Pros and Cons of Continuous Forest Inventory: Customer Perspectives

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Abstract.—The USDA Forest Service has historically conducted forest inventory on a state-by-state cycle, producing relatively high precision snapshots of forest resources for a given state at 7- to 15-year intervals. We are now considering a change to a continuous inventory system where we would operate at reduced intensity simultaneously in all states every year. Advantages for customers include the continuous availability of data that are on average half a cycle old; access to data of a uniform age across administrative boundaries; increased opportunities for partnering with Forest Inventory and Analysis, including funding intensification or special studies; a permanent role in an ongoing inventory program; and increased program efficiency. Disadvantages include the elimination of the periodic higher precision inventory; a potential loss of credibility among end users; the risk of poor program service for states unable or unwilling to contribute to the program; and the possibility that the continuous approach will be more expensive than the periodic in some parts of the country.

The USDA Forest Service Forest Inventory and Analysis (FIA) program has, over the past 70 or so years, been the major source of state-level forest inventory information across the US. The program provides periodic information on status and trends on a variety of parameters describing forests and forest use: area and type of forest; structure and composition of forests in terms of species, sizes, and volume; rates of tree growth, mortality, and removals; patterns of ownership of forest lands; and information on harvest efficiency and product flows throughout the US. This information is of vital interest to numerous customers including managers, policymakers, business interests, academics, and other interested citizens.

FIA has historically conducted forest inventory on a state-by-state cycle. Under this model, an inventory staff would focus all of its resources on collecting data within a single state, as quickly as possible. Analysis and reporting for the state would proceed once the data collection was completed, while the data collecting staff moved on to the next state. The result has been a periodic, once-every-X-years state-level inventory based on a full measurement of existing plots, with X ranging from 7 to 18 or more years. This relatively high precision snapshot would be reasonably accurate when reported; but over the subsequent years, the snapshot would not necessarily accurately describe the current state of the system due to changes occurring after the time of data collection. In practice, the difference between the inventory report and the actual state of the ecosystem would be unknown until the next measurement time. Until recently there were seven FIA field locations supporting regional cycles in different parts of the country. Average cycles ranged from 5 to 8 years in the south, 11 to 15 years in the rest of the US.

This approach to forest inventory was generally satisfactory until the 1980's. During this time, the primary focus for analysis was within a state, and program budgets were sufficient to keep the inventory cycle (time between remeasurements in a given state) at an acceptable level. However, in recent years there has been growing customer dissatisfaction with the types and amounts of information being provided. Primary areas of concern include:

1. Excessively long inventory cycles (15+ years in parts of the US) that cause long periods of high uncertainty about the state of the forest resource;

2. Lack of consistency between different regional FIA programs, which hampers the ability to conduct analyses that span administrative units;

3. Reduction in the number of analyses that are published in a timely fashion, associated with the redirection of program resources away from analysis and towards data collection to reduce the cycle.

These concerns have been expressed in two reviews of the FIA program (Anonymous 1992, 1998). This has led FIA over the past 5 years to reassess the existing program and to seek ways of better addressing customer concerns. In addition, the Agricultural Research, Extension, and Education Reform Act of 1998 directs the FIA program to

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make significant technical changes including (1) switch from a periodic to an annual (continuous) inventory approach that measures 20 percent of all plots in each state each year; (2) development of a core program that will be implemented consistently across the US forest lands, including national forests; and (3) production of complete state reports at 5-year intervals, looking back over the previous 20 years' worth of data.

FIA has been considering the possibility of an annual approach to forest inventory since 1992, when the North Central FIA unit began development of a prototype annual inventory system in Minnesota, in cooperation with the Minnesota Department of Natural Resources and the FIA research unit in Fort Collins, CO. This program, called AFIS (Annual Forest Inventory System), was designed to operate within existing budget constraints. Satellite imagery analysis was used to differentiate between plots that could be modeled rather than visited, and plots where sufficient change had taken place to warrant a field visit. By visiting a smaller set of plots annually, and leveraging that information with remotely sensed data and models, it was hoped that a state-level report could be produced at more frequent (4-year or less) intervals. Although not as precise as the report from a full inventory, the more frequent updates were expected to be more timely and hence more useful.

In 1996, the Southern FIA unit, in cooperation with a coalition of industry and state partners, began contemplating a similar experiment. They selected a simpler approach, simply dividing the existing set of field plots into five overlapping panels, with the intent of measuring one full panel each year so that each plot would be measured once every 5 years. Since the FIA unit was at that time funded for only a 7- or 8-year cycle, this approach would require additional sources of funds, either from the Forest Service or from partners. Due to the extreme interest and pressure on the FIA unit to address the cycle problem, they eventually opted to skip the pilot test phase and simply implement the annual approach in several southern states in 1997.

Other FIA units have until now been interested observers. However, recent legislation directs all FIA units to make the transition to an annual inventory system over the next 5 years. The law that gives this direction also greatly expands the FIA mission in other ways, requiring more data collection on a wider array of parameters, implementation of FIA where it presently does not exist (e.g., central Alaska), and increased analysis and reporting requirements. It is not clear if Congress will provide additional resources needed to accomplish all of this, and it is not clear what the FIA program will do if such resources are not provided.

PROS AND CONS OF THE CONTINUOUS INVENTORY APPROACH

Most of the discussion to date of advantages and disadvantages of the continuous approach has been from the technical, statistical perspective: how can we best produce continuously updated data, and how will a continuous inventory approach make life easier for FIA, the producers of that information? But little formal thought has been given to whether changing to a continuous approach will address the concerns of our dissatisfied customers. This paper attempts to look at the expected differences in program outputs from the perspective of the educated consumer of forest inventory data, so that consumers better understand the full implications—positive and negative—of the proposed changes to the strategic forest inventory program.

I have identified at least five areas related to movement to continuous inventory that are consistently of major concern to many FIA customers and partners. I will discuss pros and cons in each of these areas:

1. Information quality—how accurate and precise is the information?

2. Information utility—how useful is the information?

3. Opportunities for partnership—how will the change affect partners' abilities to participate actively in the program?

4. Program efficiency—does this approach deliver the best value for the taxpayers' dollar?

5. Risk—What new problems might this approach create for the customer?

Unless specified, I will assume for comparison that the continuous inventory approach in use is the simple systematic panel approach being implemented by the Southern FIA unit. This implies that a state has a total sample of n plots, each is assigned to exactly one of five panels so that each panel covers the entire state at approximately equal intensity, with approximately equal numbers of plots in each panel. Comparisons to the periodic inventory system will assume a 5-year periodic cycle.

Customers of FIA

The primary customers of the FIA program include:

1. State and national lawmakers who use FIA information when making and passing laws. They need nationally consistent and state-specific information, constantly updated, on a broad array of forest

ecosystem attributes for making laws. They need summaries and analyses of those data.

2. State foresters who use FIA data for developing policy proposals, communicating with their constituents, and planning economic development. They need state-specific, constantly updated information on a broad array of forest ecosystem attributes. They need access to elemental data, as well as summaries and analyses of those data.

3. Private industry and consultants who use FIA information for business planning. They need the most up-to-date information possible, consistent across space without regard for political or administrative boundaries, on a broad array of forest product attributes. They need access to elemental data, as well as summaries and analyses of those data.

4. Government and private research institutions who use FIA data as a basis for conducting their own research and analyses. They need reliable information on a broad array of forest ecosystem attributes, consistent across space without regard for political or administrative boundaries. They need access to elemental data (tree-level data), both current data as well as historical data.

5. Environmental organizations that use FIA data to monitor and assess the effects of public policies on land use. They need information on a broad array of forest ecosystem attributes, consistent across space without regard for political or administrative boundaries. They need access to summaries and analyses of those data, and are increasingly interested in access to elemental data allowing them to conduct their own analyses.

6. Media that use FIA data in preparing interesting reports and articles for their readers. They need current and historical information on a broad array of forest ecosystem attributes, generally summarized and analyzed along political boundaries, e.g., national-, state-, or county-level data. They appreciate information portrayed in a readily understood format, especially using charts and graphics.

7. Internal Forest Service officials who use FIA data in preparing a variety of internal reports including the Resource Planning Act (RPA) reports, and occasionally revising/updating forest plans. They need access to data summarized according to state and Forest Service organizational boundaries (Regions/Forest/District).

Information Quality

Both the periodic and the annual inventory approaches are assumed to be designed so that they provide unbiased estimates of some parameters of interest that describe a forest. However, the parameters estimated are not necessarily the same for each approach.

Under the periodic approach, the parameter estimates are assumed to describe the state of the forest at some specific point in time. This is not precisely correct, since data collection always spans some time interval and thus reflects some kind of average state during a period of time. For example, a large forested state such as Maine, Georgia, Minnesota, or Oregon may take up to 3 or more years for complete data collection under existing budgets. However, under the periodic approach, the inventory is generally assigned to the year in which the bulk of the data were collected.

Under the continuous inventory approach, there are several options for which parameters might be estimated. One could take the panel of n/5 plots and simply calculate the parameters of interest for the current year. This would result in estimates for parameters that truly are observations for the year in question. However, the small sample of n/5 would not yield estimates as precise as the full sample based on all n plots. The estimated standard error of the mean would be larger for the n/5 sample by a factor of (5 = roughly 2.24). This would affect all estimates of precision including confidence intervals about the mean.

A more powerful approach over time would be to use some kind of moving average, combining the latest observation for all n plots taken over the past 5 years. This would yield an estimate of a different parameter, the mean value over the past 5 years. This is not the same as the mean parameter in the present year. There are many different ways for combining estimates in time series. The expected precision for the mean over the past 5 years would tend to be higher than the estimate based on a single year observation of n/5 plots, but lower than the estimate based on all n plots measured in < 5 years.

The moving average approach would tend to mask dramatic annual changes in the value of the parameter of interest, and would tend to lag behind current changes in the state of the system. The advantage for the user of this information is that the continuous approach yields updated information each year, with the information having an average age of 2.5 years (half the length of the measurement cycle). This alternative might be preferable to a periodic approach on the same 5-year cycle, which also yields information that, over the average of the cycle,

is 2.5 years old, but at any given moment might be as much as 5 years old. If it is more important to users to be sure that they will always have information that is no more than 2.5 years old, then the continuous approach is preferable. Alternately, if users need high precision information and can accept periodicity of 5 years between snapshots, then the periodic approach would be more efficient because it would provide that higher degree of precision at the same cost.

This analysis depends greatly on the length of the cycles involved. A user might accept a periodic high precision snapshot at 5-year intervals, but find that the same level of precision at 8- or 10-year intervals is unacceptable. In such a case, the annual approach would be preferable, assuming that the continuous approach maintained the 20 percent per year sample. However, the same forces that cause the lengthening of the periodic cycle from 5 to > 5 years will likely act to reduce the continuous sample fraction from 20 percent of all plots each year to < 20 percent. In such a case, it still may be preferable to have some recent information rather than relying on a database in which all information is outdated.

In summary, users who want continuous access to data that are relatively recent, but never quite current, will prefer the continuous approach, while users who can wait longer for more accurate data will prefer the periodic approach. The preference for a continuous approach to inventory will likely be greatest for systems where the rate of change is greatest. For relatively stable systems, a periodic approach is probably more efficient.

Information Utility

It is necessary, but not sufficient, for information to be accurate and precise in order to be useful. Regardless of how accurate the data are, the information will not be useful if the ultimate consumers of the information do not believe in the reliability of the information. Accurate information presented in a manner that undermines its own credibility is not useful. With the periodic approach to inventory, we have maximum precision at fixed intervals. We can say with confidence that the data reflect observations of a trend at fixed points in time, and that changes that occur between the points are reflected with some accuracy in the periodic observations.

A drawback to the continuous inventory approach is that the lower precision inherent in the estimates based on 5 years of data will likely yield annual estimates that fluctuate more due to random error than do the estimates from the periodic inventory. This is an unfair comparison, because the true uncertainty of the estimates between years under the periodic approach is unknowable, since there are no data. However, the act of reporting updated estimates on an annual basis will inevitably invite comparison of the present estimates to those of previous years, and will cause consternation and distrust if there is deemed to be a significant variation from year to year. While statistically understandable, such behavior could nonetheless cause end users unfamiliar with technical issues to mistrust and doubt the results. This could result in good data that no one believes. This is more of a risk under the annual approach than under the periodic, where the lack of midcycle data prevents users from making the same comparison.

Increasingly, users are interested in analyzing data that span more than one administrative unit, i.e., more than one state. Under the periodic approach, each state inventory is conducted in sequence within a given region. This implies that adjacent states may have inventories that are years out of step. This presents an additional hurdle to the analyst who wants to combine data across a region. Typically all data must be somehow brought to a common year, generally by modeling or making some other assumption. This adds a component of uncertainty to the analysis—a component that is rarely quantified. The ultimate example of this problem presently occurs at 5-year intervals when the Forest Service prepares its Resource Planning Act report, when data for all 50 states, spanning some 15 years, must be updated to a common year.

The continuous approach would eliminate this problem. Data would be available for all states each year, so could be treated similarly without having to update some states to a reference year. There could be some added complexity if adjoining states had different sampling fractions (say 10 percent in one state and 20 percent in the next). However, the existence of annual data for all states would greatly simplify the task of updating or otherwise standardizing data to a common point in time.

In summary, the continuous approach to inventory will yield information that fluctuates from year to year and that may cause concern or lack of confidence in some end users. The periodic approach avoids this problem by not reporting information year to year. Data from the continuous approach will be much easier to analyze across administrative boundaries such as states or FIA units.

Partnerships

FIA is increasingly relying on and welcoming partnerships in accomplishing the FIA mission. For purposes of this paper, "partnership" is defined as a relationship in which two or more parties share in the costs of completing work. State forestry agencies in particular are frequently establishing partnerships with FIA through the contribution of office space, staff time, vehicles, and other resources that allow the FIA work to proceed at a faster

pace. Historically, many states have contributed resources to FIA for collecting additional data beyond the base program—for example, to intensify the plot network or to collect special interest variables on some or all plots. In the southern part of the US, several states are using their own resources to hire staff for field data collection for the base set plots.

Under the periodic inventory approach, it was often difficult for partners to participate in the FIA program. The long time between subsequent inventory activities made it impossible to support a permanent staff specifically for collaborating with the FIA unit. Normal employee turnover tended over time to reduce the staff familiar with the FIA program, methods, and opportunities. Additionally, partners who wanted to seek resources to invest in FIA—either to speed up the base program or to buy additional information—were often at a disadvantage because of the timing. For example, a state forester might have to ask his/her legislature for a relatively large sum of funds that might not be available in the year needed. The periodic nature of past inventory programs often led to periodicity in relationships between FIA partners, resulting in a program that was forever locked in a less productive "still-getting-to-know-you" kind of relationship.

The continuous approach offers the opportunity to grow those relationships to maturity. Since there will be operations in every state every year, FIA and partner staff will have constant contact, creating a chance to build long-term working relationships. Partners wanting to contribute to the program will be able to seek permanent budget allocations and staff to do so, at a lower annual cost. The existence of annual field work in each state means that partners now have the opportunity in any given year to inject additional resources into the program for collecting additional data about some issue relevant to their needs, without having to wait years until the next inventory for their state. For organizations looking to increase their involvement in FIA, the continuous approach to inventory is clearly preferable to the periodic approach.

What about states that are not able or willing to contribute resources to support the FIA program? It is less clear that the continuous approach is superior for them. For example, it is unlikely that FIA will be able to conduct an annual inventory in some states and a periodic one in others; the overhead burden would be too expensive. FIA resources will likely be spread across all parts of the country to provide some consistent base continuous program to everyone, but the resulting program may not be at the annual intensity desired by customers. There is a risk that states that are unable to add additional resources may be asked to settle for a lower intensity annual inventory program that may actually be less usable than the former periodic inventory. States that can't or won't contribute to implementing the FIA mission may be better off under a periodic system.

Program Efficiency

Customers are interested in program efficiency because ultimately they are paying for the program through tax dollars. If FIA can maximize its efficiency, customers will have to spend less cash and less political coin to get the resources needed to complete the work. Changing to an annual inventory program will change some of the efficiencies of the program, but it is not yet clear if the total change is a net loss or gain.

One immediate opportunity to increase efficiency is through the merger of the FIA program with the field plot portion of the Forest Health Monitoring (FHM). At present FHM is a related program that collects data on forest health parameters in all implemented states on an annual basis. There is some redundancy between the programs: for example, FHM collects a set of mensurational data that is largely duplicated on FIA plots, and it involves many of the same management and supervisory staff that also manage FIA. The biggest obstacle presently to integrating these programs is the fact that FHM needs annual data in each state during a 10-week measurement window in the summer, while FIA remains a periodic program in most states. Once FIA changes to an annual approach, it will be very easy to simply designate a subset of the annual FIA panel of plots as dual FHM plots, and measure these once with a combined crew. In addition to being more cost effective, this will reduce the likelihood of multiple visits to the same plot that might annoy private landowners. This will also provide maximal linkage between the two databases, strengthening joint analyses. Since many states are partners in both FIA and FHM, combining these programs will enable states to reduce some overhead associated with participation.

It is not clear at this time how field logistics will be impacted by a change to a continuous inventory. In places where fieldwork can be done year round, such as the southern US, there may be gains in efficiency associated with permanently locating field staff in working circles wherein they can do most of their annual plots with minimal overnight travel. This contributes to a stable workforce, which may reduce turnover and will require less training (albeit more salary) over time.

The situation becomes more complicated in less accessible areas where the working field season is shorter. It will not be cost effective to permanently station employees in areas with short field seasons. Crews will have to follow annual migration patterns, with southern "winter grounds" and northern "summer grounds." In such areas,

increased travel costs associated with the need to cover all states each year may make continuous inventory more expensive than a similar cycle periodic inventory.

The continuous approach is more efficient from the perspective of reporting. Both periodic and continuous approaches offer the same basic, comprehensive reports at fixed intervals. However, the continuous approach offers the opportunity for additional reports to reflect events that may occur between major reports. For example, each year in the US, there are some events that have dramatic impacts on forests: flooding along the Mississippi, ice storms in New England, and fires in Florida are three recent examples. A continuous approach would enable analysis and reporting on the effects of the event without having to commission or fund a special study. Any additional resources could be used more efficiently by building on the planned annual program. The continuous approach provides a constant platform for responding to unpredictable events.

Risks

Any major change has risks associated with it. It is unlikely that change to a continuous inventory will not have any downside or even that we will anticipate all of the advantages and disadvantages of such an approach. In addition to the risks already discussed above, a few more are worth noting here. All these risks should be weighed against the risk of doing nothing to the current program, which may accelerate the erosion of support for FIA as FIA meets the needs of fewer and fewer customers.

One risk is that changing to an annual inventory system may tend to favor "important" states at the expense of "unimportant" ones. There are various definitions of what constitutes "importance:" area of forest, rates of harvesting, species richness, recreation use, political clout, and proximity to population have all been used at one time or another to justify the need for increased information gathering. Since it is unlikely that FIA will be given all of the resources needed to fully implement the program called for by Congress, some choices will have to be made about resource allocation. This is not an inherent property of the continuous inventory per se, but rather an artifact of the change taking place. The change presents an opportunity to assess present and future resource allocation. States from areas deemed in the past to be "less important" need to participate in the present process of evolution to ensure that their needs are also heard.

A second risk inherent in the continuous inventory approach is that the linkage between funding, cycle, and information quality becomes less obvious. Historically, funding for FIA has tended to follow a pattern of slow declines (in real terms) over some time period, followed by sudden increases reflecting political support from customers dissatisfied with program delivery. Under the periodic approach, the gradual reduction in funding led inexorably to an increase in the cycle: if an FIA unit could only afford 11 field crews rather than 15 crews, State X would take 3 years instead of 2 years to complete. Eventually, cycles would get so long that customers would mobilize their political representation to provide a correcting influx of funds. It is relatively easy for customers to monitor the cycle length, and thus to activate a political response when the cycle becomes too long.

However, degradation under a continuous inventory system may be subtler. If circumstances change, a unit reducing from 15 to 11 crews would still measure a certain number of plots in each state each year, but it might be 17 percent rather than 20 percent. The unit could still produce an annual database, and reports at 5-year intervals that are based on 85 percent new data and 15 percent old data. The information products could still be delivered on time, but they would be of slightly lower usefulness. It seems to me that this kind of degradation would be more insidious, less obvious, and less easy to address through the raising of political awareness. A continuous approach might thus allow itself to degrade farther before being fixed. On the plus side, since everyone directly benefits in the first year following a correcting increase in funds, it may be easier to mobilize political support under a continuous system once the problem is recognized.

The third risk is that the entire debate about changing to the annual inventory approach is not a solution to the problems with the present inventory program as much as it is a classical example of a work avoidance mechanism. Heifetz (1994) outlined a theory about how individuals and organizations react to stress caused by serious problems. Rather than confronting and fixing the underlying problems, it is often easier to make some cosmetic change that gives the appearance of dealing with the problem. This is often sufficient to convince people that Something is Being Done, so the stress level subsides—for awhile. This cycle can be repeated endlessly, since the players on both sides tend to change over time. The distinction that Heifetz makes between adaptive work aimed at fixing problems, and work avoidance is simple: if the action reduces stress but does not solve the problem, it is work avoidance. If it solves the problem—even at the expense of raising or maintaining stress—then it is adaptive work.

Changing to a continuous inventory simply means changing the order in which we measure our existing set of plots. This by itself will not solve the problem of excessive cycle lengths—it will simply redistribute the problem. If all we do is mandate a change to an annual

inventory, we may reduce the stress for a few years, but it will eventually catch back up with us. A continuous inventory may have some advantages, but will not by itself solve the major problems plaguing FIA.

There are opportunities for making additional changes that will address the problem. We might reduce overall program costs and enable ourselves to reduce cycles within current budgets by substituting technology such as satellite image analysis for field visits, as is being explored in Minnesota. Alternately, we can increase the resources allocated to FIA by seeking increased federal appropriations and/or by leveraging additional support from other partners. This is the approach being taken in the south, where states are contributing significant resources to attain what is in effect a 5-year cycle. In both cases, it is worth noting that it is not the simple fact of the continuous inventory approach that is solving the problems, it is the change to a continuous system combined with other major programmatic changes. Customers of FIA need to keep this in mind: the advantages or disadvantages of the change to a continuous inventory must be considered simultaneously with other necessary program changes.

CONCLUSIONS

The FIA program is undergoing a period of major change in response to the concerns and needs of our customers. One of the major changes underway is the shift from periodic to continuous forest inventory in each state. Advantages of such an approach for our customers include the continuous availability of data that are on average half a cycle old; access to data of a uniform age across administrative boundaries; increased opportunities for partnering with FIA, including funding intensification or special studies; a permanent role in an ongoing inventory program; increased program efficiency through integration with the Forest Health Monitoring program; and more flexible opportunities for reporting, especially in response to unexpected events.

Disadvantages include the elimination of the periodic higher precision inventory; a loss of credibility among end users who do not understand why annual estimates fluctuate; the risk of poor program service for states unable or unwilling to contribute to the program; and the possibility that the continuous approach will be more expensive than the periodic in some parts of the country.

In addition, there are risks: the risk of some states being left out because their forest resources are deemed "unimportant;" the risk that future degradation of FIA information quality will be harder to detect; and the risk that excessive focus on the issue of periodic vs. continuous inventory will avoid the real work of dealing with issues such as consistency, funding, and equity in program delivery.

The change to an annual inventory program offers us the opportunity to simultaneously make other key changes that are needed to improve the FIA program. We must look carefully and equally at all aspects of the program in determining where we want to be and how best to get there. It appears that the political momentum has already decided that FIA will move to a continuous approach for the next generation of fieldwork; technical considerations have become secondary. Nonetheless, I believe that transition to a continuous inventory system, if made simultaneously with other critical changes in the FIA program, will in the long run be in the best interest of the largest number of FIA customers. If we can simultaneously address the existing problems of inconsistency in methods, incompleteness in coverage, and inadequate resources to deliver the required level of information, then we will be able to create an FIA program that will deliver useful information for many years to come.

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