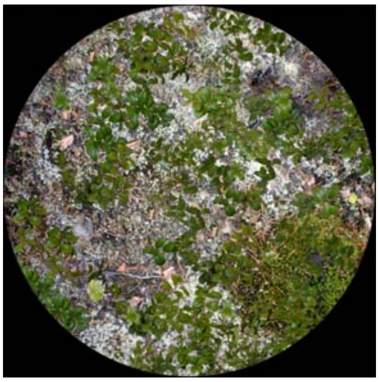
Design and evaluation of a computer aided calibration program for visual estimation of vegetation cover

Åsa Gallegos



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ABSTRACT

Compared to the number of field inventory programs that monitor change in vegetation with visual cover estimations, very few studies have been conducted to show how accurate this type of data is. In addition, no previous studies have determined whether efficient calibration of field observers can improve such data. This study concerns the design and evaluation of a computer program consisting of images of vegetation on which the true cover of vegetation has been digitally calculated. The calibration consists of estimation with immediate feedback of the true cover. The results show that even a short time of calibration greatly improves the estimations and can also drastically reduce the influence of different backgrounds, aggregation patterns and personnel experience.

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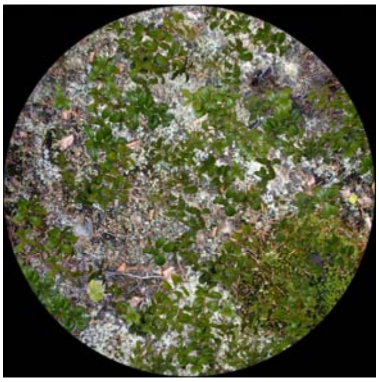

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INTRODUCTION

When working in the field with an inventory program regarding monitoring of vegetation, the field observers will inevitably be requested to perform some type of vegetation coverage estimation. This can be achieved in several different ways, but probably the most common in Europe is the visual estimation where an observer assesses the coverage percentage of a group of plant species in a plot with a predetermined size (Økland, 1990, Johansson and Moen, 2003). This is a method which has been frequently questioned for its result dependability (e.g. Tonteri, 1990, Kennedy and Addison, 1987, Floyd and Anderson, 1987), but since it is considerably more time-efficient than, for instance, the arguably more reliable point-frequency method (Johansson and Moen, 2003, Vanha-Majamaa et al, 2000, Benediktson, 2004), it is nonetheless used ubiquitously. It is a method that can be executed efficiently in the field, it requires no equipment and it seems to be quite easy to learn as well as to teach. The disadvantage is that the results depend on the observer and there is no way of knowing the "right" answer. Thus, the most common criticism of this method lies in it being subjective (van Hees and Mead, 2000, Tonteri, 1990) as opposed to the point-frequency method, which focuses on objectivity but takes more time in the field. The point-frequency method also requires equipment, usually in the form of a frame with a grid. In each of the nodes in this grid, the observer detects if the relevant species is present.

However, some studies, such as Dethier *et al.* (1993), conclude that visual estimations may be just as reliable as the objective point-frequency methods – or even more so. They found that the point-frequency method often missed species with a cover of less than 2% since it is highly unlikely that a species of low occurrence will come in contact with one of the nodes in the grid. On the other hand, if a rare species was observed at a node, it usually resulted in overestimation. Although visual estimation also sometimes resulted in overestimation of rare species, it never failed to notice a rare species occurrence. They also found that the repeatability between observers was higher with the visual estimations than with the point-frequency method.

But how closely can a person in the field estimate the actual vegetation cover? Kennedy and Addison (1987) determined that the estimation error in visual cover assessment was around 10% (20% when including between-year variation), while Tonteri (1990) found an inter-observer variance of 15-40% in her study. Van Hees and Mead (2000) found no increase in accuracy after three separate measurements even though the observers conversed after each measurement and compared methods and approaches to visual estimation. However, in these studies there was no feedback for the observers, they had no way of knowing who had the best results. In this study I will investigate if observers can improve their accuracy and become more proficient with increased learning time and rapid feedback of correct results.

In most cases, the visual estimation method requires the observer to mentally project the significant layer of vegetation vertically to the ground and from this "two-dimensional" image, as closely as possible, estimate the percentage of the area that is covered with vegetation. In field inventory programs the estimation area can vary from several hundred square meters down to a quarter of a square meter. This variation depends essentially on the aim of the study. The results from the large areas can be used to monitor the decline or the increase of different species or groups of species, but just as significant is species occurrence of rare species in particular. The smaller areas will mostly be used for monitoring detailed change in species coverage and occurrence of common species since it is very unlikely that rare species will be detected in these areas. (*Esseen et al*., 2004)

Calibration of Visual Estimation

All inventory studies which require results of this type provide training in coverage estimation for their employees. These training sessions most frequently comprise some form of calibration between all observers in order to reduce the random errors between different observers. The most common ways to calibrate a group of observers are either to compare estimations within the group and nominating the group mean value as the "correct" result, or to compare the group with a reference value estimated by an experienced observer. These calibrations are very useful in the field, but are somewhat unreliable since there is no way to determine the correct answer. Therefore, the main aim of this study is to design and test a calibration program that can be used before as well as during the field season to ensure more reliable results.

Limitations for This Study

This project was running the risk of becoming too extensive if all variable aspects of field inventory were to be considered. There are endless variables to consider in the field, overlapping foliage, indistinguishable species, light, weather, season – and the ever-annoying mosquitoes. According to Dethier *et al*. (1993) however, some of the most important sources of error in field inventory of plants are leaf morphology, color/contrast, aggregation and species identification. In this test, species identification is not relevant and we therefore concentrate on the other aspects. The difference in leaf morphology will be tested by using a whole leaf (lingonberry shoots) and a narrow leaf (blades of grass).

Five variables will be tested for both lingonberry and grass:

- **Learning Time:** No previous studies have determined how long it takes for an observer to become proficient in visual estimations and produce reliable results. This study will show if and how the test subjects increase their abilities over time.

- **Personnel experience:** Although some studies have determined that the levels of experience of the observers might be important for accurate estimations (Dethier *et al.*, 1993), others have concluded that this is not a relevant factor (Floyd and Anderson, 1987). However, in inventory programs where staff turnover is high, it would be highly important to ascertain the variability in estimation between experienced and inexperienced observers. This study will show if there is a difference in estimation error between three groups of differently experienced test personnel.

- **Quantity:** Previous studies differ in their conclusion as to how the quantity of cover affects the estimation error. This study will show if there is any difference in difficulty over a continuing spectrum of true cover.

- **Aggregation:** Several studies agree that the patterns of plant aggregation influence the ability to estimate the coverage accurately (e.g. Dethier *et al*., 1993). Two types of aggregation will be studied; scattered and clustered.

- **Background:** The fact that the background is a major influence on the cover estimations in the field is commonly known. A light background might make the plants seem smaller and vice versa. Moreover, a messy background can be quite confusing while a homogenous background makes estimation easier. Three different backgrounds will be used in this study; white, dark semi-homogenous photo of a forest floor, and a light heterogeneous photo of a forest floor.

By testing these variables, I will be able to determine which of these factors are the most critical in vegetation cover estimation and if observers are able to improve their skills by practicing with this type of equipment.

METHODS

Lingonberry (*Vaccinium vitis-idaea*) shoots were collected and fastened semi-upright in bouquets of various sizes on white paper with Bluetack. Digital photos were taken of the shoots with a Nikon Coolpix 4500 camera with flash and macro from a height of 40 cm. The background was digitally removed from the photographs with Adobe Photoshop (Ver. 7.0). New images (1477x1477 pixels) were constructed using copy-and-paste techniques in Adobe Photoshop. A black circle frame covered each image and defined the estimation area as a circle with a diameter of approximately 1475 pixels.

Different species of grasses were also photographed, but presented too great a problem for cutting out digitally. Grass images were instead produced digitally with the *dune grass brush* (400-425 pixels) in Adobe Photoshop.

In total, a batch of 180 images were constructed, 90 grass and 90 lingonberry. Since aggregation was one of the main variables, two separate sets of images were constructed; scattered and clustered. For each species, 45 images had clustered vegetation and 45 images had scattered. These four categories had an even distribution of vegetation cover as seen in Table 1.

Table 1. Distribution of images in the batch.

Lingonberry	Clustered	15 images (1-33%)
		15 images (34-66%)
		15 images (67-99%)
	Scattered	15 images (1-33%)
		15 images (34-66%)
		15 images (67-99%)
Grass	Clustered	15 images (1-33%)
		15 images (34-66%)
		15 images (67-99%)
	Scattered	15 images (1-33%)
		15 images (34-66%)
		15 images (67-99%)

In order to establish the correct cover percentage of the constructed images, a 3-class unsupervised classification was performed with ERDAS Imagine (Ver. 8.7) on single-layer tiff-images with white background constructed in Adobe Photoshop. The cover of greens (plants) in the image was calculated by dividing the amount of green pixels with the amount of green + white pixels.

Three different backgrounds were used in this experiment, one completely white (referred to as B-white), one with scattered dark wooden twigs and a few green shoots of wood anemone (*Anemone nemorosa*) (B-dark) and one with lichens (*Cladina sp.*) and a clump of moss (*Polytrichum sp.*) (B-light).

The test personnel consisted of 15 individuals selected on basis of their previous experience with visual cover estimations. They were evenly split into three categories;

1. Group N (*N*ovices, no previous experience)
2. Group S (*S*emi-experienced, minimum one week, maximum 2 seasons field work)
3. Group E (*E*xperts, minimum 3 seasons field work or similar)

The test persons are hereafter referred to individually as N1, N2 … E5. The test persons were of mixed ages, genders and occupations. Each test person received written instructions and a CD-ROM with the experiment and proceeded to complete the assignment on their own.

The Layout of the Experiment

The experiment encompassed four proficiency tests (PTs), where the subject estimated the coverage of several images without finding out the correct result, and three practice sessions, where the subject would immediately find out the correct result after estimating. Each practice session consisted of 36 images equally combining all the aforementioned variables. The maximum practice time was 15 minutes/session to ensure a level of uniformity in the experiment. However, if the subject finished the 36 images before the time was up, they would still proceed to the next stage. The entire experiment was laid out as in table 2.

Table 2. The layout of the experiment.

Stage 1	Proficiency Test 1	48 images
Stage 2	Practice 1	15 min/36 images
Stage 3	Proficiency Test 2	24 images
Stage 4	Practice 2	15 min/36 images
Stage 5	Proficiency Test 3	24 images
Stage 6	Practice 3	15 min/36 images
Stage 7	Proficiency Test 4	48 images

Image Selection

For each stage, the number of images of every type that were required was determined as shown in figure 1. The right type of image was then randomly selected from the entire batch.

PTs 1 and 4 consisted of the exact same images (presented in separate orders) to facilitate a comparison of “before-and-after” results. These PTs consisted of all three backgrounds; B-white being the most frequent (24 images) with some B-dark (16) and some B-light (8) images. In contrast, PT sessions 2 and 3 only consisted of B-white images (for time limiting purposes). For statistical reasons, two images of each type were used in the proficiency tests. Each practice session had an equal amount of B-white, B-dark and B-light images; in essence, the practice sessions consisted of one of each type of picture combining species, background, aggregation and quantity-class (the quantity classes were used purely for organizational purposes when constructing the images, PTs and practice sessions).

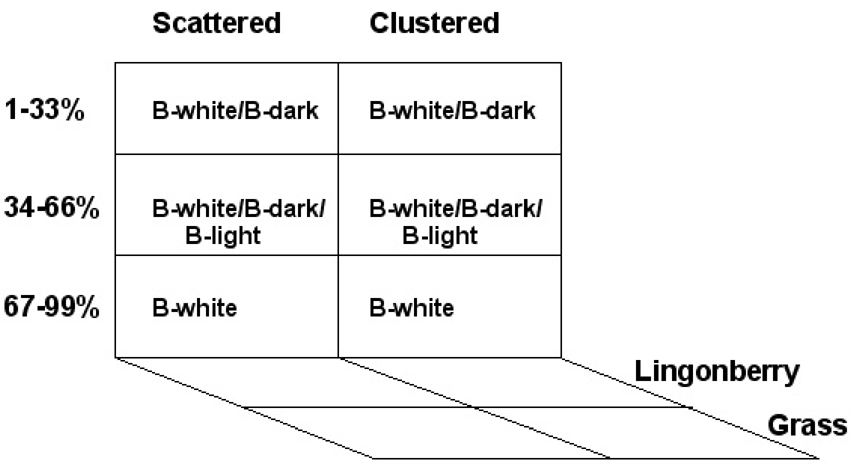


Fig. 1. The layout of images in PTs 1 and 4 (with B-dark and B-light) and PTs 2 and 3 (with only white background, B-white).

RESULTS

There was a substantial difference in total learning time between the different observers. For the five observers in Group N, the times were 24, 27, 29, 14 and 21 minutes, for Group S; 38, 29, 28, 44 and 25, and for Group E; 36, 36, 27, 41 and 7 minutes. This means that the mean practice time per group was 23, 33 and 29 minutes respectively.

Each test group underestimated the cover of both grass and lingonberry during PT 1. However, the novice observers (Group N) had the least amount of underestimation while the experienced observers (Group E) underestimated the most (figure 2). After the first calibration session however, all groups show a clearly distinguishable decrease in variation.

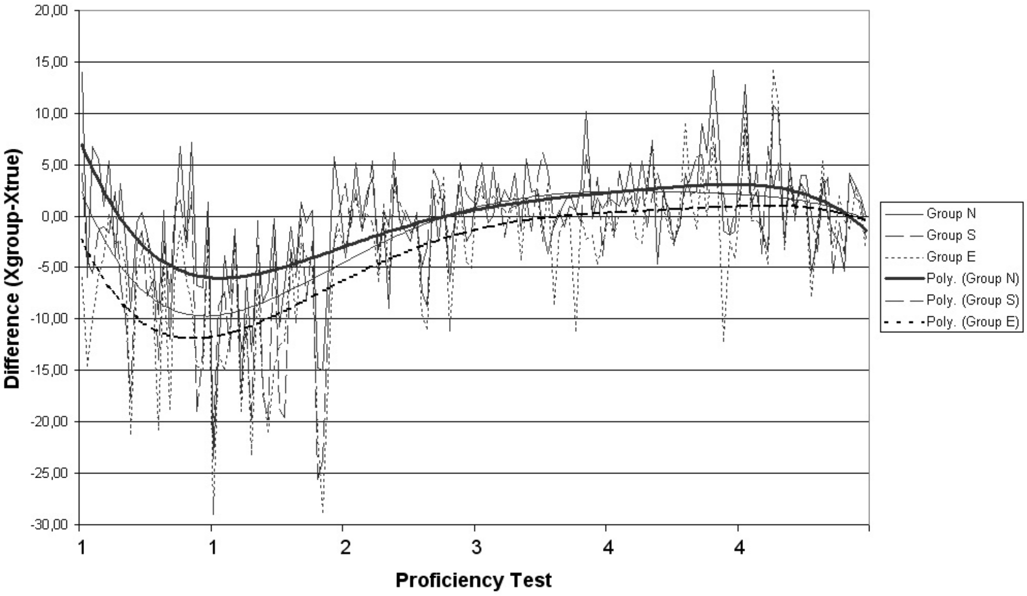


Fig. 2. The difference between the true cover and the estimations of the three observer groups (negative difference indicates underestimation). PT 1 shows most underestimation in all groups.

Figure 3 shows the difference between the estimations in PT 1 and PT 4 for each test group. These PTs comprised the exact same images and are therefore readily comparable. All three groups show an improvement in estimation in PT 4 compared to PT 1.

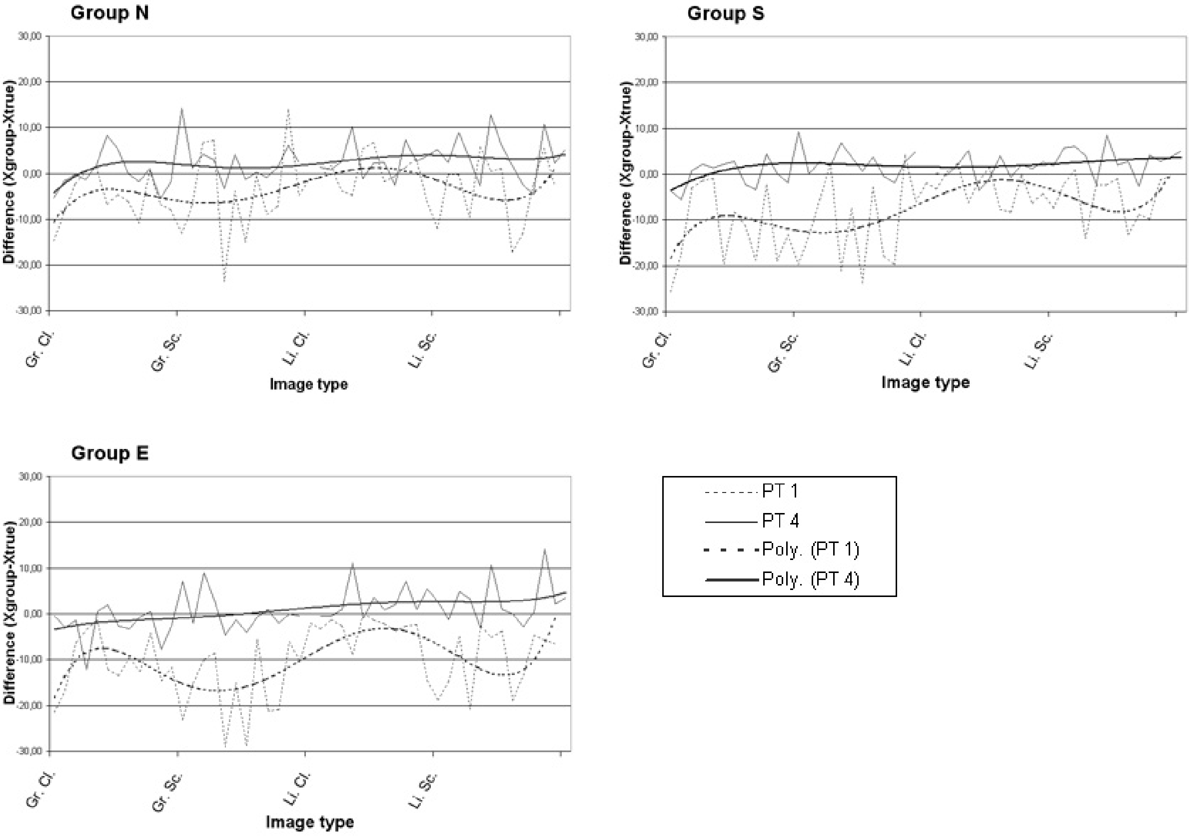


Fig. 3. The difference between the group mean cover and the true cover of PT 1 and PT 4. All groups showed significance in a GLM-ANOVA (P=0,000).

During the whole experiment, group E and Group S (semi-experienced observers) showed a statistically significant systematical error for underestimation (S; Sd = 1.64 ± 1.10, E; Sd = 3.55 ± 1.22, P = 0.000, see Appendix A). During PT 1 (before the first calibration), only N3 showed no systematical error in estimation. 13 of the test persons systematically underestimated the cover and only one overestimated (as seen in Table 3). In PT 4, 11 people overestimated the cover, but the discrepancies were much less than in the beginning (i.e. only five showed systematical error).

Table 3. The distribution of test personnel over- or underestimating in the different proficiency tests. The number in parentheses shows how many in each category had a systematical error.

	Underestimation	**Overestimation**
Proficiency Test 1	14 (13)	1 (1)
Proficiency Test 2	9 (4)	6 (2)
Proficiency Test 3	6 (5)	9 (4)
Proficiency Test 4	3 (2)	11 (5)
All PTs	10 (9)	5 (1)
PTs 2-4	5 (4)	10 (6)

Furthermore, in PT 4, seven individuals showed a systematical error in estimation (*i.e.* N1, N3, N4, S5, E2, E4 and E5) and five of these were now overestimating. Only E3, E4 and E5 were underestimating during all proficiency tests.

As seen in figure 4, every test group shows the largest estimation discrepancy where there is an intermediate amount of true cover.

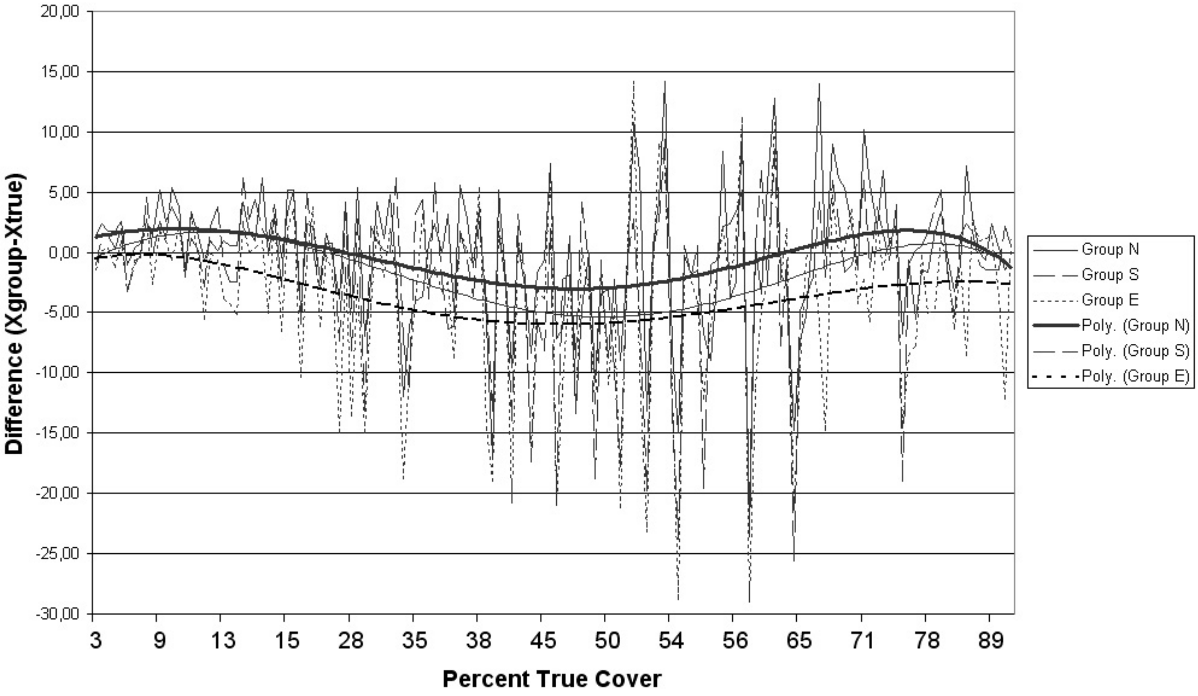


Fig. 4. Difference in cover estimation over a continuing spectrum of true cover (ranging from 3% - 93%)

The results show that grass is more difficult to estimate than lingonberry and that this is true for both scattered and clustered images (figure 5). Scattered images are more difficult to

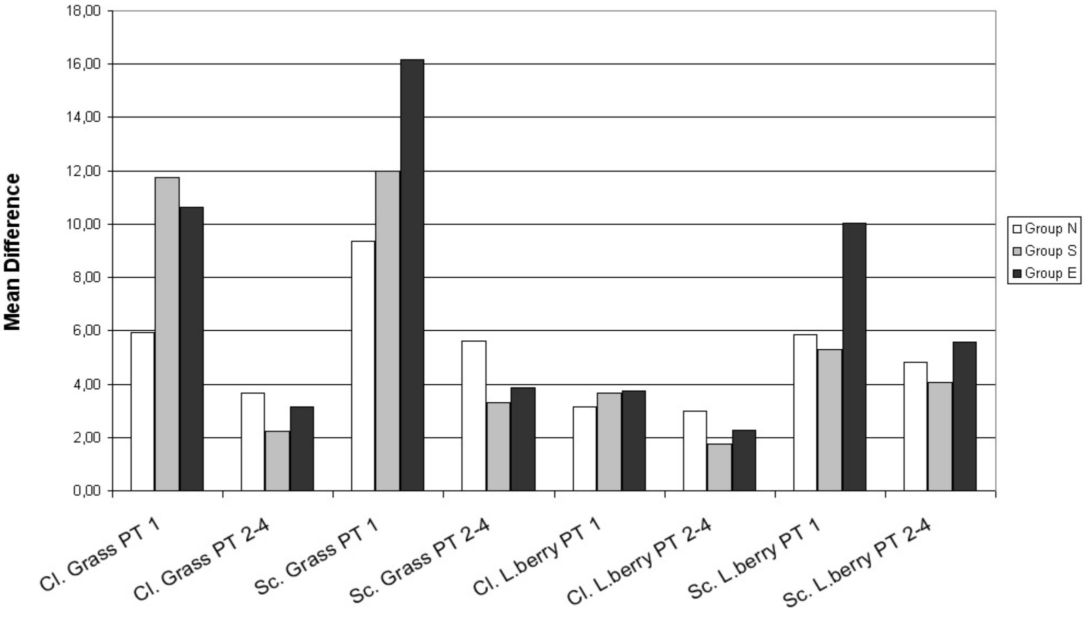


Fig. 5. The difference in estimation between clustered and scattered images of grass and lingonberry for the three test groups. The group mean difference shows the square root of the squared means.

estimate both for lingonberry and grass. Clustered lingonberry was the easiest group overall to estimate. However, after calibration every test group had dramatically decreased their estimation errors in all species- and aggregation categories.

Initially, the heterogeneous background of B-light seems to have made estimation more difficult for all the test groups (figure 6). However, after calibration there seems to be no substantial difference between the three backgrounds. And consistent with other results, each group decreases their estimation error after calibration. In fact, figure 6 shows that after calibration, the background does not seem to affect the estimation.

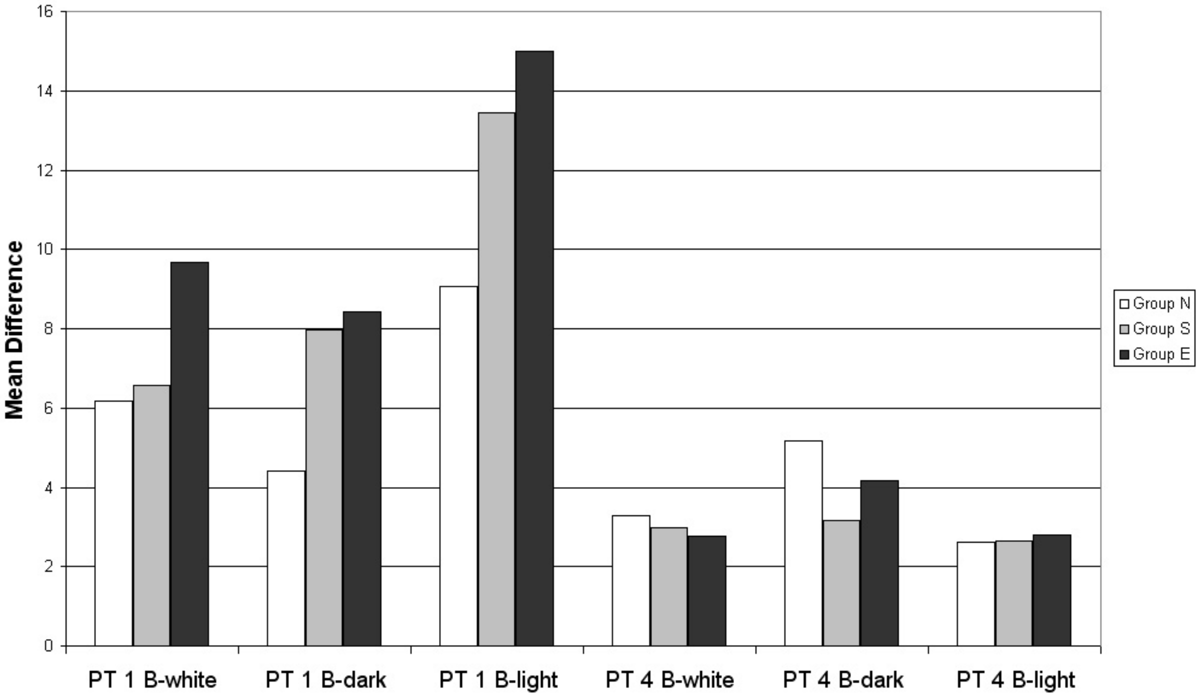
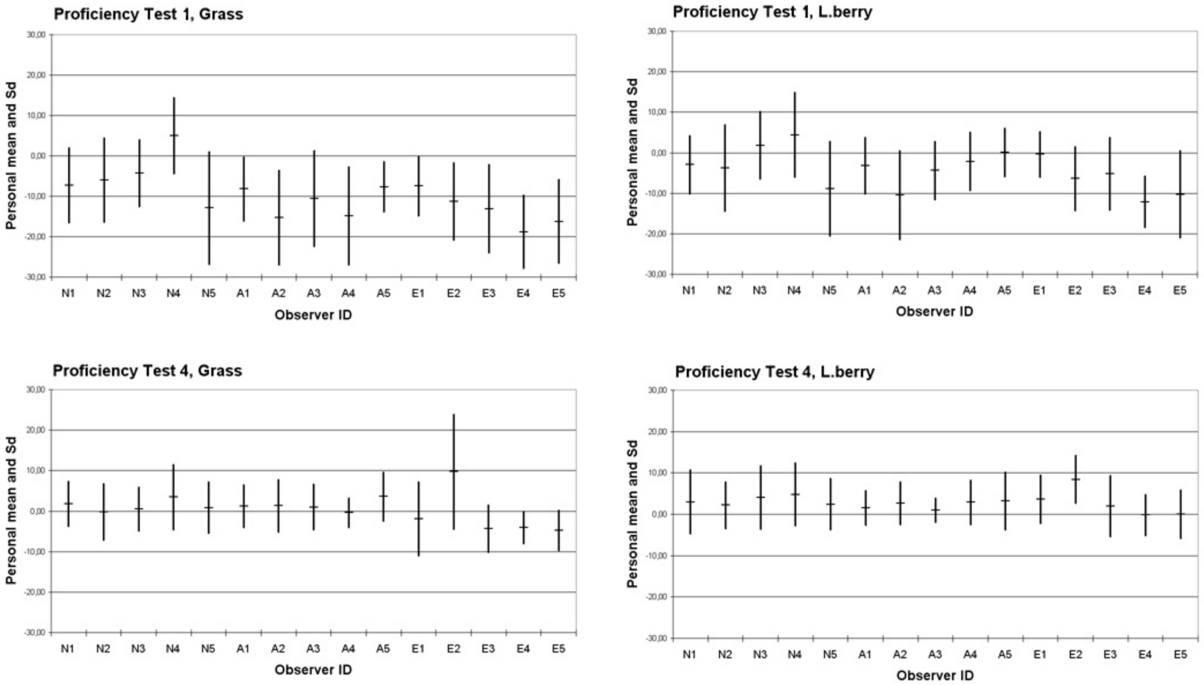


Fig. 6. The difference in estimation between different background images in PTs 1 and 4. The group mean difference shows the square root of the squared means.

Figure 7 shows a comparison between all test personnel for grass and lingonberry before and after calibration. There is a substantial decrease in both inter-observer variation and standard deviation after calibration.

Finally, figure 8 shows an interaction plot constructed in Minitab (Release 14.13) for five variables; PT, species, background, aggregation and experience. Of these, nine show significance in a GLM-ANOVA (i.e. PT vs. species/aggregation/experience (P=0.000), PT vs. background (P=0.005), species vs. background (P=0.000), species vs. aggregation (P=0.005), background vs. experience (P=0.033) and aggregation vs. experience (P=0.008). See Appendix A).


Proficiency Test 1, Grass

Proficiency Test 1, L.berry

Proficiency Test 4, Grass

Proficiency Test 4, L.berry

Fig. 7. Inter-observer variation for all test personnel, before and after calibration for both species. The graph shows individual mean and standard deviations (see Appendix A).

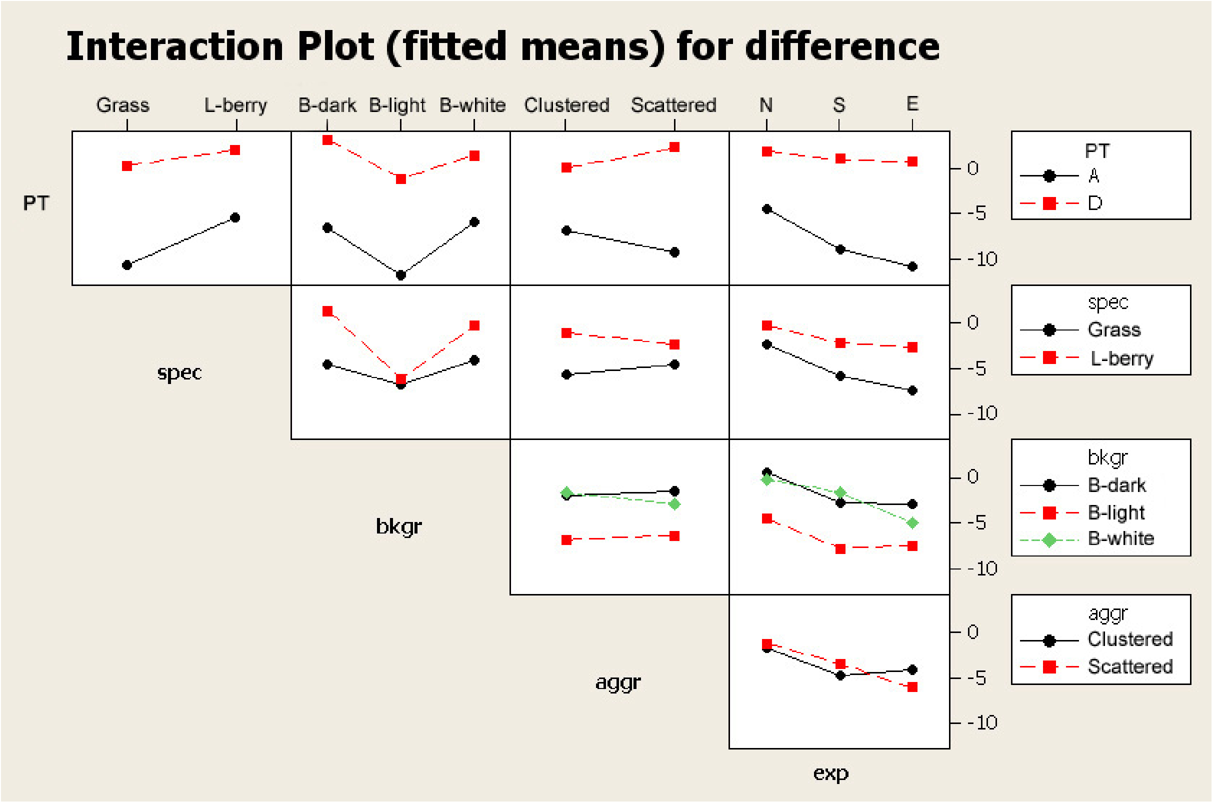

Interaction Plot (fitted means) for difference

Fig. 8. A Minitab interaction plot for difference (Xperson –Xtrue).

DISCUSSION

The results undoubtedly show that even a relatively short calibration time reduces the errors in estimation. From PT 1 to PT 4 each group shows an impressive decrease in average estimation error (Group N: 37%, Group S: 63% and Group E: 68%). Initially, the difference in estimation between the true cover and the group mean is 6 – 10 percentage points, and after calibration the same images have an estimation difference of 3 – 3,5 percentage points. Kennedy and Addison (1987), as well as Sykes et al. (1983), determined that the sequential measurement error in visual cover assessment was around 10%, which is in accordance with the initial results of this study. Van Hees and Mead (2000) found no increase in accuracy after three separate measurements even though the observers conversed after each measurement and compared methods and approaches to visual estimation. The test personnel in the other studies had no immediate feedback and did not know the true cover, whereas this study shows a dramatic decrease in estimation error after calibration. However, the studies mentioned above took place in the field and comprised many more variables that are difficult to account for. Although this study is not readily comparable to field studies or field work, we can still assume that calibration with rapid feedback of true cover is an efficient method of reducing the estimation error.

Learning Time

Discrepancies in practice time were reduced by limiting it to 3 x 15 minutes, but most test persons seldom used the full 15 minutes. The fastest used only 7 minutes in total practice time, which is approximately a sixth of the maximum time of 45 minutes. However, each test person practiced on the same number of images and practice time might not be the most important factor. It would probably have been worse to limit the time and let the test personnel practice on as many images as the time allowed. In that case, the fastest individuals would have had time to practice on six times as many images and that would probably result in a greater source of error.

After the first calibration session (lasting from 2-15 minutes depending on the observer), the decrease in estimation error is clearly noticeable (figure 2). During the rest of the experiment, the estimation error remained more or less constant.

The results show that every group underestimates the cover in the beginning of the experiment and that groups N and S overestimate at the end (figure 2). The change from underestimation in PT 1 to overestimation in PT 4 might be explained by an oscillating calibration curve. If the entire experiment would have been longer, maybe the results would have evened out. Group E’s results had improved for PT 4, but three of five test persons in this group were still underestimating, whereas everyone in groups N and S were overestimating by this point. This leads to a better mean value for Group E. The reason for the slower oscillation in Group E might be a result of the greater underestimation that Group E had from the beginning and the fact that the experienced personnel have ingrained routines that are hard to change over this limited time frame.

Personnel Experience

The results clearly stipulate that, at least in PT 1-3, experienced observers are responsible for the largest estimation errors (figure 2 and 5). All three groups show significantly better results at the end of the experiment and Group E is, not surprisingly, attributed to having the most substantial improvement.

One possible explanation for these results could be that unsubstantiated methods of visual estimation might be imprinted in experienced field observers. This is true especially for species that are difficult to estimate. In field training, observers are constantly reminded that grass, for instance, even if it seems to be covering a large area, consists of very narrow leaves with very low total coverage. Thus, field observers tend to estimate cover for grass and then reduce their initial estimation. Consequently, experienced observers might estimate grass lower to be on the safe side. Inexperienced observers have no prejudice as to how different species might be interpreted in an estimation situation. Therefore they estimate the cover without adding into the equation this type of subconscious knowledge. Since they have never performed this type of estimation before, they might also be more prone to careful consideration of every image, whereas experienced observers might glance at the image and settle with the first impression they get. Of course, this greatly depends on the individual observer as seen in the results. Several inexperienced observers went through the practice images very fast while some experienced observers used almost the full practice time of 45 minutes. In effect, Group N had the shortest mean practice time while Group S had the longest.

Inter-observer variation is an important factor in this type of study. Dethier et al. (1993) showed that variability between observers was greater than within-observer variance, even though inexperienced observers did not produce results of significantly lower quality than experienced observers. Sykes et al. (1983) showed that differences between observers were always significant. This study found that the inter-observer variance, as well as the intra-observer variance, decreased substantially after calibration (figure 7).

Encouragingly, this study shows that even though personnel might be inexperienced in cover estimation, this particular skill is definitely one that can be acquired to a satisfying degree in a short time.

Quantity

As seen in figure 4, the highest discrepancy in estimation occurs where there is intermediate cover, especially between 40 – 65% true cover. This result is consistent with the results of Sykes et al. (1983) who estimated that the most extensive discrepancies would occur in the 50% region and be less at the two extremes. In this intermediate region, the observer has an equal chance to overestimate or underestimate the cover which leads to a larger estimation error. Also, the trendlines in figure 4 are consistent with the results of Jukola-Sulonen and Salemaa (1985), who found that observers tend to overestimate low cover and underestimate high cover. The most obvious explanation being that the estimable cover has very tangible limits at 0% and 100%. This severely reduces the margin of error for high and low amounts of true cover and produces a bias for errors in the opposite direction.

The findings of this study contradict Tonteri (1990) and Kennedy and Addison (1987). They found that the species with the lowest cover showed the largest errors. It seems, however, that these studies have calculated the estimation errors based on various types of comparisons between the estimated values and the mean values, which inevitably lead to higher errors where there is low mean cover. In this study, the error has been calculated as the difference between the estimated cover and the true cover, which negates this bias. This is of course impossible to do in a study where the true cover is unknown, as with Tonteri (1990) and Kennedy and Addison (1987).

The test personnel were asked not to round off their estimates but to assess the cover as closely as possible to the nearest percent. Therefore, this study also shows that the use of 1%-classes does not produce larger estimation errors than would be expected with larger quantity classes.

Species

It was assumed from the beginning that grass was going to be more difficult to estimate correctly and the results show no deviation from that hypothesis. Grass shows a high degree of underestimation which may be attributed to reasons discussed above. However, the grass created by the *dune grass brush* in Adobe Photoshop has fairly wide leaves, which at the size used in these images may be compared to species like tufted hair-grass (*Deschampsia cespitosa*) or timothy (*Phleum pratensis*). It would be reasonable to assume that if an even narrower leaf (such as weavy hair-grass, *Deschampsia flexuosa*) would have been used, the estimation errors would have been even greater.

The lingonberry actually seems to be slightly overestimated over the whole experiment, especially in aggregated images. According to Kennedy and Addison (1987), species which are easily seen and have a limited distribution are the easiest to estimate. The lingonberry clearly falls into this category, whereas grass does not. Lingonberry shoots have clear egdes to their whole leaves and occur in clumps, even in scattered images.

Kennedy and Addison (1987) found that when observers increased their familiarity with the vegetation and thus improved their species-identification, the precision of the sampling increased. They also showed that a 1-month break in sampling reduced the accuracy to the initial level. In their study, species identification was an important factor. Many field studies using this type of visual cover estimation are nevertheless more concerned with groups of species than specific species identification, and this study has shown the difference between two large groups of plants. Even so, a well-educated staff is of course important for the correct field results.

Aggregation

Aggregation is known to be a highly important variable in field estimation (e.g. Dethier *et al*., 1993). Therefore it was surprising that the aggregation did not show any statistical significance in the ANOVA for PT 1 and 4 (P = 0.440). However, as figure 5 depicts, there is a significant differnce in estimation error between clustered and scattered images in Proficiency Test 1 (P = 0.001), at least for groups N and E. This is true for both species. After calibration, the difference between aggregation types seems to have diminished substantially, which may be an explanation as to why aggregation did not show any significance over the entire experiment.

Background

B-light, the heterogeneous photo with lichens and moss, seemed initially to be the most confusing background for all three groups (P = 0.000). However, for groups N and E, white background was the second most difficult although this could not be proven statistically (P = 0.1702), probably since Group S did not respond in the same way. Both B-light and B-white make the relevant vegetation seem smaller and this inevitably leads to underestimation.

An interesting fact is that after calibration, all three backgrounds show a similar estimation error. This means that this type of calibration can be used to eliminate the effect of background disturbance.

Sources of Error and Limitations for This Study

It is very important in this type of calibration to have confidence in the feedback of true cover during the practice sessions, since a lack of confidence in this feedback will probably make test personnel less susceptible to calibration, and might in this case lead to a poorer result. Several of the experienced test personnel expressed difficulty in trusting some of the correct answers, especially scattered grass images. The observers repeatedly underestimated these images and many were sure that the correct answers were too high. This might be attributed to the constant reminders in field training that grass, even if it seems to be covering a large area, consists of very narrow leaves with very low total coverage.

There were concerns as to how ERDAS Imagine calculated the true cover in the grass images. The digital grass may have had “fuzzy” edges which were included in the calculation of green pixels. However, these fuzzy edges were at the most 3 pixels wide and would probably not have accounted for any significant errors in the final calculation. Regardless of any miscalculations, the results show that this type of calibration is very efficient.

Many field-related variables were too time-consuming or difficult to take into account within this limited time frame. Even though the results from this study are not completely comparable to cover estimation in the field, the test personnel clearly showed an improvement in cover estimation. This improvement is beneficial for field work, as well as analyzing two-dimensional images on a computer screen. The results indicate that calibration is essential and hopefully there will be studies in the future which will consider these variables. Preferably, future studies will be able to calibrate observers in the field and somehow accurately determine the true cover of species in the field. Nevertheless, this type of calibration in combination with field training might, for now, be the best way to calibrate field observers.

This study has concentrated on small areas, basically because large areas would mean that the species in question would only look like green dots on the screen. In order to determine the difference in estimation error between species, they had to be large enough to distinguish clearly. In addition, when a field observer is estimating a large area in the field, they search the area, noticing and estimating species cover when they find a certain species. This is very difficult to simulate on a computer with a simple image. A calibration of this type of area would mean a 3-dimensional computer environment which allows the observer to navigate around the area at their own discretion.

CONCLUSIONS

The results from this study show that calibration is important and that it significantly decreases the estimation error of visual cover estimation. It also seems to be working in a short space of time. The test personnel showed a significant decrease in estimation error after the first practice session. This means that this type of calibration can be used frequently during a field season without taking valuable time away from the inventories. In fact, a little time spent at the start of every week in the field might not only produce much better results, but may also generate better confidence in the field personnel. A problem I have often encountered in the field is when the field observers are unsure if the results they produce are correct or not. This can lead to an “it-doesn’t-matter-what-I-write-nobody-knows-if-it’s-right-anyway” type of feeling. This type of calibration gives a very real feedback which the majority of my test persons have indicated as a good incentive to try and improve their results. The few observers I have watched during practice sessions often felt like they had “won” when the true value was exactly what they had estimated. This type of positive incentive boosts one’s confidence, as well as increases the result reliability during the field season.

ACKNOWLEDGEMENTS

I would like to thank my supervisor, Anders Glimskär, as well as my co-supervisors Mats Walheim and Hans Peterson, for all their help. I would also like to extend my thanks to Per-Anders Esséen, who gave me the idea for this project in the first place.

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General Linear Model: Diff versus Prof Test; Spec; Backgr; Aggr; Exp

```
Factor     Type Levels Values
Prof Test  fixed      2 1 4
Spec       fixed      2 gräs       lingon
Backgr     fixed      3 B-dark     B-light     B-white
Aggr       fixed      2 klustrad   spridd
Exp        fixed      3 N S E

Analysis of Variance for Diff, using Adjusted SS for Tests

Source              DF     Seq SS     Adj SS     Adj MS       F      P
Mfacit               1     4852,2     1917,3     1917,3   27,77  0,000
Prof Test            1    27440,1    25515,8    25515,8  369,61  0,000
Spec                 1     4795,8     2974,7     2974,7   43,09  0,000
Backgr               2     2224,3     2216,9     1108,4   16,06  0,000
Aggr                 1        0,1       24,2       24,2    0,35  0,554
Exp                  2     3932,5     2884,4     1442,2   20,89  0,000
Prof Test*Spec       1     1050,6     1050,6     1050,6   15,22  0,000
Prof Test*Backgr     2      732,3      732,3      366,2    5,30  0,005
Prof Test*Aggr       1     1932,1     1932,1     1932,1   27,99  0,000
Prof Test*Exp        2     1731,9     1731,9      865,9   12,54  0,000
Spec*Backgr          2     1108,8     1108,3      554,2    8,03  0,000
Spec*Aggr            1      550,0      549,9      549,9    7,97  0,005
Spec*Exp             2      392,4      392,4      196,2    2,84  0,059
bakgrund*Aggr        2      242,4      242,4      121,2    1,76  0,173
bakgrund*Exp         4      727,7      727,7      181,9    2,64  0,033
Aggr*Exp             2      664,3      664,3      332,2    4,81  0,008
Error             1412    97476,9    97476,9       69,0
Total             1439   149854,5

Term                    Coef   SE Coef        T      P
Constant              4,9352    0,3711    13,30  0,000
Mfacit              -0,08785   0,01667    -5,27  0,000
```

Only white background:
General Linear Model: Diff versus Prof Test; Spec; Aggr; Exp

```
Factor     Type Levels Values
Prof Test fixed      4 1 2 3 4
Spec      fixed      2 grass      l-berry
Aggr      fixed      2 clust      scatt
Exp       fixed      3 N S E

Analysis of Variance for Diff, using Adjusted SS for Tests

Source          DF     Seq SS     Adj SS     Adj MS       F      P
Mfacit           1     4706,6     4512,0     4512,0   79,84  0,000
Prof Test        3    12218,2    12205,3     4068,4   72,00  0,000
Spec             1     2143,6     2129,7     2129,7   37,69  0,000
Aggr             1        3,6        3,1        3,1    0,05  0,816
Exp              2     3055,5     3055,5     1527,7   27,03  0,000
Prof Test*Spec   3      808,4      809,9      270,0    4,78  0,003
Prof Test*Aggr   3     1136,1     1133,6      377,9    6,69  0,000
Prof Test*Exp    6     1681,8     1681,8      280,3    4,96  0,000
Spec*Aggr        1      323,7      323,7      323,7    5,73  0,017
Spec*Exp         2      542,7      542,7      271,3    4,80  0,008
Aggr*Exp         2      907,8      907,8      453,9    8,03  0,000
Error         1414    79904,2    79904,2       56,5
Total         1439   107432,3
```

Tukey Simultaneous Tests

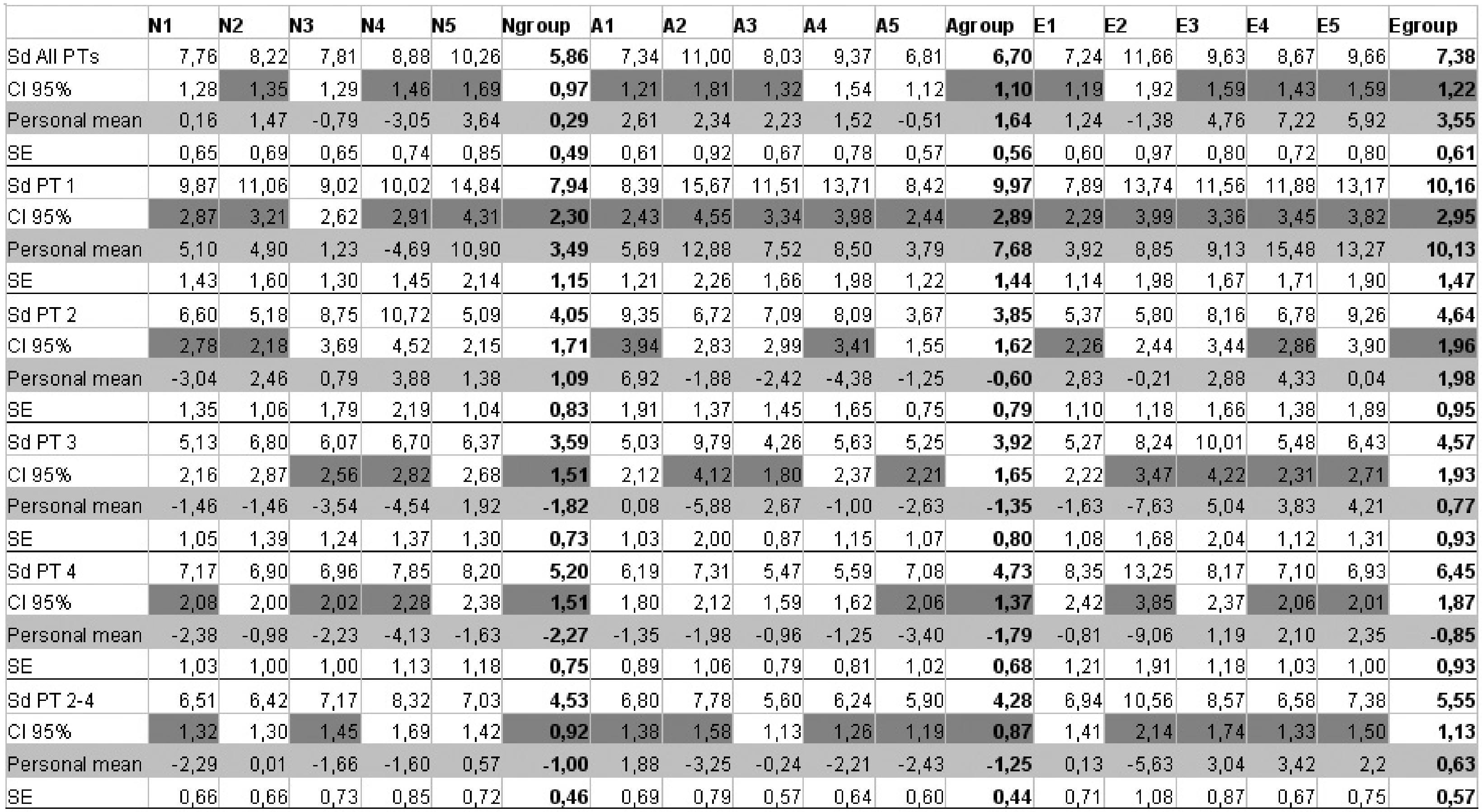
```
Tukey 95.0% Simultaneous Confidence Intervals
Response Variable Diff
All Pairwise Comparisons among Levels of Backgr

Backgr= B-dark subtracted from:

Backgr    Lower    Center     Upper  ------+---------+---------+---------+
B-light  2,2676    3,8719     5,476                          (----*----)
B-white -0,2674    0,8866     2,041                 (---*---)
                                     ------+---------+---------+---------+
                                         -3,0       0,0       3,0       6,0

Backgr= B-light subtracted from:

Backgr    Lower    Center     Upper  ------+---------+---------+---------+
B-white  -4,552    -2,985    -1,418   (----*----)
                                     ------+---------+---------+---------+
                                         -3,0       0,0       3,0       6,0

Tukey Simultaneous Tests
Response Variable Diff
All Pairwise Comparisons among Levels of Backgr

Backgr= B-dark subtracted from:

Level        Difference       SE of             Adjusted
Backgr          of Means  Difference   T-Value    P-Value
B-light           3,8719      0,6854     5,649     0,0000
B-white           0,8866      0,4931     1,798     0,1702

Backgr= B-light subtracted from:

Level        Difference       SE of             Adjusted
Backgr          of Means  Difference   T-Value    P-Value
B-white           -2,985      0,6694    -4,459     0,0000

Tukey 95.0% Simultaneous Confidence Intervals
Response Variable Diff
All Pairwise Comparisons among Levels of Exp

Exp = N subtracted from:

Exp     Lower    Center     Upper  ---+---------+---------+---------+---
S       1,262     2,650     4,038             (---------*--------)
E       2,335     3,723     5,111                     (--------*--------)
                                   ---+---------+---------+---------+---
                                     0,0       1,5       3,0       4,5

Exp = S subtracted from:

Exp     Lower    Center     Upper  ---+---------+---------+---------+---
E     -0,3148     1,073     2,461   (--------*--------)
                                   ---+---------+---------+---------+---
                                     0,0       1,5       3,0       4,5
```

```
Tukey Simultaneous Tests
Response Variable Diff
All Pairwise Comparisons among Levels of Exp

Exp = N subtracted from:

Level   Difference       SE of             Adjusted
Exp       of Means  Difference   T-Value    P-Value
S            2,650      0,5929     4,469     0,0000
E            3,723      0,5929     6,279     0,0000

Exp = S subtracted from:

Level   Difference       SE of             Adjusted
Exp       of Means  Difference   T-Value    P-Value
E            1,073      0,5929     1,810     0,1664
```

Only white background:
Tukey Simultaneous Tests

```
Tukey 95.0% Simultaneous Confidence Intervals
Response Variable Diff
All Pairwise Comparisons among Levels of Prof Test

Prof Test = 1 subtracted from:

Prof Test Lower    Center     Upper  ----------+---------+---------+------
2        -6,117    -4,674    -3,232            (---*----)
3        -8,337    -6,897    -5,458    (----*----)
4        -8,785    -7,347    -5,909   (----*---)
                                     ----------+---------+---------+------
                                             -6,0      -3,0       0,0

Prof Test = 2 subtracted from:

Prof Test Lower    Center     Upper  ----------+---------+---------+------
3        -3,671    -2,223    -0,774                    (----*---)
4        -4,115    -2,673    -1,231                  (----*----)
                                     ----------+---------+---------+------
                                             -6,0      -3,0       0,0

Prof Test = 3 subtracted from:

Prof Test Lower    Center     Upper  ----------+---------+---------+------
4        -1,890   -0,4500    0,9896                        (----*---)
                                     ----------+---------+---------+------
                                             -6,0      -3,0       0,0


Tukey Simultaneous Tests
Response Variable Diff
All Pairwise Comparisons among Levels of Prof Test

Prof Test = 1 subtracted from:

Level     Difference       SE of             Adjusted
Prof Test   of Means  Difference   T-Value    P-Value
2             -4,674      0,5619     -8,32     0,0000
3             -6,897      0,5608    -12,30     0,0000
4            -7,347      0,5603    -13,11     0,0000
```

```
Prof Test = 2 subtracted from:

Level     Difference       SE of             Adjusted
Prof Test   of Means  Difference   T-Value    P-Value
3             -2,223      0,5643    -3,939     0,0005
4             -2,673      0,5619    -4,757     0,0000

Prof Test = 3 subtracted from:

Level     Difference       SE of             Adjusted
Prof Test   of Means  Difference   T-Value    P-Value
4            -0,4500      0,5608   -0,8023     0,8534

Tukey 95.0% Simultaneous Confidence Intervals
Response Variable Diff
All Pairwise Comparisons among Levels of Exp

Exp = N subtracted from:

Exp     Lower    Center     Upper  ------+---------+---------+---------+
S     -0,7607    0,3750     1,511   (-------*------)
E      2,1247    3,2604     4,396                      (-------*------)
                                   ------+---------+---------+---------+
                                        0,0       1,5       3,0       4,5

Exp = S subtracted from:

Exp     Lower    Center     Upper  ------+---------+---------+---------+
E       1,750     2,885     4,021                    (------*-------)
                                   ------+---------+---------+---------+
                                        0,0       1,5       3,0       4,5


Tukey Simultaneous Tests
Response Variable Diff
All Pairwise Comparisons among Levels of Exp

Exp = N subtracted from:

Level   Difference       SE of             Adjusted
Exp       of Means  Difference   T-Value    P-Value
S           0,3750      0,4852    0,7728     0,7197
E           3,2604      0,4852    6,7192     0,0000

Exp = S subtracted from:

Level   Difference       SE of             Adjusted
Exp       of Means  Difference   T-Value    P-Value
E            2,885      0,4852     5,946     0,0000
```



	N1	N2	N3	N4	N5	Ngroup	A1	A2	A3	A4	A5	Agroup	E1	E2	E3	E4	E5	Egroup
Sd All PTs	7,76	8,22	7,81	8,88	10,26	**5,86**	7,34	11,00	8,03	9,37	6,81	**6,70**	7,24	11,66	9,63	8,67	9,66	**7,38**
CI 95%	1,28	1,35	1,29	1,46	1,69	**0,97**	1,21	1,81	1,32	1,54	1,12	**1,10**	1,19	1,92	1,59	1,43	1,59	**1,22**
Personal mean	0,16	1,47	-0,79	-3,05	3,64	**0,29**	2,61	2,34	2,23	1,52	-0,51	**1,64**	1,24	-1,38	4,76	7,22	5,92	**3,55**
SE	0,65	0,69	0,65	0,74	0,85	**0,49**	0,61	0,92	0,67	0,78	0,57	**0,56**	0,60	0,97	0,80	0,72	0,80	**0,61**
Sd PT 1	9,87	11,06	9,02	10,02	14,84	**7,94**	8,39	15,67	11,51	13,71	8,42	**9,97**	7,89	13,74	11,56	11,88	13,17	**10,16**
CI 95%	2,87	3,21	2,62	2,91	4,31	**2,30**	2,43	4,55	3,34	3,98	2,44	**2,89**	2,29	3,99	3,36	3,45	3,82	**2,95**
Personal mean	5,10	4,90	1,23	-4,69	10,90	**3,49**	5,69	12,88	7,52	8,50	3,79	**7,68**	3,92	8,85	9,13	15,48	13,27	**10,13**
SE	1,43	1,60	1,30	1,45	2,14	**1,15**	1,21	2,26	1,66	1,98	1,22	**1,44**	1,14	1,98	1,67	1,71	1,90	**1,47**
Sd PT 2	6,60	5,18	8,75	10,72	5,09	**4,05**	9,35	6,72	7,09	8,09	3,67	**3,85**	5,37	5,80	8,16	6,78	9,26	**4,64**
CI 95%	2,78	2,18	3,69	4,52	2,15	**1,71**	3,94	2,83	2,99	3,41	1,55	**1,62**	2,26	2,44	3,44	2,86	3,90	**1,96**
Personal mean	-3,04	2,46	0,79	3,88	1,38	**1,09**	6,92	-1,88	-2,42	-4,38	-1,25	**-0,60**	2,83	-0,21	2,88	4,33	0,04	**1,98**
SE	1,35	1,06	1,79	2,19	1,04	**0,83**	1,91	1,37	1,45	1,65	0,75	**0,79**	1,10	1,18	1,66	1,38	1,89	**0,95**
Sd PT 3	5,13	6,80	6,07	6,70	6,37	**3,59**	5,03	9,79	4,26	5,63	5,25	**3,92**	5,27	8,24	10,01	5,48	6,43	**4,57**
CI 95%	2,16	2,87	2,56	2,82	2,68	**1,51**	2,12	4,12	1,80	2,37	2,21	**1,65**	2,22	3,47	4,22	2,31	2,71	**1,93**
Personal mean	-1,46	-1,46	-3,54	-4,54	1,92	**-1,82**	0,08	-5,88	2,67	-1,00	-2,63	**-1,35**	-1,63	-7,63	5,04	3,83	4,21	**0,77**
SE	1,05	1,39	1,24	1,37	1,30	**0,73**	1,03	2,00	0,87	1,15	1,07	**0,80**	1,08	1,68	2,04	1,12	1,31	**0,93**
Sd PT 4	7,17	6,90	6,96	7,85	8,20	**5,20**	6,19	7,31	5,47	5,59	7,08	**4,73**	8,35	13,25	8,17	7,10	6,93	**6,45**
CI 95%	2,08	2,00	2,02	2,28	2,38	**1,51**	1,80	2,12	1,59	1,62	2,06	**1,37**	2,42	3,85	2,37	2,06	2,01	**1,87**
Personal mean	-2,38	-0,98	-2,23	-4,13	-1,63	**-2,27**	-1,35	-1,98	-0,96	-1,25	-3,40	**-1,79**	-0,81	-9,06	1,19	2,10	2,35	**-0,85**
SE	1,03	1,00	1,00	1,13	1,18	**0,75**	0,89	1,06	0,79	0,81	1,02	**0,68**	1,21	1,91	1,18	1,03	1,00	**0,93**
Sd PT 2-4	6,51	6,42	7,17	8,32	7,03	**4,53**	6,80	7,78	5,60	6,24	5,90	**4,28**	6,94	10,56	8,57	6,58	7,38	**5,55**
CI 95%	1,32	1,30	1,45	1,69	1,42	**0,92**	1,38	1,58	1,13	1,26	1,19	**0,87**	1,41	2,14	1,74	1,33	1,50	**1,13**
Personal mean	-2,29	0,01	-1,66	-1,60	0,57	**-1,00**	1,88	-3,25	-0,24	-2,21	-2,43	**-1,25**	0,13	-5,63	3,04	3,42	2,2	**0,63**
SE	0,66	0,66	0,73	0,85	0,72	**0,46**	0,69	0,79	0,57	0,64	0,60	**0,44**	0,71	1,08	0,87	0,67	0,75	**0,57**

Standard deviation (Sd) for each test person/group and the correspondning confidence interval (CI) and personal mean difference. Shaded CI-squares have a systematical error. A positive personal mean difference equals underestimation.

Serien Arbetsrapporter utges i första hand för institutionens eget behov av viss dokumentation. Rapporterna är indelade i följande grupper: Riksskogstaxeringen, Planering och inventering, Biometri, Fjärranalys, Kompendier och undervisningsmaterial, Examensarbeten, Internationellt samt NILS. Författarna svarar själva för rapporternas vetenskapliga innehåll.

Riksskogstaxeringen:

1995	1	Kempe, G.	Hjälpmedel för bestämning av slutenhet i plant- och ungskog. ISRN SLU-SRG-AR--1--SE
	2	Nilsson, P.	Riksskogstaxeringen och Ståndortskarteringen vid regional miljöövervakning. - Metoder för att förbättra upplösningen vid inventering i skogliga avrinningsområden. ISRN SLU-SRG-AR--2--SE
1997	23	Lundström, A., Nilsson, P. & Ståhl, G.	Certifieringens konsekvenser för möjliga uttag av industri- och energived. - En pilotstudie. ISRN SLU-SRG-AR--23--SE
	24	Fridman, J. & Walheim, M.	Död ved i Sverige. - Statistik från Riksskogstaxeringen. ISRN SLU-SRG-AR--24--SE
1998	30	Fridman, J., Kihlblom, D. & Söderberg, U.	Förslag till miljöindexsystem för naturtypen skog. ISRN SLU-SRG-AR--30--SE
	34	Löfgren, P.	Skogsmark, samt träd- och buskmark inom fjällområdet. En skattning av arealer enligt internationella ägoslagsdefinitioner. ISRN SLU-SRG-AR--34--SE
	37	Odell, P. & Ståhl, G.	Vegetationsförändringar i svensk skogsmark mellan 1980- och 90-talet. - En studie grundad på Ståndortskarteringen. ISRN SLU-SRG-AR--37--SE
	38	Lind, T.	Quantifying the area of edges zones in Swedish forest to assess the impact of nature conservation on timber yields. ISRN SLU-SRG-AR--38--SE
1999	50	Ståhl, G., Walheim, M. & Löfgren, P.	Fjällinventering. - En utredning av innehåll och design. ISRN SLU-SRG-AR--50--SE

	52	Fridman, J. & Ståhl, G. (Redaktörer)	Utredningar avseende innehåll och omfattning i en framtida Riksskogstaxering. ISRN SLU-SRG-AR--52--SE
	54	Fridman, J., Holmström, H., Nyström, K., Petersson, H., Ståhl, G. & Wulff, S.	Sveriges skogsmarksarealer enligt internationella ägoslagsdefinitioner. ISRN SLU-SRG-AR--54--SE
	56	Nilsson, P. & Gustafsson, K.	Skogsskötseln vid 90-talets mitt - läge och trender. ISRN SLU-SRG-AR--56--SE
	57	Nilsson, P. & Söderberg, U.	Trender i svensk skogsskötsel - en intervjuundersökning. ISRN SLU-SRG-AR--57--SE
2000	65	Bååth, H., Gällerspång, A., Hallsby, G., Lundström, A., Löfgren, P., Nilsson, M. & Ståhl, G.	Metodik för skattning av lokala skogsbränsleresurser. ISRN SLU-SRG-AR--65--SE
	75	von Segebaden, G.	Komplement till "RIKSTAXEN 75 ÅR". ISRN SLU-SRG-AR--75--SE
2001	86	Lind, T.	Kolinnehåll i skog och mark i Sverige - Baserat på Riksskogstaxeringens data. ISRN SLU-SRG-AR--86--SE
2003	110	Berg Lejon, S.	Studie av mätmetoder vid Riksskogstaxeringens årsringsmätning. ISRN SLU-SRG--AR--110--SE
	116	Ståhl, G.	Critical length sampling for estimating the volume of coarse woody debris. ISRN SLU-SRG-AR--116--SE
	117	Ståhl, G. Blomquist, G. Eriksson, A.	Mögelproblem i samband med risrensning inom Riksskogstaxeringen. ISRN SLU-SRG-AR--117--SE

	118	Ståhl, G. Boström, B. Lindkvist, H. Lindroth, A. Nilsson, J. Olsson, M.	Methodological options for quantifying changes in carbon pools in Swedish forests. ISRN SLU-SRG-AR--118--SE
2004	129	Bååth, H., Eriksson, B., Lundström, A., Lämås, T., Johansson, T., Persson, J A. & Sundquist, S.	Internationellt utbyte och samarbete inom forskning och undervisning i skoglig mätteknik och inventering. -Möjligheter mellan en region i södra USA och SLU. ISRN SLU-SRG-AR--129--SE

Planering och inventering:

1995	3	Homgren, P. & Thuresson, T.	Skoglig planering på amerikanska västkusten - intryck från en studieresa till Oregon, Washington och British Colombia 1-14 augusti 1995. ISRN SLU-SRG-AR--3--SE
	4	Ståhl, G.	The Transect Relascope - An Instrument for the Quantification of Coarse Woody Debris. ISRN SLU-SRG-AR--4--SE
1996	15	van Kerkvoorde, M.	An Sequential approach in mathemtical programming to include spatial aspects of biodiversity in long range forest management planning. ISRN SLU-SRG-AR--15--SE
1997	18	Christoffersson, P. & Jonsson, P.	Avdelningsfri inventering - tillvägagångssätt och tidsåtgång. ISRN SLU-SRG-AR--18--SE
	19	Ståhl, G., Ringvall, A. & Lämås, T.	Guided transect sampling - An outline of the principle. ISRN SLU-SRG-AR--19--SE
	25	Lämås, T. & Ståhl, G.	Skattning av tillstånd och förändringar genom inventeringssimulering - En handledning till programpaketet. ISRN SLU-SRG-AR--25--SE
	26	Lämås, T. & Ståhl, G.	Om detektering av förändringar av populationer i begränsade områden. ISRN SLU-SRG-AR--26--SE
1999	59	Petersson, H.	Biomassafunktioner för trädfraktioner av tall, gran och björk i Sverige. ISRN SLU-SRG-AR--59--SE

	63	Fridman, J., Löfstrand, R. & Roos, S.	Stickprovsvis landskapsövervakning - En förstudie. ISRN SLU-SRG-AR--63--SE
2000	68	Nyström, K.	Funktioner för att skatta höjdtillväxten i ungskog. ISRN SLU-SRG-AR--68--SE
	70	Walheim, M.	Metodutveckling för vegetationsövervakning i fjällen. ISRN SLU-SRG-AR--70--SE
	73	Holm, S. & Lundström, A.	Åtgärdsprioriteter. ISRN SLU-SRG-AR--73--SE
	76	Fridman, J. & Ståhl, G.	Funktioner för naturlig avgång i svensk skog. ISRN SLU-SRG-AR--76--SE
2001	82	Holmström, H.	Averaging Absolute GPS Positionings Made Underneath Different Forest Canopies - A Splendid Example of Bad Timing in Research. ISRN SLU-SRG-AR--82--SE
2002	91	Wilhelmsson, E.	Forest use and it's economic value for inhabitants of Skröven and Hakkas in Norrbotten. ISRN SLU-SRG-AR--91--SE
	93	Lind, T.	Strategier för Östads säteri: Redovisning av planer framtagna under kursen Skoglig planering ur ett företagsperspektiv ht 2001, SLU Umeå. ISRN SLU-SRG-AR--93--SE
	94	Eriksson, O. et. al.	Wood supply from Swedish forests managed according to the FSC-standard. ISRN SLU-SRG-AR--94--SE
2003	108	Paz von Friesen, C.	Inverkan på provytans storlek på regionala skattningar av skogstyper. En studie av konsekvenser för uppföljning av miljömålen. SLU-SRG-AR--108--SE

Biometri:

1997	22	Ali, A. A.	Describing Tree Size Diversity. ISRN SLU-SRG--AR--22--SE
1999	64	Berhe, L.	Spatial continuity in tree diameter distribution. ISRN SLU-SRG--AR--64--SE
2001	88	Ekström, M.	Nonparametric Estimation of the Variance of Sample Means Based on Nonstationary Spatial Data. ISRN SLU-SRG-AR--88--SE

	89	Ekström, M. & Belyaev, Y.	On the Estimation of the Distribution of Sample Means Based on Non-Stationary Spatial Data. ISRN SLU-SRG-AR--89--SE
	90	Ekström, M. & Sjöstedt-de Luna, S.	Estimation of the Variance of Sample Means Based on Nonstationary Spatial Data with Varying Expected Values. ISRN SLU-SRG-AR--90--SE
2002	96	Norström, F.	Forest inventory estimation using remotely sensed data as a stratification tool - a simulation study. ISRN SLU-SRG-AR--96--SE

Fjärranalys:

1997	28	Hagner, O.	Satellitfjärranalys för skogsföretag. ISRN SLU-SRG-AR--28--SE
	29	Hagner, O.	Textur i flygbilder för skattningar av beståndsegenskaper. ISRN SLU-SRG-AR--29--SE
1998	32	Dahlberg, U., Bergstedt, J. & Pettersson, A.	Fältinstruktion för och erfarenheter från vegetationsinventering i Abisko, sommaren 1997. ISRN SLU-SRG-AR--32--SE
	43	Wallerman, J.	Brattåkerinventeringen. ISRN SLU-SRG-AR--43--SE
1999	51	Holmgren, J., Wallerman, J. & Olsson, H.	Plot-level Stem Volume Estimation and Tree Species Discrimination with Casi Remote Sensing. ISRN SLU-SRG-AR--51--SE
	53	Reese, H. & Nilsson, M.	Using Landsat TM and NFI data to estimate wood volume, tree biomass and stand age in Dalarna. ISRN SLU-SRG-AR--53--SE
2000	66	Löfstrand, R., Reese, H. & Olsson, H.	Remote sensing aided Monitoring of Nontimber Forest Resources - A literature survey. ISRN SLU-SRG-AR--66--SE
	69	Tingelöf, U. & Nilsson, M.	Kartering av hyggeskanter i pankromatiska SPOT-bilder. ISRN SLU-SRG-AR--69--SE
	79	Reese, H. & Nilsson, M.	Wood volume estimations for Älvsbyn Kommun using SPOT satellite data and NFI plots. ISRN SLU-SRG-AR--79--SE

2003	106	Olofsson, K.	TreeD version 0.8. An Image Processing Application for Single Tree Detection. ISRN SLU-SRG-AR--106-SE
2003	112	Olsson, H. Granqvist Pahlen, T. Reese, H. Hyyppä, J. Naesset, E.	Proceedings of the ScandLaser Scientific Workshop on Airborne Laser Scanning of Forests. September 3 & 4, 2003. Umeå, Sweden. ISRN SLU-SRG-AR--112--SE
	114	Manterola Matxain, I.	Computer Visualization of forest development scenarios in Bäcksjön estate. ISRN SLU-SRG-AR--114--SE
2004	122	Dettki, H. & Wallerman, J.	Skoglig GIS- och fjärranalysundervisning inom Jägmästar- och Skogsvetarprogrammet på SLU. - En behovsanalys. ISRN SLU-SRG-AR--122--SE
2005	136	Bohlin, J.	Visualisering av skog och skogslandskap -erfarenheter från användning av Visual Nature Studio 2 och OnyxTree. ISRN SLU-SRG-AR--136--SE

Kompendier och undervisningsmaterial:

1996	14	Holm, S. & Thuresson, T. samt jägm. studenter kurs 92/96	En analys av skogstillståndet samt några alternativa avverkningsberäkningar för en del av Östads säteri. ISRN SLU-SRG-AR--14--SE
1997	21	Holm, S. & Thuresson, T. samt jägm.studenter kurs 93/97.	En analys av skogstillsåndet samt några alternativa avverkningsberäkningar för en stor del av Östads säteri. ISRN SLU-SRG-AR--21--SE
1998	42	Holm, S. & Lämås, T. samt jägm.studenter kurs 94/98.	An analysis of the state of the forest and of some management alternatives for the Östad estate. ISRN SLU-SRG-AR--42--SE

1999	58	Holm, S. & Lämås, T. samt studenter vid Sveriges lantbruksuniversitet.	En analys av skogstillsåndet samt några alternativa avverkningsberäkningar för Östads säteri. ISRN SLU-SRG-AR--58--SE
2001	87	Eriksson, O. (Ed.)	Strategier för Östads säteri: Redovisning av planer framtagna under kursen Skoglig planering ur ett företagsperspektiv HT2000, SLU Umeå. ISRN SLU-SRG-AR--87--SE
2003	115	Lindh, T.	Strategier för Östads Säteri: Redovisning av planer framtagna under kursen Skoglig Planering ur ett företagsperspektiv HT 2002, SLU Umeå. SLU-SRG--AR--115--SE

Examensarbeten:

1995	5	Törnquist, K.	Ekologisk landskapsplanering i svenskt skogsbruk - hur började det? ISRN SLU-SRG-AR--5--SE
1996	6	Persson, S. & Segner, U.	Aspekter kring datakvaliténs betydelse för den kortsiktiga planeringen. ISRN SLU-SRG--AR--6--SE
	7	Henriksson, L.	The thinning quotient - a relevant description of a thinning? Gallringskvot - en tillförlitlig beskrivning av en gallring? ISRN SLU-SRG-AR--7--SE
	8	Ranvald, C.	Sortimentsinriktad avverkning. ISRN SLU-SRG-AR--8--SE
	9	Olofsson, C.	Mångbruk i ett landskapsperspektiv - En fallstudie på MoDo Skog AB, Örnsköldsviks förvaltning. ISRN SLU-SRG-AR--9--SE
	10	Andersson, H.	Taper curve functions and quality estimation for Common Oak (Quercus Robur L.) in Sweden. ISRN SLU-SRG-AR--10--SE
	11	Djurberg, H.	Den skogliga informationens roll i ett kundanpassat virkesflöde. - En bakgrundsstudie samt simulering av inventeringsmetoders inverkan på noggrannhet i leveransprognoser till sågverk. ISRN SLU-SRG-AR--11--SE
	12	Bredberg, J.	Skattning av ålder och andra beståndsvariabler - en fallstudie baserad på MoDo:s indelningsrutiner. ISRN SLU-SRG-AR--12--SE

	13	Gunnarsson, F.	On the potential of Kriging for forest management planning. ISRN SLU-SRG-AR--13--SE
	16	Tormalm, K.	Implementering av FSC-certifiering av mindre enskilda markägares skogsbruk. ISRN SLU-SRG-AR--16--SE
1997	17	Engberg, M.	Naturvärden i skog lämnad vid slutavverkning. - En inventering av upp till 35 år gamla föryngringsytor på Sundsvalls arbetsområde, SCA. ISRN SLU-SRG-AR--17--SE
	20	Cedervind, J.	GPS under krontak i skog. ISRN SLU-SRG-AR--20--SE
	27	Karlsson, A.	En studie av tre inventeringsmetoder i slutavverkningsbestånd. ISRN SLU-SRG-AR--27--SE
1998	31	Bendz, J.	SÖDRAs gröna skogsbruksplaner. En uppföljning relaterad till SÖDRAs miljömål, FSC's kriterier och svensk skogspolitik. ISRN SLU-SRG-AR--31--SE
	33	Jonsson, Ö.	Trädskikt och ståndortsförhållanden i strandskog. - En studie av tre bäckar i Västerbotten. ISRN SLU-SRG-AR--33--SE
	35	Claesson, S.	Thinning response functions for single trees of Common oak (Quercus Robur L.). ISRN SLU-SRG-AR--35--SE
	36	Lindskog, M.	New legal minimum ages for final felling. Consequenses and forest owner attitudes in the county of Västerbotten. ISRN SLU-SRG-AR--36--SE
	40	Persson, M.	Skogsmarkindelningen i gröna och blå kartan - en utvärdering med hjälp av Riksskogstaxeringens provytor. ISRN SLU-SRG-AR--40--SE
	41	Eriksson, M.	Markbaserade sensorer för insamling av skogliga data - en förstudie. ISRN SLU-SRG-AR--41--SE
	45	Gessler, C.	Impedimentens potentiella betydelse för biologisk mångfald. - En studie av myr- och bergimpediment i ett skogslandskap i Västerbotten. ISRN SLU-SRG-AR--45--SE
	46	Gustafsson, K.	Långsiktsplanering med geografiska hänsyn - en studie på Bräcke arbetsområde, SCA Forest and Timber. ISRN SLU-SRG-AR--46--SE

	47	Holmgren, J.	Estimating Wood Volume and Basal Area in Forest Compartments by Combining Satellite Image Field Data. ISRN SLU-SRG-AR--47--SE
	49	Härdelin, S.	Framtida förekomst och rumslig fördelning av gammal skog. - En fallstudie på ett landskap i Bräcke arbetsområde. ISRN SLU-SRG-AR--49--SE
1999	55	Imamovic, D.	Simuleringsstudie av produktionskonekvenser med olika miljömål. ISRN SLU-SRG-AR--55--SE
	62	Fridh, L.	Utbytesprognoser av rotstående skog. ISRN SLU-SRG-AR--62--SE
2000	67	Jonsson, T.	Differentiell GPS-mätning av punkter i skog. Point-accuracy for differential GPS under a forest canaopy. ISRN SLU-SRG-AR--67--SE
	71	Lundberg, N.	Kalibrering av den multivariata variabeln trädslagsfördelning. ISRN SLU-SRG-AR--71--SE
	72	Skoog, E.	Leveransprecision och ledtid - två nyckeltal för styrning av virkesflödet. ISRN SLU-SRG-AR--72--SE
	74	Johansson, L.	Rotröta i Sverige enligt Riksskogstaxeringen. - En beskrivning och modellering av rötförekomst hos gran, tall och björk. ISRN SLU-SRG-AR--74--SE
	77	Nordh, M.	Modellstudie av potentialen för renbete anpassat till kommande slutavverkningar. ISRN SLU-SRG-AR--77--SE
	78	Eriksson, D.	Spatial Modeling of Nature Conservation Variables useful in Forestry Planning. ISRN SLU-SRG-AR--78--SE
	81	Fredberg, K.	Landskapsanalys med GIS och ett skogligt planeringssystem. ISRN SLU-SRG-AR--81--SE
2001	83	Lindroos, O.	Underlag för skogligt länsprogram Gotland. ISRN SLU-SRG-AR--83-SE

	84	Dahl, M.	Satellitbildsbaserade skattningar av skogsområden med röjningsbehov (Satellite image based estimations of forest areas with cleaning requirements). ISRN SLU-SRG-AR--84--SE
	85	Staland, J.	Styrning av kundanpassade timmerflöden - Inverkan av traktbankens storlek och utbytesprognosens tillförlitlighet. ISRN SLU-SRG-AR--85--SE
2002	92	Bodenhem, J.	Tillämpning av olika fjärranalysmetoder för urvalsförfarandet av ungskogsbestånd inom den enkla älgbetesinventeringen (ÄBIN). ISRN SLU-SRG-AR--92--SE
	95	Sundquist, S.	Utveckling av ett mått på produktionsslutenhet för Riksskogstaxeringen. ISRN SLU-SRG-AR--95--SE
	98	Söderholm, J.	De svenska skogsbolagens system för skoglig planering. ISRN SLU-SRG-AR--98--SE
	99	Nordin, D.	Fastighetsgränser. Del 1. Fallstudie av fastighetsgränsers lägesnoggrannhet på fastighetskartan. ISRN SLU-SRG-AR--99--SE
	100	Nordin, D.	Fastighetsgränser. Del 2. Instruktion för gränsvård. ISRN SLU-SRG-AR--100--SE
	101	Nordbrandt, A.	Analyser med Indelningspaketet av privata skogsfastigheter inom Norra Skogsägarnas verksamhetsområde. ISRN SLU-SRG-AR--101--SE
2003	102	Wallin, M.	Satellitbildsanalys av gremmeniellaskador med skogsvårdsorganisationens system. ISRN SLU-SRG-AR--102--SE
	103	Hamilton, A.	Effektivare samråd mellan rennäring och skogsbruk - förbättrad dialog via ett utvecklat samrådsförfarande. ISRN SLU-SRG-AR--103--SE
	104	Hajek, F.	Mapping of Intact Forest Landscapes in Sweden according to Global Forest Watch methdology. ISRN SLU-SRG-AR--104--SE
	105	Anerud, E.	Kalibrering av ståndortsindex i beståndsregister - en studie åt Holmen Skog AB. ISRN SLU-SRG-AR--105--SE

	107	Pettersson, L.	Skördarnavigering kring skyddsvärda objekt med GPS-stöd. SLU-SRG-AR--107--SE
	109	Östberg, P-A.	Försök med subjektiva metoder för datainsamling och analys av hur fel i data påverkar åtgärdsförslagen. SLU-SRG-AR--109--SE
	111	Hansson, J.	Vad tycker bilister om vägnära skogar - två enkätstudier. SLU-SRG-AR--111--SE
	113	Eriksson, P.	Renskötseln i Skandinavien. Förutsättningar för sambruk och konflikthantering. SLU-SRG-AR--113--SE
	119	Björklund, E.	Medlemmarnas syn på Skogsägarna Norrskog. ISRN SLU-SRG--AR--119--SE
2004	120	Fogdestam, Niklas	Skogsägarna Norrskog:s slutavverkningar och PEFC-kraven - fältinventering och intervjuer. ISRN SLU-SRG--AR--120--SE
	121	Petersson, T	Egenskaper som påverkar hänsynsarealer och drivningsförhållanden på föryngringsavverkningstrakter -En studie över framtida förändringar inom Sveaskog. ISRN SLU-SRG--AR--121--SE
	123	Mattsson, M	Markägare i Stockholms län och deras inställning till biodiversitet och skydd av mark. ISRN SLU-SRG--AR--123--SE
	125	Eriksson, M.	Skoglig planering och ajourhållning med SkogsGIS - En utvärdering av SCA:s nya GIS-verktyg med avseende på dess introduktion, användning och utvecklingspotential. ISRN SLU-SRG--AR--125--SE
	130	Olmårs, P.	Metrias vegetationsdatabas i skogsbruket - En GIS-studie. ISRN SLU-SRG--AR--130--SE
	131	Nilsson, M.	Skogsmarksutnyttjande på Älvdalens kronopark före 1870. En kulturhistorisk beskrivning och analys. ISRN SLU-SRG--AR--131--SE
2005	133	Bjerner, J.	Betydelsen av felaktig information i traktbanken -Inverkan på virkesleveranser samt tidsåtgång och kostnad vid avverkningar. ISRN SLU-SRG--AR--133--SE

138	Kempainen, E.	Ett kalkylstöd för ekonomiska analyser av avverkningsåtgärder på beståndsnivå. A calculation support program for economic analysis of cutting actions on stand level. ISRN SLU-SRG--AR--138--SE
140	González, J.D.D.	A time study and description of the work methods for the field work in the National Inventory of Landscapes in Sweden. ISRN SLU-SRG--AR--140--SE
141	Jacobsson, L.	Förbättringspotential i avverkningsplanering -En fallstudie av ett års avverkningar på två distrikt inom SCA skog, Jämtlands förvaltning. ISRN SLU-SRG--AR--141--SE
142	Gallegos, Å.	Design and evaluation of a computer aided calibration program for visual estimation of vegetation cover. ISRN SLU-SRG--AR--142--SE

Internationellt:

1998	39	Sandewall, M., Ohlsson, B. & Sandewall, R.K.	People's options of forest land use - a research study of land use dynamics and socio-economic conditions in a historical perspective in the Upper Nam Water Catchment Area, Lao PDR. ISRN SLU-SRG-AR--39--SE
1998	44	Sandewall, M., Ohlsson, B., Sandewall, R.K., Vo Chi Chung, Tran Thi Binh & Pham Quoc Hung.	People's options on forest land use. Government plans and farmers intentions - a strategic dilemma. ISRN SLU-SRG-AR--44--SE
1998	48	Sengthong, B.	Estimating Growing Stock and Allowable Cut in Lao PDR using Data from Land Use Maps and the National Forest Inventory. ISRN SLU-SRG-AR--48--SE
1999	60	Sandewall, M. (Edit.).	Inter-active and dynamic approaches on forest and land-use planning - proceedings from a training workshop in Vietnam and Lao PDR, April 12-30, 1999. ISRN SLU-SRG-AR--60--SE
2000	80	Sawathwong, S.	Forest Land Use Planning in Nam Pui National Biodiversity Conservation Area, Lao P.D.R. ISRN SLU-SRG-AR--80--SE

2002	97	Sandewall, M.	Inter-active and dynamic approaches on forest and land-use planning in Southern Africa. Proceedings from a training workshop in Botswana, December 3-17, 2001. ISRN SLU-SRG-AR--97--SE

NILS:

2004	124	Esseen, P-A., Löfgren, P.	Vegetationskartan över fjällen och Nationell Inventering av Landskapet i Sverige (NILS) som underlag för Natura 2000. ISRN SLU-SRG-AR--124--SE
	126	Allard, A., Löfgren, P. & Sundquist, S.	Skador på mark och vegetation i de svenska fjällen till följd av barmarkskörning. ISRN SLU-SRG-AR--126--SE
	127	Esseen, P-A., Glimskär, A. & Ståhl, G.	Linjära landskapselement i Sverige: skattningar från 2003 års NILS-data. ISRN SLU-SRG-AR--127--SE
	128	Ringvall, A., Ståhl, G., Löfgren, P. & Fridman, J.	Skattningar och precisionsberäkning i NILS - Underlag för diskussion om lämplig dimensionering. ISRN SLU-SRG-AR--128--SE
	132	Esseen, P-A., Glimskär, A., Moen, J., Söderström, B. & Weibull, A.	Analys av informationsbehov för Nationell Inventering av Landskapet i Sverige (NILS). ISRN SLU-SRG--AR--132--SE
2005	134	Glimskär, A., Allard, A. & Högström, M.	Småbiotoper vid åkermark – indikatorer och flygbildsbaserad uppföljning i NILS. ISRN SLU-SRG--AR--134--SE
	135	Hylander, K. & Esseen, P-A.	Lavkompendium för Nationell Inventering av Landskapet i Sverige (NILS) ISRN SLU-SRG--AR--135--SE
	137	Ericsson, S.	Arthandbok Fältskiktsarter för Nationell Inventering av Landskapet i Sverige NILS. ISRN SLU-SRG-AR--137--SE
	139	Weibull, H.	Mosskompendium för Nationell Inventering av Landskapet i Sverige (NILS) 2004. ISRN SLU-SRG-AR--139--SE