Some Practical Aspects of Designing a Large Inventory

This is a paper not easily available to working folks without library privileges. It's about some practical comments that you can't often make in print when you want to live in academia or a bureaucracy. It was requested to kick off a 1998 international meeting on forest inventory at Boise Idaho. The chairman of this meeting (Steve Fairweather) was different than most, and had a practical bent that is often lacking in conference chairman.

The paper might be of interest to those who get dropped into such a position, or those watching from the sideline. Viewing a disaster can often be instructive, particularly when you can see what's coming. Some of the issues of doing a very large inventory are not the same as with smaller sampling problems which are so typical of the work in our business. Committees, for instance, are unavoidable to some degree.

The chance to design a large inventory is infrequent in our profession. The chance of doing it well, and with the support of both a solid administrator and highly competent volunteers, is *quite* rare. This is especially the case in a government environment, but luckily a forest commission had previously reviewed the provincial situation and insisted that a new inventory be done, and that it be designed by experts from outside the ministry.

This paper has been edited only to correct the bungled changes made by the copy-editors for the proceedings, who so often change things without the knowledge of the author. When delivered orally, of course, it was shortened dramatically - but the story of Antonio de Morga seemed to strike a nerve with many of the practical people in the audience.

Abstract

Designing a large multi-resource inventory is horribly difficult. Not work for faint hearts, and the 250,000,000 acre size of British Columbia was not a trivial problem. Completion of the details (as opposed to stopping the work) is a process prone to collapse. After that point, implementation is also likely to fail.

There have been some changes in the world, and perhaps it is time to abandon some concepts like stratification, random sampling, class averages, fixed plots and many other notions that never were very good ideas, and where far better alternatives have long been available. The problem is tradition and myth on the part of forest inventory people, and a lack of experience on the part of some specialties.

The idea of a large-scale inventory might be clear to foresters, but it is not intuitive to other disciplines, in particular the ecological side of the business. In an era of coordinated inventories, this complicates matters. In order to complete the grinding number of details, there is a special need for practical people who at the same time can conceive of the principles and handle change. Hard-nosed, flexible, experienced, imaginative, diligent workers might be plentiful where you come from, but we had to work hard to conserve ours. If you confuse "specialists" with "experts" then the chances are that the project will die young. Real problems get far too much input and far too little output in any organization that harbors some vague notion about a democracy of intellect.

There is a critical need to get the political creatures away from the technical side of the business but to let them serve their own purpose. Too little attention to details will sink the ship (and these details are grindingly difficult) but heading the ship in the wrong direction is by far the most serious error, and it requires tedious repetition to keep the principles in the forefront. Details are necessary — Principles are important. Don't confuse the two concepts.

The BC inventory has made good use of some non-traditional approaches. None of these are entirely new, but the combination and thinking is not the common approach to these problems. The use of the internet both to distribute and to document issues has a powerful potential. In the final analysis, the social element is critical for both design and implementation.

The Paper

Some Practical Aspects of Designing a Large Inventory

Two weeks before Christmas, 1600, some 350 men were killed because of a fool who wanted to be in charge. Antonio de Morga was the lieutenant governor of the Philippines, and the pirate sails that passed by his colony gave him the opportunity to make his mark. He had ordered his largest ship, the "San Diego", beefed up for an encounter, with extra guns on the top decks, and other quick changes that might enhance his opportunity for fame. The "little people", the mere craftsmen who understood these matters, tried to dissuade him. They probably explained about "the center of gravity" vs. "the center of buoyancy" and other non-managerial issues, but were put in their place quickly (for de Morga was, after all, "in charge"). The ship launched, as ordered. Within a few hours, it sank due to overloading. De Morga along with many of the rats who so often occupy the upper decks in life, made his way ashore and immediately wrote to Spain to give his stirring account of the battle (before they heard otherwise). You know, of course, what happened. He was promoted. He was rewarded. He was judged a great success (the alternative is simply too embarrassing to consider). He was given a larger command.

National Geographic reported the raising of the ship in the 1990s because it was a treasure, historically. They were able to find secret testimony, and there among the accounts of the surviving crew were the words of Lt. Almayda who recorded the judgment of history upon this bozo as follows:

> The loss "was all due to the bad leadership and lack of experience of Dr. de Morga, for trying to be in charge of something he knew nothing about."

Now we all know this guy ‘de Morga’ don't we?? We have all worked for these people. They are like the characters of the TV series "Highlander" who never die off. They drift through the ages causing trouble and grief. They are always there, as constant as dump rats, ready to sink the ship. They are drawn to inventory projects like flies. You will have to kill them off somehow.

What was the task?

Our inventory was for about 100,000,000 hectares. That's a quarter of a billion acres. It's larger than the entire USFS land base. It was to be one of those integrated, multi-resource, "we are all in this together" composites of many needs and specialties. In other words, a "modern" inventory. The potential for disaster was enormous.

However, we seem to have pulled it off (the design, that is — the execution is still very much up in the air). Since many of you are in this racket, some of the lessons might be of interest, and perhaps of use. It was a big opportunity to take a single-agency dominated inventory process on a large land base and modernize it. One of our tasks was to develop processes for many kinds of measurements that could be introduced throughout the province. We needed practical improvements to methods that had drifted off track, fallen behind, or were wrong-headed from the outset. There were many of these. Some had been etched in stone by the provincial government, and many of them had seeped deeply into the bones of technical folks at all levels.

Now you do not have to be very bright to know that this is a bad news situation. The probability of failure was high, and the work was going to be difficult. At that time I was not connected to the ministry, but the director wanted me to be involved with the design and with organizing the committee. I was impressed that he always seemed to approach me in a bar. "Would you like to do this project, Kim?" No. "You will enjoy it". No. "How about if we do it this way? No !! On the third or fourth approach, he simply said, "What do you want? You tell me what you want and how we can do this." Now this struck me as unusual. This kind of director might actually be able to pull this off (and he did). I signed on, and did the work as an independent consultant (which I still am).

I was appointed as the inventory design specialist, working with a committee of folks who would know about a variety of technical requirements and problems. I had some influence over many of the principles we adopted. Some of the main ones were:

1) The entire land base would be covered, by a valid sample.
   [Sample points were chosen systematically from a sorted list.]
   [Thus far, we have given each land type equal weight.]
2) We would use older techniques, with a track record — nothing tricky.
   [Any methods begging for complications or loss of credibility we dropped quickly.]
3) We would obtain estimates, and correct those with ground sampling.

[Estimates could come from anywhere, but using photos as a default.]

4) We would assume a hostile review by intelligent opponents.
   [Therefore, we planned audits and other credibility enhancing processes.]

5) Processes would be designed for wide, thorough and critical review.
   [Designed, therefore, for display on the internet and word processor files (delivered by internet) which could be word-searched and compared to other sections.]

6) The details would be worked out ahead of time, and tested.

7) We used actual craftsmen who knew the business.
   ["Experts", not "specialists". An expert really knows a field, a specialist just has a narrowly defined job. Anybody with a title can be a specialist. Anyone who does not know the difference ... is a specialist.]
   [Having a Ph.D. was not a fatal flaw, but it was a really bad sign.]
   [The membership was largely non-ministry people.]

8) Nobody was appointed to "represent" anything. They were there to work.
   [People were surprisingly willing to do this.]
   [People were to be included "because of their deeds, not their needs".]

9) We would measure Old Growth, Biodiversity, and a few other difficult things.
   [This meant stepping on the toes of those who would not do so.]

Now this was not going to be easy. It was too big a job without the help of your friends. In BC we are fortunate to have a number of people who have made forest inventory their life, and they have a wealth of knowledge, experience and judgment to offer. We asked them, and they participated. It made all the difference. The problem was always to allow them to succeed against a chorus of de Morga's.

The committee produced 2 reports. The initial report said: "Here is the situation, here were the past mistakes, here is a useful view of it". The final report said: "Do it with these principles and approaches". Every committee member agreed to every sentence in every paragraph. They were encouraged to write dissenting opinions (to be published with the report) if they wished. None chose to do so. We did not get into details, simply because we were not the most competent people to do so. "Working groups" were formed of people who could do the details, with committee

members present who could explain the guiding principles and adjust the overall goals when appropriate. All this took several years.

Overall Design

We had two basic problems: How much is there, and where is it. In the first phase of the inventory, we make an estimate for several variables for every polygon in British Columbia. Remember that we are talking about a huge area. In some cases we will use past inventory estimates; in some cases new photointerpretation will be done. This would put the results where they belonged, and could help with the total estimate.

The ground data would establish the total, in some cases by stratified sample averages, in some cases by correcting previous estimations by regression or some similar technique.

For Trees: 5 variable plots. 1 measured, 4 "count plots".
For Ecological Information:
A (too large) fixed plot for a species list, % cover & ecological label
A soil pit
Range transects for brush cover
Coarse Woody Debris transects

Many details are available on the internet, currently at:
http://www.for.gov.bc.ca/RIC/PUBS/TEVEG/gsp/contents.htm
http://www.for.gov.bc.ca/resinv/Veginv/home.htm

The province is broken into about 40 inventory units. Each will be done independently. About 200 sample positions are chosen with a systematic sample from a sorted list. The probabilities are virtually equal, at least within an inventory unit. Each sample point has a weight assigned to it (essentially the amount of area it represents, usually they are very similar). These are lightly monumented so that tree growth and other changes can be measured 5 or 10 years from now. On the central plot the distance to each "in" tree is recorded for later growth monitoring. The final 15 metres to the sample point is carefully measured so that the field crew does not make subtle shifts in the exact position. It will be interesting to see how often we land inside trees or streams. For plots near the polygon boundary, a semi circular plot is used. There are about 16 cards to be filled out on each plot. The plots are taking too long, and we need to devise ways to reduce that field effort.

The total volume in each species (as an example) is distributed back over the land base using the estimates for each polygon. By fixing the total, we can maintain unbiasedness even if we decide to re-estimate part of the

inventory, or further adjust polygons in the future. This will allow us to incorporate a variety of biased and non-sampling data from other sources. There are a number of audit, check cruising and tree dissection procedures to check for measurement bias and as an aid to credibility. The precision of polygon accuracy is determined by a separate process.

What did we do right?

1) We got the principles right the first time.

   We emphasized the principles, and kept doing it, even during grinding detail sessions — it saved us from making many technical mistakes.

2) We met regularly, with a fairly stable and highly technical group.

   Social time was critical here. The perfect meeting would include lots of time to eat together, visit the bar, and become a family. If you want people to fight out technical issues, with no quarter given, then they have to like each other.

3) We used the opportunity to train lots of people, and introduce a common view to various parts of the province. Even if the inventory is never implemented, we will never shrink back to the same size.

4) We used first rate and experienced people whenever possible.

   You can have whomever you want attend the meetings, but the voting and working core has to be competent—not there for training. The marginal people had a rough ride. The political animals thought we were mad. The good people had fun. The work was first rate, and you cannot do that with amateurs (although you can pretend to). You had better have a bone deep appreciation of the importance and contribution of these people.

5) The work was done by the committee, not farmed out to contractors. (Unless it was very mechanical, of course). Nobody defends a poor idea when they are personally suffering to develop it. People who are pretenders drop out very early in the process if you change the question from "What do you want?" to "What do you want to contribute?" The emphasis in our committees was not on "input", it was on output.

6) We did not commit to a starting date early in the process.
   This would have rushed some decisions, and the work would have suffered.
7) Training and educational concerns were part of the process.
8) The processes were put into compartments that could succeed or fail without dragging the rest of the inventory down with them.
   This took the heat off some of the groups, who could develop the process at their own rate and join the parade later (or just watch). Closely linking the various parts of the data gathering would have been a mistake. This was good psychology as well as good management.
9) Individuals (or very small groups) did the work. The committee reviewed it.
   This is a big contrast to groups that sit around and wonder what to do together. That person was expected to lay out the leading ideas and suggest one they could defend. If they could not decide, they were not doing their job. If someone could not perform, they were hosed off forthwith and given no further work of that type. If the work was sloppy, they were given a rough ride and usually performed the next time. The time of experienced people is too valuable to waste. Chit-chat time was for the social hours. Theoretical issues need to be just as explicitly examined and understood as any list of codes.

What did we do wrong?

First, let me be clear. Every one of these problems was a "people problem". There were NO serious technical problems. The errors resulted because we weakened in applying the principles just listed. When we lost our nerve and tried to accommodate some form of insecurity or incompetence from someone — things always went wrong. Some of them went badly wrong, and we are still working to correct them. In most cases, the error was made in the face of clear advice that it would be a mistake.

1) A few people were given work based on their needs, not their competence.
   This was always a mistake. At the very least, it delayed and annoyed valuable people.

2) Compromises were almost always bad. It is better to clearly win or lose.

   New or better ideas were always welcome. In some cases we had to decide between two workable ideas. It is better to make a mistake than to create a compromise. I believe that this is so because of issues involving balance and detail. Often, these matters require a clear, complete view of the issues. A compromise muddies the water for both parties, and when something goes wrong it was always harder to fix than when a pure strategy had been adopted. There are too many loose ends in a compromise.

3) Computer people were allowed to take over work for which they were incompetent.

   This is always a mistake. In our case it has been an expensive one. Keep their tiny little hands off data and database designs they do not understand (and I say this having personally worked as a computer programmer and systems analyst).

4) We did not have a permanent field crew to continuously try out ideas. This caused delay.

   This would have saved a great deal of elapsed time and trained critical staff. I would recommend that such a crew be established in every similar project, and that they attend every meeting in order to know the background and intent of the designers.

5) A few people who were not technically qualified caused a lot of expense and delay.

   In our case, I would estimate about 1½ years of delay. The only antidote seemed to be to make them do the work and to refuse to listen to any idea they had not personally tested in the field at least 20 to 40 times. This kills a lot of dumb ideas without too much delay.

6) We did not communicate well enough to groups outside the committee.

   Everyone wanted to be involved with this, but it never got done.

7) The review of well thought out processes by marginally involved or uninformed people was a negative influence.

8) The decision to use contractors to do this work, rather than a permanent staff, has been a missed opportunity.

These mistakes were made even with a director who was capable of direct and timely action. Good people have plenty of opportunity to do other things, so this kind of project is not the place for a lack of leadership or an inability to handle conflict.

IF YOU WANT TO DESIGN A COORDINATED
MULTI-RESOURCE INVENTORY — EXPECT TROUBLE.

My advice — from a technical perspective

1) Keep processes separate so you can disconnect them (or subsample) when some fail.
2) Make it so that people can put more work in themselves to improve particular answers.

   If the "Friends of the Upland Squirrel" want to put in an extra 2,000 plots, give them a sampling plan for doing it and turn them loose. If they want to use your data, provide it. If they want to sample their own way and combine it with your results, lock the door and refuse to talk to them. If they will not use an actual sample or compatible estimates (check it, by the way) then tell them their data will help decide the distribution of upland squirrel habitat, not the total amount. If there is more habitat in one watershed, there will have to be less habitat in the others.

3) Work on the methods, not on budget or control issues. The methods are hard enough.
4) Stress compatibility and combinability, not coordination of effort.

   Make everyone think about doing it themselves, alone, with the possibility of combining it later. Make it a collection of many separate working parts, not a huge machine that is welded together. Get cooperation by producing an excellent system, not by coercion.

5) Definitions without a sampling method are bad business.

   If possible, make the sampling method part of the definition. The work is harder, but more likely to succeed.

6) Define a common sample point, and have everyone sample it any way they want.

   Concentrate on describing a point, and let them incorporate the area around that point any way they choose. I have no faith that a common plot will ever work. In our system everyone describes the same point by different size plots, transects, etc.

7) Keep your data in hard copy. Fight the urge to round or classify.

   Assume you will recalculate.

8) Expect to recompile the data and to accommodate new definitions (by subsampling).

9) Decide for yourself how to measure Old Growth, Biodiversity, and other difficult issues.

   Lots of people will want to tell you how to do this by methods they would never use themselves. In some cases they will simply enjoy the process of obstruction. Ignore them and get the job done. Think about providing information they can subsample and data that will help decide differences of option. With luck, they will only have to revisit 10% of the ground locations to apply their own (eventual) definition.

10) For biodiversity, stick to plants on a fixed plot small enough to be practical in the field.

   Keep the plot size constant.

11) Ignore setting sample size and selecting which of several estimation procedures to use for as long as possible.

   We waited until the process was finished. A system that can be scaled to work with any size land base is more likely to be general, flexible, and useful to many other people.

12) Work on the basis of providing a method without a commitment to ever do that work.

   This keeps the budget issues at bay while you do the technical work. In many cases, the overly expensive systems can be dropped or subsampled after the details are worked out.

What are the sources of the problems?

Ecosystem people are a problem

You must understand, these are people who do not use data a great deal and use sampling very little. There are exceptions, but they are rare. They do case studies, and give "typical areas" names rather than numerical values. Because they often move plots into "typical areas", their systems have a tendency to be incomplete. There may be no ecological code for roads because they do not occur when "typical areas" are chosen.

This is not a criticism. Foresters have needed almost 100 years to learn to sample trees that are long lived, self-recording, easily seen and do not move. Imagine measuring critters that breed quickly, move, die, migrate, hide, bite, and are nocturnal into the bargain. Their work is difficult, and the problems are difficult enough that ecologists have not been as deeply into the process as we have been. Little wonder that they are not familiar with many of the concepts.

The most serious problem is that they often do not understand the concept of an inventory process, where the answer is a combination of many observations, each of which is individually "inadequate". They want a complete description of each sample point. The concept of partial information at each point is hard for them to understand. No forester would expect to get every tree species in a polygon with one or two plots, but an ecologist will attempt to do that by putting in a very large plot or moving the plot to a "typical" place.

I have mentioned the problem of incomplete systems, but there is also the problem of vague definitions for which there is simply no way to sample. Suppose that "Old Growth" requires 10 snags per hectare and I put in a 1/10 hectare plot. It contains no snags. Can that sample point be in an Old Growth area? Answers to these questions become a serious roadblock to the details of designing an inventory. We have something to teach this group, and something to learn as well. If there is a future for forest measurements, it is in measuring all kinds of things, not just trees. We need to get involved with these problems and figure out how to solve them.

There is a serious need to test ecological measurement methods before they are seriously considered. There are often problems with these approaches, and many of the suggestions were entirely untested when they were proposed. A useful rule is 20 to 40 repetitions done personally by whoever is suggesting the method. Otherwise, do not consider it. Whenever we did so, it was a mistake.

Foresters are a problem

Foresters have a tendency to round, interpret data into classes, and ignore parts of the land base. They have a deep conviction that past practices have virtues that even a brief examination would dispel. They have a bone deep inclination to stratify even when it makes no sense at all, followed by a need to have plenty of samples in each of the strata. At the same time, they forget to attach weights to samples in case they are used for other purposes and instinctively feel that taking data in the middle of a stand just has to be a good idea. They worry about sample size too much, and sample placement too little. For some reason they have a deep faith in the power of "consistency" which allows them to do the most bizarre sorts of measurements in the sure and certain knowledge that it is OK "as long as the process is consistent". Removing these ideas is a painful and bloody process for everyone.

Local Heroes, Academics and Reviewers are a problem

Reviewing the process is a really important function. Done well, it can improve the balance, and particularly the credibility of the inventory plan. Done poorly, it just raises anxiety and provides a place for outsiders to quibble about what the design team has done. The key is to get people whose judgment is well respected and allow them to get a good look at the reasoning and details of the process. The mixture of technical expertise and experience is critical.

First of all, publishing papers is not the same as experience. This escapes many people. On rare occasions there is a specific question that you really need a narrow specialist to solve, and on rare occasions they can be brought in to do that. More often, they want you to change the question or the process so that they can point to a page in Cochran and say "there it lies!" In our case, one reviewer suggested that we put in random samples so that the variance estimator was exact and simple. The effect of this suggestion was not considered by the reviewer. It is hard to tell how much will eventually have to be done to kill this foolish idea. These people need to spend several weeks with the field crew. At that point you will no longer get poor advice from them. This, however, is not the fault of the reviewer. It was the fault of a system that will ask a graduate student with no experience in the field to review a process they have no way to understand.

Choose a few very solid people in the specialties that are critical and keep them lightly involved throughout the process. These folks should be heavy on actual experience and the kind of balance and judgment that only come from that source. They need to know the people involved and the history of the project. This will solve 90% of their problems and concerns. As an additional step, an outside and rather formal review of the process at the end might be very useful.

Managing the process & What to expect

Designing a multi-resource inventory will take some time. The people involved cannot do it on their lunch breaks. The group that does this will have to be fairly permanent, technically competent, and socially comfortable. I do not believe that you can get to that stage quickly. Until it happens, however, progress will be slow. Use this time to organize the paper trails and establish some administrative rules. Make some friends at all stages, if possible.

Stage 1

First, the manager-politicos will arrive. This cannot usually be avoided. They want to make sure that their interests are looked after. See that this happens. Make sure that the approaches and principles of interest to them are laid out so they will leave as soon as possible. They have their place, but it is not on an inventory design committee. When any serious time and effort are required, they will be inclined to move on. Leave open the idea of a "steering committee" that they can attend, but make sure that the working people are insulated from that committee. Steering is something that people who cannot paddle can often do – and it is sometimes helpful.

Stage 2

Next, the handmaidens of the managers will arrive. They will be chosen because their managers consider them politically reliable and know that they will report any devious behavior. They will also usually be able to spot real ability in your group, even if they do not trust it. They will get a fair idea of the technical goals, but when the work builds up they will want out. They, in turn, will eventually send their technically competent people when they are convinced that you are actually working on the problem rather than maneuvering in some way that needs watching.

Stage 3

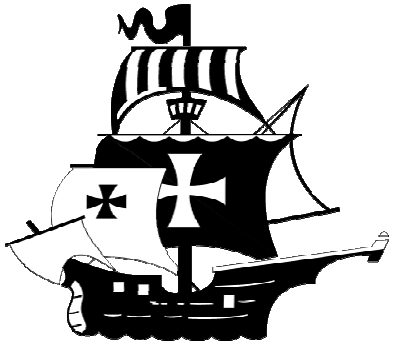
Once the craftsmen arrive, you can start making real progress. This is the time for working out the principles in detail, training eventual staff through their attendance (not membership), and field testing. At the stage that all the major issues are resolved and the technical issues are clear I would predict that you are 20% done. By the time that a procedures manual is written and field forms are tested, I believe that you will be about 60% finished. When one or two pilot projects are successful (failures do not count), you have another 10% to do, but that will be a tolerable workload. Do not firm up databases, edit processes, or handheld applications until the whole process works well on paper.

Now it is possible that you might move directly to the third stage, but I think that it is unlikely. This is all serving a purpose, and some tolerance to the process should be shown. This kind of tail-sniffing takes time, and trying to shortcut the process might well backfire. Once the craftsmen are assembled, it is important to keep that critical mass of competence. The same people that are of great help in doing this work are also sources of many of the really precious commodities needed by a forest inventory — support, tolerance, patience, credibility, and goodwill. Someone needs to insulate this technical group from the mechanical irritations and the

bureaucratic problems. At the end of each stage, make sure that appropriate credit is given. You will need these people again.

If you can make this process work, it's a wonderful experience. I'm glad I did it. I learned things that I would not have otherwise believed. The committees that functioned were proud of their work, had fun, and contributed something really useful. The failures had very little fun, although they did all the politically correct things about running their committee. They did not make a contribution. It is their own fault — *for trying to be in charge of something they knew nothing about*.

If you cannot get it right then you might want to stay on the dock and let this ship sail without you. You have that choice these days, although lieutenant Almayda did not. The de Morga's will run the ship at some point. Make sure they don't organize it if YOU are going to be on board [1].



Acknowledgments :

I would like to thank the reviewers:

Dr. Dave Marshall, Forest Biometrician, Weyerhaeuser Company.

Dr. Don Reimer, D.R. Systems, Nanaimo, BC, Canada

[1] Note : added in 2010 … And they did run the ship eventually – and quite predictably ran it onto the rocks. By that time, however, the competent people had moved on, much useful work had been done, and a number of principles were established that served the region well – as predicted. The techniques developed are still making the rounds, and being used by several different organizations.