THE UNIVERSITY OF ARIZONA
Cooperative Extension

az2004 September 2022

The Importance of Strategic Questions and Tactical Ground Rules in Rangeland Studies for Grazing Management

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Introduction

All parties participating in rangeland studies (i.e., monitoring, inventory, or assessment) should clearly understand strategic questions concerning "why?, what?, when?, where?, who? and how often?" data are being collected, as well as tactical ground rules that should be followed when conducting a particular sampling technique. This information should be clearly recorded either directly on data sheets or described in each report or cover sheet that accompanies the data. The information should also be catalogued and stored in a safe location in both hard copy and electronic formats where it is easily accessible by current and future observers.

This is especially important when observers who are not involved in the planning and execution of the original study will be responsible for repeating a study at some point in the future, which is often the case for rangeland monitoring. Understanding the original intent of the study and precisely how data were collected provides transparency and repeatability for future efforts. Even if a particular observer believes they will be the one repeating future studies, they probably won't remember all the important nuances pertaining to how it was done the first time. People come and go -- memory is often short and fallible. The objectives of this paper are to discuss the importance of permanently recording and referring to: 1) strategic questions that should be addressed before performing any rangeland study, and 2) tactical ground rules germane to four rangeland sampling techniques commonly used in Arizona.

Strategic Questions

Observers should ask themselves six "strategic" questions before going to the field to conduct any rangeland study (Ruyle 1997; Smith and Ruyle, 1997). Answering these questions will help ensure the data collection process has not been compromised by arbitrary sampling protocols, personal biases, and/or unintentional sampling errors. We frame these six questions within the context of sampling during rangeland monitoring studies, but the same questions are important to ask before conducting all rangeland studies (i.e., monitoring, inventory, or assessment). Documenting the answers to these questions, and including stakeholders when planning the monitoring, is a critical part of the preparatory work that should be done before heading to the field.

1. Why Monitor?

Rangeland monitoring studies are conducted to document whether there have been changes in important rangeland attributes (e.g., vegetation cover, biomass, density) across time. If data are not collected the same way every time, observers won't know if changes detected are real, or if results are merely artifacts of different sampling protocols being haphazardly implemented from one occasion to the next. Having different procedures and rules on different monitoring dates destroys the value, intent, and purpose of collecting rangeland monitoring data.

2. What to Monitor?

What characteristics of the rangeland (utilization, frequency, density, etc.) you monitor is influenced by many things including, but not limited to: the goals and objectives of the study, the training and observer skills required for a particular technique, the time required to obtain an adequate sample size necessary to draw meaningful conclusions, and the vegetation type present on the landscape. Having clearly defined goals and objectives framed within a site's ecological potential is an important first step towards deciding what to monitor.

Some vegetation sampling techniques (e.g., plant species frequency, discussed later) require less training, are well suited for collecting many samples over a large area and are highly repeatable. Other techniques (also discussed later in this paper) may require more training to confirm repeatability among observers (e.g., dry weight rank, comparative yield), or to obtain an adequate sample size to account for site variability (e.g., point ground cover). Vegetation type may also dictate what technique is most appropriate for sampling a particular vegetation attribute or life form (e.g., line intercept/canopy cover for shrubs, point sampling/basal cover for herbaceous plants).

3. When to Monitor?

Determining when to monitor is often related more to plant development and phenology than to a particular calendar date. Litter, seedlings, annuals, cover and other vegetation attributes will vary due to spatial and temporal variability of precipitation patterns.

Because monitoring studies are intended to provide quantitative estimates of trends (i.e., changes) in rangeland attributes (including species composition), it is important to sample when most plants can be correctly identified. For example, sampling during late summer or early fall for warm season plants is generally when plant reproductive parts are most visible (e.g., seedheads, flowerheads), and accordingly, when plants are easier to identify.

If your objective is to measure utilization[1], it is important to sample at the end of the growing season after key forage species have reached peak standing crop. The timing of when this occurs also varies depending on temporal and spatial rainfall patterns, plant species and vegetation type (e.g., warm vs. cool season, annual vs. perennial, woody vs. herbaceous, etc.), and ecological site potential.

4. Where to Monitor?

On landscape scale grazing allotments common in the western U.S., it is only feasible to monitor a few locations selected to represent larger areas (e.g., ecological site, pasture, ranch, allotment).

Key areas are selected with the aim of obtaining maximum information from a few representative monitoring locations (Schalau 2010). It is assumed if a key area is properly grazed, so will the larger management unit except possibly for critical areas (discussed below).

Key areas **should**: 1) be representative of average grazing management practices that occur on the management unit, 2) be located on prominent ecological sites which produce a large portion of the forage, 3) have potential to detect changes due to management practices should they occur, 4) have potential for measuring vegetation changes that are tied to realistic management objectives that are framed within a site's current ecological potential (Bestelmeyer et al., 2003; Brischke et al., 2018), 5) be located within a single ecological site and plant community (i.e., not in a transitional zone), 6) be specific to the type of animal and their corresponding season of use, and foraging behavior, e.g., deer vs. cattle, 7) be carefully chosen and if possible agreed upon by all stakeholders with points 1-6 in mind. Once established, key areas should not be changed without good reason as their value is in the long-term data they provide. If locations or attributes monitored are changed, stakeholders should be involved, and reasons for any changes should be well documented.

Key areas **should not** be located near or around: 1) livestock watering points (generally, no closer than ¼-mile), 2) livestock driveways, trails, fences, or historical disturbances, 3) recreation or dispersed camping sites, 4) salt or bedding grounds for wild, feral, or domestic ungulates, 5) areas inaccessible to livestock, although such areas might be considered as comparison areas (Sprinkle et al., 2007).

Comparison areas may be fenced to exclude livestock (Courtois et al., 2004; Holechek et al., 2006; Davies et al., 2009), or may be inaccessible to livestock due to topography (Sprinkle et al., 2007). The aim is for ungrazed comparison areas and grazed areas to be ecologically similar in every aspect except for grazing management practices, helping managers to assess and distinguish the effects of grazing management from climate and weather.

Critical areas are established to measure grazing management effects on special or unique ecosystem values or services, such as endangered species, nesting or fawning cover, or riparian habitats. They are monitored and assessed separately from key areas and comparison areas.

5. Who Monitors?

The University of Arizona Cooperative Extension (UACE) has taught science-based rangeland monitoring techniques for over 40 years through workshops for ranchers, agency professionals, and interested members of the public. For example, on the Yavapai Ranch (near Seligman, Arizona), ranch personnel, agency professionals, and volunteers have collected and discussed monitoring data as a team since 1994. The Reading the Range (RTR) project is another collaborative rangeland monitoring program that was initiated by UACE in central Arizona in 2001. Partners from RTR have included UACE, Tonto National Forest range staff, the Tonto Natural Resource Conservation

[1] Utilization or use is defined by SRM (1998) as, "The proportion of current year's forage production that is consumed or destroyed by grazing animals. May refer either to a single species or to the vegetation as a whole. Syn. degree of use."

District, the Natural Resources Conservation Service, other government employees, and grazing permittees.

Many livestock producers across the West have adopted similar cooperative monitoring efforts which provide meaningful opportunities for people to work together while sharing the workload. The process can be valuable because planning and implementing rangeland monitoring programs can serve as a catalyst for building trust among participants (Hawkes et al., 2018; Tanoue et al., 2019). Moreover, the use of science-based data in the National Environment Policy Act (NEPA) process ultimately engenders more durable decisions that embrace adaptive management on state and federal grazing permits. This can provide ranchers more stability and flexibility in managing their livestock operations while meeting the objectives of other stakeholders concerned about additional resource values and ecological services.

6. How Often to Monitor?

The frequency of monitoring may vary on several factors. These include the purpose, vegetation type, stakeholder involvement and a compromise between what is desirable and what is feasible (Smith et al 2012). For example, utilization studies are usually conducted every year, while long-term trend studies are generally conducted every 3-5 years.

Tactical Ground Rules

Once you have considered the six "strategic" questions (**before going to the field!**), and have documented the answers to those questions, it is time to review tactical ground rules that will be followed while sampling. It is important for monitoring teams to agree **in advance** how specific ground rules will be applied before initiating rangeland studies. In other words, ground rules provide **a priori** guidance for unique scenarios that inevitably arise during the execution of a particular sampling method.

In Arizona, a suite of four monitoring techniques (i.e., Point Ground Cover, Pace Frequency, Dry-Weight Rank, and Comparative Yield) are often executed simultaneously to collect data on a myriad of rangeland trend attributes. Thus, a major advantage of combining these four techniques is that an enormous amount of rangeland trend data (e.g., ground cover, species abundance and distribution, species composition, and production) can be collected in a relatively short period of time using an inexpensive rangeland sampling frame (Hall et al., 2018; Photo 1).

Photo 1. Rangeland sampling frame (40 x 40 cm, 0.16 m2). Photo credit, Ashley Hall.

In the following sections, we provide brief descriptions and discuss specific ground rules for each of the four techniques[2]. Detailed descriptions, step-by-step protocols, and ground rules for these, and many other rangeland sampling techniques, can be found in previous publications: Interagency Technical Reference (1999); Ruyle (1997); Smith et al. (2012) and McReynolds and Brischke (2015).

Point Ground Cover -- Description

Ground cover is an important indicator of the risk for accelerated soil erosion when evaluated with measures of ground cover fragmentation within the context of ecological site potential (Bestelmeyer et al., 2003; Brischke et al., 2018). A significant increase in bare ground may indicate an increased potential for soil erosion. The point ground cover technique is used to evaluate trends in ground cover from year to year by recording the percentage of the soil surface occupied by biotic or abiotic cover types, e.g., bare ground (i.e., lack of cover), gravel, rock, litter, or live basal vegetation. Detailed descriptions of this technique can be found in the Interagency Technical Reference (1999; page 70), Smith et al. (2012; page 132), and McReynolds and Brischke (2015; page 6).

The rangeland sampling frame (Photo 1) typically has 1-3 metal points that protrude slightly from the frame's base. A point is, by definition, a dimensionless entity (i.e., a point's area = 0) so, unlike the 3 monitoring techniques that follow,

[2] An important ground rule that universally applies to this suite of four monitoring techniques is to record a starting point, the direction of transects, and a standard distance between sampling frame placement so that the same general area is being sampled each time. As mentioned in the Introduction, **all** ground rules should be clearly recorded and permanently stored in a safe location in both hard copy and electronic formats for the benefit of those who will be repeating the same sampling protocols in the future.

there are no "ground rule" decisions related to proper frame size, whether an attribute is "inside" of "outside" a frame, ranking or estimating vegetation attributes, etc. Observers simply record the number of "hits" for a minimum of five different cover types (defined below). For each point placement, only one ground cover type is recorded as a "hit" according to what lies directly beneath the point at the soil surface. Total hits for all cover types across a key area transect provides percent estimates for each ground cover type which collectively sum to 100%.

Point Ground Cover Ground Rule #1 -- Definitions of Ground Cover Types

The most important ground rule for the point ground cover technique is how each cover type is defined. Ground cover is objective and repeatable if observers adhere to strict definitions for ground cover types during each sampling session. Below are definitions for ground cover types that the UACE uses in their rangeland monitoring sampling procedures[3].

Bare ground- Record this as a "hit" when none of the following ground cover types are present under the point.

Gravel- Mineral particle with a diameter between 0.25-3 inches (Note: a mineral particle "hit" with a diameter of < 0.25 inch would be recorded as bare ground).

Rock- Mineral particle with a diameter > 3 inches.

Litter[4]- Any identifiable plant material lying on the soil surface, regardless of size or composition (i.e., woody or herbaceous).

Live basal vegetation- Area of the stem where it enters the ground on single-stemmed herbaceous or woody species. For bunchgrasses, a hit occurs whenever the point intersects the inside of a basal tuft.

Pace Frequency -- Description

The purpose of measuring plant frequency is to estimate the relative abundance of plant species occurring across a rangeland landscape. Thus, frequency can be used to document whether desirable or undesirable plants are increasing (or decreasing) between sampling occurrences. Detailed descriptions of this technique can be found in Despain et al. (1997; page 7), the Interagency Technical Reference (1999; page 37), Smith et al. (2012; page 140), and McReynolds and Brischke (2015; page 8).

Pace frequency is a repeatable, objective, and rapid technique that requires less training and fewer decisions than most other techniques. Observers simply note the presence (or absence) of plant species occurring within a series of sampling frames (aka "quadrats") that are systematically located along a permanent paced transect within a key area. Frequency is calculated as the percentage of quadrats in which a given plant species is detected within a predetermined number of randomly placed transects. Another way of thinking of frequency is that it is the probability of a plant being present within a frame when randomly placed on the site.

Frequency by itself does not provide an estimate of species composition which is estimated by the Dry Weight Rank technique (discussed later). Frequency is best suited for moderate to dense stands of perennial grasses, forbs and/or low shrubs. It does not work as well in stands of sparse vegetation or in very dense stands of herbaceous or woody vegetation.

Pace Frequency Ground Rule #1 -- Proper Quadrat Size

To detect changes in plant abundance across two points in time, percent frequency for an individual plant species should fall within the range of 5% and 95%, and preferably, between 20-80% for statistical analysis (Smith et al., 2012). If frequency of an individual plant species is < 5%, quadrat size for that species is too small to reliably detect any increases or decreases that may have occurred. Conversely, if frequency of an individual plant species is > 95%, quadrat size is too big. In such cases, it may be beneficial to use a "nested" frame (Photo 2) to ensure that all species of interest fall within an acceptable range of percent frequency.

The 40-cm^2 sampling frame has been found to work well on most Arizona uplands because frequency usually falls within an acceptable range for most plant species (Despain et al.,

Photo 2. A "nested" sampling frame which can be used as a 10-, 20-, or 40-cm2 quadrat. Photo credit, George Ruyle.

[3] Some entities may define these categories further, for example, live basal vegetation may be identified by species, and, litter may be defined further as woody or herbaceous or by depth.

[4] "Litter is defined by SRM (1998) as, "The uppermost layer of organic debris on the soil surface; essentially the freshly fallen or slightly decomposed vegetal material."

1997). If frequency for a particular plant species exceeds 95%, the 10- or 20-cm² quadrat could be considered for sampling more abundant plant species (Photo 2). Conversely, larger frame sizes can be used to capture less abundant plant species (i.e., < 5% frequency). However, a disadvantage to using larger frames is that they become unwieldy to use in the field. It is critical to use the same quadrat size selected for an individual plant species during subsequent sampling occasions.

Pace Frequency Ground Rule #2 -- "Inside" or "Outside" the Quadrat

There are two kinds of frequency that may be recorded as "inside" a quadrat, i.e., "rooted frequency" or "canopy frequency." In both cases, if a plant "hits" the quadrat frame it is counted as inside the quadrat.

"Rooted frequency" is recorded for herbaceous plants (i.e., grasses and forbs) that are rooted within a quadrat (i.e., those plants are counted as "inside" the quadrat). Herbaceous plants merely overhanging a quadrat are not counted unless they are also rooted within the quadrat (Photo 3).

"Canopy frequency" is recorded for larger trees and shrubs that have a significant canopy but low density (e.g., mesquite, juniper, creosote bush). If any part of the live canopy of these woody plants overhangs the quadrat it is counted as "inside", irrespective of whether it is rooted within the quadrat. This is appropriate for many southwestern vegetation types because these shrubs and trees are often scattered and will not be sampled if the ground rule for herbaceous species (i.e., being rooted within the frame) was applied to larger woody plants. For small or half-shrubs, either "rooted" or "canopy" frequency may be recorded (Photo 4). Thus, ground rules for frequency vary among plant life forms. As with all ground rules, they must be permanently recorded so that others can repeat the same sampling protocol and so that valid statistical comparisons may be made.

Photo 2. A "nested" sampling frame which can be used as a 10-, 20-, or 40-cm² quadrat. Photo credit, George Ruyle.

Photo 4. When recording canopy frequency, larger woody plants are recorded as "inside" if any part of their live canopy overhangs the quadrat, irrespective of whether the plant is rooted within the quadrat. Photo credit, George Ruyle.

Pace Frequency Ground Rule #3 -- Species Groups or Individuals

Annual grasses, annual forbs, or seedlings may either be recorded as species groups or as individual species. Likewise, individual species can be refined by qualifiers such as seedlings. These, and other ground rule decisions, must be permanently recorded so that others can repeat the same sampling protocol and ground rules.

Dry-Weight Rank (DWR) -- Description

The purpose of measuring dry-weight rank (DWR) is to estimate relative species composition (by dry weight) which provides a quantitative estimate of the dominant plant species across a rangeland landscape. This can be helpful when interpreting frequency data which only provides an estimate of the relative abundance of each species. Detailed descriptions of the DWR technique can be found in Smith and Despain (1997; page 27), the Interagency Technical Reference (1999; page 50), Smith et al. (2012; page 126), and McReynolds and Brischke (2015; page 10).

When using the DWR technique there is no requirement for observers to estimate actual weights of plant species. Instead, observers apply a simple, repeatable ranking system to individual plant species encountered in quadrats along a transect which ultimately provides an estimate of species composition by weight. Comparing species composition to a desired plant community or some other standard (e.g., ecological site guide, exclosure data) can be used to assess a site's range condition or ecological status if the data elements are the same attribute, which, in this case is above-ground biomass. Comparing species composition data collected via the DWR technique at the same place across two points in time can provide quantitative trend data for a key area located within a particular ecological site. DWR works best in moderate to dense stands of grasses, forbs, and low shrubs.

DWR Ground Rule #1 -- Proper Quadrat Size

Ideally, most quadrats should contain 3 or more plant species. The 40-cm^2 sampling frame works well in this regard for most situations encountered on Arizona uplands. It is acceptable if a few quadrats contain < 3 plant species (see ground rule #3, below), but if this happens repeatedly, frame size may be too small for the site and may need to be increased.

DWR Ground Rule #2 -- “Inside” or “Outside" the Quadrat

Observers are trained to rank current year’s production (dry weight) for plant species (herbaceous and woody) that occur within the vertical projection of a quadrat's boundary with no requirement that plants be rooted within the quadrat. Portions of plants that occur outside the vertical projection of the quadrat boundary are not included in the ranking even if the plant is rooted within the quadrat.

DWR Ground Rule #3 -- Ranking Plant Species

If there are 3 or more species detected inside a quadrat (as per ground rule #2), observers assign ranks of "1, 2, or 3" to the top 3 species in the quadrat that are respectively estimated to contribute the most, 2nd-most, and 3rd-most dry weight within the quadrat. In effect, DWR method assumes that a rank of 1 corresponds to 70% composition, rank 2 ~ 20%, and rank 3 ~ 10%. All other plant species are ignored for DWR, although they may be tallied for frequency as described earlier. If quadrats occasionally contain less than 3 plant species, observers may assign multiple ranks to the one or two plants detected. For example, if only one plant is found in a quadrat it may be given 1, 2, and 3 (or 100%); if two species are found one of the species may be given ranks 1 and 2 (90%), ranks 1 and 3 (80%), or ranks 2 and 3 (30%) depending on the relative dry weight of the two species (Despain et al., 1997; Figure 1). If the frame is empty, which occurs from time to time, no ranks are given.

DWR Ground Rule #4 -- Species Groups or Individuals

Annual grasses, annual forbs, or seedlings may either be: 1) disregarded, 2) recorded as species groups, or 3) recorded as individual species. This ground rule decision will ultimately depend on your goals and objectives for the data set. For example, if annuals comprise a significant portion of the forage base from year to year you may want to include them in your rankings so you can compare their relative contributions during wet and dry years. Whatever is decided, all ground rule decisions must be permanently recorded so that others can repeat the same sampling protocol and ground rules.

Comparative Yield (CY) -- Description

The purpose of the comparative yield (CY) technique is to estimate total standing crop or production of a site. Detailed descriptions of this technique can be found in Despain and Smith (1997; page 49), the Interagency Technical Reference (1999; page 116), and Smith et al. (2012; page 123).

This technique works best in areas with open to dense annual or perennial grasses. As with DWR, there is no requirement for observers to estimate actual weights of plants. Instead, observers use reference quadrats (explained in Ground Rule #1) to rank total plot yield (not on a per species basis[5]) of above ground, current year's production within quadrats along a transect.

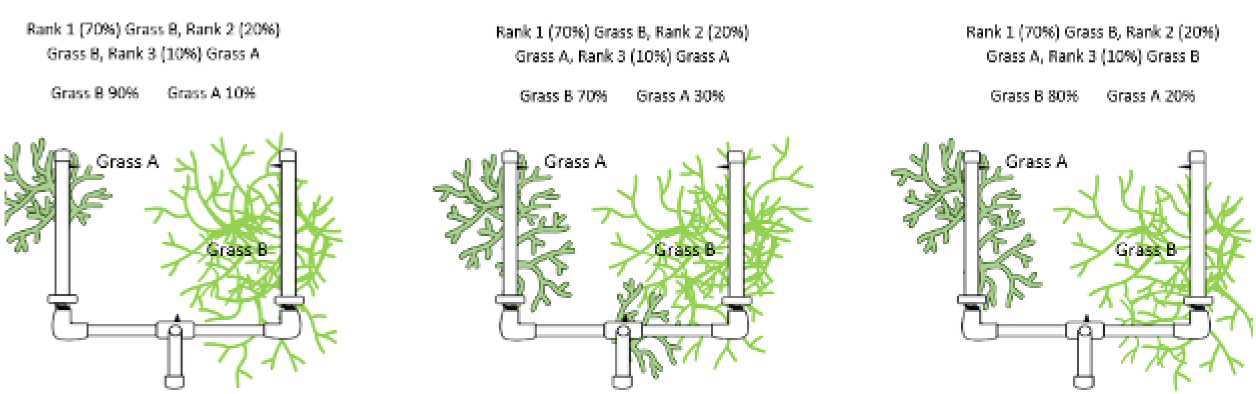

Figure 1. If only two plants are within the vertical projection of the quadrat, a species can receive multiple ranks. Figure credit, Ashley Hall.

[5] If production per species is needed (e.g., lbs/acre or kg/ha, for a particular plant species), % composition derived from the DWR method can be multiplied by total production obtained from the CY method.

CY Ground Rule #1 -- Proper Quadrat Size/Ranking Reference Quadrats

The 40-cm^2 sampling frame works well for the CY technique for most situations encountered on Arizona uplands. Before sampling a transect, five "reference quadrats" are selected to represent an increasing linear relationship of dry weight production that is unique for the site, i.e., 1-5 rankings, least to most (Photo 5). Reference quadrats should be intentionally selected so that "Reference Quadrat 5" contains roughly 5x's more production than "Reference Quadrat 1" (Photo 5). It is important to avoid the temptation to select reference quadrats that contain too little or too much biomass for Ranks 1 and 5, respectively. The intent of the 5 reference quadrats is to capture a representative linear relationship of site productivity while recognizing there will be extremes encountered along the transect that will be lower than Rank 1 and higher than Rank 5. Reference quadrats are clipped and weighed in the field to check an observer's initial ratings. This may have to be done more than once until an observer is confident with their ability to properly rank the five reference quadrats. Then, a new set of reference quadrats are selected and left in place until sampling is complete for a transect. Upon completion of sampling, these quadrats are then clipped and weighed as additional reference data.

CY Ground Rule #2 -- “Inside” or “Outside" Quadrats

Include portions of the total plot's current year’s production within a vertical projection of the quadrat boundary, whether plants are rooted within the frame or not. Exclude portions of plants that are outside the frame's boundary, even if rooted within the frame. This ground rule applies to both reference quadrats and transect quadrats.

CY Ground Rule #3 -- Ranking Quadrats on Transects

Assign ranks from 1 to 5 to each quadrat along the transect revisiting the reference quadrats as needed. When there is doubt between two ranks, half ranks may be used. If an occasional plot is estimated to exceed Reference Quadrat 5, a higher rank (e.g., 6 or 7) can be assigned. Conversely, if

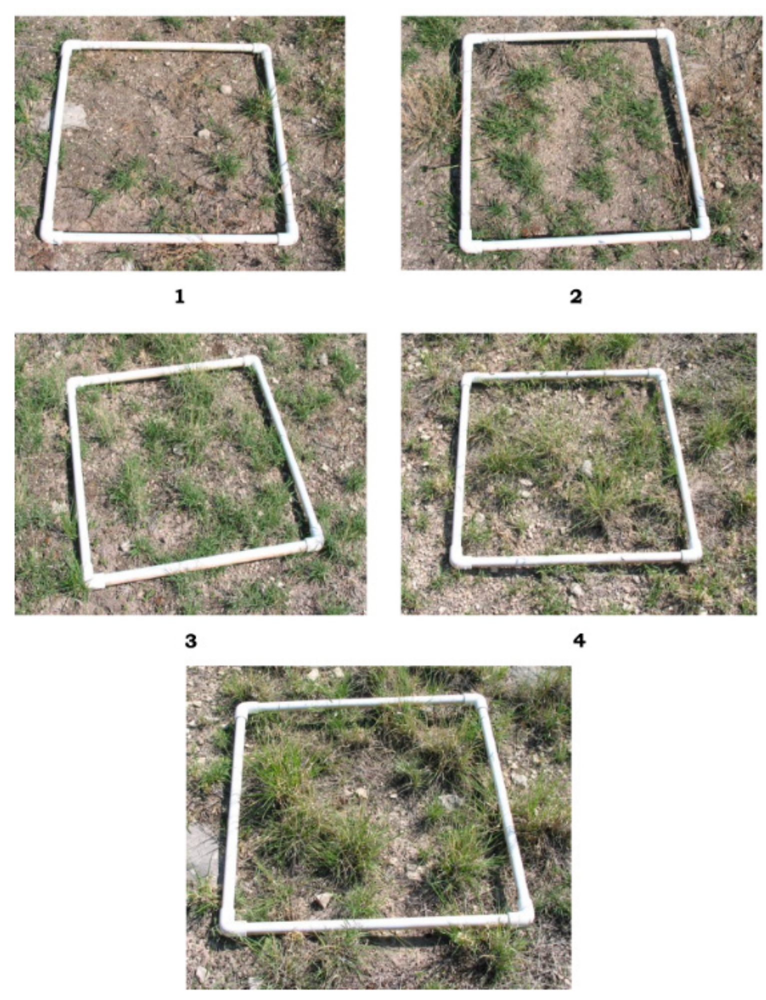

Photo 5. Set of five reference quadrats selected for the CY method. These quadrats (ranked 1-5) represent approximately 5-gram increments in current year's weight, i.e., 1=5g, 2=10g, 3=15g, 4=20g, 5=25g. The actual gram increment among reference quadrats will depend on site productivity and quadrat size. Photo credit, Smith et al., 2012.

a quadrat contains no plant biomass, or a quadrat contains biomass that is estimated to weigh less than Reference Quadrat 1, those respective quadrats may be assigned the ranks of 0 or 0.5. After sampling has been completed, the current year's production is clipped, bagged, dried, and weighed within the 5 reference quadrats as well as within 10-15 ranked quadrats along the transect. Linear regression or ratio analyses can be used to establish relationships between rankings and clipped production obtained from the transect and reference quadrats to derive average production (e.g., lbs/acre or kg/ha) for the transect (see Despain and Smith, 1997; pages 55-57, and, Smith et al., 2012; pages 123-125).

Conclusions

If rangeland studies are to produce reliable results data must be collected in a consistent and repeatable manner over time. Observers should be confident they are following the same sampling protocol and adhering to the appropriate ground rules that are unique to each sampling technique.

The six strategic questions (i.e., why?, what?, when?, where?, who? and how often?) discussed in this paper provide an excellent starting point to help observers: 1) properly frame the rationale for conducting a rangeland study before venturing into the field, and, 2) decide which techniques are best suited to accomplish the goals and objectives of a particular study. Once the appropriate technique(s) has (have) been selected, it is imperative to carefully follow all ground rules that have been developed specifically for each technique.

When strategic sampling protocols and tactical ground rules are clearly and consistently documented and followed, the probability of consistent data collection is high, and the reliability and veracity of data are not likely to come into question. On the other hand, failure to take appropriate measures leads to equivocal sampling protocols, personal bias, and/or unintentional sampling errors which destroys the value of the data collected. Thus, the importance of recording and permanently storing strategic questions and ground rules related to each sampling technique cannot be overemphasized.

The University of Arizona has also created a suite of software, VGS, which can be used on field-going computer tablets increasing the efficiency and accuracy of data collection as well and the analysis and storage of data. Information about using VGS can be found at https://vgs.arizona.edu.

Acknowledgements

The authors would like to thank four anonymous reviewers whose comments and suggestions greatly improved an earlier version of this paper.

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Issued in furtherance of Cooperative Extension work, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture, Edward C. Martin, Interim Director, Extension, Division of Agriculture, Life and Veterinary Sciences, and Cooperative Extension, The University of Arizona.