THE HEXAGON/PANEL SYSTEM FOR SELECTING FIA PLOTS UNDER AN ANNUAL INVENTORY

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ANNOTATION. Forest Inventory and Analysis (FIA) is changing to an annual nationwide inventory. This paper describes the sampling grid used to distribute FIA plots across the landscape and to allocate them to a particular measurement year. We also describe the integration of the FIA and Forest Health Monitoring (FHM) plot networks.

In 1998, Federal legislation (Agricultural Research, Extension, and Education Reform Act of 1998 – PL 105-185) was passed that requires major changes in the way Forest Inventory and Analysis (FIA) conducts inventories of the Nation's forests resources. This legislation resulted from concerns expressed by FIA clients that changes were needed in existing FIA methods (Van Deusen *et al.* 1999, Gillespie 1999).

A fundamental change that the legislation requires is an annual inventory of each State, with 20 percent of the plots within a State measured each year. In contrast, FIA inventories have historically been conducted within a single State over one to three years; each State has been re-inventoried every 6 to 8 years in the South and every 11 to 18 years in the rest of the country (Gillespie 1999).

In addition to FIA, the Forest Health Monitoring (FHM) program also collects data on our Nation's forests. FHM data are collected annually on a 4-year cycle. Given the overlap in the FIA and FHM programs, we have an opportunity to increase the efficiency of data collection by merging the two programs (Gillespie 1999).

The remainder of this paper describes the sample design for implementing the annual inventory and how it is modified to accommodate the integration of the FIA and FHM programs.

CONSTRUCTING THE HEXAGON SAMPLING FRAMEWORK

One advantage of an annual inventory is the increased ability to quickly measure the effects of events that occur over large areas, such as hurricanes, ice storms, and windstorms. To do so requires a spatially regular distribution of plots across the landscape measured each year. The FHM program has addressed this same need for regularly distributed plots by using a lattice of hexagonal cells as a sampling framework (Scott *et al.* 1993). A base hexagon positioned over the conterminous United States was subdivided into approximately 28,000 hexagons whose centers are about 16.9 mi (27 km) apart (White *et al.* 1992). One field plot was selected for each hexagon, usually the existing FIA plot closest to the center of the hexagon. Each of the hexagons was assigned to one of four panels; a panel corresponds to a given measurement year of the cycle. After the fourth panel is measured, the cycle is repeated. One of the advantages of this framework is that it is unlikely to be aligned with regularly spaced landscape features.

Because of these desirable features, we explored the possibility of using the FHM framework as the basis for the FIA annual inventory sampling framework. To meet its mandated maximum sampling errors, the FIA program requires a sampling intensity of one plot per approximately 6,000 acres (M. H. Hansen 1998, pers. commun.). By creating a new lattice of hexagonal cells where each hexagon is 1/27 the size of an FHM hexagon, the desired sampling intensity is achieved (A. R. Olsen 1998, pers. commun.). The size of each FIA hexagon is 5937.2 acres.

Staff of the Western Ecology Division of the US Environmental Protection Agency National Health and Environmental Effects Research Laboratory in Corvallis, Oregon, performed a 27-factor enhancement of the FHM hexagons, resulting in more than 360,000 FIA hexagons within and adjacent to the border of the conterminous United States. To minimize distortion of the area associated with each hexagon, the Lambert azimuthal equal-area projection was used when creating the FHM and FIA hexagons. Figure 1 shows the spatial arrangement of an FHM hexagon and the FIA hexagons. Attributes included for each hexagon were a unique 8-digit hexagon ID, a hierarchical ID that can be used to decipher how the hexagon was generated, and another ID that can be used to determine the U.S. Geological Survey 7.5 minute quadrangle containing the center of the hexagon. We also determined the state and county where each FHM and FIA hexagon center was located based on 1:100,000 U.S. Bureau of the Census TIGER/Line files.

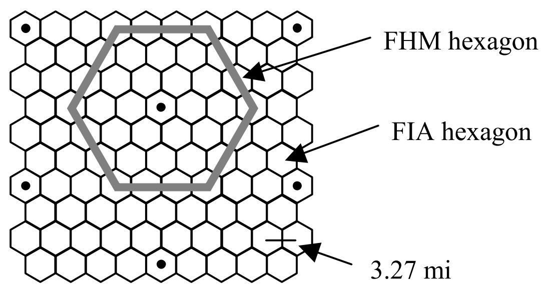

Figure 1. The FIA hexagon lattice. Each black dot is at the center of an FHM hexagon.

By assigning one plot to each FIA hexagon, we create a regular spatial distribution of plots across the landscape. The 1998 legislation requires that 20 percent of the plots be measured each year. To distribute the hexagons temporally, each is assigned to one of five panels. The arrangement shown below (fig. 2) distributes the hexagons among the five panels in such a way that no adjacent hexagons belong to the same panel. The plots in hexagons from panel one were measured from the fall of 1998 through the summer of 1999 in Indiana, Iowa, Minnesota, and Missouri. Each of the remaining panels is assigned to succeeding years; panel one will be measured again from the fall of 2003 through the summer of 2004. As annual inventories begin in new States, we start with the same panel that is being measured that year in States already under an annual inventory. Although the intent in the Eastern U.S. is to operate on a 5-year cycle, funding or ecological conditions may require other cycles. In particular, 7-year (as an eastern option) and 10-year (as a western standard) cycles have been proposed. These two panel arrangements are shown in figure 3.

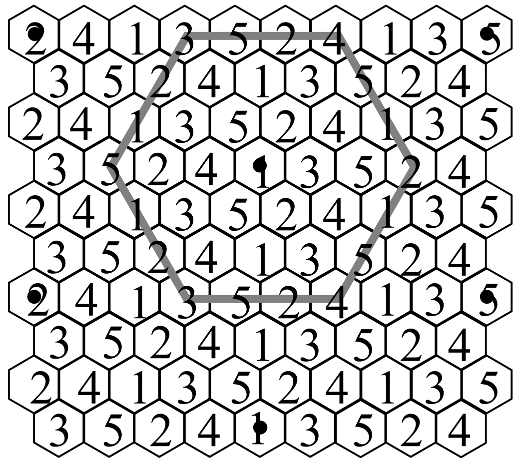

Figure 2. Assignment of hexagons to one of five panels (shown by number).

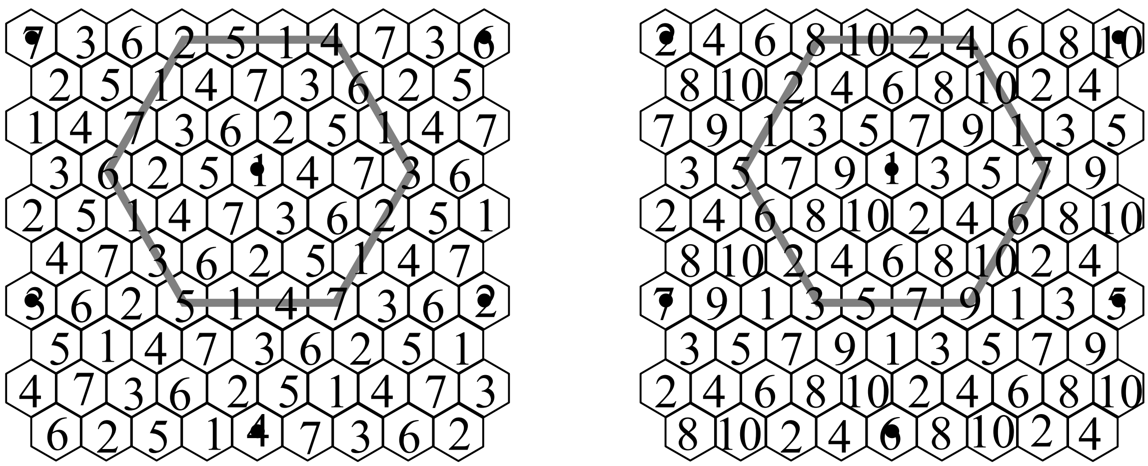

Figure 3. seven-panel (left) and ten-panel (right) arrangements.

SELECTING PLOTS

There are many ways to select a ground plot for each FIA hexagon. We followed two guiding principles for determining plot selection procedures. The plot selected for an FIA hexagon:

1) must be located in that hexagon and
2) should be an existing FIA ground plot, if one exists, thereby retaining as much historical information as possible.

However, to satisfy the first principle, the geographic location of existing plots must be known. Therefore, the first step in plot selection was to establish the latitude and longitude for all existing plots. This was most often done by transferring marked plot locations on aerial photos to geo-referenced satellite imagery. The next step was to spatially overlay the plot locations and the FIA hexagons in a GIS application. The distance from the plot to the center of its hexagon was also computed and recorded. A database management procedure then assigned one plot to each hexagon based on the following criteria:

1) if the hexagon contains an FHM plot, select it;
2) if not, then select the FIA plot within the hexagon that is closest to the center of the hexagon;
3) if there are no FHM or FIA plots in the hexagon, select the center of the hexagon as the location for a new plot (some regions may choose a location near the center).

In some of our States we had to adjust the probability of selection because of unequal sampling intensities in the previous inventory. For example, in Wisconsin reserved areas were sampled more intensively than other areas. Figure 4 illustrates the selection of plots for various situations encountered.

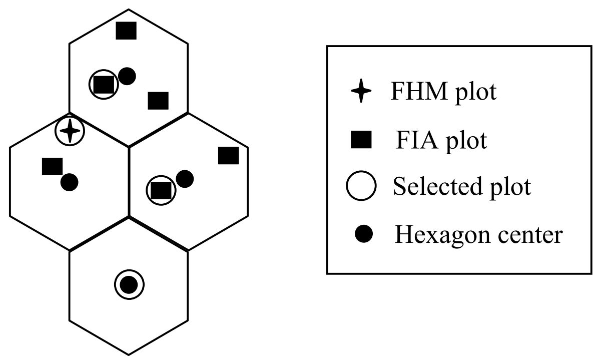

Figure 4. Example results of plot selection criteria.

INTEGRATING FIA AND FHM SAMPLING FRAMEWORK

Although Forest Health Monitoring is a national program, FHM plots have not yet been established in all States. For example, in the North Central region, FHM plots have not been established in five (Iowa, Kansas, Nebraska, North Dakota, and South Dakota) of our 11 States. However, in States where there are existing FHM plots, it is important to retain these plots, not only to keep them as plots selected for their respective FIA hexagons, but also to measure them in their same temporal order.

As noted earlier, the FHM plots were measured on a 4-year cycle, whereas the legislation mandating annual inventories specified a 5-year cycle. In addition to a 4-year cycle, one-third of the FHM plots were also measured in two consecutive years (overlap plots). To maintain the existing temporal intensity of FHM plot measurements over a 5-year cycle, the FHM program elected to increase the number of plots established in most States by 67 percent. Half of the additional plots are needed to make up for the overlap plots (years one to four). The other half are needed for the fifth year. The only exceptions were in Maryland and Minnesota where State funding permitted an original sampling intensity three times greater than in other States.

We obtained a grid of both new and original locations and panel assignments for FHM plots from the Forest Health Monitoring Program, USDA Forest Service, Research Triangle Park, NC (William D. Smith, 1999, pers. commun.). The grid point designates the desired approximate location for an FHM plot, but not necessarily the ultimate location of the plot. In States where FHM plots had not been selected, this grid was regularly spaced across the State and equally distributed among the five panels. In States where FHM plots had been selected, additional grid points were systematically interspersed among the original grid points. Old locations kept their original FHM panel assignment. Approximately 50 perecent of the new grid points were assigned to a new fifth panel, and the rest were spread evenly among the other four panels. In Maryland and Minnesota, no new grid points were needed and the panel assignment was based on the FIA panel assigned to that location. That is, the existing FHM plots were simply distributed among five panels.

We chose an FIA hexagon for every FHM grid point within the conterminous U.S. based on the following rules:

1) if there is an existing FHM plot associated with an FHM grid point, then choose the FIA hexagon containing the FHM plot as the FIA/FHM hexagon; change its panel to match the panel of the FHM grid point (fig. 5),

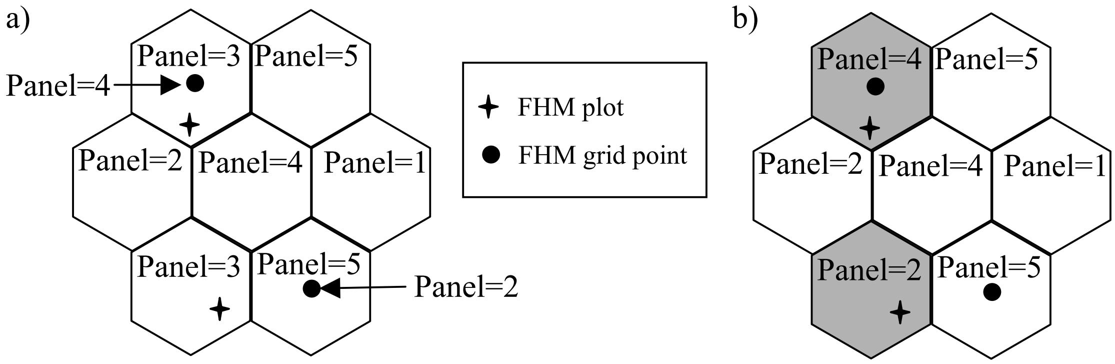

Figure 5. Examples where rule 1 changes the original panel of the FIA hexagon a) to a different panel b). The shaded hexagons have different panels.

2) if an existing FHM plot is not associated with the FHM grid point, then choose the nearest FIA hexagon of the same panel and in the same State as the FHM grid point to be the FIA/FHM hexagon (fig. 6),

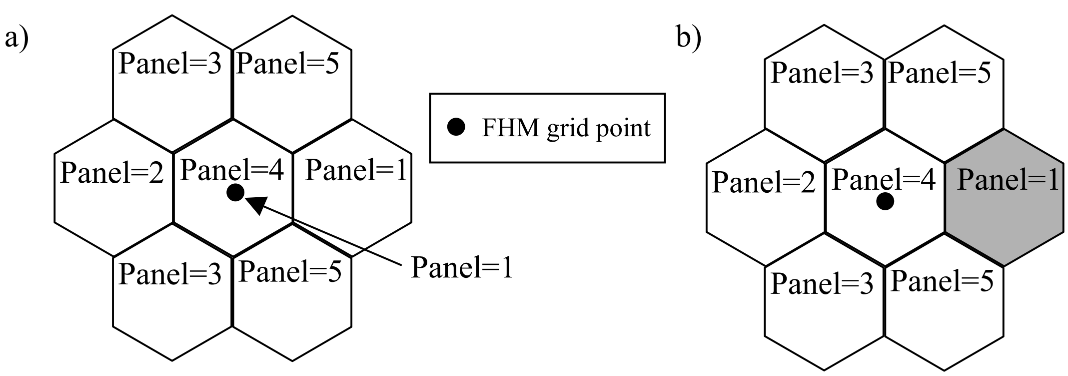

Figure 6. Implementation of rule 2. The panel of the FHM grid point in a) results in the shaded hexagon b) becoming the FHM/FIA hexagon.

3) if none of the nearby FIA hexagons (nearer than 8,500 m) are of the same panel and State as the grid point, then choose the one containing the FHM grid point as the FIA/FHM hexagon; change its panel to match the panel of the FHM grid point (fig. 7). This condition occurs along State borders and coastlines.

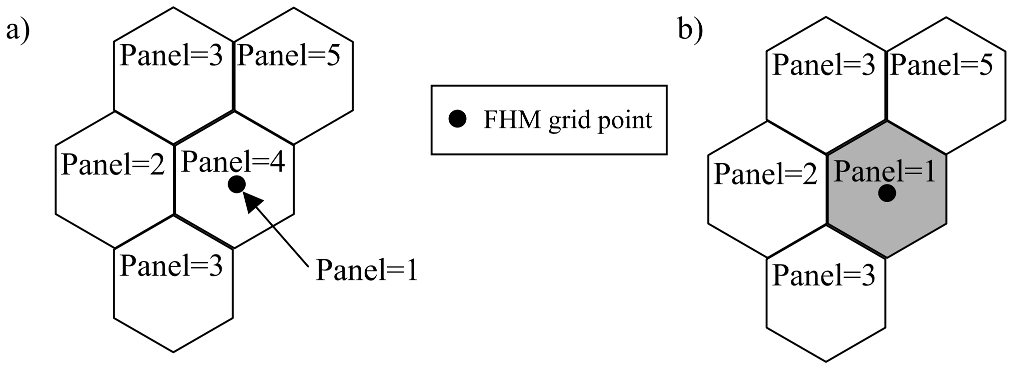

Figure 7. Before a) and after b) implementing rule 3. The panel of the shaded hexagon has been changed.

Rules 1 and 3 change the panels assigned to FIA hexagons and therefore disrupt the original FIA pattern. However, because there are only about 1/16 as many FHM grid points as FIA hexagons, and not all of the FHM grid points will cause the panel of the FIA hexagon to change, this disruption was considered acceptable.

CONCLUSIONS

The hexagon/panel system is one way to distribute FIA plots systematically across the conterminous United States and through time. One plot is selected for each FIA hexagon. Existing FHM and FIA plots are selected whenever possible. To maintain the existing temporal order of FHM plots, some perturbation of the FIA panels was accepted and incorporated into the system. The expected results will be a consistent inventory of all forested lands that preserves historic data. This system will incorporate the FIA and FHM forest inventory efforts, comply with legislative mandate, and provide a framework for future forest inventories.

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