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Silviculturist Re-Certification Report - 2003
Rodeo-Chediski Fire 2002
Most-Similar Neighbor Analysis Evaluated

BACKGROUND

Lack of stand exam data is a common difficulty in doing a complete analysis for project planning. The provisions of the National Environmental Protection Act (NEPA) require detailed disclosure of the affected environment and projected effects of each alternative considered. Many of the issues that must be addressed to do so involve questions that can only be answered satisfactorily if existing stand attributes are known. The same level of information is needed for consultation with the US Fish and Wildlife Service under Section 7 of the Endangered Species Act (ESA) to further determine effects of proposed activities on threatened, endangered and sensitive species. Cases challenged on many fronts through the court system have established that none of these requirements can be met satisfactorily with subjective conclusions or professional opinion alone. Project proposals without factual data like basal area, trees per acre by diameter class, and vegetative structural stage (VSS) distributions to support professional conclusions are simply inadequate in today's political climate.

Shortfalls in complete coverage of existing stand data are usually filled by extrapolation or some process of data substitution. Most commonly, the existing data is summed and averaged and assumed to represent the entire area, even if only a portion of it actually has current data. This may be satisfactory if existing data adequately represents the full range of variability that occurs in the project area, and if it was collected in proportions representing the relative abundance of each condition. However, it is not uncommon for potential treatment areas to be sampled while areas with little potential for treatment are not. Hence, using averages from these pre-stratified parts to represent the whole is fraught with potential bias.

Where such weaknesses are recognized, some method of photo interpretation is often employed. Under this approach, a stand without data is compared under a stereoscope to nearby stands with data for similar textural appearances. Data from the best-matched stand is then substituted for the stand in question. This avoids some of the bias inherent with blind averaging, but is still quite subjective and lacks consistency and repeatability. It also requires data from a full range of conditions to provide sufficient variation among matches to choose from. The time and study required to observe and assimilate the subtle differences between stand images and mentally process those differences consistently and accurately usually limits this method to fairly small areas.

Complete stand information is imperative for good analysis. Organizational and budgetary restraints have never allowed for complete data collection in advance of project planning. Silviculturists are resourceful in finding ways of supplementing that existing information, within the time limits imposed, to fill in the data gaps the best way they can so analysis can proceed. There may be statistical weaknesses in these methods, and most silviculturists recognize them. But until better methods become available, the gap between existing data and needed data will continue to be a challenge.

INTRODUCTION

The ID Team preparing the Environmental Impact Statement (EIS) for salvage of the 2002 Rodeo-Chediski Fire determined that an analysis of habitat for Management Indicator Species (MIS), both before the fire and after, was a necessary baseline for describing the effects of salvage on wildlife species. The computer model used for this analysis requires VSS and canopy cover as input variables. Where stand exam data has been collected, VSS is easily determined and is already incorporated into the standard RMSTAND outputs. Canopy cover can be inferred from Stand Density Index information, which is also already incorporated into the standard reports. Stand exam data processed through the Forest Vegetation Simulator (FVS) to simulate treatments or disturbance events can also be re-processed through RMSTAND to calculate post-activity or future VSS and canopy cover. Therefore, there is no problem in generating this information – where stand exam data has already been collected.

However, making those determinations where there is no current exam data is problematic. Even though two-thirds of this particular project area did have data (which is actually more than typically available for project planning), we had 58,457 acres in 858 stands that did not have current data. Aerial photo interpretation to locate suitable matches over that much area would be exhausting and time-consuming. Averaging the stands with data to represent those without data, even with its inherent potential for bias, seemed our only option.

Some team members from the Black Mesa District had, however, recently attended a presentation where use of a process for filling in data gaps called Most Similar Neighbor (MSN) analysis was introduced. After discussing the possibility of using that procedure with Region 3 staff, the Forest Supervisor and ID Team elected to give it a try. Two Forest Service analysts experienced in MSN analysis were engaged to apply it to fill in the data gaps. They were Eric Twombly, a Washington Office employee stationed on the Wallowa-Whitman National Forests in Oregon; and Lynne Bridgford from the Grand Mesa-Uncompahgre-Gunnison National Forests in Colorado. They spent the last two weeks in October of 2002 running existing stand exam data through the MSN software and compiling it for the Rodeo-Chediski analysis area.

As outputs of the MSN process began to materialize into VSS ratings for stands without exam data, there was great interest by all involved to field check some of these outputs and see if it seemed to be working. The MSN process is still (or at least it was at the time) undergoing beta testing and results had not been extensively validated for accuracy beyond limited trials leading up to the current model version. But with over 2,000 stands scattered over 173,000 acres in the analysis area, field verification of very many stands in this instance would not be possible – especially within the short timeframe available to pursue salvage opportunities.

However, the Region 3 Silviculturist, Regis Cassidy, and the Region 3 Data Processing Specialist, Pat Jackson, did spend a day in the field with several members of the ID Team and Eric Twombly. We compared several stands with an imputed VSS with their respective stands selected by the MSN process as their data source. We found conditions between the two stands of these pairs to vary considerably, but could usually see enough similarities (depending upon where exam plots may have fallen) to rationalize why each particular match was made. An observation about dissimilarities in slope position led Eric to make a subsequent adjustment in the model to take this characteristic into account – a variable already built into the program, but not used in the first iteration. MSN was rerun, including the slope position variable, and resulted in better matches for a couple of the stands visited that day. Everyone seemed comfortable that there would be a correspondingly better match across the data set as a whole.

This second run of MSN was then used for the rest of the vegetation analysis for the Rodeo-Chediski salvage, including the VSS determinations for the MIS modeling. The ID Team had already determined that there was not sufficient time to field verify the MSN matches, but the possibility occurred to me of actually doing some stand exams in a sample of the imputed stands at a later time to further test the accuracy of MSN. I visited with Regis at the time about the possibility of taking that on for my upcoming silviculture recertification and he concurred.

STUDY AREA

On June 18, 2002 an arsonist ignited the Rodeo Fire on the Fort Apache Indian Reservation near Cibecue, Arizona. Suppression action was underway on this fire when 2 days later a lost hiker started the Chediski Fire to facilitate her rescue by a news helicopter that happened to be flying by. This fire was also on the Reservation a dozen air miles west of the Rodeo Fire. The two fires grew rapidly and merged on June 22nd. By the time the fires were contained two weeks later, the complex had grown to a little over 460,000 acres – Arizona's largest ever wildfire. Most of the acreage was on the Reservation, but over 170,000 acres had also spread onto the Tonto and Apache-Sitgreaves National Forests.

Of the 173,107 acres of National Forest within the burn that had a tree cover type, 114,650 acres in 1,483 stands had tree data from field surveys prior to the fire that were still reasonably current up until the fire. That is, there had been no disturbance or management activity inside the stand since it was surveyed that would have substantially altered the collected information. The remaining 58,457 acres in 858 stands had no such data (or the collected data had been nullified by treatment since it was examined).

The MSN analysis was done in support of the EIS to salvage merchantable timber on the Tonto and Apache-Sitgreaves Forests. It assigned stand characteristics to those stands without current data based on the MSN methodology. The stands sampled for this case study came from those stands without previous data that were assigned stand attributes during the MSN analysis. The stand exam outputs of these sampled stands are compared to values assigned by the MSN analysis to see how well the MSN model predicted those values.

METHODS

The basic MSN process involves running existing data through FVS to "grow" each stand from the year data was collected to the present. This normalizes all data to the current year. This information is stored as the reference data for the analysis area. Then recent satellite imagery (pre-fire in this case), spatial relationships, and topographic information are used to match each target site (a stand without data) to the nearest reference site (a stand with data) with the greatest similarity in physical characteristics.

Tree data from the reference site is then assigned to the target site. Excerpts from the "Users Guide to the Most Similar Neighbor Imputation Program Version 2" are included as an Appendix to this report and describe this "canonical correlation analysis" in more detail.

The results of this analysis were tabulated into a spreadsheet of all 2,341 stands in the project area with a list of attributes for all stands, whether from existing exam data or imputed by MSN. Each stand occupied one row in the spreadsheet and had fields for stand VSS; stand acreage; cover type; and trees per acre, percent SDI, and basal area by VSS class. This spreadsheet became the basis for the vegetation analysis and no distinctions were made between stands with existing data and stands with imputed data from that point forward. We proceeded as if we had exam data for every stand in the project area and gave imputed data the same weight as collected data. Figure 1 (**See Attachment Doug Beal Analysis 2)** on the next page is a one-page sample of this initial spreadsheet.

Although the accuracy of the imputed data was not field verified for the salvage analysis, the MSN process seemed superior to previous methods of filling in data gaps in several respects. The use of satellite imagery has the same advantage as aerial photo interpretation in matching stands of like textural appearance, but MSN is infinitely more powerful in being able to assimilate information from hundreds of stands in making those comparisons. The MSN analysis is also repeatable – an important feature of objective analysis. It is unlikely that human photo interpretation would come up with the same matches on two attempts for the same analysis area. But given the same dataset with the same selection parameters, MSN would produce the same results every time. Plus MSN integrates other physical, spatial and quantitative data along with the image interpretation – something not possible by human cognition alone.

Nonetheless, some validation of the MSN results still seems appropriate, even if after the fact. The need for filling data gaps will continue and some objective, repeatable, analytical process like MSN is badly needed to perform that function. A case study does not have the necessary rigor to be statistically valid in making an authoritative assessment of the suitability of MSN, but it may provide some anecdotal evidence of how well it performed in this instance. Hence, an examination of a few of the stands with MSN imputed VSS values was undertaken in this case study as one way of evaluating its performance.

Prior to the exams, I decided on two measures I would use to determine whether the MSN imputed VSS rating was satisfactory or not. First, the results would be satisfactory if the MSN imputed VSS rating was no more than plus or minus one class from the examination-determined VSS value. And secondly, a good match would be indicated if no more than two of the MSN imputed zipcode subclasses were more than plus or minus one digit from the examination-determined zipcode. There was no analytical procedure for determining these measures, they are simply an expression of my personal expectations of the MSN process and what I thought would be a satisfactory level of accuracy for the purposes for which it was used in the salvage analysis.

I limited myself to collecting plot data for no more than a half dozen stands – a number I felt was feasible for me to do over the coming field season considering the time already committed to the EIS analysis. Although it may have induced some unknown bias, I also thought it would be better to examine stands that had experienced low or underburned severity. I wanted to examine as closely as possible the same conditions the satellite "saw", and thought the probability of that was best in stands that had experienced the least change since the pre-fire imagery was taken. Diameter measurements might have been affected enough in high and moderately burned stands that some stems could have had part of the bark burned away resulting in smaller diameter measurements post-fire than what was present before the fire – and when it comes to VSS, a missed class-break on a tree or two on a plot can easily make a class difference.

I further limited my selection to stands with ponderosa pine cover type. This cover type comprised over 80% of the forest cover type in the fire and was the cover type with the best coverage in pre-fire data. I overlaid ponderosa pine stands in GIS with burn severity rating and narrowed my search to 56 stands with a high proportion in low or underburned severity. Within this listing were 25 stands with imputed data. I examined the burn severity rating of the reference stand for each of these target stands and found 5 pairs where both stands of each pair were only lightly burned. This became my data set to examine for this case study. Later, I discovered that I'd mistakenly included one stand that burned at moderate severity (5040/0033). But I elected to leave it in my sample as it was a reference site (the pre-fire data had already been collected) and I would only be doing a walk-thru to assess how well the point data reflected the overall stand condition.

Having thus selected five sample pairs, I visited each stand in order of geographic occurrence from west to east. That is, I didn't first sample an imputed stand and then immediately follow-up with a walk-thru of its reference stand. I didn't want to consciously associate any stand with its matched pair at this point in case that would influence my walk-thru perceptions. I also didn't run any exam data until I'd made all my field visits because I didn't want to influence my walk-thru assessment with a pre-knowledge of what VSS resulted from my examination of its imputed pair. I was only able to cover one or two stands any given day and my field days were often widely separated, so "perception retention" from stand to stand was minimal. (Thanks in part to a mind that can remember a fishing trip with my dad forty years ago, but can't remember the next morning where I set the car keys the night before!) Anyway, I found it easier than I anticipated to focus on measurements or walk-thru notes without conscious comparison to any previously visited stand.

The examination of target stands (those with imputed data) followed this protocol: If the stand was large enough and had sufficient width and depth, examination was by systematic grid. If the stand was narrow, examination was on a zig-zag azimuth through the stand on a pre-selected interval. Either way, a sample ratio of one plot per 10 acres with a minimum of three plots per stand was done. A 10 BAF was used in all stands for trees 5 inches or larger (DBH or DRC). A 1/300th acre plot was used in all stands for trees smaller than the breakpoint. Diameters of all variable plot trees were measured to the nearest 1/10th inch with a diameter tape. Heights of all trees and diameters of small fixed plot trees were estimated. Growth tree and site index measurements were not taken. Dead trees were coded as "live" if they appeared to have been killed by the fire (to reflect pre-fire satellite imagery conditions).

A walk-thru examination was also done in reference stands (those with existing pre-fire data used as the data source for the imputed stands). A subjective evaluation was made of the predominant VSS class while traversing the stand. Notes were made on presence and approximate distribution of tree groups that were an exception to the predominant class. I purposely did not review the VSS class rating generated by the original stand data for these stands prior to the walk-thru.

After the field exams were completed, collected data for the target stands were entered into the RMSTAND program to generate the standard *stand.prt* outputs. The VSS rating and zipcode on page 6 of the printouts was then compared to the VSS class and zipcode imputed through MSN. The VSS class assigned to reference stands was also compared with the walk-thru notes.

The Supplemental Package to this report contains the following: A vicinity map of the case study area; maps of each of the MSN pairs; stand printouts for each reference stand for the year it was examined; stand printouts for each reference stand for the year 2002 as projected by FVS; and stand printouts for each target stand based upon data collected in 2003 for this case study. (Not included in the electronic copy)

RESULTS

Four of the five stands examined had calculated VSS classes within one class of what MSN projected. All of the five stands examined met the criteria for VSS distributions as depicted by the stand zipcode (i.e. no more than two VSS subclasses more than plus or minus one difference from the examined zipcode). Figure 2 (**See Attachment Doug Beal Analysis 3**) shows the pertinent data for each reference/target pair and summarizes the differences. Pass/Fail criteria are also re-listed in the notes at the bottom.

DISCUSSION

Target stand #1 was the only stand examined that did not calculate out within one class of what MSN projected. It calculates out as a 4C from the exam data, whereas MSN projected it to be 2C. That appears to be a large difference at first look, but I believe it is really more a weakness in assigning a single VSS class to multi-storied stands than it is a weakness of MSN, for the following reason. The reference stand used by MSN to assign the 2C class was a 3BMS at the time it was examined in 1985 (see orange-tabbed “REF 1985 p. 6” in Supplemental Package). At that time, it had a slim plurality of 3 more square feet of basal area in the VSS 3 class than in the VSS 2 class, so it rated out as VSS3. However, in the FVS projection to “grow” this stand up to the year 2002 for the MSN comparison (see orange-tabbed “REF 2002 p. 6” in Supplemental Package), the basal area increment was greater in the VSS 2 class than in the VSS 3 class, which resulted in the plurality of basal area shifting to VSS 2 in 2002. It is somewhat contrary to VSS theory for a 3C stand to revert back to a 2C stand after 17 years of growth! However, when multiple stories interact over time, the “mathematics” of which class has the plurality of basal area can shift and result in such incongruities. I believe the actual appearance and character of the reference stand is much more similar to the target stand than the data comparison depicts. In fact, my walk-thru exam of the reference stand classed it as a 3C, which supports the notion that the mathematically assigned class of 2C is an artifact of the VSS calculation process and not necessarily an accurate representation of this stand's development over time. I believe the reference stand selected by MSN really is a VSS3 (and hence within one class of the target stand's VSS4).

Although the comparison of VSS ratings for pair #2 appears to be an excellent match (4BSS vs. 4BMS), a closer look at the data reveals a troubling inconsistency. Exam data for the reference stand selected by MSN (see blue-tabbed REF 1995 & REF 2002 printouts in Supplemental Package) makes it a pinyon-juniper stand, clearly dominated by both juniper and pinyon with only 10 and 12 basal area in ponderosa pine for the year of examination and the FVS projection, respectively. There's well over 90% of the basal area in both instances in the 5-10.9 inch class, which makes it a solid VSS4 for the pinyon-juniper cover type. The target stand, however, turns out to be a ponderosa pine stand (see blue-tabbed TARGET printout in Supplemental Package). It has 10 basal area in Gambel oak but no other woodland species at all. It is a multi-storied stand with a 7-square foot basal area plurality in the 12-17.9 inch class, which makes it a VSS4 for ponderosa pine. So our matching VSS4's is not a perfect match at all. A single-storied pinyon-juniper stand dominated by 5-10 inch trees is nothing like a multi-storied ponderosa pine stand with only a quarter of its stand basal area in the same 5-10 inch range (and no pinyon or juniper at all). They just happen to both be a VSS4 for their respective forest type, but their spectral signatures would certainly appear much different on a satellite image, would they not? Why would MSN make such a poor match?

A first look at the relative location of these two stands only makes their match-up more questionable (see blue-tabbed "PAIR 2" map in Supplemental Package). The reference stand is in the pine-woodland transition zone near Highway 260; the target stand is on the brink of the Mogollon Rim – over 11 air miles away and 600 feet higher in elevation – the largest combined spread of any of the five pairs studied... more evidence of a first order flaw in the MSN matching process? Perhaps, until the walk-thru notes for the reference stand are revisited.

The walk-thru notes refer to pinyon, juniper and transition zone in describing the adjacent stand, but the reference site was judged to be a low site ponderosa pine VSS3. The notes make no mention of the clear dominance of juniper and pinyon the original exam data suggests. In fact, no pinyon or juniper was noted within the stand at all and a woodland cover type was not even considered as a possibility. So, neither the visual characteristics of the reference stand as expressed by the MSN match, nor the walk-thru exam notes jibe with the exam data for the reference stand. A new possibility for this apparent mismatch, and my personal conclusion, begins to materialize – the wrong data is stored in the database for the reference site. I believe MSN made an acceptable visual match – a pine draw in the pine-woodland transition zone was matched with pine side-draws between ridges dropping off the Rim – both low productivity conditions (see topo maps of each site preceding their blue-tabbed printouts in the Supplemental Package). MSN only imputed the data from the former as representative of the latter, without prejudice, on the assumption that the reference data was correct.

The reference data could be incorrect through an error in data entry or because the data points were not collected in the right stand. Or perhaps this untreated 13-acre pine draw was split out from the 410-acre pinyon-juniper firewood unit that surrounds it, and three data points of the parent stand (which weren't representative) were assigned to it during the split (a practice once allowed under the old RMRIS database). But, either way, I conclude in this instance that the MSN process really did match a ponderosa pine target stand with a ponderosa pine reference stand and it's the reference site base data that is in error.

That kind of error is beyond the design of MSN to detect and would result in erroneous data imputation even if the textural, visual, slope position, and canonical match were perfect. In the case of this pair, the erroneous VSS just happened to match the examined VSS and the error would have gone undetected altogether had the difference in cover type not triggered a closer look. So although this is one case where the imputed data for the target stand was inaccurate, the MSN matching process was not at fault – the base reference data was incorrect.

No abnormalities or mismatches were detected for any of the other pairs. In fact, the abnormalities and mismatches identified for the #1 and #2 pairs discussed above are really not MSN mismatches anyway. They were a VSS calculation incongruity in the case of the first pair, and erroneous reference stand data in the second case. In both instances, the actual stand characteristics (as depicted by the stand data for the target stand and the walk-thru observations of the reference stand) support the MSN match. Given the slight differences that can bump a VSS class one way or the other, especially in multi-storied stands, a plus or minus one class on the match seems perfectly reasonable. Over an entire analysis area, I suspect the sum of the stand-by-stand VSS class pluses and minuses would likely cancel each other out anyway.

I was initially concerned about one other aspect of the MSN process – that being, the FVS projection of older data to the current year. It's an essential step to make. A stand VSS rating from data collected 20 years ago has a high likelihood of having changed since then and, in most cases, the FVS projection probably comes pretty close in making that adjustment. But by using the regional average growth algorithm on a rocky site on the upper part of a slope, for example, it may over-estimate growth and class a stand (after FVS projection) one class higher than it really is; or conversely, a class lower on a highly productive site. But after conducting this case study and becoming aware of all the other "ifs" that could possibly affect the outcome, I'm less concerned about this one. And given the plus or minus one class of accuracy that I've granted the process anyway, I suspect a sum of the differences between projected average growth and actual growth on non-average sites would also zero out at the analysis area scale.

Although every pair met my criteria for zipcode comparison, the large differences for some individual subclasses is a little disconcerting, especially the 4's and 5 in pairs #1, #2 and #3 (see "difference" row under the "Zipcode/VSS Comparison" fields in Figure 2). I expected differences more like those of pairs #4 and #5 with possibly a few 2's and maybe a 3, but I wouldn't have thought larger differences would have survived the spectral image screening process. However, in considering that the zipcodes come from a sample of a few points in the stand whereas the spectral signature receives input from 100% of the stand, those zipcode differences may be more a reflection of sample error than population error. That is, the total population of both stands may be more alike than the sample points indicate. So once again, my doubts shift from reservations about the matching process to shortcomings in the collected data.

Looking at the zipcode comparisons in Figure 2 in summary, five of the total 25 subclass total comparisons were the same, i.e. the target stand "decimal C" rating for that VSS subclass was the same as the reference stand (and show up as a "0" in the difference row); 14 of the 25 were only off by plus or minus 1; and 6 of 25 were off by 2 or more. So 76% of the comparisons (19 out of 25) showed a difference of 1 or less, which seems like a fairly solid result. Or stated conversely, from my limited case study sample (even including pair #2 with bad reference data), one might conclude that differences in zipcode subclasses of greater than plus or minus one can be expected for about one-fourth of the subclasses (6 out of 25). Given the dynamics of multi-storied stands (of which either or both the reference and target stands were in all pairs), I'm not certain any other data substitution process would do any better.

I was particularly interested in this comparison because I used the zipcode proportions to determine trees per acre and volume by diameter class (i.e. VSS subclass) for the EIS analysis. I was concerned that it might be stretching the limits of this stand-level, broad-scale analysis process to utilize information at the sub-stand level. Like the rules of statistical precision – one doesn't measure stand acres for a group of stands to the nearest tenth and then compute an average for the group to the nearest hundredth. Because stand level input is the lowest common denominator of input into MSN, stand-level results are the lowest level at which the output should be expected to be valid. While stand zipcode is still a stand-level attribute, breaking it down into its component parts could be likened to averaging "to the nearest hundredth" in my example above. I'm still not certain that it was statistically valid to do so, but I've confirmed my personal expectations of MSN's ability to reasonably predict the zipcode attribute.

CONCLUSIONS

I am satisfied that the MSN process did a consistent job of matching target stands to reference stands of similar characteristics for the Rodeo-Chediski EIS analysis. There are data imputation problems associated with how average stand VSS is calculated in multi-storied stands, and where reference stand data is erroneous (e.g. pairs #1 and #2 of this case study, respectively); but those are baseline data problems, not stand matching deficiencies. It's my conclusion that based upon on-the-ground conditions, all five pairs of stands included in this case study were good MSN matches.

The results of this case study indicate to me that use of MSN to fill in data gaps for stand level VSS for the MIS baseline analysis was sound. The use of the zipcode components to determine trees per acre and volume by VSS subclass likewise appears to have been reasonably representative.

While not tested in any way by this case study, I suspect the MSN process may work better where it has a large area from which to "choose" reference sites. The straight-line distances between the target site and its best match for the five pairs I examined were 10½, 11, 3, ½, and 8 miles respectively. This suggests to me that an area at least 10 miles across may be needed to find the best match in some cases. While MSN will still find the best matches in smaller areas, those "best matches" may be significantly improved if the analysis area is larger. Of course that's all a function of site variability and will differ from area to area.

The strength of the MSN process is in its use over large areas anyway. Smaller analysis areas may be hand-matched with aerial photos or supplemented with a couple of days of fill-in stand exams. However, given that it's not likely we'll ever reach a point where we have complete stand data coverage, we may want to rethink our stand exam priorities. Perhaps we should pay closer attention to collecting information in all stand conditions and cover types represented (including inoperable and unmerchantable stands), whether they have treatment potential or not, instead of simply concentrating on treatment areas as we have in the past. Under those conditions MSN will be a more effective tool in filling in the data gaps because its repertoire of reference stands to choose from will include a sample of everything out there. MSN could be a real lifesaver when it comes time for Forest Plan revisions, for example, if we have a good representative sample of the Forest and want to use MSN to populate a complete dataset.

We may be tempted to be critical of MSN if we zero in on the imputed tree details of a particular stand, but it's an area analysis tool, not a tree analysis tool. And like most large-scale analysis models, it's the aggregation of many comparisons that it is based upon, and small pluses and minuses at the individual unit level are usually self-compensating over the scale of the analysis area. MSN will never substitute for a Relaskop™ where plot-level precision is required, but it is a tool that the silviculturist may find just as useful to expand the utility of collected information to areas where prism or tape, for whatever reason, "has never dared to go".

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