

# Satellite Remote Sensing & Carbon Market Transparency

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## Abstract

Forest preservation has become a financial priority with the United Nations REDD+ (Reducing Emissions from Deforestation and Forest Degradation) program. In 2011, US\$30 billion in transactions occurred directly related to forest preservation. This effectively created a market for carbon sequestration and will likely evolve into a means for establishing credits for voluntary carbon standards (VCS).

By 2020, the market is estimated to grow to US\$100 billion with the United Nations (UN) playing the central role in its administration [1]. Driving this market will be the voluntary trading of carbon as a commodity with carbon value as a new global currency.

Transparency of this market will be key to its success. Those nations participating in the UN-administered REDD+ funding will find that their conservation performance will be monitored. Quantifiable forest measurements using remote sensing allow experts to understand not only deforestation and forest degradation, but reforestation. These measurements are necessary for the transparent function of the VCS market.

Independent monitoring of the forests is analogous to the audits that are standard accounting practice in the operation of other industries. Third-party assurance will be needed at the center of the REDD+ program for the healthy functioning of global carbon financial markets. Currently academic and non-governmental organizations (NGOs) are monitoring forest health using satellite remote sensing. Large archives of satellite data reach back 40 years, thus we have an excellent baseline for these measurements. New Earth Observation (EO) satellites will continue to monitor this process. Thus remote sensing will be the most cost effective and accurate tool in the third-party audit and assurance processes used to validate the transparency of the VCS market.

## Keywords

*REDD+; Voluntary Carbon Standards, Audit; Assurance; Third-Party Verification; Transparency; Remote Sensing; Carbon Bank*

## Forests as Capital Assets

Forests provide a diverse array of direct and indirect use values, as well as important non-use values. Extraction and commoditization of forest materials

such as timber and fuel offer two principle examples of direct use values. Market prices paid for such products reflect the value of these resources. Conversely, forests also provide resources and ecosystem services that have indirect use and non-use values. In this latter instance, individual preferences, and hence, values, are not reflected through the market mechanism. Without an effective mechanism to reflect non-market values, there is an imbalance in the relevant trade-offs present within forest resource use decisions. This imbalance has led to unsustainable forest management and even illegal deforestation, with clear-cutting turning forests into pastures and croplands. Both sustainable and unsustainable practices reflect the perceived economic value of the forest; the latter exemplify a problematic approach to forest “development” around the world.

Climate change has entered the non-use value discussion because forests serve as a foundation in the carbon cycle. The carbon sequestered as biomass in tree canopy, woody branches and tree trunks, as well as peat in the soil, plays a critical role in the planet’s carbon cycle by holding carbon and keeping it from entering the atmosphere. When trees are cut, the leafy canopy and wood decompose. This action is accelerated when felled trees are burned, a process that more rapidly releases carbon into the atmosphere as aerosol and smoke. Soils from which trees are removed begin to dry, and the organic matter, especially peat, begins to decompose, releasing even more carbon. Thus, a healthy forest ecosystem is the reservoir where nature “banks” its carbon, holding it from entering the atmosphere as a greenhouse gas.

The value of a forest as a carbon bank fits within the set of non-use values derived from preservation, habitat conservation, biodiversity, and the preservation of indigenous cultures. A challenge for proponents of non-use forest values is that the price mechanism has not traditionally reflected the total economic value of forest resources. In the case of

carbon sequestration, however, significant movement has been made towards developing a functioning market in non-use ecosystem service flows.

The UN REDD+ program provides an example of how market incentives can be used to capitalize the value of eco-system service flows into resource use and allocation decisions. In this instance, the value of carbon sequestration is reflected within the prices paid for tradable carbon offset credits. Prices for tradable instruments reflect the underlying set of preferences that market participants have for non-use service flows. Importantly, the prices paid for offset credits allow for a more accurate reflection of the relative trade-offs present within forest resource use choices (e.g. conservation or extraction). REDD+ calls for monetary value to be exchanged not for receipt of a product or service but for the act of withholding a product (in this case, forest lands) from other potential uses in the marketplace. The scope, magnitude, and value of the REDD+ program help set the stage for a new market based on the trading of sequestered carbon stocks in the form of forests.

This new market is already evolving, with nation-to-nation cash transfers underway or planned. Norway and Indonesia have concluded a deal valued at US\$1 billion, in which Indonesia will implement a forest conservation effort based on the REDD+ program. The REDD+ cash transfers for 2011 are estimated to be US\$30 billion, with anticipated cash transfers by 2020 of US\$100 billion. These values will certainly grow as the market becomes more accepted and supported by government policies.

REDD+ is not the only program to use market incentives to encourage the provision of non-market goods. Although voluntary in nature, carbon offset markets in the U.S. have continued to grow as individuals have sought out means to reduce their carbon "footprint." Verification of realized offsets is an important component of voluntary offset programs. A recent study found that approximately 65% of offset consumers factored third-party verification into their purchase decision.

As the REDD+ trading scheme is more fully implemented, its investors will seek assurance that carbon values are accurately and transparently calculated. Its investors likely will be guided by several factors, including their own risk appetites and access to reliable information from multiple sources. An investment in the preservation of remote forest lands trusts that the offset's suppliers (local

governments, property owners, and caretakers of sequestered carbon) live up to their side of the bargain. After all, this type of market involves assets that are difficult for investors to assess for themselves. They can't stroll by tropical rainforests in the same way they might jog through Central Park or hike in Yosemite to gain comfort that the value purchased remains intact.

For carbon-offset trading markets to function effectively, external means of verification are needed to minimize information asymmetries and the concomitant uncertainty that may act as a disincentive to broad-based market participation. Just as other capital markets rely on the audit function to provide third-party attestation of management assertions, so will the REDD+ program, and ultimately the carbon trade, need a reliable form of auditing and assurance.

### Satellite Remote Sensing

Measuring the sequestered carbon in biomass is possible, but direct measurements with time-consuming ground surveys are not practical for entire forests. The cost of field surveys would be greater than the value achieved, so an indirect method of estimating the biomass is needed. The definition of remote sensing is to indirectly measure something with a camera or another sensor. Survey options become more vastly more affordable with airborne and space-based remote sensing technology collecting more information in a shorter amount of time.

There are numerous remote sensing technologies available for mapping forest stands and calculating biomass. The classic tool has been aerial photography. Depending on the altitude of the aircraft, individual trees can be counted in an air photo. After the Second World War, photo-interpreters trained by the military found careers in forestry. And at this time, the use of infrared film found a niche in monitoring forest health because healthy, green tree leaves reflect infrared energy more strongly than stressed vegetation.

These vintage air photos create a baseline for measuring change. However they are only useful on a local or regional basis because of their scale and limited availability. This changed with the first EO satellites used to build a global baseline of the planet's forests. In the 1970's the Landsat and SPOT satellites began capturing imagery from low-earth orbit. Both of these satellite programs are still in operation with the Americans preparing to launch additional Landsat missions in 2013 and another later in the decade. The French SPOT 6 satellite was launched in 2012 and

SPOT 7 is planned for 2013. In the case of the Landsat data, the imagery is freely available. The SPOT satellite data is available on a commercial basis. National governments, universities, and NGO's have been using both imagery archives to create baseline measurements.

Cameras on aircraft and satellites have limitations. Darkness, fire smoke, fog, and clouds limit when optical sensors can collect useful images. The tropics are known for persistent clouds, thus collecting an image may be a matter of waiting for a cloud-free day, which could be a matter of weeks in some places. Optical remote sensing with satellites may not be the best tool for mapping tropical forests, but it is relatively inexpensive and easy to use compared to other remote sensing technologies.

An intriguing optical sensor that has shown great promise for understanding the three-dimensional characteristics of forests is LiDAR (Light Detection and Ranging). This laser scanning technology has been proven useful as a tool for profiling tree canopies. Some of the laser energy penetrates to the ground, allowing volumetric calculations of the tree crowns. The laser energy is also reflected off of the woody portions of the tree, allowing more detailed estimates of the carbon sequestered in the wood structure.

LiDAR can operate on both aircraft and satellites. As expected, low flying aircraft permit the most precise and detailed mapping, but the costs are significant and the area inventoried small. Satellite systems map larger areas more quickly, but at a coarser resolution. The airborne LiDAR systems are now fairly common for mapping cities and for flood plain delineation, and are entering the forestry industry. LiDAR on satellites, such as IceSat, was originally designed for mapping ice heights and the data is being studied for forest monitoring.

A limitation of LiDAR, as with all optical systems, is they only work with the skies are clear of smoke, fog, and clouds. LiDAR, however, is an active sensor, with the laser illuminating the ground and vegetation, so can work at night unlike cameras.

A very interesting remote sensing technology that has been of great interest to the REDD+ community has been synthetic aperture radar (SAR). SAR creates photo-like images using microwave radar pulses. The movement of the aircraft or satellite allows these pulses to create minute Doppler shifts of the same portion of the ground. And these minute changes in

radar range measurements allow a very detailed image to be created by mathematically synthesizing a much larger antenna length.

The microwave energy of SAR also has special properties when interacting and scattering among various features. For example, metal reflects the radar pulse so metal features glow brightly in a radar image. Water absorbs this energy, appearing as dark features in an image. And depending on the wavelength of the energy, the radar pulse can be scattered by the wood in a forest in a variety of ways. This special property allows the reflected radar energy to be analyzed in great detail, recreating three dimensional data. The concept is similar to a medical scanning technique known as computed tomography, where the tomographic image is a "slice" of data through the forest. This 2D slicing for detailed study is known as "windowing" which then allows the rendering of the 3D-volumetric forest structure.

The BIOMASS satellite mission planned by the European Space Agency for 2018 is designed specifically for this form of tomographic radar mapping. With BIOMASS, the most accurate measurement of the global carbon stock will be calculated and the flux in the carbon bank can be tracked.

Working back through time, BIOMASS will be building on the SAR baselines created for tropical and boreal forests. The Japanese Aerospace Exploration Agency (JAXA) has long played a role in the development of SAR satellites. The JERS-1 was used in the 1990s to create the first SAR forest baselines. Its follow-on ALOS mission acquired significant amounts of radar data to perform the Pan-Tropical Forest Inventory led by the Woods Hole Research Center. The Pan-Tropical Forest Inventory contributed greatly to the science used to set the policy of the REDD+ program.

Unfortunately, SAR data processing is still largely in the realm of technical researchers. Some simple tools have been developed to incorporate SAR data as GeoTIFF files for elementary analysis in a geographic information system (GIS). But SAR is uncommon for terrestrial ecology and forestry applications. Working with SAR data can be complicated, and accurate biomass estimates are not derived from standardized processes. But this will change as we place more emphasis on understanding biomass, carbon sequestration, and carbon fluxes.

As with all tools, you need to choose the right tool for a particular problem to solve. Optical aerial photography and satellite imagery is easy to interpret and work with in a GIS. It can also be accessible and inexpensive, in the case of Landsat. But as described earlier, it may not be the best tool for monitoring deforestation in the tropics where clouds are common. LiDAR could be an effective technology, but it also faces the same challenges of other optical sensors in that the atmosphere must be clear of any haze. LiDAR could also be relegated to a tool for calibrating the accuracy of other methods of remote sensing in biomass monitoring, such as SAR. Multiple remote sensing technologies will need to be available in the tool kit for those monitoring carbon banking. This tool kit will also need methods of managing very large, global datasets.

SAR is an intriguing technology, but its use may only be practical in the hands of experts, which calls into question how transparent a true, third-party, audit and assurance process could be. An independent audit of the carbon sequestered in forest biomass should follow rules that investors can agree upon. This means REDD+ policy should consider how independent audits can be part of a long-term observation strategy. This protocol would ensure the integration of future remote sensing systems like BIOMASS and a global data collection strategy.

Remote sensing by itself may not offer a complete solution to the transparent function of the carbon trading market. Often remote sensing data is checked from the field and this requires local officials on the ground. The UN REDD+ program has established procedures called MRV (Measurement, Recording & Verification) where these field checks are used to validate the data collected from aircraft and spacecraft.

### Carbon Market Transparency

Complex commodities trading markets should have operational transparency and investor trust as part of their fundamental design. The trading of VCS credits will need clear and uniform definitions, requirements, rules, and reporting if they are to be used in the valuation. VCS are defined and compatible with the Kyoto Protocol. However, much of the data used to define VCS is self-reported – meaning the nations and organizations attesting to the value of the VCS have determined those values using their own methods of calculation. This could lead to inconsistency in reporting, or worse, corruption and fraud.

So the participants in REDD+ will need to have their VCS assessed by a community of examiners following a consistent and standardized process with access to independently derived data. This is because a principal of the audit profession is the auditor cannot attest to data the same auditor has had a hand in creating. The role of an independent, third-party auditor is key to this market assurance.

An independent audit system also allows for specialized expertise needed to process the remote sensing data. Multiple remote sensing technologies will have to be brought to bear on this issue to balance technological strengths with operational costs. An external audit solution could also help spread the costs of assurance among all program participants, potentially reducing audit costs and limiting the need for new bureaucratic institutions.

### Conclusion

The VCS capital market will serve many stakeholders: not only those nations, property owners and indigenous peoples in control of forests sequestering carbon, but also the nations, corporations and individuals making investments in carbon assets. Investors in any market demand and require transparency to achieve confidence; forest carbon value is no exception. Such reporting would have to be validated by a reliable third party to ensure the accuracy and transparency of the information. Confidence in the VCS markets means international accounting rules are followed. Otherwise, institutional stakeholders expecting this level of reporting and good governance will not invest.

Remote sensing and auditing expertise and technology will be integral to providing effective and efficient assurance of the VCS markets as they emerge and mature. Forests that are clean, green and healthy is the goal of REDD+ and market transparency supports this goal.

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