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How Much Wood Could A Woodchuck Chuck, If a Woodchuck Could Chuck Data?

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Why do we need to know how much wood is in the forest and how much carbon is in that wood? More than a century ago, foresters managing for timber harvests developed measurement methods to estimate how much merchantable timber they would get from a forest harvesting operation so that they could calculate how profitable it would be before investing time and money. While forests are still being managed for harvesting wood and other products, they are also now starting to have significant economic value as repositories of carbon. As long as the forest is left standing and in good shape, then the carbon – which makes up about half of the dry weight of the wood – will remain there and not go into the atmosphere as carbon dioxide, where it would further exacerbate the growing problem of climate change. Some industrialized countries and corporations are willing to pay other countries to keep their forests standing in order to avoid carbon dioxide emissions, but they want to know how much carbon bang they are getting for their buck. Therefore, knowing how much carbon is in the forest is now becoming economically and politically important.

If we only needed to know about the amount of carbon in a few forests, that would be easy enough. We would send out trained crews to make the measurements. Instead, we need to know how much carbon is in an entire country's forests, or in the forests of several countries, and how that carbon is distributed across those countries. Making that many measurements on the ground is often impossible, especially in places like the middle of Congo or the Amazon. For that reason, we need to find proxies for on-the-ground measurements, which satellites orbiting the Earth provide. We have known for a long time how to map deforestation using satellite imagery, although the process is not trivial. Satellite data have to be calibrated and corrected for consistency so that comparisons can be made through time, from one year (or decade) to the next. Mapping deforestation also requires substantial computational capabilities and data storage, particularly with newer and higher resolution imagery. However, mapping where the forests are present, or not, is only a start. Estimating the amount of carbon as it varies in forests across the landscape is equally important and, in some ways, trickier.

In a recent *Nature Climate Change* paper by lead author WHRC Assistant Scientist Alessandro Baccini, two types of satellite data were combined with strategically located ground measurements to make a high quality map of forest carbon throughout the tropics, including South America, Africa, and Asia. Optical satellite sensors, such as the one called "MODIS," were previously thought to be limited in their sensitivity to biomass density, but when those data were coupled with satellite laser (LiDAR) measurements and linked to field data, the situation changed dramatically. Suddenly, we were able to measure with high accuracy and at moderately high (500m) resolution across all of the world's tropical forests. This is an important break-through. For decades, the UN Food and Agricultural Organization's country-level reports tabulating the amount of tropical forest biomass would change dramatically from one reporting period to the next. Sometimes the reported forest biomass of some tropical countries doubled, or halved, depending not on deforestation but rather on the methods used or the density of sampling conducted. Estimates were sometimes biased towards commercially viable species and were often sparse (or even non-existent) in vast tracts of remote forest, such as those of the Democratic Republic of the Congo.

Not only can we now say that a certain plot of land has a certain amount of carbon based on our analysis, we can also say how confident we are in that estimate. Scientists call this an "error term" or an "uncertainty," but it doesn't mean that someone made a mistake or doesn't know what he or she is doing. Rather, it acknowledges that every estimate is somewhat imperfect, and we put bounds on how far off it could be. When the nurse has you step on a scale in the

doctor's office to measure your weight, the reading isn't exactly right, because you wear bulkier clothes in the winter than in the summer, but the measurement is good enough, within a few pounds.

Likewise, in this new paper, Baccini et al. estimate how much the carbon in the forest weighs for each spot in the satellite image, plus or minus a few tons per hectare, and they estimate how much that "plus or minus" is. This is important if someone is willing to pay for keeping the carbon in the forest. If it is 100 tons per hectare, plus or minus 50, then they might only really be paying for 50 tons in the worse case scenario. However, if it is 100, plus or minus 20, then they know that they'll be conserving at least 80 tons per hectare. Most investors will pay more if the "plus-or-minus" term (which scientists call "uncertainty") is small. We are now collaborating with economists to put this knowledge to work in improved designs of carbon credit programs, so that our improved estimates of carbon stocks (and their uncertainties) are included in payment protocols.

We at WHRC are proud to be at the very cutting edge of this type of research in tropical forests. It turns out that knowing how much carbon is in these forests is key to devising effective programs and finances to conserve them. To ensure that these improvements continue in the future, we not only need robust research to push the leading edge, but we have to continually work to ensure that the essential satellite observations are in place. To that end, we also work as advisors to NASA and to space agencies of other governments to help design and promote the most important technologies for advancing Earth science. We are also seeking to expand this analysis to temperate and boreal forests, and to put the forest biomass maps to work, identifying candidate areas for preservation of existing forests, for reforestation, and for productive agriculture. The most remarkable aspect of this work is that, under one roof, we combine break-through remote sensing research with applications that yield solutions for conservation of the forests of the world.