Estimating bias of scaling effects on satellite based forest area estimation for the conterminous U.S.

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ABSTRACT

We quantified the scaling effects on forest area estimates in the conterminous U.S. using 2001 30-m National Land Cover Datasets (NLCD) through regression analysis. The original data were aggregated to: 1) broad cover types (forest vs. non-forest); and 2) coarser resolutions (1 km and 10 km). Our model improved the accuracies for 1-km by 0.6% (12 556 km^2) in 2001 and 1.9% (43 198 km^2) in 1992 (for model test), compared to the unadjusted estimates. Forest area observed from MODIS 2001 for the conterminous U.S might differ by 80 811 km^2 from what would be observed at 30 m. Of this difference, we estimated 58% could be a net improvement, equivalent to 1444 Tg (1.5%) of total nonsoil forest CO_2 stocks (Zheng et al. In press).

METHODS

Study area & data sources: 48 states 7.8 million km^2, NLCD 1992 and 2001 30-m maps (Homer et al. 2004), and MODIS 2001 (MODIS12Q1).

Data processing and model development: 1) aggregated the general classes into forest (classes 41, 42, and 43); and non-forest (all the other classes; 2) aggregated to 1-km and 10-km pixel sizes respectively using majority rule; 3) all 3 land-cover maps were overlaid with the states' boundary map and areas of forest and non-forest lands in % were calculated at with different resolutions for each of the 48 states; and 4) we developed models (2001 data) to predict scaling effects on area estimation between 30 m & 1 km, and 30 m & 10 km.

Model validation: testing model performance using the independent NLCD 1992 data.

Model application: We used the MODIS 2001 1-km land-cover map to illustrate how and how much forest area estimates at the state and national levels could be improved using our model because MODIS products have become the most commonly used remote sensing data for terrestrial ecosystems studies at large-scales since 2000.

Table 1. Statistics of observed and predicted scaling effects on forest area estimates as differences in % of total land area between 30-m and 1-km and 30-m and 10-km (values in the parentheses) at state and national levels based on 2001 data.

	Observed, Predicted scaling effects in %				
Scale	Min.	Mean*	Max.	SD*	Error[+]
State	-9.7, -2.3	3.0, 2.3	9.4, 10.1	2.5, 2.1	2.3%
	(-24.7, -6.3)	(6.5, 6.4)	(22.6, 16.1)	(6.0, 3.6)	(4.9%)
U.S.	N/A	2.2	N/A	N/A	N/A
		(3.3)			

* Mean and standard deviation in absolute value.
[+] Standard errors of model estimates.

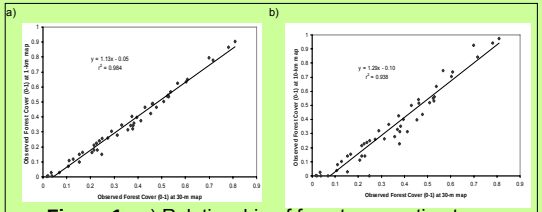

Figure 1. a) Relationship of forest area estimates (decimal fraction) between NLCD 2001 30-m and 1-km; and b) 30-m and 10-km. Each dot = a state.

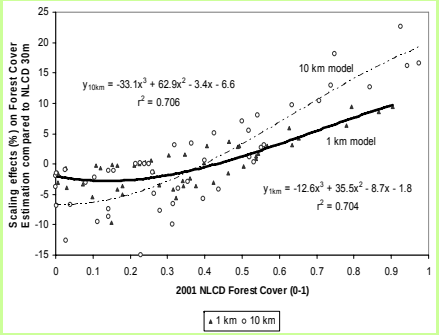

Figure 2. Empirical models to quantify scaling effects on forest area estimates (%) between 30 m and 1 km and between 30 m and 10 km for the conterminous U.S. ($P < 0.001$). Each triangle or empty square represents a state.

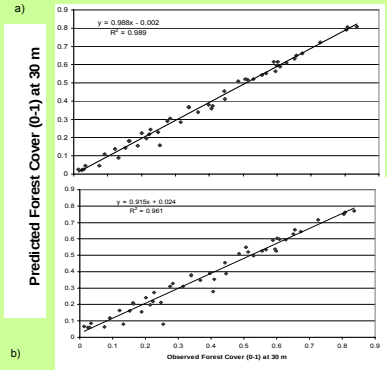

Figure 4. Comparisons of NLCD 1992 observed and predicted forest area (in decimal fraction) at 30-m resolution using 1-km (a) and 10-km (b) models presented in Fig. 1. Each dot represents a state in the conterminous U.S.

RESULTS & DISCUSSION

Significant correlations in forest area between fine resolution (30 m) and coarse resolutions (1 km and 10 km) were observed with r^2 of 0.984 and 0.938 ($P < 0.001$), respectively (Fig. 1). These strong relationships allowed us to quantify the scaling effects on forest area estimates between resolutions.

Figure 2 shows the results of fitting cubic models. The SE of scaling effects was 2.3% and 4.9% for 1-km and 10-km resolutions, respectively (Table 1). Differences in and variability of forest area estimates caused by the scaling process increased in general as pixel size increased, especially where forestland is less prevalent. The scaling effects tended to be smaller when forest cover percentages at coarser resolutions approached medium values.

Our models improved forest area estimates in 32 of the 48 states in 2001, compared to the area estimates obtained on the 2001 30-m map (Fig. 3). Ten of the 16 states not showing improvement were in the western U.S, which may be due to the larger state sizes as well as large areas of non-forest. Model validation indicated there were strong relationships between the observed and predicted forest cover percentages from NLCD 1992 with a net improvement of 43 198 km^2 (Fig. 4).

There was about an 80 811 km^2 difference between unadjusted (1 747 594 km^2) and adjusted (1 828 405 km^2) forest area estimates based on the MODIS 2001 map (Fig. 3). Using the mean improvement rate of 58% from NLCD 1992 and 2001, we improved the MODIS estimation for the conterminous U.S. by 46 870 km^2, ≈ 1444 Tg (1.5%) of total nonsoil forest CO_2 stocks in the conterminous U.S. (after area weighting) reported by the U.S. EPA (2007).

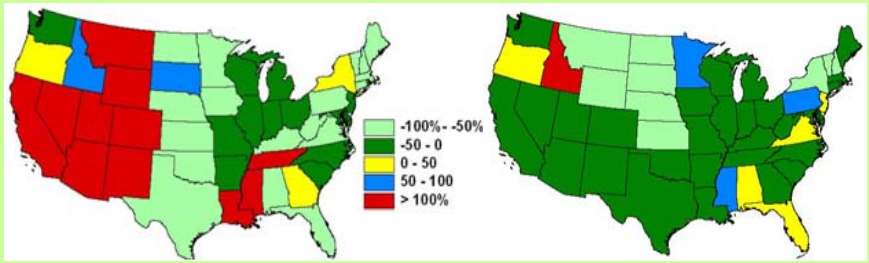

Figure 3. Spatial distribution of area calibration by %, calculated as (|KM_Pre – 30m_Obs| - |KM_Obs – 30m_Obs|) / |KM_Obs – 30m_Obs| * 100. Negative numbers = improvements & positive numbers = errors. Left: NLCD2001, Right: MODIS2001.

CONCLUSIONS

Sensor-resolution effects on forest area estimation over large areas deserve more attention. We provided useful and practical models to improve forest area estimation accuracy observed from coarse resolutions, which has insightful implications for a range of related issues such as modeling, resource and environmental monitoring, and carbon studies across scales. The models should be applied on a scale similar to that of the observation scale from which they were developed.

ACKNOWLEDGEMENTS

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KEY REFERENCES

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