How Reliable Is a Satellite Forest Inventory?

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Previous Finnish studies have shown that at stand level, the standard error of volume estimates derived using high resolution (Landsat TM etc.) satellite data inventories is quite high. It is usually 40–60%, which from the viewpoint of practical forestry applications is too much (Päivinen et al. 1993; Hyyppä et al. 2000). High volumes tend to be underestimated and vice versa (Pussinen 1992).

It has often been suggested, however, that for larger areas, the estimates are more reliable (see Tomppo et al. 1998, p. 641). In Fig. 1, curve A1 is based on empirical differences between multi-source inventory and standwise field inventories for various sizes of forest blocks (Tomppo et al. 1998). The right side of the curve (A2, Tomppo et al. 1998) is the standard error of National Forest Inventory of Finland (NFI), based on systematic field sampling.

Both curves A1 and A2 decline as the reference area increases. The reason for the decline of the NFI-curve A2 is obvious because the number of sample plots in a large area is larger than that in a smaller one. For A1 the link to the number of field plots is weaker, since in the multi-source method the connection between the number of field plots involved in the computation and the area size for the estimation is not straightforward.

Our hypothesis is that curve A1 is declining because variation of mean volume for small forest

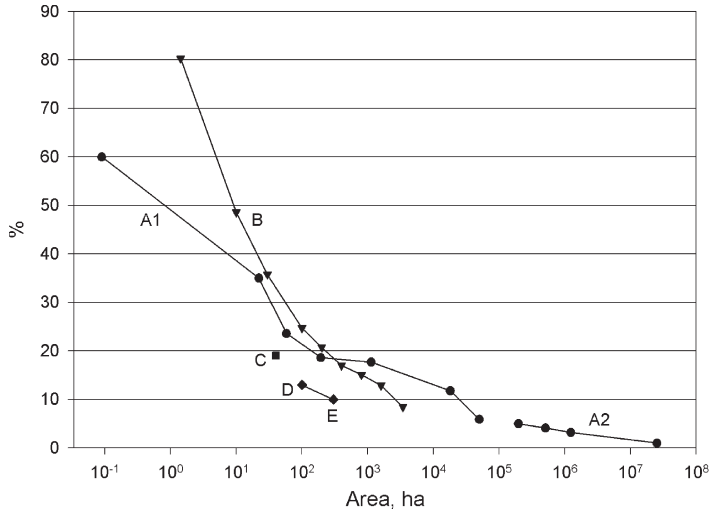

Fig. 1. The relative root mean squared error of the mean volume based on NFI multi-source inventory (curve A1), NFI field inventory (A2) and the relative standard deviation of the mean volume based on the stand-wise inventories (curve B) in the various area sizes. Point C is the RMSE of 40 ha estates; D and E points are the RMSE of 100 and 300 ha forest blocks, respectively.

blocks is greater than that for the large ones. To find evidence for this hypothesis, we derived the standard deviation of mean volumes for forest stands, and larger blocks of up to 3200 ha (curve B). The data is from stand-wise management inventories for 36 000 ha around the town of Kuopio in North Savo. The mean volume of 36 000 hectare test area was 109 m^3/ha, and the one for forestry land in North Savo was 108 m^3/ha.

Curve B indicates a higher standard error for small forest blocks and a lower error for larger forest blocks than curve A1. It could be concluded that more reliable results for all forest blocks of 1000 ha can be obtained for test area (standard deviation 14%, curve B) by using the mean volume of North-Savo province (which is known from NFI based on field plots), than by using multi-source inventory (RMSE 17%, curve A1). Taking into account the limited data used in deriving both curves A1 and B, that conclusion may be premature, but it certainly merits further investigation of the reliability of satellite-based inventories.

The results presented by Tokola and Heikkilä (1997) show that for 100 and 300 hectares, the RMSE of their satellite based forest inventory would be 13% and 10%, respectively (D and E). This result supports the assumption that satellite-based inventory will provide better results than the mean volume of the whole province only. Unfortunately, the authors do not report the original variations in their study material (as in Tokola 2000).

Using data for 60 forest estates, Pussinen (1992) derived volume estimates using NFI multi-source inventory for forest lots (average size 40 ha). The original standard deviation of mean volumes of estates was 32 m^3/ha (29%), and the RMSE 21 m^3/ha (= 19%, C), respectively. In this case it was shown that the satellite-based method was able to reduce the variation from 29% to 19%.

There is also something to add to the argument that 'larger areas have smaller variation'. That is the case if the original target area remains the same. However, small blocks can be compiled either from a small geographical area, or from the whole country. Large blocks, if not overlapping, can be compiled only from a large area, which may contain varying ecological and climatic conditions. Since the data used in deriving curve A1 is from various parts of Southern Finland, it may include some 'geographical' variation, whereas curve B does not.

Even if the data used for different curves presented in Fig. 1 are not fully comparable, our conclusion is that declining RMSE-curves for larger reference areas are only a part of the picture. Those curves do not provide a full indication of the effectiveness of an inventory method. In order to evaluate the additional value of the satellite data, the RMSE should not be analysed alone, but should be compared with the 'original' variation. Regarding the multi-source inventories, it would be interesting to know, how much the different components (satellite imagery, peatland mask, field mask) contribute to the result.

This type of study requires a good data set in order to produce reliable and representative results. Collection of sufficient field data would be expensive. In planning such an exercise, one should consider if a simulation approach would provide a cost-effective way to study the consequences of various combinations of error sources.

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