United States Department of Agriculture

# Mitigating Budget Constraints on Visitation Volume Surveys: **The Case of U.S. National Forests**

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Forest Service
Research & Development
Southern Research Station
General Technical Report SRS-192

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### Cover photo

Bottomland hardwoods in eastern North Carolina. (Photo by Paul Bolstad, University of Minnesota, Bugwood.org)



**May 2014**

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## ABSTRACT

Stratified random sampling (SRS) provides a scientifically based estimate of a population comprising mutually exclusive, homogenous subgroups. In the National Visitor Use Monitoring (NVUM) program, SRS is used to estimate recreation visitation and visitor characteristics across activities on National forests. However, with rising costs and declining budgets, carrying out an annually established SRS poses challenges in how and where to reduce sampling while maintaining statistical precision. Furthermore, any reductions must produce results that validly compare to previous years' SRS in trend analyses.

Accurate estimates are necessary to manage resources for current and future demand; we explore this need through simulations and describe a methodology which can be generalized to any SRS-based process facing budgetary challenges. In this research, recent historic NVUM responses serve as groundwork for simulating various reduction scenarios. The ultimate goal is a manageable set of strategies from which to systematically assign a suitable reduction scenario for each sampling unit (i.e., forest). Using baseline historic data, we determine the sampling error variability by reduction scenario and experiment with various sets of three or four pre-defined strategies to identify viable reduction candidates. A desirable candidate is one that achieves acceptable error bounds (based on historic values) and reductions overall while meeting specified budget constraints (e.g., 20 percent overall fewer sampling days).


**Keywords:** Budget, National Visitor Use Monitoring, precision, sampling, scenarios, simulations, strata.

## INTRODUCTION

The sample is a valuable scientific tool in estimating features of a population of interest because it may be impractical or even unnecessary to carry out a complete census. A population may be too expansive to evaluate within a timeframe or budget. In another case, a population may comprise homogeneous but distinct subunits which can be sampled in smaller numbers while maintaining a high level of statistical precision. Re-sampling on a recurring periodic basis produces estimates which may be analyzed for trends over time and space, especially when the samples are part of a nationwide data collection system with scientific foundations and trained employees collecting the data. There can be fiscal and administrative challenges, particularly when the budget is nominally static through time but sampling costs rise.

This research is motivated by the objective to maintain the same level of statistical precision while adjusting for budget constraints. Our particular application is to the National Visitor Use Monitoring (NVUM) program for U.S. National forests. However, the approach is applicable to a wider array of stratified random sampling designs. Though there are multiple approaches in meeting budget goals through cutbacks, we examine various strategies in reducing the number of sampling days.

The NVUM program uses a survey-based approach in estimating the volume and characteristics of recreation visitation to units within the National Forest System (Zarnoch and others 2011b). The goals include evaluating the number of visits and the mix of activities in which they engage on National forests, as well as describing recreationists in terms of demographics, satisfaction, travel patterns, spending patterns, and visit duration. Understanding recreation at National forests in terms of visits and activity participation across space and time is essential for long-range resource planning, and it allows for more efficient policymaking and proactive management of resources.

In this research, we simulate various schematics for reducing the total number of sampling days. The goal is to accommodate budgetary reductions by reducing the volume of survey effort by 20 percent, while preserving the statistical validity of visitation estimates. Further, since it is not likely that a single strategy will be applicable to all National forests, we seek to develop a manageable set of reduction strategies so that one can be systematically assigned to each national forest in the future. Our context is the NVUM survey framework for estimating visitation volume, but simulating reductions as described here can be generalized to stratified random sampling designs with historic observations as a testing ground for comparing the accuracy of reduced samples. The methodology presented here allows for experimenting with sampling rate reductions at different levels according to some property of the stratum. The end product is a reduction strategy which has been tested on recent data as opposed to making completely ad hoc cuts in the field which could disrupt a trend analysis. After establishing the background and motivation in further detail for this application to the NVUM, we discuss the results and future implications of this work.

## BACKGROUND: SAMPLING STRATEGIES AND THE NVUM SAMPLING PROGRAM

The NVUM program, initiated in 1998 and still evolving, utilizes a stratified random sampling design for estimating and characterizing visitor volume (Cochran 1977). In general, a stratified sampling approach is appropriate when the population can be divided into subgroups known as strata, which are homogeneous and mutually exclusive. Together, the members of each stratum make up a sub-population with its own distinguishing characteristics. If a single sampling method is not well-suited for all strata, then stratification allows for varying sampling methods by subgroup (Cochran 1977). For instance, if a stratum has a low and variable volume of participation, it would not be advisable to use a sampling method that works well for a large and steady inflow of participants. Furthermore, stratification is well-suited for studies that involve surveys administered by an agency with field offices responsible for surveying a portion of a population (Cochran 1977).

The step of stratification maximizes variability between strata but minimizes variability within each stratum. The resultant estimators have reduced variance (greater precision) and improved accuracy (de Vries 1986, Gregoire and Buhyoff 1999). Due to the estimators' precision properties, we can use the individual strata estimates to produce a precise estimate for the overall population (Cochran 1977). If a simple random sample is carried out in each stratum, then the method is known as stratified random sampling. For each stratum, each member has an equally probable chance of being selected.

For a population consisting of $L$ strata, suppose that there are $N_1, N_2, \ldots, N_L$ members, so that the total population size is $N = N_1 + N_2 + \ldots + N_L$ and samples of size $n_1, n_2, \ldots, n_L$ are taken for each stratum. An important question in stratified sampling is how to allocate the sample sizes for each stratum, operating under the assumption that the subgroups have already been delineated. The appropriate allocation will maximize the precision of the estimators. A strategy known as the Neyman allocation provides a convenient representation for the optimal size $n_i$ ($i = 1, \ldots, L$) to sample for maximizing precision based on the size of the population in stratum $i$ and the true variance of the variable measured/calculated on the stratum (Cochran 1977). However, this formula assumes that the population size in stratum $i$ is known to be $N_i$, which is not the case with the NVUM process—in fact, it is a component of the very estimates we are trying to obtain. Thus, a methodology used in optimal allocation of sample sizes for SRS does not apply to the NVUM sampling reduction problem.

As a result of collaborative research efforts, NVUM data are collected in a systematic fashion across all National forests, and the subsequent visitation estimates obtained from surveys are within a satisfactory level of statistical accuracy. The sampling procedure does not treat the exiting volume of visits in the population of site days (the combination of a given site and a calendar day) across the National forests as uniform. Rather, it accounts for the inherent variation imposed by site-type and expected exiting volume via a stratified random sampling methodology.

The two measures of visitation used in NVUM are recreation site visits (SV) and national forest visits (NFV) (Zarnoch and others 2011b). Each NFV comprises one or more SV. SV is estimated as a combination of traffic counts on sampled site-days, the average number of people per vehicle, and the proportion of exiting traffic that is last-exiting recreationists (LER) (Zarnoch and others 2011b). An LER is an individual who has visited a national forest site or area for recreation and is concluding the visit by exiting the site for the last time for that day. Visit durations can vary, being as short as a few minutes or as long as several days; in addition, the individual can engage in one or more recreation activities on lands and/or waters in the national forest (at a single site or at multiple locations). NFV is estimated by dividing SV by the average number of sites visited per NFV. The simulations developed in the current analysis use statistics based on SV and NFV to observe which sampling reductions are most effective. Though not necessarily globally optimal, they are at least practical and computable, as we later discuss in the analysis.

The NVUM process identifies four site-types on each forest: day-use developed sites (DUDS), overnight-use developed sites (OUDS), undeveloped general forest areas (GFA), and designated wilderness [1] (WILD). The sites and areas in these four site-types make up the spatial dimension of the population to be sampled. The estimates from Federal fiscal year (FY) 2007 to 2011 indicate that the majority of recreation within National forests occurs in the GFA portions; exiting survey data suggest that 52 percent of SV and 63 percent of NFV were in the GFA portion of forests.

Another important identifier or aspect of sites is whether they are proxy or nonproxy. On a proxy site, recreation visitation may be assessed using data that characterize all users of the site, are exact counts rather than estimates,

[1] Wilderness includes lands and waters within the National Wilderness Preservation System; it does not include Wilderness Study Areas, Research Natural Areas, or other roadless areas.

and are of an NVUM-approved type, such as fee receipts, fee envelopes, mandatory permits, permanent traffic counters, and ticket sales (English and others 2002). A much smaller portion of sampling occurs at these sites with visitation proxy data, which more accurately reflect the recreation traffic and do so over a period of months. This property reduces the variation of visitation estimates (Zarnoch and others 2011b). Proxy sites do not require use of a traffic counter, but some sampling of recreationists is needed to estimate conversion factors from the data (e.g., fee envelopes) to the relevant SV or NFV measure. Thus, interviews are carried out in a 6-hour period of daylight which maximizes the opportunities to survey LERs. Further details on how these data are incorporated into calculations of visitation estimates are available in publications devoted to or employing the NVUM methodology, such as in English and others (2002), White and others (2007), or Zarnoch and others (2011a).

A site which does not meet the above criteria is a nonproxy type, in which case estimates utilize 24-hour traffic counts as a measure of use for one sampled site day. Compared to nonproxy sites, a proxy site requires lower levels of sampling. For the present simulation exercise, it is important to note that proxy sites have very low costs for sampling and thus are not included in these exercises and subsequent discussions. We consider the challenge of reducing the more expensive sampling of nonproxy site days.

At each site, every day of the year is characterized by an expected exiting volume of visitation: No use (N), Low (L), Medium (M), High (H), and Very High (VH). These daily exiting volume levels define the temporal dimension of the population. For nonproxy sites, the combination of site-type and use-level defines a sampling stratum: for example, a Medium use day for a day-use developed site (DUDS) is denoted as DUDS-M. After dividing the sample space into these 4×4=16 strata with visitation, the stratified random sampling procedure conducts a simple random sample on each stratum (de Vries 1986) from the selection of site days (the combination of site-type and use-level). If desired, estimators may be determined for each of the strata, or forests, but the overall estimate of visitation on all National forests is the primary goal. Standard NVUM procedure prescribes no more than 50 proxy site days and appropriate sampling of nonproxy site days subdivided by site-type and use-level. The latter is dependent upon a minimum of 8 site days (or fewer, if 8 are not available), computations from the site's previous year's estimates, and weighting by importance of strata.

A survey round is completed over the course of five years, where on-site survey questionnaires and data collection occur on approximately 20 percent of all National forests each FY, running from 1 October to 30 September. Thus, the monitoring process for a given national forest takes place on a 5-year cycle. The majority of sampling is carried out at sites where the amount of traffic for the 24-hour period of the interview day is recorded in conjunction with 6 hours of visual calibration of the counter and onsite interviews to estimate the proportion of those exiting who are LER. For this portion of the sample, the traffic tally from the counters is recorded, and surveys are administered by personnel during a randomly designated time period, chosen out of two possible time slots ideal for encountering exiting recreationists.

The NVUM survey form consists of a core set of questions asked of all eligible, randomly chosen respondents; to qualify, the respondent must be at least 16 years of age and must be exiting the site or area. If multiple individuals are in a vehicle selected for the interview, the person who is at least 16 years of age with the most recent birthday is designated the primary respondent. The first set of questions determines what proportion of traffic is there for recreation versus other purposes, and what proportion are LER. For non-LERs, the survey terminates; for LERs, additional information includes demographics, activity participation, and duration. Approximately one-third are also asked questions related to the levels of satisfaction with the conditions and access of resources, as well as the perception of crowding; another one-third are asked about their economic spending during the trip. Responses provide insight into contribution of tourism to the local economy and satisfaction of recreationists, as well as identifying the primary recreation clients in terms of gender, age, ethnicity, and other socioeconomic characteristics.

## CONSIDERATIONS AND CHALLENGES FOR A MODIFIED SAMPLE PROGRAM

Balancing survey administration and tighter budget constraints entails several challenges: (1) determining the mix of sampling rates across the strata; (2) spatial and temporal distribution of sample days to ensure adequately representing recreationists by stratum while minimizing loss of precision effected by a decrease in sampling days; and (3) meeting budget constraints while maximizing information obtained. As results are based on traffic counts and survey responses obtained on the site-days chosen for field sampling, two important considerations arise: one is statistical in nature and the other fiscal. First, there is the issue of how to best distribute the sampling days for forests across the 16 strata while maintaining accuracy of estimators. To achieve an accurate estimation, a forest or stratum that has high variability in visitation may require more sampling days versus one that has a consistent exit volume of recreationists. Second, the NVUM process must adapt to a static nominal dollar budget despite rising in-field costs, thereby necessitating approximately 20-percent reduction in sampling days over all national forest sampling days.

A day of field data collection is currently budgeted at around $400, but actual costs average about 20 percent higher. The cost covers preparation by personnel, travel to and from sites, setup of traffic counters and appropriate signage, 6 hours of onsite interviewing, and retrieval of traffic counter data. Annual national workload assignments average around 5,500 days of sampling for approximately 24 National forests per FY. The work described here is motivated by the need to reduce sampling days to remain within budget constraints, fully fund the fieldwork, and attempt to maintain the current confidence levels for visitation estimates. Another constraint is to allocate reductions so that each forest has some cutback in sampling days but none exceeds roughly 25 percent (the highest threshold we have set that allows for some flexibility with the goal of 20 percent but not excessively so).

## Simulation Study

The FY 2011 data from 29 National forests, including some forest subunits that were sampled as independent units, were used as a baseline for simulating sample size reductions which meet budgetary constraints and statistical accuracy goals. The NVUM sample size allocation from the FY 2011 survey must be reduced in an appropriate manner to meet these objectives. Though the simulations were based on estimates, the computations were rooted in an established scientific methodology and thus were treated as reasonably accurate representations of the FY 2011 SV and NFV measures. Additionally, the original prework of NVUM calls for the use of previous year estimates (standard errors) in deciding nonproxy site day allocations by stratum; this dependency upon the recent historical survey was satisfied in the use of FY 2011 estimates as recent historical sample data. (The list of forests/subunits and days of FY 2011 sampling for each is found in the appendix.) We are able to select an appropriate sample size reduction by evaluating the properties of the SV and NFV estimators under various sample size reduction scenarios and comparing them against the estimators from the complete FY 2011 sample.

For a set of sampling units, we may achieve a most accurate estimate (under the necessary constraint of reduction) by tailoring the reductions to each forest. For 29 National forests, this may produce at most 29 different reduction strategies. This decisionmaking by individual forests is an undesirable sampling reduction strategy: it is cumbersome, time-consuming, and non-systematic. Though it may produce more accurate estimators relative to the historic estimates, the costs make it impractical. A more general, practical approach is to maintain a reasonable set of scenarios and to assign each forest an appropriate reduction strategy from the set. Thus, we consider six general sampling scenarios (see table 1 for descriptions). In Scenario 1, reductions are carried out equally across all strata, regardless of site-type and use-level. Scenario 2 reduces the sampling equally for the DUDS and OUDS strata, while Scenario 3 does that for the GFA and WILD strata. The reductions in sample size for Scenario 4 affect only strata based on the GFA

**Table 1—Sampling strategies by site-type and use-level for simulation scenario**

| Scenario | Description of sampling rate modifications for simulation |
|---|---|
| **Scenario 1** | Reduce DUDS, OUDS, GFA, and WILD simultaneously from 100% to 70% in increments of 10%. |
| **Scenario 2** | Reduce DUDS and OUDS simultaneously from 100% to 70% in increments of 10%; maintain 100% for GFA and WILD. |
| **Scenario 3** | Maintain 100% for DUDS and OUDS; reduce GFA and WILD simultaneously from 100% to 70% in increments of 10%. |
| **Scenario 4** | Maintain 100% for DUDS, OUDS, and WILD; reduce from 100% to 70% in increments of 10% for GFA. |
| **Scenario 5** | Reduce DUDS, OUDS, GFA, and WILD simultaneously from 100% to 10% in increments of 10% for use-level L only; maintain 100% otherwise. |
| **Scenario 6** | Reduce DUDS, OUDS, GFA, and WILD simultaneously from 100% to 25% in increments of 25% for use-level H and VH only; maintain 100% otherwise. |

Site-types: DUDS = day-use developed site; OUDS = overnight-use developed site; GFA = undeveloped general forest area; WILD = designated wilderness.

Use-level: L=low; H=high; VH=very high.

site-type. In Scenarios 5 and 6, reductions are based on use-level: only use-level low (L) in 5 and only high or very high (H or VH) in 6. Within each scenario there are subscenarios that produce different levels of reductions. An example subscenario would be Scenario 5 with 40 percent sampling (60 percent sampling reduction) for strata DUDS-L, OUDS-L, GFA-L, and WILD-L; another would be Scenario 1 with 80 percent sampling from all strata (20 percent sampling reduction).

The sampling cost savings are assumed to be a linear function of the overall reduction in on-site interview days. For example, if a certain strategy produces 5 percent fewer sampling days overall than another, then the total cost will be 5 percent lower. From a cost standpoint, it is irrelevant whether the fewer days come from a reduction in only the use-level L or are spread across all strata. What is not clear is how the performance of the visitation estimators relates to a cutback in a certain site-type or use-level; we explore this challenging matter through simulations.

We simulate sampling reductions based on the scenario/subscenarios from table 1 using PROC SURVEYSELECT (SAS Institute Inc. 2009) to repeatedly sample from the actual FY 2011 survey data. However, we recognize the possibility of a scenario/subscenario diminishing the number of sampling days so low that it is no longer useful for estimation. To avoid that result, we impose a minimum requirement of at least 10 sample days per site-type use-level stratum in order to represent members from each stratum. If a stratum has fewer than 10 sample days to start, then no reduction is allowed. All reductions occur in strata which can afford some loss in membership. If the initial stratum size is > 10 but the reduction would produce a count < 10, the reduction was forced to stop at a sample of size 10. In preliminary work, we determined that a minimum of five sampling days per stratum was insufficient; this resulted in underrepresentation in multiple strata. Setting the threshold too high can preclude some useful reduction strategies. However, care must be taken with PROC SURVEYSELECT to ensure that all strata are included in the sampling, specifically when the full stratum size is < 10. Without the appropriate programming steps in SAS, PROC SURVEYSELECT excludes strata with counts less than the minimum.

We carried out 100 simple random sample replicates of site days without replacement using the appropriate sampling rates for each stratum, given by scenario/subscenario. For each forest *i* and sampling scenario, we compute the average visitation estimates ($\overline{SV_i}$, $\overline{NFV_i}$), standard errors [$\overline{SE(SV)_i}$, $\overline{SE(NFV)_i}$], and coefficients of variation [$\overline{CV(SV)_i}$, $\overline{CV(NFV)_i}$] for SV and NFV, respectively, across the 100 replicates. To create a ratio of the statistic to the "baseline" value, i.e., the one from the complete sample (such as the SV estimate denoted by $\overline{SV_{base}}$), we compute for the 29 forests as follows:

$$R\left(\overline{SE(SV)_i}\right) = 100\frac{\overline{SE(SV)_i}}{SE(SV)_{base,i}} \quad (1)$$

$$R\left(\overline{SE(NFV)_i}\right) = 100\frac{\overline{SE(NFV)_i}}{SE(NFV)_{base,i}} \quad (2)$$

$$R\left(\overline{CV(SV)_i}\right) = 100\frac{\overline{CV(SV)_i}}{CV(SV)_{base,i}} \quad (3)$$

$$R\left(\overline{CV(NFV)_i}\right) = 100\frac{\overline{CV(NFV)_i}}{CV(NFV)_{base,i}} \quad (4)$$

All of the ratios are indexed at 100 relative to the baseline, essentially becoming a percentage of error relative to the full set. Averaging over 100 replicates avoids the possibility of basing all inference on a single or few samples that may fail to adequately represent the population. For any of these ratio statistics, a value > 100 indicates that the reduced sample exceeds the full-sample estimate; a ratio < 100 means that the reduced-sample estimate is less than the baseline value. For example, an indexed ratio of 107 for equation (1) indicates that the reduced sample has exceeded the full sample SE of SV by 7 percent. From this we have a convenient measure for assessing relative error and designating a tolerance for error, or the maximum absolute percentage deviation permitted for further consideration. If the tolerance is set at 10 percent, then for an interval centered at indexed statistics of 100, we will accept sampling schemes which produce estimates between 90 and 110. Preliminary analysis shows the means to be consistent, as the SV and NFV estimators are unbiased for any of the reduced sample sizes. The sums of squared errors (SSEs) provide guidance as to which scenarios are most desirable. The SSEs are based on the indexed statistics created by averaging over all 100 replicates; we sum over all forests the squares of the difference between the indexed statistics for the reduced sample ($I_{i,j}$) and the full set ($F_{i,j}$), or

$$SSE_j = \sum_{i=1}^{29}\left(I_{ij} - 100\right)^2 \quad (5)$$

where $I_{ij}$ is equation (1) or (2) or (3) or (4) for forest *i*, that is,

$$I_{ij} = R\left(\overline{SE(SV)_i}\right) \text{ or } R\left(\overline{SE(NFV)_i}\right) \text{ or } R\left(\overline{CV(SV)_i}\right) \text{ or } R\left(\overline{CV(NFV)_i}\right)$$

The SSEs are computed for six statistics (*j* = 1, …, 6, respectively): NFV mean, NFV standard error, NFV coefficient of variation, SV mean, SV standard error, and SV coefficient of variation. By using the SSEs, we aggregate individual deviations relative to the full sample and provide a sense of the overall performance of the estimators. Thus, SSEs are a guideline for judging how well the estimators perform under a sampling scenario/subscenario. The goal is to select those that produce lower values. If there is a large discrepancy between the statistics computed for the full and reduced samples, then we will see a larger contribution to the SSE. Though the summation alone does not determine which forests contribute the most or least error, we can ascertain a desirable sampling reduction (using the low-SSE sampling criterion) by observing a small overall SSE.

We assess the performance of the scenario/subscenarios according to four criteria: (1) the ability to reduce an individual forest's sampling days by 15 to 25 percent; (2) SV and NFV statistics (standard error and coefficient of variation) within a specified tolerance of error from the baseline value; (3) lower SSEs for the mean, SE, and CV of SV and NFV; and (4) overall reduction across all forests amounting to approximately 20 percent to satisfy the budget constraint. If no candidates reduce by 15 to 25 percent, we then consider those that reduce by less than 15 percent while remaining within the tolerance limits for error.

SV and NFV estimates exist for the full FY 2011 data set for each forest. The reduced samples from 100 SRS provide a new estimate of SV and NFV for each scenario/subscenario. The simulations allow us to observe the effects of various scenario/subscenario reductions, using the computed statistics for gauging accuracy. We examined a tolerance of error from the baseline ranging from 10 percent down to 5 percent in 1-percent increments. With an 8-percent error tolerance, it was not possible to achieve a 20-percent reduction overall. Since the more accurate estimates are typically affiliated with lower sampling-day reductions, we did not consider a tolerance limit below 10 percent. This meets the sampling reduction needs while maintaining a pool of desirable reduction strategies per national forest. With a 10-percent tolerance, the indexed estimates for consideration must fall between 90 and 110; occasionally, it was necessary to consider candidates slightly above the interval.

This project is concerned with both accuracy and sample size reduction using the estimates of FY 2011 as baselines in simulated reduction strategies. In most cases, accuracy was a function of sample size reduction; less reduction produces a more accurate sample estimate. We are seeking a sampling scenario assignment that balances accuracy and sample size allocations based on the reduction goals. The criteria of sample size reduction and membership in the error tolerance interval results in a pool of possible subscenario candidates of $< 10$, in most cases. Each forest produces a unique set of viable candidates within this range. The most desirable candidates for each forest are those whose reduction-of-days percentage approaches 20 pecent, while remaining close to the baseline value on all six statistics. A number of subscenarios in table 1 can be readily eliminated, specifically those affiliated with reductions over 70 percent. Since certain subscenarios work for multiple forests, the feasibility of a systematic allocation seems possible.

Each forest or forest subunit is associated with a set of candidate scenario/subscenarios; some of these do not respond well to a given forest, a result of characteristics to be determined. The following process determines which candidates to consider for a given forest:

1) The initial pool consists of candidates producing a 15 – 25 percent reduction in sample size; occasionally, a lack of candidates necessitated consideration of some outside this interval.
2) Candidates are filtered by the criterion of being within 10 percent of the baseline value for the SV and NFV statistical measures; occasionally, it was necessary to relax this value to slightly over 10 percent in order to consider a candidate that achieved greater reduction levels.
3) The best candidates are those that both meet accuracy standards and produce the largest reduction in sampling days.
4) The goal of overall 20-percent reduction in sample size is assessed after all forests are assigned a subscenario. This functions as the final criterion, which further narrows the field of candidates.

## Triplet and Quadruplet Assignments

It is not likely that a single scenario applied to all forests will yield an optimal result in reducing the sample size while maintaining accuracy. Each national forest is unique on some set of characteristics, such as proximity to population centers, geographical influences on recreation, and seasonality. The next objective is to identify a small subset of subscenarios that will—as a set—sufficiently meet the objectives while achieving lower sums of squared errors for indexed statistics. That is, we seek a small pool of reduction scenarios that can be allocated methodically according to some features of the national forests, such as visitation volume, size, or location. For this, we consider three- or four-scenario sets (called triplets and quadruplets). Each forest is assigned one of the scenarios in the set. We included eight scenarios as possible set candidates, drawn from the ones that performed best on the individual forests. The eight were: (i) Scenario 1 with 20-percent reduction, (ii) Scenario 1 with 30-percent reduction, (iii) Scenario 2 with 30-percent reduction, (iv) Scenario 4 with 30-percent reduction, (v) Scenario 5 with 30-percent reduction, (vi) Scenario 5 with 40-percent reduction, (vii) Scenario 5 with 50-percent reduction, and (viii) Scenario 5 with 60-percent reduction. Almost all triplets and quadruplets formed from this group of eight included at least one subscenario that worked well for each forest. We did not include subscenarios that worked for only one forest, even if that scenario one was the best reduction strategy for the forest; we exchange customization for a generalizable approach at a slight cost in accuracy.

We created all possible sets of three and four from these eight scenarios, for a total of 56 triplets and 70 quadruplets. For example, one triplet is the set of Scenario 1 with 20-percent reduction, Scenario 1 with 30-percent reduction, and Scenario 5 with 60-percent reduction. An exhaustive simulation with unlimited computing power could examine all permutations of these three scenario/subscenarios for all 29 forests and obtain a best assignment. For efficiency, we further restricted the analysis to limiting each forest to candidates from the triplet which had been shown to work well.

In some triplets and quadruplets, there were clear leading candidates for a given national forest; in others, one candidate was best for accuracy but another for reduction. In the latter case, the simulations often considered both candidates just to ensure that both were included among the possibilities. In some cases, none of the triplet or quadruplet scenario/subscenario combinations worked strictly within the desired constraints; therefore, it was necessary to consider reducing an individual national forest's sampling days by < 15 percent or slightly > 25 percent, but never as much as 30 percent. Additionally, it was sometimes necessary to relax the 10-percent error tolerance to 13 percent in order to find which candidate from the triplet or quadruplet worked best. Under the relaxed conditions, if a triplet or quadruplet did not result in a viable assignment across the 29 National forests, it was discarded from consideration.

There were 21 triplets and 35 quadruplets in the final set of assignments that we assessed. We assessed these by the ability to produce an overall sample-day percentage reduction of 19 – 20 percent and have lower SSEs for the statistical measures (mean, standard error, and coefficient of variation for SV and NFV). Among the statistical measures, the distinguishing feature is the SSEs, especially in the case of the indexed SV and NFV means. Accuracy is the sum of the variance and the squared bias, so a bias that is close to zero implies that accuracy is evaluated by the variance.

## RESULTS

The simulations examined assignments within 21 triplets and 35 quadruplets for the 29 National forests. We used the following color code to represent the percentage reductions by scenario:

| | |
|---|---|
| (dark blue) | 10% Reduction (Scenarios 1-5), 25% Reduction (Scenario 6) |
| (red) | 20% Reduction (Scenarios 1-5), 50% Reduction (Scenario 6) |
| (green) | 30% Reduction (Scenarios 1-5), 75% Reduction (Scenario 6) |
| (yellow) | 40% Reduction (Scenario 5) |
| (light blue) | 50% Reduction (Scenario 5) |
| (dark red) | 60% Reduction (Scenario 5) |
| (purple) | 70% Reduction (Scenario 5) |
| (gray) | 80% Reduction (Scenario 5) |
| (orange) | 90% Reduction (Scenario 5) |

In supporting Excel® worksheets, this code is used to color cells to represent the percentage reduction while the text in the cell represents the scenario number. For instance, the following quadruplet involves Scenario 1 at 20-percent reduction, Scenario 1 at 30-percent reduction, Scenario 4 at 30-percent reduction, and Scenario 5 at 40-percent reduction, respectively.

| | | | |
|---|---|---|---|
| 1 | 1 | 4 | 5 |

The top candidates for triplets and quadruplets appear in tables 2 and 3, along with the SSEs for the six indexed statistics. Here, the triplet or quadruplet ID is the unique number used to reference an assignment in a convenient manner. The percentage reduction column shows the percentage reduction for overall sample size (sampling days). The next six columns contain the SSE measures for the indexed (at 100) statistics for the SV mean, SV standard error, SV coefficient of variation, NFV mean, NFV standard error, and NFV coefficient of variation, respectively. The SSE for any of the indexed statistics provides a measure of variability of the estimate adjusted to the baseline, and this may provide additional insight that is not available through the original estimate. As the SV mean estimate may be unbiased, it is more informative to consider how the estimates fluctuate under the scenario/subscenario by the corresponding SSE. Furthermore, the SSEs for the SV, SE, and CV reflect the variability of the standard errors and coefficient of variation, which are related to the mean by computation. Thus, there is a relationship among the three SSEs under consideration that provide an overall assessment of the candidate.

As in tables 2 and 3, the overall sample size percentage reduction appears in the 19- to 20-percent range. These top candidates were chosen on the basis of balancing the

**Table 2—Top triplet candidates for 29 forests from simulation study, with selected candidate highlighted in orange**

| Triplet ID | % Sample Size Reduction | SSE SV Mean | SSE SV SE | SSE SV CV | SSE NFV Mean | SSE NFV SE | SSE NFV CV |
|---|---|---|---|---|---|---|---|
| 17 | 0.1893905 | 16.17968 | 1438.769 | 1256.743 | 13.86722 | 1703.125 | 1536.33 |
| 19 | 0.1914221 | 20.03314 | 1435.095 | 1282.951 | 18.53394 | 1708.317 | 1583.459 |
| 32 | 0.2006772 | 24.33266 | 1645.481 | 1442.783 | 21.50427 | 1939.316 | 1732.364 |
| 35 | 0.1995485 | 24.13526 | 1489.247 | 1322.569 | 21.2975 | 1774.063 | 1610.153 |
| 39 | 0.2011287 | 24.52816 | 1940.505 | 1591.717 | 21.59005 | 2116.518 | 1841.076 |

SSE = sums of squared errors; SV = site visit; SE = standard error; CV = coefficient of variation; NFV = national forest visit.

**Table 3—Top quadruplet candidates for 29 forests from simulation study, with selected candidate indicated in orange**

| Quad ID | % Sample Size Reduction | SSE SV Mean | SSE SV SE | SSE SV CV | SSE NFV Mean | SSE NFV SE | SSE NFV CV |
|---|---|---|---|---|---|---|---|
| 13 | 0.1878104 | 18.93423 | 1394.297 | 1217.442 | 16.48626 | 1637.501 | 1485.249 |
| 33 | 0.2013544 | 23.59944 | 1971.89 | 1663.471 | 20.75768 | 2202.976 | 1918.124 |
| 55 | 0.1936795 | 17.08092 | 1435.854 | 1272.793 | 15.14705 | 1709.232 | 1552.95 |
| 80 | 0.1941309 | 20.25986 | 1434.657 | 1284.046 | 18.66755 | 1699.362 | 1572.586 |
| 101 | 0.2002257 | 23.71797 | 1560.447 | 1389.108 | 20.86359 | 1911.046 | 1737.189 |

SSE = sums of squared errors; SV = site visit; SE = standard error; CV = coefficient of variation; NFV = national forest visit.

percentage reduction with the SSEs. First, we filtered the pool of combinations for each triplet or quadruplet, choosing those with overall reductions of at least 19 percent. From this reduced set, we manually select the candidates which yield lower SSEs in both the SV and NFV measures (relative within the statistic over all candidates) at varying levels of percentages. We then chose the one which balanced the two goals. We also note that from an administrative standpoint it is more efficient to manage assigning forests to a set of three reduction scenarios than to four scenarios, which gives some preference for a triplet as the final choice. Adding in more scenarios creates more administrative overhead, becoming more cumbersome to manage which scenario to assign to each forest.

Figures 1 and 3 illustrate the plots for 50 randomly chosen candidates per triplet or quadruplet, respectively, showing the overall sampling day percentage reductions against the SSEs of the six statistics. Figures 2 and 4 are based on the same plot as in figures 1 and 3 but also show the top five candidates indicated by the nontransparent points.

On the prescreened or preselected set of scenario/subscenarios per triplet or quadruplet, we explore the possibilities in one of two ways. First, if the permutations from the prescreened triplet or quadruplet are less than 100,000, then we carry out an exhaustive search of the prescreened pool; otherwise, we randomly choose 100,000 unique assignments. For example, if we have determined that 10 forests respond favorably to two scenario/subscenarios from a triplet and the remaining 19 forests to just one, then we will have 1,024 permutations to consider. If each forest works well with two scenario/subscenarios from a triplet, then we have 229 = 536,870,912 possibilities. In this case, we randomly choose 100,000 unique assignments from the pool of candidates. This value was chosen arbitrarily large in order to explore more possibilities; in another study, we might observe the efficacy of using a smaller value and thus a lower running time.

We present 50 points in order to show the clusters which form by the triplet or quadruplet; otherwise, the point density is so great that any useful patterns are obscured. A convenient way to view the clusters is the convex hull on the set of those permutations we explore and not just on the 50 points. A two-dimensional convex hull can be thought of as a polygon adjoining the outermost points such that a line drawn between any two points is contained within the set. Figure 5 is an example of the point density (A) forming the shape which delineates the convex hull shown in (B). The points are from the triplet containing the top candidate, which is indicated in red. Figures 6 and 7 are the convex hulls for each of the triplets and quadruplets under study, respectively. There is a poorly performing triplet in figure

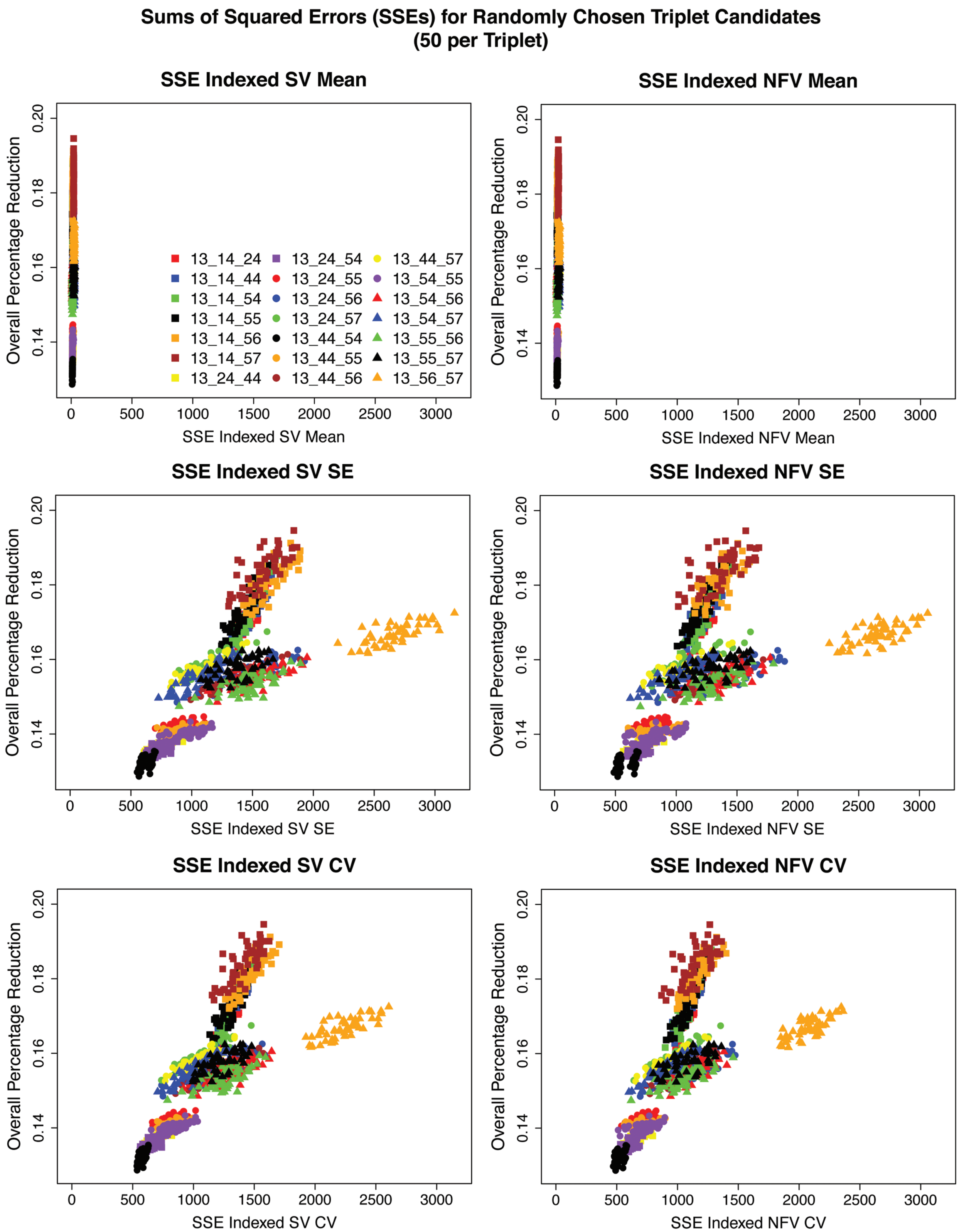


*Figure 1—Plot of sums of squared errors (SSEs) for six indexed statistics computed for 50 randomly chosen members of 21 triplets under study. For convenience, the legend displays the triplets as a sequence of three numbers, such as 13_14_24. The first digit of each of the three numbers symbolizes the scenario, and the second the level of reduction (i.e., 1 = no reduction, 2 = one increment reduction, 3 = two increment reduction, and so on, where increments are in 10 percent for Scenarios 1 to 5 and 25 percent for Scenario 6). Thus, 13_14_24 is the triplet with Scenario 1 at 20-percent reduction, Scenario 1 at 30-percent reduction, and Scenario 2 at 30-percent reduction.*

**Sums of Squared Errors (SSEs) for Randomly Chosen Triplet Candidates (50 per Triplet) and Top Triplet Candidates**

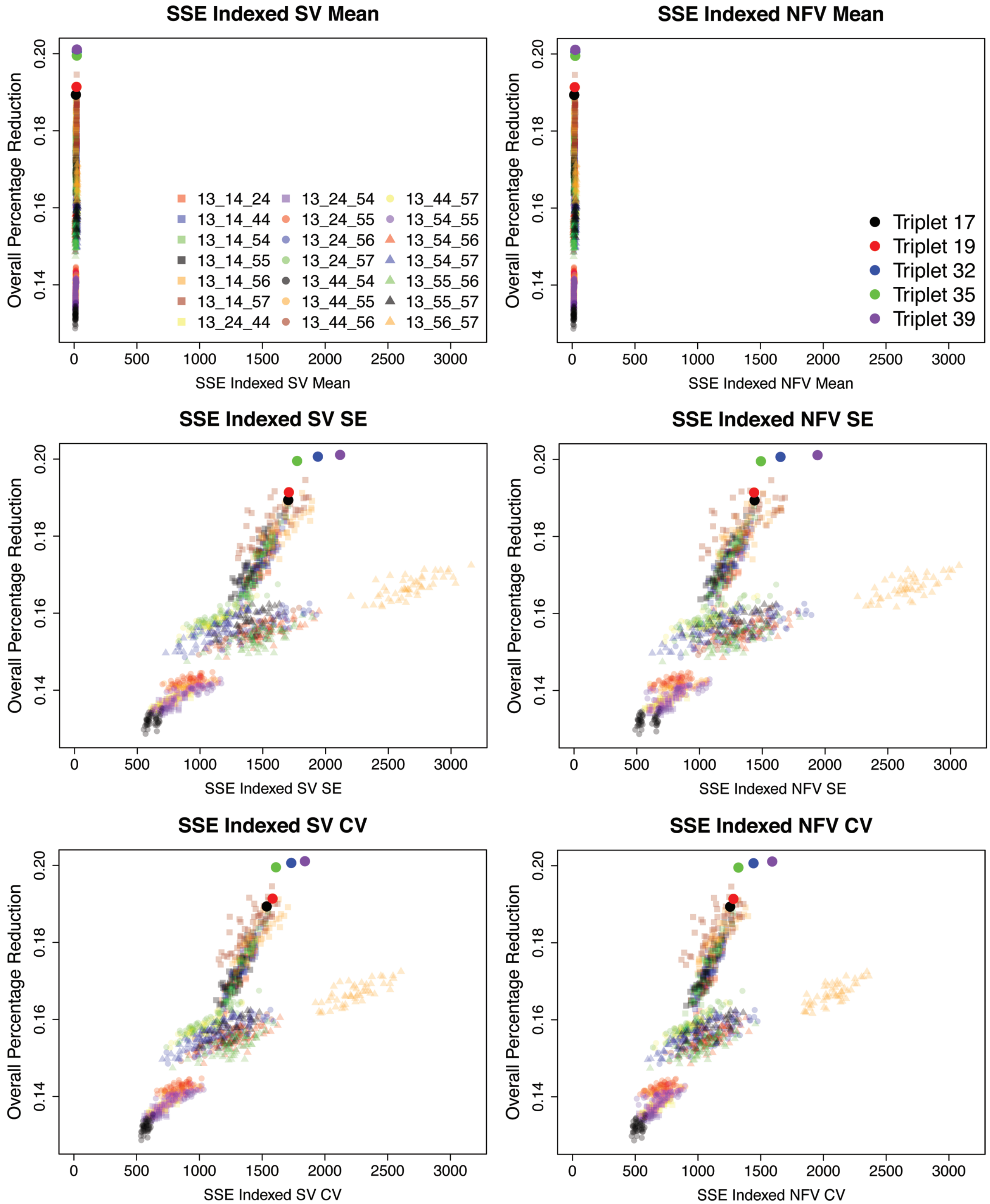


*Figure 2—Plots of 50 randomly chosen members of the 21 triplets under study showing the relative position of the top five triplets: 17, 19, 32, 35, and 39. For convenience, the legend displays the triplets as a sequence of three numbers, such as 13_14_24. The first digit of each of the three numbers symbolizes the scenario, and the second the level of reduction (i.e., 1 = no reduction, 2 = one increment reduction, 3 = two increment reduction, and so on, where increments are in 10 percent for Scenarios 1 to 5 and 25 percent for Scenario 6). Thus, 13_14_24 is the triplet with Scenario 1 at 20-percent reduction, Scenario 1 at 30-percent reduction, and Scenario 2 at 30-percent reduction.*

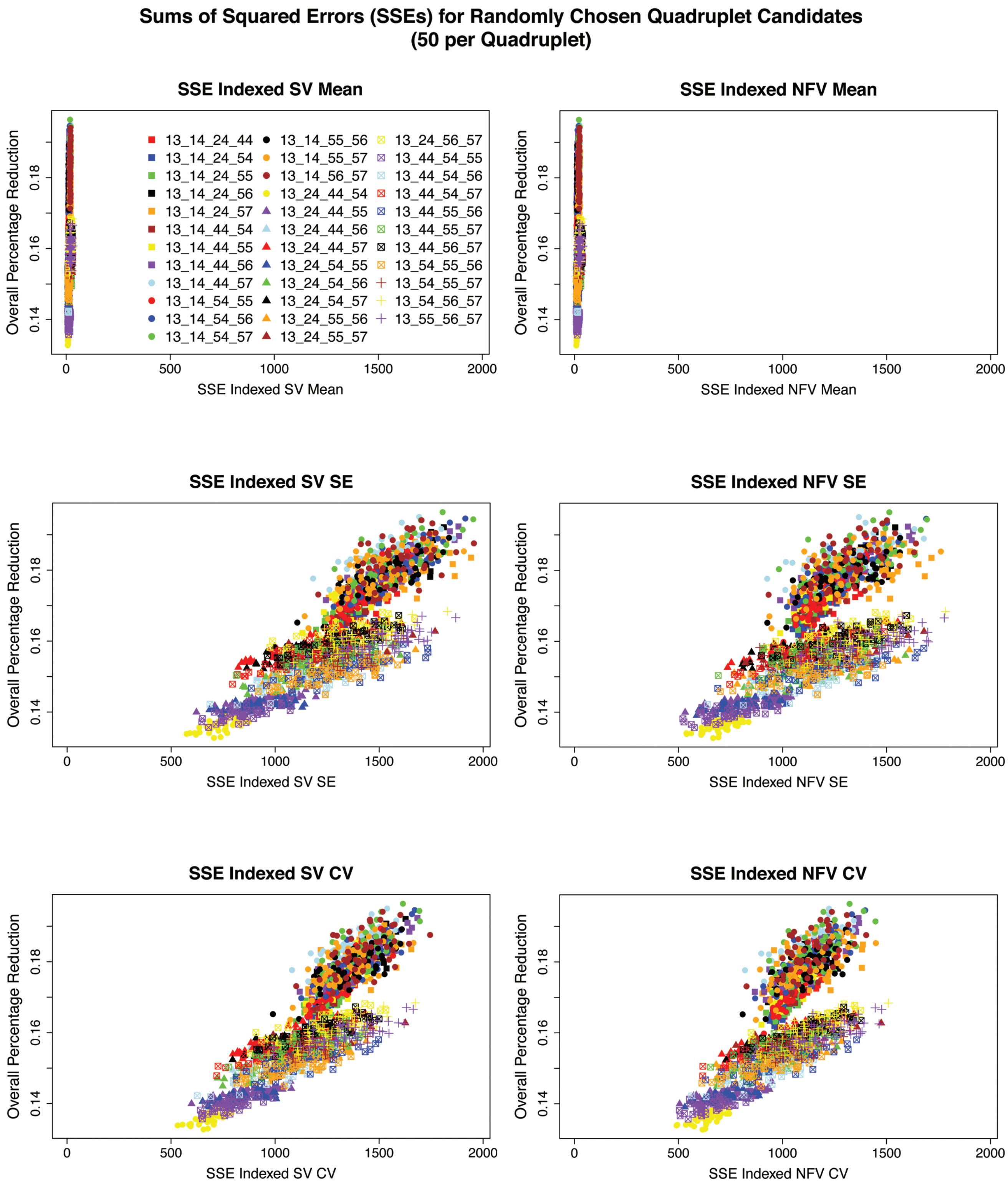


*Figure 3—Plot of sums of squared errors (SSEs) for six indexed statistics computed for 50 randomly chosen members of 35 quadruplets under study. For convenience, the legend displays the quadruplets as a sequence of four numbers, such as 13_14_24_44. The first digit of each of the four numbers symbolizes the scenario, and the second the level of reduction (i.e., 1 = no reduction, 2 = one increment reduction, 3 = two increment reduction, and so on, where increments are in 10 percent for Scenarios 1 to 5 and 25 percent for Scenario 6). Thus, 13_14_24_44 is the quadruplet with Scenario 1 at 20-percent reduction, Scenario 1 at 30-percent reduction, Scenario 2 at 30-percent reduction, and Scenario 4 at 30-percent reduction.*

**Sums of Squared Errors (SSEs) for Randomly Chosen Quadruplet Candidates (50 per Quadruplet) and Top Five Quadruplet Candidates**

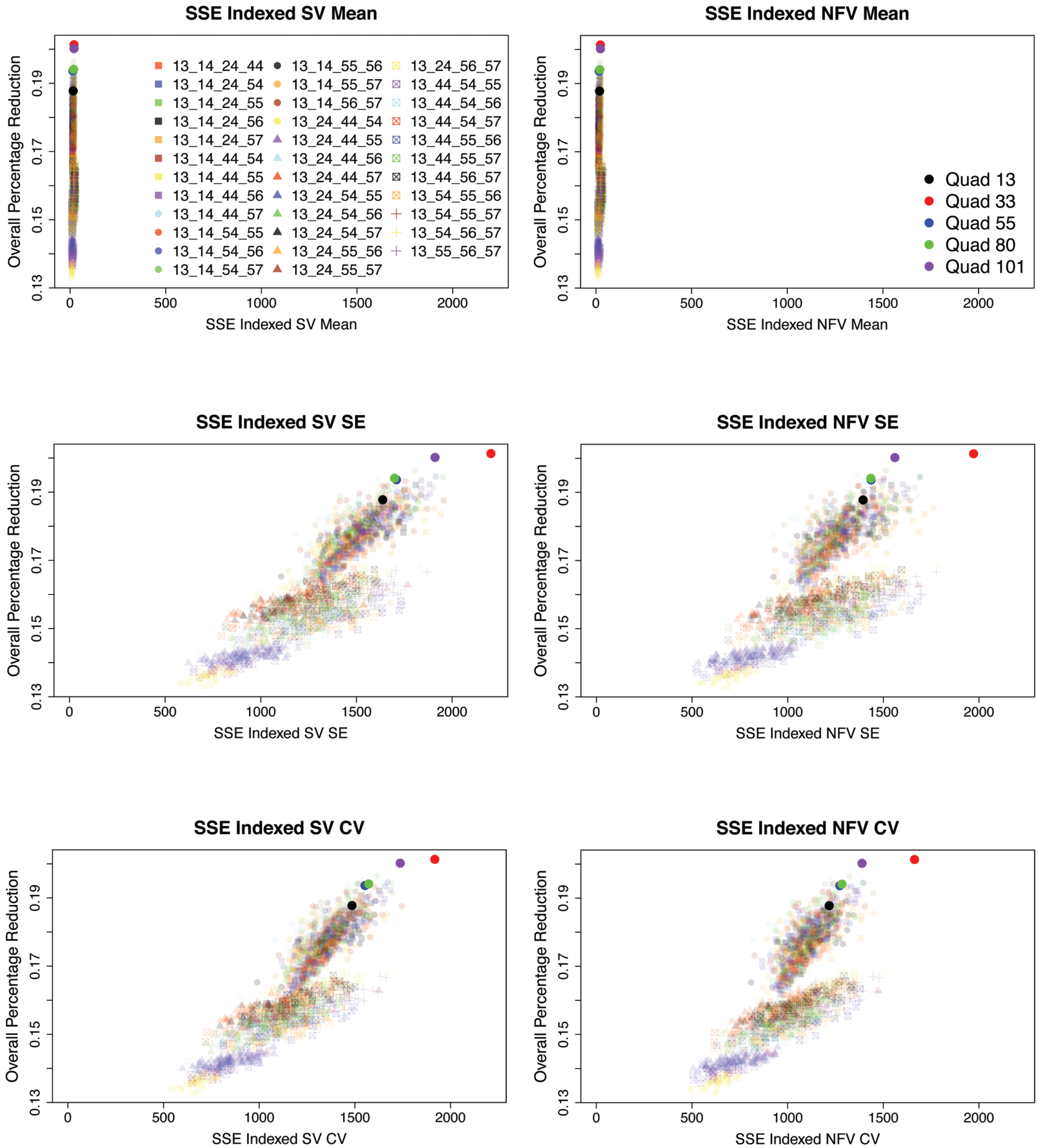


*Figure 4—Plots of 50 randomly chosen members of the 35 quadruplets under study showing the relative position of the top five quadruplets: 13, 33, 55, 80, and 101. For convenience, the legend displays the quadruplets as a sequence of four numbers, such as 13_14_24_44. The first digit of each of the four numbers symbolizes the scenario, and the second the level of reduction (i.e., 1 = no reduction, 2 = one increment reduction, 3 = two increment reduction, and so on, where increments are in 10 percent for Scenarios 1 to 5 and 25 percent for Scenario 6). Thus, 13_14_24_44 is the quadruplet with Scenario 1 at 20-percent reduction, Scenario 1 at 30-percent reduction, Scenario 2 at 30-percent reduction, and Scenario 4 at 30-percent reduction.*

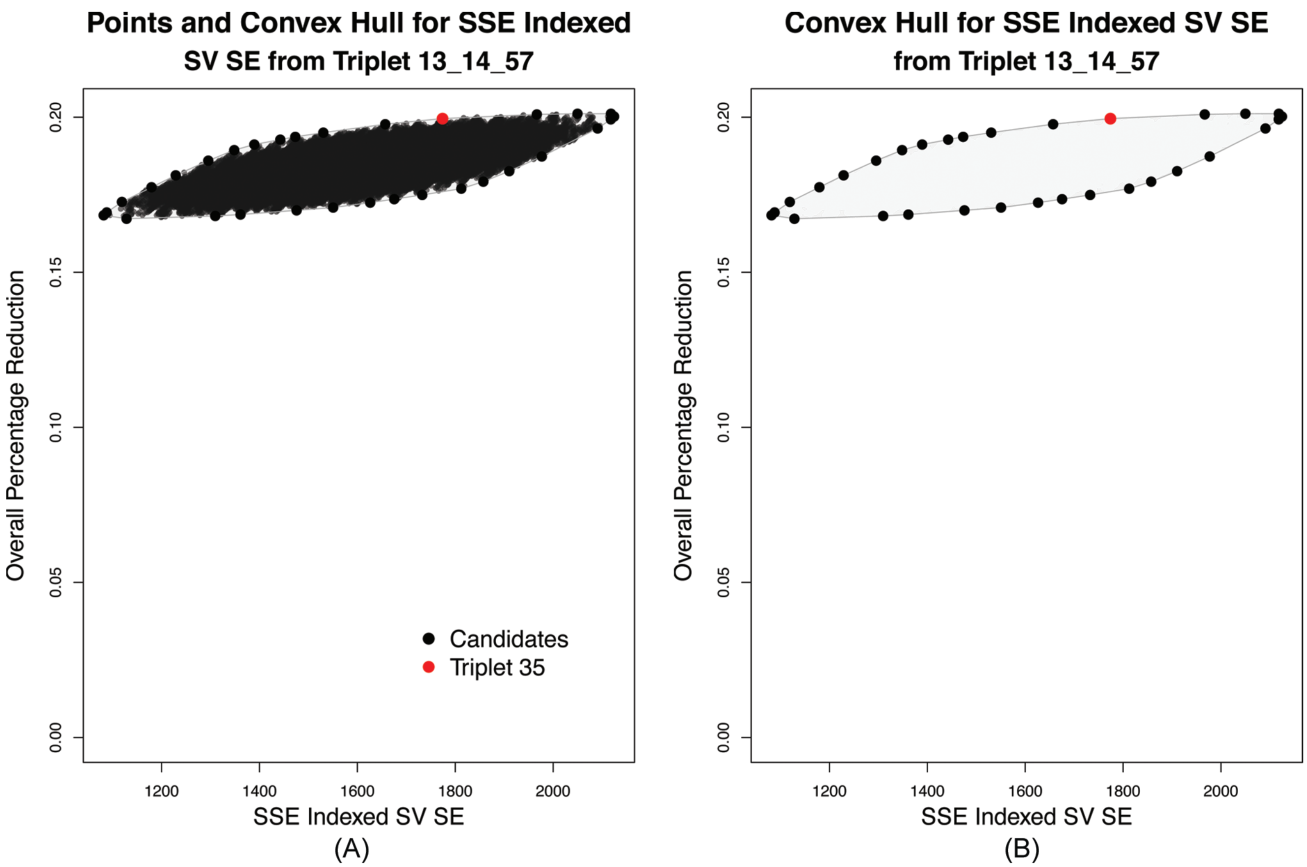


*Figure 5—(A) Panel showing the plots of all 100,000 points for the SSEs computed on the indexed SE SV statistic for Triplet 13_14_57, the triplet from which the leading candidate 35 comes. The top candidate appears as a red point in both panels, and the outlined polygon represents the convex hull generated by the points. (B) Panel simplifying the plot and showing only the convex hull and the top candidate's relative position.*

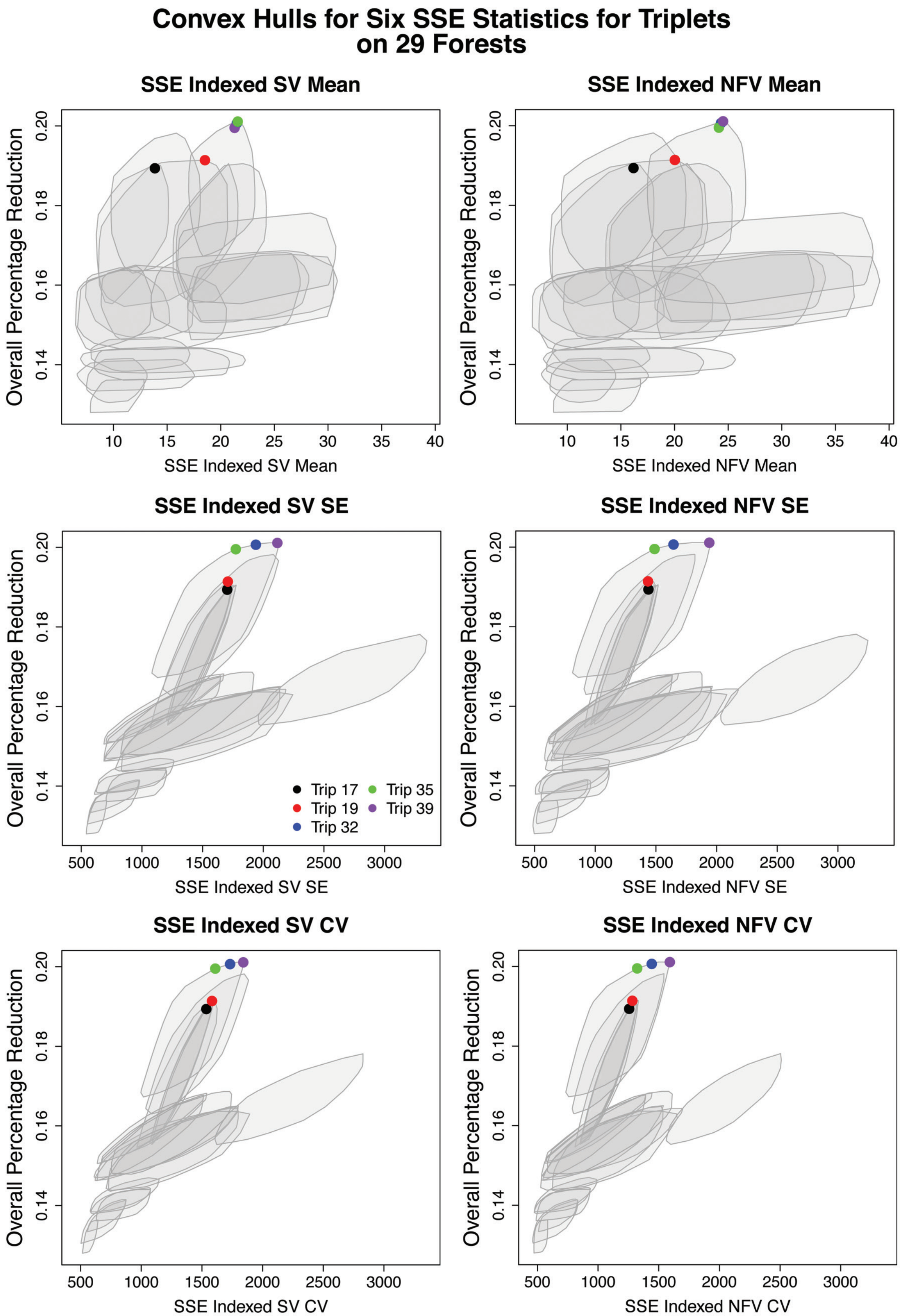


*Figure 6— If a triplet has fewer than 100,000 candidates, then we exhaust all permutations. Otherwise, we take a random selection of 100,000. All points generate a two-dimensional convex hull per statistic, which gives a sense of the coverage of the corresponding triplet. In these plots, there are some triplets which perform very well in terms of SSE, but the levels of reductions do not meet the goal of around 20 percent. Likewise, there is a very poorly performing triplet, as shown in figure 1 to be 13_56_57, which includes Scenario 1 at 20-percent reduction and Scenario 5 at high levels of reduction (50 and 60 percent). The top candidates are those which produce around 20-percent reductions overall while achieving desirable levels of SSEs relative to the others.*

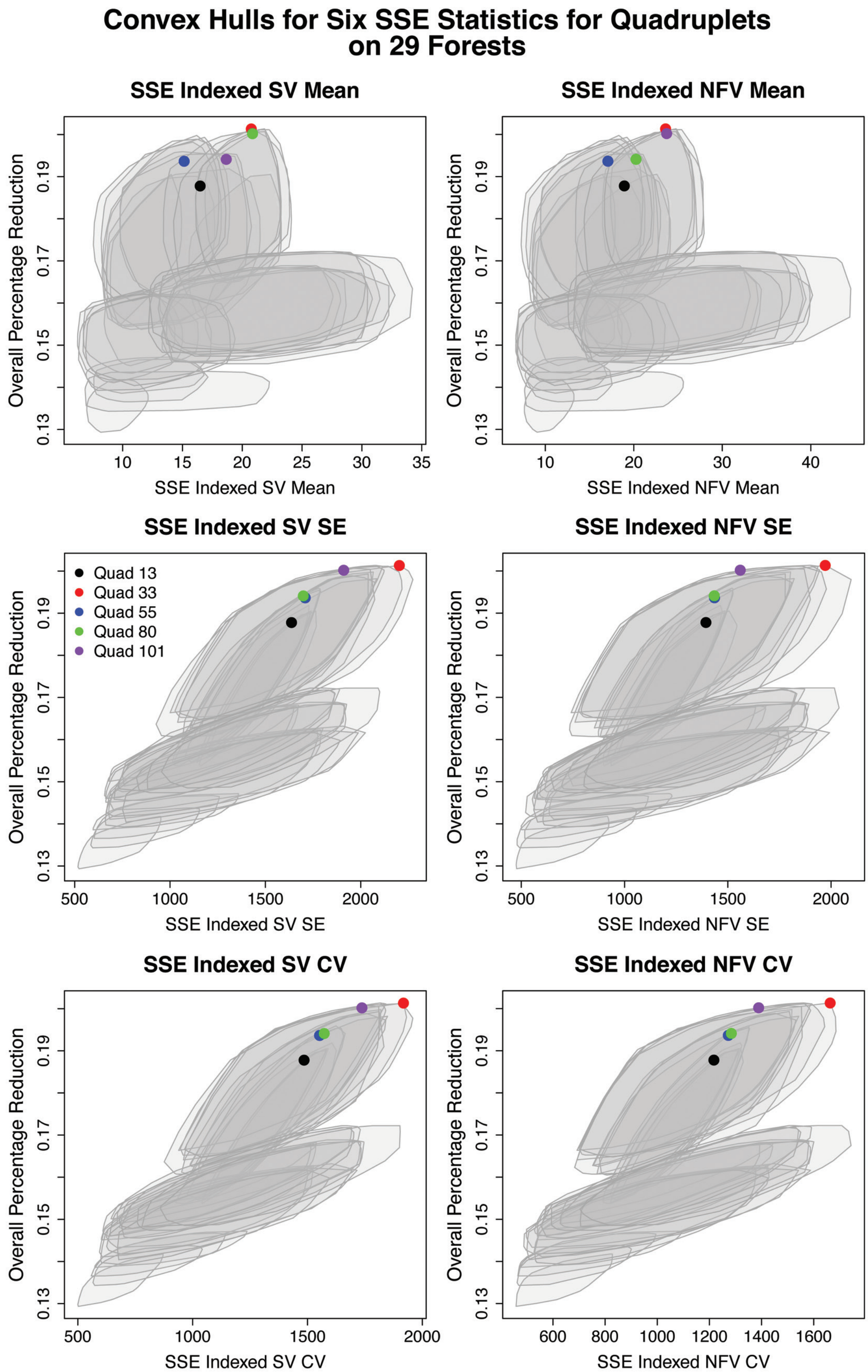


*Figure 7— If a quadruplet has fewer than 100,000 candidates, then we exhaust all permutations. Otherwise, we take a random selection of 100,000. All points generate a two-dimensional convex hull per statistic, which gives a sense of the coverage of the corresponding quadruplet. In these plots, there are some quadruplets which perform very well in terms of SSE, but the levels of reductions do not meet the goal of around 20 percent. The poorly performing triplet from figures 1 and 2 disappears because of the inclusion of an additional scenario/subscenario from which to choose.*

6, with a low percentage reduction and high SSEs on the SE and CV statistics. Conversely, most of the quadruplets do not show a similar pattern; instead, there is a tendency for the SSEs to go up with increasing percentage reductions.

Each assignment involves some permutation of the preselected scenario/subscenarios per forest (i.e., not the entire pool of exhaustive permutations of the triplet or quadruplet). Some candidates may produce a small SSE on one measure, but have a larger one on another. Since the budget implications are essentially the same, if candidates produce lower SSEs at 19-percent reduction, then we will opt for the improved accuracy at the cost of a percentage point lower reduction. The top five candidates chosen from all triplets and quadruplets would be those corresponding to triplets 17, 19, 32, 35, and 39 and quadruplets 13, 33, 55, 80, and 101.

Among the top three triplets, the SSEs for the means are roughly equivalent; the SSEs for the SE and CV measures are relatively low for triplet 35, which also achieves the reduction goal (19.95 percent). Quadruplet 55 was chosen due to the low SSEs across all of the estimators compared to all other combinations. In some cases, quadruplets with minimum SSEs for a given NFV statistic resulted in a less accurate SV estimator. The choices reflect which quadruplet performs well overall, not just on an individual statistic basis. Quadruplet 55 also produces a near-goal reduction overall (19.4 percent).

Triplets 32, 35, and 39 use the same set of scenario/subscenarios but with differing assignments to National forests. The other triplets differ by one scenario/subscenario. The top five candidates for the quadruplets have in common Scenario 1 at 20-percent and 30-percent reduction, which is also common to all the top triplet candidates. The overlapping of the scenario/subscenarios seen across the triplets and quadruplets lends a measure of confidence that we have identified a set that is among the fittest of the practical strategies. The question becomes which of the nonoverlapping sets best groups the forests by features which lends to a fast classification for future application.

The groupings produced by these top four candidates across triplets and quadruplets are given in tables 4 and 5. In the triplet and quadruplets, there is a tendency to have a large group with two and three smaller groups, respectively. Triplet 35 (table 4) has a largest group, followed by a second-largest group, and a group with only two members. The subunits of a given national forest (say, A02012) may belong to separate categories, which is not unexpected given the differing levels of variability of sites within National forests. Quadruplet 55 (table 5) has a marked distinction between the largest group and three smaller groupings of decreasing size.

**Table 4—Assignment of scenario/subscenarios from Triplet 35 to 29 forests from simulation study**

| Triplet 35 | | |
|---|---|---|
| 1 | 1 | 5 |
| U0401702 | A01005 | U0201201 |
| A05001 | A01016 | U0201202 |
| | A01017 | A02013 |
| | U0300301 | U0300302 |
| | A03006 | U0401701 |
| | A04010 | U0800501 |
| | A05004 | U0800502 |
| | A05009 | U0800503 |
| | A05013 | A08016 |
| | A06003 | A09013 |
| | A06006 | |
| | A06012 | |
| | A06022 | |
| | A08008 | |
| | A09003 | |
| | A09009 | |
| | A10105 | |

**Table 5—Assignment of scenario/subscenarios from Quadruplet 55 to 29 forests from simulation study**

| Quadruplet 55 | | | |
|---|---|---|---|
| 1 | 1 | 4 | 5 |
| U0401702 | A01005 | U0800501 | U0300302 |
| A05001 | A01016 | U0800502 | U0401701 |
| A05009 | A01017 | | A08016 |
| A06022 | U0201201 | | |
| U0800503 | U0201202 | | |
| | A02013 | | |
| | U0300301 | | |
| | A03006 | | |
| | A04010 | | |
| | A05004 | | |
| | A05013 | | |
| | A06003 | | |
| | A06006 | | |
| | A06012 | | |
| | A08008 | | |
| | A09003 | | |
| | A09009 | | |
| | A09013 | | |
| | A10105 | | |

## Evaluation

Looking at the top two candidates (Triplet 35 and Quadruplet 55), we now examine the behaviors of the indexed statistics for each of the 29 National forests (see figs. 8 and 9). This allows us to evaluate each subunit individually, as certain subunits could perform poorly even though the candidate performs well overall. The horizontal lines are the means of the statistics taken over all 29 forests. The indexed SV and NFV means are accurate for the most part over all the forests, partly due to the unbiased nature of the statistic. Nevertheless, the indexed standard errors and coefficients of variation reveal a more interesting story. The closer the index is to 100, the more accurate the statistic is relative to the full sample. In most cases, the standard errors and coefficients of variation were greater than the baseline, mainly due to reduction of sample size. The top candidates show how the individual percentage reductions behave on an individual forest basis. In some cases, it is necessary to make smaller reductions on the forests because they cannot afford to lose more sampling days.

Triplet 35 has the advantage of one less scenario/subscenario to maintain, and the results are also satisfactory with respect to the SSEs and percentage reductions. Of these final candidates, Triplet 35 offers both simplicity (one less scenario/subscenario to maintain) and desirable properties in the statistics, specifically SSEs which are comparable to the top three quadruplets.

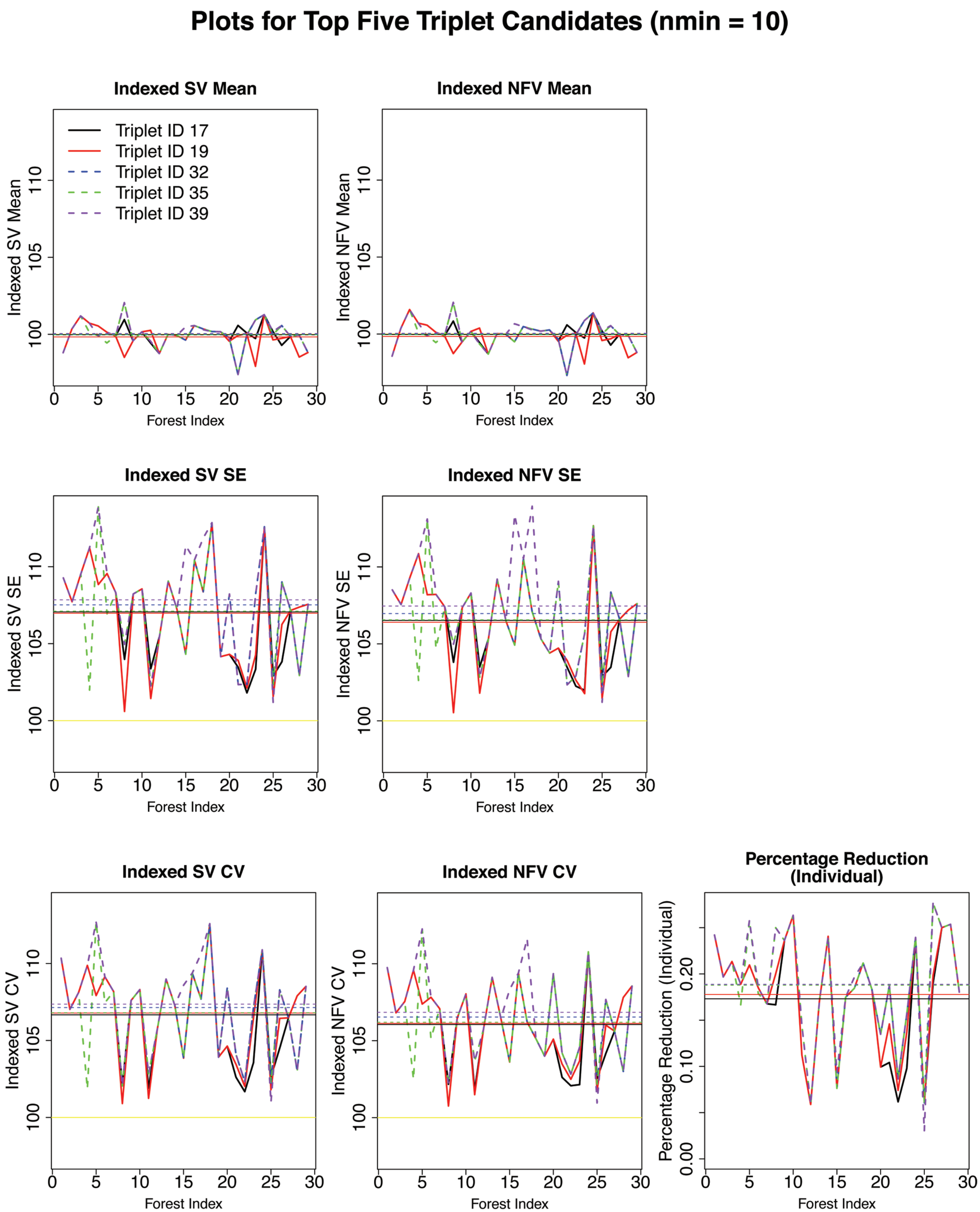


*Figure 8—Plots of individual values of six indexed statistics by forest for the top five triplet candidates: 7, 19, 32, 35, and 39.*

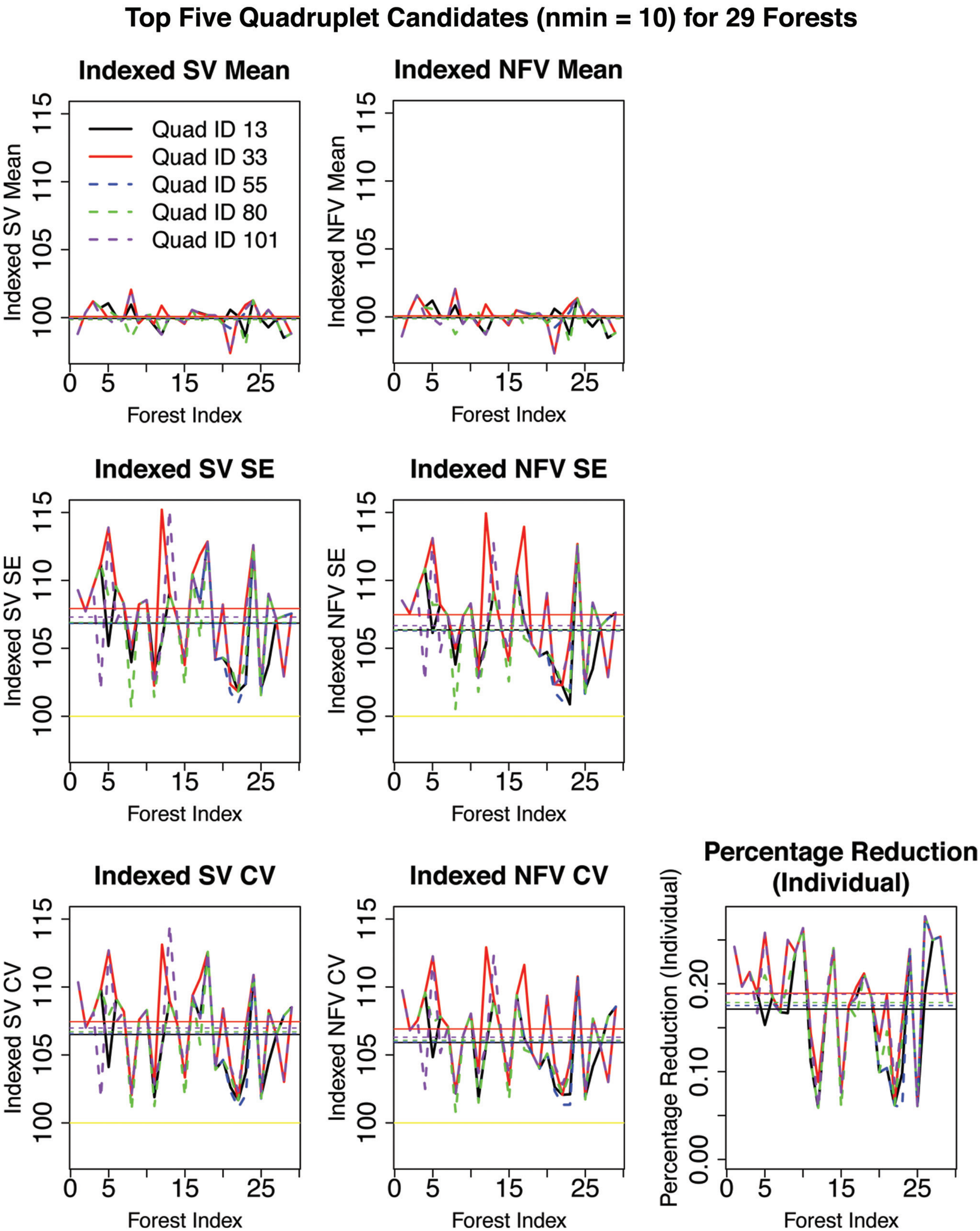


*Figure 9—Plots of individual values of six indexed statistics by forest for the top five quadruplet candidates: 13, 33, 55, 80, and 101.*

## SUMMARY AND CONCLUSIONS

With any survey procedure undergoing reductions in sampling days, it is prudent to conduct a preliminary statistical investigation before imposing ill-informed cutbacks in the field that could possibly produce inferior estimators. A survey methodology as complex as the NVUM system requires careful and strategic planning in reductions so as not to reduce sampling days vital to strata for each national forest. Such investigations are relegated to the simulation process described in this work using historic but recent data. The values under the full sample are treated as the true baseline values, and the reductions provide estimates which may be gauged against this in the form of indexed statistics. In the end, it is the SSEs of the indexed statistics and the goal percentage reductions which provide the best method for selecting candidates.

For the NVUM program, sampling and surveys are used to obtain adequate estimation of visitation because a complete census would be impractical and unrealistic. Now, facing nominally flat budgets, even the surveying procedure is in need of reduction. The most statistically accurate approach would be to lower the number of sampling days on those National forests that can still effectively provide estimates. However, having such customized reduction scenarios for each national forest is not feasible due to the time it takes to make such decisions, and this violates the goal of systematic assignments. The simulation procedure demonstrated herein is an effective means of investigating how to best adapt a stratified random sampling process to varied conditions. The goal for simulations is to identify a manageable set of three or four reduction strategies that are shown to have satisfactory results in reducing the sample size/cost with modest losses in reliability of the estimators.

The simulations assigned to the National forests surveyed in FY 2011 were grouped by scenario/subscenario. An important next step would be the identification of one or more criteria (e.g., proximity to large population centers, visitation proportions in certain site-types or strata, or geographical or climatological features) which best explain the assignments. Determining what features best predict assignments of forests by scenario/subscenario can be accomplished through a discriminant analysis. Another option would be to use a logistic model with covariates based on the characteristics of the national forest subunit (size, location, etc.). This model would also yield insight into the influences of the factors, which best explain the groupings and are statistically significant. We can then generalize findings from this exercise to all forests in the National Forest System.

In conclusion, this simulation process serves as a useful means by which decisions about how best to implement sampling reduction decisions can be made beforehand. By deciding on a set of possible reduction strategies, it is possible to simulate the effects on a historic sample and to evaluate variability of estimates through SSEs. Though reduction strategies can be made individually, it becomes a time- and cost-prohibitive method, especially with large numbers of forests. The identification of a small set of strategies to be applied across all the forests to be sampled is essential to achieving an efficient, valid, and tractable solution to the problem.

## ACKNOWLEDGMENTS

This research benefitted from the constructive comments of Lynne Seymour, Ray Souter, and Eric White. Remaining errors and omissions are the sole responsibility of the authors.

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**Appendix—National forests and subunits sampled in FY 2011**

| Administrative code | Forest name | FY 2011 sampled days |
|---|---|---|
| A01005 | Clearwater NF | 211 |
| A01016 | Lolo NF | 238 |
| A01017 | Nez Perce NF | 202 |
| U0201201 | Pike–San Isabel, Forest portion | 215 |
| U0201202 | Pike–San Isabel, Cimarron and Comanche Grasslands | 112 |
| A02013 | Rio Grande NF | 213 |
| U0300301 | Cibola NF, Forest portion | 196 |
| U0300302 | Cibola NF, Black Kettle, Kiowa, and Rita Blanca Grasslands | 58 |
| A03006 | Gila NF | 219 |
| A04010 | Manti–LaSal NF | 266 |
| U0401701 | Humboldt–Toyiabe NF, Spring Mountains NRA | 156 |
| U0401702 | Humboldt–Toyiabe NF, outside of SMNRA | 109 |
| A05001 | Angeles NF | 291 |
| A05004 | Inyo NF | 241 |
| A05009 | Modoc NF | 124 |
| A05013 | Sequoia NF | 243 |
| A06003 | Gifford Pinchot NF | 235 |
| A06006 | Mt. Hood NF | 237 |
| A06012 | Siuslaw NF | 241 |
| A06022 | Columbia Gorge | 165 |
| U0800501 | NFS in Florida, Apalachicola portion | 64 |
| U0800502 | NFS in Florida, Ocala portion | 132 |
| U0800503 | NFS in Florida, Osceola portion | 68 |
| A08008 | George Washington–Jefferson NF | 281 |
| A08016 | El Yunque NF | 71 |
| A09003 | Chippewa NF | 255 |
| A09009 | Superior NF | 212 |
| A09013 | Chequamegon–Nicolet NF | 223 |
| A10105 | Tongass NF, Sitka and Hoonah districts | 128 |

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Stratified random sampling (SRS) provides a scientifically based estimate of a population comprising mutually exclusive, homogenous subgroups. In the National Visitor Use Monitoring (NVUM) program, SRS is used to estimate recreation visitation and visitor characteristics across activities on National forests. However, with rising costs and declining budgets, carrying out an annually established SRS poses challenges in how and where to reduce sampling while maintaining statistical precision. Furthermore, any reductions must produce results that validly compare to previous years' SRS in trend analyses.

Accurate estimates are necessary to manage resources for current and future demand; we explore this need through simulations and describe a methodology which can be generalized to any SRS-based process facing budgetary challenges. In this research, recent historic NVUM responses serve as groundwork for simulating various reduction scenarios. The ultimate goal is a manageable set of strategies from which to systematically assign a suitable reduction scenario for each sampling unit (i.e., forest). Using baseline historic data, we determine the sampling error variability by reduction scenario and experiment with various sets of three or four pre-defined strategies to identify viable reduction candidates. A desirable candidate is one that achieves acceptable error bounds (based on historic values) and reductions overall while meeting specified budget constraints (e.g., 20 percent overall fewer sampling days).

**Keywords:** Budget, National Visitor Use Monitoring, precision, sampling, scenarios, simulations, strata.

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