Investigation Instruments

Overview

Before you collect field data, be certain you have all the necessary equipment as listed in the *Field Guides* for the protocols. Some of the instruments used in the *Land Cover/Biology Investigation* you can make yourself and/or require special instruction regarding their use. This section details the construction and use of these instruments, which include:

A. The MUC System – This is the land cover classification system used by GLOBE. To perform a classification according to the MUC system, you will need to have either the *MUC System Table* (given later in this section) and the *MUC Glossary of Terms* (found in the *Appendix* of this chapter) or the *MUC Field Guide* (supplied by GLOBE as a separate book). You will also need to be familiar with the system and its conventions.

B. Densiometer – an instrument used for taking measurements of canopy cover as part of the biometry measurements described in the *Biometry Protocol.* You will need to construct and become familiar with the use of densiometers before taking field measurements.

C. Clinometer – an instrument used for measuring tree height as part of the biometry measurements described in the *Biometry Protocol.* You will need to construct and become familiar with the use of clinometers before taking field measurements.

D. Pacing – a technique used to easily measure distances during the Investigation. It is important that you measure the length of your pace and become comfortable with using this measurement technique.

E. Tape Measure – Used extensively throughout your land cover investigation.

At the end of this section, you will find the *Investigation Instrument Assessment.* Before you proceed to the field, use this assessment to make sure you know how to use the instruments correctly.

A. The MUC System

MUC as a Classification System

The labeling or classification of land cover is one of the major focuses of the *Land Cover/Biology Investigation.* In order for students, teachers and scientists who use GLOBE data to understand exactly what kind of land cover is identified at a site, we must all have a common land cover "language." The GLOBE Program uses the Modified UNESCO Classification (MUC) System, a classification system which follows international standards and uses ecological terminology for the identification of specific land cover classes. The Land Cover Team modified a classification system used by the United Nations Educational, Scientific and Cultural Organization (UNESCO) by adding developed land cover and made some other small changes.

All classification systems, including the MUC System, have four characteristics. These are:

1. All classification systems have labels, which are the titles of the classes, and definitions or rules, the criteria you apply in order to decide the appropriate class an object belongs in.
2. All systems are arranged in a *hierarchical* (multiple levels of classes) or branching structure. At any level of detail, all the different classes should be able to "collapse" into the next, less detailed, level of the system and be consistent with the definition of that class level.
3. They are totally *exhaustive,* that is there is a class for every data point or object.
4. Finally, every system is *mutually exclusive*, meaning there is one and only one appropriate class for every data point or object.

By using a standard international classification system, all the GLOBE data may be compiled into a single regional or global land cover data set. This classification system is a tool for putting every possible land cover type on Earth into a

unique land cover class. Thus, ground data may be gathered and used to validate remotely sensed data following the same scientific protocols worldwide. This classification system enables GLOBE participants to accurately describe the land cover at any point on Earth using the identical criteria as all other GLOBE participants. In order to collect information about Land Cover Sample Sites, you must understand how to use the MUC System.

MUC System Organization

There are two components of the MUC System. Part one is the outline of the classification system, the *MUC System Table* (given later in this section), containing the hierarchical list of labels for every class. Part two is the *MUC Glossary of Terms* (found in the *Appendix* of this chapter), with rules and definitions. These two parts are combined in the *MUC Field Guide*. At a GLOBE training, you will receive the *MUC Field Guide* in your teacher's kit. You and your students can choose to use the *MUC System Table* and the *MUC Glossary of Terms* or the *MUC Field Guide* in your classification. Some students choose to use both. However, no matter what you use, before classifying any land cover type, it is crucial to *always* check the definition of the particular land cover class you believe is appropriate. Even if you think you know what a Closed Forest is, you should check the definition to confirm that your site is, in fact, a Closed Forest and not a Woodland.

MUC has a hierarchical, or decision tree structure, with 10 Level 1 classes. These classes are very general and easily identified. You must select one unique MUC class to identify a land cover type at each MUC level, beginning at Level 1. Within each Level 1 class there are two to six more detailed Level 2 classes. Level 2 classes are still quite general and easily distinguished. Levels 3 and 4 are more specific communities or vegetative associations. The hierarchical structure of the MUC System simplifies the classification process. At each level your choices are restricted to only those classes which fall within the single class you have selected at the previous level. Thus while the whole MUC System has over 150 classes, at each step your choice is typically among only three to six land cover types.

In order to conduct the *Land Cover/Biology Investigation,* it is necessary to begin by identifying the MUC Level 1 class for each homogeneous Land Cover Sample Site. Each Level 1 class is general and can be identified by estimating the percentage of the canopy and ground cover by the dominant

Table LAND-SS-1: Level 1 MUC Land Cover Classes

MUC Code	MUC Level 1 Classes	Coverage Required
0	Closed Forest	>40% trees, at least 5 meters tall, crowns interlocking
1	Woodland	>40% trees, at least 5 meters tall, crowns not interlocking
2	Shrubland or Thicket	>40% shrubs or thickets, 0.5 to 5 meters tall
3	Dwarf-Shrubland or Dwarf-Thicket	>40% shrubs or thickets, under 0.5 meters tall
4	Herbaceous Vegetation	>60% herbaceous plants, grasses, and forbs (broad-leaved)
5	Barren	<40% vegetative cover
6	Wetland	>40% vegetative cover, includes marshes, swamps, bogs
7	Open Water	>60% open water
8	Cultivated Land	>60% cultivated species
9	Urban	>40% urban land cover (buildings, paved surfaces)

land cover at the sample site. Often, the percent cover can be visually estimated. Sometimes it will be necessary to take a measurement of the dominant land cover to accurately determine the MUC Level 1 class. The procedure for taking this measurement is found in the *Biometry Protocol*. Table LAND-SS-1 shows the 10 MUC Level 1 classes. Once the MUC Level 1 class is selected, then only those associated MUC Level 2 classes should be considered. The same process is followed for MUC Level 3 and MUC Level 4. It is critical that the definitions of each class be carefully checked to make sure that the correct class is chosen.

Using the MUC System

Using the MUC System Glossary of Terms and Table in the Teacher's Guide

When classifying land cover using the MUC System, always begin with the most general classes (Level 1) and proceed sequentially to the more detailed (higher level) classes. There are 10 Level 1 land cover classes in MUC. Eight of these choices are natural land cover and two are developed land cover.

The MUC System has 10 Level 1 classes, including Closed Forest, Woodland, and Urban. The Level 2 classes within Closed Forest are Mainly Evergreen, Mainly Deciduous, and Extremely Xeromorphic (Dry). These Level 2 classes contain more detail than the Level 1 class, Closed Forest, and they may all be collapsed into the Closed Forest class. In other words, any member of one of these three Level 2 classes is always a member of the Closed Forest Level 1 class. See Table LAND-SS-2. This is a condensed version of MUC, showing only the Level 1 and Level 2 classes.

The MUC System has up to four levels of classes arranged hierarchically. Each higher level is based on more detailed properties of land cover. MUC class "codes" of up to four digits are associated with each MUC class, with one digit for each level in the class. See Table LAND-SS-3.

To Classify Land Cover Using the MUC System Table and the MUC Glossary of Terms

- Observe the land cover site and read the definitions for the 10 Level 1 classes. Pick the one that best describes the site. If necessary, take measurements of vegetation height, canopy cover and ground cover and identify dominant and co-dominant vegetation in order to help you decide which Level 1 class is the best choice. See *Field Guides* for *Biometry Protocol.*
- Once you have chosen the Level 1 class, read the definitions of the Level 2 classes you have to choose from. If none of the definitions seem to fit, go back and rethink your Level 1 choice.
- Choose the Level 2 class that best describes the land cover site. You may need to take biometry measurements and reread the definitions.
- Once you have chosen the Level 2 class, read the definitions of the Level 3 classes you have to choose from. If none of the definitions seem to fit, go back and rethink your Level 2 choice. If there are no Level 3 choices, you are done.
- Choose the Level 3 class that best describes the land cover site. You may need to take biometry measurements and reread the definitions.
- Once you have chosen the Level 3 class, read the definitions of the Level 4 classes you have to choose from. If none of the definitions seem to fit, go back and rethink your Level 3 choice. If there are no Level 4 choices, you are done.
- Record the MUC class (up to 4 digits) in the appropriate place on your *Data Sheet.*

Table LAND-SS-2: MUC Level 1 and 2

	Level 1	Level 2
Natural Cover	0 Closed Forest	01 Mainly Evergreen 02 Mainly Deciduous 03 Extremely Xeromorphic (Dry)
	1 Woodland	11 Mainly Evergreen 12 Mainly Deciduous 13 Extremely Xeromorphic (Dry)
	2 Shrubland or Thicket	21 Mainly Evergreen 22 Mainly Deciduous 23 Extremely Xeromorphic (Subdesert) Shrubland or Thicket
	3 Dwarf-Shrubland or Dwarf-Thicket	31 Mainly Evergreen 32 Mainly Deciduous 33 Extremely Xeromorphic (Subdesert) Dwarf-Shrubland or Dwarf Thicket 34 Tundra
	4 Herbaceous Vegetation	41 Tall Graminoid 42 Medium Tall Graminoid 43 Short Graminoid 44 Forb Vegetation
	5 Barren Land	51 Dry Salt Flats 52 Sandy Areas 53 Bare Rock 54 Perennial Snowfields 55 Glaciers 56 Other
	6 Wetland	61 Riverine 62 Palustrine 63 Estaurine 64 Lacustrine
	7 Open Water	71 Freshwater 72 Marine
Developed Cover	8 Cultivated Land	81 Agriculture 82 Non-agriculture
	9 Urban	91 Residential 92 Commercial and Industrial 93 Transportation 94 Other

How to Use the MUC Field Guide

The *MUC Field Guide* is designed to lead you through the MUC levels from the most general (Level 1) to the most detailed. The most detailed will be Level 2, 3, or 4, depending on the particular land cover class. At each level, either you will be asked one or more questions about the site or given a list of options from which you select the best description of your site. Your selection or response to a question (usually either YES or NO) will direct you to the next question until you finally reach the most specific MUC level for your site. When you reach the most detailed level, you will be told 'DONE'.

Every class within each level has a unique identifier or numerical code. Your most detailed classification will be identified by a string of these numbers. In the *MUC Field Guide*, the definition from the *MUC Glossary of Terms* is given for each MUC level. The questions described above and these definitions are given on the left side of the page. Along the right side of the page, there may be definitions of words used in defining the MUC class, as well as some notes to help you decide how to make a selection. Drawings are interspersed throughout the guide to help you better understand the types of vegetation and the rules used in the MUC System. A table showing all the MUC classes is included at the end of this guide.

Helpful Hints

- Your students should refer to the definitions in the *MUC Field Guide* or *MUC Glossary of Terms* when determining MUC for an area.
- Distinguishing among some MUC classes requires quantitative measurements of the percentage of your site that is covered by different types of vegetation and/or the height of the dominant vegetation. You can identify the appropriate MUC class using the measurements found in the *Biometry Protocol.*
- To classify land cover, you may use either the *MUC Field Guide,* or the *MUC Glossary of Terms* along with the *MUC System Table*.
- In order to simplify the *MUC System Table* and *MUC Glossary of Terms* for students, some teachers have modified them by eliminating some of the highly unlikely choices, i.e. glaciers and salt water in a land-locked desert community, xeromorphic (extremely dry) forests in a very humid environment, etc.

Table LAND-SS-3: MUC System Table

LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	NOTES AND EXAMPLES
Natural Cover	01 Mainly Evergreen	011 Tropical Wet (Rain)	0111 Lowland	
			0112 Submontane	Costa Rica: Atlantic slope
			0113 Montane	Costa Rica: Sierra de Talamanca
			0114 Subalpine	
			0115 Cloud	Jamaica: Blue Mountains
		012 Tropical and Subtropical Seasonal	0121 Lowland	
			0122 Submontane	
			0123 Montane	
			0124 Subalpine	
		013 Tropical and Subtropical Semi-Deciduous	0131 Lowland	*Ceiba* spp.
			0133 Montane and Cloud	
		014 Subtropical Wet	0141 Lowland	Queensland, Australia, and Taiwan
			0142 Submontane	
			0143 Montane	
			0144 Subalpine	
			0145 Cloud	
		015 Temperate or Subpolar Wet	0151 Temperate	Chilean Coast
			0152 Subpolar	
0 Closed Forest		016 Temperate with Broad-Leaved Deciduous	0161 Lowland	
			0162 Submontane	
			0163 Montane	
			0164 Subalpine	
		017 Winter-Rain Broad-Leaved Sclerophyllous	0171 Lowland and Submontane >50m	*Eucalyptus regnans, E. diversicolor*
			0172 Lowland and Submontane <50m	USA: California live-oak forest
		018 Tropical and Subtropical Needle-Leaved	0181 Lowland and Submontane	*Pinus* spp. forest of Honduras and Nicaragua
			0182 Montane and Subalpine	*Pinus* spp. forest of Phillippines and southern Mexico
		019 Temperate and Subpolar Needle-Leaved	0191 Giant (>50 m)	*Sequoia* and *Pseudotsuga* spp., Pacific W. of N. America
			0192 Irregularly Rounded Crowns	*Pinus* spp.
			0193 Conical Crowns	*Picea* and *Abies* spp.; USA California Red Fir forests
			0194 Cylindrical Crowns	Boreal, short branches

Table LAND-SS-3: MUC System Table (continued)

LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	NOTES AND EXAMPLES
Natural Cover				
0 Closed Forest	02 Mainly Deciduous	021 Tropical and Subtropical Drought-Deciduous	0211 Broad-Leaved Lowland and Submontane	Northwest Costa Rica
			0212 Montane and Cloud	Northern Peru
		022 Cold-Deciduous with Evergreens	0221 With Evergreen Broad-Leaved Trees and Climbers	Western Europe: *Ilex aquifolium, Hedera helix*
				North America: *Magnolia* spp.
			0222 With Evergreen Needle-Leaved Trees	Northeastern US: maple-hemlock forest
		023 Cold-Deciduous without Evergreen Trees	0231 Temperate Lowland and Submontane Broad-Leaved	
			0232 Montane and Boreal	
			0233 Subalpine and Subpolar	Grades into woodland
	03 Extremely Xeromorphic (Dry)	031 Sclerophyllous-Dominated		
		032 Thorn-Dominated	0321 Mixed Deciduous-Evergreen	
			0322 Purely Deciduous	
		033 Mainly Succulent		
1 Woodland	11 Mainly Evergreen	111 Broad-Leaved		
		112 Needle-Leaved	1121 Irregularly Rounded Crowns	*Pinus* spp.
			1122 Conical Crowns	Mostly subalpine
			1123 Cylindrical Crowns	Boreal regions: *Picea* spp.
	12 Mainly Deciduous	121 Drought-Deciduous	1211 Broad-Leaved Lowland and Submontane	
			1212 Montane and Cloud	
		122 Cold-Deciduous with Evergreens	1221 With Evergreen Broad-Leaved Trees and Climbers	
			1222 With Evergreen Needle-Leaved Trees	
		123 Cold-Deciduous without Evergreen Trees	1231 Broad-Leaved	
			1232 Needle-Leaved	
			1233 Mixed	
	13 Extremely Xeromorphic (Dry)	131 Sclerophyllous-Dominated		
		132 Thorn-Dominated	1321 Mixed Deciduous-Evergreen	
			1322 Purely Deciduous	
		133 Mainly Succulent		

Table LAND-SS-3: MUC System Table (continued)

LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	NOTES AND EXAMPLES
Natural Cover	21 Mainly Evergreen	211 Broad-Leaved	2111 Low Bamboo	
			2112 Tuft-Tree	Mediterranean dwarf-palm, Hawaiian tree-fern
			2113 Broad-Leaved Hemi-Sclerophyllous	Subalpine *Rhododendron* thickets, or *Hibiscus tiliaeceus* matted thickets of Hawaii, USA
			2114 Broad-Leaved Sclerophyllous	Chapparral or macchia
			2115 Suffruticose	*Cistus* heath
		212 Needle-Leaved or Microphyllous	2121 Needle-Leaved	*Pinus mughus* , "Krummholz"
			2122 Microphyllous	Tropical subalpine
2 Shrubland or Thicket	22 Mainly Deciduous	221 Drought-Deciduous with Evergreen Woody Plants		
		222 Drought-Deciduous without Evergreen Woody Plants		
		223 Cold-Deciduous	2231 Temperate	
			2232 Subalpine and Subpolar	
	23 Extremely Xeromorphic (Subdesert) Shrubland	231 Mainly Evergreen	2311 Purely Evergreen	
			2312 Semi-Deciduous	Australia, N. America: *Atriplex-Kochia-saltbush*
		232 Mainly Deciduous	2321 Without Succulents	
			2322 With Succulents	
3 Dwarf-Shrubland or Dwarf-Thicket	31 Mainly Evergreen	311 Dwarf-Thicket	3111 Caespitose	*Calluna* heath
			3112 Creeping	*Loiseleuria* heath
		312 Dwarf-Shrubland	3121 Cushion	E. Mediterranean: *Astragalus* and *Acantholimon* spp.
		313 Mixed Evergreen and Herbaceous Dwarf-Shrubland	3131 True Evergreen & Herbaceous Mixed	*Nardus-Calluna* heath
			3132 Partial Evergreen & Herbaceous Mixed	Greece: *Phrygana* spp.
	32 Mainly Deciduous	321 Facultative Drought-Deciduous		
		322 Obligate Drought-Deciduous	3221 Caespitose Dwarf-Thicket	
			3222 Creeping Dwarf-Thicket	
			3223 Cushion Dwarf-Shrubland	
			3224 Mixed Dwarf-Shrubland	
		323 Cold-Deciduous	3231 Caespitose Dwarf-Thicket	
			3232 Creeping Dwarf-Thicket	
			3233 Cushion Dwarf-Shrubland	
			3234 Mixed Dwarf-Shrubland	

Table LAND-SS-3: MUC System Table (continued)

LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	NOTES AND EXAMPLES
Natural Cover				
3 Dwarf-Shrubland or Dwarf-Thicket	33 Extremely Xeromorphic (Subdesert) Dwarf-Shrubland	331 Mainly Evergreen	3311 Purely Evergreen	
			3312 Semi-Deciduous	
		332 Mainly Deciduous	3321 Without Succulents	
			3322 With Succulents	
	34 Tundra	341 Mainly Bryophyte	3411 Caespitose	
			3412 Creeping	
		342 Mainly Lichen		
4 Herbaceous Vegetation	41 Tall Graminoid	411 With Trees Covering 10-40 %	4110 Trees: Needle-Leaved Evergreen	
			4111 Trees: Broad-Leaved Evergreen	
			4112 Trees: Broad-Leaved Semi-Evergreen	
			4113 Trees: Broad-Leaved Deciduous	
		412 With Trees Covering < 10 %	4120 Trees: Needle-Leaved Evergreen	
			4121 Trees: Broad-Leaved Evergreen	
			4122 Trees: Broad-Leaved Semi-Evergreen	
			4123 Trees: Broad-Leaved Deciduous	
			4124 Tropical and Subtropical with Trees and Shrubs in Tufts on Termite Nests	Termite savannah
		413 With Shrubs	4130 Shrubs: Needle-Leaved Evergreen	
			4131 Shrubs: Broad-Leaved Evergreen	
			4132 Shrubs: Broad-Leaved Semi-Evergreen	
			4133 Shrubs: Broad-Leaved Deciduous	
			4134 Tropical and Subtropical with Trees and Shrubs in Tufts on Termite Nests	Termite savannah
		414 With Tuft Plants	4141 Tropical with Palms	Bolivia: *Arocomia totai* and *Attalea princeps*
		415 Without Woody Synusia	4151 Tropical	Low-latitude Africa, lower Amazon, upper Nile
	42 Medium Tall Graminoid	421 With Trees Covering 10-40 %	4210 Trees: Needle-Leaved Evergreen	
			4211 Trees: Broad-Leaved Evergreen	
			4212 Trees: Broad-Leaved Semi-Evergreen	
			4213 Trees: Broad-Leaved Deciduous	
		422 With Trees Covering < 10 %	4220 Trees: Needle-Leaved Evergreen	
			4221 Trees: Broad-Leaved Evergreen	
			4222 Trees: Broad-Leaved Semi-Evergreen	
			4223 Trees: Broad-Leaved Deciduous	
			4224 Tropical and Subtropical with Trees and Shrubs in Tufts on Termite Nests	Termite savannah

Table LAND-SS-3: MUC System Table (continued)

LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	NOTES AND EXAMPLES
Natural Cover				
4 Herbaceous Vegetation	42 Medium Tall Graminoid	423 With Shrubs	4230 Shrubs: Needle-Leaved Evergreen	
			4231 Shrubs: Broad-Leaved Evergreen	
			4232 Shrubs: Broad-Leaved Semi-Evergreen	
			4233 Shrubs: Broad-Leaved Deciduous	
			4234 Tropical and Subtropical with Trees and Shrubs in Tufts on Termite Nests	Termite savannah
			4235 Woody Synusia of Deciduous Thorny Shrubs	
		424 Open Synusia of Tuft Plants	4241 Subtropical with Open Palm Groves	
		425 Without Woody Synusia	4251 Mainly Sod Grasses	USA, Eastern Kansas: tall-grass prairie
			4252 Mainly Bunch Grasses	New Zealand: *Festuca novae-zelandiae*
	43 Short Graminoid	431 With Trees Covering 10-40 %	4310 Trees: Needle-Leaved Evergreen	
			4311 Trees: Broad-Leaved Evergreen	
			4312 Trees: Broad-Leaved Semi-Evergreen	
			4313 Trees: Broad-Leaved Deciduous	
		432 With Trees Covering < 10 %	4320 Trees: Needle-Leaved Evergreen	
			4321 Trees: Broad-Leaved Evergreen	
			4322 Trees: Broad-Leaved Semi-Evergreen	
			4323 Trees: Broad-Leaved Deciduous	
			4324 Tropical and Subtropical with Trees and Shrubs in Tufts on Termite Nests	Termite savannah
		433 With Shrubs	4330 Shrubs: Needle-Leaved Evergreen	
			4331 Shrubs: Broad-Leaved Evergreen	
			4332 Shrubs: Broad-Leaved Semi-Evergreen	
			4333 Shrubs: Broad-Leaved Deciduous	
			4334 Tropical and Subtropical with Trees and Shrubs in Tufts on Termite Nests	Termite savannah
			4335 Woody Synusia of Deciduous Thorny Shrubs	
		434 Open Synusia of Tuft Plants	4341 Subtropical with Open Palm Groves	
		435 Mainly Bunch Grasses with Woody Synusia	4351 Tropical Alpine with Tuft Plants	
			4352 Tropical Alpine without Tuft Plants	
			4353 Tropical and Subtropical Alpine with Open Stands of Evergreens	
			4354 With Dwarf Shrubs	
		436 Without Woody Synusia	4361 Short-Grass Communities	USA, Colorado: short-grass prairie
			4362 Bunch-Grass Communities	

Table LAND-SS-3: MUC System Table (continued)

LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	NOTES AND EXAMPLES
Natural Cover				
4 Herbaceous Vegetation	44 Forb Vegetation	437 Short to Medium Tall Mesophytic Communities	4371 Sodgrass Communities	N. America, Eurasia: Low altitude, cool, humid
			4372 Alpine and Subalpine Meadows	High latitudes
		441 Tall Communities	4411 Fern Thickets	
			4412 Mainly Annual	
			4413 Mainly Perennial Flowering Forbs and Ferns	
		442 Low Communities	4421 Mainly Perennial Flowering Forbs and Ferns	
			4422 Mainly Annual	
5 Barren Land	51 Dry Salt Flats			
	52 Sandy Areas			
	53 Bare Rock			
	54 Perennial Snowfields			
	55 Glaciers			
	56 Other			
6 Wetland	61 Riverine			
	62 Palustrine			
	63 Estuarine			
	64 Lacustrine			
7 Open Water	71 Freshwater			
	72 Marine			
Developed Cover				
8 Cultivated Land	81 Agriculture	811 Row Crop and Pasture		
		812 Orchard and Horticulture		
		813 Confined Livestock feeding		
		814 Other Agriculture		
	82 Non-Agriculture	821 Parks and Athletic fields		
		822 Golf Courses		
		823 Cemeteries		
		824 Other Non-Agriculture		
9 Urban	91 Residential			
	92 Commercial and Industrial			
	93 Transportation			
	94 Other			

Example of MUC Classification

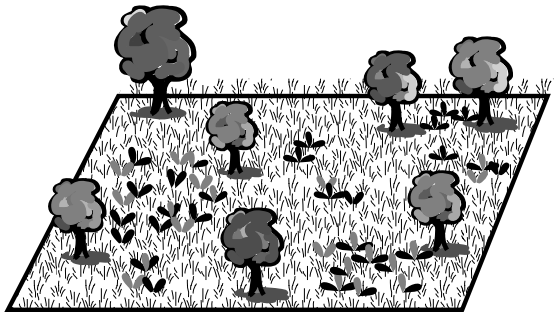
Below is an example for assigning a MUC class to a given homogeneous area. Three additional examples are also in the *Appendix*. This first example is for your students to follow along, while the rest (in the *Appendix*) are for them to try for themselves. Students should be able to confidently assign a MUC class by the time they complete the last example.

The answer for the example below is 4213.

The definitions of the MUC classes and scientific terminology are given in the *MUC Glossary of Terms* **and in the** *MUC Field Guide.* **ALWAYS refer to these definitions rather than trusting your memory or general knowledge when determining the MUC class for an area.**

Example 1

For your land cover site (90 m x 90 m), you picked a homogeneous area. This means that the entire area will have the same MUC class. About 80% of the site is covered by graminoid (grass) and forb (broad-leaved) vegetation about 1 meter tall. It is 75% graminoid and 25% forb mix. Broad-leaved deciduous trees cover about 15-20% of the site.



Level 1: Look in the *MUC System Table* at all the Level 1 classes. Note that class 4, Herbaceous Vegetation, is probably the appropriate Level 1 class. Look in the *MUC Glossary of Terms*. Class 4 requires greater than 60% total ground cover of herbaceous vegetation over the entire site. Class 4 is the correct choice.

Level 2: Look in the *MUC System Table* at the four choices at Level 2 (41-44). Review the definitions of these four classes in the *MUC Glossary of Terms*. You should determine that, since the dominant cover type (herbaceous) is more than 50% graminoid, the Level 2 land cover type must be Graminoid. Since the graminoid is between 50 cm and 2 m tall, you should select class 42, Medium Tall Graminoid.

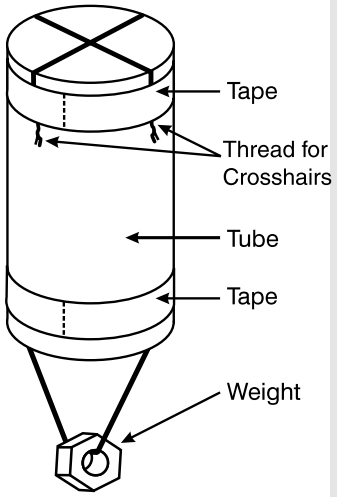
Level 3: Look in the *MUC System Table* at the five Level 3 choices (421-425). Since trees cover 15-20% of the site, you should select Class 421, "With Trees Covering 10-40%." To be sure this is the correct answer, read the definition in the *MUC Glossary of Terms*.

Level 4: You now have four choices at Level 4 (4210-4213). Since the trees are broad-leaved deciduous, you should select class 4213. You have completed your MUC Level 4 classification.

B. Densiometer

A densiometer is an instrument used for taking measurements of canopy cover as part of the biometry measurements described in the *Biometry Protocol*. The following includes directions to construct and use the densiometer.

Figure LAND-SS-4: Homemade



Required Materials

- 4 cm diameter by 7.5 cm long tube (toilet paper tubes, construction paper, PCV pipe)
- 34 cm of thread or dental floss
- metal nut or washer
- tape

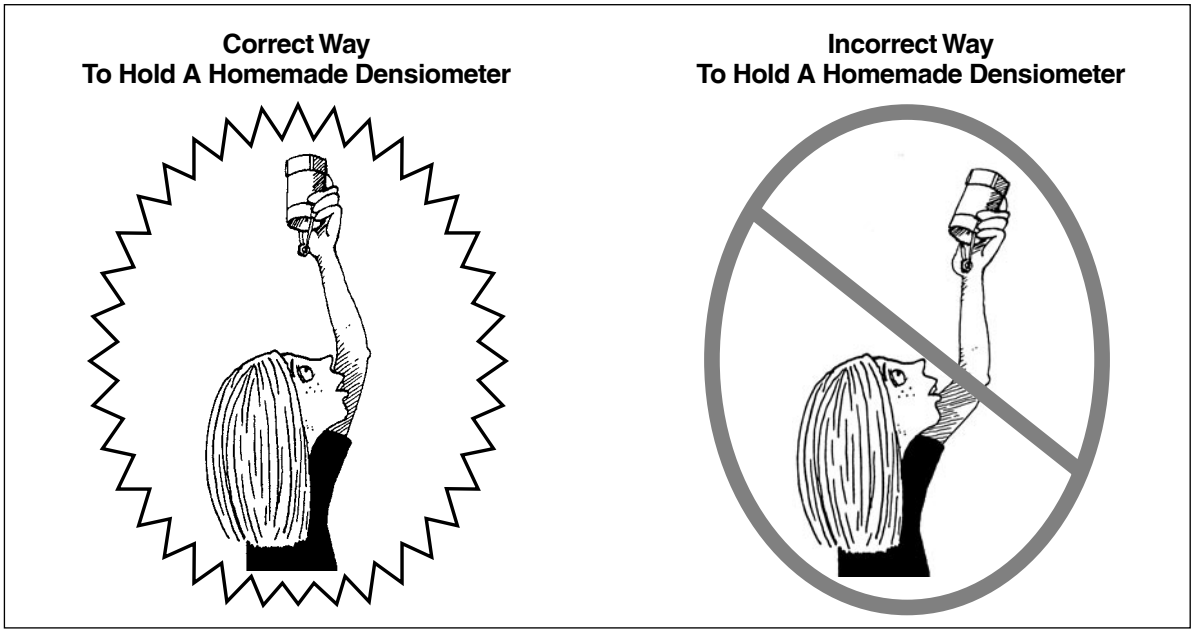
Construction

1. Gather the required materials for each densiometer.
2. Attach (with tape) two threads at right angles across the diameter of one end of the tube to form a crosshair. Leave a slight end hanging at the bottom of the tape so you can tighten the threads if they loosen.
3. Attach (with tape) an 18 cm piece of thread with a metal nut or washer hanging loosely from it across the diameter of the other end of the tube (opposite the crosshairs).

Directions for Use

1. Look up through the densiometer, making sure the densiometer is vertical and the metal nut/washer is directly below the intersection of the crosshairs at the top of the tube. See Figure LAND-SS-5 and Figure LAND-SS-6. **Note:** Only use the densiometer for looking UP at the canopy cover. Do not use it for looking DOWN at ground cover.
2. If you see vegetation, twigs, or branches **touching the crosshair intersection**, you would call this "T" meaning that there is tree canopy or "SB" meaning that there is shrub canopy.
3. If you **do not** see vegetation, twigs, or branches **touch the crosshair intersection**, you would call this minus "–" meaning that you saw the sky above the intersection of the crosshairs.

Figure LAND-SS-5: Correct and Incorrect Way to Hold a Homemade Densiometer



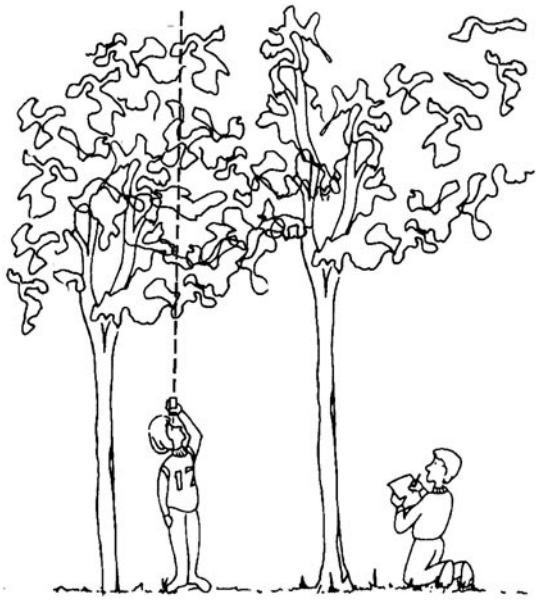
Modified from TEREZA, Association for Environmental Education, Czech Republic (1996).

Frequently Asked Questions

1. What should we do if there is a multi-storied canopy?

If there is a multi-story canopy, try to identify the highest level of the canopy without changing your position. If the vegetation touches the intersection of the crosshairs, mark a "T" or an "SB". See LAND-SS-6.

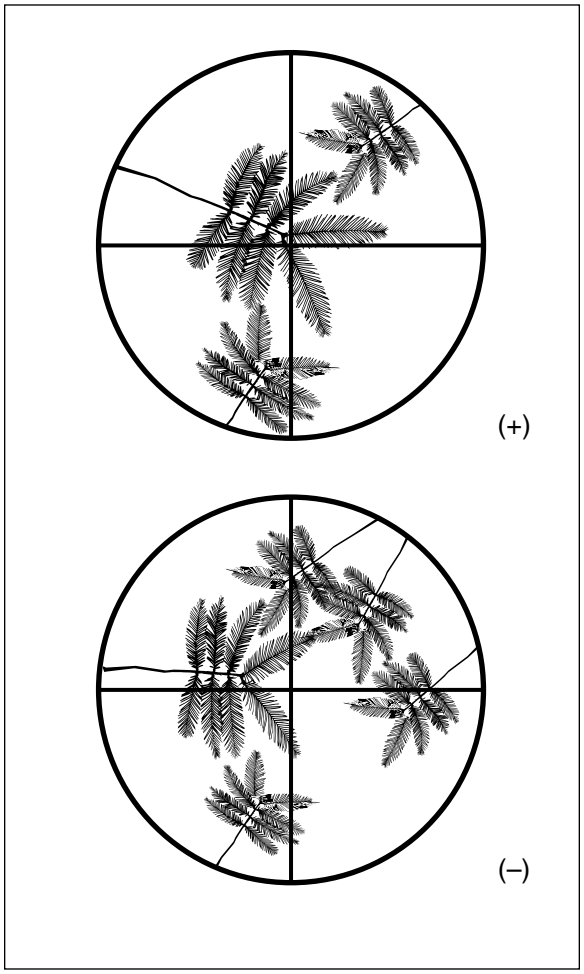
Figure LAND-SS-6: Using a Homemade Densiometer in Multi-Story Canopy



2. What if the entire circle I see through the densiometer is full of vegetation, but there is no vegetation at the crosshairs?

This is a sampling question. The Land Cover/ Biology Team has chosen the intersection of the crosshairs as the sample. Therefore, this would be a (–).

Figure LAND-SS-7: Densiometer Sampling



3. What if we can't get to our site during peak vegetation (full leaf-on) conditions?

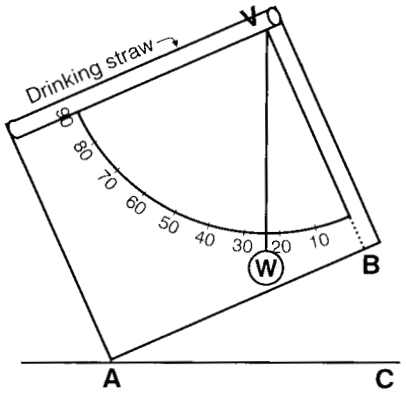
If you cannot get to your site during peak growth (leaf-on), measure your site during the leaf-off period and try your best to get the peak growth (leaf-on) data, when you can.

C. Clinometer

A clinometer is an instrument used for measuring angles. In GLOBE, you use it to find the angle for calculating tree heights. It is also used to determine obstacles at an Atmosphere Study Site. The calculations work by applying the principles based on the properties of right triangles. You construct and use the clinometer by following the directions and using the formula below. The clinometer also lends itself for additional hands-on teaching exercises of trigonometric principles.

Required Material

- *Clinometer Sheet* and *Table of Tangents* (located in the *Appendix*)
- Piece of stiff cardboard at least the size of the sheets above
- Drinking straw
- Metal nut or washer
- 15 cm of thread or dental floss
- Glue
- Scissors
- Something to punch one small hole
- Tape



Modified from Bennett, A. and Nelson, L. (1961) Mathematics an Activity Approach, Allyn & Bacon, Boston

Construction

1. Gather the materials for each clinometer.
2. Glue a copy of the *Clinometer Sheet* onto a same-size piece of stiff cardboard (cut cardboard if necessary).
3. Glue a copy of the *Table of Tangents* to the other side of the cardboard.
4. Punch a hole through the marked circle on the *Clinometer Sheet.*
5. Thread one end of a 15 cm piece of thread through the hole and tie or tape it on the *Table of Tangents* side of the cardboard.
6. Tie a metal nut or washer to the other end of the thread so that it hangs in front of the *Clinometer Sheet.*
7. Tape a drinking straw along the designated line on the *Clinometer Sheet,* to use as a sighting device.

   Note: A clinometer measures angles to determine the heights of objects without directly measuring them. It is a simplified version of the quadrant (a medieval measuring instrument), and the sextant (an instrument used to locate the positions of ships). Like these instruments, the clinometer has an arc with graduated degree markings that go from 0 to 90 degrees.

Directions for Use

1. Stand up straight and measure the height of your eyes from the ground. Record this number for future reference.
2. Stand at the same elevation (level ground) as the base of the object that you are measuring.
3. Sight the top of the object through the clinometer's drinking straw. Have your partner read the number of degrees of angle BVW (see Figure LAND-SS-8) by noting where the thread touches the arc on the *Clinometer Sheet.* (Angle BVW is equal to angle BAC, which is the angle of elevation of the clinometer.)
4. Measure the horizontal distance from you to the object that is being measured.
5. If you know the angle of elevation, your eye height, and your distance away from an object, as in Figure LAND-SS-9, you can calculate the height of that object using a simple equation. Add your eye height to the number you determine using the equation below.

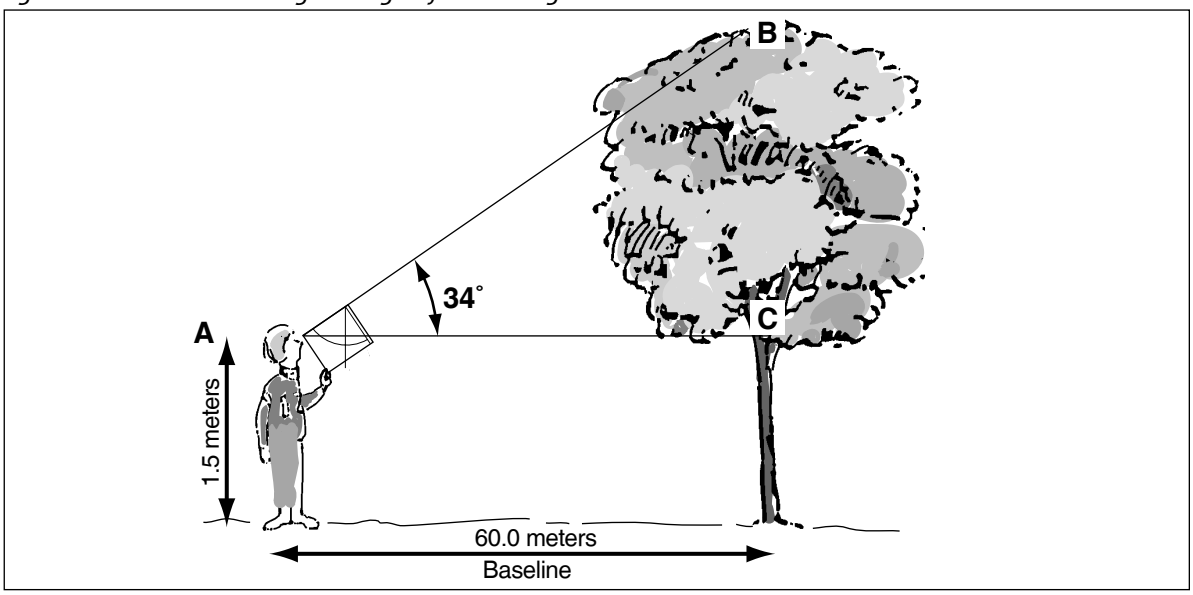
BC = AC x Tan ∠ A

Height of the Tree above your eye height (BC) = Distance to the Base of the Tree (AC) x Tan of the Angle of the Clinometer (Tan ∠ A)

(see example next page)

Note: If you would like to practice measuring heights before going to your site, find a tall outdoor object for which you know or can directly measure the height (such as a flagpole or the school building). After completing the above process, compare your results with the known height of the object.

Figure LAND-SS-9: Determining the Height of a Tree Using a Homemade Clinometer



Example:

In the example (Figure LAND-SS-9 and LAND-SS-10), a student stands 60 m away from the base of a tree and sites the top of the tree through his clinometer. His eye is 1.5 meters above the ground. He reads an angle of 34 degrees on his clinometer (figures are not drawn to scale). Use your *Table of Tangents* and the following equation to solve for the height of the tree:

TAN 34 = BC/60.0 Therefore,

BC = 60.0 m (TAN 34). Therefore,

BC = 60.0 m (.67) = 40.2 m

Add the height of BC to the height of the clinometer from the ground (your eye level) to get the total height of the tree. In the above example, the height of the tree is 40.2 m + 1.5 m = 41.7 m.

Note: Adjust your distance from the tree so that you are at least as far away from the tree as the tree is tall. For the most accurate measurement, adjust your distance so that the angle of the clinometer is as close to 30 degrees as possible.

Figure LAND-SS-10: Trigometric Equation

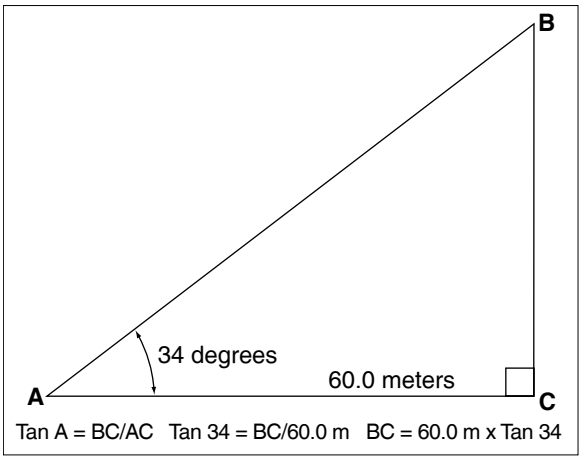
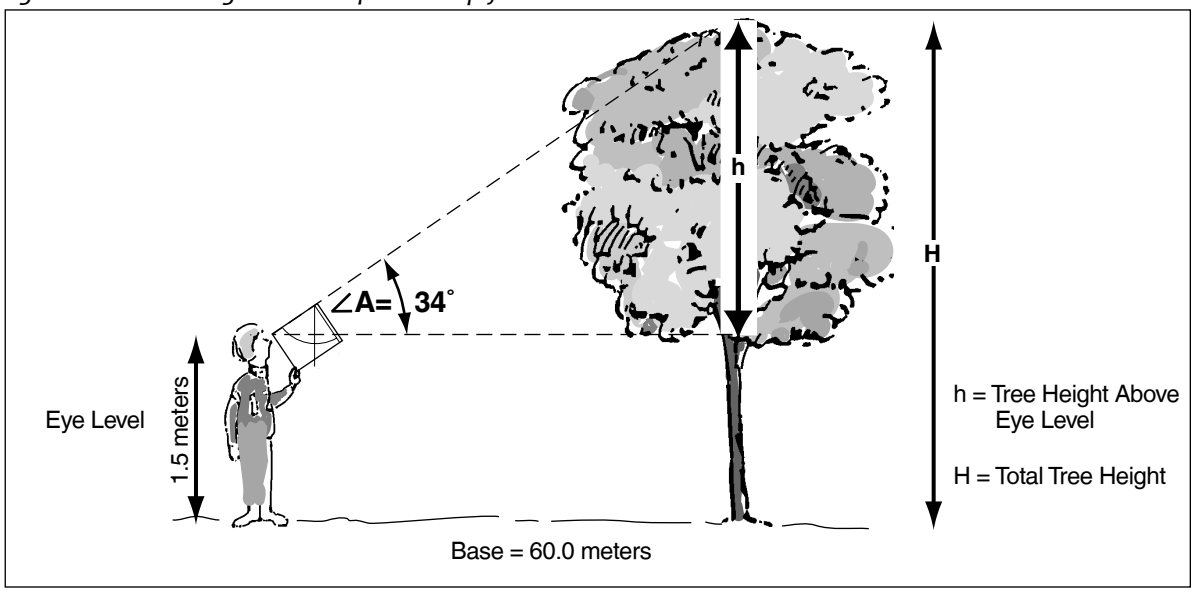


Figure LAND-SS-11: Trigonometric Equation Simplified



For students who are not familiar with geometry yet, here is another way to simplify this example. See Figure LAND-SS-11.

h = Base x Tan ∠ A

h= 60.0m x Tan 34

h = 60.0m x 0.67 = 40.2m

H = h + Eye Level

H = 40.2 + 1.5m = 41.7m

Frequently Asked Questions

1. What if my students are too young to understand the math used to determine tree height?

For younger students, if the angle BVW is 45 degrees, the distance from the tree will equal the height of the tree above the student's eye level. This can be illustrated for students by drawing an isosceles right triangle without any additional explanation of the mathematics involved. Run a tape measure from the student's eye to his or her feet and then to the base of the tree. This distance will equal the height of the tree. See the *Alternate Technique to Measure Tree Height on Level Ground: Simplified Clinometer Technique Field Guide* in the *Biometry Protocol*.

2. What if the tree is leaning?

If the tree is leaning, just measure to the top of the tree as usual.

3. If I cannot be on the same level as the base of the tree I am measuring, how do I estimate the height of the tree? Or what if there is no level ground to measure the tree heights?

There are three methods to handle this problem. They are presented in the *Biometry Protocol's Alternate Techniques to Measure Tree Height Field Guides*. Use the one that seems the most appropriate.

D. Pacing

A pace is equal to walking two steps. Knowing how long your pace is will be helpful throughout your investigation of land cover. Specifically, when you walk diagonals to take measurements at Sample Sites (according to the *Biometry Protocol*), you will need to know how many paces it takes to travel 21.2 meters (the length of half of a diagonal). There are two options given below for determining this number.

Directions for Determining Pace

1. Lay out a 30 meter or longer measuring tape on a flat, open area (a parking lot, field, or hallway is good).
2. Remember that one pace is two steps. Starting with your toe at the 0-meter mark, pace off 10 paces, using a normal stride. It is important to use a normal, comfortable stride because of the wide variety of conditions encountered in the field.
3. Note the marking on the tape where your toe is on the tenth pace. This value is the length of ten of your paces.
4. Divide that value by 10 to find the length of your pace.
5. Repeat Steps 2-4 three times. Calculate the average (by adding up the three lengths of one pace, from Step 4, and dividing by three) to determine your average pace distance.

Example:

Repetition Number	Distance of 10 Paces	Distance of Single Pace
1	17.0 m	1.70 m
2	17.5 m	1.75 m
3	16.8 m	1.68 m
Average Pace = 1.71 meters per pace		

Note: Pacing in the woods or over hilly terrain is quite different than pacing a flat distance in a schoolyard or parking area. Remember the following tips:

- When initially measuring your pace, walk using a comfortable stride. Resist the temptation to take exaggerated steps because your pace will naturally become shorter in the woods or over hilly terrain.
- When pacing up or down a hill, you are actually traveling a shorter horizontal distance than it seems, and you may also pace irregularly due to the terrain. Be aware of your paces and compensate by taking slightly shorter or longer steps as necessary.
- When large objects (boulders, large trees, etc.) are in the way, take a few lateral side steps, pace forward, then take the same number of lateral side steps back to your original compass bearing. See Figure LAND-SS-12. If an observation is required

Figure LAND-SS-12: How to Side Step Around Large Obstacles

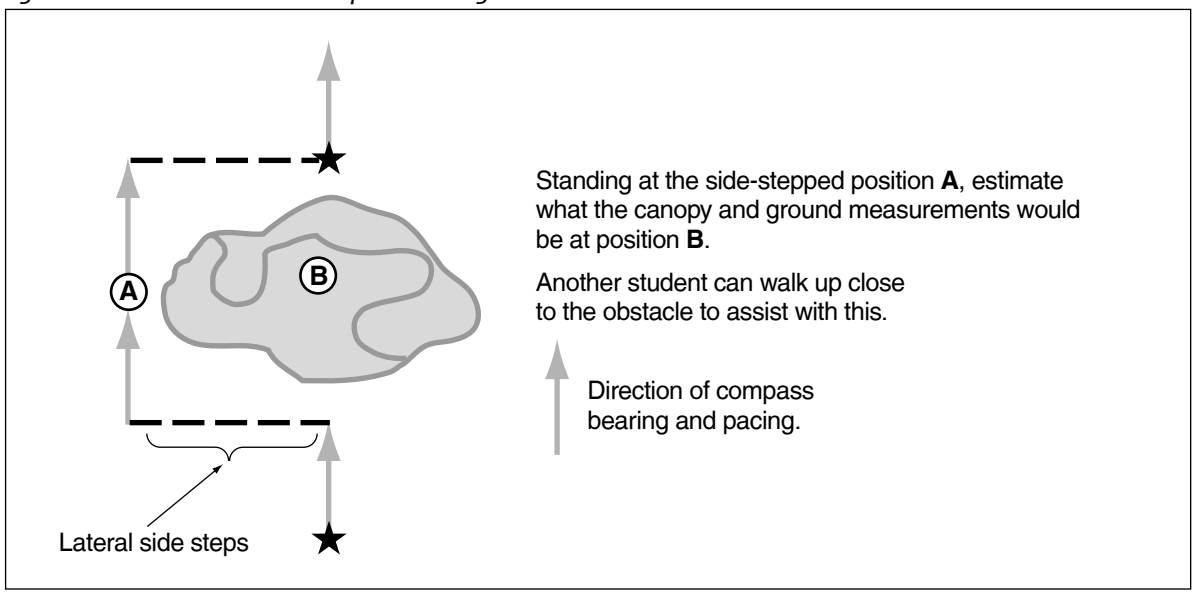
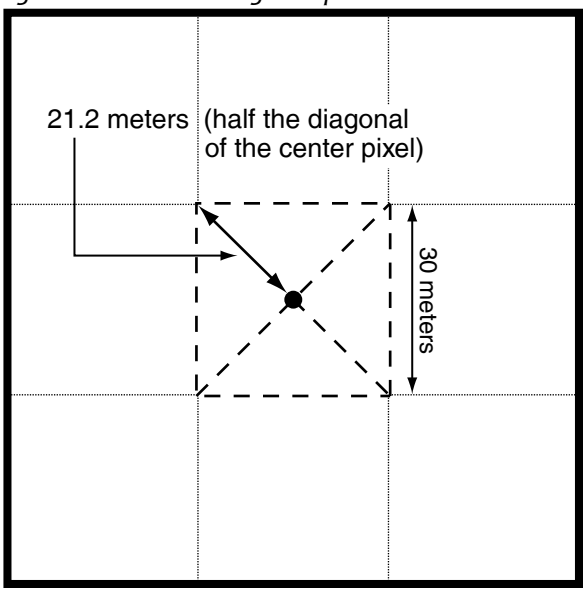


Figure LAND-SS-13: Pacing Example



while sidestepping and pacing around an obstacle, then estimate the reading from the sidestepped position.

- If an object is too large to conveniently side step, stop at the object and determine the direction you are pacing using your compass. Walk around the object until you are pacing in the same direction. Start counting again when you are going in the correct direction.

Determining the Number of Paces Required to Travel Half the Diagonal in a 30 m x 30 m Pixel

Note: If your students are able to divide using decimals, use the length of one of their paces to determine the number of paces in half a diagonal using the following formula:

$$\text{\# paces in half diagonal} = \frac{21.2 \text{ meters}}{\text{length of one pace (meters)}}$$

If they cannot divide using decimals, use the procedure below.

1. Measure a distance of 21.2 meters (length of half the diagonal, see Figure LAND-SS-13) out on a flat, open area (a parking lot, field, or hallway is good).
2. Remember that one pace is two steps. Starting with your toe at the 0-meter mark, count the number of paces required to travel the entire distance using a normal stride.
3. Repeat this measurement three times and calculate the average to determine an average number of paces.
4. Round the number of paces that you calculate to the nearest half pace. This is the number of paces that it takes you to walk a half diagonal.
5. Record the number of paces required for each individual to walk a half diagonal so it can be referred to when collecting data at a Land Cover Sample Site.

Frequently Asked Questions

1. Why must I pace 21.2 meters?

21.2 meters is the distance of half the diagonal of a 30 m x 30 m area. This is the length that you will pace in each of four directions while taking biometry measurements.

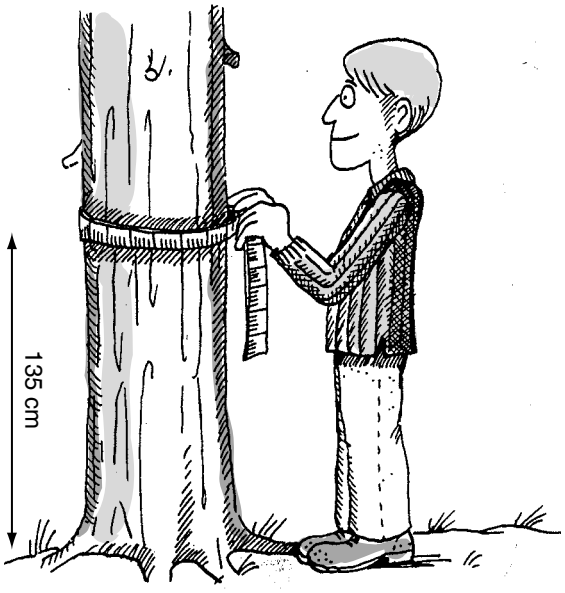
E. Tape Measure

You use a tape measure often when taking measurements at Land Cover Sample Sites. It is critical that you use the tape measure in the correct manner.

Directions for Reading a Tape Measure

Always use a metric tape measure.

Figure LAND-SS-14: Measuring Tree Circumference



Frequently Asked Questions

1. Why do we use the metric system?

The metric system is used for scientific investigations throughout the world.

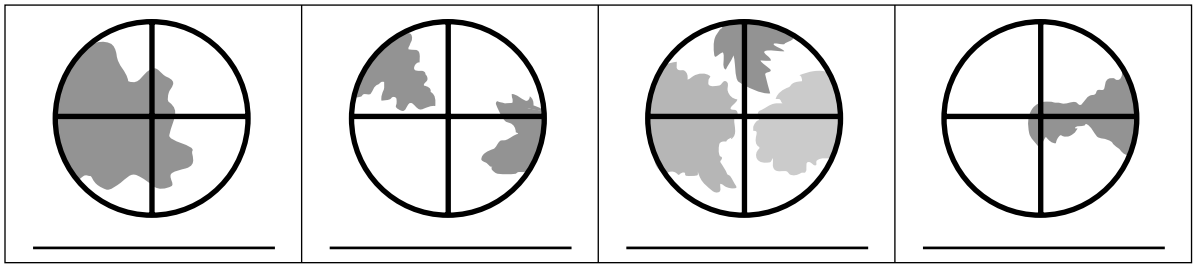
2. What if we only have a tape measure in English units (feet and inches)?

If you only have a tape measure in English units, you must convert all your measurements into metric units before reporting your data.

Investigation Instrument Assessment

The instruments in the previous sections are all important to carrying out the *Land Cover/Biology Investigation* accurately. Use the following assessment to gauge how well you understand the instruments and skills before going into the field. Answers to selected questions appear on the bottom of the page. If you are not able to perform these exercises or answer the questions, then review the relevant material in this section before proceeding to the field.

1. Demonstrate the correct way to hold the densiometer.
2. Below are several diagrams showing examples of what you might see when looking through the densiometer. Assuming that trees are overhead, label each diagram with a "T" or minus "-".



3. What are the three measurements you must take in order to calculate the height of an object?
4. Stand at one end of the room and demonstrate how you would sight with your clinometer to measure the height of an object your teacher chooses. Have another student read the angle.
5. Measure the distance between you and the object your teacher chose for Number 4, take any other measurements you need and calculate the height of the object.
6. When you are measuring the height of a tree, you should look at the base of the tree and your feet, to be sure that they are

   _____.
7. Determine the number of paces it takes you to walk a distance of 15 meters. (Mathematically using your previous measurement or using the tape measure on the floor).
8. What is the minimum height for a tree?
9. At what height from the ground do you measure the circumference of a tree? Where is this (using your body as a reference)?

1) student should hold the densiometer vertically over his or her head so the washer is straight down 2) +, -, -, + 3) height of your eyes above the ground, distance from you to the tree and angle to the top of the tree as sighted through the clinometer 4) student should look through the straw from the correct end of the clinometer, he or she should site the top of the object 5) all measurements listed in question 3 should be taken and used in the calculation (use the formula in the Clinometer section) 6) at the same elevation on level ground 7) various answers based on each student's pace length 8) 5 meters 9) 135 cm, location on body varies based on each student's height