

Density (DE) Sampling Method



EXECUTIVE SUMMARY

The FIREMON Density (DE) method is used to assess changes in plant species density and height for a macroplot. This method uses multiple quadrats and belt transects (transects having a width) to sample within plot variation and quantify statistically valid changes in plant species density and height over time. Herbaceous plant species are sampled with quadrats while shrubs and trees are sampled with belt transects. Quadrats for sampling herbaceous plants are placed systematically along randomly located transects. Belt transects for sampling shrub and tree density use the same randomly located transects. The number of individuals for each plant species in a quadrat or belt transect are calculated. Density is calculated as the number of individuals per unit area using the area of the sampling unit, quadrat or belt transect. This method is primarily suited for grasses, forbs, shrubs, and small trees in which individual plants or stems can be distinguished. However, we recommend using the FIREMON TD sampling methods for estimating tree density.

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INTRODUCTION

The Density (DE) method was designed to sample within plot variation and quantify changes in plant species density and height over time. This method uses multiple quadrats to sample herbaceous plant density and belt transects to sample shrub and tree density. First, a baseline is established from which to run the transects from. Transects are placed randomly along the baseline. Quadrats for sampling herbaceous plants are then placed systematically along each transect. Belt transects for sampling shrub and tree density are placed along the length of each transect. Characteristics are recorded about the general sample design and for individual plant species. First the transect length, number of transects, and number of quadrats per transect are recorded. Within each quadrat or belt transect, density and average height are recorded for each plant species. The quadrat length and width or belt transect width is also recorded for each species. Different size quadrats and belts can be used for different plant species.

This method is primarily used when the fire manager wants to monitor changes in plant species numbers. This method is primarily suited for grasses, forbs, shrubs, and small trees which are easily separated into individual plants or counting units, such as stems. However, we recommend using the FIREMON TD sampling method for estimating tree density. This sampling method uses density to assess changes in plant species numbers over time. The quadrat size and belt width varies with plant species or item and size class, allowing different size sampling units for different size plants or items. Quadrat size and belt width should be adjusted according to plant size and distribution.

Density is defined as the number of items per unit area. When sampling density, the examiner must be able to recognize and define individual plants. This may be relatively easy for single stemmed plants, but is more difficult for plants which reproduce vegetatively such as rhizomatous plants (e.g. western wheatgrass) or clonal species (e.g. aspen). It is critical to define exactly what item will be counted before sampling. The item counted may be individual plants for single stem plants or individual stems for a clonal species such as quaking aspen.

Density is used for monitoring an increase or decrease in the number of individuals or counting units. Density is more effective for detecting changes in recruitment or mortality than changes in vigor. It is not a practical monitoring method when plants respond to management treatments or disturbance with decreased cover rather than mortality. In such cases, density may not change much although cover and biomass may change considerably.

The accuracy of the density estimate depends largely on the size and shape of the quadrat or belt transect. Note that a belt transect is essentially a long, narrow quadrat. Pound and Clements (1898) considered plant dispersion, quadrat size and shape, and number of observations required as important characteristics to sample design. Van Dyne (1963) reviewed results from studies on quadrat sizes and shapes used to sample grassland communities of the western United States. Long narrow quadrats tend to include more species since vegetation tends to occur in clumps rather than be randomly distributed. The desired size and shape for a quadrat depends largely on

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the distribution of plant species being sampled. In general, sampling in sparse vegetation requires the use of larger quadrats. However quadrats should not be too large, since counting large numbers of plants in a quadrat can be overwhelming, and can lead to errors. In order to increase the sampling area, it is better to sample more quadrats than to use overly large quadrats.

With small quadrats, there is a greater chance of boundary error because of the greater perimeter to area ratio. Boundary problems are due to erroneously including or excluding plants near the quadrat perimeter. Some portion of basal vegetation must intersect the quadrat boundary for a plant to be considered a boundary plant. Boundary rules must be established before sampling. We recommend counting boundary plants “in” on two adjacent sides of a quadrat and “out” on the other adjacent sides. See **How to Count Boundary Plants**.

There are many ways to streamline or customize the DE sampling method. The FIREMON three-tier sampling design can be employed to optimize sampling efficiency. See the sections on **User Specific DE Sampling Design** and **Sampling Design Customization** below.

SAMPLING PROCEDURE

This method assumes that the sampling strategy has already been selected and the macroplot has already been located. If this is not the case, then refer to the FIREMON **Integrated Sampling Strategy** and for further details.

The sampling procedure is described in the order of the fields that need to be completed on the DE field form, so it is best to reference the DE Field form when reading this section. The sampling procedure described here is the recommended procedure for this method. Later sections will describe how the FIREMON three-tier sampling design can be used to modify the recommended procedure to match resources, funding, and time constraints.

See **How To Locate a FIREMON Plot**, **How To Permanently Establish a FIREMON Plot** and **How to Define the Boundaries of a Macroplot** for more information on setting up your macroplot.

Preliminary Sampling Tasks

Before setting out for your field sampling, layout a practice area with easy access. Try and locate an area with the same species or vegetation life form you plan on sampling. Get familiar with the plot layout and the data that will be collected. This will give you a chance to assess the method and will help you think about problems that might be encountered in the field. For example, how close do two bunchgrasses have to be before they are counted as one? It is better to answer these questions before the sampling begins so that you are not wasting time in the field. This will also let you see if there are any pieces of equipment that will need to be ordered.

Many preparations must be made before proceeding into the field for DE sampling. First, All equipment and supplies in the DE Equipment List must be purchased and packed for transport into the field. Since travel to FIREMON plots is usually by foot, it is important that

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supplies and equipment be placed in a comfortable daypack or backpack. It is also important that there be spares of each piece of equipment so that an entire day of sampling is not lost when something breaks. Spare equipment can be stored in the vehicle rather than the backpack. Be sure all equipment is well maintained and there are plenty of extra supplies such as plot forms, map cases, and pencils.

All DE Field forms should be copied onto waterproof paper because inclement weather can easily destroy valuable data recorded on standard copier paper. Plot forms should be transported into the field using a plastic, waterproof map protector or plastic bag. The day's sample forms should always be stored in a dry place (i.e., office or vehicle) and not be taken back into the field for the next day's sampling.

We recommend that one person on the field crew, preferably the crew boss, have a waterproof, lined field notebook for recording logistic and procedural problems encountered during sampling. This helps with future re-measurements and future field campaigns. All comments and details not documented in the FIREMON sampling methods should be written in this notebook. For example, snow on the plot might be described in the notebook, which would be very helpful in plot re-measurement.

It is beneficial to have plot locations for several days of work in advance in case something happens, such as the road to one set of plots is washed out by flooding. Locations and/or directions to the plots you will be sampling should be readily in order to reduce travel times. If the FIREMON plots were randomly located within the sampling unit it is critical that the crew is provided plot coordinates before going into the field. Plots should be referenced on maps and aerial photos using pin-pricks or dots to make navigation easy for the crew and to provide a check of the georeferenced coordinates. It is easy to mis-record latitude and longitude coordinates and marked maps can help identify any erroneous plot positions.

A field crew of two people is probably the most efficient for implementation of the DE sampling method. There should never be a one-person field crew for safety reasons, and any more than two people will probably result in some people waiting for critical tasks to be done. The crew boss is responsible for all sampling logistics including the vehicle, plot directions, equipment, supplies, and safety. The crew boss should be the note taker and the technician should perform most quadrat measurements. The initial sampling tasks of the field crew should be assigned based on field experience, physical capacity, and sampling efficiency, but sampling tasks should be modified as the field crew gains experience. Tasks should also be shared to limit monotony.

Designing the DE Sampling Design

There is a set of general criteria recorded on the DE Plot form that forms the user-specified design of the DE sampling method. Each general DE field must be designed so that the sampling captures the information needed to successfully complete the management objective within time, money and personnel constraints. These general fields should be determined before the crews go

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into the field and should reflect a thoughtful analysis of the expected problems and challenges in the fire monitoring project.

Plot ID construction

A unique plot identifier must be entered on the DE sampling form. This is the same plot identifier used to describe general plot characteristics in the Plot Description or PD sampling method. Details on constructing a unique plot identifier are discussed in the **How to Construct a Unique Plot Identifier** section. Enter the plot identifier at the top of the DE field form.

Determining sample size

The size of the macroplot ultimately determines the length of the transects and the length of the baseline along which the transects are placed. The amount of variability in plant species composition and distribution determines the number and length of transects and the number of quadrats required for sampling. The typical macroplot sampled in the DE method is a 0.10 acre (0.04 hectare) square measuring 66 x 66 feet (20 x 20 meters), which is sufficient for most monitoring applications. The size of the macroplot may be adjusted to accommodate different numbers and lengths of transects. However, it is more efficient if you use the same plot size for all FIREMON sampling methods on the plot.

If you are sampling shrubs and trees we recommend sampling five belt transects within the macroplot. This should be sufficient for most studies however, there are situations when more transects should be sampled. See **How To Determine Sample Size** for more details. Enter the number of transects in Field 1 on the DE Belt Transect field form. The recommended transect length is 66 ft (20 m) for a 66 x 66 ft (20 x 20 m) macroplot. However, the macroplot size may be adjusted to accommodate longer or shorter transects based on the variability in plant species composition and distribution. The FIREMON DE field form and data entry screen allow a maximum of 10 transects per macroplot

We recommend sampling at least five quadrats per transect for herbaceous plants, and this should be sufficient for most studies. There are situations when more quadrats should be sampled. Additional quadrats may be sampled by placing more quadrats along a transect or by sampling more transects within the macroplot. Enter the number of quadrats per transect in Field 2 of the DE Quadrat field form. The FIREMON DE Quadrat field form and data entry screen allow a maximum of 25 quadrats per transect.

Determining the belt transect size and quadrat Size

Density is typically recorded in quadrats for herbaceous species and in belt transects for shrubs. We recommend using a 66 x 3 foot (20 x 1 m) belt width for sampling smaller shrubs (< 3 ft. (1 m) average diameter) and a 66 x 6 foot (20 x 2m) belt width for larger shrubs (> 3 ft. (1 m) average diameter). Belt length and width may be adjusted to accommodate different sizes and densities of shrubs and trees. Longer, wider transects can be sampled for larger or sparsely

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distributed shrubs and trees, and shorter, narrower transects can be sample for smaller, and more dense shrubs and trees. Enter the belt transect length in Field 5 and width in Field 6 of the DE Transect field form. You may vary the belt length and width for different plant species you encounter on the macroplot but be sure to enter the appropriate length and width for each species on the field form.

We recommend using 3 x 3 ft (1 x 1 m) quadrats for sampling herbaceous vegetation, however quadrat size and transect length may be adjusted to accommodate the size and spacing of the plants being sampled. Larger plants can be counted in larger quadrats on longer transects and smaller plants in smaller quadrats on shorter transects. See **How To Construct a Quadrat Frame** for instructions on building and using quadrat frames. Enter the quadrat length and width in feet (m) in Fields 7 and 8 on the DE Quadrat field form. Quadrat length and width is entered by item and size class and can may vary for different items and size classes. Be sure to record all of the length and width measurements on the field form.

Conducting DE Sampling Tasks

Establish the baseline for transects

Once the plot has been monumented, a permanent baseline is set up as a reference from which you will orient all transects. The baseline should be established so that the sampling plots for tall of the methods overlap as much as possible. See **How To Establish Plots with Multiple Methods**. The recommended baseline is 66 feet (20 m) long and is oriented upslope with the 0-foot (0 m) mark at the lower permanent marker and the 66-foot (20 m) mark at the upper marker. On flat areas, the baseline runs from south to north with the 0-foot (0 m) mark on the south end and the 66-foot (20 m) mark on the north end. See **How To Establish a Baseline for Transects** for more details.

Locating the transects

Transects are placed perpendicular to the baseline and are sampled starting at the baseline. On flat areas, transects are located from the baseline to the east. Starting locations for each transect are determined using the FIREMON random transect locator or from supplied tables. If the CF method is used in conjunction with other replicated sampling methods (LI, PO, RS or CF), use the same transects for all methods, if possible. In successive remeasurement years, it is essential that transects be placed in the same location. See **How To Locate Transects and Quadrats** for more details.

Locating the quadrats

There will typically be five 3 x 3 ft (1 x 1 m) quadrats located at 12 ft (4 m) intervals along a transect, with the first quadrat placed 12 ft. (4 m) from the baseline. However, the spacing of the quadrats will depend on the size of the quadrat and the length of the transect. See **How To Locate Transects and Quadrats** for more details. If macroplots are being sampled for

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permanent remeasurement, quadrats must be placed in the same location in successive sampling. When sampling macroplots that are not scheduled for permanent remeasurement, the distance between quadrats may be estimated by pacing.

Density Sampling

When sampling herbaceous species, enter the transect number in Field 3 on the DE Quadrat field form. The transect number is not entered on the DE Transect field form for sampling shrub or tree species using belt transects. Enter the species code or item code (e.g. moose pellets) in Field 4 on the DE Quadrat Option field form or Field 2 on the Transect Option field form. FIREMON uses the NRCS Plants species codes, however you may use your own species codes. See **How to Customize Plant Species Codes** for more details.

Next enter the plant species status in Field 5 on the DE Quadrat Field form and Field 3 on the DE Transect field form. Status describes the general health of the plant species as live or dead using the following codes:

- L – Live:** plant with living tissue
- D – Dead:** plant with no living tissue visible
- NA – Not Applicable**

Plant status is purely qualitative but it does provide an adequate characteristic for stratification of pre-burn plant health and in determining post-burn survival. Use care in determining plant status during the dormant season.

Size class

Plant species size classes represent different layers in the canopy. For example, the upper canopy layer could be defined by large trees, while pole size trees and large shrubs might dominate the middle layer of the canopy, and the lower canopy layer could include seedlings, saplings, grasses and forbs. Size class data provide important structural information such as the vertical distribution of plant cover. Size classes for trees are typically defined by height for seedlings and diameter at breast height (dbh) for larger trees. Size classes for shrubs, grasses, and forbs are typically defined by height. If the vegetation being sampled has a layered canopy structure, then density can be recorded by plant species and by size class.

FIREMON uses a size class stratification based on the ECODATA sampling methods (Jensen and others, 1994). Group individual plants by species into one or more trees size classes (table DE-1) or shrub, grass, and forb size classes (table DE-2). There can be multiple size classes for each species. See **How To Measure DBH** for detailed information on measuring DBH to group trees into size classes. See **How to Measure Plant Heights** for detailed information on measuring height for grouping shrubs into size classes.

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Table DE-1. Tree size class codes.

Tree Size Class Codes	Tree Size Class English	Tree Size Class Metric
TO	Total count	Total count
SE	Seedling (<1 in. DBH or <4.5 ft height)	Seedling (<2.5 cm DBH or <1.5 m height)
SA	Sapling (1.0 in. - < 5.0 in. DBH)	Sapling (2.5 - <12.5 cm DBH)
PT	Pole Tree (5.0 in. - <9.0 in. DBH)	Pole Tree (12.5 - <25 cm DBH)
MT	Medium Tree (9.0 in. - <21.0 in. DBH)	Medium Tree (25 - <50 cm DBH)
LT	Large Tree (21.0 in. - <33.0 in. DBH)	Large Tree (50 - <80 cm DBH)
VT	Very Large Tree (33.0+ in. DBH)	Very Large Tree (80+ cm DBH)
NA	Not Applicable	Not Applicable

Table DE-2. Shrub, grass, and forb size class codes.

Shrub / Herb Size Class Codes	Shrub / Herb Size Class English	Shrub / Herb Size Class Metric
TO	Total count	Total count
SM	Small (<0.5 ft height)	Small (<0.15 m height)
LW	Low (0.5 - <1.5 ft height)	Low (0.15 - <0.5m height)
MD	Medium (1.5 - <4.5 ft height)	Medium (0.5 - <1.5 m height)
TL	Tall (4.5 - <8 ft height)	Tall (1.5 - <2.5 m height)
VT	Very Tall (8+ ft height)	Very Tall (2.5+ m height)
NA	Not Applicable	Not Applicable

If recording density by size class, enter the size class code for each plant species in Field 6 on the DE Quadrat field form and Field 4 on the DE Transect field form. If size class data is not recorded, indicate that by entering using the code “TO”.

Density

Record the number of individual plants for each plant species or individual plants for each plant species by size class within the quadrat (figure DE-1). Decisions about counting boundary plants (plants which have a portion of basal vegetation intersecting the quadrat) need to be applied systematically to each quadrat. See **How to Count Boundary Plants** for more details. Enter the count for each plant species or plant species by size class in the Count field by quadrat on the DE Quadrat field form or by transect on the DE Transect field form. Use the workspace below each Count field for a dot tally. See **How to Dot Tally** for more details.

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Figure DE-1. Count individual plants by plant species or plant species by size class. In this example there are five individuals of a grass species, three individuals of a tree species, and two individuals of a forb species.

Estimating average height

Measure the average height for each plant species in feet (meters) within +/- 10 percent of the mean plant height. If plant species are recorded by size class, measure the average height for individual species by each size class recorded. See **How to Measure Plant Heights** for more details. Enter plant height in the Height field for each transect on the DE Transect form or for each quadrat on the DE quadrat form.

Precision Standards

Use these precision standards for the DE sampling.

Table DE-3. Precision guidelines for DE sampling.

Component	Standard
Count	±10 percent total count
Average height	±10 percent average height
Size class	±1 class

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SAMPLING DESIGN CUSTOMIZATION

This section will present several ways that the DE sampling method can be modified to collect more detailed information or streamlined to collect basic information.

Recommended DE Sampling Design

The recommended DE sampling design follows the Recommended FIREMON Sampling Strategy and is listed below:

Macroplot Size: 0.1 acre, 66 ft x 66 ft. (400 square meters, 20 x 20 m)

Quadrat Size (herbaceous plant sampling): 3 x 3 ft. (1 x 1 m)

Belt Transect Width (shrubs and tree sampling): 3 feet (1 m) or 6 feet (2m)

Number of Transects: 5

Number of Quadrats / Transect: 5

Count plant species within each quadrat.

The quadrat size and shape and belt transect width should be adjusted according to the plant community being sampled.

The number of transects and quadrats sampled should be adjusted according to the appropriate methods in the “How To” section of the FIREMON manual.

Streamlined DE Sampling Design

The streamlined DE sampling design follows the Simple FIREMON sample strategy and is designed below:

Macroplot Size: 0.1 acre, 66 ft x 66 ft. (400 square meters, 20 x 20 m)

Quadrat Size (herbaceous plant sampling): 3 x 3 ft. (1 x 1 m)

Belt Transect Width (shrubs and tree sampling): 3 feet (1 m) or 6 feet (1m)

Number of Transects: 3

Number of Quadrats / Transect: 5

Count plant species within each quadrat.

The quadrat size and shape and belt transect width should be adjusted according to the plant community being sampled.

The number of transects and quadrats sampled should be adjusted according to the appropriate methods in the “How To” section of the FIREMON manual.

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Comprehensive DE Sampling Design

The comprehensive DE sampling design follows the Detailed FIREMON sampling strategy and is detailed below:

Macroplot Size: 0.1 acre, 66 ft x 66 ft. (400 square meters, 20 x 20 m)

Quadrat Size (herbaceous plant sampling): 3 x 3 ft. (1 x 1 m)

Belt Transect Width (shrubs and tree sampling): 3 feet (1 m) or 6 feet (2 m)

Number of Transects: 5

Number of Quadrats / Transect: 5

Count plant species by size class and measure average plant species height by size class within each quadrat.

The quadrat size and shape and belt transect width should be adjusted according to the plant community being sampled.

The number of transects and quadrats sampled should be adjusted according to the appropriate methods in the “How To” section of the FIREMON manual.

User-specific DE Sampling Design

The user can modify the DE sample fields a number of ways in order to make sampling more efficient and meaningful for local situations. This will usually mean adjusting the number of transects, transect length, transect width, quadrat size, or number of quadrats as needed for the specific task. Use the MD form to record any changes in sampling methods that are modified from the standard or to remark on any other DE matter that needs to be explained or defined for subsequent sampling and data use.

Many different sizes and shapes of quadrats and belt transects can be used to sample density. It is probably most efficient to conduct a pilot study to determine the size and shape of quadrat or belt transect that allows number of plants to be easily counted and also minimizes the variance between sampling units. See Elzinga and others (1998) for a detailed discussion on this topic. Plant species density may be sampled using quadrats of various sizes, belt transects of various sizes, or a combination of both belts and quadrats. If circular plots are being used to count plants, then enter the radius of the plot in the quadrat length field and leave the quadrat width field blank on the DE field forms. The FIREMON sampling forms and databases will accommodate most sampling variations of the DE method.

Sampling Hints and Techniques

Examiners must be able to identify plant species, identify individual plants, and be able to determine whether a plant species occurs within a quadrat. It can be difficult to distinguish individual plants for some species such as sod-forming grasses. If individual plants are difficult

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to identify, guidelines should be determined before sampling as to what constitutes the individual counting unit. Some examples include counting individual stems in aspen communities, culm groups in rhizomatous grasses, and flowering stems for mat-forming forbs. However, the counting unit chosen to monitor should reflect a real change in the plant community.

Measuring tapes come in a variety of lengths, increments, and materials. Examiners should choose English (metric) tapes for this method and select a tape that is at least as long, or a little longer, than the transect length being sampled. Steel tapes do not stretch and are the most accurate over the life of the tape. Steel is probably the best choice for permanent transects where remeasurement in exactly the same place each time is important. Cloth and fiberglass tapes will stretch over the life of the tape, but are easier to use than steel tapes since they are lighter and do not tend to kink.

The sampling crew may encounter an obstacle, such as a large rock or tree, along one of the transect lines that interferes with the quadrat sampling. If that happens offset using the directions described in **How To Offset a Transect**.

When entering data on the DE Transect Option plot forms, examiners will most likely run out of space on the first page. The form was designed to print one copy of the first page, and several copies of the second page. The second page can be used to record more plant species on the first three transects or to record data for additional transects. The second page of the field form allows the examiner to write the transect number on the form. This allows the examiner to design the form to accommodate the number transects sampled. Print out enough pages to record all species on all transects for the required number of intercepts. The FIREMON data entry screens and database allow a maximum of 10 transects.

When entering data on the DE Quadrat Option plot forms, examiners will most likely run out of space on the first page. If so, use the DE continuation form. The continuation page can be used to record more plant species on the first five quadrats or to record data for additional frames. The continuation page allows the examiner to write the quadrat number on the form, thus allowing the examiner to design the form to accommodate the number frames sampled per transect. Print out enough pages to record all species on all transects for the required number of counts. The FIREMON data entry screens and database allow a maximum of 25 frames per transect and an unlimited number of transects.