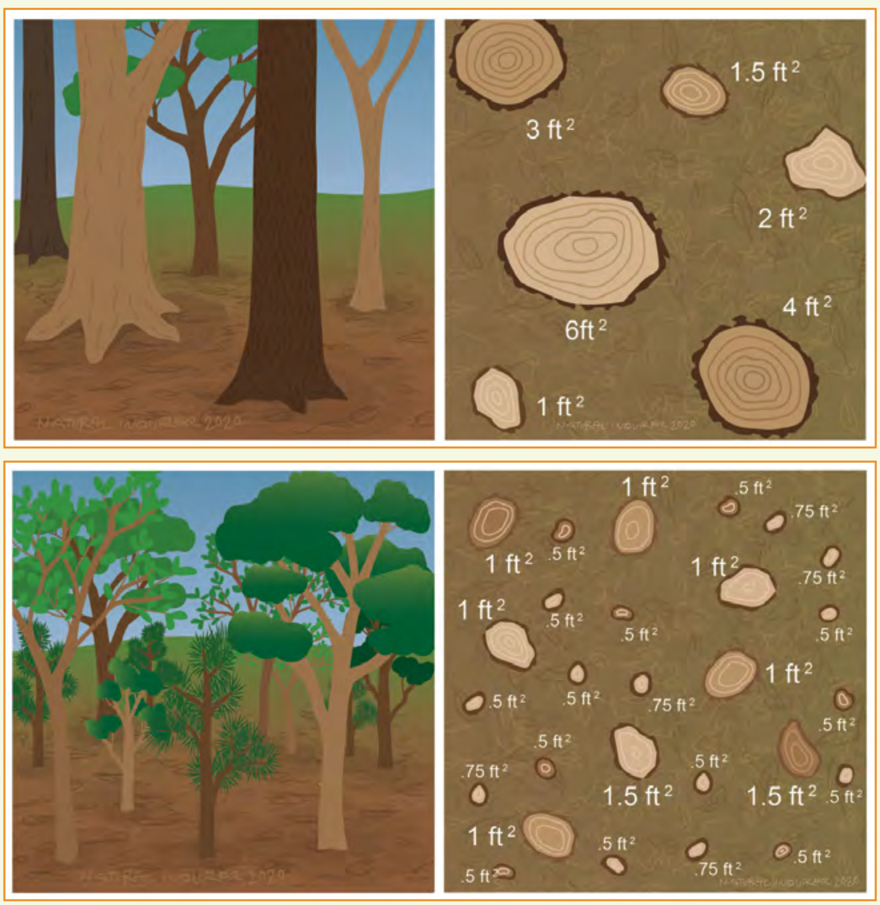
Basal area is the average amount of an area occupied by tree stems. Basal area is calculated as the total area of the cross-section of all tree stems at breast height.

Basal area is usually expressed in number of square feet per acre.



This illustration shows two views of basal area. In the second view, each circle represents a stem's size at breast height.
FIND Outdoors illustration by Liz Sisk.

Stem density is the number of tree stems per area.



The basal area of the trees in these illustrations are about equal, but the stem density is different. Which illustration has a lower stem density?
FIND Outdoors illustration by Liz Sisk.

Five forest communities were sampled in Micronesia. These forest communities include lowland rain forest, montane rain forest, strand forest, agroforest, and mangrove forest (**figures 8–13b**).

Most tropical rain forests are classified as lowland tropical rain forest (**figure 8**). Lowland rain forests grow on relatively flat land at lower elevations (**figure 9**). Lowland rain forests are usually taller and have more plant diversity than montane rain forests.

In the forest inventory done in the United States, one plot of forest is **intensely** investigated, measured, and the data are recorded for every 6,000 acres of forest. For this research in Micronesia, one plot of forest was investigated for every 222 acres of forest.

Figure 8. Lowland rain forest. Conservation Society of Pohnpei photo.

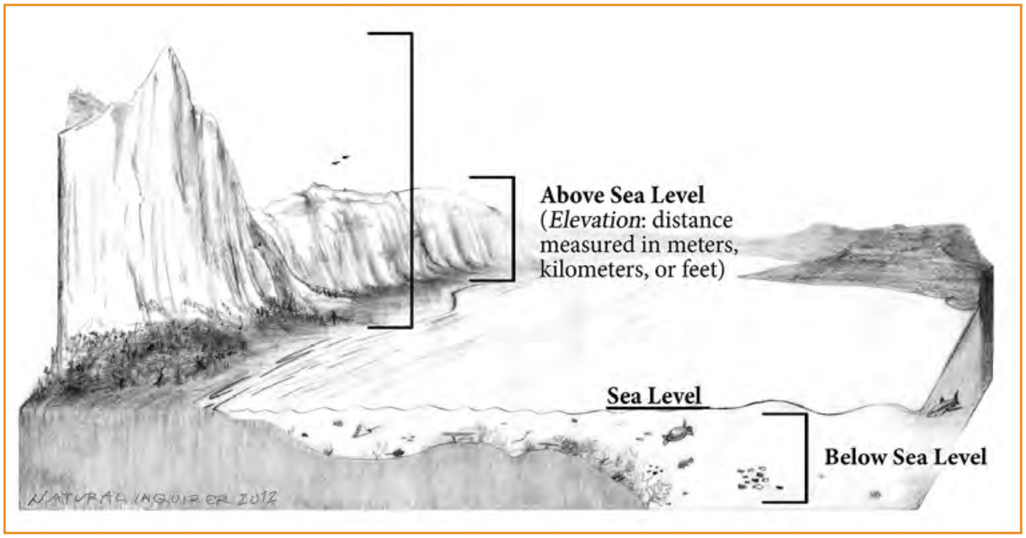


Figure 9. Elevation is the height above sea level. FIND Outdoors illustration by Stephanie Pfeiffer Rossow.

Figure 10. A montane rain forest is found at higher elevations than lowland forest. The tree and plant species found in tropical montane forests are different than the tree and plant species found in lowland tropical forests. Conservation Society of Pohnpei photo.

Figure 11. Strand forests grow in the sand at the top of the beach. These forests include trees, shrubs, grasses, and other small plants. Strand forests protect the shoreline and inland areas. Conservation Society of Pohnpei photo.

Figure 12. Agroforests are forests planted to provide a variety of food crops for people. These forests include food crops and trees planted among native plants and trees. In Micronesia, food grown in agroforests include breadfruit, coconuts, cacao, papaya, guava, mango, and other fruits. Breadfruit comes from a tree that is related to fig and mulberry trees. Agroforests also provide products used for medicines, and their wood may be used for building boats and houses. Foods available in this agroforest photo include yam, breadfruit, banana, taro, sakau, and noni. Micronesia Conservation Trust photo by Roseo Marquez.

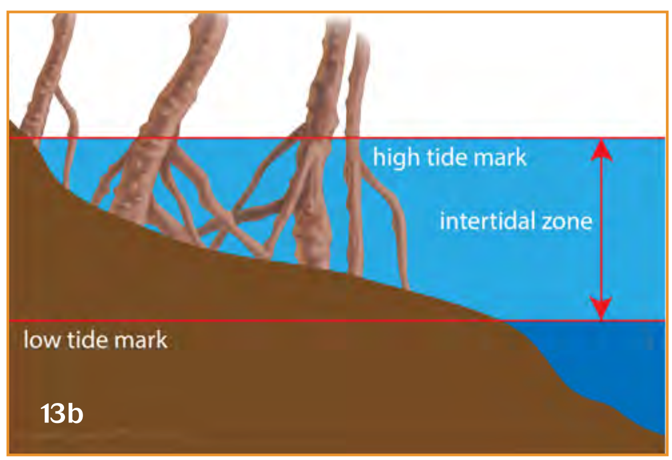


Figure 13a. Mangroves are a group of trees and shrubs that grow in the coastal intertidal zone. Mangrove forests have a dense network of roots that slow tidal waters and allow sediment to settle on the mangrove forest floor. Photo by Babs McDonald.

Figure 13b. The intertidal zone is the area between high tide and low tide. FIND Outdoors illustration by Megan Reeves.

Reflection Section

- What is the advantage of using a standard measure, such as DBH or total basal area, when describing the trees in a forest?
- The scientists studied five forest communities. One of these forest communities is different in one respect from the other communities. Which community is this and how is it different?

Findings

Despite the more intense sampling done in Micronesia compared with what is normally done in the United States, small sample sizes made comparisons difficult. The scientists, however, found differences between forests managed for conservation and those not managed for conservation (**table 3**). Look closely at the last two columns in table 3.

Forests managed for conservation in the three areas had, in general, fewer invasive species and more endemic species as compared with nonconservation forests. Results were mixed between conservation forests and nonconservation forests for the other **variables**.

Table 3. Measured forest characteristics in the Federated States of Micronesia (FSM), the Republic of Marshall Islands (RMI), and Guam.

		Average DBH in inches	Average height in feet	Average stem density in stems per acre	Average basal area in square feet per acre	Average percent invasive trees	Average percent endemic trees
FSM	Conservation forests	5.4	31.3	572	168	0.00	34.30
	Nonconservation forests	4.1	26.5	619	140	6.50	21.30
RMI	Conservation forests	3.4	20.6	1062	35	0.00	0.00
	Nonconservation forests	4.3	24.3	672	89	0.03	0.04
Guam	Conservation forests	3.0	21.1	1132	87	28.80	37.80
	Nonconservation forests	3.1	23.5	965	82	30.70	7.00

Reflection Section

- Examine table 3. This table reveals a difference in one of the independent nations. In which republic do you notice a difference, and what is the evidence?
- This is the second time that scientists had done a forest inventory and analysis in Micronesia. What will be the advantage, if any, of doing another inventory and analysis in the future?

Discussion

Recall that Micronesia is at a high risk for losing its endemic tree species. This study indicates that with conservation management, Micronesia's endemic tree species may be conserved into the future.

Micronesia has a relatively small acreage of land area and the five forest communities measured are distinct forest communities. The tree species between each community, therefore, are mostly different. Other than lowland rainforest, each forest community was sampled only a few times by management type (conservation and nonconservation) in each country and territory. In addition, forests have only recently begun to be managed for conservation. Differences between conservation forests and nonconservation forests may not yet be observable.

The forest inventory and analysis process, however, offers advantages for understanding Micronesian forest change over time. Because this process is well defined, data may be compared over time and between forests and areas if future inventories and analyses are conducted.

Reflection Section

- Explain in your own words why this study may not have clearly identified a wide range of differences due to conservation management between forests.
- The forest inventory and analysis processes are standard. This means that the same process is used in every forest. Name one standard process in which you have participated. How has this process enabled you and others to observe and measure changes over time? What is a characteristic that all these processes have in common?

Adapted from Dendy, J.; Kuegler, O.; Lehman, A.; Marquez, W.R. 2020. Forest status and trends across Micronesia from an assessment of Micronesia Challenge terrestrial measures and Forest Inventory and Analysis data. Micronesica. (2020-2): 1–16.

Glossary

canopy (ka nə pē**):** A protective covering: such as, the uppermost spreading branchy layer of a forest.

conservation (kän(t) sər **vā** shən): The care and protection of natural resources such as forests and water.

consultation (kän(t) səl tā **shən**): A meeting held to talk things over.

density (den(t) sə tē): The quantity of something per a particular space, length, or volume.

extinction (ik **stiŋk** shən): No longer existing.

geospatial (jē ō **spā** shəl): Consisting of or relating to data that are directly linked to specific geographical locations.

indigenous (in **di** jə nəs): Produced, growing, living, or occurring naturally in a particular region or environment.

intense (in **tens**): Very strong or great.

monitor (mä nə tər): To watch, keep track of, or check, usually for a special purpose.

sample (sam pəl): A small subset group, representative of the entire group

sapwood (sap wu̇d): The young wood through which sap travels that is found just beneath the bark of a tree and is usually lighter in color than the heartwood.

variable (ver ē ə bəl): A factor, trait, or condition that can be changed or controlled.

vulnerable (vəl n(ə-)rə bəl): Open to attack or damage.

*Accented syllables are in **bold**. Marks and definitions are from http://www.merriam-webster.com.*
Definitions are limited to the word's use in the article.

FACTivity

Time Needed

1 class period

Materials

For each group of at least two students:

- Flexible measuring tape at least 60 inches long. You may make your own tape by cutting a strip of paper 1 inch wide and 60 inches long. If you make your own tape, mark the inches from 1 to 60.
- Measuring tape at least 100 feet long (or a 100-foot rope or clothesline)
- Graphic organizer on page 115. (Your teacher may make copies for you.)
- Extra paper. You will need one extra sheet for calculations.
- Calculator
- Pencil
- A square piece of cardstock or paper folded in half, so it forms a triangle
- Clipboard (optional) or other hard surface for writing
- Two pieces of masking tape or electrical tape, each about 2 inches long

The question you will answer in this FACTivity is:
What are the advantages and disadvantages of different types of scientific description?

Methods

Your teacher will divide your class into groups of no more than four students, or you may work in pairs.

Each pair or group will identify two trees in your schoolyard or in a nearby accessible public park.

Each pair or group will perform the following measurements on each tree:

1. Measure and record each tree's DBH (diameter at breast height).
2. Measure and record each tree's height.
3. Calculate each tree's basal area.

How To Measure DBH

Using the tape measure, measure vertically up the tree's trunk from the highest ground level. Using one of your pieces of tape, mark the tree's trunk at 4.5 inches. This height is called breast height. Now, use the tape measure to measure around the tree trunk at breast height. This is the tree's circumference. Record each tree's circumference to the nearest inch on the graphic organizer. Once you have the circumference, you will calculate the diameter. Calculate the diameter using the following formula:

$d = C/\pi$

Where d is diameter, C is the measured circumference, and π (pi) = 3.14.

Record each tree's DBH on the graphic organizer.

How To Measure Tree Height

Now you will estimate each tree's height. To do this, you will use the triangular paper or cardstock. The triangle will have one right angle (90 degrees) and two 45-degree angles.

Hold the triangle in front of one eye by holding a corner opposite from the 90-degree right angle and point the rest of the triangle toward you. One of the short sides should be horizontal (flat), and the other should be vertical (pointing straight up). You should be able to look up along the longest side by raising your eyes.

Move back from the tree until you can sight the top of the tree at the top tip of the triangle along the longest side of the triangle (**figure 14**).

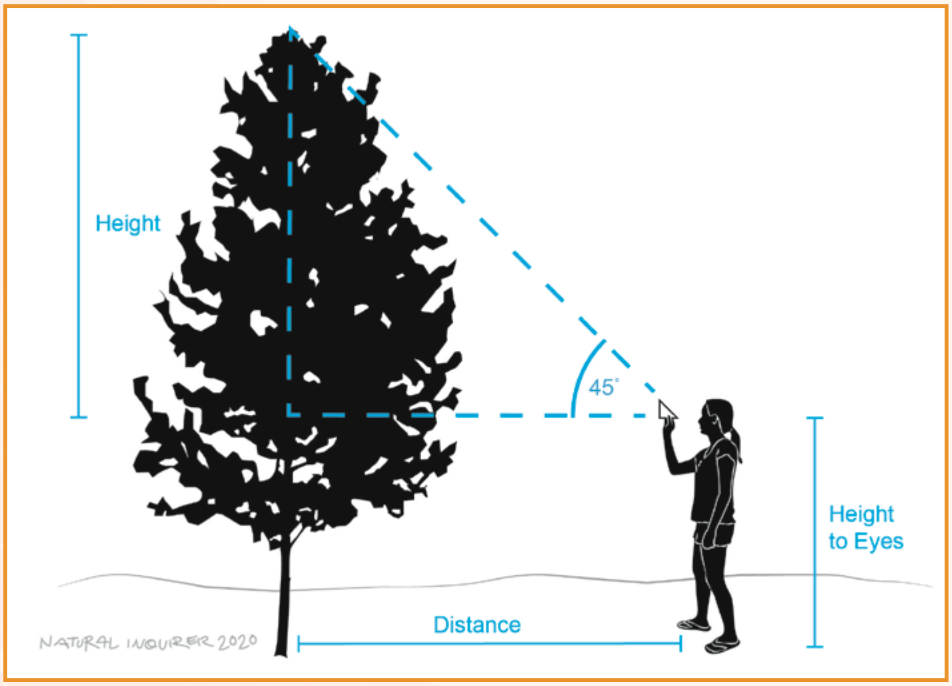


Figure 14. Hold the triangular paper so you can see the top of the tree. FIND Outdoors illustration by Liz Sisk.

Using the second piece of tape, mark the spot where you are standing. Using the tape measure, measure the distance from the spot to the base of the tree. If you are using a rope instead, measure the rope's length from your spot to the tree's base. This distance is *almost* the full height of the tree. Add your own height to this distance since you were looking at the tree from the height of your eyes off the ground. Record each tree's height on the graphic organizer.

How To Calculate Basal Area

Next, you will estimate basal area using each DBH measure. Estimate the area of the cross section of each of your tree's stems at breast height. Although tree stems are not perfect circles, you will use the formula that calculates the area of a circle to estimate the stem's area at breast height. This area is equal to the tree's basal area.

The area of a circle is calculated using the formula: $A = \pi r^2$ where A is the area of the circle and r is the radius of the circle. Recall that the value of π (pi) is about 3.14. The radius of a circle is equal to one-half of the diameter. For each of your trees, first calculate their radius by dividing the diameter (the DBH value you calculated earlier) by 2. Then, for each tree, square the radius by multiplying the radius by itself. For example, if the radius is 4 inches, you will calculate 4 X 4 = 16. Then, multiply that number by 3.14 to calculate the area. Record the area of each tree stem on the graphic organizer. This is the tree's basal area.

Graphic Organizers for "Tropical Four-est Inventory" FACTivity

Student Names: ____

Graphic Organizer 1: Tree Measurements

Tree	Circumference in inches	DBH in inches	Height in feet	Radius (DBH/2) in inches	Basal area (πr^2) in inches
1					
2					

Examine Graphic Organizer 1. You have used numbers to describe the two trees. Scientists call this kind of description "quantitative." Numbers, therefore, express quantity. You can easily compare your two trees with each other or with other similarly described trees.

Another way to describe something is called "qualitative." Qualitative description expresses qualities. Your pair or group will now list qualities you observe in each of the two trees and record your observations in the second graphic organizer. Examples of qualities include:

- Gray, smooth bark
- Rough, deep brown bark
- Large, deep green, jagged leaves
- Many branches starting at about head height
- Fat trunk

You can be creative as you notice qualities. For example, do the trees move with the breeze? Do they have an aroma? Do you see any insects or other wildlife on or near the tree?

Graphic Organizer 2: Qualities You Observe About the Trees

	Tree 1	Tree 2
1		
2		
3		
4		
5		
6		
7		
8		

Now, your group will identify and discuss advantages and disadvantages of each type of description. Record these in the following graphic organizer.

Graphic Organizer 3: Advantages and Disadvantages of Different Types of Descriptions

		Quantitative description	Qualitative description
Advantages	1		
	2		
	3		
	4		
Disadvantages	1		
	2		
	3		
	4		

Discuss your findings as a class. Take a vote to see how many students prefer each method of description. Why is one method preferred over the other?

Scientists use both quantitative and qualitative descriptions. Most natural resource science is quantitative, but qualitative research may also be found.

Quantitative tree measurements adapted from the Minnesota Department of Natural Resources Forestry Education, August 2005, and WikiHow (https://www.wikihow.com/Measure-the-Height-of-a-Tree).

Another FACTivity

Common Core Connection


Photo courtesy of J. B. Friday.

The scientists in this study found that, even with more intense sampling, they did not have enough samples to say for certain if the differences they found were real or the result of error. Let's see why that might have been the case.

Pretend that the scientists began their study with 100 samples. If each sample size was 222 acres, how many total acres were being studied? Now, divide this amount by the total acreage included in the study (218,800 acres). This is the percentage of the total acreage that was studied in our pretend example.

Divide 100 samples by the number of different forest communities sampled in Micronesia. These forest communities included lowland rain forest, montane rain forest, strand forest, agroforest, and mangrove forest. Now, divide this number by the number of the types of forest management studied. These management types were management for conservation and no management for conservation. What number did you get? This is the number of samples in each category studied in our pretend example.

In scientific research, scientists feel most comfortable when they can study a sample that includes at least 30 of whatever it is they are studying. Every time a sample is split for a comparison, the sample sizes become smaller and comparisons become more difficult.

Let's pretend that the scientists began their study with 200 samples. How many samples in each category would they end up with? Are these enough samples to feel comfortable with their results? What percentage of the total acreage would these 200 samples represent?

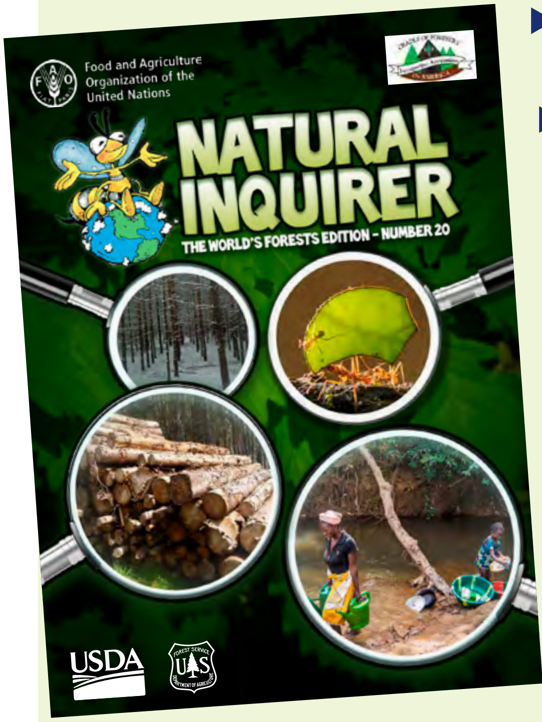
In forest research, scientists cannot easily study entire forests. Usually, they must settle for studying a sample. Studying even 10 percent of a forest is a big job. In your own words, describe why the scientists found making forest comparisons challenging in the Federated States of Micronesia, the Republic of the Marshall Islands, and Guam.

What's in a Name?

"Tropical Four-est Inventory: Using Measurement to Understand the Condition of Forests in Micronesia": "Four-est" is a creative misspelling of the word "forest" to emphasize that numbers are the foundation of a forest inventory.

Natural Inquirer Connections

You may want to reference these *Natural Inquirer* resources for additional information and FACTivities:



- World's Forests 1, World's Forests 2, and World's Forests 3 editions
- Hawai'i-Pacific Islands edition—"Beam Me Down, Scotty! The Use of Airborne and Satellite Technology to Measure Carbon in Hawaiian Forests"
- Hawai'i Pacific Islands edition—"Koa Constrictors: Studying Things That Slow the Growth of Koa Crop Trees"
- Wilderness Benefits edition—"Wild and Free! The Quality of Wildness in Wilderness in the United States"
- Climate Change edition—"The GLAS is Half Full: Satellites and Changing Tropical Forests"

These resources, along with others, can be found at https://www.naturalinquirer.org/all-issues.html.

Project Learning Tree®

If you are a Project Learning Tree educator, you may use "400-acre Wood" or "We Can Work It Out" as additional resources.

Web Resources

USDA Forest Service: Forest Inventory and Analysis
https://www.fs.usda.gov/pnw/projects/pnw-fia-pacific-islands-Inventory

Encyclopedia Britannica: Micronesian culture
https://www.britannica.com/place/Micronesia-cultural-region-Pacific-Ocean

Micronesia Challenge
https://mcterrestrialmeasures.org/#/intro

USDA Forest Service: Forest Inventory and Analysis State Fact Sheets
https://public.tableau.com/views/FIA_OneClick_V1_2/StateSelection?:showVizHome=no